PENOBSCOT RIVER MERCURY STUDY

Chapter 14

Temporal and geographic trends in mercury in biota in the Penobscot estuary

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1. Penobscot River Mercury Study

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1 SUMMARY

Mercury (Hg) concentrations in fish, birds and bats were monitored between 2006 and 2010 in the lower Penobscot River, upper Penobscot Bay and in upstream and coastal reference sites. The monitoring study was designed to examine trends in Hg concentrations over time, the geographic pattern of Hg contamination in relation to the HoltraChem site, health threats created by the Hg contamination, and the severity of the contamination in comparison to other sites sampled throughout the world. Note that the current four to five-year monitoring period is insufficient to determine long-term trends in the region. The presence or absence of significant trends in Hg concentrations over time is relevant only for the current monitoring period.

Between 2006 and 2010 we found significant variation in Hg concentrations at a few sites, but no overall trends in most species of biota, including fish (American eels, tomcod, rainbow smelt, winter flounder), lobster, and birds (Nelson's sparrow, song sparrow, swamp sparrow, red-winged blackbird, Virginia rail). Hg in blue mussels declined significantly at the more contaminated sites of the upper estuary but did not change at sites below Fort Point. Trends were difficult to assess in mummichogs and double-crested cormorants due to sampling limitations. American black ducks were sampled in only two years, and bats were sampled in only one year, precluding trend analysis.

Hg concentrations generally declined with distance from the HoltraChem site. This geographic trend in Hg concentrations was found in most fish (American eels, tomcod, rainbow smelt, winter flounder), lobster, mussels, and double-crested cormorants. The greatest Hg concentrations in marsh birds (Nelson's sparrow, song sparrow, swamp sparrow, red-winged blackbird, Virginia rail and American black duck) were found in the area of Mendall Marsh, often the closest sampling area to the plant site, and reflecting the high Hg methylation rates present in Mendall Marsh.

Hg concentrations in most individuals in the majority of species exceeded targets set for protection of human and wildlife health. The Hg target concentration to protect human health (200 ng methyl Hg/g muscle wet wt.) was exceeded by more than 90% of American eels in the vicinity of HoltraChem, American black ducks from Mendall Marsh, and lobster in the area north of Fort Point, and by the majority of tomcod in the area north of HoltraChem (in BO (Brewer – Orrington sampling reach)) and mummichog in the area south of HoltraChem (in OB (Orrington – Bucksport sampling reach)). The Hg target to protect fish predators (50 ng methyl Hg/g muscle wet wt.) was exceeded by all American eel, tomcod, and mummichog and most rainbow smelt in the area south of HoltraChem (OB). The Hg targets to protect bird health (1.2 µg/g blood wet wt.; 5.0 µg/g feather fresh wt.) were exceeded by over 90% of Nelson's sparrows and Virginia rails in Mendall Marsh, and in the majority of swamp sparrows and red-winged blackbirds sampled at Mendall Marsh; in some cases (e.g., Nelson's sparrows) blood concentrations of Hg far exceeded target safety levels. The Hg targets to protect mammal health (0.10 µg/g blood wet wt.; 10.0 µg/g fur fresh wt.) were exceeded by over 80% of the little brown bats and over 65% of the adult northern long-eared bats sampled along the lower Penobscot River.

Hg concentrations in biota sampled in the lower Penobscot were often considerably greater than reported for uncontaminated areas, and equaled or often exceeded concentrations reported in Hg contaminated areas. In fish and shellfish, Hg concentrations in American eel, smelt, mummichog, winter flounder, lobster and blue mussels were equal to or greater than reported for the same species in contaminated areas outside of Maine. In birds and mammals, Hg concentrations found in Mendall Marsh were 2 to 25 times greater than found in areas reported to be contaminated by Hg (Nelson's sparrow, song sparrow, swamp sparrow, red-winged blackbird, Virginia rail, and little brown bats). Concentrations in double-crested cormorants and American black ducks equaled those reported for Hg-contaminated areas of San Francisco Bay and mallards in the South River, Virginia, respectively.

2 INTRODUCTION

This chapter provides the monitoring results of mercury (Hg) concentrations in various species of biota (shellfish, fish and birds) over the period 2006 to 2010. Data for the following species are presented: blue mussels, American lobster, American eel, Atlantic tomcod, winter flounder, mummichog, rainbow smelt, Nelson's sparrow, swamp sparrow, song sparrow, double-crested cormorant, red-winged blackbird, Virginia rail, American black duck, and bats. There are four main objectives in presentation of data. The **first objective** for each species is to determine temporal trends in Hg over the length of the sampling period, especially to examine the data for any significant increases or decreases. The null hypothesis being tested in each case is that concentrations remain unchanged over the sample period. It is useful to know whether Hg contamination in biota is tending to decrease or increase in recent years, from the point of view of the risk to people eating fish, shellfish and birds, from the point of view of the risk to the animals themselves, and from the point of view of risk to predators eating those biota species. The **second objective** for each species is to draw conclusions regarding the geographic pattern of Hg concentrations. That is, are concentrations apparently related to the location of the HoltraChem facility? The **third objective** asks whether Hg concentrations are great enough to pose a risk to humans, predators, or the animals themselves. And the **final objective** for each species is to compare Hg concentrations in biota in the Penobscot with both contaminated and uncontaminated (reference) locations. This provides an indication of the severity of contamination of Hg in the Penobscot, relative to other sites sampled throughout the world.

Regarding temporal trends in biota, we know from sampling surface sediments over the period 2006 to 2010 (the source of Hg for most biota species sampled) that total Hg levels in surface sediments were generally stable, showing no significant overall declines at any of the six classes of sites (Chapter 15). Similarly, methyl Hg concentrations also showed no significant overall declines at any of the six classes of sites sampled. Because most of the animals bioaccumulate methyl Hg that comes from surface sediments, these findings would suggest that Hg in biota from both aquatic and wetland habitats might have remained unchanged in recent years. However, conditions that affect the concentrations of Hg in biota are many, including factors affecting Hg methylation and bioaccumulation (e.g. temperature, rainfall, freshwater outflow, food chain length, feeding patterns). Also, some species such as blue mussels and rainbow smelt in the lower reaches of the study area, feed in the pelagic rather than the benthic food web (Chapter 16). Trends in Hg in biota may be different from those found in sediments.

3 METHODS

Table 14-1 provides an outline of the years in which the various species of biota were sampled. Sampling of biota is necessarily limited to where each species occurs naturally. Environmental conditions change significantly in the Penobscot River from upstream of Veazie Dam to Penobscot Bay, changing from freshwater and non-tidal to brackish and tidal to marine environments. Therefore few species of biota can survive throughout the whole river and bay. Rather, the geographic ranges of the biota sampled in this study varied by species.

Table 14-1: Fish, shellfish and bird species monitored along the lower Penobscot River and upper Penobscot Bay between 2006 and 2010.

Species	Years sampled
American eels (Anguilla rostrata)	2007, 2008, 2009, 2010
Atlantic tomcod (Microgadus tomcod)	2006, 2008, 2009, 2010
Rainbow smelt (Osmerus mordax)	2006, 2008, 2009, 2010
Mummichog (Fundulus heteroclitus)	2006, 2008, 2009, 2010
Winter flounder (Pleuronectes americanus)	2006, 2008, 2009, 2010
Lobster (Homarus americanus)	2006, 2008, 2009, 2010
Blue mussels (Mytilus edulis)	2006, 2008, 2009, 2010
Nelson’s sparrow (Ammodramus nelson subvirgatus)	2007, 2008, 2009, 2010
Swamp sparrow (Melospiza georgiana)	2007, 2008, 2009, 2010
Song sparrow (Melospiza melodia)	2007, 2008, 2009, 2010
Virginia rail (Rallus limicola)	2007, 2008, 2009, 2010
Red-winged blackbird (Agelaius phoeniceus)	2007, 2008, 2009, 2010
Double-crested cormorant (Phalacrocorax auritus)	2006, 2007, 2008, 2009, 2010
American black duck (Anas rubripes)	2010/2011, 2011/2012
Little brown bat (Myotis lucifigus)	2008
Northern long-eared bat (Myotis septentrionalis)	2008

3.1 Sampling methods

American eel: Eels were captured in fresh and brackish water reaches of the Penobscot River, from upstream of the Veazie Dam, then downstream to approximately the town of Bucksport. We sampled eels in the OV, BO, and OB reaches. Eels were captured using electrofishing and baited eelpots. Only yellow eels were retained and silver eels were not sampled. Yellow eels are the sexually immature, non-migratory phase of the species. Total length and fresh weight were taken for each fish. Total Hg was analyzed from a sample of axial muscle whereas methyl Hg was analyzed on a subsample of fish. Eels were aged using otoliths; age was used as a co-variate to adjust Hg concentrations.

Atlantic tomcod: Tomcod occur in the brackish sections of the Penobscot estuary, from the OB reach in Orrington, north of the HoltraChem site, to the coastal area near Searsport. Tomcod were sampled primarily using trawl nets. Total length and fresh weight were determined for each fish. Muscle tissue was analyzed for total Hg for each fish with a subsample of those also analyzed for methyl Hg. Length was a significant co-variate with Hg for this and all other fish species except American eels.

Rainbow smelt: Smelt occur in the Penobscot system in brackish areas, from the north end of the OB reach, just south of the HoltraChem site, to near Searsport. Smelt were captured primarily using trawl nets. Total length and fresh weight were determined for each fish. Muscle tissue was analyzed for total Hg for each fish and a subsample of those fish were also analyzed for methyl Hg.

Mummichog: Mummichogs were sampled using trawl nets and minnow traps, at sites in the river and bay, and, starting in 2010, in tidal sloughs within wetlands. Total length and fresh weight were taken for each fish. Total Hg was analyzed from a sample of axial muscle whereas methyl Hg was analyzed on a subsample of those fish.

Winter flounder: Flounder occur in brackish and marine waters of the study area. They were collected from the upper end of the OB reach, just south of HoltraChem, down river and west to Searsport. Flounder were captured using trawl nets. Total length and fresh weight were determined for each fish. Muscle tissue was analyzed for total Hg for each fish while a subsample was also analyzed for methyl Hg.

Lobster: Lobsters occur as far north as the south end of Verona Island. Lobsters were sampled at eight sites over the years, from Verona Island on the north to Islesboro Island on the south, and on the east and west sides of Penobscot Bay. Some sites were specific to lobsters and therefore did not coincide with sites where other species were sampled, while the Odom Ledge lobster site is near to ES15, the South Verona site is close to ES13, the Fort Point site is close to ESFP, and the Parker Cove site is close to ES01. Lobsters were captured with commercial lobster traps, baited with commercial bait (usually marine-derived herring). Size (carapace length), weight and sex were determined for each animal. Three different tissues have been analyzed, claw muscle, tail muscle and tomalley (hepatopancreas), for total Hg in all samples and for methyl Hg in a subset of samples. Most sampling in the early years was of claw muscle, based on the assumption that tail muscle would be equivalent to claw muscle. When we found that Hg concentrations in tail muscle was significantly greater, more sampling was done to define that relationship and in later years, sampling has mainly concentrated on tail muscle.

Blue mussels: Mussels generally occur throughout Penobscot Bay, but in intertidal areas not further upstream than the middle of Verona Island (a special collection was made in 2010 in the river channel north of Bucksport, using a van Veen dredge). Mussels were usually collected by hand at sites in the intertidal zone of Penobscot Bay. Collections have been made at sites as far south as Islesboro Island. Mussels were measured (2008-2010; total length) soft tissues removed and frozen before being shipped to the analytical laboratory. Soft tissues were freeze dried, re-weighed and analyzed for total Hg and methyl Hg by standard methods.

Songbirds and shorebirds (Nelson's sparrow, swamp sparrow, song sparrow, red-winged blackbirds, Virginia rail): Songbirds were captured in marsh habitats with mist nets. Virginia rails were captured using calls and spring nets. Standard measurements including body weight and beak size were taken for each bird sampled. Also, age class, adult and hatch year, and sex were determined when possible. Blood samples were taken from all birds and tail, secondary and/or primary feathers were sampled from most birds. Blood and feathers were analyzed for total Hg.

Cormorants: Double-crested cormorant eggs were collected from colonies located north of Bucksport to Islesboro. Whole eggs were taken and frozen. The developmental state of each egg was estimated according to a standard ornithological scale. Total Hg was analyzed on a sample after the egg (without the shell) was freeze-dried and homogenized. The Hg present in bird eggs is methyl Hg (Ackerman et al 2013).

Black ducks: American black ducks were sampled during the fall waterfowl hunting season in Mendall Marsh and in the winter from Mendall Marsh, from a site near the south end of Verona Island, and from a reference site to the east in Frenchman Bay, Maine. In the fall, breast muscle was sampled from birds collected in Mendall Marsh by Maine Department of Inland Fisheries and Wildlife biologists and hunters. Muscle samples were analyzed for total Hg, and methyl Hg in a subset of samples. In January collections, birds from three sites were sampled using baited traps. Blood samples were drawn from these birds and analyzed for total Hg. The P1 primary feather was collected from every bird sampled; feathers were analyzed for total Hg in 2010-2011. Age class, sex, weight, and numerous size metrics were recorded for each bird sampled.

Little brown bats and northern long-eared bats: Bats were captured at night using mist nets between late July and mid-August in 2008 at seven sites along the Penobscot River from Orrington to the southern tip of Verona Island. Blood and fur samples were taken from each bat and analyzed for total Hg. Information on sex, reproductive status, and size was recorded.

Raw data for all biota are found in Appendices 14-1 to 14-15.

4 AMERICAN EEL (*Anguilla rostrata*)

4.1 American Eel Biology

Several aspects of the life history of eels make them excellent indicators of long-term trends in Hg accumulation in biota. Eels have two distinct life stages. Yellow eels, sexually immature subadults, live in fresh or brackish water for 5 to 20 years. Yellow eels have strong site fidelity with small home ranges and limited seasonal movements (Oliviera 1999) and a broad diet that includes scavenged food, benthic polychaete worms, crustaceans, and bivalves. Female yellow eels grow faster than males, mature at a later age and can grow longer than 400mm, large enough to capture and eat fish (Oliviera and McCleave 2000). Eel growth rates are highly variable and so eel length cannot be used as a surrogate for eel age. In this study eel age was determined by counting the annular rings on otoliths necropsied from the individual eels.

When eels reach sexual maturity they transform into the silver phase, and begin migrating seaward from the lakes, rivers and streams where they have spent years as sub-adult yellow eels. This downstream migration occurs in the fall months and eel foraging is reduced or suspended during this phase. The Hg concentrations in migrating silver eels netted at downstream sites do not represent Hg exposure at the location sampled, but exposure at the upstream site where they resided and fed as sub-adult yellow eels.

In this study we report on Hg concentrations in yellow eels only, though in one year we suspected that a few silver eels may have also been collected. In 2008 eels were sampled in September and early October. Several eels electrofished from the OV reach had some of the physical characteristics of migratory silver eels. We collected additional external measurements and gonad weights from all OV eels and a subset of the BO eels, to confirm whether the suspect eels were non-migratory yellow eels or silver eels migrating down the Penobscot River from upstream sites. One female eel, OV5-1, was 16 years old, had a total length of 750 mm, weighed 890g, had a gonadosomatic index of 4.96 (GSI; gonad weight/total weight*100), and a Pankhurst eye index of 11.7 (PEI; [((horizontal + vertical eye diameters/4)2*3.14159)/body length]*100; Pankhurst 1982; Cottrill et al. 2002). Given the preponderance of the evidence this eel was determined to be a silver eel migrating downstream in the Penobscot River and omitted from the dataset.

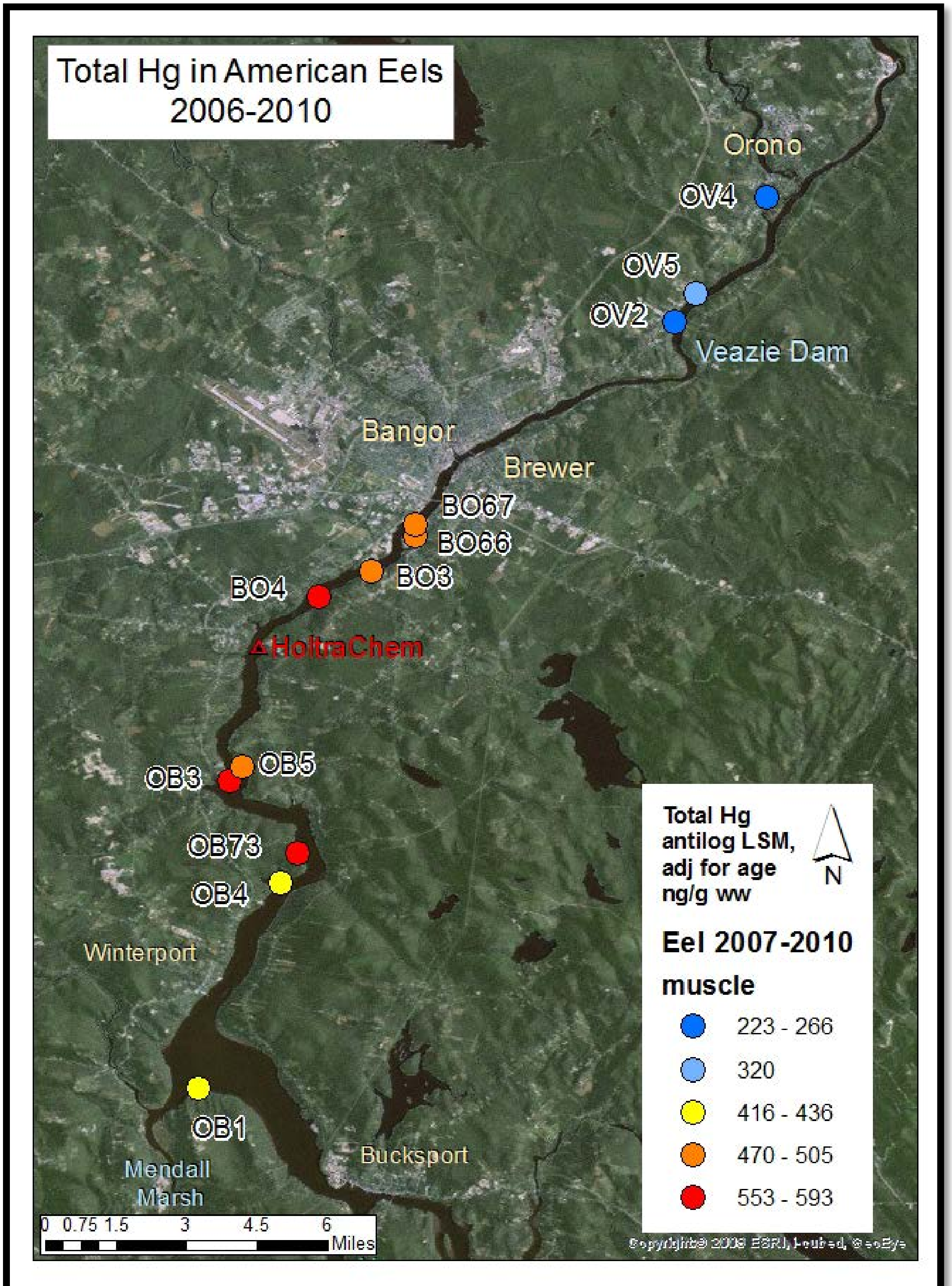


Figure 14-1. American eel sampling locations and mean Hg concentrations (antilog of least squares means, adjusted for eel age) during the five year monitoring period (2006 - 2010).

4.2 Temporal Comparison of Hg in American Eels

There were no significant temporal trends in total Hg concentrations in eels at any of the sites (Figure 14-1) monitored between 2007 and 2010 ($P > 0.05$; Figure 14-2). Trend analysis used a linear regression of Hg on year, adjusted for eel age, within each sample site, with all regressions combined in one linear model with a pooled variance. Total Hg was log-transformed to meet statistical assumptions of normality. As the average age of the eels sampled was 7 years and the half-life of Hg in fish muscle exceeds 2 years (Trudel and Rasmussen 1997), Hg concentrations in eels are unlikely to respond quickly to changes in exposure levels.

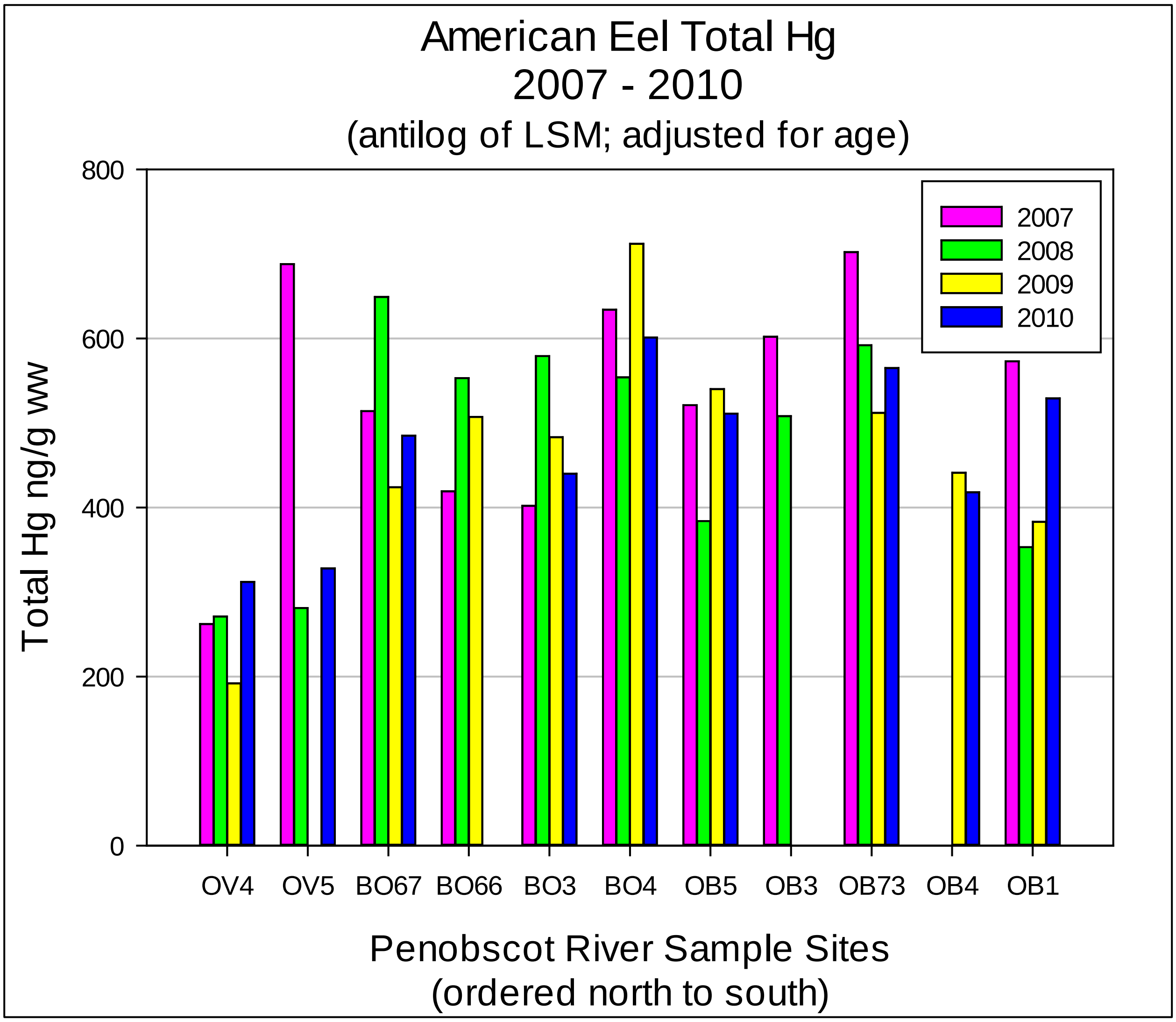


Figure14- 2. Temporal comparison of mean total Hg concentrations (antilog of least squares means adjusted for eel age across all years) in eel muscle within each site sampled in multiple years. No significant trends were found within any site sampled.

4.3 Geographic Comparisons of Hg in American Eels

Total Hg concentrations were lower in eel samples collected from the OV reach relative to the downstream reaches of BO and OB in all years sampled, 2007-2010 (ANCOVA, adjusted for age, $P < 0.001$; Tukey HSD, $\alpha = 0.05$; Figure 14-3; Appendix 14-1). The OV reach is upstream of the Veazie Dam and so outside of the aquatic influence of the HoltraChem facility, but would be subject to the same Hg inputs from municipal and industrial facilities upstream of the dam and from aerial deposition to the Penobscot watershed.

Similarly, in most individual years, total Hg concentrations in eels were significantly lower at the sites in the OV (Old Town-Veazie) reach relative to eels sampled in the BO and OB sites. In the years 2007, 2008 and 2009 total Hg concentrations in eels, sampled at individual sites in the OV reach, with an $n > 1$, were significantly lower than Hg in eels at all other sites in the BO and OB reaches (ANCOVA, adjusted for eel age, $P < 0.01$, Tukey HSD, $\alpha = 0.05$). In 2010, the geographic pattern of Hg contamination was not as distinct as found in earlier years. In that year, eels were sampled at two OV sites, OV4 and OV5, with a sufficient sample size for comparison with other sites. Total Hg concentrations in eels sampled at OV4 were significantly less than found in eels at four of the seven sites in the downstream reaches (BO4, BO67, OB5, and OB73), and OV5 was significantly less than one of the seven downstream sites (BO4).

It is not known whether this change in the geographic pattern of Hg in eels found in 2010 signals a change in Hg exposure to eels. Changes in Hg in the food web of downstream reaches may have reduced the eels' exposure to Hg relative to the upstream OV reach; both areas would be subject to ongoing Hg input from upstream sites and aerial deposition. Alternately, the eels collected in the OV reach were sampled earlier in 2010 (June 16^{th}) than in previous years in order to comply with electrofishing restrictions mandated by the State of Maine to protect Atlantic salmon, a federally listed endangered species that migrates up the Penobscot River to spawn in the late summer and fall. As year-round residents, Hg concentrations would not be expected to vary over a period of weeks, but eels in the downstream reaches were sampled 3-4 weeks later in mid-July.

Methyl Hg was significantly lower in the eels from the OV reach in 2009, but not in other years sampled. In most years methyl Hg analyses were done on 10% of the samples analyzed for each site, producing one to two methyl Hg samples per site. In those years, 2007, 2008 and 2010, there was no significant difference in methyl Hg concentrations among sample sites (ANCOVA, adjusted for age, $P > 0.05$). In each of those years the sample size reduced the statistical power of the tests. In 2009 methyl Hg was analyzed on all eel samples collected, creating a sample size large enough effectively analyze methyl Hg concentrations among sites. In 2009 methyl Hg concentrations were significantly lower in eel samples collected at OV5 relative to all sites in the BO and OB reaches (ANCOVA, adjusted for age, $P < 0.001$; Tukey HSD, $\alpha = 0.05$).

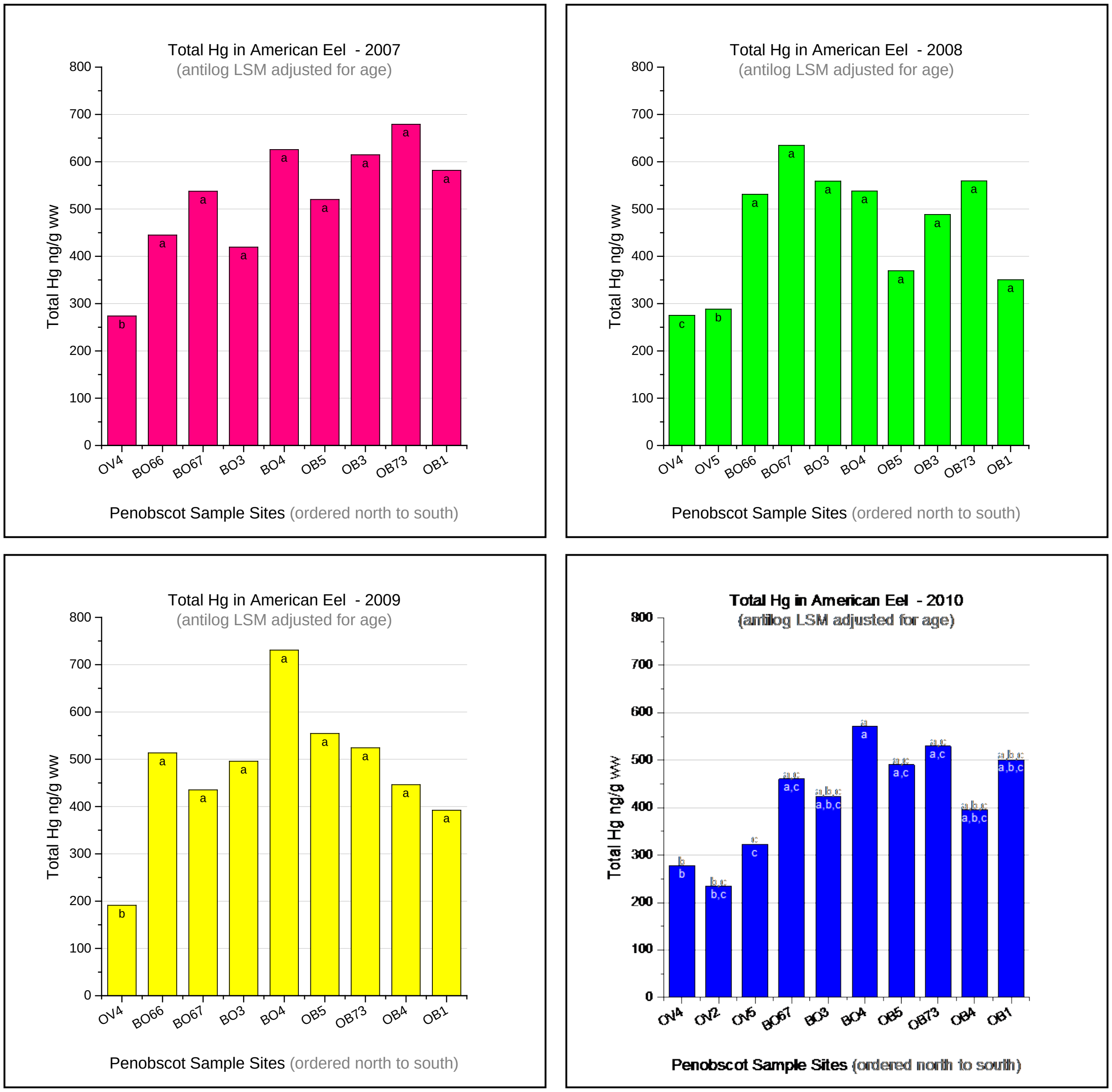


Figure 14-3. A geographic comparison of mean total Hg concentrations (antilog of least squares means adjusted for eel age) in eel muscle at all sites sampled in each year of the study. Letters in each bar define homogenous groups within each year where adjusted Hg concentrations were statistically equivalent.

4.4 American Eel Hg Concentrations and Biota Targets

Most eels sampled in the lower Penobscot River had muscle Hg concentrations greater than the target to protect human health (Chapter 2; 200 ng methyl Hg/g wet wt. action level defined by the Maine Department of Environmental Protection). In this study, the average percentage of total Hg that was methyl Hg for all eels was 88%. Using that value, a total Hg concentration of 227 ng Total Hg/g wet wt. or greater exceeds the target of 200 ng methyl Hg/g wet wt. In the BO and OB reaches, 95% of eels sampled between 2007 and 2010 had total Hg concentrations that exceeded the Maine methyl Hg action level (Table 2). A lower percentage (74%) of the eels sampled in the OV reach exceeded this level.

Table 2. The percent of fish and shellfish samples exceeding Hg targets to protect fish, predator and human health, and the mean Hg concentrations in muscle for each reach (2006 -2010).

PERCENT of SAMPLES EXCEEDING FISH MERCURY TARGETS (2006 - 2010)					
SPECIES	REACH/ AREA	Total Hg in Muscle ng/g ww	Fish Muscle Hg Target to Protect Human Health 200 ng MeHg/g ww	Fish Muscle Hg Target to Protect Fish Health 500 ng THg/g ww	Whole Fish Hg Target to Protect Fish Predator Health 50 ng MeHg/g ww
American eel	OV	340.3 ± 175.5 (61)	74%	18%	100%
	BO	556.1 ± 265.3 (268)	95%	51%	100%
	OB	504.4 ± 218.5 (200)	94%	41%	100%
Tomcod	BO	277.8 ± 57.3 (13)	80%	0%	100%
	OB	169.0 ± 82.0 (256)	16%	0%	100%
	ES	119.7 ± 45.4 (305)	2%	0%	97%
Rainbow smelt	OB	106.8 ± 60.0 (90)	4%	0%	70%
	ES	70.8 ± 46.8 (480)	2%	0%	27%
Mummichog	BO	195.6 ± 84.7 (44)	30%	0%	100%
	OB	234.4 ± 100.9 (110)	52%	0%	100%
	ES	202.0 ± 110 (3)	3%	0%	100%
Winter flounder	OB	76.4 ± 35.7 (99)	0%	0%	19%
	ES	49.9 ± 38.2 (410)	0%	0%	12%
Lobster	Northern ES	306.9 ± 179.9(127)	90%	15%	NA*
	Southern ES	148.9 ± 82.2 (375)	15%	0%	NA
Mussels	Northern ES	573.4 ± 279.3* (463)	0%	0%	19%
	Southern ES	168.0 ± 89.1* (270)	0%	0%	0%
			* no lobster were sampled in the juvenile age class subject to predation		

Further, all eels, in every reach, had Hg concentrations greater than the target to protect fish predators. Again using the mean % methyl Hg of 88%, and assuming a 25% reduction from muscle to whole body Hg concentrations, a total Hg concentration of 76 ng/g muscle wet wt. would exceed the methyl Hg target to protect predator health of 50 ng/g whole fish wet wt.

4.5 Regional Comparison of Hg in American Eels

Hg concentrations in eels from the lower Penobscot River below Veazie Dam were greater than those in eels from other waters in North America and Europe, after adjusting for size, age and life-stage. Hg concentrations in eels increase with age (Arleny 2007), and the life-stage of the eel indicates the location where the eel was exposed to Hg. Yellow eels are exposed to Hg near their site of capture, while migrating silver eels were exposed at an unknown location upstream of where they were captured. Leaman (1999) reported Hg concentrations in silver eels migrating out to sea from upstream lakes and tributaries and captured near the mouths of three small Maine rivers. The average age of those silver eels was 12-16 years, up to twice as old as the non-migratory yellow eels sampled in the lower Penobscot (6-8 years in OB and BO; 8-11 years of age in OV). Despite this difference in age and lifestage, Hg concentrations in eels from BO and OB reaches were equivalent to the greatest Hg concentrations reported for eels in Leaman (1999), indicating greater Hg exposure for eels residing along the lower Penobscot River.

Hg concentrations in eels in the lower Penobscot River exceed levels reported in European eels (*Anguilla anguilla*), except for notably larger eels sampled near Liverpool, England at a site historically contaminated by the chlor-alkali industry. Total Hg levels in the European eel ranged from 60 ng/g wet wt. in the Tiber River in Italy and 160 ng/g in Bosnia and Herzegovina (Mancini et al. 2005, Has-Schön et al. 2008) to 310 ng/g in estuarine waters with industrial Hg sources along the coast of France (Arleny et al. 2007). The greatest mean levels were reported in eels sampled in the early 1990s in the Mersey Estuary near Liverpool, where Hg reached 1,350 ng/g wet wt. in eels exceeding 500 mm in length. The larger size of eels from the Mersey Estuary precludes a direct comparison with Hg levels in the smaller Penobscot River eels.

4.6 Eel Summary

Hg concentrations in Penobscot eels did not significantly increase or decrease in the four years monitored (2007 – 2010). Within all years, Hg concentrations in eels from the BO and OB reaches, areas under direct aquatic influence from the HoltraChem facility, were significantly greater than in eels sampled in the OV reach, upstream of the Veazie Dam. Muscle Hg concentrations in virtually all eels (95%; mean Hg 416 – 593 ng/g wet wt.)) in the contaminated reaches of BO and OB, and in 74% of the eels in the upstream OV reach (mean Hg 223 – 320 ng/g wet wt.), exceeded the Hg target to protect human health (200 ng/g wet wt.; Chapter 2).

5 ATLANTIC TOMCOD (*Microgadus tomcod*)

5.1 Tomcod Biology

Tomcod are year-round residents of estuaries, except for short upstream migrations to freshwater during the winter for spawning. Historically, tomcod were harvested by commercial fisheries; they are now caught by sport fishermen during the fall months. In the Northeast the diet of adult tomcod includes polychaete worms, amphipods, small decapod crustaceans and *Crangon* shrimp (Stewart and Auster 1987; Collette and Klein-McPhee 2002). Our analyses of tomcod stomach contents in September of 2009 had similar findings. *Crangon* shrimp and fish remains comprised the largest part of the tomcod diet in the OB reach, while in the ES reach near Verona Island their diet was roughly split between *Crangon* shrimp and pelagic Mysid shrimp (see Chapter 16).

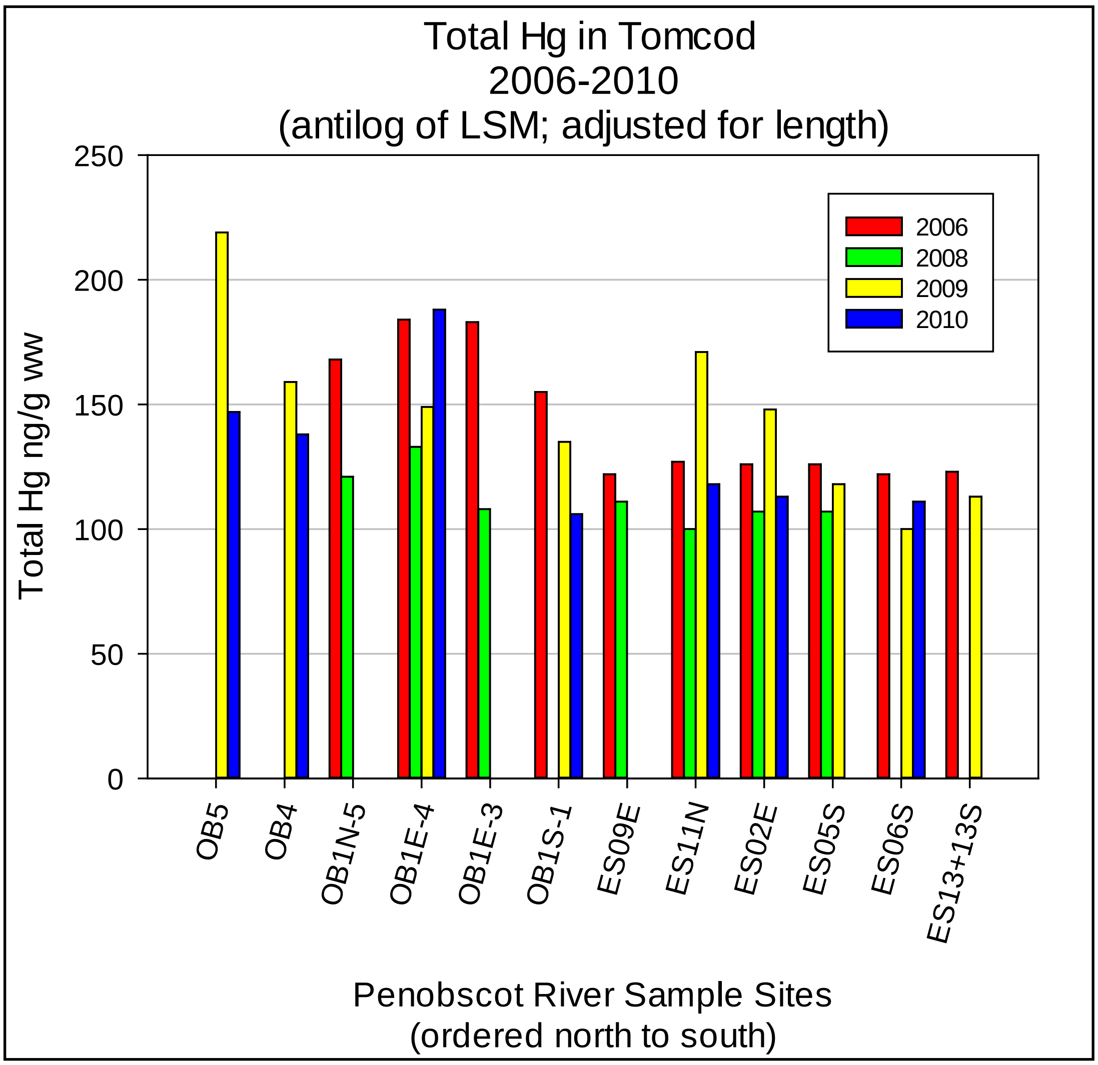


Figure 14-4. A temporal comparison of mean Hg concentrations (antilog of least squares means adjusted for fish length) in tomcod within individual sites that were sampled in multiple years. Significant declines in Hg concentrations were found at one site sampled in three or more years, OB1S-1.

5.2 Temporal Comparisons of Hg in Tomcod

There was a significant decline in total Hg concentrations in tomcod at one site in the OB reach (Figure 14-4). Only two sites were sampled in three or more years and, of those, OB1S-1, was found to have a significant decline in Total Hg concentrations between 2006 and 2010. Three other sites, all located upstream, had declining Hg concentrations, but the results are suspect. At OB5, OB1N-5 and OB1E-3, samples were collected in only two years and may represent natural variation in Hg concentrations rather than a meaningful trend over time. Further, the site OB1E-4, which lies directly between OB1N-5 and OB1E-3, was sampled in all four years of monitoring, and had no trend in total Hg over time. No sites in the ES reach had any significant trend in total Hg concentrations.

5.3 Geographic Comparisons of Hg in Tomcod

In most years, total Hg concentrations in tomcod muscle were significantly greater at the sites closer to the HoltraChem facility relative to sites toward the southern end of the sample area (Figure 14-5; Appendix 14-2). In 2006, the 12 tomcod sampled in the BO reach, between two and three miles north of the plant site, had a range of total Hg concentrations between 280 and 311 ng/g wet wt. (antilog of LSM, adjusted for length; Figure 14-6), significantly greater than that at all other sites sampled in 2006 (119 – 182 ng/g wet wt., antilog of LSM; ANCOVA, adjusted for length, $P < 0.05$; Tukey's HSD test, $\alpha = 0.05$). In 2008, total Hg in two tomcod sampled at the northernmost sites of OB5 and OB3 (275 – 434 ng/g wet wt., length adjusted) were significantly greater than all tomcod sampled further to the south, from OB1 near the mouth of the Marsh River, to ES05S, on the west side of Verona Island (108-140 ng/g wet wt.; ANCOVA, adjusted for length, Tukey's HSD test, $\alpha = 0.05$). In 2009, the tomcod sampling range expanded up to OB5 to the north and down to the southern tip of Verona Island. The fish sampled in 2009 were significantly shorter (mean length, 123 mm) than those sampled in the other three years (141-159 mm; ANOVA, $P < 0.001$). Total Hg concentrations were significantly different among sites, with a general north to south trend in the data (ANCOVA, adjusted for length, $P < 0.001$, Tukey's HSD test, $\alpha = 0.05$). In 2010, tomcod were again sampled as far north as OB5, and south to ES15S, just west of the southern tip of Verona Island. Samples from ES15S (81 ng/g wet wt., antilog of LSM, adjusted for length) were significantly lower than those at all other sites sampled (118-285, ng/g wet wt., antilog of LSM; ANCOVA, adjusted for length, $P < 0.05$; Tukey's HSD test, $\alpha = 0.05$).

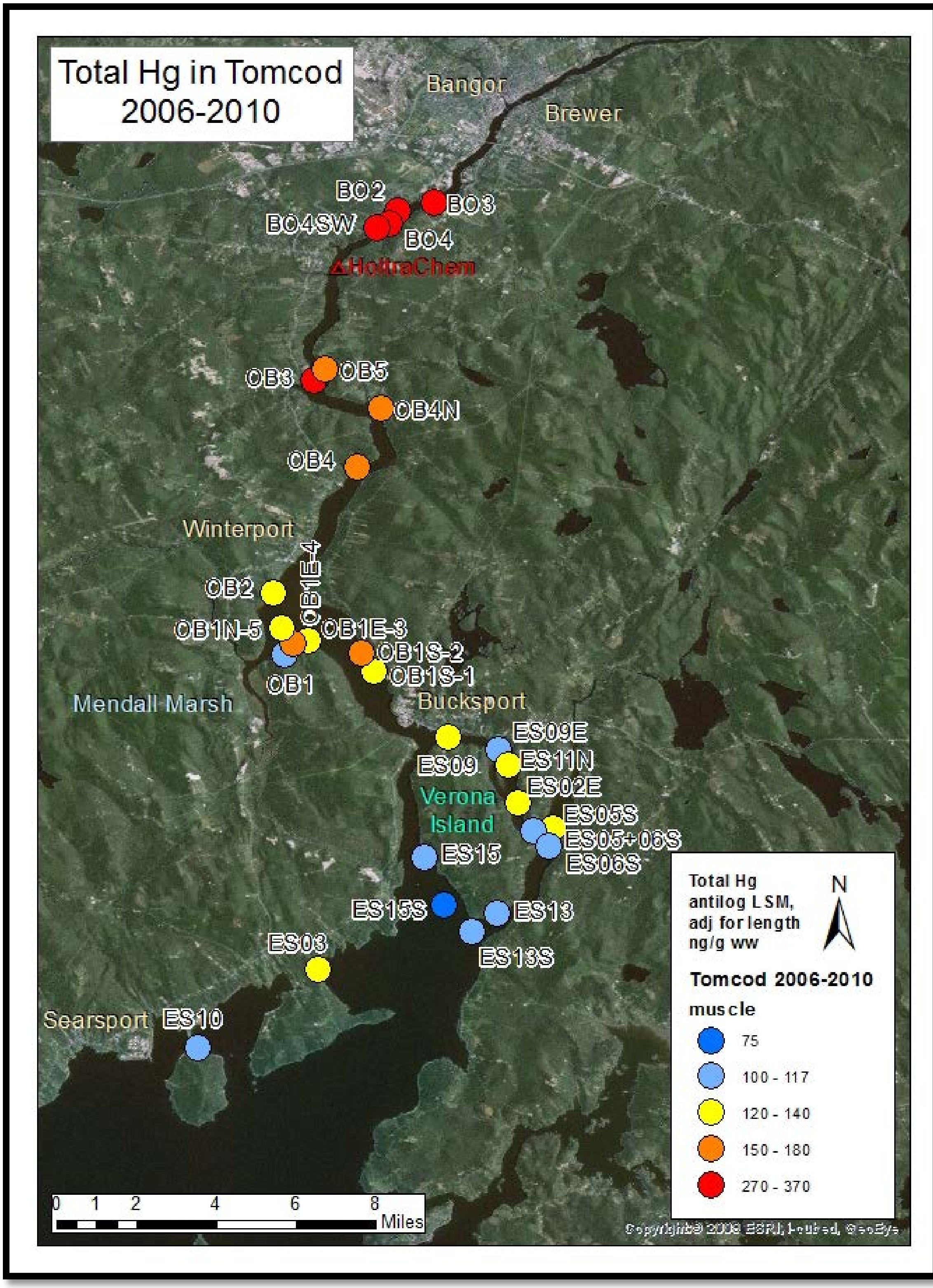


Figure 14-5. Tomcod sampling locations and mean Hg concentrations (antilog of least squares mean, adjusted for fish length) during the entire 5-year monitoring period (2006-2010).

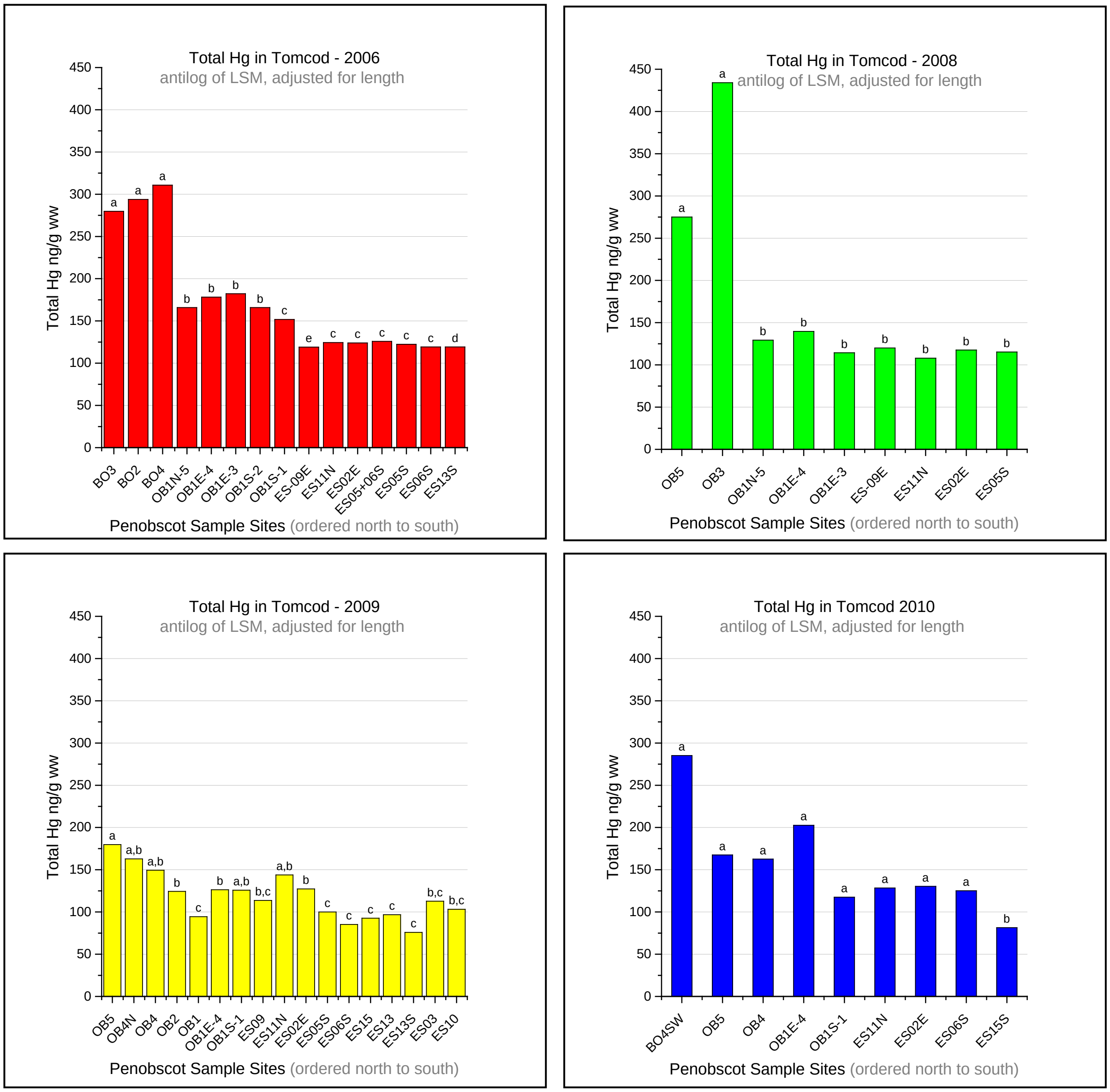


Figure 14-6. A geographic comparison of mean total Hg concentrations (antilog of lease squares means adjusted for fish length within each year) in tomcod muscle at all sites sampled within each year of the study. Letters above each bar define homogenous groups where adjusted Hg concentrations were statistically equivalent.

Methyl Hg concentrations in tomcod were also compared among the sites sampled each year, but in most years, power was not sufficient for meaningful analyses of variation in methyl Hg concentrations due to the small number of samples analyzed for methyl Hg from each site (n = 1 – 3). However, in 2009, a greater number of samples were analyzed for methyl Hg (n = 2 – 6 per site), and the ANCOVA was not significant (P = 0.06).

5.4 Tomcod Hg Concentrations and Biota Targets

Most tomcod sampled in the BO reach of the river (80%) exceeded the target for MeHg to protect human health. This calculation used the Maine advisory limit for human consumption of fish of 200 ng/g wet wt. methyl Hg, and converted total Hg to methyl Hg concentrations using the average % methyl Hg value of 83% across all years. In the OB and ES reaches, 16% and 2%, respectively, of the tomcod sampled exceeded this target concentration. Only one tomcod had total Hg concentrations greater than the target to protect fish health, 500 ng/g wet wt.

Almost 90% of the tomcod sampled exceeded the target to protect fish predators. Using the mean % methyl Hg of 83%, and assuming a 25% reduction from muscle to whole body Hg concentrations, a total Hg concentration of 80 ng/g muscle wet wt. would exceed the methyl Hg target to protect predator health of 50 ng/g whole fish wet wt..

5.5 Regional Comparisons of Hg in Tomcod

Hg in tomcod downstream of a Hg-elevated hydroelectric reservoir in Labrador, Canada averaged 170 ng/g wet wt. (Anderson 2011) and Hg in tomcod in the Hg-contaminated Meadowlands (New Jersey) averaged 140 ng/g (Santoro and Koepp 1986). These levels are not as high as the highest Hg concentrations observed in tomcod in the contaminated parts of the Penobscot, but they are similar to concentrations found at sites in the southern portion of the Penobscot sample area (i.e. in the ES reach).

5.6 Tomcod Summary

No overall trend in Hg concentrations in tomcod was found during the five-year monitoring period. Hg concentrations in tomcod declined significantly at one of the six sites sampled in three or more years (OB1S-1). Several other OB sites, sampled in only two years, also had significant declines in Hg in tomcod, but those findings may represent inter-annual variation rather than a meaningful trend. No trends in Hg concentrations were evident in tomcod sampled in the ES reach, even in the area near Verona Island. Within each year, significantly greater Hg concentrations were found at sites closer to the HoltraChem facility than further downstream. Virtually all tomcod, regardless of reach, exceeded the target to protect fish predators.

6 RAINBOW SMELT (*Osmerus mordax*)

6.1 Rainbow Smelt Biology

Rainbow smelt are pelagic and, except for spring spawning migrations, spend their lives in coastal estuarine waters. They are anadromous, spawning during spring ice-out in coastal freshwater streams, and returning to estuarine waters by early May. There is a large spring sport fishery for smelt, primarily using dip-nets during night-time spawning runs. Mature, spawning smelt are two to three years old, and between 125 to 200 mm in length. Smelt are carnivorous, feeding throughout their range on shrimp, amphipods and marine worms when young, and on small fish, including herring and shiners as they mature (Collette and Klein-McPhee 2002). The smelt diet in the Penobscot region during September of 2009 varied by reach, as defined by stomach content analyses (see Chapter 16). In the OB reach, Atlantic herring dominated the diet, with lesser amounts of mysid shrimp eaten. In the ES reach, planktonic shrimp made up 90% of the diet.

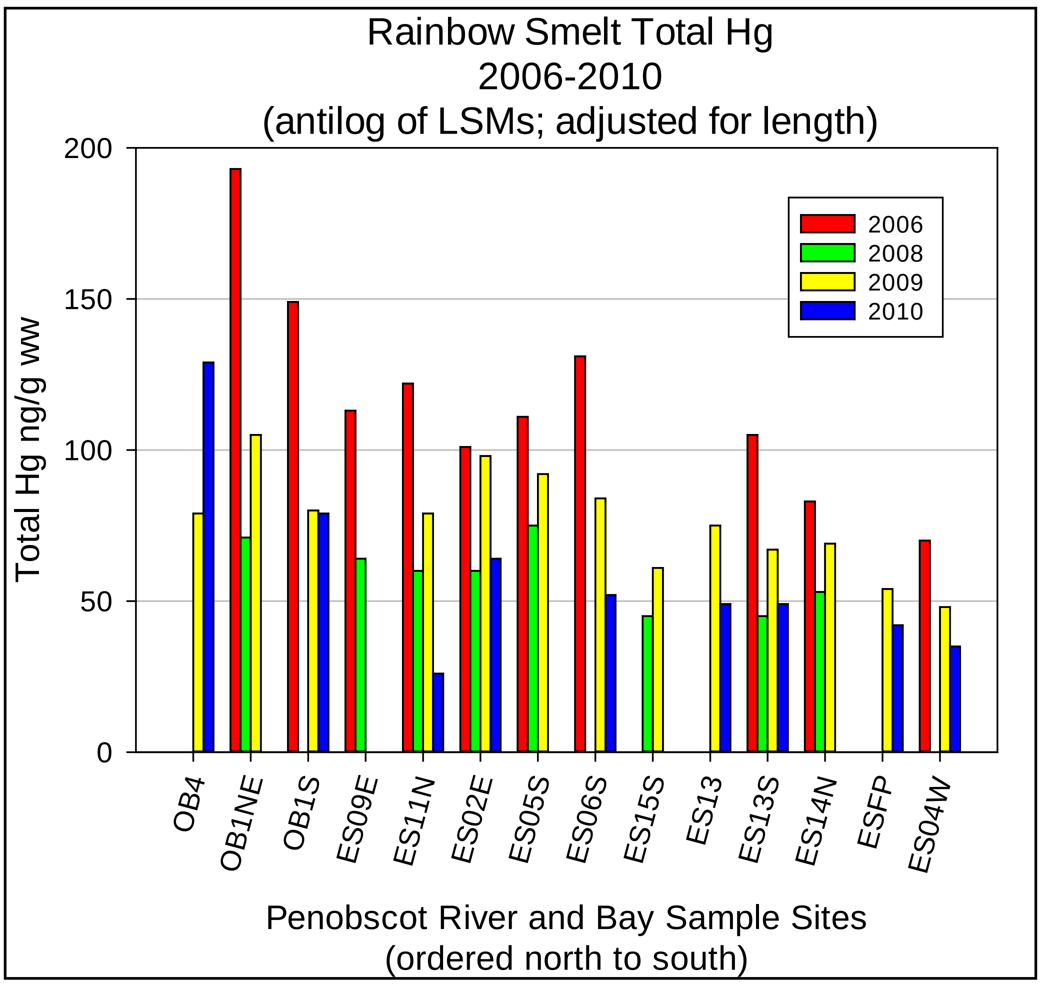


Figure 14-7. A temporal comparison of mean Hg concentrations in rainbow smelt (antilog of lease squares means adjusted for fish length) within individual sites that were sampled in multiple years. Significant declines in Hg concentrations were found at three sites that were sampled in three or more years, ES11N, ES06S and ES13S.

6.2 Temporal Comparisons of Hg in Rainbow Smelt

No overall trend in Hg concentrations was found, though significant declines in total Hg concentrations over time were found at three of the 14 sites sampled in more than one year. Figure 14-7 illustrates the relative concentration of total Hg, adjusted for length, in smelt muscle for sites sampled in two or more years. Solid statistical declines in total Hg concentrations were found at three sites, ES11N, ES06S and ES13S, for which we had 3 or 4 years of data (linear model with site and the year*site interaction as independent variables; adjusted for length, $P < 0.05$). Declines, and one increase, at an additional six sites should be viewed with caution, as they represent only two years of data and in at least one year, relatively small sample sizes, and may indicate interannual variation, rather than a trend over time.

6.3 Geographic Comparisons of Hg in Rainbow Smelt

In all years surveyed, significantly greater total Hg concentrations were found in rainbow smelt from sites generally closer to the HoltraChem facility (Figure 14-8; Appendix 14-3). In 2006, samples collected from the OB reach, and near Bucksport and the mouth of the Orland River were significantly greater than samples from sites further to the south and west (ANCOVA, adjusted for length, $P < 0.001$; Tukey's HSD, $\alpha = 0.05$; Figure 14-9). The OB samples, all from the area near OB1 at the southern end of the reach, ranged from 110 to 210 ng/g wet wt. (length adjusted; antilog of LSM), while at the sites near Searsport (ES04, ES07, ES10), 25 miles to the southwest, total Hg ranged from 44 to 51 ng/g wet wt. (length adjusted; antilog of LSM). In 2008, samples were collected from a smaller area, from OB1 to Fort Point Cove, but still had significantly greater total Hg concentrations at the OB1 sites, and at ES09W, and ES06S, than found at ES03W in Fort Point Cove (ANCOVA, adjusted for length, $P < 0.001$; Tukey's HSD, $\alpha = 0.05$). In 2009 the sample area expanded southwest to ES04 near Searsport and in 2010, north to OB4, and OB5, creating a 32 mile long sample area. In both years total Hg concentrations were significantly different among sites, generally greater at the more northerly sites, with the lowest concentrations in smelt found near Searsport in the southwest corner of the sampled area (ANCOVA, adjusted for length, $P < 0.001$; Tukey's HSD, $\alpha = 0.05$).

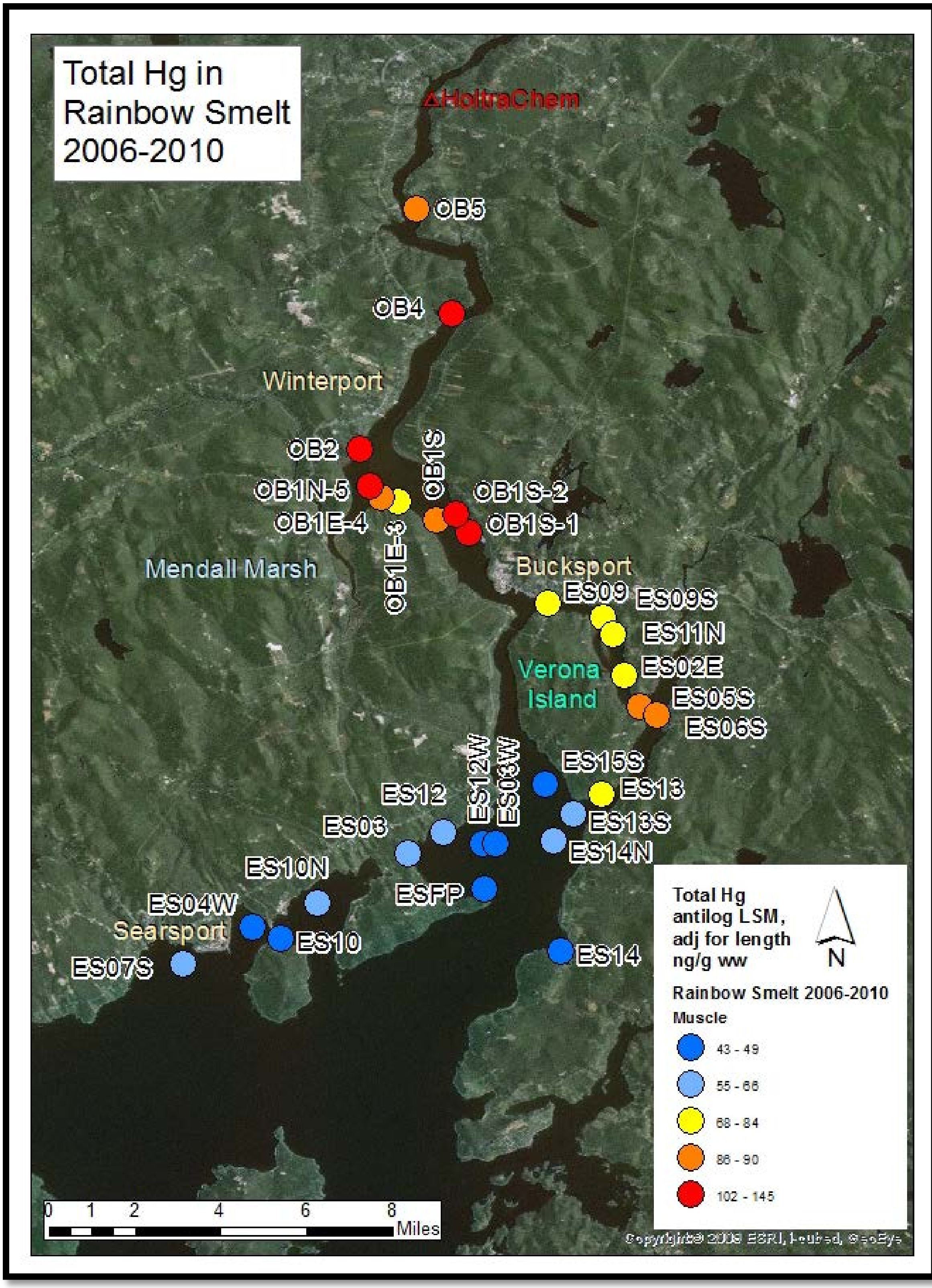


Figure 14-8. Rainbow smelt sampling locations and mean Hg concentrations (antilog of least squares mean, adjusted for length) during the entire 5-year monitoring period (2006 – 2010).

Methyl Hg concentrations were significantly different among sites in only one year, 2009 (ANCOVA, adjusted for length, $P < 0.001$; Tukey's HSD, $\alpha = 0.05$), when sufficient samples sizes allowed a statistical comparison to be made. Again, methyl Hg concentrations were significantly greater at the more northern sites, though there was not a clear geographic distinction among sites at the southern end of the more contaminated area. Small sample sizes in other years prevented a meaningful comparison.

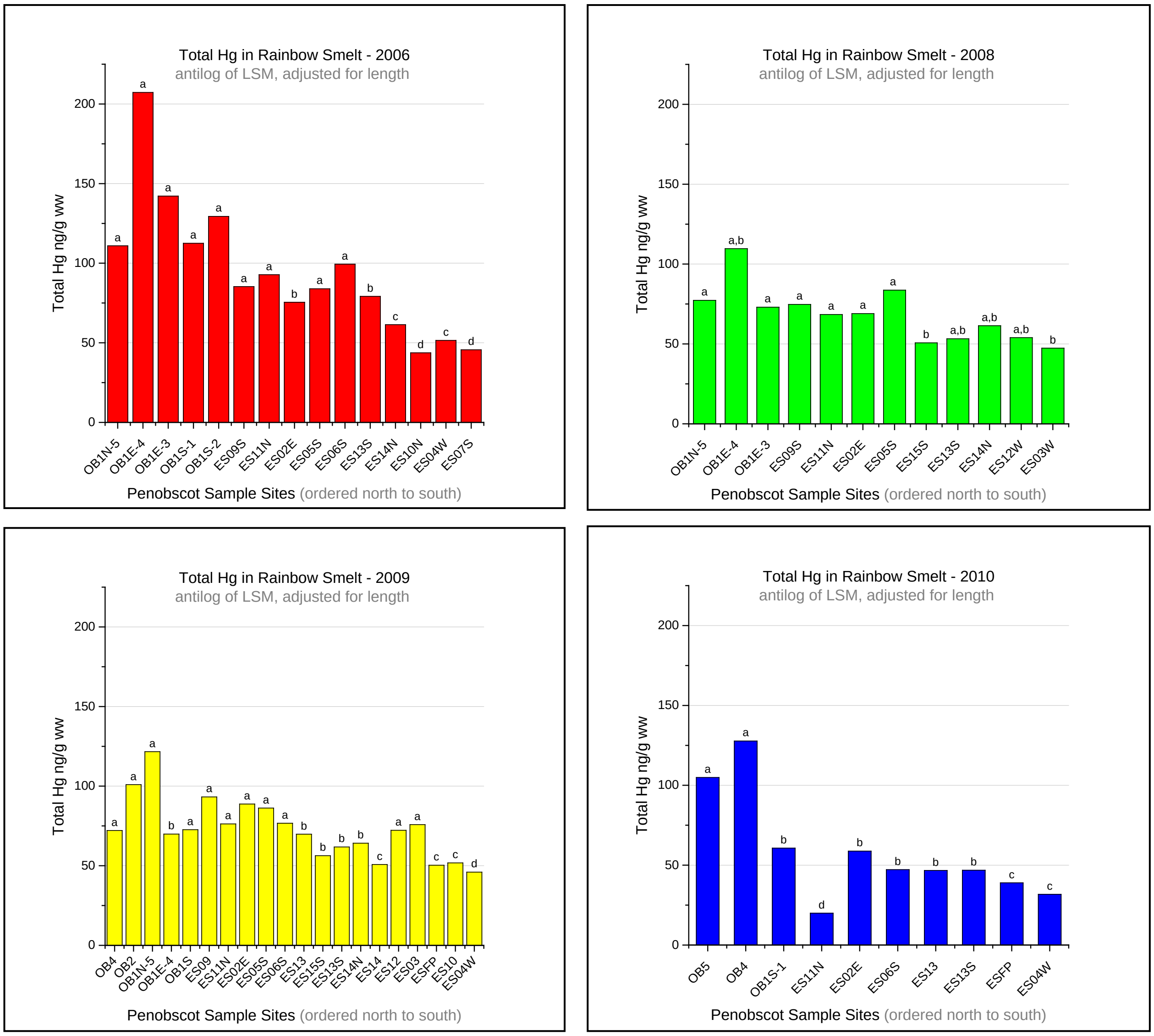


Figure 14-9. A geographic comparison of mean total Hg concentrations (antilog of least squares mean ,adjusted for fish length within each year) in muscle from rainbow smelt at all sites sampled in each year of the study. Letters above each bar indicate homogenous groups in which adjusted Hg concentrations are statistically equivalent within each year.

Note that all sites sampled in 2006 had greater Hg concentrations than found in subsequent years at the same site. This may indicate that in 2006, six years after the plant closed, Hg exposure was greater than in later years. Alternately, greater Hg concentrations in 2006 may be linked to changes in the smelt diet as they grow from juveniles to adult fish (i.e., ontogenetic changes). As stated, the diet of younger fish includes benthic worms and amphipods (Collette and Klein-McPhee 2002) which may have relatively greater Hg concentrations than pelagic prey. The fish sampled in 2006 had an average length of 70 ± 19 mm, and no fish sampled in 2006 exceeded the reported minimum length of adult fish of 125mm. In contrast, larger fish were sampled in 2008 through 2010, with mean lengths ranging from 100 mm to 130 mm, with 25 to 40% of the fish sampled exceeding the minimum adult length of 125 mm. A pelagic diet was found in rainbow smelt sampled in 2009 as part of the food web study. Hg exposure in the smaller, younger fish sampled in 2006 may have been greater due to a diet including benthic organisms, relative to the larger, older fish caught in later years that are expected to feed primarily on pelagic prey.

6.4 Rainbow Smelt Hg Concentrations and Biota Targets

The Hg concentrations in rainbow smelt do not represent a risk to human health as, across all years, less than 2% of the smelt sampled had Hg concentrations greater than the defined target to protect human health (200 ng methyl Hg/g wet wt.; Table 2). For smelt, this target was the equivalent of a total Hg concentration of 250 ng/g, based on an average of 80% methyl Hg in muscle (range 72% in 2009 to 95% in 2010).

Roughly a third of the rainbow smelt sampled pose a risk to predatory fish due to Hg accumulations in their body. Again, using the mean of 80% methyl Hg in rainbow smelt and assuming a 25% reduction from muscle to whole body Hg concentrations, a muscle total Hg concentration of 79 ng/g is equivalent to the target of 50 ng methyl Hg/g wet wt. whole fish to protect predator health. Overall, 34% of the rainbow smelt had total Hg concentrations greater than this concentration. The fish exceeding this total Hg concentration varied among years, from 46% in 2006 to 18% in 2010, possibly reflecting the ontogenetic changes in diet mentioned previously, as younger fish were sampled in 2006. If this is the case, it would mean that younger rainbow smelt pose a greater threat to predatory fish than older, larger smelt.

6.5 Regional Comparisons of Hg in Rainbow Smelt

Total Hg concentrations in rainbow smelt in the OB reach of the Penobscot were about 70 to 190 ng/g wet wt. This range can be compared to an average of 60 ng/g wet wt. in 25 lakes in central Canada (Swanson et al 2006), although methyl Hg exposure of lake populations would be expected to be greater than Hg exposure of river populations. Thus, Hg concentrations in smelt from a contaminated section of the Penobscot were higher than has been observed in freshwater lakes.

6.6 Rainbow Smelt Summary

Hg concentrations in rainbow smelt did not change at the majority of sites sampled, however significant declines were found at 3 of the14 sample sites, ES11N, ES06S and

ES13S, all on the east side of Verona Island. Similar declines, and one increase, in Hg concentrations at an additional 6 sites should be viewed with caution as they were each sampled only twice during the study and may represent year-to-year variation rather than a trend. Geographically, Hg concentrations generally declined with distance from the HoltraChem facility. Hg accumulations in our sample of rainbow smelt did not represent a direct risk to humans, less than 2% exceeded the target to protect human health, while 34% of the smelt sampled posed a risk to fish predators.

7 MUMMICHOG (*Fundulus heteroclitus*)

7.1 Mummichog Biology

Mummichogs are a small, minnow-like fish common in tidal streams, marshes and near-shore areas. They have strong site fidelity during the summer months, moving up onto the marsh platform during flood tides to forage on the marsh surface, and returning to tidal channels on the receding tides. They are tolerant of high salinity and low dissolved oxygen concentrations and may remain on the marsh platform in pannes, small pools of water common on the lower Penobscot marshes. Mummichogs feed on annelid worms, snails, slugs and small crustaceans. During the winter they likely move to deeper waters although in southern New Jersey they were found to bury into the mud at the bottom of marsh pools (Collette and Klein-MacPhee 2002).

In 2006 the *Fundulus* samples collected were reported to be killifish, *F. diaphanous*, a freshwater species found only occasionally in brackish water. In subsequent years the Fundulus were positively identified as mummichogs, *F. heteroclitus*. Since no *F. diaphanous* were collected in 2008-2010, it is now recognized that *F. heteroclitus* were actually sampled in 2006.

7.2 Temporal Comparisons of Hg in Mummichog

There was a significant decline in total Hg concentrations in mummichog at the one site sampled in three or more years (OB1NE; linear model, independent design with pooled variance, $P < 0.005$; Figure 14-10). A decline in Hg concentrations was also found at another site, BO5, although this site was sampled in only two years and may indicate interannula variation rather than a trends in Hg concentrations. Note that OB1NE combines mummichog collected in the designated years from one or more of the adjacent trawl sites of OB1N-5, OB1E-4, or OB1E-3, all of which were located near the mouth of the Marsh River.

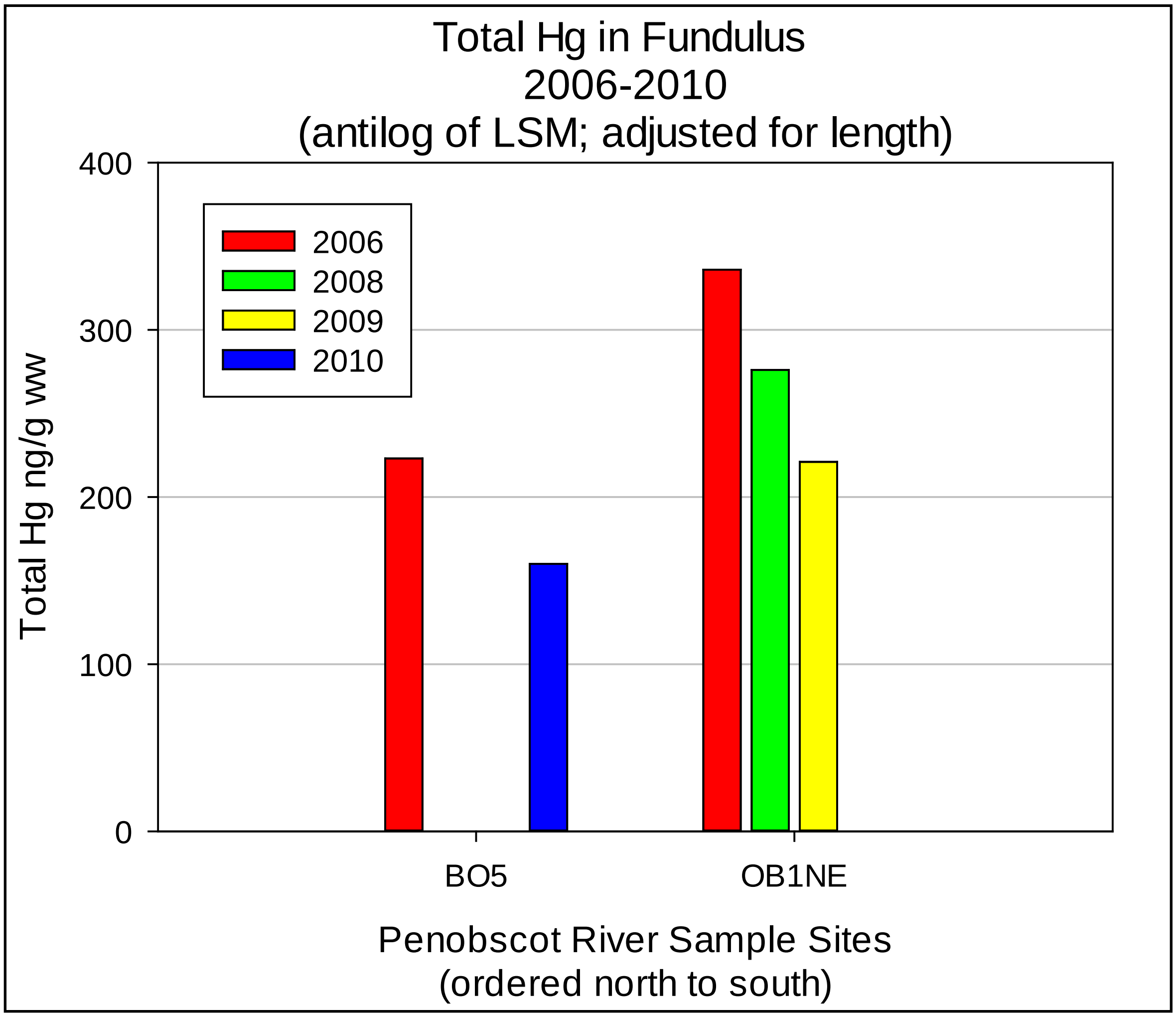


Figure 14-10. A temporal comparison of mean Hg concentrations (antilog of lease squares means adjusted for fish length) in mummichog (*Fundulus*) within individual sites that were sampled in multiple years. A significant decline in Hg concentration was found at one site sampled in three or more years, OB1NE.

7.3 Geographic Comparisons of Hg in Mummichog

No consistent geographic pattern in Hg concentrations was found for mummichog. While we found significant differences in total Hg concentrations in mummichog among sample sites along the lower Penobscot in all years with a sufficient dataset, a clear geographic pattern was not evident. In 2006, samples from BO4, with a mean of 130 ng/g wet wt., were significantly lower than in samples from all other sites (ANCOVA, $P < 0.003$; Tukey's HSD, P $\alpha = 0.05$; Figure 14-12; Appendix 14-4). BO4 is two miles north of the HoltraChem facility. In 2009, the southernmost sites sampled, OB1 and ES13, 15 to 30 miles south of the plant site, with length-adjusted total Hg between 204 and 274 ng/g wet wt., had significantly greater Hg concentrations than OB5 and OB4N, sites 4 to 6 miles south of the plant. In contrast, in 2010, samples from OB5 and W21 (a slough channel within Mendall Marsh), had significantly greater Hg concentrations (length-adjusted means between 275 and 375 ng/g wet wt.) than sites both north (BO5) and south (W17) of the plant site (one mummichog sampled in Southerly Cove, at the plant site, also had a relatively low Hg concentration at 133 ng/g wet wt., length adjusted). This wide geographic variation in Hg concentrations in mummichog may be related to habitat differences among sample sites, especially in 2010 when fish were sampled both from tidal sloughs in marshes and from the main stem of the river.

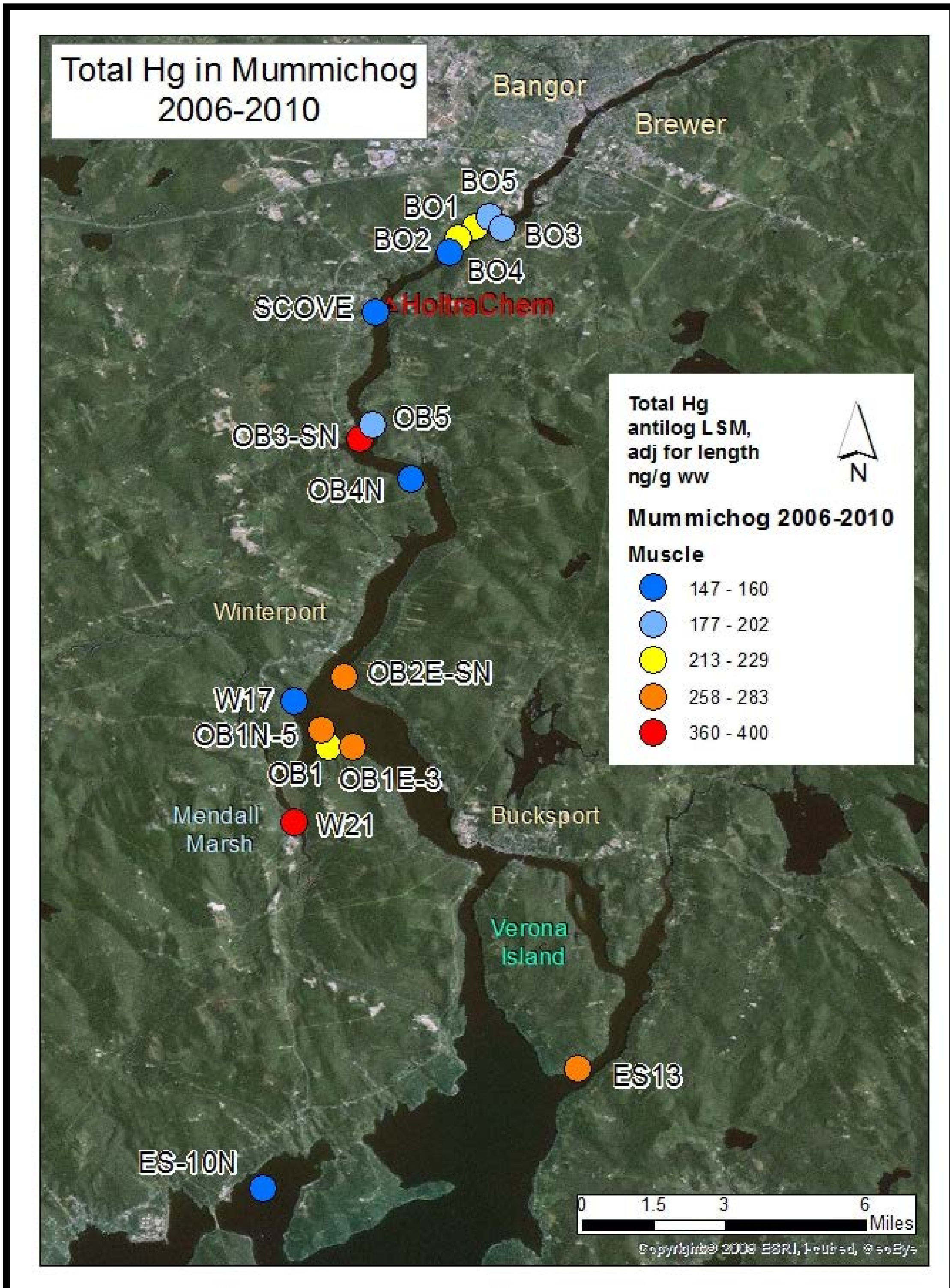


Figure 14-11. Mummichog sampling locations and mean Hg concentrations (antilog of least squares means, adjusted for length) calculated for the entire 5-year monitoring period.

7.4 Mummichog Hg Concentrations and Biota Targets

Almost half of the mummichog sampled in the lower Penobscot River exceeded the methyl Hg target concentration to protect human health (Table 14-2). Given that mummichog had an average percent methyl Hg concentration of 89%, a total Hg concentration of 225 ng/g wet wt. is equivalent to a methyl Hg concentration of 200 ng/g wet wt.. In the combined dataset from all years, 46% of the mummichog sampled exceeded a total Hg concentration of 225 ng/g wet wt. This number varied greatly among years, from 28% to 94%, possibly reflecting the shift in sample locations among years. Only one individual mummichog had a total Hg concentration above the target to protect fish health (500 ng/g wet wt.).

All of the mummichog sampled had Hg concentrations greater than the target to protect predator health. A total Hg concentration of 56 ng/g wet wt. would be the equivalent of 50 ng methyl Hg/g wet wt., at 89% methyl Hg. Assuming a reduction of 25% between muscle and whole fish Hg concentrations, a muscle total Hg concentration of 70 ng/g wet wt. would exceed the whole fish target to protect predator health of 50 ng methyl Hg/g wet wt. All mummichog sampled, 100%, exceed this target concentration. Mummichogs are preyed on by many piscivorous fish and birds.

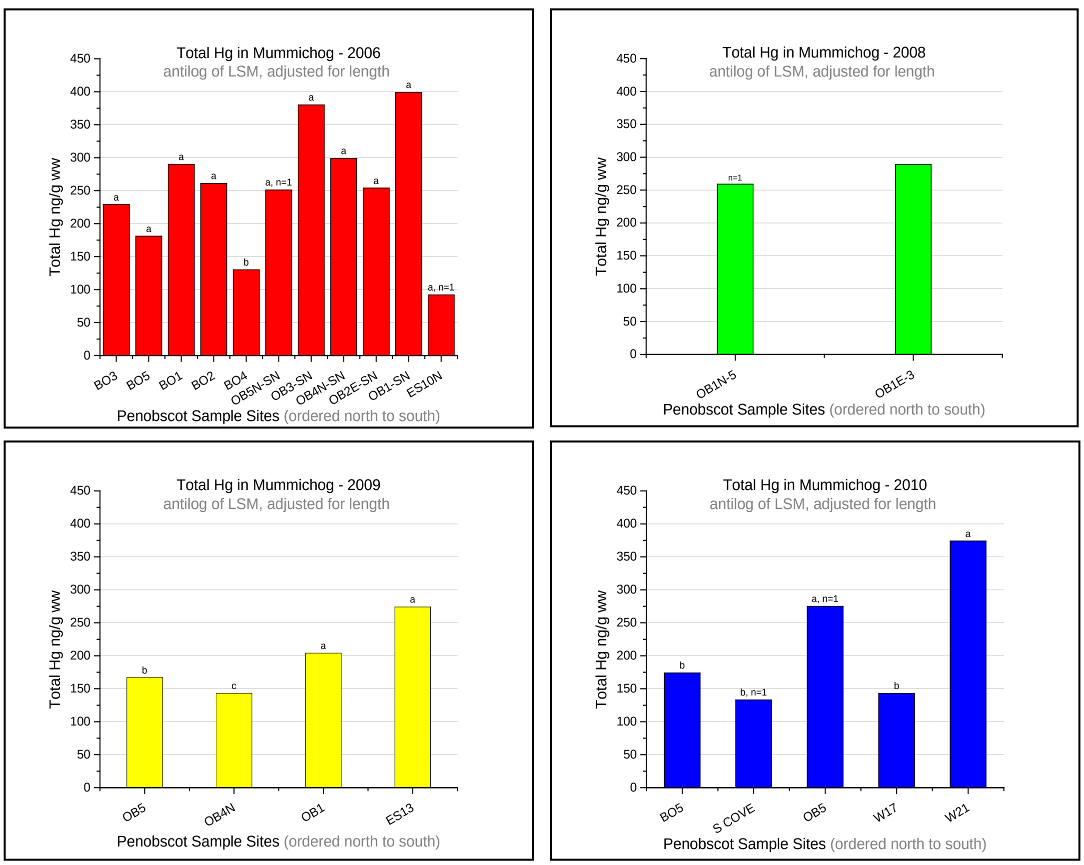


Figure 14-12. A geographic comparison of mean total Hg concentrations (antilog of least squares means adjusted for fish length within each year) in mummichog muscle at all sites sampled in each year of the study. Letters above each bar, if present, define homogenous groups in which adjusted Hg concentrations were statistically equivalent within each year.

7.5 Regional Comparisons of Hg in Mummichog

Hg concentrations in mummichogs in the Penobscot were 4 to 10 times greater than reported for composite samples of mummichogs (whole-body) collected in the lower Passaic River (New York, New Jersey), an area known for industrial and urban contamination (Ianuzzi et al. 2004).

7.6 Mummichog Summary

Trends in Hg concentrations over time were difficult to assess in mummichogs due to sampling limitations. Mummichog from the one site sampled in three or more years had a significant decline in Hg concentrations. Mummichog had no consistent geographic trend in Hg concentrations in relation to HoltraChem. Hg concentrations exceeded the target to protect human health (200 ng/g wet wt., Chapter 2) in almost half of the mummichog sampled, and all of the mummichog had accumulated Hg in excess of the target to protect fish predators (50 ng/g wet wt., Chapter 2). Mummichog are a common forage (prey) fish to many fish and birds.

8 WINTER FLOUNDER (*Pleuronectes americanus*)

8.1 Winter Flounder Biology

Winter flounder, a common flat-fish in the Gulf of Maine, have strong site fidelity, especially in younger age classes, and small foraging ranges that combine to create many independent stocks along the Gulf of Maine coast. They prefer a muddy sand bottom where they bury themselves up to their eye stocks, but may also inhabit sand or pebbly substrates (Collette and Klein-MacPhee 2002). Their diet is limited by their small gape and is dominated by benthic polychaete worms and amphipods (Bowman et al. 2000), especially in the smaller fish, those less than 160 mm long, that make up the majority of winter flounder sampled in this study.

In our data set, winter flounder length, and so age, varied significantly among all years (ANOVA, $P<0.001$; Tukey's HSD, $\alpha = 0.05$). The smallest fish, sampled in 2006, had a mean length of 61 mm and so were young of the year that hatched during the spring spawning in April or May (using the age and growth curves published for this species from Georges Bank (Pentilla et al. 1989). The largest fish, sampled in 2008 and 2009, mean length of 120 and 126 mm, respectively, were primarily age 1 fish, while the 2010 sample was again primarily young of the year fish, with a mean length of 97 mm.

8.2 Temporal Comparisons of Hg in Winter Flounder

We found no overall change in Hg concentrations in winter flounder over time. Flounder from one site, out of seven sites sampled in three or more years, had a significant increase in Hg concentrations. OB1E-4, sampled in 2008 through 2010, had a significant, steady increase in total Hg, from 45 to 95 ng/g wet wt. (independent ANOVA, adjusted for length, with pooled variance, $P < 0.001$; Figure 14-13). ES06S, on the east side of Verona Island at the mouth of the Orland River, had a significant decline in Hg concentrations, but as that site was sampled in only two years this finding may only indicate interannual variation. All other sites had statistically equivalent Hg concentrations throughout the sample period, although nine of the sixteen sites were sampled in only two years.

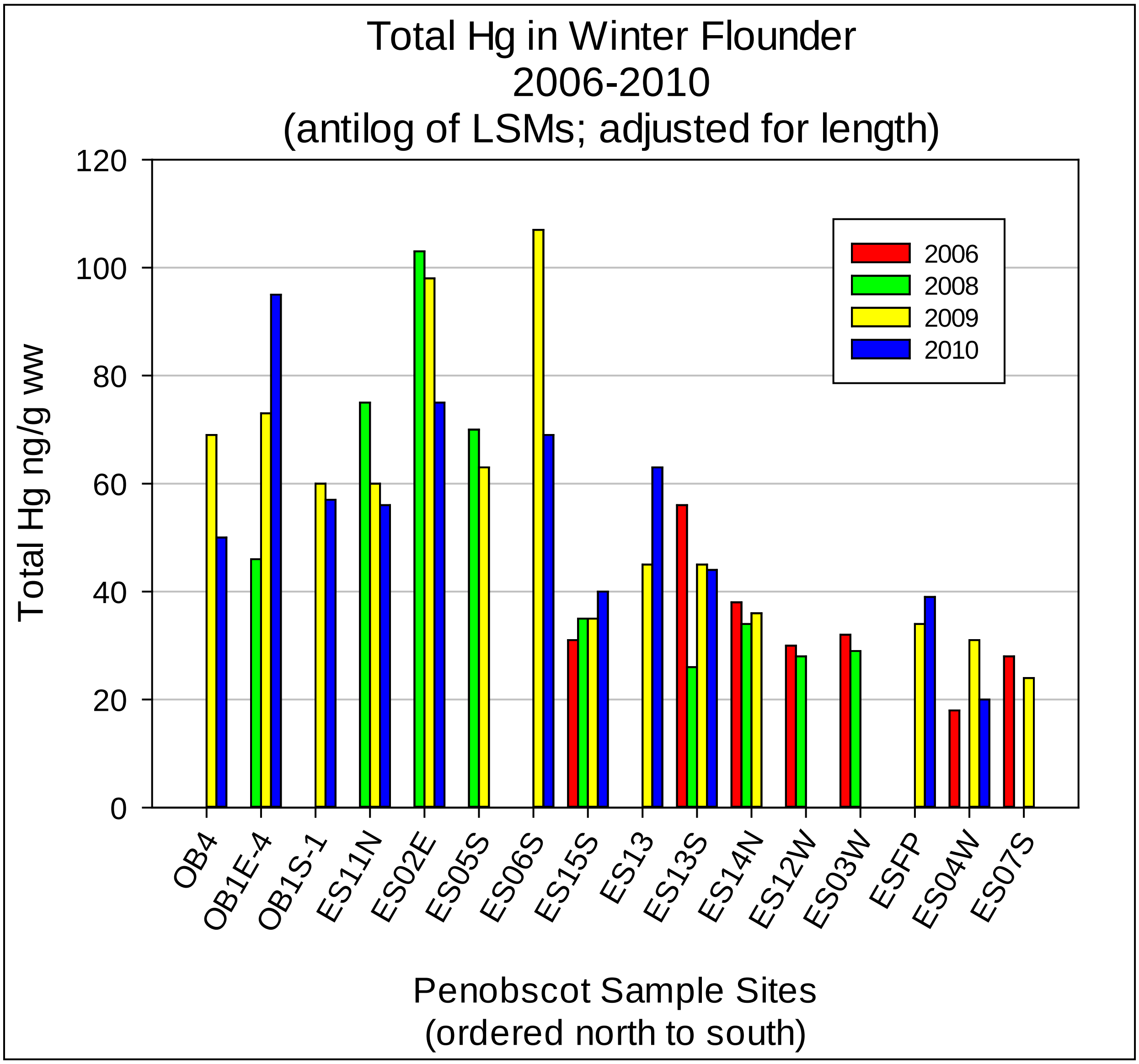


Figure 14-13. A temporal comparison of mean Hg concentrations in winter flounder (antilog of least squares means adjusted for length) within individual sites which were sampled in multiple years. A significant decline in Hg concentration was found at one site sampled in three or more years, OB1E-4.

8.3 Geographic Comparison of Hg in Winter Flounder

Significant geographic differences in total Hg concentrations were found in winter flounder among sites sampled throughout the Penobscot region in 2006 and 2007 – 2010 (Figure 14-14; Appendix 14-5). Within individual years, the sites with the greatest total Hg concentrations varied between the northern-most sites in the OB reach and the sites on the east side of Verona Island (Figure 14-15). In 2006, when small young-of-the-year flounder were sampled, there was a clear geographic pattern in total Hg, with significantly greater total Hg in the northern-most samples, which were collected from the cluster of trawl sites on the northern edge of Ft. Point Cove (ES15S, ES13S and ES14N; 30 – 39 ng/g wet wt., length adjusted). Progressively lower concentrations were found in flounder samples collected from sites to the south and west. In 2008, the collection area expanded north, average fish length increased to a grand mean of 119 mm, and the geographic pattern shifted with total Hg in winter flounder greater from sites on the east side of Verona Island, relative to sites to the north and south. Flounder from four sites on the east side of Verona had total Hg concentrations ranging from 73 to 106 ng/g wet wt., length adjusted, significantly greater than from trawl sites near OB1 (46-57 ng/g wet wt., length adjusted), and sites in Ft. Point Cove (27-36 ng/g wet wt., length adjusted; ANCOVA, adjusted for length, $P < 0.001$; Tukey HSD, $\alpha = 0.05$). Larger winter flounder were sampled in 2009, with a mean length of 126 mm, and total Hg concentrations were greatest in the OB reach and the upper ES reach around Verona Island. Total Hg concentrations in this more northern area ranged from 120 ng/g wet wt., length adjusted, at OB2, to 46 ng/g wet wt., length adjusted, at ES13, at the southern tip of Verona Island, and ES14, again the exception further to the south. These concentrations were significantly greater than those in flounder at the majority of sites in Ft. Point Cove and at sites to the west near Searsport (25-44 ng/g wet wt., length adjusted; ANCOVA, adjusted for length, $P < 0.001$; Tukey's HSD test, $\alpha = 0.05$). In 2010 smaller, younger winter flounder (mean length 97 mm) were again sampled, the sample area expanded north to OB5, and the greatest total Hg concentrations were found in the central portion of the sample area. As in 2008, the greatest total Hg concentrations were found at the OB1 site closest to the mouth of the Marsh River, 91 ng/g wet wt., length adjusted, and down the east side to Verona Island to ES13, at 60 ng/g wet wt., length adjusted. Total Hg at these sites were significantly greater than in winter flounder sampled further north at OB4 and OB5, 46-48 ng/g wet wt., length adjusted, and to the south near Bucksport and down in Ft. Point Cove, 20-42 ng/g wet wt., length adjusted; ANCOVA, length adjusted, $P < 0.001$; Tukey's HSD, $\alpha = 0.05$).

Note that Figure 14-15 appears to show an increase in total Hg concentrations in the later years of the study. This is not the case, as the sample area expanded in later years to include more sites in the northern part of the study area, often closer to the HoltraChem facility. As seen in Figure 14-13, which illustrates the relative total Hg concentrations in winter flounder across all years and sites, the lower concentrations found in 2006 (red bars) reflect sample sites below Verona Island.

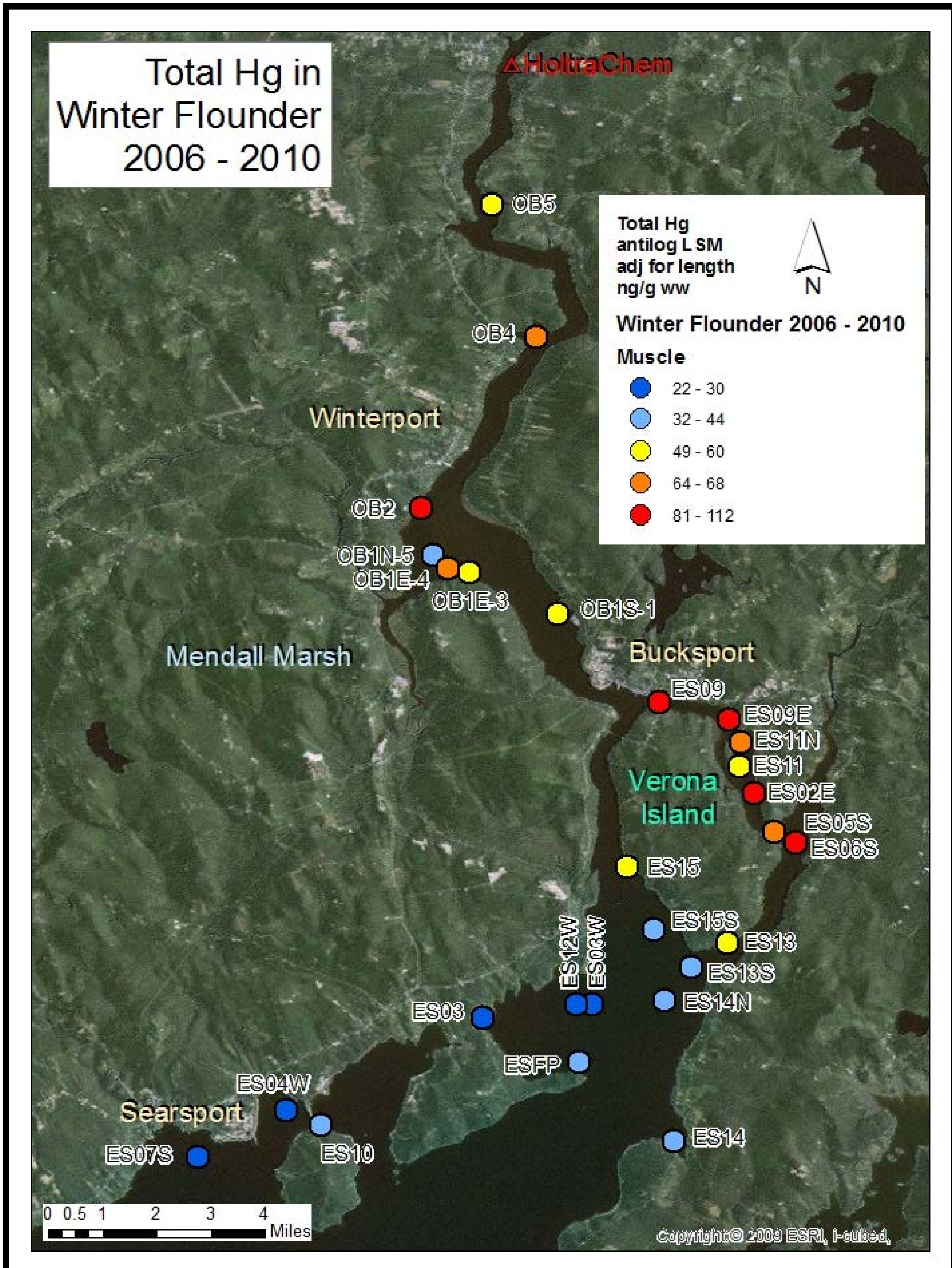


Figure 14-14. Winter flounder sampling locations and mean Hg concentrations (antilog of least squares means, adjusted for fish length)calculated for the entire 5-year monitoring period (2006 – 2010).

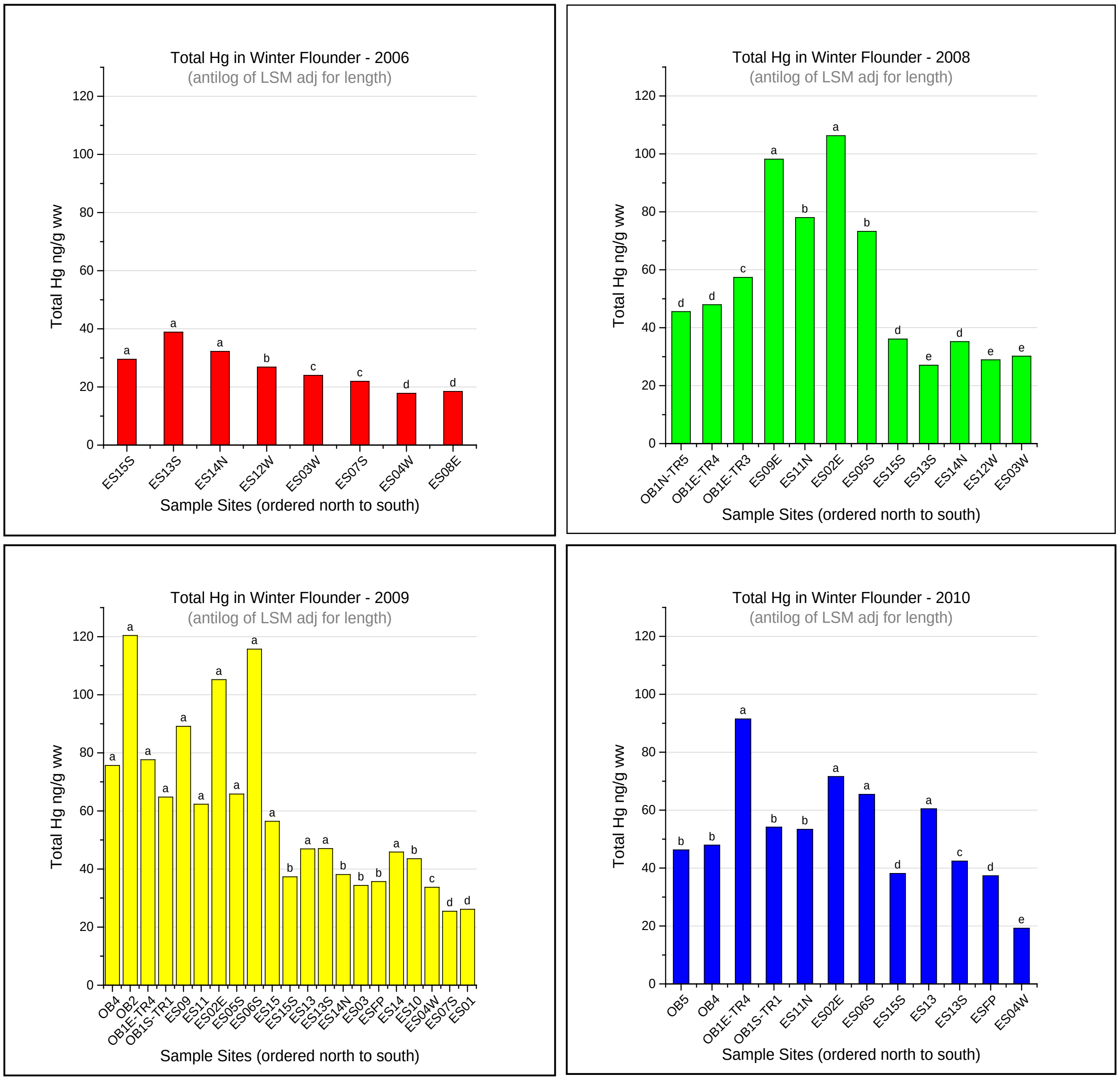


Figure 14-15. A geographic comparison of mean total Hg (antilog of least squares means adjusted for fish length) in winter flounder muscle at all sites sampled in each year of the study. Letters in each bar define homogenous groups where adjusted Hg concentrations were statistically equivalent.

8.4 Winter Flounder Hg Concentrations and Biota Targets

Total Hg concentrations were low in the winter flounder sampled in this study, relative to the other species monitored in the Penobscot, but likely do not reflect Hg concentrations in legal-sized flounder consumed by sport fishermen. In Maine the minimum legal size for winter flounder is 305 mm, generally age 3 fish, whereas the majority of fish caught were young-of-the-year or age-1 fish, with mean lengths between 61 and 126 mm; only one fish sampled in four years was of legal size. Total Hg concentrations in our samples of (mostly) young-of-the-year and age-1 winter flounder were well below the State of Maine action level of 200 ng methyl Hg/g wet wt. (270 ng total Hg/g wet wt., given the average of 74% methyl Hg). Similarly, no winter flounder sampled in this study exceeded the 500 ng Total Hg/g wet wt. concentration designed to protect fish health (Table 14-2; Chapter 2). The concentrations reported in this study do not reflect concentrations in winter flounder consumed by humans.

However, winter flounder are eaten by numerous benthic foraging fish, and the Hg concentrations in these small flounder may pose a threat to predator health. Winter flounder are prey to 11 species of fish in the Gulf of Maine, from cod, hake and striped bass, to dogfish and skates (Bowman et al, 2000), and prey to seals and pisciverous birds. The whole fish Hg concentration designed to protect predator health is 50 ng methyl Hg/g wet wt. Assuming a 25% reduction in Hg between muscle and whole fish concentrations, a muscle concentration of 67 ng methyl Hg/g wet wt. is protective of predator health. Given that, and a %methyl Hg concentration of 74%, the total Hg concentration in winter flounder muscle to protect fish predator health would be 91 ng/g wet wt. This muscle concentration was exceeded in 2% of the samples in 2006, 10% in 2010 and in 20% of the samples collected in 2008 and 2009, when older flounder were sampled.

8.5 Regional Comparison of Hg in Winter Flounder

Hg concentrations in winter flounder from the Penobscot study area were equal to or up to 6 times greater than reported for other contaminated areas. Hammerschmidt and Fitzgerald (2006) reported mean methyl Hg concentrations in winter flounder muscle in Long Island Sound of 21 ± 18 ng/g wet wt. These methyl Hg concentrations were over three times lower than found in the more contaminated areas of the Penobscot study area, despite the larger fish (mean length, 236 mm) comprising the Long Island Sound samples. A long-term monitoring study in Boston Harbor reported annual mean concentrations of total Hg in fillets from winter flounder (size not reported) of 40 to 90 ng/g, wet wt. (Kane-Driscoll et al. 2008), equivalent to or lower than found in the OB and upper ES reaches of the Penobscot study area. Similarly, Gerhardt (1977) reported total Hg concentrations in winter flounder muscle from Delaware Bay of 57 ± 29 ng/g wet wt., up to 2 times lower than found in the more contaminated region of the Penobscot sample area. Finally, total Hg concentrations in winter flounder sampled in Frenchman Bay and Schoodic Point, Maine, directly east of Penobscot Bay, but outside of the aquatic influence of the Penobscot River, were a tenth of the levels in flounder from the more contaminated areas of Penobscot Bay. In 2001 samples of winter flounder from Frenchman Bay, Maine averaged 11.1 ± 2.0 ng/g wet wt. in muscle (assuming a 25% increase in Hg from whole fish to muscle samples), and 13.2 ± 4.9 ng/g wet wt. from samples collected at Schoodic Point, for fish averaging 160 to 200 mm in length (Kopec, 2009).

8.6 Winter Flounder Summary

Hg concentrations in winter flounder did not pose a threat to human health in our sample set; however, the flounder in our sample set were much smaller than the legal size limit. Up to 20% of the winter flounder we sampled exceeded the Hg target to protect fish predators. Hg concentrations in winter flounder did not vary over time at most sites, though a significant increasing trend in Hg concentrations was found at one of the seven sites sampled in three or more years. Hg concentrations in winter flounder varied significantly among sites in all years sampled, with the greatest concentrations found at either the more northern sites or those on the east side of Verona Island.

9 AMERICAN LOBSTER (*Homarus americanus*)

9.1 American Lobster Biology

Lobsters are present in most of the ES reach, extending as far north as the southwest side of Verona Island. Seasonal movements of lobsters, onshore during the spring and summer and offshore to deeper water in late fall, may be driven by the need for shelter in ice-free water, though up to half the population may overwinter in inshore areas (Karnofsky et al. 1989, Bowlby et al. 2007). Within seasons, the home range of lobsters may be as small as 760 m^2 or, as reported for the closely related European lobster, extend to 20,000 m^2 (Scopel et al. 2009; Moland et al. 2011). Lobsters prefer a cobble bottom where they can shelter in burrows, and rocky substrates may be associated with longer residence times in winter months (Geraldi et al. 2009). Up to 45% of the lobster diet may come from trap bait, as lobster can move into and out of traps at will (Jury et al. 2001; Grabowski et al, 2010). Their natural diet comes primarily from benthic invertebrates including crabs, mussels, snails, and urchins (Elner and Campbell 1987; Hudon and Lamarche 1989; Grabowski et al. 2010).

Most lobsters sampled in 2006 were below Maine's legal size limit but in the three subsequent collection years roughly 75% of the lobsters sampled were at or above the legal limit of 82 mm (carapace length). Lobsters sampled in 2006, with a mean length of 79 ± 6.1 mm were significantly shorter than collected in 2008-2010 (mean lengths 85 – 87 mm; ANOVA, $P < 0.05$; Tukey HSD test, $\alpha = 0.05$). While carapace length is not a consistent indicator of lobster age across regions, due to variable growth rates in response to water temperature, food availability, and population density, reports indicate that lobsters in this size range are likely 4 to 6 years old (Hughes and Matthiessen 1962, Wahle et al. 1996).

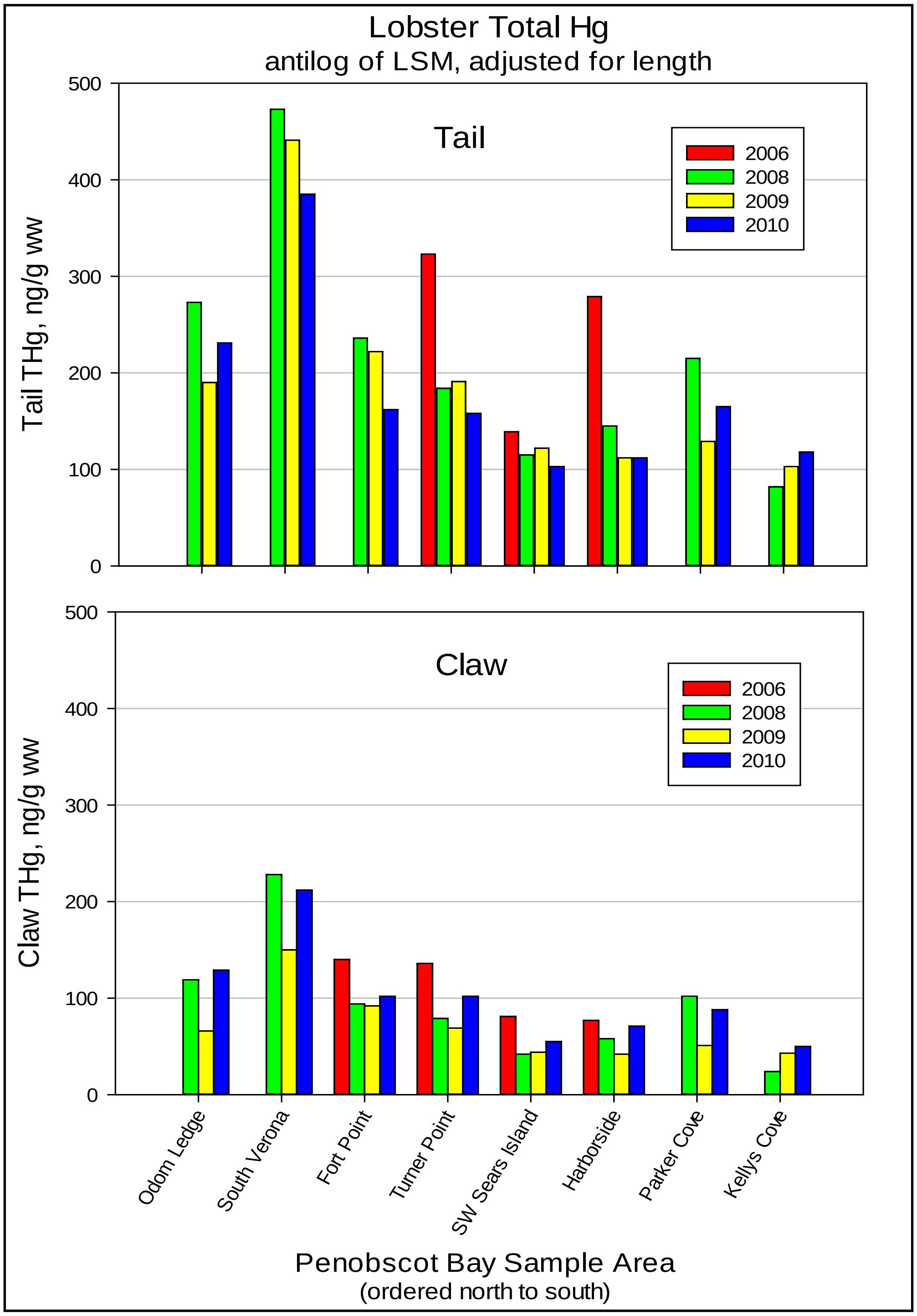


Figure 14-16. A temporal comparison of mean total Hg concentrations in tail and claw muscle (antilog of least squares means adjusted for carapace length) from American lobster from individual sites sampled in multiple years. Significant declines in Hg concentrations were found in tail muscle at two sites and in claw muscle at three sites. One site, Harborside, had significant declines in both tail and claw muscle.

9.2 Temporal Comparisons of Hg in Lobster

There was no significant trend in total Hg concentrations in lobster at the majority of sites monitored in the Penobscot study region. Between 2006 and 2010, there were significant declines in total Hg concentrations in tail muscle at two of the eight sites sampled and for claw muscle at three of the eight study sites (Figure 14-16; Appendix 14-6). Only one site, Harborside, had a significant decline in total Hg in both claw and tail samples. Since claw and tail samples were collected from the same individuals, the statistical declines at the other sites, where total Hg declined in only one tissue, should be viewed with caution as evidence of declines in Hg exposure at those sites. All eight lobster sites were sampled in at least three years, 2008, 2009 and 2010, and four of those sites, located in the center of the study area, were also sampled in 2006. In tail muscle, significant declines over time were found at Fort Point and Harborside (linear model, independent design with pooled variance, $P < 0.01$). Fort Point was sampled in three consecutive years and Harborside in four years between 2006 and 2010. Significant declines in total Hg in claw muscle were found for Turner Point, SW Sears Island and Harborside, all sites which were sampled four times between 2006 and 2010.

9.3 Geographic Comparisons of Hg in American Lobster

In most years we found significant differences in Hg concentrations in lobster in all three tissues sampled consistent with a Hg source originating in the Penobscot River (Appendices 12-6a, tail; 12-6b , claw; 12-6c , tomalley, wet wt.; 12-6d, tomalley, dry wt.). Figure 14-17 illustrates this geographic pattern with the mean Hg concentrations in lobster tail muscle.

In 2006, lobster were collected from only the central portion of the eventual sample area, limiting the contrast in Hg concentrations among more distant sampling sites. Despite this, significantly greater Hg concentrations were found in claw muscle collected from the northwest corner of the sample area, closer to the mouth of the Penobscot River, while Hg concentrations in tail and tomalley samples did not vary geographically. Sample size also influenced this finding; claw samples were analyzed for Hg from all lobster collected ($n = 180$), while tail muscle and tomalley were analyzed in a small subset ($n = 8$). Lobster claws collected from Turner Point (Figure 14-18) had significantly greater total Hg concentrations (128 ng/g wet wt., length adjusted) than found in lobsters from Harborside to the south and SW Sears Island to the west (74 and 76 ng/g wet wt., length adjusted; ANCOVA, adjusted for length, $P < 0.001$, Tukey's HSD test, $\alpha = 0.05$). Lobster from the vicinity of Ft. Point had the greatest mean total Hg concentration in claws, 134 ng/g wet wt., length adjusted, but with a small sample of five individuals, the mean was not statistically different from other sites. Lobster tails were analyzed from three sample areas (Figure 14-19), length-adjusted means ranged from 324 ng/g wet wt. at Turner Point, to 142 ng/g wet wt. at SW Sears Island. These sites had very small sample sizes, from 1 to 5 individuals, and were not statistically different. Tomalley were sampled from the same individuals from which tail were collected, and had no variation in total Hg among the three sites sampled, ranging from 325 to 367 ng/g wet wt., length adjusted (Figure 14-20). In 2006, mean % methyl Hg concentrations in tail (75%) and claw (76%) muscle were notably lower than found in any other year, while the % methyl Hg in tomalley, 56%, was similar to the proportion found in other years.

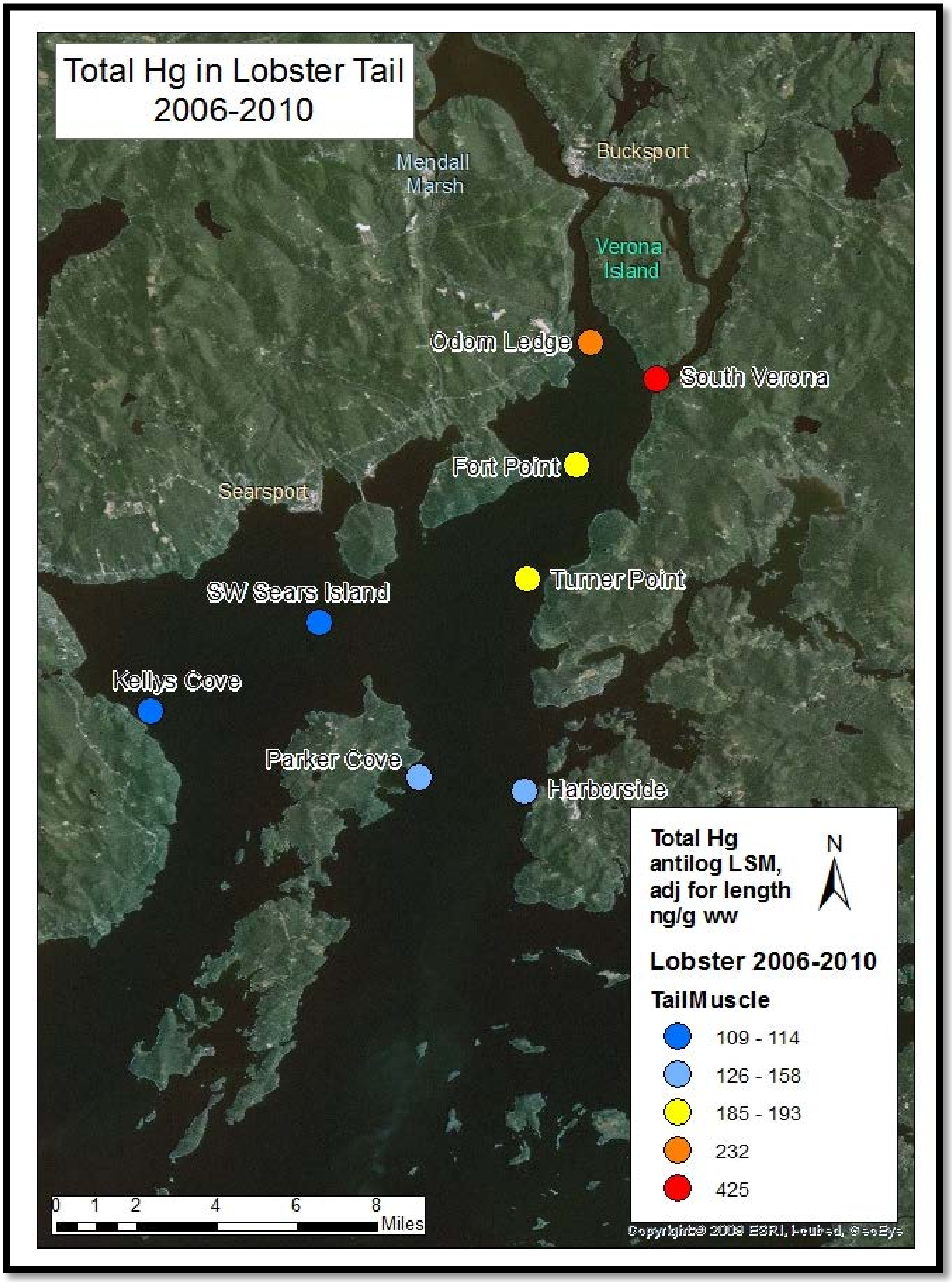


Figure 14-17. Lobster sampling locations and mean Hg concentrations in tail muscle (antilog of least squares mean adjusted for carapace length) calculated for the 5-year monitoring period (2006 – 2010).

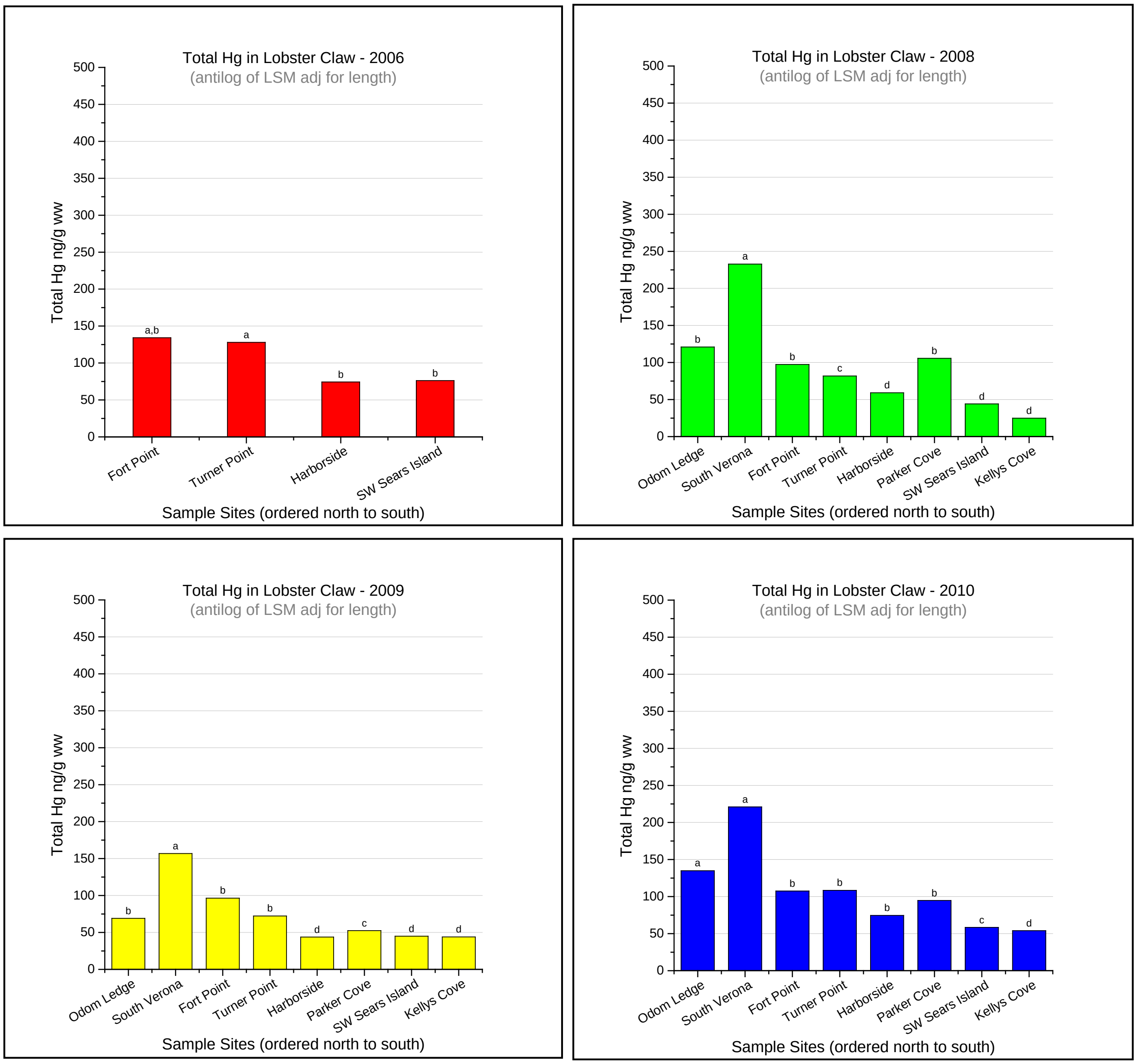


Figure 14-18. A geographic comparison of total Hg concentrations in lobster claw at all sites sampled in each year of the study. Letters above each bar indicate homogenous groups in which adjusted Hg concentrations were statistically equivalent.

In 2008 total Hg concentrations were greater in all three types of lobster tissues collected from the northern most sample sites. In that year, lobster collections were expanded north, to Odom Ledge on the west side of Verona Island and South Verona, and west to Kelly's Cove, south of Belfast (Figure 14-17), and both claw and tail samples were analyzed for all lobster. The South Verona sample area had significantly greater total Hg concentrations in lobster tail (478 ng/g wet wt., length adjusted), lobster claw (233 ng/g wet wt., length adjusted), and tomalley (482 ng/g dry wt., length adjusted; ANCOVA, adjusted for length, $P < 0.001$; Tukey's HSD test, $\alpha = 0.05$; Figures 14-18 14-20). Hg concentrations in lobster from the other northern sites, Odom Ledge and Fort Point, also formed a homogenous group significantly greater than sites to the south and west, with the exception of Parker Cove, a site far to the south on the west side of Islesboro, which had Hg concentrations in tail (210 ng/g wet wt., length adjusted) and claw (106 ng/g wet wt., length adjusted) equivalent to levels found in the northern region of the sample area. The lowest total Hg concentrations in tail (83 ng/g wet wt., length adjusted) and claw (25 ng/g wet wt., length adjusted) were found at Kellys Cove. Methyl Hg was not analyzed in the 2008 samples.

In 2009, significantly greater Hg concentrations were again found in samples from the more northern sites in all three tissue types and for both total and methyl Hg. In that year, both total Hg and methyl Hg were analyzed in all samples, claw, tail and tomalley. South Verona was significantly greater in both tail (433 ng/g wet wt., length adjusted; Figure 14-19) and claw (157 ng/g wet wt., length adjusted; Figure 14-18), than found at all other sites (ANCOVA, adjusted for length, $P < 0.001$; Tukey's HSD test, $\alpha = 0.05$), and tomalley samples from the three sites north of Fort Point (360 – 425 ng/g dry wt.; Figure 14-20) were greater than from all sites to the south. Parker Cove had lower relative concentrations than found in 2008, tail samples (128 ng/g wet wt., length adjusted) grouping with the other distant sample sites, and claw samples (52 ng/g wet wt., length adjusted) slightly greater than neighboring sites. The percent methyl Hg findings for 2009, in tail (96%) and claw (89%), may better represent %methyl Hg in the population, as the 2009 sample size of 207 was much larger than the eight samples collected in 2006.

In 2010 South Verona again stood out with significantly greater total Hg concentrations in tail (392 ng/g wet wt., length adjusted) and claw (221 ng/g wet wt., length adjusted; ANCOVA, adjusted for length, $P < 0.001$; Tukey's HSD test, $\alpha = 0.05$; Figures 14-18 and 14-19) relative to sites at Fort Point and further south. No significant differences in Hg concentrations were found for tomalley, despite visually obvious differences among sites, likely due to the small sample size of two samples from each site (Figure 14-20). Lobster from Parker Cove again had elevated Hg concentrations relative to surrounding sites. The lowest total Hg concentrations were found at Kellys Cove and SW Sears Island for tail (105-123 ng/g wet wt., length adjusted) and claw (54-58 ng/g wet wt., length adjusted), but there was an anomalous increase in tomalley total Hg at SW Sears Island, 547 ng/g dry wt. (length adjusted), relative to Kelly Cove (276 ng/g dry wt., length adjusted). Essentially all of the Hg in tail and claw muscle was methyl Hg in 2010. Percent methyl Hg concentrations exceeded 100%, but were within the accepted analytical error rate for each analysis. Given the close parity between total and methyl Hg, the finding that methyl Hg also varied significantly from north to south was expected. Methyl Hg in tomalley was not significantly different among sites (ANCOVA, adjusted for length, $P = 0.09$), and the %methyl Hg in tomalley varied widely among sites, 37 – 70%, the variance likely driven by small sample sizes.

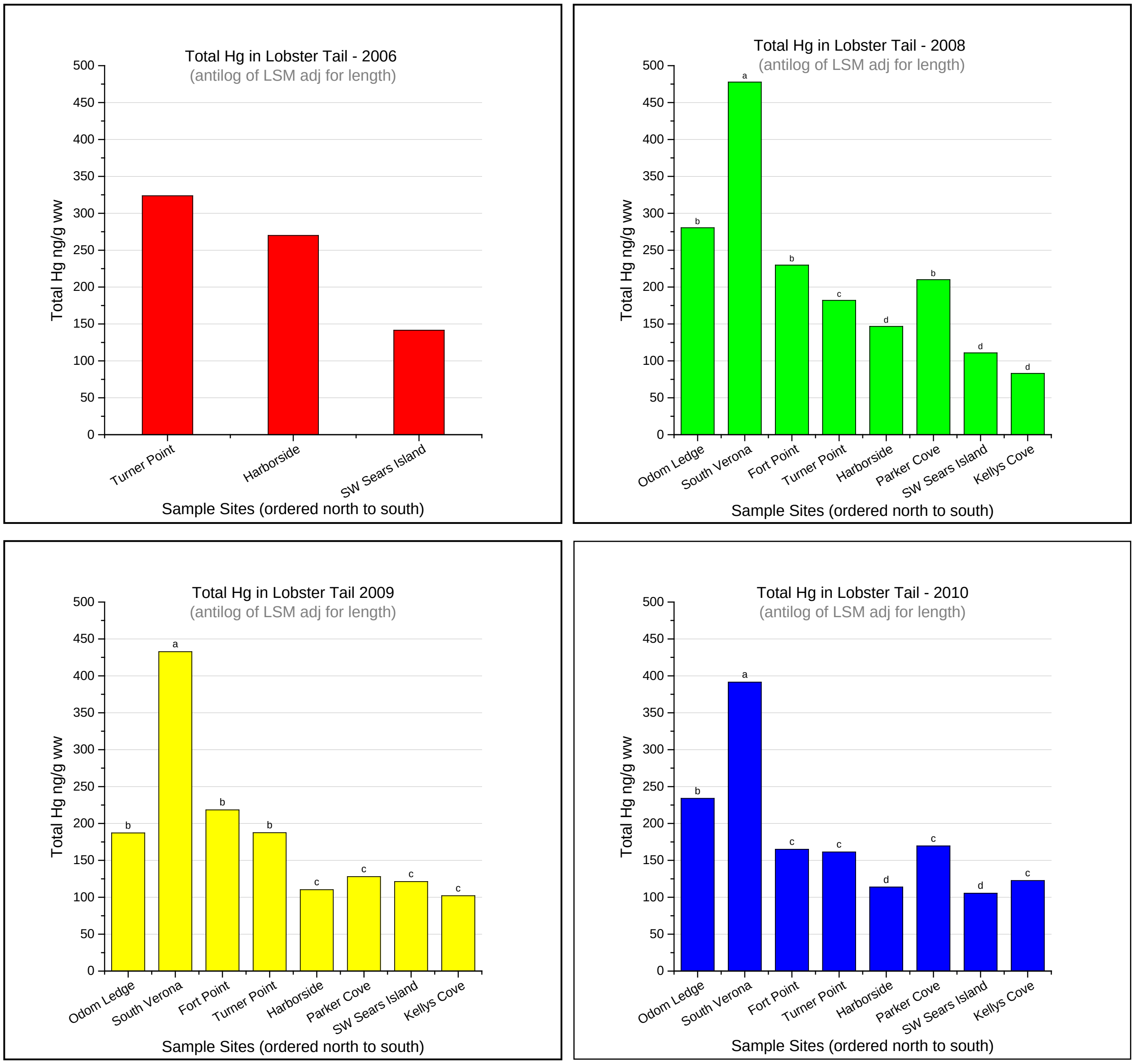


Figure 14-19. A geographic comparison of mean total Hg concentrations (antilog of least squares means adjusted for carapace length) in lobster tail at all sites sampled in each year of the study. Letters above each bar indicate homogenous groups in which adjusted Hg concentrations were statistically equivalent.

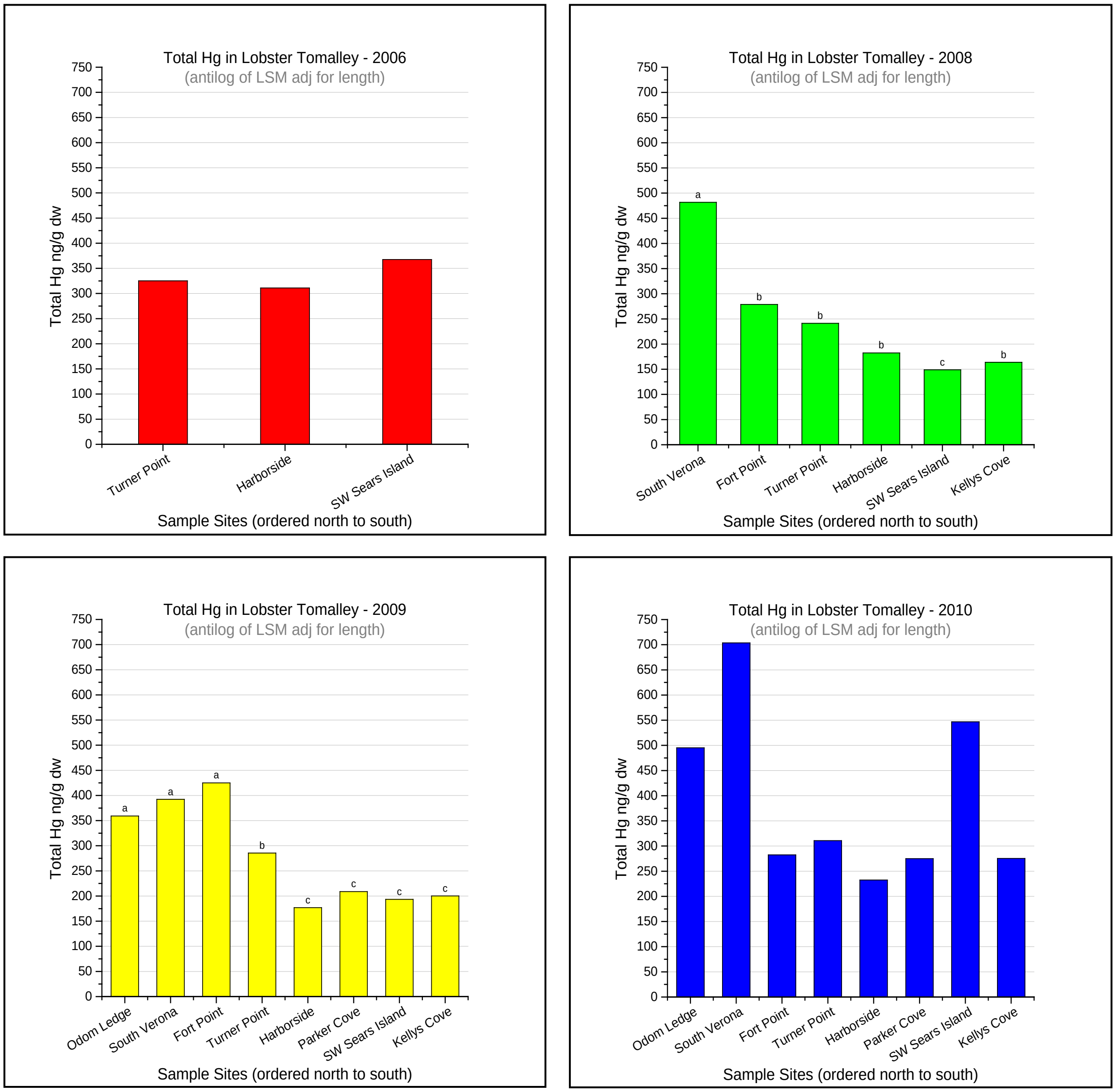


Figure 14-20. A geographic comparison of mean total Hg concentrations (antilog of least squares means adjusted for carapace length) in lobster tomalley at all sites sampled in each year of the study. Letters above each bar indicate homogenous groups in which adjusted Hg concentrations were statistically equivalent.

9.4 American Lobster Hg Concentrations and Biota Targets

Lobsters inhabiting the area near the mouth of the Penobscot River have elevated concentrations of Hg in their edible muscle up to twice as high as levels designed to protect human health (Table 2). Combining all lobster tail samples collected between 2006 and 2010, 90% of the 124 tail muscle samples collected at the three northern-most sites, those closest to the mouth of the Penobscot River - Odom Ledge, South Verona and Fort Point - exceeded the Maine action level of 200 ng/g wet wt., while only 15% of the tail samples collected from sites to the south and west exceeded that concentration. Total Hg was used to evaluate the number of lobster tail samples exceeding the action level for methyl Hg, as the proportion of total Hg that was methyl Hg was 99% in tail muscle in the combined dataset. Fifteen percent of the lobsters north of Fort Point exceeded the target of 500 ng/g wet wt. as the level protective of fish health. One lobster from the Turner Point site also exceeded this concentration. Predation on lobster by fish is almost exclusively on small juveniles (Hanson and Lanteigne 2000) which were not sampled as part of this study.

9.5 Comparison of Hg in Tail and Claw Muscle

The unexpected finding in the 2006 sample set that Hg concentrations were significantly greater in tail muscle relative to claw muscle in the same individual lobsters prompted additional testing as to the source of this difference, and a shift in sample distribution to emphasize tail muscle. In paired samples, total Hg in tail muscle was 2.3 times that in claw muscle (n=427; geometric means 157 to 68 ng/g wet wt., respectively; paired t-test, $P < 0.001$). This same relationship was found in each individual year sampled. We hypothesized that the protein or fat content might differ between these two tissue types, and influence the accumulated Hg concentrations. Given the strong affinity of Hg for sulfur (and thus protein), we would expect, *a priori*, that the greater Hg content in lobster tail than in claw (see below) is related to the higher protein content of the tail. To test this hypothesis, we analyzed the lipid and protein content in a subset of ten 2008 claw and tail muscle samples representing a range of differences in total Hg between claw and tail muscle. In this subset, claw total Hg ranged between 35% and 87% of tail total Hg (Figure 14-21). The total lipid content (% by weight) was significantly greater in tail (mean,1.69%) relative to claw muscle (mean, 0.81%; paired t-test, $P < 0.001$). However, the overall lipid content was very low, and often hovered near the lab's lipid quantification limit. Similarly, the total protein content was significantly greater in tail (mean, 83%) than in claw (mean, 77%; paired t-test, $P = 0.04$). However, there was no relationship between the percent difference between total Hg, in claw and muscle, and the lipid and protein content of those tissues. If the percent composition of the lipid or protein in the tissue influenced the total Hg concentration in that tissue, we would expect to see a relationship.

9.6 Regional Comparison of Hg in American Lobster

As noted in the Phase I report, Hg in lobsters from other Maine estuaries averaged from 82 to 208 ng/g wet wt. (Sowles 1997), whereas those from the four northern-most sites in Penobscot Bay were considerably higher, ranging from 228 to 485 ng/g, (see Chapter 2). In the New York harbor/New Jersey/Long Island Sound area, mean Hg in lobster muscle was 153 – 308 ng/g wet wt., a lower range than in the contaminated zone of Penobscot Bay (Roberts et al. 1982; Hammerschmidt and Fitzgerald 2006).

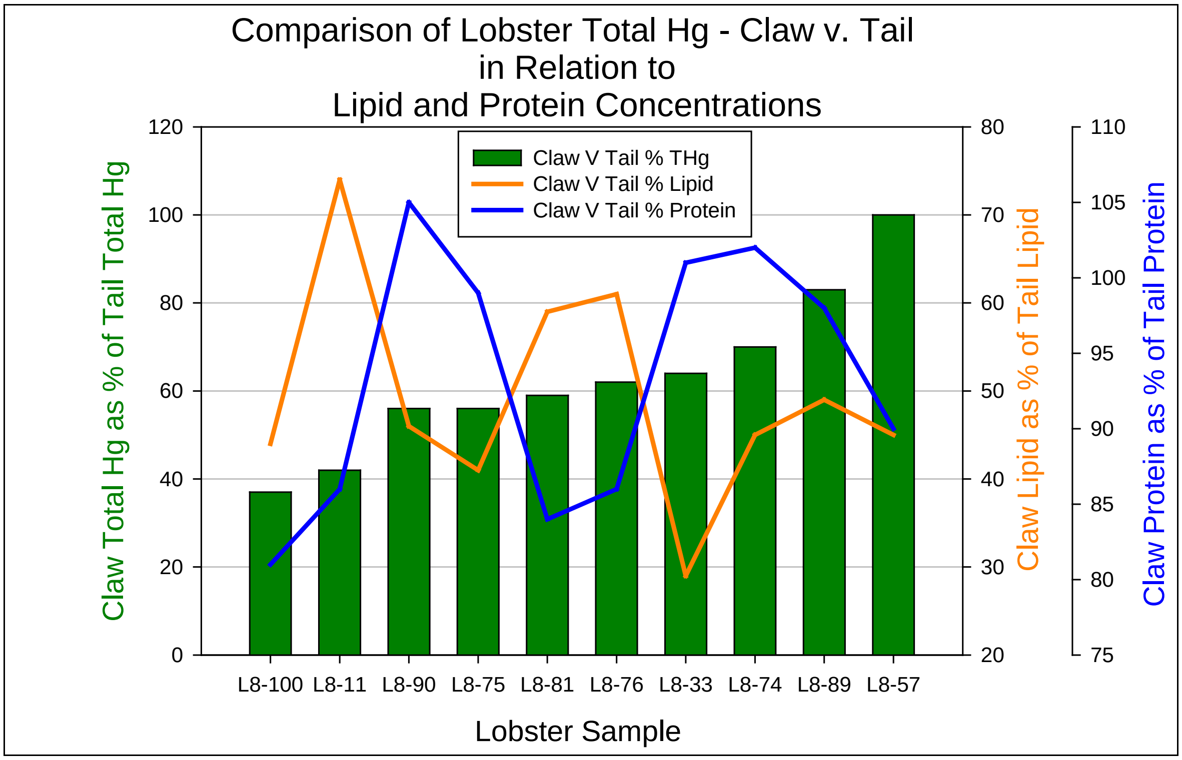


Figure 14-21. Percent total Hg, lipid and protein concentrations in claw muscle relative to tail muscle Hg, lipid and protein concentrations in a subset of lobster samples.

9.7 Lobster Summary

Hg concentrations in tail samples from lobster collected from Ft. Point, Odom Ledge and South Verona exceeded the Hg target to protect human health (200 ng/g wet wt.) in 90% of the lobster sampled. Fifteen % of the lobster collected from areas to the south and west of Ft. Point exceeded the target to protect human health. The Hg target to protect fish health, 500 ng/g wet wt., was exceeded by 15% of the lobster collected in the more contaminated area north of Ft. Point. Hg concentrations in lobster held constant at the majority of sites sampled in Penobscot Bay. At one site, Harborside, Hg declined significantly during our sample period in both claw and tail muscle. At four other sites Hg declined in either tail or claw muscle, but not in both, raising doubt as to the value of this finding. Significant geographic trends in Hg in lobster claw and tail were found in the last three years sampled, 2008-2010, with the greatest concentration in all three years at the South Verona site, located at the southern tip of Verona Island. Tail and claw muscle Hg concentrations declined south of Ft. Point. Hg concentrations in tomalley had a similar but more variable geographic pattern. Hg concentrations in tail muscle were two times greater than found in matched claw samples from the same individual animals.

10 BLUE MUSSEL (*Mytilus edulis*)

10.1 Blue Mussel Biology

Blue mussels are harvested commercially in New England, with most landings from wild mussel beds along the Maine coast. The blue mussel is an epibenthic species that attaches primarily to stabile substrates of rock or cobble, though any solid surface, such as a rock embedded in mud or sand, may serve as an anchor point. Juvenile mussels attach permanently to the substrate after six months of age, unless storm surge breaks the byssal threads anchoring them to the bottom. Blue mussels are active suspension feeders, filtering organic material from the water column with most nutrition gained from phytoplankton cells. Predation on mussels is greatest during the planktonic larval stage, but even after attachment and formation of a hard shell they remain vulnerable to decapod crustaceans, especially lobster and crabs, and birds including diving ducks, gulls and certain shorebirds. Predation by crustaceans can limit their distribution below the sublittoral zone in marine areas, but less so in brackish water where marine predators are absent. While growth rates vary with habitat depth, food availability, temperature and salinity, in Maine it may take a mussel 7 to 12 years to reach a shell length of 65 mm (Newell 1989).

10.2 Temporal Comparisons of Hg in Blue Mussels

Within our 5-year study period (2006 – 2010) there was a significant decline in total Hg concentrations in blue mussels at most sites in the more contaminated area north of Fort Point. This downward trend was not found at the three less contaminated sites near Searsport. Significant declines in total Hg were found for ES15, ES13, ES12, ES03, and ES14 (ANOVA independent linear model, adjusted for length with pooled variance, $P < 0.001$; Figure 14-22). One site, ES12, was sampled in only two years and may represent inter-annual variation rather than an actual trend. The absence of length data for samples collected in 2006 created a potential weakness in the comparison, for the elevated Hg reported in 2006 at many sites in the more contaminated area could be due to greater Hg accumulations in larger, older individuals. Length was a significant co-variate with total Hg in all three years in which length data were available. However, the same trend of declining Hg concentrations at most sites north of Ft. Point was found whether using the full data set not adjusted for mussel length (2006 – 2010) or using only length-adjusted data from 2008 through 2010.

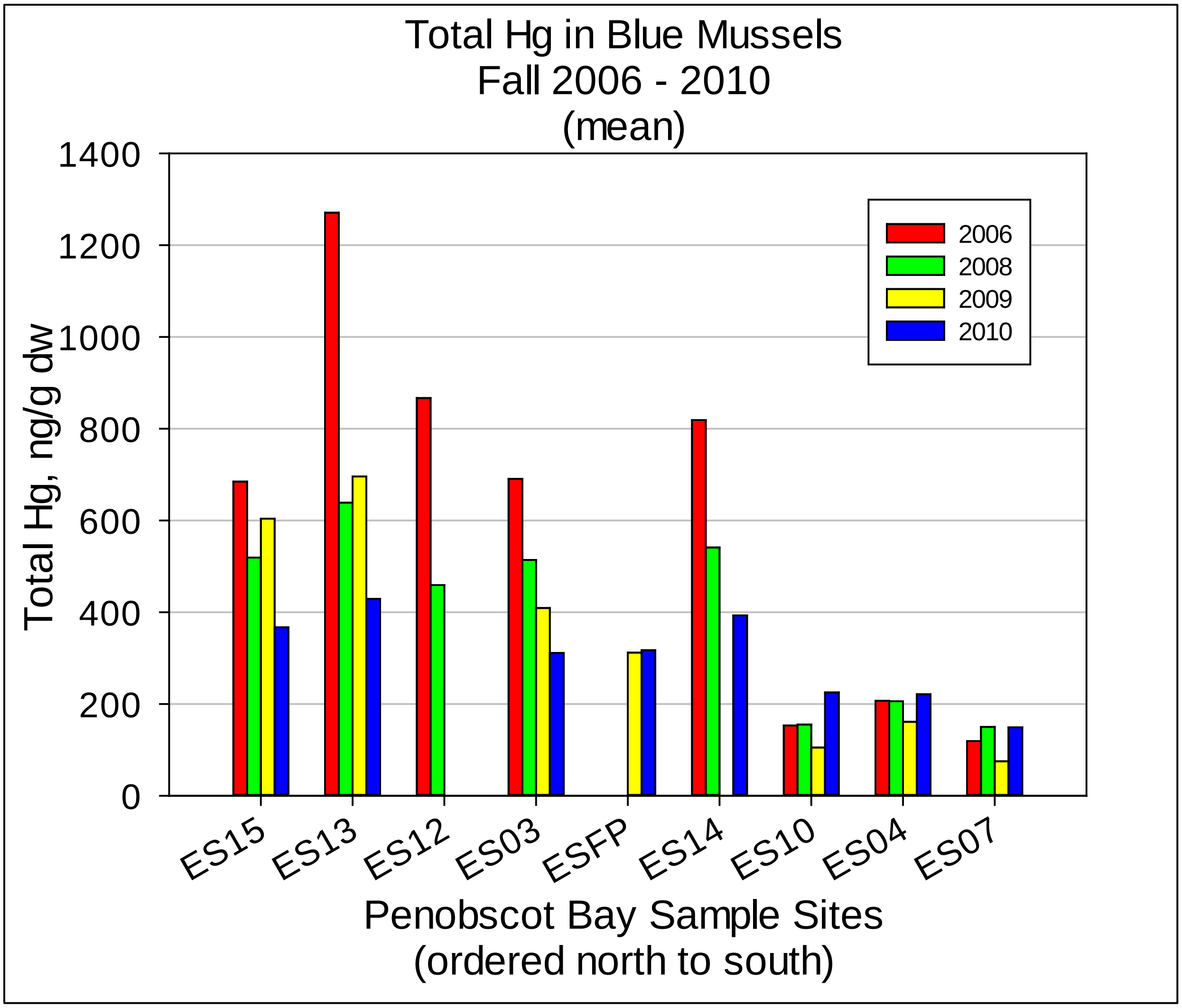


Figure 14-22. A temporal comparison of mean Hg concentrations in blue mussels within individual sites which were sampled in multiple years. There was a significant decline in Hg at four sites sampled in three or more years, ES15, ES13, ES03, and ES14.

10.3 Geographic Comparisons of Hg in Blue Mussels

Blue mussels showed a consistent trend in declining Hg concentrations with increasing distance from the Penobscot River (Figure 14-23; Appendix 14-7). In most years the greatest concentrations were found at ES13, at the southern tip of Verona Island. This site is where the extensive mudflats of the East Channel of the Penobscot and the Orland River drain into Penobscot Bay (Figure 14-24). The exception was in 2010 when mussels sampled from a subtidal site in the Penobscot River, just north of Bucksport, had the greatest Hg concentration (length adjusted) found for that sample year.

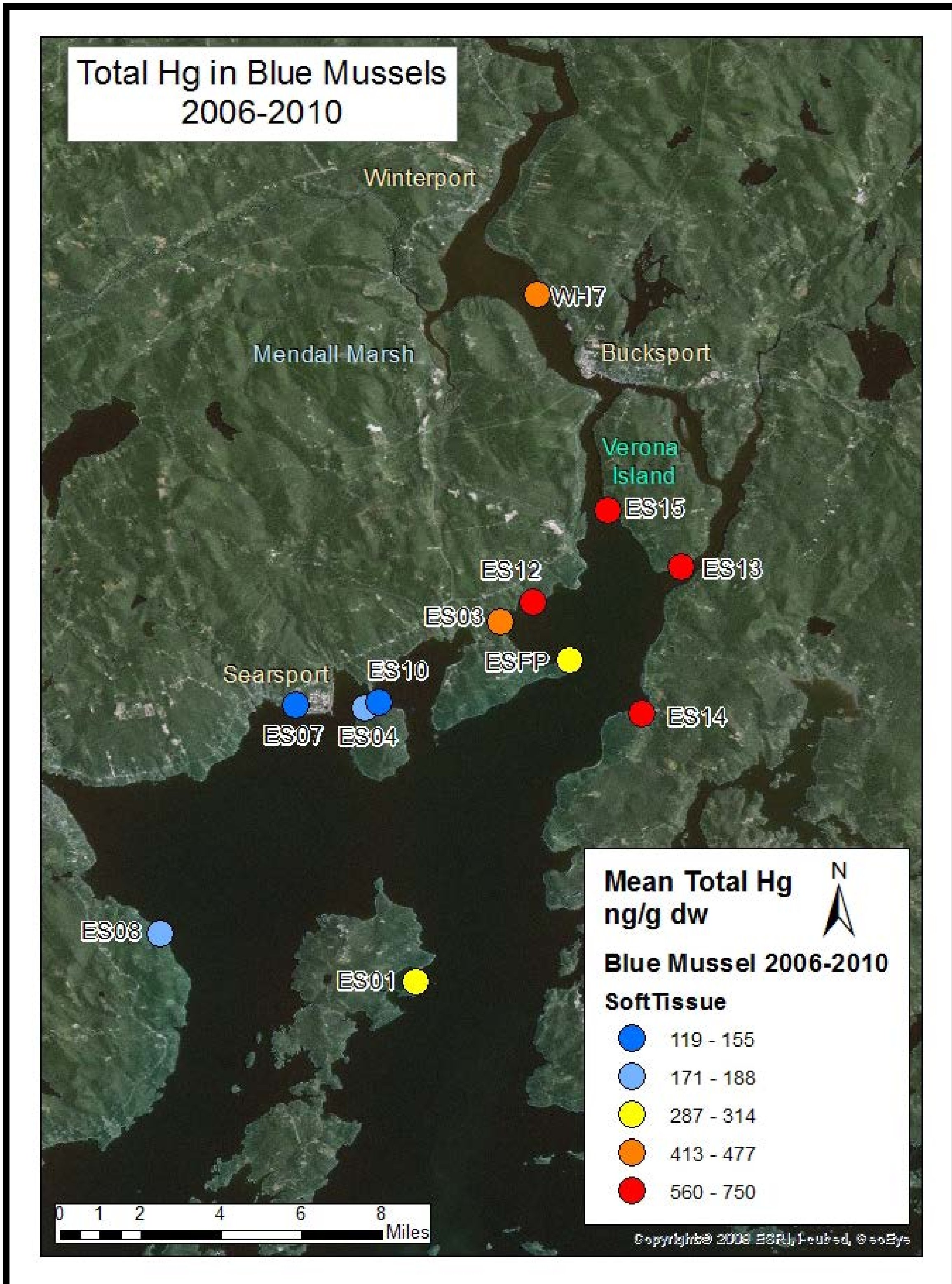


Figure 14-23. Blue mussel sampling locations and mean Hg concentrations calculated for the entire 5-year monitoring period (2006 – 2010).

In 2006 significantly greater total Hg concentrations were found in mussels in the area from south Verona Island to coastal areas near Fort Point (690 to 1270 ng/g dry wt.; ANOVA, $P < 0.001$, Tukey's HSD test, $\alpha = 0.05$; Figure 14-24), relative to sites south and west, on Islesboro, near Searsport and south of Belfast on the west shore of Penobscot Bay. (Hg concentrations were not length adjusted in 2006 as shell lengths were not available.) This same trend was found in subsequent years (2008-2010), with significantly greater total Hg concentrations from sites at or north of Ft. Point or ES14, east of Ft. Point (300 to 630 ng/g dry wt.), relative to three sites sampled near Searsport (74 – 205 ng/g dry wt., length adjusted; ANCOVA, adjusted for length, $P < 0.001$, Tukey's HSD, $\alpha = 0.05$). Methyl Hg concentrations were found to have the same significant trend of decreasing concentrations southwest of Ft. Point, except in 2008 when only samples from north of Ft. Point were analyzed for methyl Hg.

10.4 Hg and Spawning in Blue Mussels

In 2010 blue mussels were sampled from four sites in both early spring (April 13th) and mid-fall (September 24-28th) to examine the influence of the summer spawning season on Hg accumulations (Figure 14-25). Significantly greater total Hg concentrations were found in mussels sampled in the spring at the three sites north of Ft. Point, ES03, ES13 and ES15; two-sample t-test, $P < 0.001$), but not at ES04 near Searsport ($P = 0.08$). Phillips (1980; cited in Lauenstein et al. 1993) had discussed the influence of spawning on contaminant accumulations in mussels and reported that greater Hg accumulations were expected in mussels sampled in the spring prior to the release of gametes during the spring-summer spawning.

The timing of spawning is quite variable in estuarine habitats with annual changes in freshwater outflow and temperature (Newell 1989), so a gross examination to determine spawning stage was performed on all mussels. As seen in the graph below, spawning activity was independent of the spring and fall sample dates and may instead relate to seasonal changes in Hg concentrations in phytoplankton (Chen and Folt 2005).

10.5 Historical Mussel Watch Data at ES04

The ES04 sampling site was adjacent to the NOAA Mussel Watch monitoring site of PBSI (Penobscot Bay Sears Island), permitting an examination of long-term trends in Hg concentrations in blue mussels in upper Penobscot Bay (Figure 14-26). Hg concentrations at ES04 between 2006 and 2010 were in the same range as reported for the Mussel Watch site PBSI in the mid-1980s. However, the Mussel Watch data show a long-term increase in total Hg concentrations in this area from 1986 to 1997, followed by a decline over the next eight years. These long-term trends in the Mussel Watch data illustrate the need for long-term monitoring to accurately assess temporal trends.

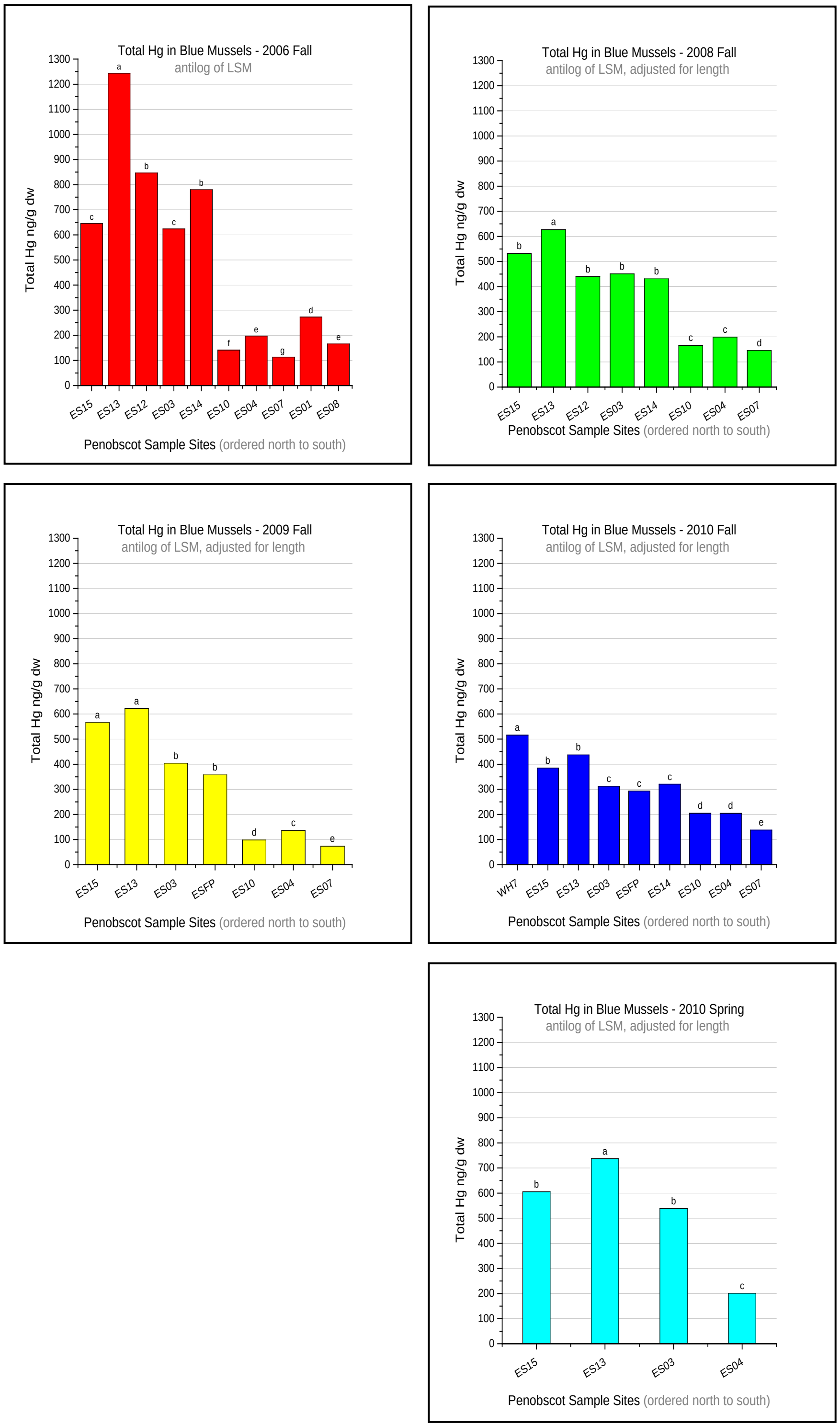


Figure 14-24. A geographic comparison of total Hg concentrations in blue mussel at all sites sampled in each year of the study. Samples were collected in both spring and fall in 2010. Letters above each bar define homogeneous groups where adjusted Hg concentrations were statistically equivalent. Mussel samples collected in 2006 were not adjusted for length.

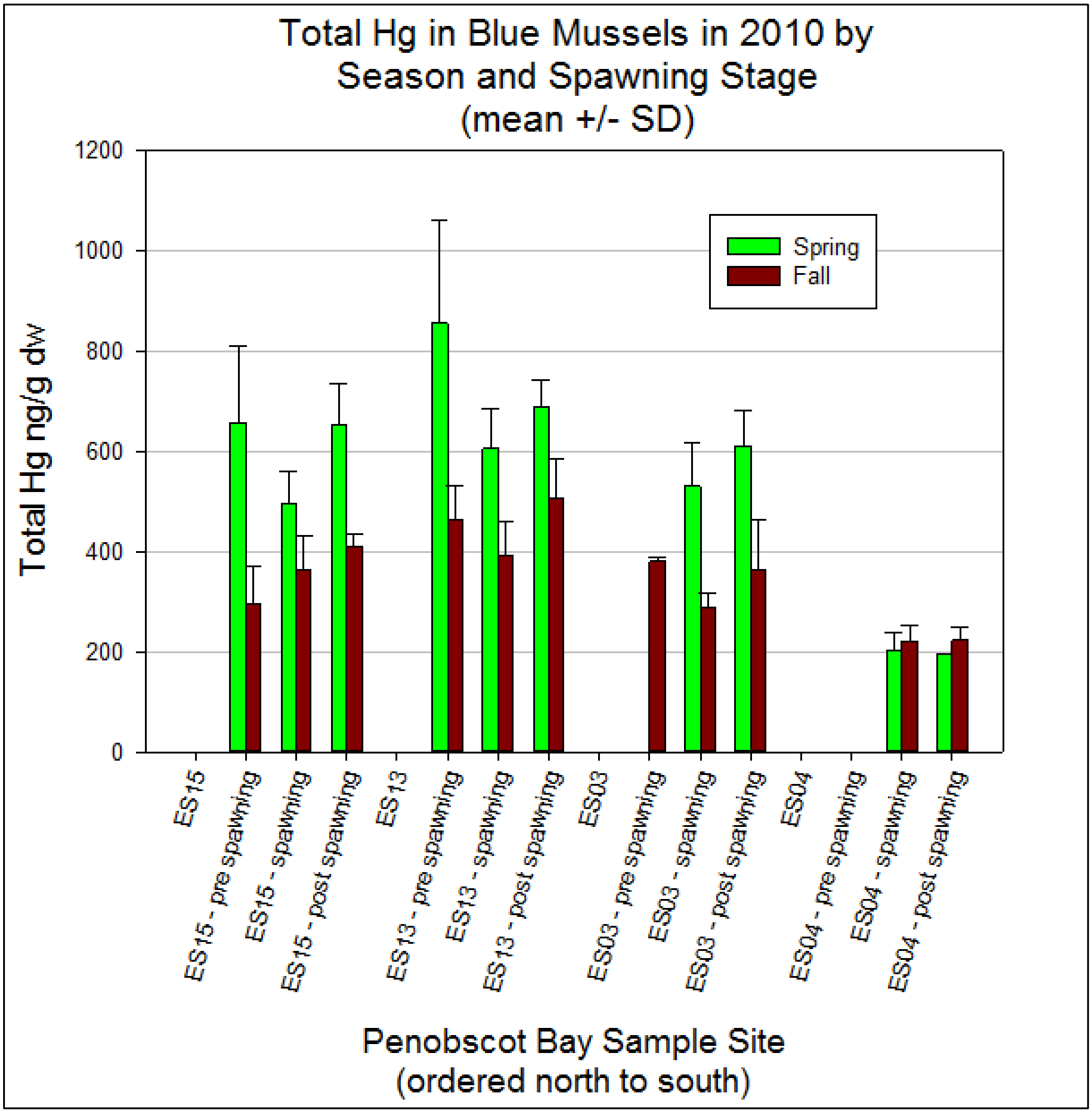


Figure 14-25. Hg concentrations in blue mussels by season and spawning stage. In the more contaminated area north of Fort Point Hg concentrations were significantly greater in the spring relative to the fall sampling period.

10.6 Blue Mussel Hg Concentrations and Biota Targets

None of the blue mussels sampled in this study area exceeded the target for methyl Hg to protect human health (Table 2). Using the Maine advisory limit for human consumption of 200 ng/g wet wt. methyl Hg, and converting total Hg to methyl Hg concentrations using the average %methyl Hg value of 43% across all years, and assuming a moisture content of 85%, none of the mussels sampled exceeded the Maine advisory limit. Using the same conversion methods, 12% of the mussels exceeded the methyl Hg target of 50 ng/g wet wt. to protect predator health. All but one of those mussels with elevated Hg concentrations were collected in the more contaminated area north of Ft. Point. Limiting the calculations to that more contaminated area, 19% of the mussels sampled pose a threat to predator health.

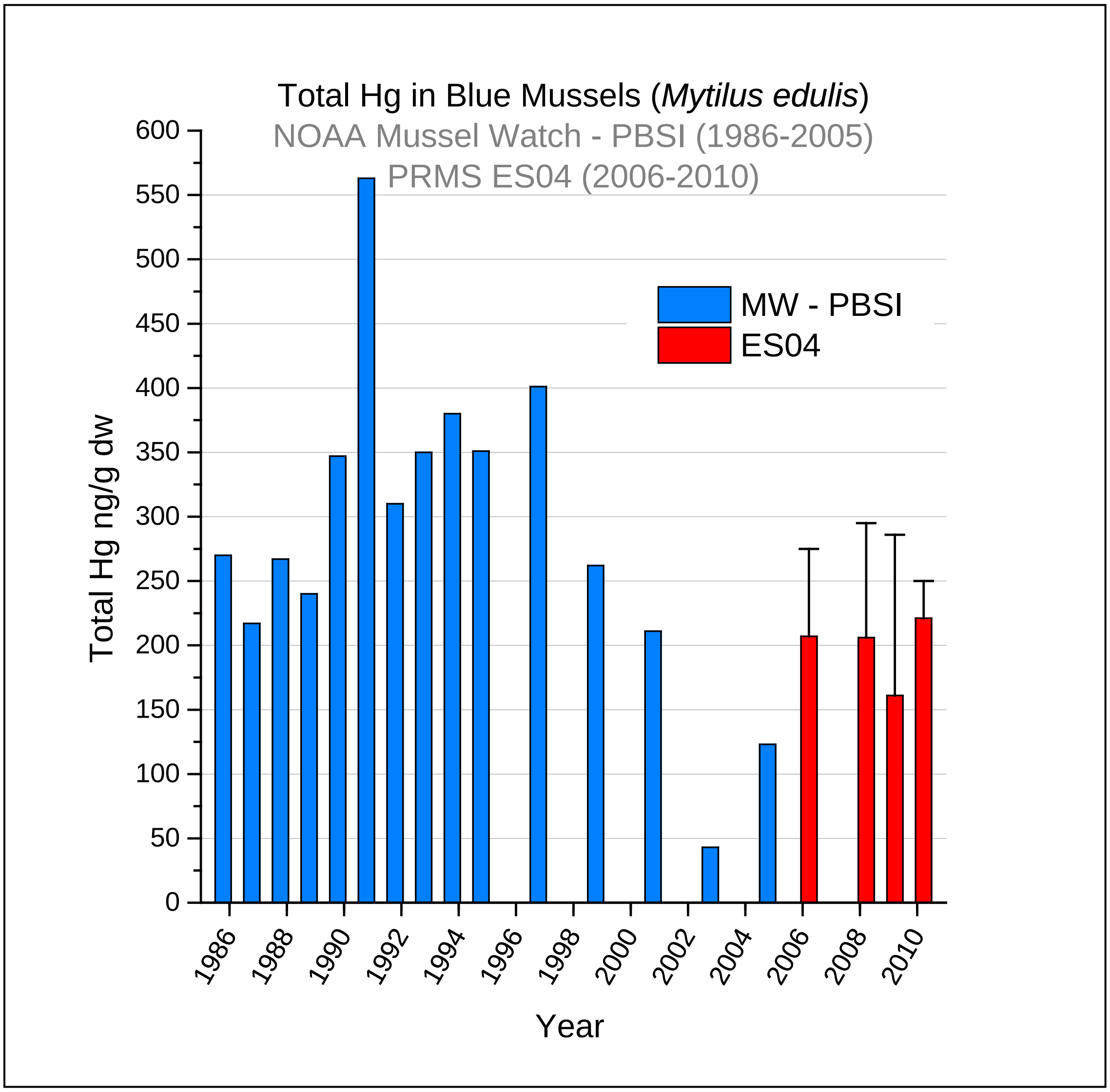


Figure 14-26. Historical mean Hg concentrations in blue mussels at the Mussel Watch site PBSI (Penobscot Bay Sears Island) and the adjacent PRMS site ES04.

10.7 Regional Comparisons of Hg in Blue Mussels

Concentrations of Hg in mussels in the contaminated zone of the Penobscot are high relative to other, less contaminated sites. As noted in the Phase I report, Hg in mussels in 2006 in upper Penobscot Bay were high compared to other sites in Maine. They were similar to those reported for a chlor-alkali contaminated site in New Brunswick, Canada (Garron et al 2005).

10.8 Blue Mussel Summary

Hg concentrations in blue mussels declined during our 5-year sample period at the majority of sites north of Ft. Point but held constant at the less-contaminated sites to the west in Penobscot Bay. Note that over the longer-term Mussel Watch study (Figure 14-26), Hg concentrations in blue mussels in the Penobscot showed periods of increasing and declining values, and a trend over a 5-year period may not be indicative of a longer-term trend. Geographic trends were found in all years sampled, with Hg concentrations declining with increasing distance from the mouth of the Penobscot River. Hg concentrations in 2010 were significantly greater in the spring relative to the fall sample periods, though spawning stage was not a significant influence. Hg concentrations at the reference site ES04 are similar to historical levels in mussels reported for an adjacent Mussel Watch site, PBSI, from the mid to late 1980s, but lower than found in mussels at PBSI in the 1990s.

11 NELSON'S SPARROW (*Ammodramus nelsoni subvirgatus*)

11.1 Biology of Nelson's Sparrow

Nelson's sparrows return to breeding sites in Maine in late April or early June from wintering sites in tidal marshes from South Carolina to northeast Florida. The breeding populations of Nelson's sparrows are localized and small, reflecting the patchy distribution of their marsh habitats. Females occupy a small breeding home range as small as 0.4 ha, with male home ranges larger, up to 4.0 ha. They begin nesting within a week of arrival, attempting to raise a clutch within one spring tide cycle. Chicks are fed invertebrate prey captured by the female from the vicinity of the nest. Adults forage at ground level among dense grasses, at the edge of marsh pools and pannes, and around the edges of tidal wrack. Animal prey is eaten during the breeding season, including adult and larval insects, spiders and amphipods. The Nelson's sparrow is listed as a Species of Special Concern in Maine, Alabama and Wisconsin due to severe habitat loss at both breeding and wintering sites (Shriver et al. 2011).

11.2 Temporal Comparison of Hg in Nelson's Sparrows

There was no consistent trend in Hg concentrations in Nelson's sparrows during our 4-year monitoring period. Opposing trends were found in Hg concentrations in Nelson's sparrows sampled in breeding marshes along the lower Penobscot River. Significant increases in Hg concentrations in blood were found in adult birds at two sites, W17S (ANOVA, independent design with pooled variance, $P = 0.003$; Figure 14-27) and at Mendall Marsh Southeast ($P = 0.015$). Significant decreases in Hg concentrations in blood were found at Mendall Marsh Northeast ($P = 0.015$) and Mendall Marsh

Southwest (P = 0.016). Note that Mendall Marsh Southeast, where Hg statistically increased, is immediately south of Mendall Marsh Northeast, where Hg concentrations statistically decreased, and directly across the narrow Marsh River from Mendall Marsh Southwest, where Hg concentrations also statistically decreased. It is unlikely that Hg exposure to Nelson's sparrows varied across adjacent sample sites in Mendall Marsh. Continued monitoring is needed to document long-term trends in Hg exposure.

11.3 Geographic Comparisons of Hg in Nelson's Sparrows

Nelson's sparrows had the greatest maximum Hg concentrations in their blood of any bird sampled along the lower Penobscot River. Also, the mean Hg concentrations in Nelson's sparrows for the entire 4-year monitoring period were ten times greater than found at reference sites along the southern Maine coast and on Mt. Desert Island (Figure 14-28, Appendices 14-8a, blood; 14-8b, feathers).

This same pattern of elevated Hg concentrations in birds from the Mendall Marsh area was found in each individual year sampled. In 2007, the mean concentrations of Hg in blood in adult Nelson's sparrows sampled in Mendall Marsh ranged from 6.1 to 8.0 µg/g wet wt., significantly greater than found in Nelson's from three reference marshes along the southern Maine coast (0.3 to 1.2 µg/g wet wt.; ANOVA, $P < 0.001$; Tukey's HSD test, $\alpha = 0.05$; Figure 14-29). The same pattern was found in each subsequent year, significantly greater Hg concentrations in blood from adult birds sampled at Mendall Marsh or W17, relative to reference sites outside of the Penobscot watershed ($P < 0.001$, 2008 – 2010). Similar geographic comparisons of blood Hg concentrations were not possible for hatch year birds, as they were only collected at two sites, both within Mendall Marsh.

Hg concentrations in feathers told a more complex story, with strikingly high concentrations in feathers from hatch year birds and in adult primary feathers, both of which were formed on the Penobscot breeding grounds and with generally lesser concentrations in adult tail feathers, likely formed before their arrival to the Penobscot area. Understanding the molt pattern for Nelson's sparrows is critical for interpreting Hg accumulations in the feathers from this species. Adult Nelson's sparrows display a Complex Alternate Strategy in their molt sequence. A complete (pre-basic) molt, in which all the feathers are replaced, occurs on the breeding grounds in late summer, July to September, starting with the P1 primary feather. A partial to incomplete pre-alternate molt occurs on non-breeding grounds in the early spring, March to April, in which the body feathers, most tail feathers and some of the wing feathers are replaced. However, a central block of wing feathers, the inner primaries and the outer secondaries, are not replaced in this pre-alternate (eccentric) molt (Shriver et al. 2011; Pyle 2008). To summarize, tail feathers are likely grown before arrival to the Penobscot breeding grounds, while the wing feathers, the P1 primary feather and the S2 secondary feather, both located in the central portion of the wing, are formed on the breeding ground.

Given the molt sequence described above, the Hg concentrations in different types of feathers are expected to vary with the differences in Hg exposure between the sparrows' wintering sites and their breeding sites. Adult tail feathers collected in June or early July were likely formed before arrival to the breeding grounds, and so do not reflect Hg exposure on the breeding grounds. However, tail feathers from the hatch-year birds, chicks born that summer and sampled soon after they fledged from the nest, will indicate Hg exposure on the breeding grounds, as their feathers grew after hatching. The wing feathers in adults (P1 and S2 feathers) which are molted on the summer breeding grounds, will reflect Hg exposure from the prey they eat at those breeding grounds. However, if those feathers were collected before the late-summer molt, they were grown the previous summer, and may not indicate Hg exposure at the site of sampling if the birds did not return to the same site two years in a row. The year-to-year return rate to breeding grounds for Nelson's sparrow is reported to be between 32 and 39%, based on a mark-recapture study (Shriver et al. 2011).

This pattern of Hg concentrations in bird feathers, between different age classes and between different feather types, is clearly illustrated in the Hg concentrations found in the feathers collected from Nelson's sparrows. Hatch year birds were sampled the first two years of the study. In 2007 the mean Hg concentration in tail feathers collected from hatch year birds in the Mendall Marsh area (mean Hg, 36 ± 5.4µg/g fresh wt.) was ten times greater than in adult birds collected from the same sites (mean Hg 2.9 µg/g fresh wt.; two-sample t-test, pooled variance, $P < 0.001$). The same relationship was found in 2008, when tail feathers from hatch year birds averaged 18.3 ± 12.3 µg/g fresh wt., again significantly greater than found in adult birds (mean Hg 2.9 ± 4.8 µg/g fresh wt.; two-sample t-test, separate variance, $P = 0.007$). The low concentrations of Hg in the tail feathers from adult birds indicate their low exposure to Hg before they arrived at their summer breeding grounds along the Penobscot River, confirming reports of low Hg exposure to Nelson's on wintering grounds along the Atlantic coast (Cristol et al. 2011). While Hg concentrations in adult tail feathers were generally low, one site in 2008, Mendall Marsh-Car, had consistently elevated concentrations, averaging 18.2 ± 6.5 µg/g fresh wt. (min-max, 10.7-27.3). The reason is unclear.

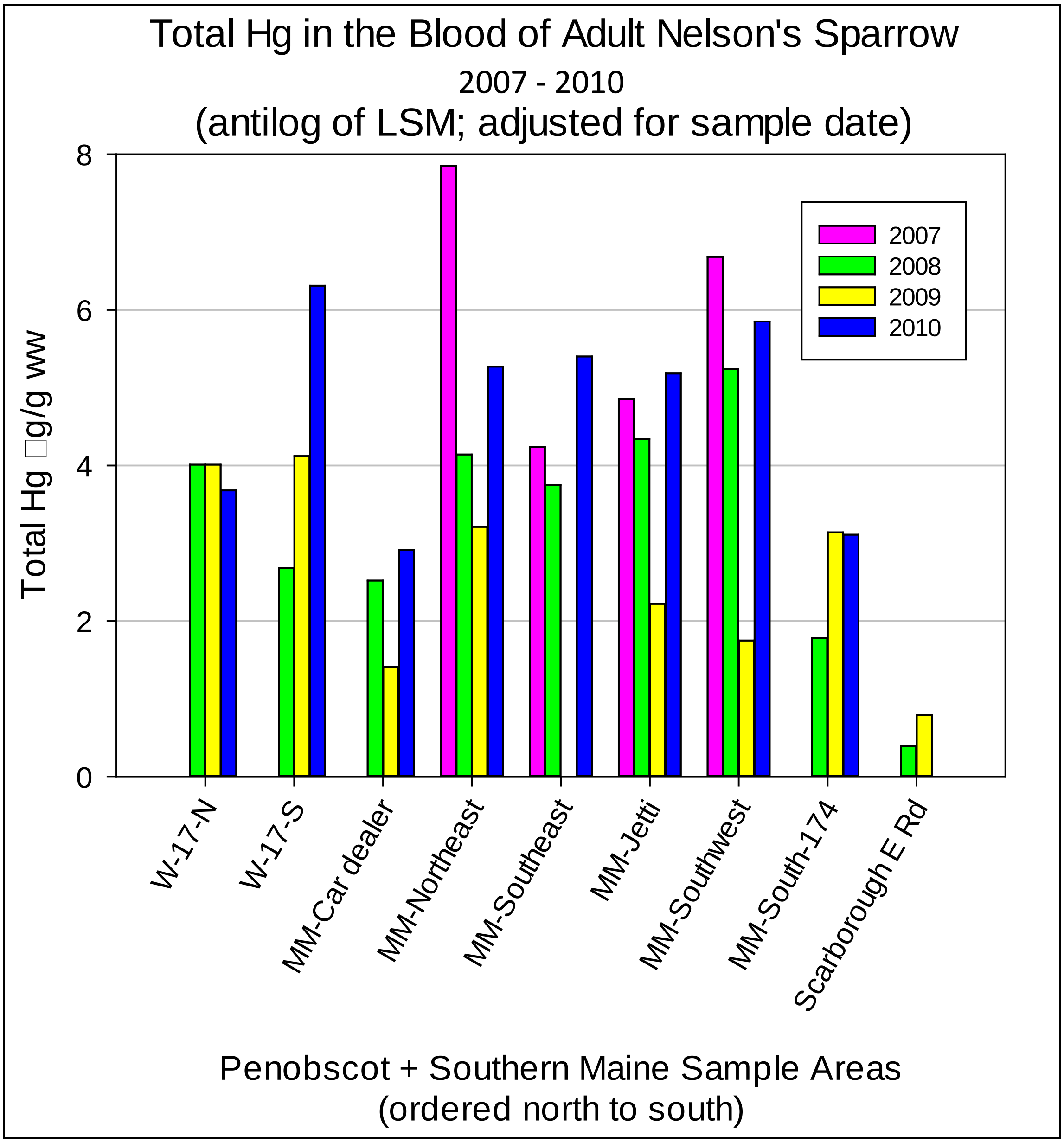


Figure 14-27. Temporal comparisons of mean total Hg concentrations (antilog of least squares means, adjusted for sample date) in Nelson's sparrows within individual sites sampled in multiple years. Significant increases in Hg concentrations were found at two sites, W-17-S and MM-Southeast, and significant decreases in Hg concentrations were found at MM-Northeast and MM-Southwest.

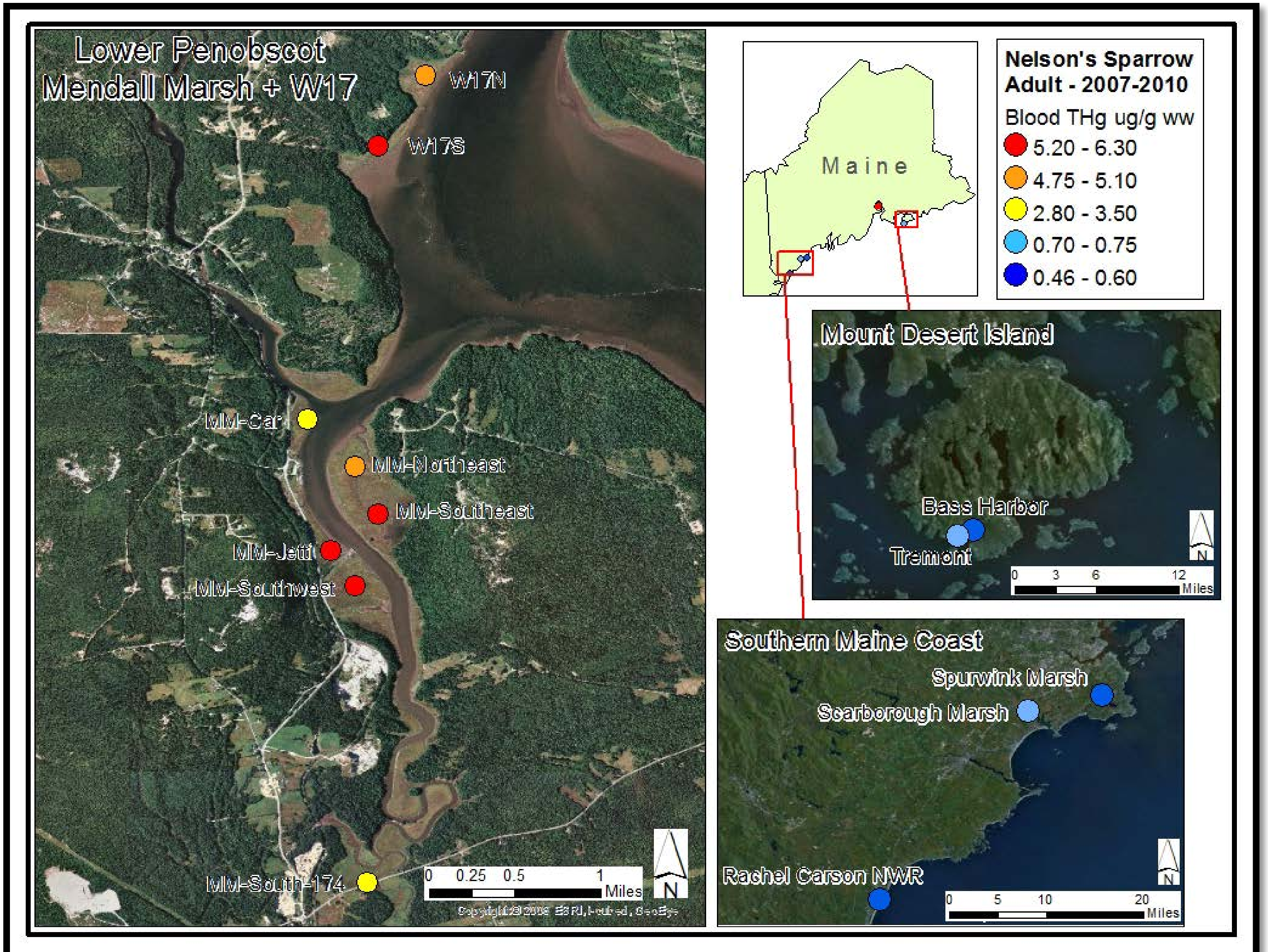


Figure 14-28. Nelson's sparrow sampling locations and mean Hg concentrations calculated for the entire 4-year monitoring period (2007 – 2010).

Hg concentrations in the P1 primary feathers from Nelson's sparrows sampled in the Mendall Marsh area were uniformly high, and 15 to 25 times greater than found in tail feathers sampled from the same birds. The P1 feather was sampled at selected sites in 2009 (n= 13) and in all birds in 2010 (n = 61). In 2009, paired samples of tail feathers (mean Hg 1.8 µg/g fresh wt.) and P1 primary feathers (mean Hg 33.7 µg/g fresh wt.) were significantly different (paired t-test, $P < 0.001$). The same extreme difference in Hg concentrations was found in 2010, when the mean concentration of Hg in tail feathers (2.0 µg/g fresh wt.) was significantly lower than found in paired samples of primary feathers (51.6 µg/g fresh wt.; paired t-test, $P < 0.001$).

And, like the Hg concentrations in blood from Nelson's sparrows, Hg in the P1 primary feathers from adults were 10 times greater in birds from the lower Penobscot than found in Nelson's from the Spurwink Marsh reference site. In 2010, primary feathers were significantly lower at the reference site of Spurwink Marsh (mean Hg, P1 = 6.5 ± 2.5 µg/g fresh wt.) compared to adult Nelson's sampled in Mendall Marsh and W17 (mean Hg, P1 = 47.6 ±31.8 µg/g fresh wt.; ANOVA, $P < 0.001$, Tukey's HSD test, $\alpha = 0.05$). Clearly, Hg exposure in the Mendall Marsh area was roughly 10 times greater than at either the Spurwink Marsh reference site, or at the wintering grounds used by the Nelson's sparrows before their arrival to marshes along the lower Penobscot River.

11.4 Nelson's Sparrows Hg Concentrations and Biota Targets

High Hg concentrations pose a serious risk to the health of Nelson's sparrows inhabiting marshes along the lower Penobscot River. Ninety eight percent of the adult Nelson's sparrows sampled at marshes along the lower Penobscot River had Hg concentrations in their blood in excess of the target concentration to protect bird health (1.2 µg/g wet wt.) (Table 14-3), with mean blood concentrations at individual sites up to 8 times greater (averaging 4 – 8 µg/g wet wt.) than this toxicity threshold associated with both reproductive and immunological toxicity (Chapter 2). In contrast, at reference sites outside of the Penobscot watershed, only 2% of the adult birds sampled had concentrations greater than the target to protect bird health. In hatch year birds, all of which were sampled in the Penobscot region, 70% had blood Hg concentrations greater than the target concentration to protect bird health, despite the known reduction in blood Hg concentrations in young hatch year birds associated with feather growth and somatic growth dilution of their Hg burden (Ackerman et al. 2011).

Hg concentrations in tail feathers provide further evidence of the threat posed by Hg to the health of Nelson's sparrows. In hatch year birds that grew their tail feathers at the Penobscot marshes, mean Hg concentrations far exceeded the target to protect bird health (5 µg/g fresh wt.; Chapter 2) in 92% of the birds (mean tail total Hg in hatch year birds: 2007 = 36 ± 5 µg/g fresh wt. (n=3); 2008 = 18 ± 12 µg/g fresh wt. (n = 9)). In contrast, tail feathers from only 6% of adult Nelson's sampled in the Penobscot region exceeded this target concentration. Again, in adults, tail feathers were likely formed before the birds' arrival on the Penobscot breeding grounds, and do not reflect local Hg exposure; hatch year birds formed their tail feathers at the breeding site where they were sampled, reflecting Hg exposure at that site.

Table 14-3. The percent of bird samples with Hg concentrations in excess of Hg targets to protect human or bird health, and the mean Hg concentrations in blood, feathers and muscle by species and region sampled.

PERCENT of SAMPLES EXCEEDING BIRD MERCURY TARGETS (2007 - 2010)															
		Blood Hg Target to Protect Bird Health (Blood) 1.2 µg THg/g ww				Feather Hg Target to Protect Bird Health (Tail feathers - T6) 5.0 µg THg/g fw				Feather Hg Target to Protect Bird Health (Primary feathers - P1) 5.0 µg THg/g fw				Muscle Hg Target to Protect Human Health 0.20 µg MeHg/ g muscle ww	
		ADULTS		HATCH YEARS		ADULTS		HATCH YEARS		ADULTS		HATCH YEARS			
SPECIES	REACH/ AREA	above target	blood THg mean ± SD (n)	above target	blood THg mean ± SD (n)	above target	tail feather THg mean ± SD (n)	above target	tail feather THg mean ± SD (n)	above target	primary feather THg mean ± SD (n)	above target	primary feather THg mean ± SD (n)	above target	mean ± SD (n)
Nelson's sparrow	lower Penobscot	98%	4.98 ± 2.28 (322)	69%	1.95 ± 1.03 (13)	6%	2.50 ± 3.77 (297)	92%	22.78 ± 13.8 (12)	95%	47.6 ± 31.8 (76)	NA			
	reference	2%	0.58 ± 0.35 (44)	NA		0%	0.91 ± 0.96 (32)	NA		60%	6.51 ± 2.54 (10)	NA			
Song sparrow	lower Penobscot	20%	0.73 ± 0.92 (98)	11%	0.41 ± 0.51 (73)	13%	2.20 ± 3.88 (93)	20%	4.02 ± 6.13 (70)	35%	5.13 ± 6.55 (26)	15%	2.30 ± 3.38 (13)		
	reference	0%	0.15 ± 0.17 (29)	0%	0.09 ± 0.07 (23)	0%	0.92 ± 0.81 (23)	5%	2.09 ± 1.56 (21)	0%	2.65 ± 0.14 (3)	0%	1.49 ± 1.26 (8)		
Swamp sparrow	lower Penobscot	65%	1.97 ± 1.22 (84)	20%	0.96 ± 0.66 (41)	57%	7.56 ± 6.56 (69)	47%	6.41 ± 4.80 (34)	58%	9.01 ± 9.37 (19)	8%	3.37 ± 1.58 (12)		
	reference	16%	0.39 ± 0.47 (7)	0%	0.23 ± 0.20 (20)	17%	6.60 ± 7.51 (6)	50%	5.29 ± 3.33 (19)	33%	2.97 ± 2.44 (3)	13%	2.52 ± 1.68 (8)		
Red-winged blackbird	lower Penobscot	72%	4.07 ± 3.42 (111)	33%	1.16 ± 1.36 (91)	4%	1.90 ± 5.03 (93)	38%	7.35 ± 8.60 (88)	44%	11.71 ± 15.07 (18)	69%	11.52 ± 9.42 (13)		
	reference	0%	0.20 ± 0.08 (2)	0%	0.16 ± 0.18 (3)	0%	1.27 ± 1.63 (2)	0%	1.89 ± 1.72 (2)	NA	1.46 (1)	0%	1.20 ± 1.20 (3)		
Virginia rail	lower Penobscot	77%	2.24 ± 1.37 (61)	50%	1.19 ± 0.35 (14)	88%	22.42 ± 14.46 (52)	100%	32.05 ± 16.92 (7)	100%	33.34 ± 13.46 (10)	NA			
	reference	0%	0.20 ± 0.11 (12)	NA		25%	2.99 ± 2.51 (12)	NA		50%	6.15 ± 1.73 (2)	NA			
American black duck	Mendall Marsh	19%	0.78 ± 0.54 (16)	NA		NA		NA		0%	2.12 ± 1.20 (13)	NA		100%	0.79 ± 0.16 (11)
	Verona-ES13	0%	0.23 ± 0.25 (11)	NA		NA		NA		0%	2.03 ± 2.11 (3)	NA		NA	
	Frenchman Bay	0%	0.09 ± 0.03 (14)	NA		NA		NA		0%	2.30 ± 1.19 (8)	NA		NA	

The extreme concentrations of Hg found in adult primary feathers, up to 136 µg/g fresh wt. (mean, 48 µg/g fresh wt.), further indicate a threat to the health of Nelson's sparrows on the Penobscot marshes. Primary (wing) feathers from birds along the lower Penobscot exceeded the Hg target to protect bird health in virtually all birds sampled. The P1 feather would be the first feather formed in the pre-basic molt, which occurs in late summer on the breeding grounds, and best reflects Hg exposure on the breeding marsh. The S2 feather would be molted soon after. Hg concentrations in the P1 primary feather, collected in 2009 and 2010, exceeded the Hg target for feathers, 5 µg/g fresh wt., in 95% of the Penobscot birds sampled. For 2009 and 2010 samples combined, the mean total Hg concentration, in the P1 feather, 48 ± 32 µg/g fresh wt., was over 9 times greater than the feather Hg target to protect bird health. In contrast, at the Spurwink Marsh reference site, Hg concentrations in the P1 feather averaged 6.5 ± 2.5 µg/g fresh wt.. The S2 secondary feather, sampled in 2008, exceeded the Hg feather target in 85% of birds sampled (mean total Hg, 15 ± 7 µg/g fresh wt.).

The elevated Hg concentrations found in 95% of the Nelson's P1 feather samples from the lower Penobscot indicate that we may be sampling P1 feathers soon after they are formed, at the very beginning of the molt. If the feathers were formed the previous year, with a reported year-to-year return rate of under 40%, we would expect to find a lower percentage of the feathers with elevated concentrations. In order to definitively answer this question, we collected molt cards in the 2012 monitoring program, which record the progress of the molt for each individual feather, prior to sampling. Data from the molt cards will document whether the feather was formed in the current season at the capture site, or formed a year earlier.

11.5 Regional Comparisons of Hg in Nelson's Sparrow

Hg concentrations in both blood and wing feathers from adult birds sampled in the Mendall Marsh area far exceed the highest Hg concentrations reported in the literature for this species. Hg in the P1 primary feathers at Mendall Marsh averaged 34 and 52 µg/g in 2009 and 2010, respectively, 5 to 10 times greater than concentrations reported for Nelson's sparrows from other North American breeding sites. Winder and Emslie (2011) reported Hg in the P1 primary feathers of Nelson's sparrows at two breeding sites, N Dakota and northern Ontario, where Hg averaged between 3 and 5 µg/g fresh wt. Winder (2012) reported Hg concentrations between 4.8 to 9.8 µg/g fresh wt. in the primary feathers from Nelson's sparrows sampled at North Carolina wintering sites; the North American breeding sites where the feathers were actually formed was not reported.

Hg concentrations in the blood of adult Nelson's sparrows sampled in marshes along the lower Penobscot were 5 to 15 times greater than found in Nelson's and related sparrow species from other regions. Shriver et al. (2006) reported Hg concentrations in blood from Nelson's and sharp-tailed sparrows from five breeding marshes along the southern Maine coast. Mean Hg concentrations for Nelson's sparrows ranged from 0.26 to 0.56 µg/g wet wt. and from 0.56 to 0.87 µg/g wet wt. for the closely related sharp-tailed sparrow; these concentrations are roughly 10 times lower than found in Nelson's sparrows sampled along the lower Penobscot. Cristol et al. (2011) found even lower mean Hg concentrations in blood for the same two species on wintering grounds in

Virginia (Nelson's 0.14 µg/g wet wt.; saltmarsh 0.37 µg/g wet wt.). Winder and Emslie (2011; 2012) presented data for Hg in blood of Nelson's sparrows on breeding grounds in North Dakota and northern Ontario (Canada), and in wintering grounds in North Carolina. Blood Hg varied from approximately 0.05 to 1.1 µg/g wet wt. depending on location and season, concentrations that were 8 to 15 times lower than concentrations found along the lower Penobscot.

11.6 Nelson's Sparrow Summary

Hg concentrations in both blood and wing feathers from adult birds sampled in the Mendall Marsh area far exceed the highest Hg concentrations reported in the literature for this species. These high concentrations pose a serious risk to the health of Nelson's sparrows inhabiting marshes along the lower Penobscot River. Geographically, Nelson's sampled along the lower Penobscot had Hg concentrations in their blood that were roughly 10 times greater than in Nelson's sampled at reference sites on Mt. Desert Island and along the southern Maine coast (Figure 14-28). Hg concentrations varied with feather type, with higher mean concentrations in P1 primary feathers grown on the Penobscot breeding grounds (48 µg/g wet wt.) and significantly lower mean concentrations in tail feathers (2.5 µg/g fresh wt.) generally grown before arrival to the Penobscot area. Virtually all Nelson's sparrows sampled along the lower Penobscot River had Hg concentrations in their blood exceeding the target to protect bird health, while only 2% of the birds from reference sites exceeded that target. Hg concentrations also exceeded the target to protect bird health in the majority of tail feathers in hatch year birds and the primary and secondary feathers in adult birds, both of which were grown while the birds were resident in marshes along the lower Penobscot. Hg concentrations in the blood sampled from Nelson's sparrows did not change over our 4-year sampling period, though it did vary at individual sites. Significant increases in Hg over time were found at two sites (W17-S and Mendall Marsh-Southeast) while significant decreases were found at two other sites (Mendall Marsh-Northeast and Mendall Marsh-Southwest).

12 SONG SPARROW (*Melospiza melodia*)

12.1 Song Sparrow Biology

Migrating song sparrows return to breeding sites in Maine in late March to early April. They use a range of habitats, from forest and oldfield to riparian and marsh habitats. Pairs establish breeding territories, as small as 400 m2 in tidal marshes, where prey are abundant, but reports indicate variable site fidelity as the season progresses. Song sparrows often raise at least two clutches per year. Their annual molt may occur from July to early September, so newly molted feathers may have been sampled in our study. In chicks, the wing and tail feathers emerge about 10 days after the molt begins and the body is already fully feathered. In adults the molt begins with the 1st primary feather, with body feathers beginning to molt 5-6 days later. Song sparrows are not obligate marsh feeders, even when nesting in a marsh. Their diet during the spring and summer breeding season includes up to 60% seeds and fruit in addition to invertebrates, including snails, polychaete worms, and insects (Arcese et al. 2002).

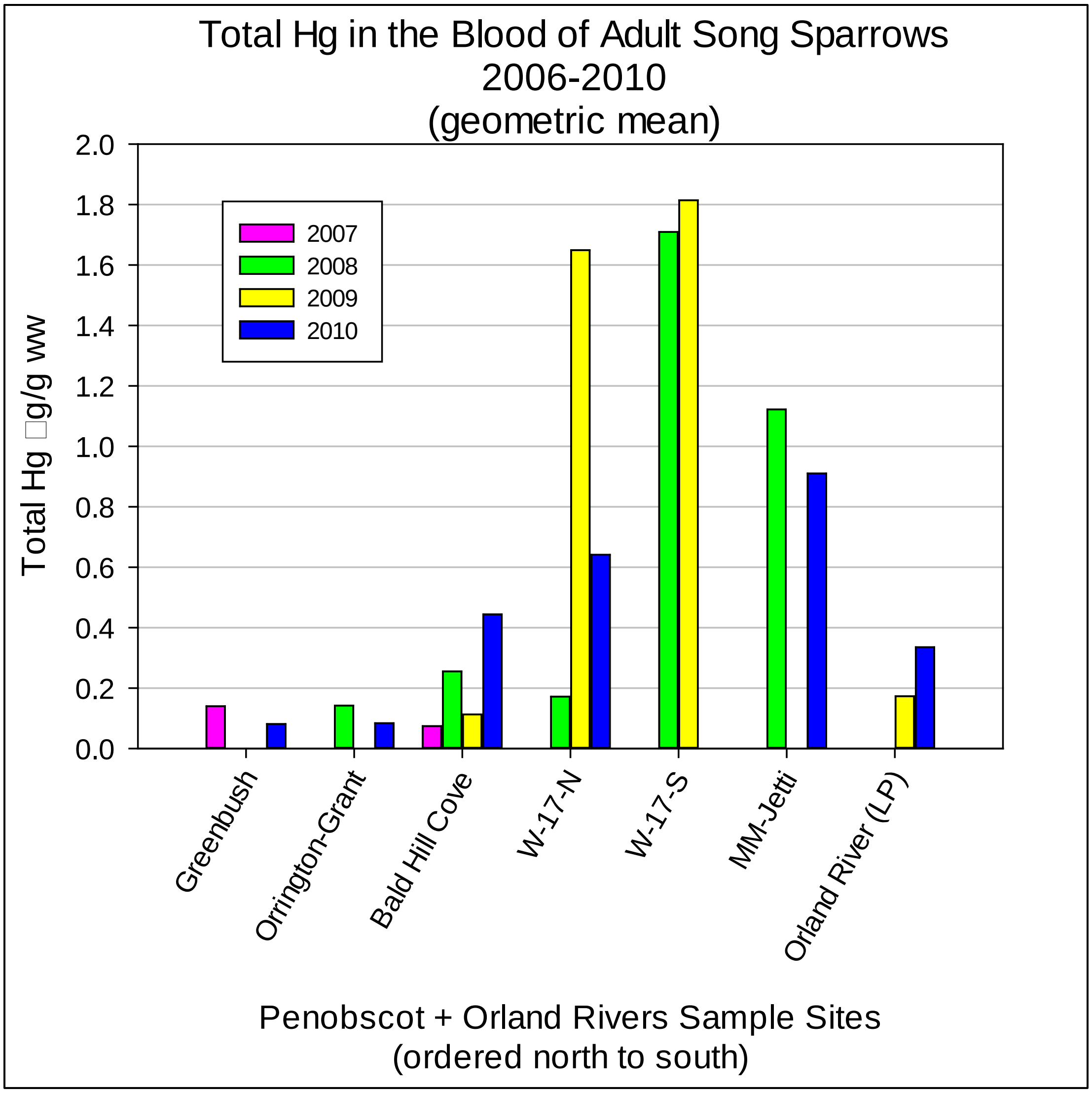


Figure 14-29. Temporal comparisons of mean Hg concentrations in song sparrows within individual sites sampled in multiple years. Hg concentrations in song sparrows significantly increased during our 4-year monitoring period at one site, Bald Hill Cove.

12.2 Temporal Comparison of Total Hg in Song Sparrows

Hg concentrations in the blood of adult song sparrows remained essentially constant during our 4-year monitoring period, although trend analyses were limited by changing sample locations and small sample sizes not suitable for statistical testing. There was a significant increase in Hg concentrations in the blood of adult song sparrows at one of eight sites (Bald Hill Cove) sampled in multiple years (Figure 14-30). Most sites tested were sampled in only two years, reducing the strength of the finding of no trend over time. The one site found to have a significant trend was sampled in all four years.

12.3 Geographic Comparisons of Total Hg in Song Sparrows

The greatest Hg concentrations in song sparrows were found at Mendall Marsh and W17, breeding marshes along the lower Penobscot River (Figure 14-31; Appendices 14-9a+b, blood; 14-9c+d, feathers). Significantly elevated Hg concentrations were found at those sites in three of the four years sampled, relative to sites upstream in the Penobscot River, sites far south in Penobscot Bay and distant reference sites (Figure 14-32). In 2007 song sparrows from the three Mendall Marsh sites averaged 1.5 to 3.5 µg/g wet wt. in blood, significantly greater than all other sites which had mean concentrations below 0.5 µg/g wet wt. (ANOVA, $P< 0.001$, Tukey's HSD test, $\alpha = 0.05$). Concentrations were also high in the lower Penobscot marshes in 2008, but small sample sizes in those marshes limited the statistical power of the tests. In 2009 blood Hg concentrations at the W17 sample sites and in the central area of Mendall Marsh (0.6 – 2.2 µg/g wet wt.) were significantly greater ($P < 0.001$) than at Bald Hill Cove to the north and sites on the east side of Verona Island (Leaches Point) and along the coast. The same significant pattern was found in 2010 ($P = 0.001$), though overall concentrations were lower except for birds sampled at W17South (3.3 µg/g wet wt.) and Mendall marsh South 174 (1.9 µg/g wet wt.). Hg concentrations in tail feathers varied significantly in 2007 (ANOVA, $P =0.04$), averaging 12.2-13.0 µg/g fresh wt. at Mendall Marsh Northeast and Southeast, but sample sizes were small and no significant pairwise differences were found. Hg in adult feathers were not significantly different in any other year.

Hatch year birds had significantly greater Hg concentrations at certain Mendall Marsh and W17 sites in 2007 and 2008, but not in 2009 or 2010 when sample numbers were reduced. In 2007, hatch year birds from Mendall Marsh Southeast had significantly greater blood (14.6 ± 0.7 µg/g wet wt.) and tail feather (18.7 ± 4.1 µg/g fresh wt.) concentrations than young birds sampled from all other sites (ANOVA, $P < 0.001$). In 2008 blood concentrations were generally lower, but still significantly greater at all sites relative to Bald Hill Cove North (0.03 µg/g wet wt.). Tail concentrations varied significantly ($P = 0.024$), but had no pairwise differences, perhaps due to small sample sizes.

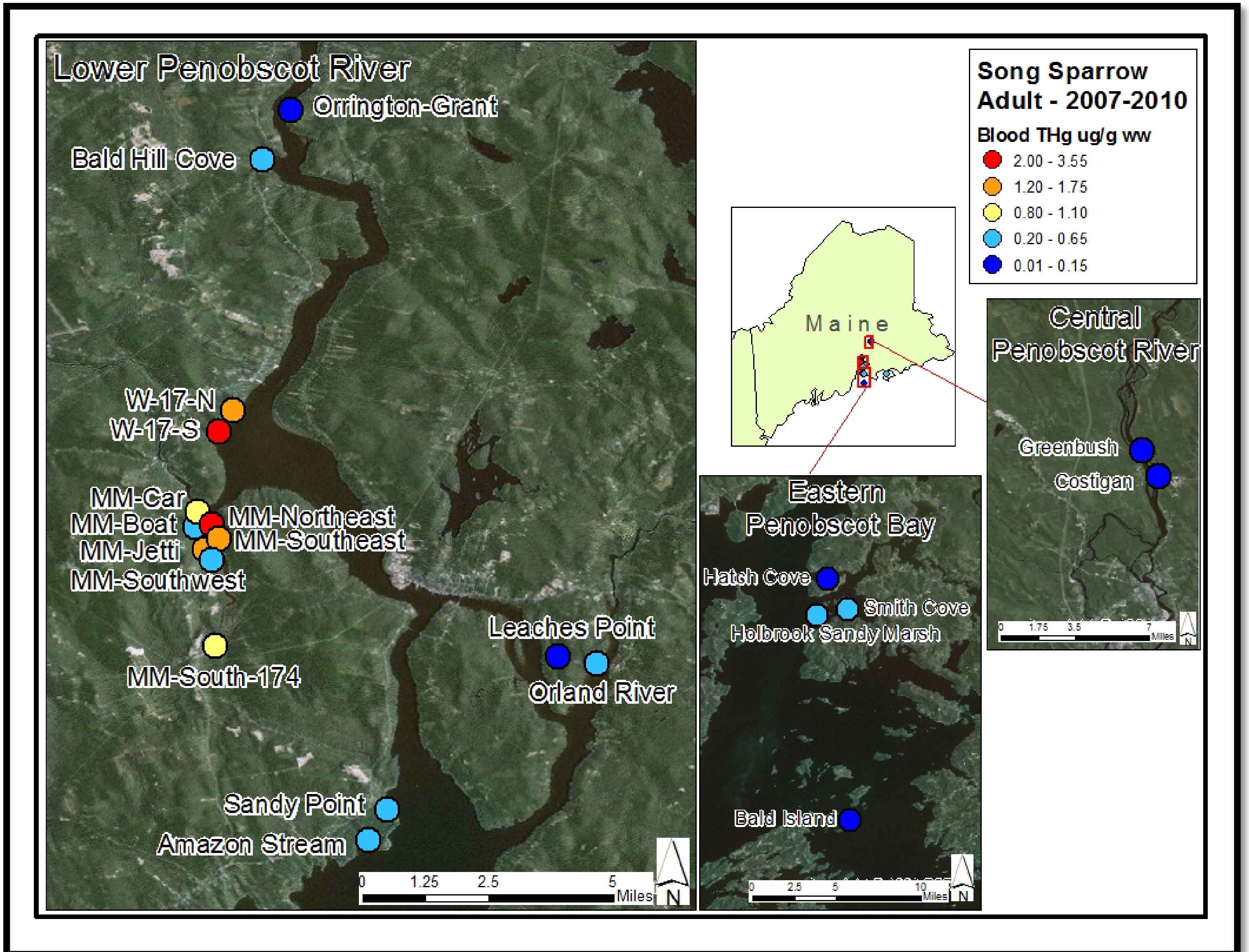


Figure 14-30. Song sparrow sampling locations and mean Hg concentrations calculated for the entire 4-year monitoring period (2007 – 2010).

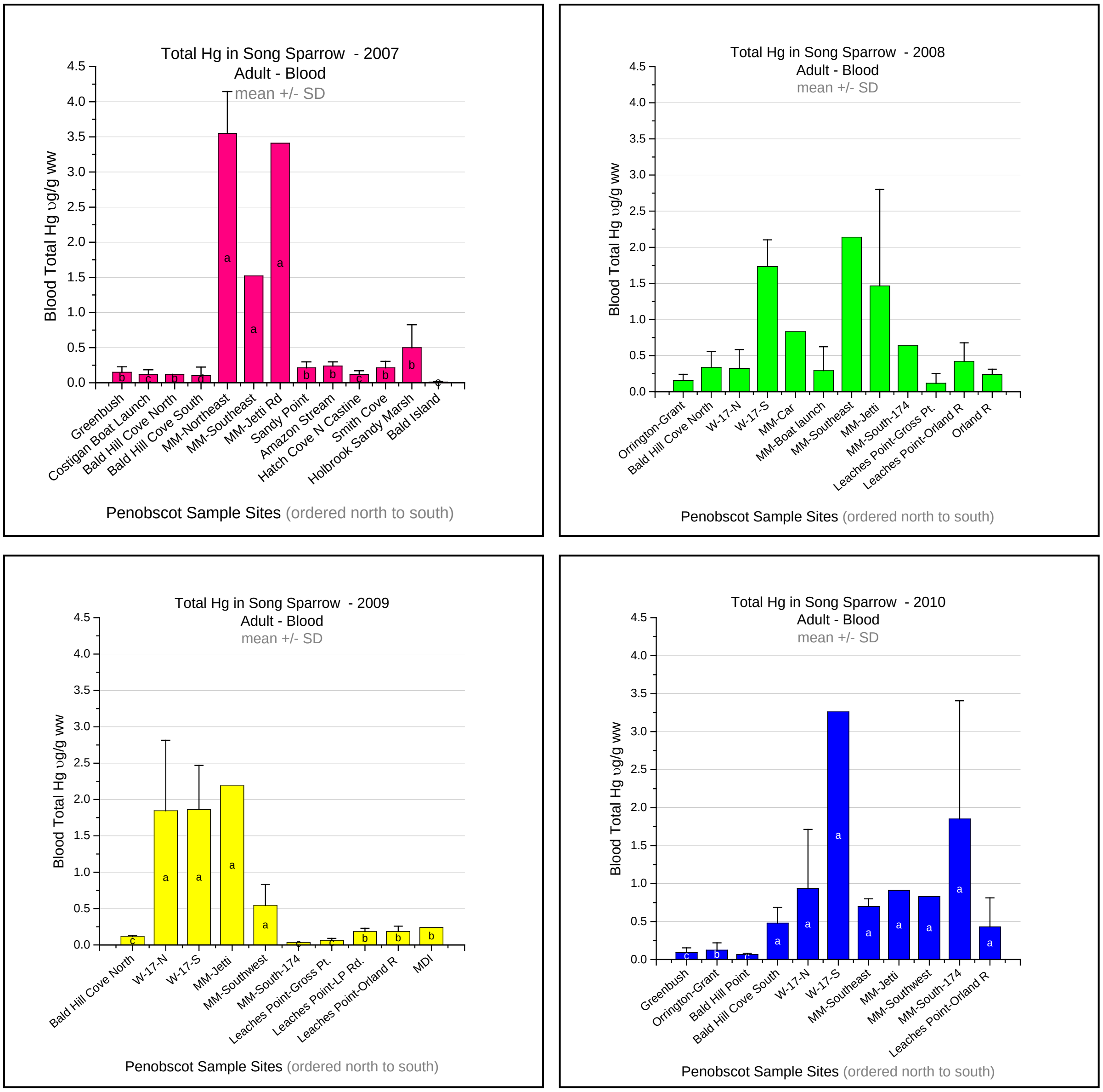


Figure 14-31. Geographic comparisons of mean Hg concentrations in adult song sparrows at all sites sampled in each year of the study. Letters in each bar define homogenous groups where Hg concentrations were statistically equivalent.

12.4 Song Sparrow Hg Concentrations and Biota Targets

Hg concentrations in song sparrows were lower than found in other sparrow species sampled, due in part to their mixed diet and broad foraging areas. Sixteen percent of adult song sparrows had Hg concentrations in the blood in excess of the target concentration intended to protect bird health (Table 3). This number peaked in 2009 when 30% of adults' blood levels exceeded the target. In hatch year birds, 11% had blood concentrations in excess of the target of 1.2 µg/g wet wt.

Few adults, around 10% overall, had tail feather concentrations in excess of the target of 5 µg/g fresh wt. A greater proportion of the hatch year birds had Hg concentrations in tail feathers in excess of the target (20%). As tail feathers emerge toward the end of feather formation in hatch year birds the feather concentrations in body feathers may be greater.

In 2010, we sampled the P1 primary feather, the first feather to emerge in adults during their annual molt. In adults, 35% exceeded the target concentration of 5 µg/g fresh wt., as did 15% of hatch year birds from the lower Penobscot; no birds from reference marshes exceeded the Hg target in primary feathers.

12.5 Regional Comparison of Hg in Song Sparrows

Hg in song sparrows in the contaminated zone of the Penobscot River was over 2 times greater than found at other contaminated sites and up to 10-times greater than reported for uncontaminated sites. Hg in the blood of song sparrows sampled at Mendall Marsh and sites along the lower Penobscot ranged broadly from 0.03 to 3.5 µg/g wet wt. Song sparrows at reference sites sampled in this study (Figures 14-30 to 14-32) had Hg concentrations from 0.1 to 0.2 µg/g wet wt. Hg in their blood. Evers et al. (2005) found about 0.2 µg/g wet wt. in the blood of song sparrows in the Sudbury and Charles rivers, MA. Jackson et al (2011) found 0.05 µg/g wet wt. in blood upstream of the Hg source in the South River, VA (a Hg contaminated river) and 0.42 to 1.63 µg/g wet wt. Hg in song sparrow blood downstream of the source.

12.6 Song Sparrow Summary

Hg concentrations in song sparrows were consistently greater at the Mendall Marsh sites and the W17 marshes, relative to upstream and coastal reference sites. Mean Hg concentrations at two sites, W17-South (2.0 µg/g wet wt.) and Mendall Marsh-Northeast (3.6 µg/g wet wt.), were greater than previously reported for this species. Song sparrows exceeded the Hg target in blood to protect bird health in 10 to 30% of the adult birds sampled. Between 20% and 35% of feathers likely grown in song sparrows resident on the Penobscot exceeded the Hg target to protect bird health, including tail feathers in hatch year birds and primary feathers in adult birds. Hg concentrations in blood sampled from song sparrows held constant at most sites during the four year sample period. A significant increase in Hg concentrations was found at one site, Bald Hill Cove, located between Winterport and Orrington.

13 SWAMP SPARROWS (*Melospiza geogiana*)

13.1 Swamp Sparrow Biology

Swamp sparrows establish small breeding territories in brackish marshes soon after their arrival in late April or early May along the Maine coast. They breed exclusively near water, and forage almost entirely in shallow water for a diet that includes insect larvae, aphids and aquatic invertebrates. They remain on the breeding habitat through their annual (complete) molt in August and early September, migrating south to wintering grounds in October. Roughly 50% of swamp sparrows return to a given breeding site the next year, half of those males hold the same territory, while females generally do not (Mowbray 1997). Given this, feathers collected in mid-summer had a 50% chance of being from birds that had bred and molted new feathers at that site the previous year.

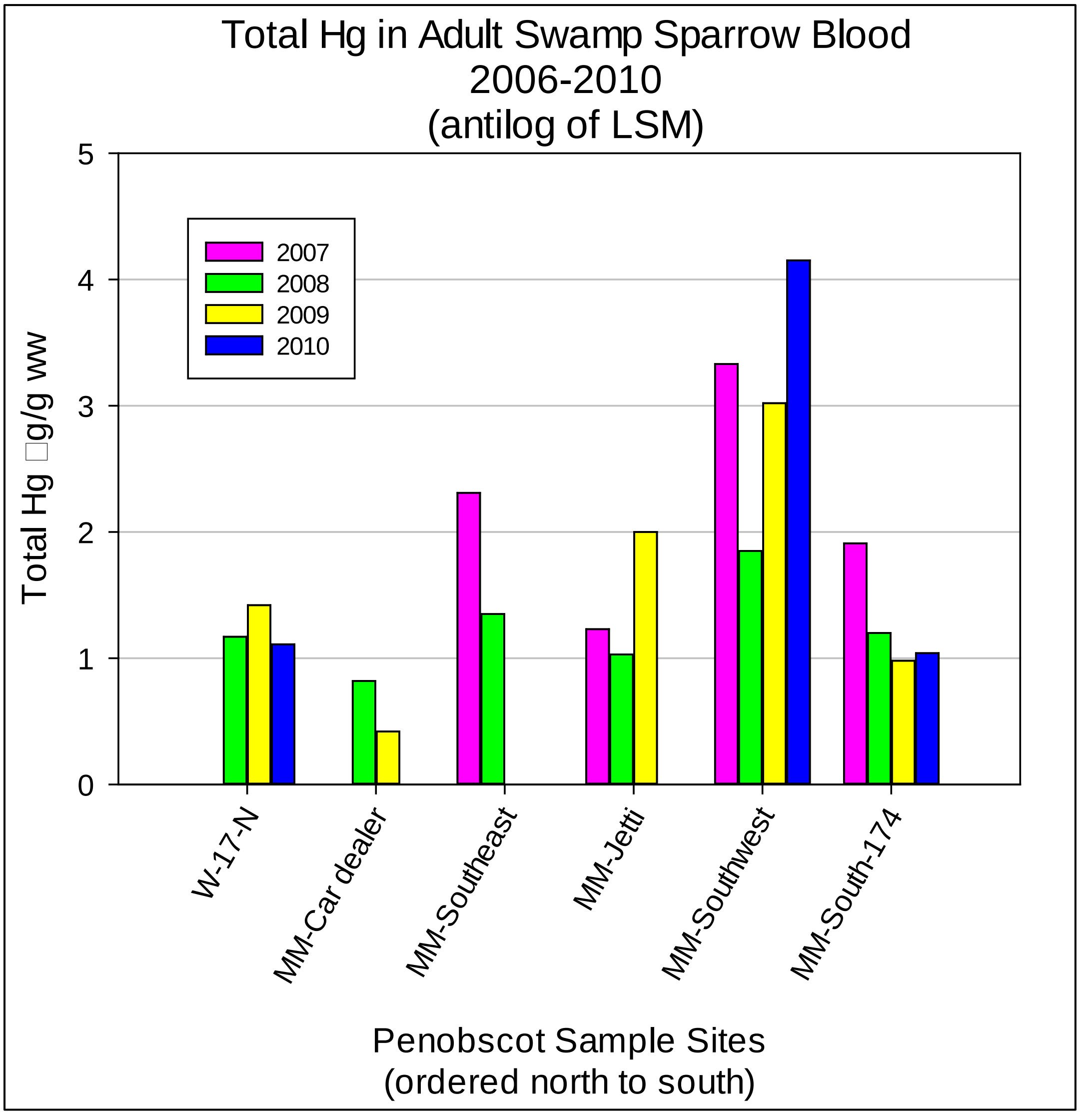


Figure 14-32. Temporal comparisons of mean Hg concentrations in swamp sparrows within individual sites sampled in multiple years. A significant decline in Hg concentrations was found at one site, MM-South-174.

13.2 Temporal Comparisons of Hg in Swamp Sparrows

Hg concentrations in the blood of adult swamp sparrows varied widely within individual sites during the 4-year sample period, yet no consistent pattern of increase or decrease was found (Figure 14-33). One of the six sites sampled in multiple years, Mendall Marsh – South 174, had a significant decline in blood Hg concentrations (ANOVA, independent linear model with pooled variance, P=0.045). Differences at the other five sites were not statistically significant.

13.3 Geographic Comparisons of Hg in Swamp Sparrow

The greatest Hg concentrations in swamp sparrows were found at sites in and near Mendall Marsh (Figure 14-34; Appendices 14-10a, blood; 14-10b, feathers). In most years, Hg concentrations were significantly greater in adult swamp sparrows sampled in two adjacent marshes, Mendall Marsh and W17, relative to reference sites upstream of the HoltraChem site or along the southern Maine coast (Figure 14-35). In all years the greatest blood Hg concentrations were found at one site, Mendall Marsh Southwest. In 2007, swamp sparrows from all Mendall Marsh sites had greater Hg concentrations than found in swamp sparrows from the one reference area, Passadumkeag, north of Old Town (ANOVA, $P = 0.026$; Tukey's HSD, $\alpha = 0.05$). In 2008, swamp sparrows were not sampled from a reference area and no significant difference was found in Hg concentrations among the W-17 and Mendall Marsh sites. Hg concentrations were more variable in 2009, still significantly greater at W-17 and two Mendall Marsh sites relative to reference sites ($P < 0.001$), but one bird sampled at Bass Harbor on Mount Desert Island also had statistically greater concentrations than birds from the other reference sites. In 2010, swamp sparrows had the same pattern of significantly elevated Hg concentrations at Mendall Marsh ($P<0.001$) relative to other sites.

Concentrations in adult feathers were not significantly different among birds from the lower Penobscot marshes and reference sites. Tail feathers were sampled in all years, and the 1st primary feather in 2009 and 2010. Given the timing of their annual molt and migrations, feathers did not consistently reflect local Hg exposure.

In all but one year, Hg concentrations did not vary significantly in the blood or feathers of hatch year birds, born that summer and recently fledged. Hatch years were generally sampled in lower numbers than the adults. But in 2010 the hatch year birds, sampled in larger numbers and at both contaminated and reference sites, had significantly greater blood Hg concentrations at W-17 North and South (0.70-0.89 µg/g wet wt.) relative to the reference sites (0.09-0.25 µg/g wet wt.; ANOVA, $P < 0.001$, Tukey's HSD, $\alpha = 0.05$). In feathers the hatch year birds from the Greenbush reference site had Hg concentrations equivalent to that found in hatch year birds from W-17, indicating similar Hg exposure at the time of feather formation. These feather Hg concentrations were significantly greater than found in feathers at the other reference site at Spurwink Marsh along the southern coast.

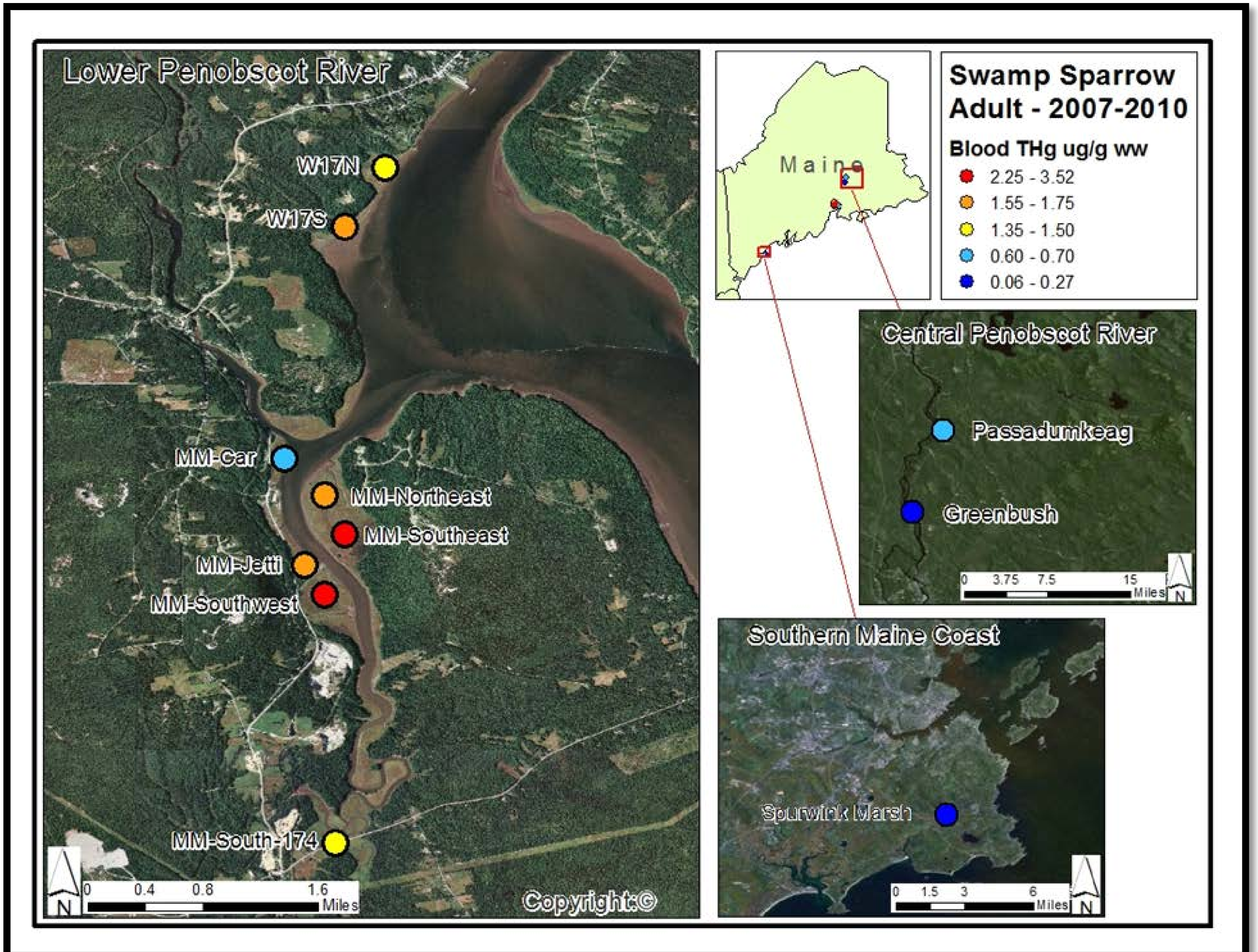


Figure 14-33. Swamp sparrow sampling locations and mean Hg concentrations in adults calculated for the entire 4-year sampling period (2007 – 2010)

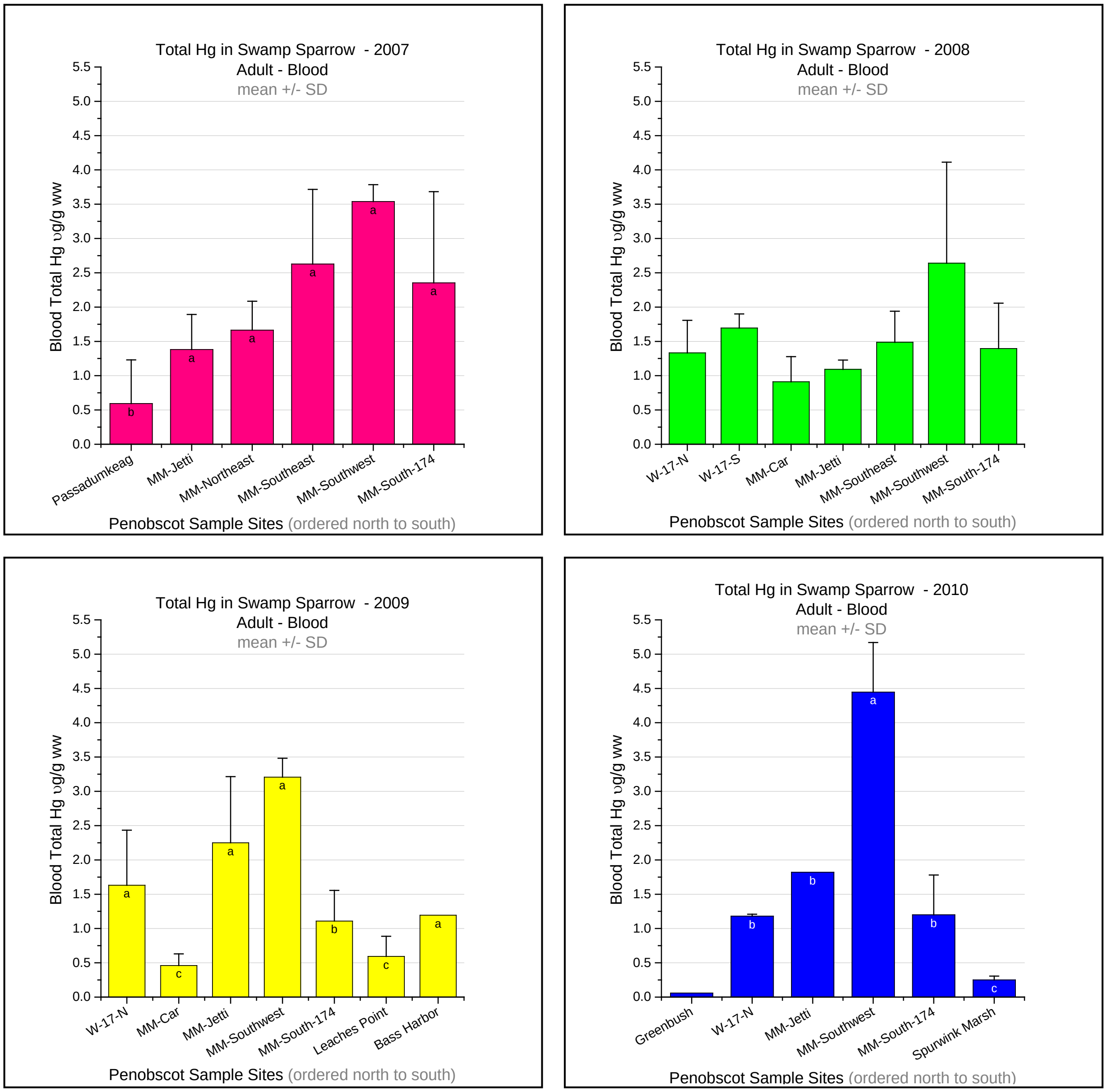


Figure 14-34. Geographic comparisons of Hg concentrations in swamp sparrows at all sites sampled in each year of the study. Letters in each bar, if present, define homogenous groups where Hg concentrations were statistically equivalent.

13.4 Swamp Sparrow Concentrations and Biota Targets

Hg concentrations exceeded the Hg target for blood in 65% of adult swamp sparrows (52% to 74%, depending on year) and in 20% of hatch year swamp sparrows (Table 3). The mean Hg concentrations in blood from adults from the most contaminated marshes were 2 to 4 times greater than the target concentration. In hatch year birds, the percent of blood samples exceeding this target was variable, from 11% in 2007 to 40% in 2008, and none in excess of this target in 2009 or 2010. As found for the Hg concentrations in blood, roughly 60% of both the tail and primary feathers from adults exceeded the feather target of 5 µg/g fresh wt. to protect bird health.

13.5 Regional Comparisons of Hg in Swamp Sparrows

Hg concentrations in adult swamp sparrows sampled in Mendall Marsh are greater than any reports for this species found in the literature (mean blood Hg 2.5 - 4.5 µg/g wet wt., min-max 0.06 – 5.2 µg/g). Evers et al (2005) reported Hg in swamp sparrow blood of approximately 0.33 µg/g wet wt. in the Sudbury and Charles rivers, MA. Strom and Brady (2011) found that Hg in the blood of swamp sparrows averaged 0.14 µg/g wet wt. in northern Wisconsin wetlands and 0.19 µg/g in southern Wisconsin wetlands. These concentrations are over 10 times lower than those found in Hg contaminated wetlands in the Penobscot system.

Warner et al. (2012) reported Hg in swamp sparrows sampled at a breeding marsh in Delaware. Feathers were sampled before the pre-basic molt in both adults (in which they sampled the previous year's feathers) and in hatch years (sampled the juvenile plumage). In adults, mean Hg concentrations in the R6 tail feather averaged 0.50 ± 0.23 µg/g fresh wt. (mean ± SD), and in the P1 primary feather Hg averaged 2.1 ± 0.96 µg/g fresh wt.; mean Hg concentrations in the same feathers from adult birds sampled along the lower Penobscot were 8 to 30 times greater in tail feathers and 2 to 4 times greater in primary feathers. Hg in tail feathers in hatch year birds from the lower Penobscot (mean Hg 4.4 to 16.6 µg/g fresh wt.) were 2 – 7 times greater than reported for hatch-year birds in Delaware (mean tail Hg 1.72 ± 1.22 µg/g fresh wt.).

13.6 Swamp Sparrow Summary

Hg concentrations in blood and feathers from adult swamp sparrows sampled along the lower Penobscot were 8 to 30 times greater than concentrations previously reported for this species, and exceeded the Hg targets to protect bird health in over 60% of the adult birds sampled. Sixteen percent of the adults from reference sites had concentrations greater than the target. Within individual years, Hg concentrations in the blood from swamp sparrows were consistently greater at the W17 and Mendall marshes, relative to reference sites, with the greatest concentration in every year at Mendall Marsh-Southwest. No consistent pattern of increase or decrease in Hg concentrations in blood was found. A significant decline in blood Hg concentrations was found at one of four sites sampled in three or more years, Mendall Marsh-South-174.

14 RED-WINGED BLACKBIRDS (*Agelaius phoeniceus*)

14.1 Red-winged Blackbird Biology

Red-winged blackbirds arrive at breeding sites along the lower Penobscot River in April and early May from more temperate coastal areas or inland wintering grounds to the south. The males arrive first, establishing territories at or near sites of successful breeding in previous years. In marshes their territories average 1,600 m^2, and may be used by up to 15 nesting females. The red-wing diet varies with habitat, but in marshes is 100% animal prey. Nestlings are fed insects, especially dragonflies and damselflies, flies, and butterflies and moths. Adults have one annual molt from mid-July through September, peaking in August. Feathers collected one year reflect Hg exposure on the previous year's breeding grounds. After nesting ends in July, red-wings, including those that bred elsewhere, congregate in marshes until the fall migration.

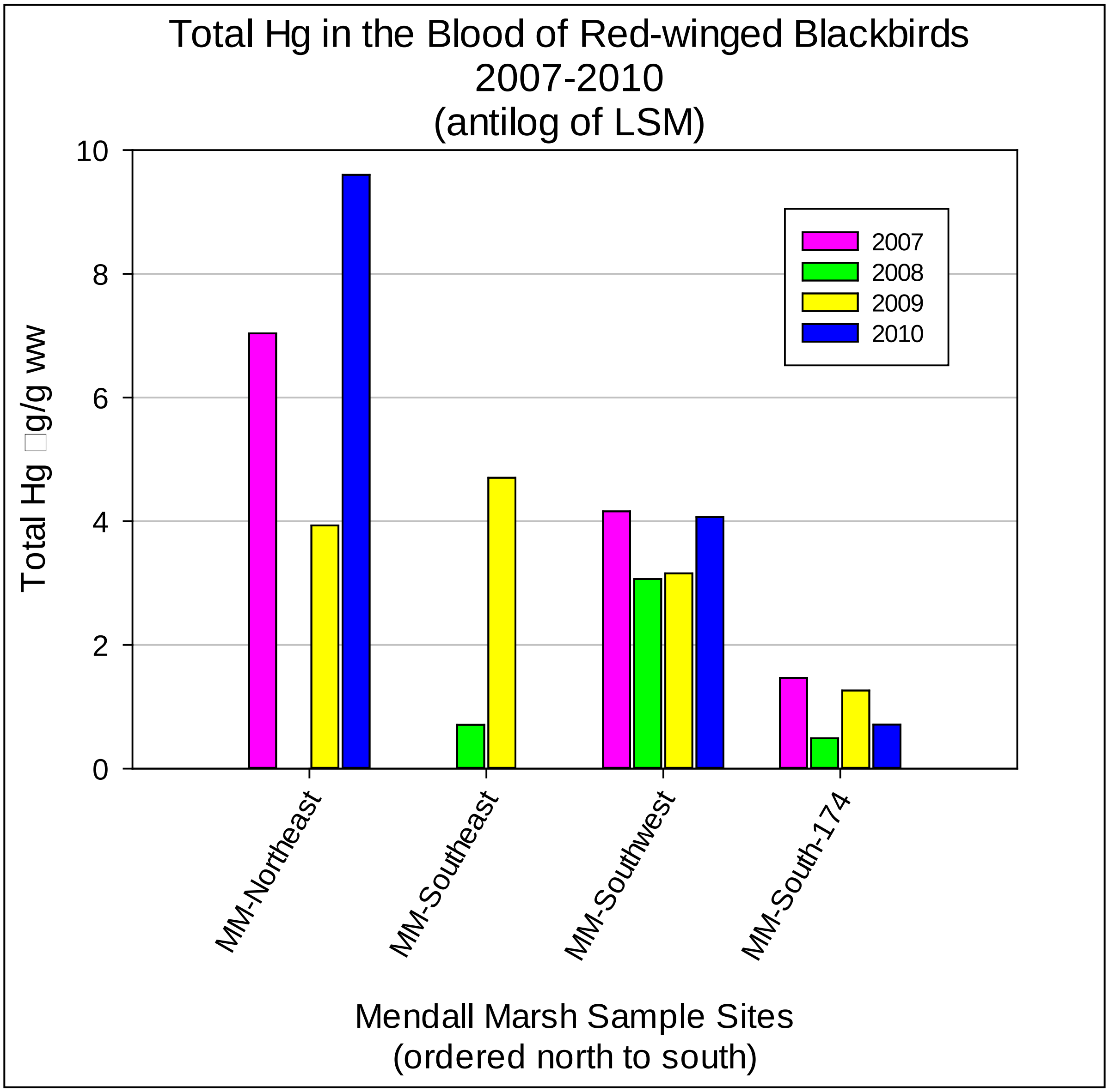


Figure 14-35. Temporal comparisons of mean Hg concentrations in red-winged blackbirds within individual sites sampled in multiple years. No sites sampled in three or more years had a significant trend in Hg concentrations.

14.2 Temporal Comparisons of Total Hg in Red-winged Blackbirds

There was no overall trend in Hg concentrations over time in the blood of adult red-winged blackbirds (Figure 14-36). Birds sampled at one site, Mendall Marsh-Southeast, had a significant increase in Hg concentrations, but as the site was sampled in only two years the finding was of limited value. No other sites sampled had significant trends in Hg concentrations in blood.

14.3 Geographic Comparisons of Total Hg in Red-winged Blackbirds

In the first three years of monitoring, red-winged blackbirds were sampled only in Mendall Marsh and W17, and there was little geographic difference in Hg concentrations within that area (Figure 14-37; Appendices 14-11a, blood; 14-11b, feathers). However, red-wings sampled at one site Mendall Marsh-South 174, located at the narrow southern tip of the marsh, had somewhat lower Hg concentrations in blood (1.1 – 2.4 µg/g wet wt.) relative to the other sites. A reference site was sampled in 2010, Spurwink Marsh. In that year, adult red-wings sampled at W17 and the northern sites in Mendall Marsh had significantly greater Hg concentrations in blood (mean Hg, 3.0 to 9.7 µg/g wet wt.; ANOVA, $P = 0.004$; Tukey's HSD test, $\alpha = 0.05$) than found at MM-South 174 (0.9 µg/g wet wt.) and at the Spurwink Marsh reference site (0.2 µg/g wet wt.) along the southern Maine coast (Figure 14-38).

Blood concentrations in hatch year birds were 75% lower than in adult red-wings, reflecting the lateral transfer of Hg to growing feathers in nestlings (Ackerman et al. 2011). Blood Hg concentrations were significantly different among sites in 2007 and 2010, but with limited to no significant pairwise differences.

Hg concentrations in adult feathers were not significantly different among sites in any year for any feather type sampled, though the absence of reference samples in most years again limited these geographic comparisons. Hg concentrations in adult tail feathers were variable in 2007, with concentrations in two individuals (one male, one female) above 30 µg/g wet wt., but were uniformly low in all adults in subsequent years, with mean Hg values always below 5, and often below 2 µg/g fresh wt. The P1 primary feather, the first feather molted each year in adults, and expected to most accurately reflect adult blood Hg concentrations from exposure on the breeding grounds, was also not statistically different among the sites tested (ANOVA, $P = 0.26$). However, only one P1 feather sample was collected from the Spurwink Marsh reference site (Hg 1.46 µg/g fresh wt.) limiting the power of the test. The mean Hg concentrations in the P1 feathers from the Mendall Marsh and W17 sites ranged from 3.1 to 28.9 µg/g fresh wt.

The Hg concentration in tail feathers from hatch year red-winged blackbirds (mean Hg, 7.2 ± 8.5 µg/g fresh wt.) was 75% greater than in adult red-wings (mean Hg, 1.9 ± 5.0 µg/g fresh wt.). The tail feathers in adult birds were likely formed at the previous year's breeding site, which may not have been the same site where feathers were sampled.

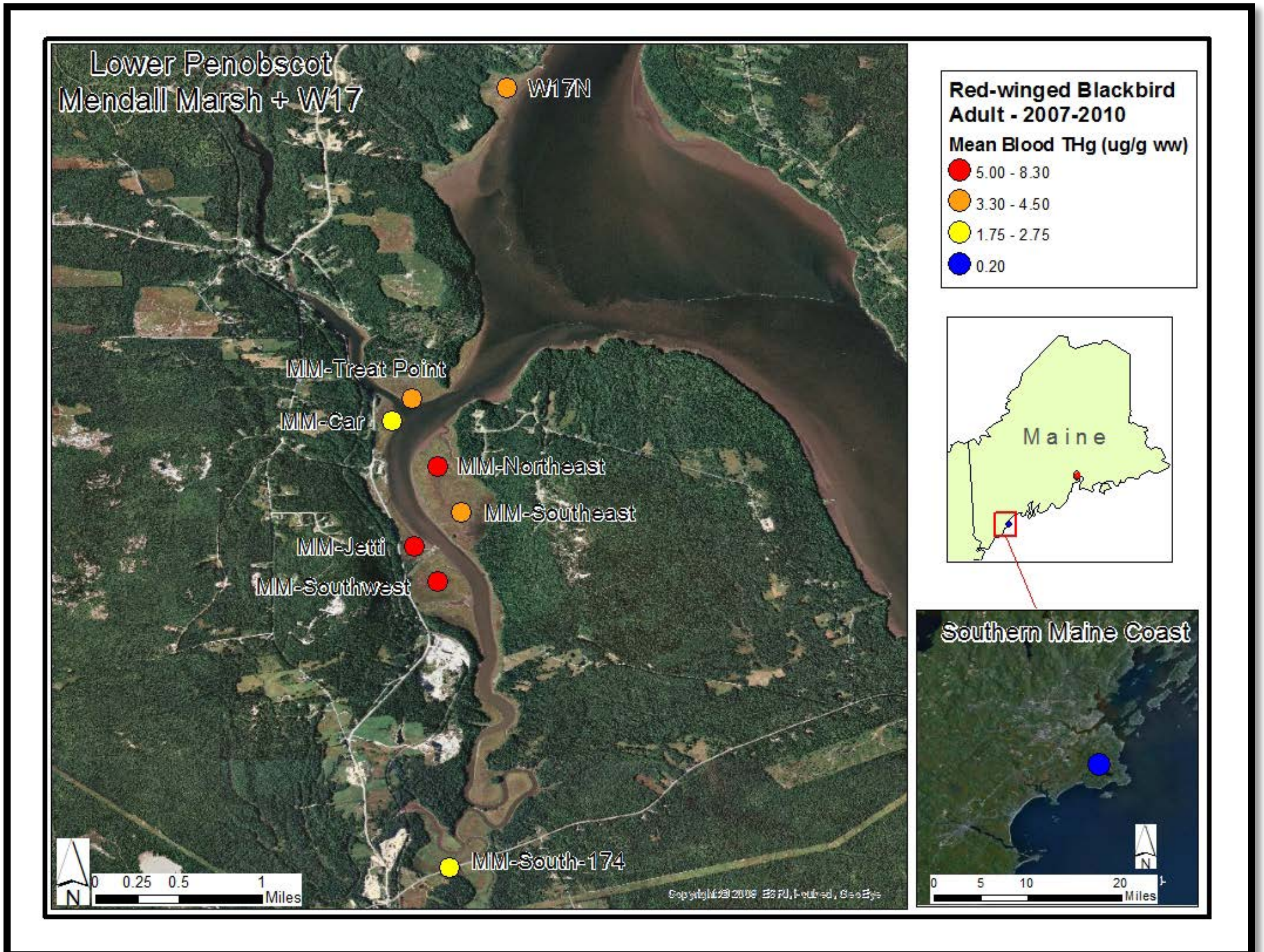


Figure 14-36. Red-winged blackbird sampling locations and mean Hg concentrations calculated for the entire 4-year monitoring period (2007 – 2010).

However, Hg concentrations in the P1 primary feathers, sampled only in 2010, were essentially the same for adult and hatch year birds from the lower Penobscot, with Hg concentrations of 11.7 ± 15.1 for adults and 11.5 ± 9.4 for hatch years. Greater variability in the adults may reflect incomplete year-to-year returns to the lower Penobscot. Further, reflecting the biological complexity that must be considered when interpreting Hg concentrations in biota, Hg concentrations in adults were notably greater in the P1 feather relative to the tail feather (P1 mean, 11.7 ± 15.1 µg/g fresh wt.; tail mean 0.8 ± 0.8 µg/g fresh wt.). In contrast, Hg concentrations in the P1 and tail feathers of hatch year birds were very similar (P1 mean, 11.5 ± 9.4 µg/g fresh wt.; tail mean 14.6 ± 10.7 µg/g fresh wt.). Whether the greater difference between P1 and tail feathers found in adults results from the timing of the P1 molt, as it is the first feather formed which may allow it to be sampled in the year in which it is formed, or from greater Hg in the blood at the time the first feather is formed, relative to feathers formed later in the molt sequence, cannot be determined with the available data. This issue was addressed in the 2012 monitoring program as molt cards were used to define the age of each feather prior to collection.

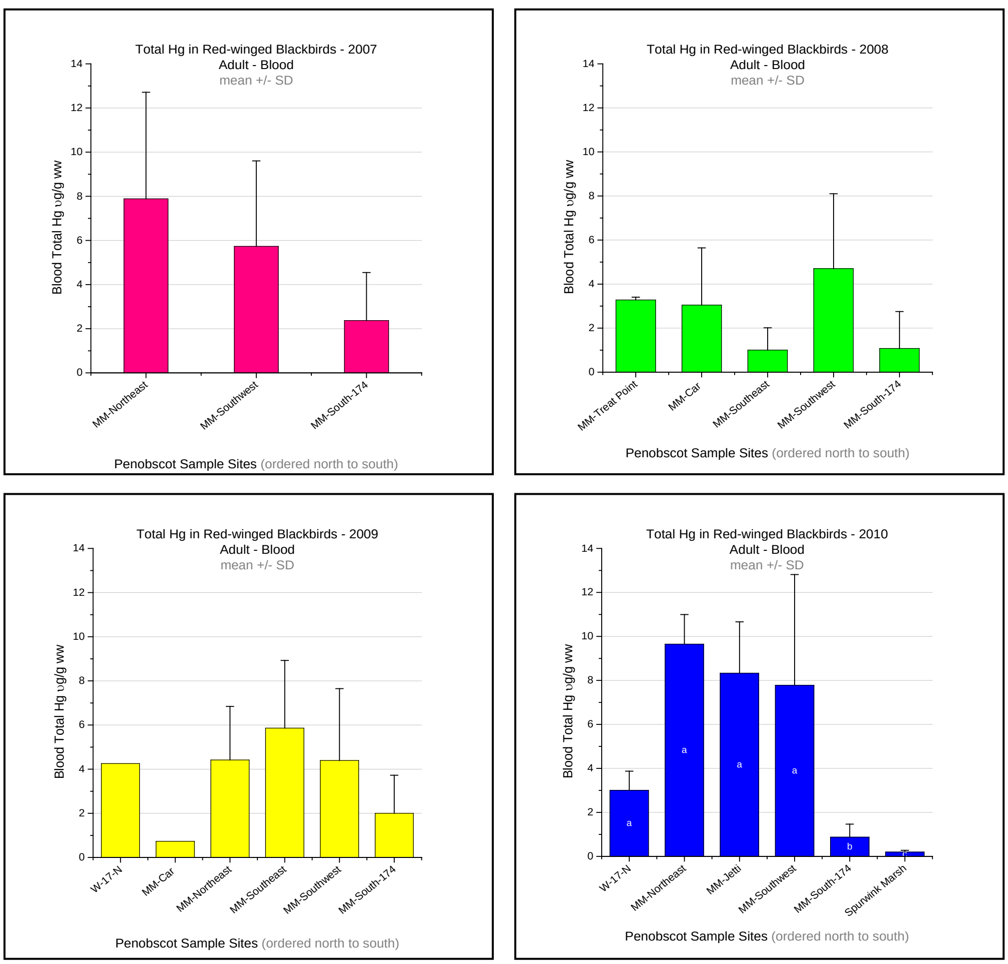


Figure 14-37. Geographic comparisons of Hg concentrations in red-winged blackbirds at all sites sampled in each year of the study. Letters in each bar, if present, define homogenous groups where Hg concentrations were statistically equivalent.

14.4 Red-winged Blackbird Hg Concentrations and Biota Targets

Hg poses a risk to the health of red-winged blackbirds breeding in marshes along the lower Penobscot. Over 70% of the adult red-winged blackbirds exceeded the target for Hg concentrations in blood and at some sites in Mendall Marsh, mean concentrations in blood in adult birds were 8 to 10 times greater than the Hg target (Table 3). Fewer hatch year birds had potentially harmful concentrations of Hg in their blood, 33% overall. This reduction in the Hg concentration in blood in the growing chicks does not indicate lower Hg exposure, but instead reflects the lateral transfer of Hg from blood to feathers in growing chicks, and Hg dilution from rapid somatic growth (Condon and Cristol 2009; Ackerman et al. 2011).

Hg concentrations in feathers also indicate high Hg exposure at the lower Penobscot marshes. Hg concentrations in primary feathers, sampled in 2010, exceeded the feather target to protect bird health (5 µg/g wet wt.) in 44% of the adult birds and in 70% of the hatch year birds. Concentrations in tail feathers were similar for hatch year birds, with 38% of the hatch year tail feathers exceeding the Hg target, and lower for adults with 4% exceeding the target. Lower concentrations in the tail feathers from adults may result from feathers grown on a different site the previous year (Chapter 2).

14.5 Regional Comparisons of Hg in Red-winged Blackbirds

Hg concentrations in the blood and feathers from red-winged blackbirds sampled along the lower Penobscot (blood mean, 4 µg/g wet wt.; primary feather mean, 12 µg/g fresh wt.) were 15 to 25 times greater than reports for the same species found in the literature. Tsipoura et al. (2008) found mean Hg concentrations in the blood of 0.23 µg/g wet wt. and in feathers of 0.83 µg/g fresh wt. for red-winged blackbirds sampled in the Hackensack Meadowlands (NJ); the Meadowlands is considered to be a Hg-contaminated site. Evers et al. (2005) found a mean of approximately 0.6 µg/g wet wt. in red-winged blackbird blood from the Sudbury and Charles rivers (MA). Wolfe and Norman (1998) found a mean of approximately 0.1 µg/g fresh wt. in a composite feather sample taken from Clear Lake (CA), again, a Hg contaminated site. As noted above, Hg in the blood of blackbirds sampled from contaminated sites in the Penobscot were 10 to 40 times greater than at the Spurwink Marsh reference site in southern Maine.

14.6 Red-winged Blackbird Summary

Hg concentrations in the blood from red-winged blackbirds sampled along the lower Penobscot are up to 25 times greater than reports for the same species found in the literature, and pose a threat to bird health. Hg concentrations in blood varied among sites in the Mendall Marsh area, but significant geographic differences were found only in 2010, when blackbirds were sampled at a coastal reference marsh where Hg concentrations were 10 to 40 times lower than found in the Penobscot marshes. Hg concentrations in adult red-winged blackbirds exceeded the targets designed to protect bird health in 70% of the blood samples and in 40% of the primary feathers sampled. During our study period there was no consistent trend over time in Hg concentrations in blood from red-winged blackbirds.

15 VIRGINIA RAIL (*Rallus limicola*)

15.1 Virginia Rail Biology

Virginia rails arrive for breeding in Maine's wetlands by mid-May from wintering grounds to the south. They breed and forage only in wetlands, preferring stands of cattails, bulrushes or other emergent vegetation. Breeding pairs form territories of varying size, with the distance between nests ranging from 17 to 46 m, but their surrounding foraging ranges likely overlap as the borders are rarely defended. Their diet during the breeding season is composed of over 90% animal prey. They forage on mudflats and in shallow water for slugs, snails, small fish, insect larvae, amphipods, crayfish, frogs and tadpoles. Chicks are able to forage independently by day seven, but they stay with their parents near the nesting site for 3-4 weeks. The adults molt their wing and tail feathers simultaneously on the breeding grounds in July and August; body feathers molt on the wintering grounds in March. They can have strong year-to-year site fidelity, returning to the same site four years in a row, but overall return estimates have not been reported (Conway 1995).

15.2 Temporal Comparisons of Total Hg in Virginia Rails

During our sample period there was no significant change in total Hg concentrations within sites in the blood of adult Virginia rails (Figure 14-39). One site, MM-South-174, had a significant increase in Hg concentration (ANOVA, independent design with pooled variance, $P < 0.001$), but the site was only sampled twice during the study period, and may represent interannual variation rather than a trend.

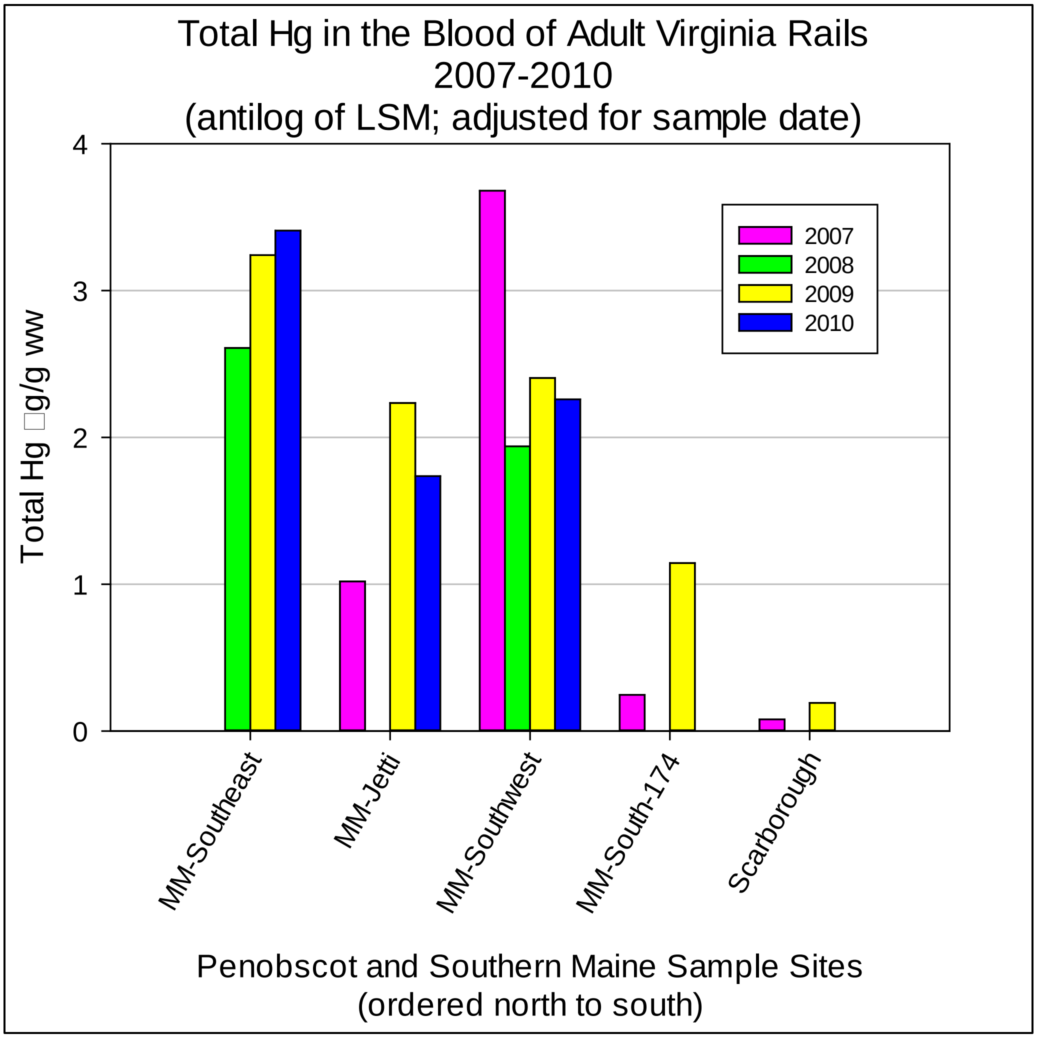


Figure 14-38. Temporal comparisons of mean Hg concentrations (antilog of least squares means adjusted for sample date) in Virginia rails within individual sites sampled in multiple years. No significant changes in Hg concentrations were found at any sites sampled in three or more years.

15.3 Geographic Comparisons of Total Hg in Virginia Rails

Hg concentrations in Virginia rails varied within Mendall Marsh but were consistently greater than found at reference sites (Figure 14-40; Appendix 14-12). In each year of the study, Hg in blood samples from adult Virginia rails were significantly greater in the marshes along the lower Penobscot River (Mendall Marsh and W17, between Mendall and Winterport) as compared to a reference site (Figure 14-41).

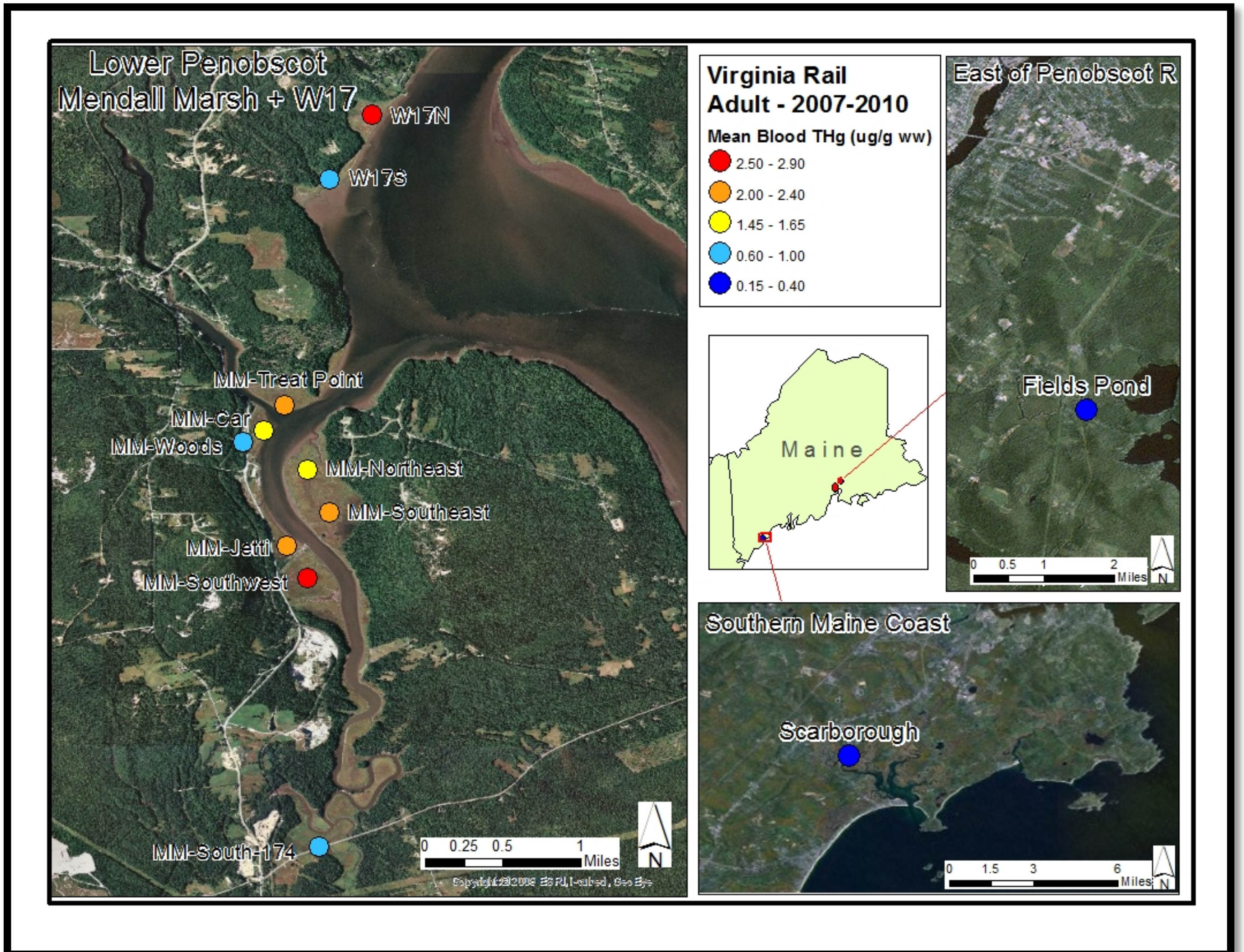


Figure 14-39. Virginia Rail sampling locations and mean Hg concentrations calculated for the entire 4-year monitoring period (2007 – 2010).

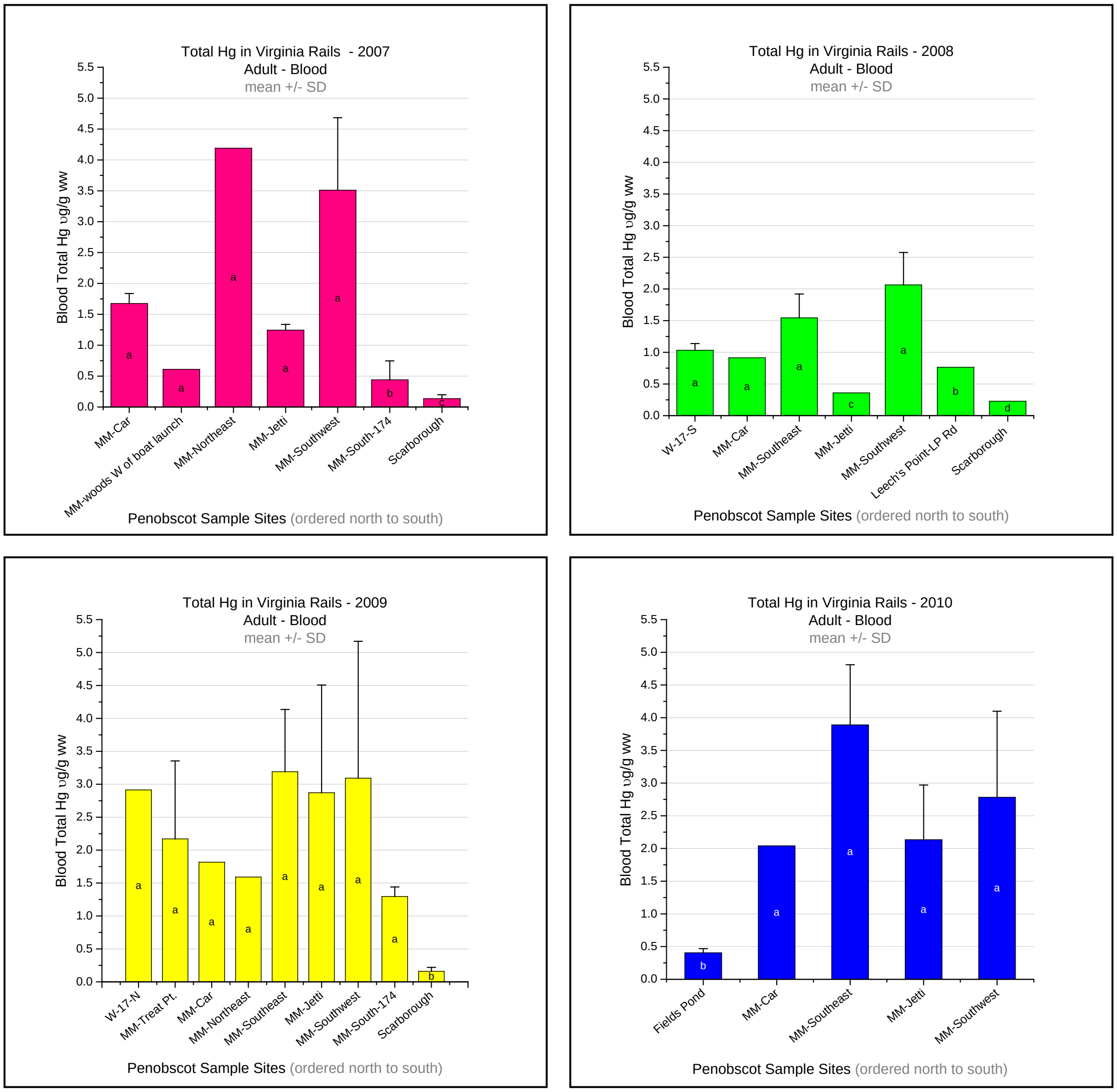


Figure 14-40. Geographic comparisons of Hg concentrations in Virginia rails at all sites sampled in each year of the study. Letters in each bar, if present, define homogenous groups where Hg concentrations were statistically equivalent.

Hatch year rails were sampled at multiple sites in 2008, but in low numbers, and Hg levels in that age class did not differ among sites. In 2007, adults from the central and northern areas of Mendall Marsh had significantly greater blood Hg concentrations (1.4 - 4.2 µg/g wet wt.) than rails at the southern end of the marsh (0.44 µg/g wet wt.) or at the Scarborough reference site (0.14 µg/g wet wt.; ANOVA, P =0.001, Tukey's HSD test, α = 0.05). A similar pattern was found in 2008 with the greatest blood Hg concentrations in rails from sites in Mendall Marsh and W17 (0.9 – 2.1 µg/g wet wt.). Birds sampled at all Mendall Marsh and W17 sites in 2009 (mean Hg 1.3 – 3.2 µg/g wet wt.) and 2010 (mean Hg 2.0 – 3.9 µg/g wet wt.) were significantly greater (P ≤ 0.01) than reference sites at Scarborough (mean Hg 0.16 µg/g wet wt., 2009) and Fields Pond (0.41 µg/g wet wt., 2010).

Hg concentrations in feathers were significantly different among sites in two of the four years sampled. In 2007 Hg concentrations in tail feathers had significant differences among sites (ANOVA, P = 0.02), but there were no pairwise differences. In 2009 tail feathers sampled from rails from Mendall Marsh and W17 had mean Hg concentrations ranging from 20 to 34 µg/g fresh wt., significantly greater than found in rails from the Scarborough marsh reference site (2.8 µg/g fresh wt.; ANOVA, P = 0.002, Tukey's HSD test, α = 0.05). In 2010, the P1 primary feathers from Mendall Marsh rails (mean Hg 28 – 41 µg/g fresh wt.) were not significantly different from primary feathers collected from rails at the Fields Pond reference site (mean Hg 6.2 µg/g fresh wt.; P = 0.077).

15.4 Virginia Rail Hg Concentrations and Biota Targets

Hg exposure in the lower Penobscot marshes threatens the health of Virginia rails, as evidenced by the large majority of rails with Hg concentrations in excess of targets established to protect bird health (Table 14-3; Chapter 2). This finding was especially serious for Virginia rails, given rails' high sensitivity to Hg exposure in the egg. Heinz et al. (2009) reported an LC50 (the median lethal concentration) in eggs from clapper rails (*Rallus longirostris,* the same genus as Virginia rails), of 0.33 µg/g wet wt., 6-times lower than reported for ducks and seabirds. Hg concentrations in the blood of female birds are positively correlated to the Hg deposited in the egg (Evers et al. 2003).

In adult rails from the lower Penobscot, all years combined, 77% had blood concentrations in excess of 1.2 µg/g wet wt. (blood Hg target to protect bird health; mean Hg of samples exceeding the target, 2.7 µg/g wet wt.) and 88% of the tail feather concentrations were greater than 5 µg/g fresh wt. (feather Hg target to protect bird health; mean Hg of samples exceeding the target, 22 µg/g fresh wt.). All of the primary feathers (100%) sampled from adult birds in 2010 exceeded the 5 µg/g target concentration; those birds in excess of the feather Hg target had an average feather Hg concentration of 33 µg/g fresh wt., 7-times greater than the target to protect bird health.

In hatch year birds, blood concentrations were more variable, likely reflecting the rapid changes in Hg concentrations in developing chicks (Ackerman et al. 2011). Hatch year birds exceeded the Hg target for blood in 14% of the young birds sampled in 2008, in 80% of those sampled in 2007 and in both hatch year birds sampled in 2009. All tail feathers from hatch year birds (100%) were 3 to10-times greater (Hg range 16 to 57 µg/g fresh wt.) than the feather target for Hg designed to protect bird health.

15.5 Regional Comparisons of Hg in Virginia Rails

As noted above, Hg in Virginia rails was 10-times greater than Hg in rails in the Scarborough Marsh reference site in southern Maine. No published results for Hg concentrations in blood from Virginia rails could be found, but Tsao et al. (2009) measured Hg in the blood of California black rails (*Laterallus jamaicensis*) in the Petaluma River CA. The Petaluma River is tributary to the Hg contaminated San Francisco Bay, but the authors stated that they know of no Hg point sources to the Petaluma. Means at different sites in different years for Hg in blood ranged from 0.2 to 0.6 µg/g wet wt.; these levels are also 10-times lower than at most contaminated sites in the Penobscot. Ackerman et al. (2012) reported Hg in blood and body feathers from clapper rails sampled in San Francisco Bay, and found a correlation between Hg and reduced body condition within a range of blood total Hg concentrations from 0.18 to 1.8 µg/g wet wt. Reduced body condition was one factor implicated in the high mortality rates seen in this species. The range of mean Hg concentrations in blood in the Virginia rails sampled in Mendall Marsh is between 0.44 and 4.2 µg/g wet wt., 4 times greater than Ackerman et al. correlated with reduced body condition in clapper rails.

15.6 Virginia Rail Summary

The majority of rails sampled, both adults and hatch years, had Hg concentrations in their blood and feathers in excess of targets established to protect bird health. Hg concentrations in rail blood were 10-times greater in the marshes along the lower Penobscot (overall mean Hg 2.2 µg/g wet wt.) relative to reference sites in central Maine and along the southern Maine coast (overall mean 0.20 µg/g wet wt.). Hg concentrations found in primary feathers from adults sampled along the lower Penobscot (mean Hg 33 µg/g fresh wt.) were 7-times greater than found at reference sites. These elevated Hg concentrations in the tissues of Virginia rails are especially serious given rails' high sensitivity to Hg exposure in the egg. There was no overall temporal trend in Hg concentrations in the blood from Virginia rails during the study period.

16 DOUBLE-CRESTED CORMORANTS (*Phalacrocorax auritus*)

16.1 Biology of Double-crested Cormorants

In Maine, double-crested cormorants arrive at their breeding sites along the coast in mid to late April. Adults have a strong year-to-year return rate if they were successful breeders. They usually forage within 10 km of their breeding colony, but they may travel as far as 60 km. They feed primarily on fish, mostly smaller or younger fish, less than 15 cm in length. Prey include rainbow smelt, cunner, rock gunnel, eel, and sand shrimp. They usually raise one clutch of eggs per season, but may lay a second clutch if the first is unsuccessful. Cormorants migrate back to the southern United States or the coast of the Gulf of Mexico in the fall (Hatch and Weseloh 1999).

16.2 Temporal Comparisons of Hg in Double-crested Cormorant

No overall trends were found in total Hg concentrations in cormorant eggs sampled in Penobscot Bay (Figure 14-42). Two sites were sampled in multiple years with sufficient sample sizes to analyze statistically. Hg concentrations in eggs sampled at Sandy Point, west of the southern tip of Verona Island, had no significant pairwise differences among years (ANCOVA, adjusted for sample date, $P = 0.05$; Tukey's HSD test, $P > 0.17$). Similarly, there was no significant trend in Hg concentrations in cormorant eggs collected from Thrumcap Island (ANCOVA, adjusted for sample date, $P = 0.11$).

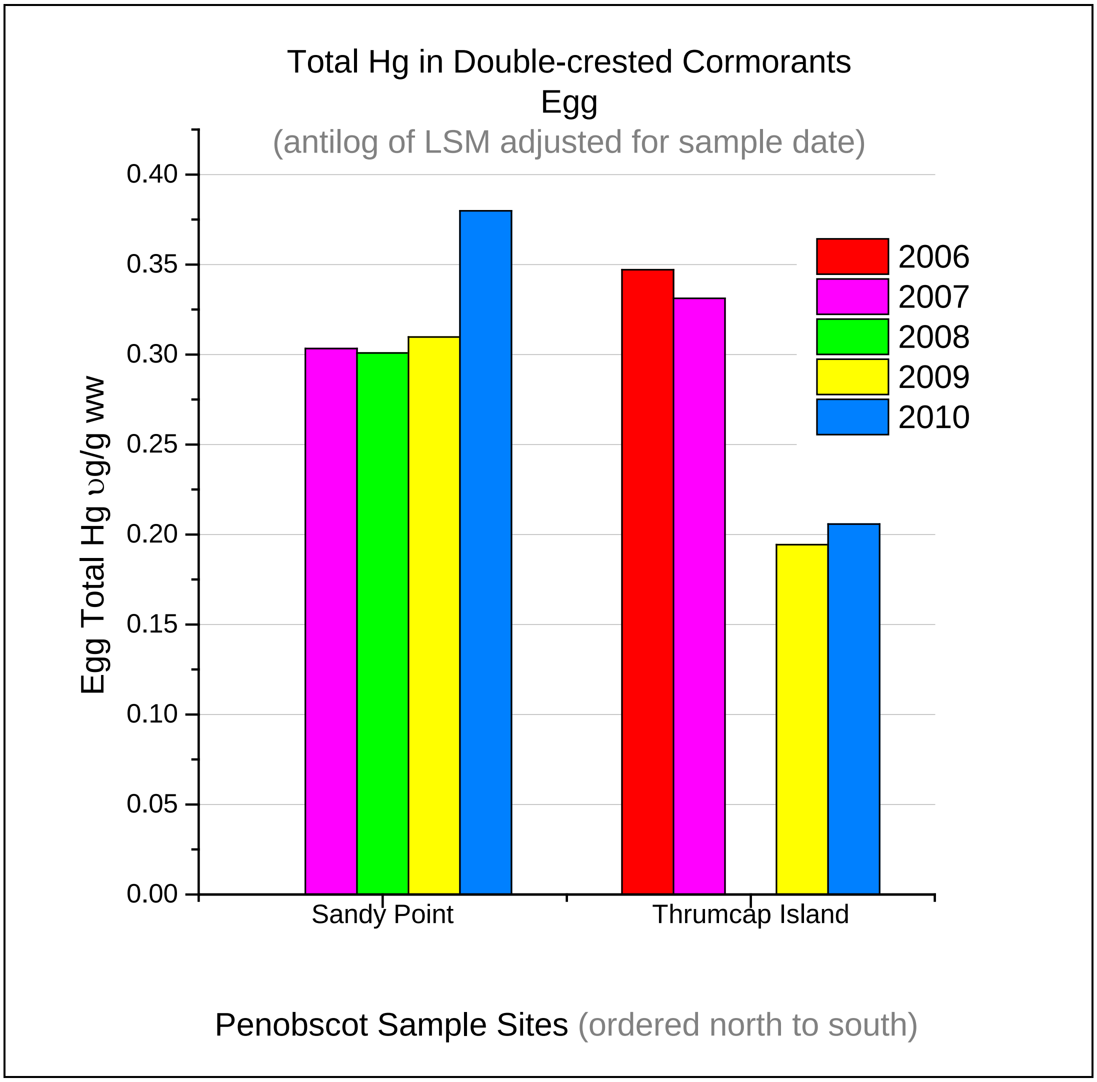


Figure 14-41. Temporal comparisons of mean total Hg in eggs (antilog of least squares means adjusted for sample date) collected from double-crested cormorants within the two individual sites sampled in multiple years. No significant trends in Hg concentrations were found at these sites.

16.3 Geographic Comparison of Hg in Double-crested Cormorants

Hg concentrations in eggs from double-crested cormorants were generally greater from breeding colonies located in or near the Penobscot River, relative to colonies to the south and east in Penobscot Bay (Figure 14-43; Appendix 14-13). Within most years, significantly greater concentrations were found at the northern-most site sampled (ANOVA, $P < 0.05$); in 2006 (Fort Point, mean Hg 0.89 µg/g wet wt.), 2007 (Luce Cove, mean Hg 0.68 µg/g wet wt.), 2008 (Sandy Point, mean Hg 0.37 µg/g wet wt.) and 2010 (Luce Cove, mean Hg 0.65 µg/g wet wt.). No significant difference among sites was found in 2009.

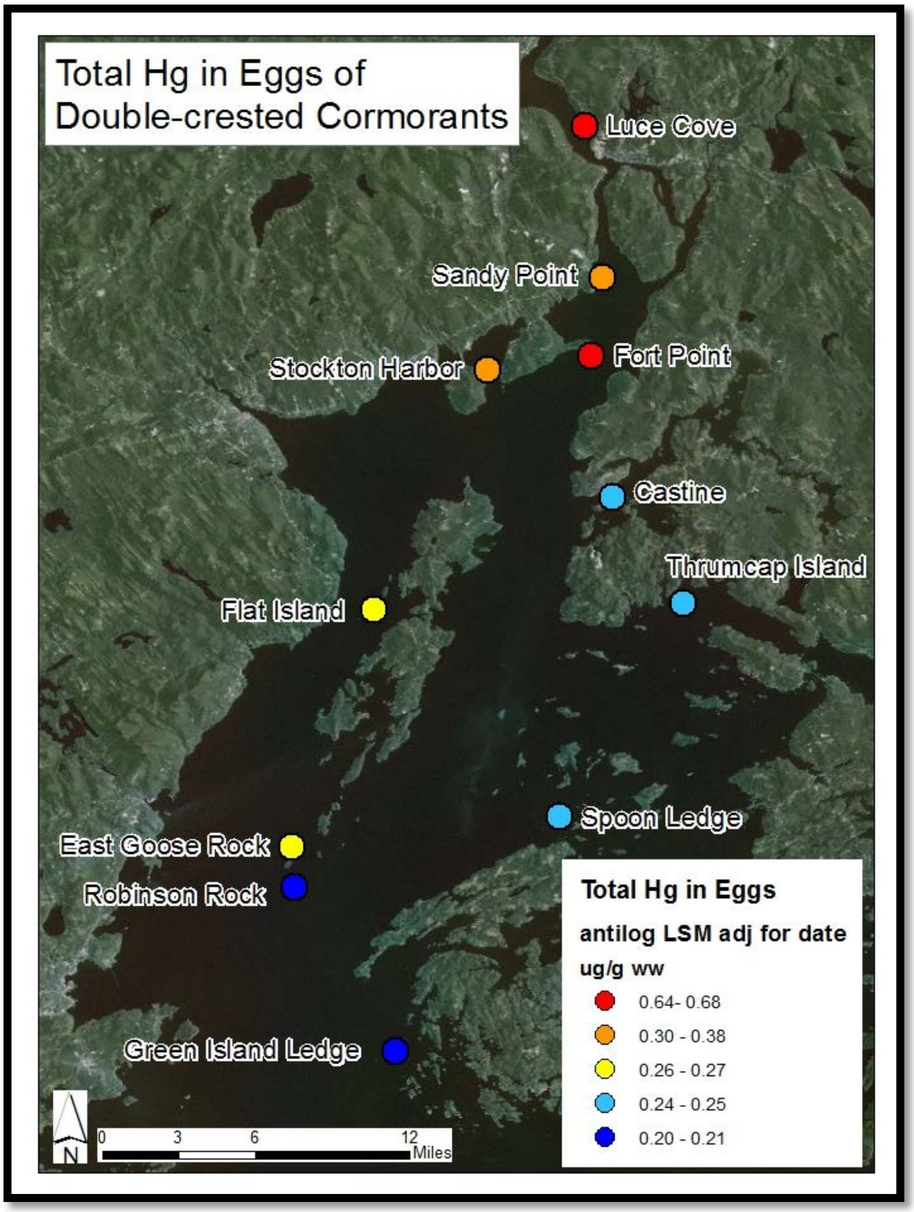


Figure 14-42. Double-crested cormorant sampling locations and mean Hg concentrations in eggs calculated for the entire 5-year monitoring period (2006 – 2010).

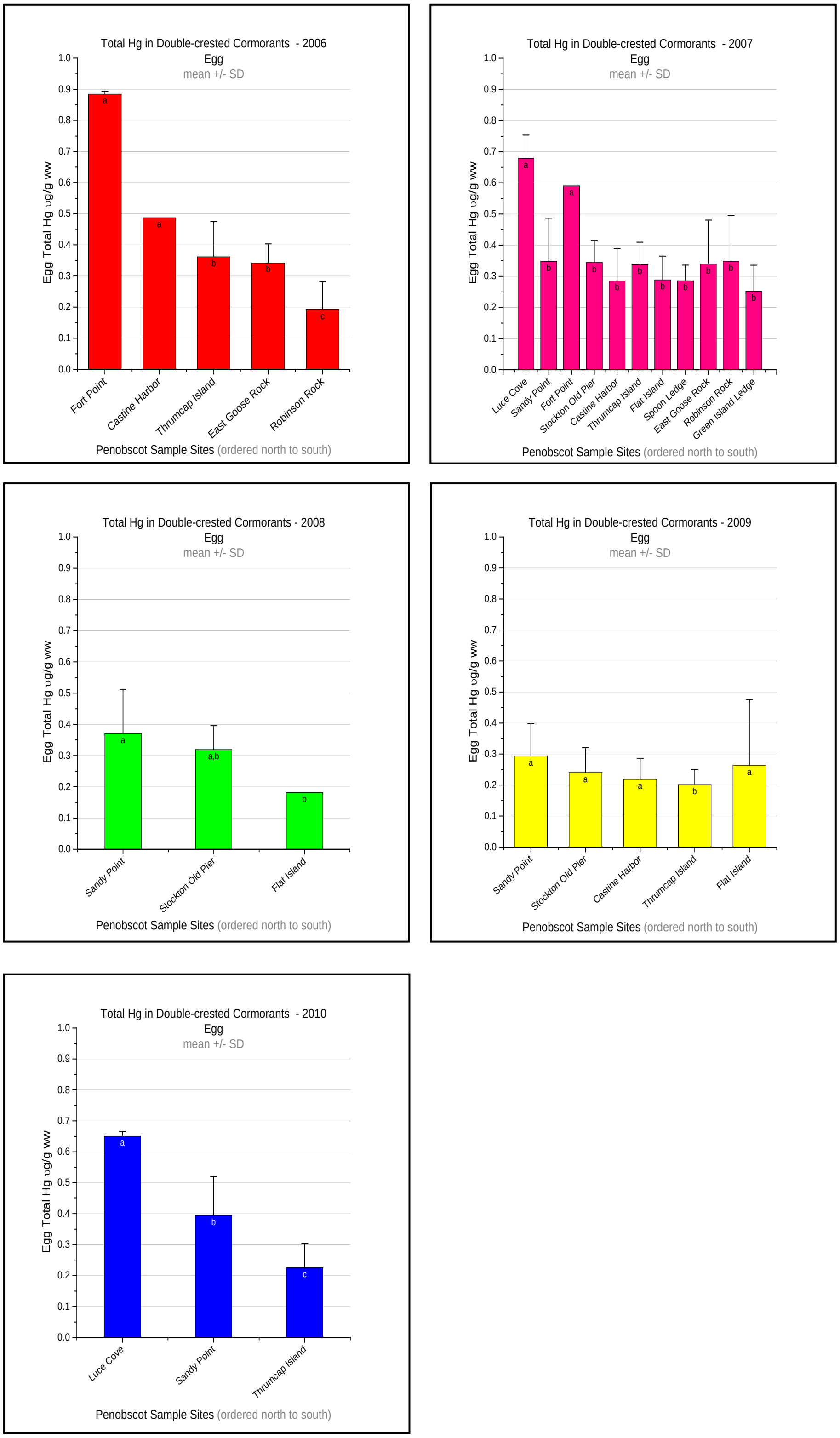


Figure 14-43. Geographic comparisons of Hg concentrations in eggs from double-crested cormorants at all sites sampled in each year of the study. Letters in each bar, define homogenous groups where Hg concentrations were statistically equivalent.

At some sites, and in some entire years, insufficient residence time of the cormorants prior to sampling may have reduced the Hg concentrations we found in cormorant eggs below levels proportionate with local Hg exposure through the food web. In 2009 cormorant eggs were sampled especially early (mean sample dates May 12th to June 3rd) and Hg concentrations in eggs likely did not reflect local Hg exposure as the females had not been resident at the colonies for the time needed for uptake of methyl Hg from local food webs (Ackerman et al. 2008, Eagles-Smith et al. 2009). In 2010 this hypothesis was confirmed when we found a 35%increase in Hg in eggs sampled over a 40 day period (5 May 2010 to 15 June 2010) at Sandy Point. To address this issue, in 2012 egg sample dates were standardized to a date later in the season.

16.4 Hg Concentrations in Double-crested Cormorants and Biota Targets

The target for Hg concentrations in cormorant eggs designed to protect bird health, 0.8 µg/g wet wt., was exceeded in 2% of the eggs sampled from sites in the upper estuary north of Fort Point. Both eggs with these elevated concentrations were sampled at Fort Point in 2006. All other eggs sampled had lesser concentrations and Hg should not pose a health risk to cormorants at the Penobscot sites where eggs were collected. Heinz et al. (2009) found double-crested cormorants to be the least sensitive species to methyl Hg exposure of 26 species tested.

16.5 Regional Comparison of Hg in Double-crested Cormorants

A number of comparisons between Hg in cormorant eggs in the Penobscot system to other reference and contaminated systems were made in the Phase I report. These comparisons demonstrated that Hg levels in the Penobscot were generally higher than reference systems and similar to the Hg-contaminated San Francisco Bay/Delta area. In addition, a study of Hg in cormorant eggs in two lakes in S Dakota found a mean value of 0.29 µg/g wet wt. (Greichus et al. 1973), similar to other reference systems noted in the Phase I report.

16.6 Double-crested Cormorant Summary

In each year sampled, Hg concentrations were significantly greater at the sites in or close to the mouth of the Penobscot River, relative to sites further south in Penobscot Bay. Hg in cormorant eggs did not exceed the target to protect bird health in most (98%) of the eggs sampled. No significant temporal trends in Hg concentrations in cormorant eggs were found in the two sites where analyses of temporal trends were possible.

17 AMERICAN BLACK DUCKS (*Anas rubripes*)

17.1 Black Duck Biology

Black ducks begin to arrive at their wintering grounds along the Maine coast in late September and early October, migrating from breeding areas in the Canadian Maritimes. By December, the winter duck population at Mendall Marsh ranges from 120 to 150 birds, over 90% of which are American black ducks. They remain in the area through the winter, beginning their northern migration from mid-March through early April (Longcore et al. 2000; K. Sullivan, Maine Department of Inland Fisheries and

Wildlife, Bangor, Maine, pers. comm.). Historically, American black ducks were the primary species harvested by hunters in the eastern United States and, despite hunting limits imposed in the early 1980's in response to population declines, the species remains intensively hunted. Ducks at Mendall Marsh are hunted regularly during the fall season, which ends December 25th.

During the winter, black ducks in coastal habitats forage on invertebrates found on mud flats and marsh vegetation (Mendall 1949). Jorde and Owen (1990) examined the winter diet of black ducks along the central Maine coast, and reported that invertebrates comprised 96% of the diet, primarily periwinkle snails (*Littorina*), amphipods (*Gammarus*), blue mussels (*Mytilus*), soft-shelled clams (*Mya*), and worms (*Nereis*). Yerkes et al. (2009) found that invertebrates made up 93% of the diet on tidal mudflats, and 71% of the diet in brackish marshes in black ducks wintering in Virginia. They further reported strong selection for amphipods (Amphipoda), snails (Hydrobiidae), and bivalves (Mytilidae). While black ducks are primarily low-tide foragers in warmer climates, during cold weather their foraging times increase in response to greater energy demands, and ducks are regularly observed foraging among flooded marsh vegetation during extreme high tides (Longcore et al. 2000; Cramer et al. 2012).

Black ducks molt their wing feathers on their summer breeding grounds. The P1 feather, the first primary feather to be molted in the wing, was grown on the summer breeding grounds and collected months later from ducks on their wintering grounds in Maine. The Hg concentration in that feather indicated Hg exposure in the summer diet of the ducks, not their winter diet in Maine (Johnels et al. 1979; Ackerman et al. 2008).

17.2 Notes on Methods in Black Ducks

Hg concentrations in black ducks wintering along the lower Penobscot River were monitored in two consecutive winters, 2010-11 and 2011-12, using three different tissue types. Each tissue offered useful information relevant to this study. Muscle samples, collected primarily in Mendall Marsh, were analyzed to document Hg concentrations in duck breast muscle eaten by hunters and their families. Muscle samples were collected twice each winter in sample periods four to eight weeks apart, to determine whether Hg concentrations increased with residence time. Blood samples were used to examine geographic differences in Hg concentrations among two sites in the lower Penobscot, Mendall Marsh and Verona Island and reference sites in Frenchman Bay. The first primary feather, P1, was collected from all ducks sampled, and analyzed in the 2010-11 ducks to determine Hg exposure on their summer breeding grounds. Feathers from the winter of 2011-12 have been archived.

17.3 Stomach Contents of Black Ducks

The reported winter diet of black ducks, dominated by invertebrates (Jorde and Owen, 1990; Yerkes et al. 2009), was supported by a limited analysis of stomach contents in black ducks sampled during the 2011 fall hunting season at Mendall Marsh. Stomachs were examined from nine black ducks, six stomachs contained identifiable remains. Partial digestion of stomach contents prior to sampling limited the quantitative analysis of the results. Prey items identified, in order of frequency, included mud snails

(Hydrobiidae), soft-shelled clams (*Mya arenia*), mud crabs (*Rhithropanopeus harrisi*), dung fly larvae (Scathophagidae), rock crab debris (*Cancer irroratus*), water scavenger beetle (*Tropisternus* sp.), caddis fly (Limnephilidae), and a beetle (Coleoptera). The stomach of one mallard contained only plant debris.

17.4 Hg in Blood vs. Muscle in Black Ducks

Hg concentrations in breast muscle and blood of black ducks are strongly correlated. In January of 2011 we sampled both blood and breast muscle from a limited number of ducks captured in traps from Mendall Marsh. Our goal was to learn whether non-lethal blood samples accurately represented Hg concentrations in breast muscle. Sampling breast muscle requires sacrifice of the bird. Hg concentrations were strongly correlated between the two tissues (linear regression, $P < 0.001$, $r^2 = 0.99$; Figure 14-45), and slightly greater in blood than in muscle. Given the greater protein concentration in muscle relative to blood, the muscle was expected to have greater total Hg concentrations. However, the half-life of Hg in blood is shorter than in muscle, making the blood a more sensitive indicator of current exposure levels. Greater Hg concentrations in blood may indicate greater recent exposure levels relative to Hg exposures over the preceding several months.

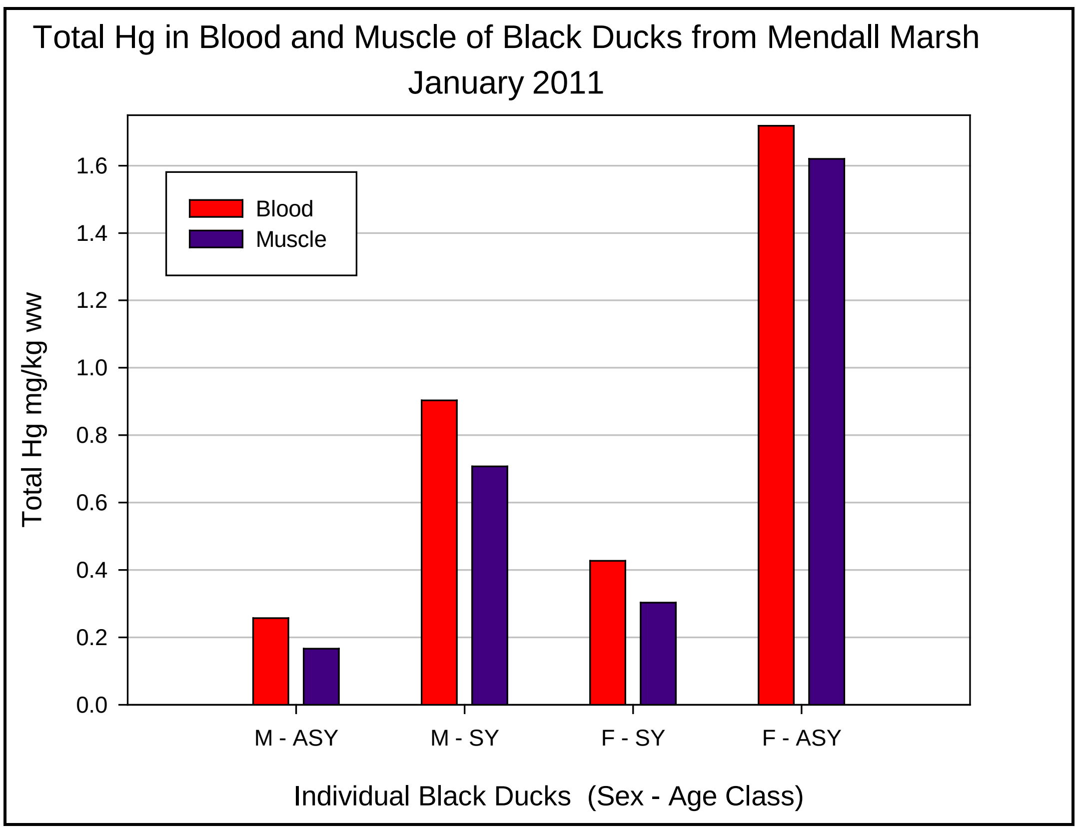


Figure 14-44. Total Hg in blood and breast muscle from black ducks sampled in January 2011. Hg concentrations in blood and muscle were strongly correlated ($P< 0.001$, $r^2=0.99$).

17.5 Temporal Comparisons of Hg in Black Ducks

Hg concentrations in both blood and muscle at all three sample sites were statistically equivalent in the 2010-11 and 2011-12 winter sample sets. The two years of monitoring data in black ducks allows a basic comparison of Hg concentrations over time but does not permit a full analysis of statistical trends. At Mendall Marsh, Hg concentrations in breast muscle from ducks sampled in December of 2010 (total Hg, mean ± SD; 0.752 ± 0.076 µg/g wet wt.) were equivalent to Hg concentrations in muscle found the following December of 2011 (0.815 ± 0.213 µg/g wet wt.; two-sample t-test, P = 0.664, pooled variance; Figure 14-46).

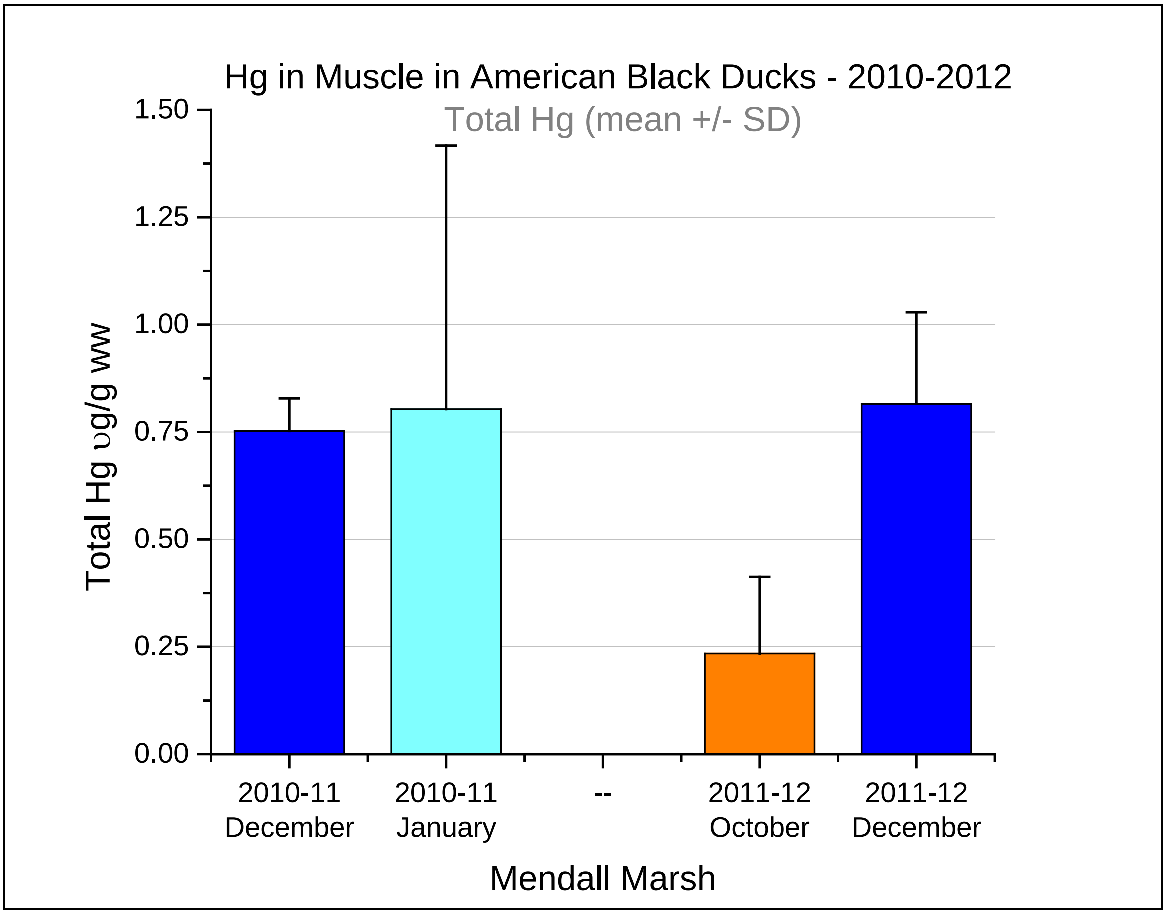


Figure 14-45. Hg concentrations in black duck muscle sampled in December 2011 and January 2012 and the following year in October and December 2011. Hg increased significantly over eight weeks at Mendall Marsh during the 2011 hunting season, but the increase was not significant over a four week period from December 2010 to January 2011.

Similarly, Hg concentrations in blood from ducks sampled on Mendall Marsh in January of 2011 (0.811 ± 0.516 µg/g wet wt.) were equal to concentrations found in ducks from the same site in January of 2012 (0.741 ± 0.602 µg/g wet wt.; two-sample t-test, P = 0.837, pooled variance; Figure 14-47). Similar results were found in ducks from the Frenchman Bay reference sites, where Hg concentrations in blood in January of 2010 (0.083 ± 0.022 µg/g wet wt.) were equivalent to concentrations found in January a year later (0.105 ± 0.031 µg/g wet wt.; two-sample t-test, P = 0.132, pooled variance). While Hg concentrations in blood varied more at the ES13-Verona site, 0.487 ± 0.427 µg/g wet wt. in 2011 and 0.139 ± 0.031 µg/g wet wt. in 2012, they were still statistically equivalent in those two years (two-sample t-test, P = 0.169, separate variance).

An increase in Hg concentrations with longer residence time in Mendall Marsh was generally supported by our findings (Figure 14-46). In the fall of 2011 breast muscle was sampled from black ducks in mid-October (10/15 – 10/21) and eight weeks later in mid-December (12/10-12/21). Hg concentrations in breast muscle from black ducks increased significantly from 0.234 ± 0.178 µg/g wet wt. in October to 0.815 ± 0.213 µg/g wet wt. in December (two-sample t-test, P =0.002, separate variance). In the winter of 2010-2011, breast muscle was sampled in mid-December (12/16 -12/22) and four weeks later in mid-January (1/20). Mean Hg concentrations were not significantly different in those two sample periods (December, 0.752 ± 0.076 µg/g wet wt.; January 0.803 ± 0.614 µg/g wet wt.; two-sample t-test, P = 0.602). However the January sample set was much more variable than found in December, Hg concentrations ranging from 0.17 to 1.62 µg/g wet wt.. This variation may result from greater Hg accumulations in ducks that had been resident in Mendall Marsh since October and lower concentrations in recent immigrants from inland wintering sites that had frozen over earlier in January. Black ducks may shift to wintering sites with open water when inland marshes ice over (Longcore et al. 2000).

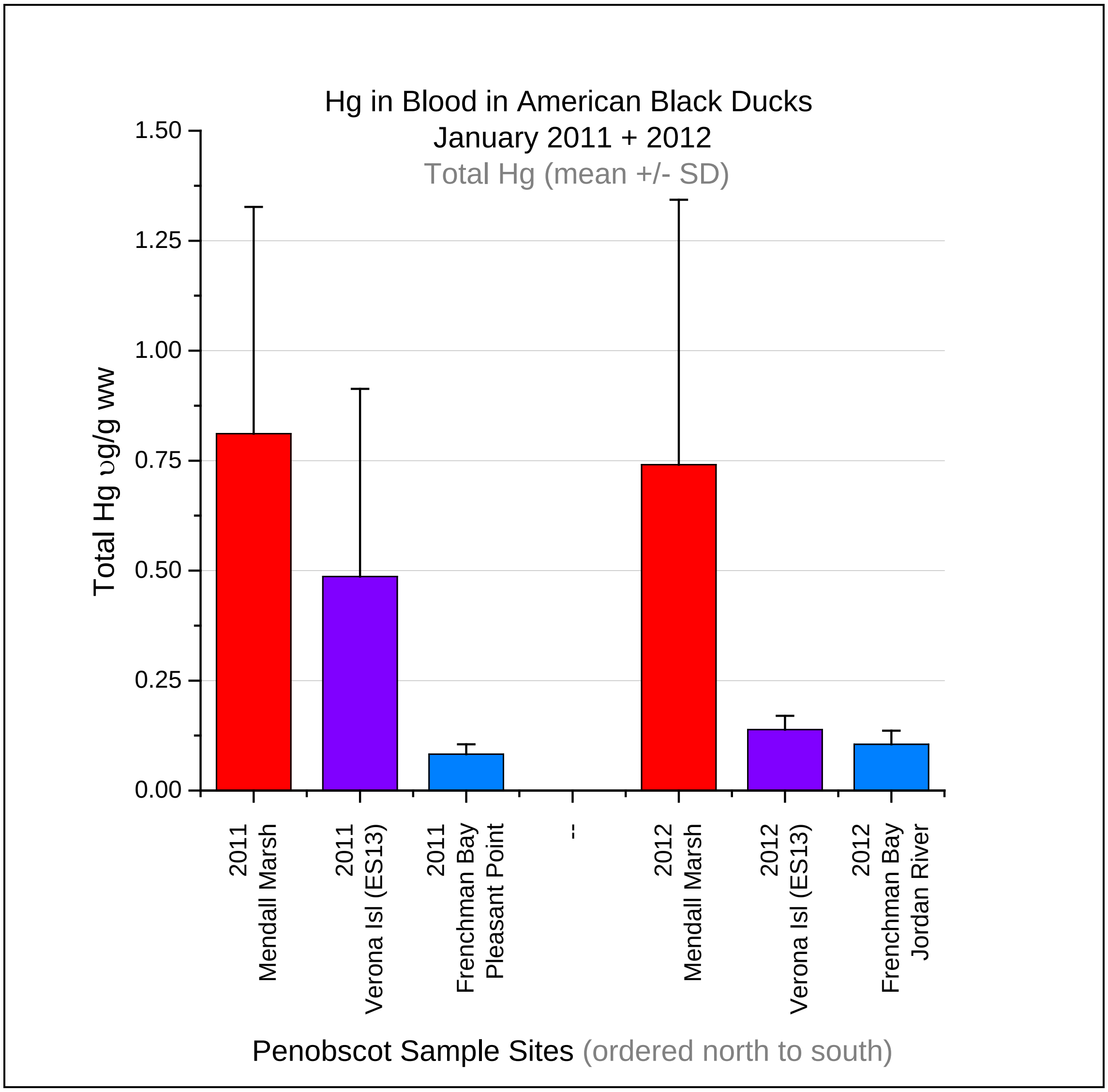


Figure 14-46. Hg concentrations in blood sampled at two sites on the lower Penobscot River, Mendall Marsh and Verona Island, and from reference sites in Frenchman Bay. Hg concentrations were significantly greater in black ducks sampled at Mendall Marsh compared to reference sites in Frenchman Bay.

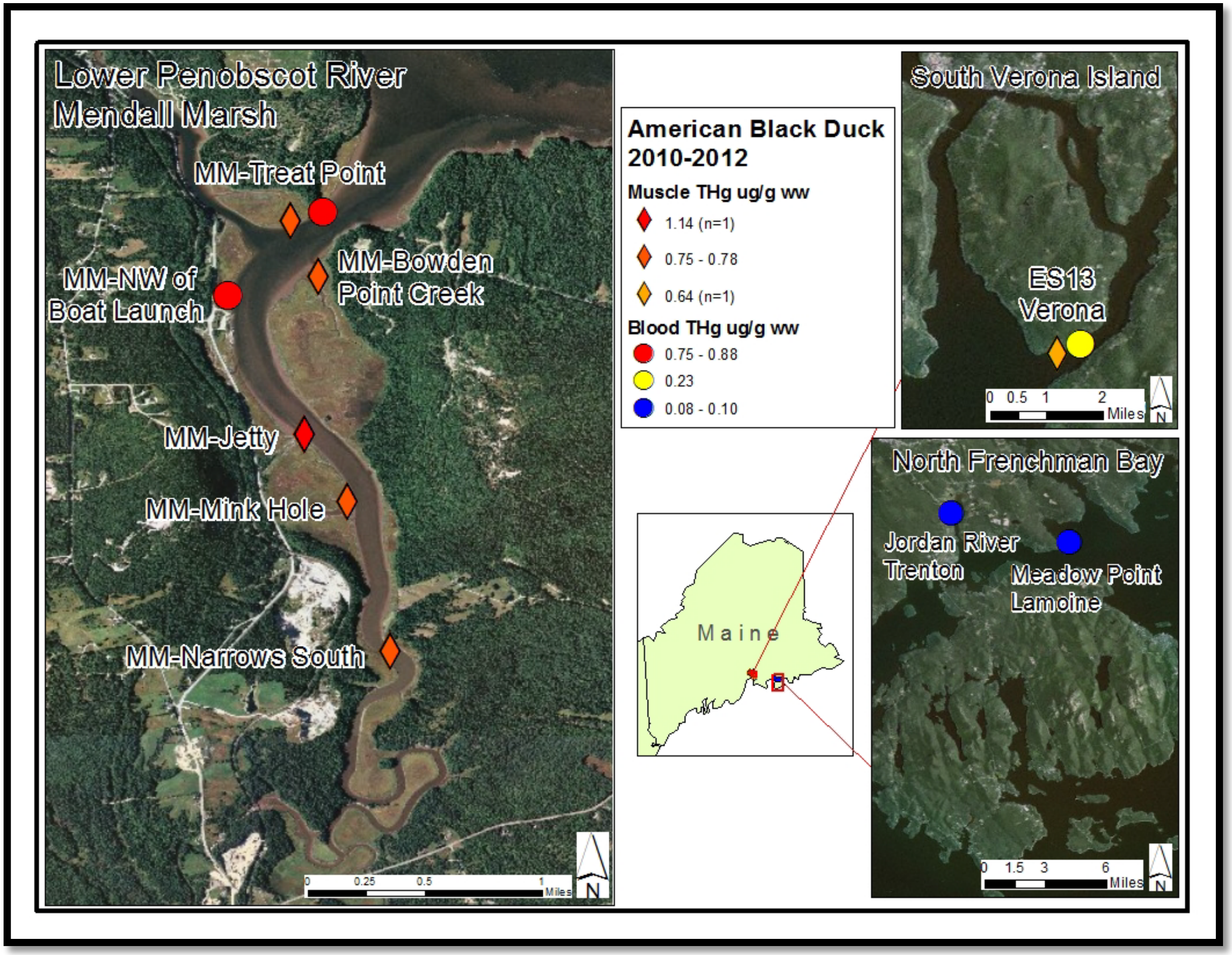


Figure 14-47. Black duck sampling locations and mean Hg concentrations in blood (January collections) and muscle (December and January collections) calculated for the 2-year sample period (2010 – 2012).

17.6 Geographic Comparison of Hg in Black Ducks

Hg concentrations were greater in ducks wintering along the lower Penobscot than those sampled at reference sites in Frenchman Bay (Figure 14-48; Appendix 14-14). In January of 2011, blood samples from ducks at Mendall Marsh (total Hg, 0.811 ± 0.516 µg/g wet wt.) and ES13-Verona Island (0.487 ± 0.427 µg/g wet wt.) had significantly greater Hg concentrations than in ducks sampled at Pleasant Point in Frenchman Bay (0.083 ± 0.022 µg/g wet wt.; ANOVA, $P < 0.001$, Tukey's HSD test, $P < 0.05$). The following year, mean Hg in ducks from Mendall Marsh (0.741 ± 0.602 µg/g wet wt.) was significantly greater than found in ducks from both ES13-Verona Island (0.139 ± 0.031 µg/g wet wt.) and the Jordan River in Frenchman Bay (0.105 ± 0.031 µg/g wet wt.; ANOVA, $P < 0.001$; Tukey's HSD test, $\alpha = 0.05$).

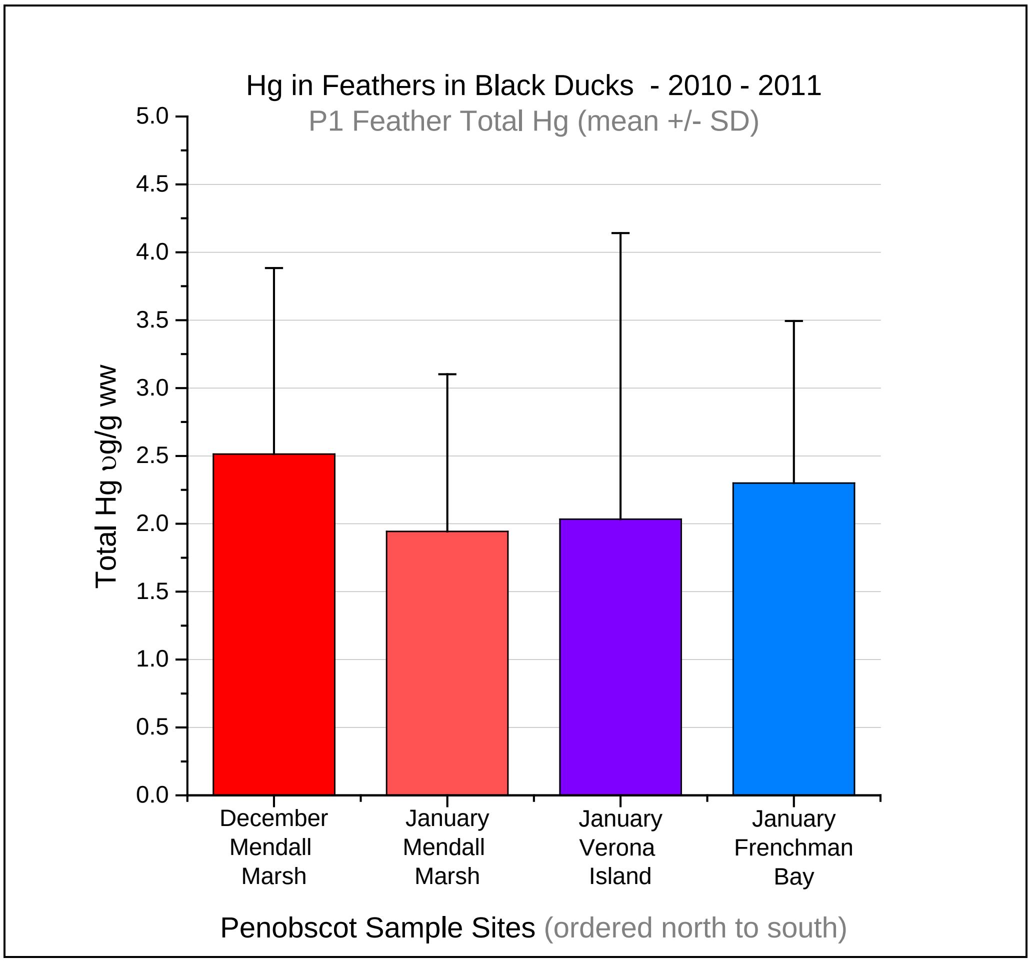


Figure 14-48. Hg concentrations in the P1 primary feather from black ducks collected in the winter of 2010-11 did not vary among the sites sampled.

Hg concentrations in feathers from black ducks indicated that all ducks sampled in 2010-11 were exposed to uniformly low Hg concentrations the summer before they arrived at wintering sites in Maine. The P1 feather collected from all ducks in this study, grown in late summer on the breeding grounds, indicates Hg exposure at the breeding site. Figure 14-49 below illustrates the consistently low concentrations of Hg (means, 1.9 to 2.5 µg/g fresh wt.) found at all sites. From this it is clear that the wide range in Hg concentrations found in muscle and blood samples from ducks over-wintering on the lower Penobscot was not due to exposure on the breeding grounds that was carried back to Maine.

17.7 Regional Comparisons of Hg in Black Ducks

Hg concentrations in black ducks sampled at Mendall Marsh were 3 to 8 times those reported for the same or similar species in other regions of North America. Braune and Malone (2006) report median total Hg concentrations of 0.096 (range: n.d – 0.297; mg/kg wet wt.) in black duck breast muscle collected from 33 sites during the fall hunting season across Canada. This median concentration is less than one-eighth the concentration in black ducks at Mendall Marsh. Duchesne et al. (2004) reported Hg concentrations in the pectoral muscle of dabbler ducks, including black ducks, in the St. Lawrence region. The mean Hg concentrations in dabblers in four sub-areas ranged from 0.09 to 0.15 µg/g wet wt., with a maximum Hg concentration for the entire region of 0.25 µg/g wet wt. Rothschild and Duffy (2005) reported Hg concentrations in the cervical muscle of waterfowl from western Alaska. In that dataset, the waterfowl species that fed primarily on insects and aquatic invertebrates (lesser scaup, old squaw, black and white-winged scoters) had the greatest muscle Hg concentrations, with means ranging from 0.080 to 0.270 µg/g wet wt., still 3 times lower than found in ducks from Mendall Marsh.

Hg concentrations in black ducks from Mendall Marsh were equivalent to concentrations found in mallards sampled in the Hg-contaminated South River, Virginia. Cristol et al. (2012) reported blood, muscle and feather Hg concentrations in three waterfowl species sampled in the South River. Mallards, described as likely year-round residents of the area, had the greatest Hg concentrations of the waterfowl sampled. During the hunting season, the mean muscle total Hg concentration was 0.67 ± 0.66 µg/g wet wt. (range: 0.03-2.38 µg/g) and during the breeding season the mean Hg concentration in blood was 0.94 ± 0.87 µg/g wet wt. (range: 0.02 – 5.41 µg/g). Feather Hg concentrations were quite variable (range 0.02-12.43), but since a secondary feather was sampled from the south river mallards (feather number not defined), not the P1 primary feather sampled from Penobscot ducks, a direct comparison is not valid. Mallards have a more omnivorous diet than the winter diet of black ducks, which would reduce their Hg exposure, but year-round residence would allow tissue concentrations of Hg to reach equilibrium with Hg exposure levels in the area. The black ducks sampled on the lower Penobscot had been in residence a maximum of 3 to 4 months prior to sampling, and were unlikely to have reached equilibrium with local exposure levels.

17.8 Hg Concentrations in Black Ducks and Biota Targets

By the end of the hunting season each fall, Hg concentrations in all samples of breast muscle from black ducks collected at Mendall Marsh were 3 to 4 times greater than the Hg target to protect human health (0.20 ug/g wet wt.; Table 3). This finding prompted the Maine Department of Inland Fisheries and Wildlife to issue a health warning in 2011 advising pregnant and nursing women and children under the age of 8 to not eat any breast meat from ducks taken in the area and that others limit consumption to 2 meals per month.

By January, when ducks had resided along the Maine coast for up to 3 months, Hg concentrations in the blood of black ducks from Mendall Marsh exceeded the target to protect bird health (1.2 µg/g wet wt.) in 20% of the ducks sampled. The average Hg concentration in the blood of those birds was 1.67 µg/g wet wt. As black ducks would remain at these coastal marshes another 2 to 3 months, their exposure to Hg-contaminated prey would continue and it is expected that blood Hg concentrations would increase to toxic levels in a greater number of ducks before they migrated from Mendall Marsh. The blood Hg target was not exceeded in samples from any ducks collected from Verona Island or the reference sites in Frenchman Bay.

None of the P1 primary feathers collected from black ducks in 2010 and 2011 had Hg concentrations greater than the feather Hg target to protect bird health (5.0 µg/g fresh wt.). This confirms that the ducks we sampled in Maine had been exposed to low background concentrations of Hg at their summer breeding grounds, where the P1 feather was grown.

17.9 Black Duck Summary

Black ducks wintering along the lower Penobscot River, especially those foraging in Mendall Marsh, accumulate Hg concentrations during the fall hunting season that may threaten the health of hunters and their families. Hg concentrations in blood sampled from black ducks foraging in Mendall Marsh (mean Hg 0.76 – 0.88 µg/g wet wt.) were 10 times greater than found in black ducks from reference sites in Frenchman Bay, outside of the Penobscot watershed (mean Hg 0.08 µg/g wet wt.). Feather Hg concentrations were uniformly low, indicating low Hg exposure at the ducks' summer breeding grounds. Hg concentrations in ducks from Mendall Marsh remained at the same levels over the two winters in which samples were collected.

18 LITTLE BROWN BAT (*Myotis lucifigus*) & NORTHERN LONG-EARED BAT (*Myotis septentrionalis*)

18.1 Bat Biology

Female little brown bats leave winter hibernacula from early April through mid-May, and fly to summer maternity colonies up to 150-300 kilometers from their winter roost (Davis and Hitchcock 1965). Only reproductive females occupy maternity colonies, and give birth to generally one pup between early June and early July. Pups start to wean at three weeks of age and both young of the year and the adult females leave the maternity colonies in late summer. Females show strong site fidelity to both winter and maternity colonies. Male summer fidelity is less well documented given their often solitary summer roost sites (Fenton and Barclay 1980). Both males and females range widely in late summer and early fall before returning to winter at hibernacula (Davis and Hitchcock 1965).

The little brown bat feeds on a range of flying aquatic insects. In New England and southern Canada, midges (Chironomidae), mosquitoes (Culicidae) and moths (Lepidoptera) are their primary prey taxa (Fenton and Barclay 1980). In July, when energy demands peak during lactation, reproductive females specialize on beetles (Coleoptera; Anthony and Kunz 1977). The northern long-eared bat has a broader diet as it consumes both aquatic insects and those gleaned from forest vegetation (Caceres and Barclay 2000). Both midges and mosquitoes are aquatic in their larval stage where they would be exposed to Hg in aquatic habitats.

Both *Myotis* species described here undergo one annual molt. Males molt in the spring, after leaving their winter hibernacula and often occurs before migration to the summer breeding areas. Reproductive females molt in the summer, after offspring are weaned (Hill and Smith 1984).

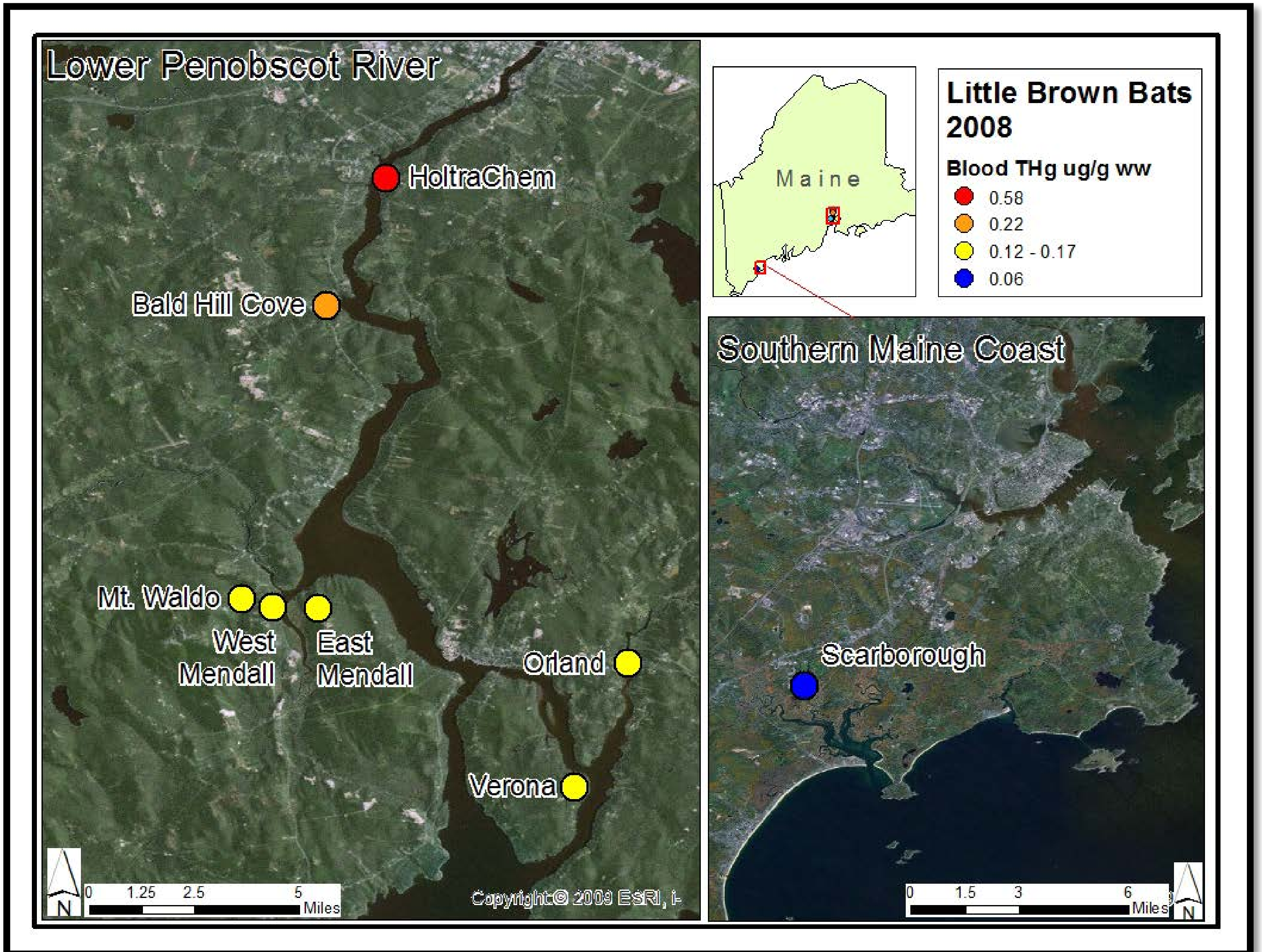
18.2 Geographic Comparisons of Hg in Little Brown Bats

During the summer of 2008 blood and fur samples were collected from 90 little brown bats. This species was sampled at seven sites along the Penobscot River from Orrington to the southern tip of Verona Island in numbers that were sufficient to examine variations in Hg exposure along the lower reaches of the Penobscot River (Figure 14-50; Appendix 14-15). An additional 13 little brown bats were sampled from a reference site near Scarborough Marsh, along the southern Maine Coast. Other species of bats were sampled in smaller numbers and at limited sites, including the northern long-eared bat (*Myotis septentrionalis*)), two big brown bats (*Eptesicus fuscus*) and one Eastern red bat (*Lasiurus borealis*).

Total Hg concentrations in blood were significantly greater in little brown bats relative to northern long-eared bats (geometric mean 0.181 µg/g wet wt. and 0.109 µg/g wet wt., respectively; 2-sample t-test, pooled variance, $P = 0.018$) in the three Penobscot sites where both species were sampled. Total Hg concentrations in fur were not significantly different between the two species. Data from the little brown bat were used to examine regional variation in bat Hg concentrations and comparisons with the reference site.

In the little brown bat, total Hg concentrations in blood varied significantly among sites (ANOVA, $P < 0.001$, Tukey's HSD test, $\alpha = 0.05$; Figure 14-51), with blood total Hg concentrations significantly greatest at the HoltraChem site (mean Hg 0.580 µg/g wet wt.). Bats from the HoltraChem site and the other sites sampled in the Penobscot region (mean Hg, 0.225 to 0.120 µg/g wet wt.) were significantly greater than found in bats from the Scarborough reference site (mean Hg, 0.06 µg/g wet wt.).

Figure 14-49. Little brown bat sampling locations and mean blood Hg concentrations in 2008.



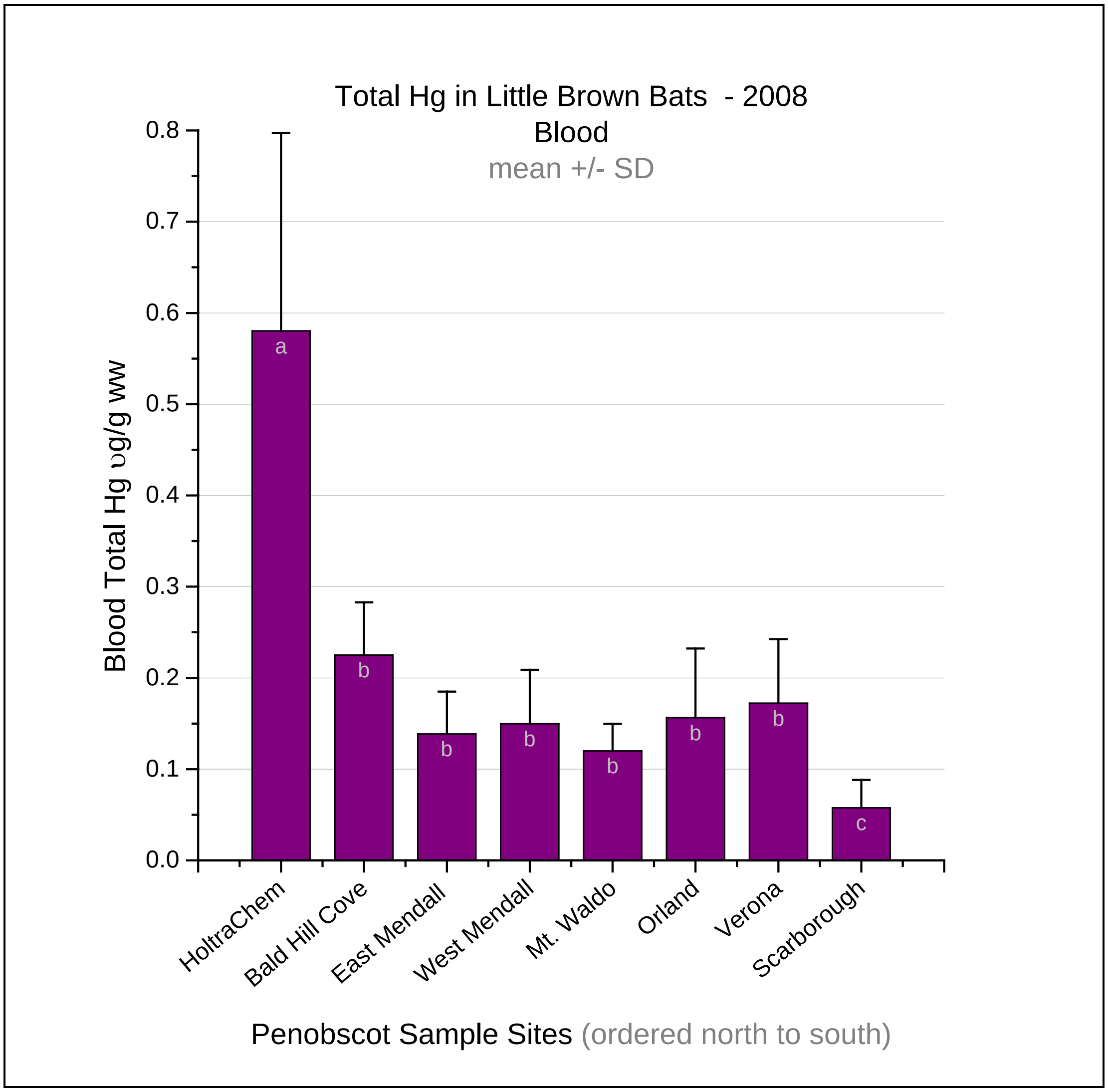


Figure 14-50. Geographic comparisons of mean Hg concentrations in blood from little brown bats at sites sampled in 2008. Letters in each bar define homogenous groups where Hg concentrations were statistically equivalent.

Total Hg concentrations in the fur of little brown bats varied significantly by site for female bats but not for male bats (Figure 14-52). In females, Hg concentrations in the fur was significantly greater at all Penobscot sites except Orland, relative to the reference site at Scarborough Marsh (ANCOVA, adjusted for age, $P < 0.001$, Tukey's HSD test, $\alpha = 0.05$). Note that the Orland sample site, while geographically north of Verona, lies upstream of Verona on the Orland River (Figure 14-50), adjacent to that river's head tide dam. And, at the Orland site bats were sampled at a maternity roost, and could be foraging upstream of the dam, outside of the aquatic influence of HoltraChem. At the other sites along the Penobscot, bats were sampled not at roosts but at foraging areas.

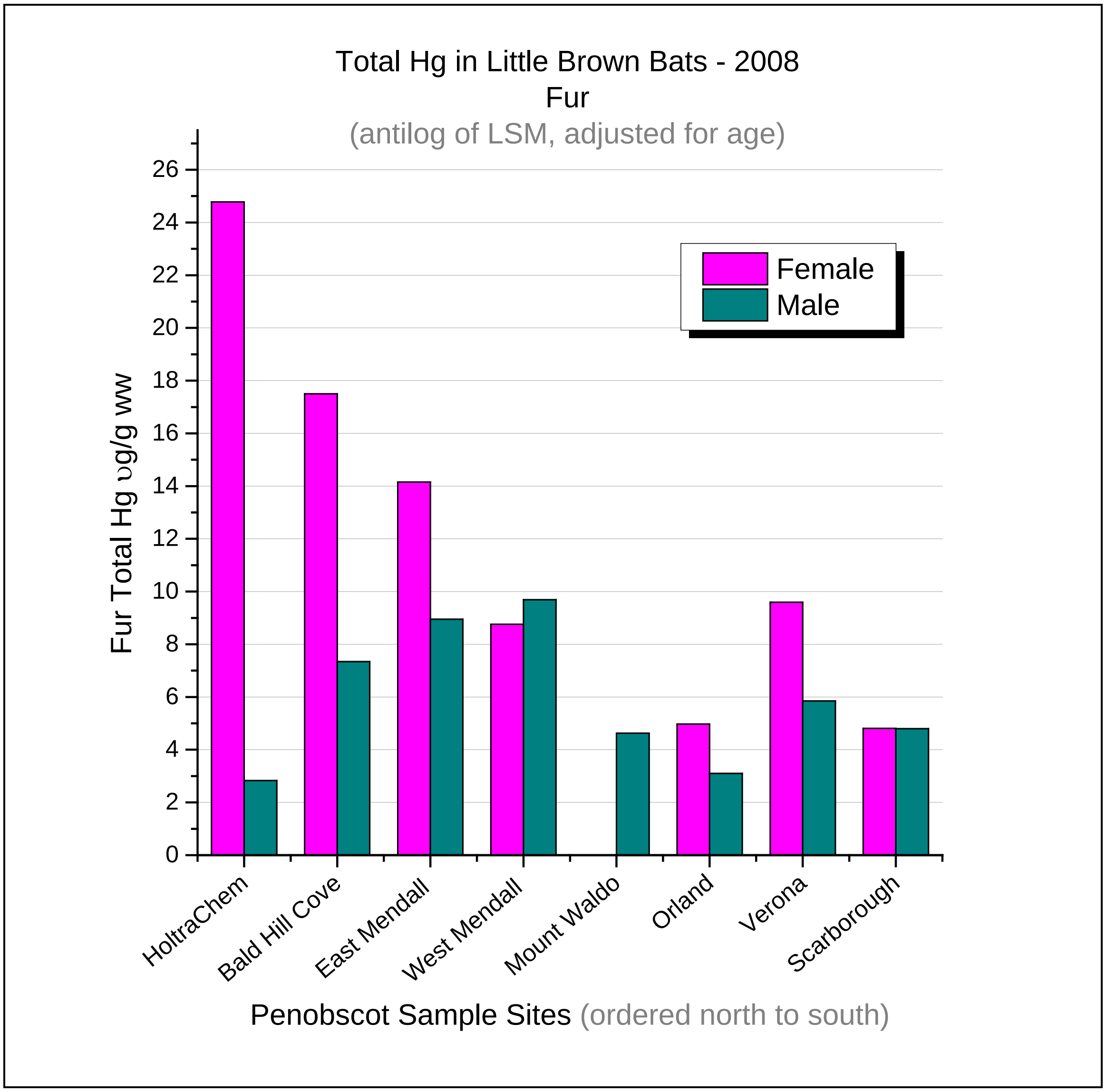


Figure 14-51. Geographic comparisons of Hg concentrations in fur from male and female little brown bats at sites sampled in 2008.

Fur total Hg concentrations in male little brown bats did not vary significantly among sites sampled along the Penobscot River (ANCOVA, adjusted for age, $P = 0.572$). This finding may relate to the timing of the molt in male and female bats. In males, new fur is formed during the late spring molt, soon after the males leave their winter hibernacula. Total Hg in male fur reflects circulating blood total Hg concentrations resulting from Hg exposure via prey near the hibernacula site and during migration to and at summer roosts. Total Hg concentrations in female bats better reflect local Hg exposure levels. Females show strong site fidelity at summer maternity roosts and grow fur during a summer molt, after foraging for roughly 90 days near the maternity roosts, allowing their blood Hg concentrations to approach equilibrium with local exposure levels.

18.3 Bat Hg Concentrations and Biota Targets

Hg concentrations pose a threat to the health of little brown bats foraging in the Penobscot study area. The Hg target to protect mammal health in blood, 0.100 µg/g wet wt., was exceeded by 92% of the adult little brown bats and by 82% of the juveniles sampled in the Penobscot study area (Table 4). In contrast, 8% of the bats sampled at the Scarborough Marsh reference site had Hg concentrations in blood above the target. The target for Hg in fur to protect mammal health, 10 µg/g fresh wt., was exceeded by 80% of the adult female little brown bats and by 58% of the adult males sampled in the Penobscot area. A smaller proportion of the juvenile bats, 11%, had Hg concentrations in their fur above the target. At Scarborough Marsh, 8% of the little brown bats (1 male), most of which were juveniles, had Hg concentrations in fur above the target concentration.

Table 4. The percent of bat samples with Hg concentrations in excess of targets to protect mammal health, and the mean Hg concentrations found in blood and fur, by area, age and sex.

PERCENT of SAMPLES EXCEEDING MAMMAL MERCURY TARGETS (2008)										
			Blood Hg Target to Protect Mammal Health 1.0 µg THg/g ww				Fur Hg Target to Protect Mammal Health 10.0 µg THg/g fw			
SPECIES	REACH/ AREA	SEX	ADULTS		JUVENILES		ADULTS		JUVENILES	
			above target	blood THg mean ± SD (n)	above target	blood THg mean ± SD (n)	above target	fur THg mean ± SD (n)	above target	fur THg mean ± SD (n)
Little brown bats	lower Penobscot	all	92%	0.21 ± 0.14 (62)	82%	0.18 ± 0.14 (28)				
		female					80%	20.8 ± 13.5 (51)	14%	5.7 ± 5.2 (14)
		male					58%	14.3 ±9.9 (12)	7%	5.3 ± 6.8 (14)
	reference	all	NA	0.03 (1)	8%	0.06 ± 0.03 (12)				
		female					NA	2.4 (1)	0%	3.6 ± 2.9 (7)
		male							20%	6.2 ± 7.4 (5)
Northern long-eared bats	lower Penobscot	all	64%	0.15 ± 0.14 (11)	33%	0.09 ± 0.04 (3)				
		female					75%	18.4 ± 13.3 (4)	NA	2.7 (1)
		male					43%	10.3 ± 5.0 (7)	0%	4.2 ± 4.2 (2)
	reference	all	NA	0.06 (1)	33%	0.10 ± 0.06 (15)				
		female							14%	5.0 ± 5.6 (7)
		male					NA	6.5 (1)	13%	6.8 ± 5.7 (8)

While the majority of northern long-eared bats sampled in the Penobscot study area exceeded Hg targets for blood and fur (females), many of this species from the reference site also had elevated Hg concentrations. In the Penobscot sample area, 64% of the adult northern long-eared bats had Hg concentrations in their blood above the target of 0.100 µg/g wet wt., as did 33% of the juveniles of this species. Similarly, at the Scarborough Marsh reference site, 33% of the juvenile northern long-eared bats had Hg concentrations in the blood above the target concentration. The one adult sampled at Scarborough did not have elevated Hg in the blood. Fur samples collected in the Penobscot area from northern long-eared bats had concentrations greater than the Hg target in 75% of the adult females and in 33% of the adult males. None of the three juveniles sampled in the Penobscot area had elevated Hg in their fur. At Scarborough Marsh, three juvenile males, 19% of the sample set, had Hg concentrations in fur above the target level.

18.4 Regional Comparisons of Hg in Bats

Hg concentrations in bats sampled along the lower Penobscot were notably greater than all but one report of concentrations given in the literature. Fur total Hg concentrations in little brown bats sampled along the Penobscot River (min-max, 0.52 – 79.6 µg/g wet wt.), especially bats sampled in the vicinity of HoltraChem, were up to 30 times greater than reported for the same species in Ontario and Québec (min-max, 1.3 – 2.5 µg/g dry wt.; Hickey et al. 2001). Miura et al. (1978) reported fur Hg concentrations between 3 and 10 µg/g fresh wt. for 5 species of bats in Japan, except for two species sampled during mercurial pesticide dusting in the 1960s, when Hg concentrations in fur jumped to a mean of 33 ± 6 µg/g fresh wt.. Wada et al. (2010) report Hg concentrations in blood and fur from the big brown bat sampled at Hg-contaminated sites along the South River in Virginia and from a references site 9 km upstream of the Hg source. The mean Hg concentration in adult female blood from the contaminated site (0.110 ± 0.012

µg/g wet wt.) was one-fifth that in bats sampled near the HoltraChem site on the Penobscot River. The Hg concentration in fur from female big brown bats from the South River contaminated site (28.01 ± 4.06 µg/g fresh wt.) was also lower than found in adult female bats at the HoltraChem site (39 ± 28, *M. lucifigas* ; 38 µg/g fresh wt., *M. septentrionalis*). Another study of female little brown bats on the South River reported a markedly higher mean fur total Hg concentration (132 ± 94 µg/g fresh wt.) than found in female bats along the lower Penobscot (Nam et al. 2012).

18.5 Bat Summary

The greatest Hg concentrations found were in little brown bats sampled while foraging at the HoltraChem plant site (mean blood Hg 0.58 µg/g wet wt.). Hg concentrations in blood remained elevated at sites further south along the Penobscot and were 10 times lower at the Scarborough reference site (mean blood Hg 0.06 µg/g wet wt.). Fur samples from female bats, which molt during the summer months at their breeding areas, were elevated at the HoltraChem site (mean fur Hg 40 µg/g fresh wt.), and then decreased steadily at sites further downriver. The Hg targets to protect mammal health were exceeded in over 90% of the bats' blood samples and in 80% of the fur samples from adult females. Northern long-eared bats had lower Hg concentrations than the little brown bats, yet blood and fur concentrations in the majority of adults sampled along the Penobscot exceeded the targets to protect mammal health.

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APPENDIX

Appendix 14-1. American eel summary statistics using raw data for age, length, total and methyl Hg concentrations in muscle, 2007 – 2010. Samples were collected in the lower Penobscot River. OV = Old town – Veazie reach; BO = Brewer – Orrington reach; OB = Orrington – Bucksport reach. Sites are listed from north to south, within each year.

American eel year	American eel site	age n	age mean years	age SD	age min	age max	length mean mm	length SD	length min	length max	THg n	THg mean ng/g ww	THg SD	THg min	THg max	MeHg n	MeHg mean ng/g ww	MeHg SD	MeHg min	MeHg max	% MeHg mean
2007	OV4	6	8.2	3.9	4	14	370	127	210	557	7	313	207	186	780	1	210		210	210	87.1
2007	OV5	1	6.0		6	6	422	82	364	480	2	427	281	228	626	1	578		578	578	92.3
2007	BO66	16	8.9	2.2	6	13	292	38	254	430	20	466	102	275	679	2	405	167	287	523	86.5
2007	BO67	16	8.2	2.7	5	15	274	32	204	340	20	633	431	193	2,303	2	1014	504	657	1,370	72.7
2007	BO3	14	8.1	1.8	5	12	278	31	244	384	20	421	128	210	658	2	371	7	366	376	85.7
2007	BO4	14	6.1	1.8	4	11	246	40	180	335	18	621	160	391	974	2	463	55	424	502	75.3
2007	OB5	18	6.5	1.3	5	10	280	30	242	373	22	499	239	213	1,130	2	757	146	654	860	91.6
2007	OB3	9	7.3	1.7	5	9	310	44	239	380	10	654	267	342	1,030	1	544		544	544	97.8
2007	OB73	3	5.3	0.6	5	6	262	48	193	298	4	595	98	489	706	1	442		442	442	68.8
2007	OB1	9	7.1	1.3	6	9	269	34	229	338	10	567	77	491	691	1	457		457	457	91.8
2008	OV4	11	8.3	3.0	4	13	414	125	199	584	12	356	205	130	729	2	486	88	424	548	86.8
2008	OV5	7	8.7	3.0	5	12	464	172	285	750	7	328	76	182	392	1	241		241	241	62.1
2008	BO66	13	6.3	1.2	4	8	285	42	216	375	14	528	90	412	664	2	547	63	502	591	86.0
2008	BO67	17	6.9	1.9	4	11	294	64	202	451	20	683	301	357	1,460	2	903	81	846	960	62.7
2008	BO3	17	6.5	1.9	3	9	264	57	138	380	20	596	210	346	1,040	2	699	0	699	699	72.6
2008	BO4	16	6.7	3.2	3	17	265	74	164	487	19	586	327	85	1,060	4	375	369	77	879	80.4
2008	OB5	13	6.3	0.9	5	8	286	36	233	390	17	385	113	185	589	2	417	141	317	517	83.6
2008	OB3	3	6.3	0.6	6	7	322	15	305	335	3	489	145	388	655	2	346	18	333	359	70.3
2008	OB73	8	5.8	0.5	5	6	283	20	247	308	9	563	277	240	1,130	2	454	277	258	650	69.1
2008	OB1	4	7.5	2.4	6	11	307	61	242	424	6	383	129	231	591	2	217	34	193	241	83.8
2009	OV4	7	10.4	1.3	9	12	469	63	408	570	7	282	156	124	514	7	227	113	114	428	82.9
2009	BO66	16	8.8	3.1	4	13	319	65	230	478	18	618	338	211	1,355	18	584	314	180	1,300	95.1
2009	BO67	18	6.6	1.5	4	11	286	53	179	445	20	466	210	153	972	20	403	195	127	809	85.2
2009	BO3	20	6.9	2.3	4	13	286	97	137	546	20	513	251	265	1,400	20	477	265	238	1,470	92.1
2009	BO4	4	6.8	1.9	4	8	293	82	161	373	5	705	202	407	940	5	610	190	352	872	86.4
2009	OB5	16	6.8	1.0	5	8	309	41	260	412	16	577	277	288	1,260	16	518	236	231	1,015	90.1
2009	OB73	14	7.2	1.3	5	9	323	36	272	391	15	534	183	273	923	15	439	190	163	917	80.8
2009	OB4	4	8.5	2.4	7	12	375	58	318	473	6	471	157	282	682	6	412	163	225	670	86.4
2009	OB1	16	7.1	1.7	5	11	312	38	224	397	20	408	182	148	846	20	369	172	140	762	90.5
2010	OV4	13	7.8	2.0	4	11	392	84	197	482	14	361	117	123	552	2	488	63	443	532	93.9
2010	OV2	2	5.0	2.8	3	7	220	53	182	257	2	202	88	140	264	1	231		231	231	87.5
2010	OV5	10	5.9	3.7	1	12	267	145	106	459	10	371	254	108	900	2	160	23	143	176	103.9
2010	BO67	19	6.5	1.7	4	11	312	106	184	670	20	518	256	238	1,230	2	911	565	511	1,310	108.6
2010	BO3	18	6.2	1.7	4	10	309	66	195	462	20	460	247	158	1,185	2	328	110	250	405	91.0
2010	BO4	12	6.5	1.8	4	10	313	73	199	470	14	682	310	229	1,320	1	568		568	568	94.7
2010	OB5	20	6.3	1.4	4	10	317	63	176	468	20	520	230	164	1,160	2	451	393	173	729	107.1
2010	OB73	18	6.7	1.4	4	10	336	64	250	502	19	575	274	262	1,370	2	397	237	229	564	89.3
2010	OB4	19	6.5	1.2	4	9	320	64	238	485	19	439	206	162	1,010	2	396	217	243	550	106.1
2010	OB1	4	6.5	1.7	5	9	353	80	254	449	4	506	81	421	615	1	622		622	622	101.1

Appendix 14-2. Tomcod summary statistics using raw data for length, and total and methyl Hg concentrations in muscle, 2006 and 2008 – 2010. Samples were collected in the lower Penobscot River. OV = Old town – Veazie reach; BO = Brewer – Orrington reach; OB = Orrington – Bucksport reach; ES = estuarine reach (Penobscot Bay). Sites are listed from north to south, within each year.

Tomcod year	Tomcod site	length mean (mm)	length SD	THg n	THg mean ng/g ww	THg SD	THg min	THg max	MeHg n	MeHg mean ng/g ww	MeHg SD	MeHg min	MeHg max	% MeHg mean
2006	BO2	120	8	3	260.3	51.4	201.0	291.0	0					
2006	BO3	113	6	2	249.5	129.4	158.0	341.0	1	333.0		333.0	333.0	97.7
2006	BO4	127	6	7	286.5	45.0	195.0	329.0	1	242.0		242.0	242.0	124.1
2006	OB1N-5	154	32	10	196.6	83.7	81.0	372.0	1	181.0		181.0	181.0	98.9
2006	OB1E-4	132	25	8	172.5	39.7	108.0	231.0	1	199.0		199.0	199.0	101.5
2006	OB1E-3	157	46	10	217.1	90.7	130.0	416.0	1	174.0		174.0	174.0	90.6
2006	OB1S-1	142	25	10	160.7	64.4	103.0	334.0	1	132.0		132.0	132.0	105.6
2006	OB1S-2	147	27	10	181.2	57.0	95.0	275.0	1	312.0		312.0	312.0	113.5
2006	ES-09E	137	12	19	121.4	38.3	66.5	226.0	3	99.3	12.1	90.0	113.0	96.2
2006	ES-11N	143	24	17	137.0	61.1	56.2	296.0	1	244.5		244.5	244.5	126.0
2006	ES-02E	151	22	17	147.7	70.8	46.8	288.0	1	282.0		282.0	282.0	97.9
2006	ES-05+06S	137	15	30	128.6	40.7	68.3	235.0	0					
2006	ES-05S	129	9	5	114.3	17.9	92.2	141.0	1	118.0		118.0	118.0	100.0
2006	ES-06S	144	10	5	133.2	70.4	78.1	256.0	1	85.0		85.0	85.0	108.8
2006	ES-13S	132	9	7	113.3	16.9	85.4	139.5	1	92.0		92.0	92.0	107.7
2008	OB-5	144		1	254.0		254.0	254.0	1	228.0		228.0	228.0	89.8
2008	OB3	115		1	315.0		315.0	315.0	1	291.0		291.0	291.0	92.4
2008	OB1E-5	155	34	15	138.9	46.3	73.1	231.0	2	133.1	107.4	57.1	209.0	84.3
2008	OB1E-4	181	42	15	193.8	85.9	82.9	357.0	2	181.1	166.7	63.2	299.0	81.9
2008	OB1E-3	169	35	15	145.8	77.7	76.5	325.0	2	164.3	136.8	67.5	261.0	84.3
2008	ES-09E	144	37	15	116.8	42.4	70.2	223.5	2	75.8	5.0	72.3	79.4	61.5
2008	ES-11N	153	30	15	113.5	40.9	60.4	178.0	2	101.1	62.2	57.1	145.0	77.7
2008	ES-02E	128	25	15	99.6	32.2	60.8	158.5	2	95.1	0.6	94.7	95.5	71.1
2008	ES-05S	149	36	15	118.0	40.3	49.6	176.5	2	102.6	33.1	79.2	126.0	74.9
2009	OB5	99	30	22	160.8	34.1	112.0	239.0	5	138.6	45.1	103.0	217.0	72.7
2009	OB4N	185		1	229.0		229.0	229.0	0					
2009	0B4	172	38	21	215.0	122.3	96.6	698.0	5	257.6	225.7	80.7	643.3	87.0
2009	OB2	114	14	20	129.8	88.1	86.0	499.0	4	179.0	158.2	89.9	416.0	90.3
2009	OB1	135	57	4	102.9	25.2	71.5	133.0	1	73.2		73.2	73.2	69.1
2009	OB1E-TR4	116	14	24	121.9	14.1	91.4	146.0	5	93.2	21.0	67.7	112.0	77.5
2009	OB1S-TR1	166	39	9	184.5	103.1	67.2	352.0	2	176.3	166.5	58.5	294.0	91.1
2009	ES09	123		1	113.5		113.5	113.5	1	69.5		69.5	69.5	61.2
2009	ES11N	111	11	20	140.2	42.5	89.1	212.0	4	96.5	11.8	86.3	113.0	63.5
2009	ES02E	124	33	20	132.6	40.0	74.1	239.0	4	102.8	32.1	73.0	144.0	65.7
2009	ES05S	114	17	14	97.1	20.5	64.0	136.0	3	49.2	3.5	46.3	53.1	51.4
2009	ES06S	117	21	18	88.2	44.7	50.9	254.0	4	111.7	101.0	53.4	263.0	87.9
2009	ES15	145	44	8	112.0	47.8	63.8	200.0	3	58.3	15.6	40.3	68.3	69.3
2009	ES13	112	16	13	94.3	26.4	54.2	140.0	5	96.8	30.5	53.4	131.0	87.3
2009	ES13S	97		1	65.5		65.5	65.5	1	62.5		62.5	62.5	95.4
2009	ES03	105	13	4	112.0	54.1	50.1	182.0	1	138.0		138.0	138.0	75.8
2009	ES10	97		1	89.1		89.1	89.1	1	47.6		47.6	47.6	53.4
2010	BO4SW	171		1	325.0		325.0	325.0	1	311.5		311.5	311.5	95.8
2010	OB5	154	15	15	172.9	77.0	79.6	319.5	2	257.0	131.5	164.0	350.0	102.2
2010	OB4	144	24	15	157.9	89.3	76.0	315.0	2	183.3	155.1	73.6	293.0	81.9
2010	OB1E-TR4	170	17	15	245.1	92.8	90.8	467.0	0					
2010	OB1S-TR1	163	24	15	137.1	62.8	54.0	228.0	2	120.0	100.5	48.9	191.0	93.3
2010	ES11N	167	26	15	149.0	57.0	65.1	296.0	2	136.5	58.2	95.4	177.7	87.2
2010	ES02E	149	13	15	118.9	21.2	83.4	170.0	2	124.3	42.1	94.5	154.0	89.0
2010	ES06S	157	10	2	124.5	31.8	102.0	147.0	1	92.5		92.5	92.5	62.9
2010	ES15S	167	31	13	95.3	36.3	49.4	155.0	2	97.5	46.0	65.0	130.0	78.9

Appendix 14-3. Rainbow smelt summary statistics using raw data for length, and total and methyl Hg concentrations in muscle, 2006 and 2008 – 2010. Samples were collected in the lower Penobscot River. OB = Orrington – Bucksport reach; ES = estuarine reach (Penobscot Bay). Sites are listed from north to south, within each year.

Rainbow smelt year	Rainbow smelt site	length mean mm	length SD	THg n	THg mean ng/g ww	THg SD	THg min	THg max	MeHg n	MeHg mean ng/g ww	MeHg SD	MeHg min	MeHg max	% MeHg mean
2006	OB1N-5	52.0		1	96.5		96.5	96.5	1	84.0		84.0	84.0	87.0
2006	OB1E-4	56.0		1	186.0		186.0	186.0	1	124.0		124.0	124.0	66.7
2006	OB1E-3	49.5	9.2	2	122.0	18.4	109.0	135.0	1	93.0		93.0	93.0	85.3
2006	OB1S-2	49.0		1	110.0		110.0	110.0	1	67.0		67.0	67.0	60.9
2006	OB1S-1	39.6	11.0	9	92.1	25.4	54.0	138.0	2	55.5	12.0	47.0	64.0	89.7
2006	ES09S	64.0	7.3	10	83.3	18.4	50.5	119.0	2	85.5	0.7	85.0	86.0	102.3
2006	ES11N	56.9	6.2	10	85.3	16.5	62.2	116.0	2	75.5	7.8	70.0	81.0	81.3
2006	ES02E	72.8	11.0	10	79.9	22.9	51.7	125.0	2	62.0	18.4	49.0	75.0	89.1
2006	ES05S	64.5	7.7	10	106.2	95.9	42.7	373.0	2	52.5	30.4	31.0	74.0	68.5
2006	ES06S	60.8	8.0	10	124.6	53.3	67.8	245.0	2	102.0	53.7	64.0	140.0	79.0
2006	ES13S	62.0	12.7	10	75.3	23.2	40.6	126.0	2	60.0	7.1	55.0	65.0	94.9
2006	ES14N	88.4	22.2	10	75.4	22.9	42.6	118.0	2	63.0	31.1	41.0	85.0	75.6
2006	ES07S	83.4	12.2	10	51.2	15.9	34.0	79.6	2	30.5	7.8	25.0	36.0	72.3
2006	ES04W	90.4	7.6	10	63.4	22.4	40.7	101.0	2	48.5	23.3	32.0	65.0	59.3
2006	ES10N	90.8	8.5	10	53.7	18.7	33.6	94.7	2	27.5	10.6	20.0	35.0	65.3
2008	OB1N-5	178.3	50.1	8	140.0	83.3	62.2	289.0	2	157.5	96.9	89.0	226.0	87.3
2008	OB1E-4	107.0		1	90.1		90.1	90.1	1	71.4		71.4	71.4	79.2
2008	OB1E-3	144.5	39.7	15	99.9	67.1	45.0	279.0	2	168.3	158.0	56.6	280.0	97.4
2008	ES09S	109.8	13.9	15	66.6	26.3	42.2	135.0	2	79.2	46.5	46.3	112.0	96.0
2008	ES11N	125.2	33.5	15	74.3	39.2	40.3	148.0	2	74.6	37.4	48.1	101.0	93.4
2008	ES02E	117.4	11.6	15	66.4	24.7	38.0	108.0	2	61.6	41.1	32.5	90.6	85.9
2008	ES05S	136.2	16.8	5	96.2	42.4	61.6	167.0	2	73.1	27.4	53.7	92.5	71.3
2008	ES15S	125.1	26.1	16	52.7	20.6	28.2	89.9	2	72.7	29.2	52.0	93.3	101.9
2008	ES13S	109.8	10.7	15	46.2	10.8	25.9	63.1	2	50.3	12.7	41.4	59.3	82.9
2008	ES03W	138.1	32.3	15	55.7	26.3	34.8	137.0	2	48.3	22.1	32.6	63.9	77.8
2008	ES12W	138.4	31.9	15	68.5	44.9	36.1	180.0	2	102.7	92.4	37.3	168.0	92.6
2008	ES14N	120.1	16.1	15	58.5	15.1	35.2	102.0	3	60.0	0.2	59.8	60.2	96.5
2009	OB4	170.3	83.4	3	180.2	194.9	47.9	404.0	1	301.0		301.0	301.0	74.5
2009	OB2	57.7	4.0	3	74.4	23.9	60.4	102.0	1	53.8		53.8	53.8	89.1
2009	OB1N-5	63.1	19.4	18	92.0	18.3	69.2	135.0	4	83.3	21.2	60.3	104.0	79.7
2009	OB1E-4	156.9	23.5	10	107.1	22.5	73.6	140.0	2	78.5	4.2	75.5	81.5	77.2
2009	OB1S	180.0	19.8	2	135.8	58.2	94.7	177.0	1	127.0		127.0	127.0	71.8
2009	ES09	59.2	5.9	15	70.5	22.6	38.8	126.0	3	57.0	2.9	54.2	60.0	82.5
2009	ES11N	57.0	8.8	6	54.4	5.6	49.3	62.5	1	44.1		44.1	44.1	89.5
2009	ES02E	177.9	28.5	20	175.9	86.3	65.8	364.0	4	157.7	113.6	56.7	296.0	79.0
2009	ES05S	124.8	58.1	18	120.0	87.1	54.6	391.0	4	66.0	28.4	44.0	107.0	69.9
2009	ES06S	169.2	32.5	5	133.7	49.7	79.0	198.0	1	90.0		90.0	90.0	45.5
2009	ES15S	133.7	40.4	7	75.4	26.2	40.1	108.0	1	21.9		21.9	21.9	28.7
2009	ES13	123.3	15.7	20	84.0	22.0	58.1	136.0	4	58.6	23.6	32.3	88.9	54.8
2009	ES13S	136.2	25.4	13	81.5	19.3	54.2	115.0	3	39.4	18.6	19.4	56.1	43.5
2009	ES12	42.5	2.4	4	48.1	16.5	35.1	69.6	1	59.5		59.5	59.5	85.5
2009	ES03	47.3	6.2	20	51.2	11.2	36.5	71.9	4	42.5	13.7	30.9	59.8	83.0
2009	ESFP	113.3	13.5	20	56.0	14.3	40.1	101.0	4	39.4	4.0	36.6	45.2	68.0
2009	ES14N	127.3	21.7	10	80.0	22.0	45.7	114.0	2	32.4	8.6	26.3	38.4	41.7
2009	ES14	47.4	7.9	12	34.6	9.0	25.6	51.7	2	33.7	17.1	21.6	45.8	110.3
2009	ES04W	71.5	23.2	20	38.4	12.1	17.9	62.5	4	29.2	7.8	19.0	37.4	86.6
2009	ES10	82.4	20.1	12	45.4	8.8	26.0	60.5	2	39.7	9.4	33.0	46.3	75.1
2010	OB5	43.6	8.8	5	65.3	16.9	39.0	86.3	1	68.7		68.7	68.7	104.6
2010	OB4	63.8	13.2	6	95.4	25.4	71.0	134.0	1	46.9		46.9	46.9	54.8
2010	OB1S-1	184.8	55.5	5	155.4	103.8	70.3	332.0	1	143.7		143.7	143.7	92.7
2010	ES11N	176.7	10.2	3	43.4	17.9	25.4	61.2	1	58.5		58.5	58.5	95.5
2010	ES02E	100.0	46.3	11	66.2	36.6	34.4	160.0	2	46.2	5.4	42.3	50.0	93.3
2010	ES06S	100.0	48.1	2	55.1	38.7	27.7	82.4	1	82.2		82.2	82.2	99.8
2010	ES13	81.5	28.3	4	41.9	16.3	31.1	65.7	1	72.9		72.9	72.9	111.0
2010	ES13S	76.5	4.9	2	38.3	5.0	34.8	41.9	1	36.5		36.5	36.5	87.1
2010	ESFP	91.2	10.0	15	37.1	7.8	25.8	56.5	2	35.0	15.6	24.0	46.0	95.9
2010	ES04W	100.5	26.8	15	33.4	9.4	23.1	55.9	2	44.5	29.8	23.4	65.5	107.7

Appendix 14-4. Mummichog summary statistics using raw data for length, and total and methyl Hg concentrations in muscle, 2006 and 2008 – 2010. Samples were collected in the lower Penobscot River. BO = Brewer – Orrington reach; OB = Orrington – Bucksport reach; ES = estuarine reach (Penobscot Bay). Sites are listed from north to south, within each year.

Mummichog year	Mummichog site	length mean mm	length SD	THg n	THg mean ng/g ww	THg SD	THg min	THg max	MeHg n	MeHg mean ng/g ww	MeHg SD	MeHg min	MeHg max	% MeHg mean
2006	BO1	87.6	6.5	5	300	92	232	438	1	470.0		470	470	107.3
2006	BO2	85.2	2.9	5	263	33	210	293	1	289.0		289	289	98.6
2006	BO3	79.6	3.2	5	248	115	144	434	1	202.0		202	202	116.8
2006	BO4	60.2	2.9	5	138	50	78	206	1	149.0		149	149	88.2
2006	BO5	50.5	5.2	6	194	84	123	345	1	130.0		130	130	105.7
2006	OB1N-5	76.0		1	251		251	251	1	281.0		281	281	112.0
2006	OB1E-4	63.5	26.2	2	310	112	230	389	1	354.0		354	354	91.0
2006	OB1E-3	67.0	17.0	2	380	25	362	398	1	398.0		398	398	109.9
2006	OB1S-2	68.5	14.8	2	257	54	218	295	1	313.0		313	313	106.1
2006	OB1S-1	82.0	8.5	2	421	189	287	554	1	311.0		311	311	108.4
2006	ES-10N	34.0		1	92		92	92	1	95.0		95	95	103.3
2008	OB1N-5	59.0		1	234		234	234	1	25.6		25.6	25.6	10.9
2008	OB1E-3	78.9	9.4	15	297	65	184	465	2	81.9	52.5	44.8	119	27.8
2009	OB5	71.8	15.8	24	189	68	77.7	360	4	202.8	62.1	162	295	93.6
2009	OB4N	60.5	14.1	20	131	30	78.7	200	4	97.4	12.5	84.4	112	84.3
2009	OB1	73.1	5.9	12	224	38	165	290	2	204.5	29.0	184	225	84.3
2009	ES13	62.0	1.4	2	257	78	202	312	1	264.0		264	264	84.6
2010	BO5	63.0	9.1	18	150	40	93.8	259	3	162.7	36.9	123	196	83.0
2010	SCOVE	85.0		1	182		181.5	181.5	1	188.0		188	188	103.6
2010	OB5	79.0		1	328		328	328	1	338.0		338	338	103.0
2010	W17	84.6	11.8	13	218	104	78.8	464.5	2	142.3	85.8	81.6	203	91.7
2010	W21	67.1	9.2	14	352	77	204	489	3	295.3	93.4	191	371	93.3

Appendix 14-5. Winter flounder summary statistics using raw data for length, and total and methyl Hg concentrations in muscle, 2006 and 2008 – 2010. Samples were collected in the lower Penobscot River. OB = Orrington – Bucksport reach; ES = estuarine reach (Penobscot Bay). Sites are listed from north to south, within each year.

Winter flounder year	Winter flounder site	length mean mm	length SD	THg n	THg mean ng/g ww	THg SD	THg min	THg max	MeHg n	MeHg mean ng/g ww	MeHg SD	MeHg min	MeHg max	% MeHg mean
2006	ES15S	52.7	7.0	10	26.1	6.1	19.6	35.9	2	21.5	0.7	21.0	22.0	103.4
2006	ES13S	76.4	15.7	10	60.4	40.2	19.8	141.0	2	81.5	44.5	50.0	113.0	80.7
2006	ES14N	59.9	15.8	18	35.9	16.6	19.5	75.4	2	41.5	10.6	34.0	49.0	82.3
2006	ES12W	57.0	7.0	10	25.8	5.3	17.8	38.0	2	24.5	0.7	24.0	25.0	92.8
2006	ES03W	69.3	14.5	10	29.3	13.2	18.1	63.9	2	33.5	14.8	23.0	44.0	79.5
2006	ES07S	65.7	15.6	9	24.7	8.0	15.6	39.7	1	11.0		11.0	11.0	52.1
2006	ES04W	50.2	7.1	10	15.1	3.4	10.8	21.1	2	11.0	4.2	8.0	14.0	75.3
2006	ES08E	59.8	9.0	10	18.1	2.6	15.0	23.3	2	14.5	0.7	14.0	15.0	73.9
2008	OB1N-TR5	125.7	23.2	9	46.8	4.7	40.1	54.0	2	37.0	2.3	35.3	38.6	73.1
2008	OB1E-TR4	148.7	38.0	15	55.2	16.7	39.0	90.9	2	32.4	3.5	29.9	34.9	80.8
2008	OB1E-TR3	122.3	13.5	4	58.5	8.7	46.6	67.3	2	40.9	1.6	39.8	42.0	68.2
2008	ES09E	114.5	13.4	15	104.3	47.3	50.6	244.0	2	86.8	28.6	66.6	107.0	69.5
2008	ES11N	121.4	23.7	15	85.1	32.8	32.0	142.0	2	52.8	11.1	44.9	60.6	55.4
2008	ES02E	110.0	17.7	15	107.0	28.1	50.5	152.0	2	55.0	30.2	33.6	76.3	63.6
2008	ES05S	139.9	32.1	9	84.9	32.4	32.5	141.0	2	44.0	33.4	20.4	67.6	62.4
2008	ES15S	119.4	37.4	15	39.8	20.7	18.7	95.0	2	28.7	9.7	21.8	35.5	81.6
2008	ES13S	105.3	24.1	15	26.2	4.6	20.1	36.9	2	18.8	2.1	17.3	20.3	67.9
2008	ES14N	114.7	23.3	15	35.6	8.7	24.3	56.2						
2008	ES12W	104.2	27.1	15	28.9	10.9	18.5	61.3	2	17.4	4.2	14.4	20.4	67.7
2008	ES03W	117.4	46.6	15	34.6	24.8	17.8	116.0	2	22.2	4.2	19.2	25.1	65.4
2009	OB4	151.3	23.3	20	82.8	16.8	59.0	126.0	4	46.3	7.3	36.4	52.4	51.6
2009	OB2	132.4	21.7	19	125.5	26.9	76.2	187.0	4	64.5	16.1	51.1	83.1	56.6
2009	OB1E-TR4	123.4	35.8	20	80.3	24.7	48.6	137.0	4	32.0	9.8	22.7	44.2	47.5
2009	OB1S-TR1	134.3	11.0	10	67.8	15.7	49.0	102.0	2	42.5	6.0	38.2	46.7	53.6
2009	ES09	155.0	59.7	4	109.4	61.5	50.7	191.0	1	38.3		38.3	38.3	75.5
2009	ES11N	101.5	7.9	4	58.6	9.6	48.1	71.4	1	51.7		51.7	51.7	89.8
2009	ES02E	130.0	43.1	13	120.8	63.1	38.6	247.0	3	59.6	36.9	24.1	97.7	53.8
2009	ES05S	103.3	20.1	3	63.3	18.6	51.7	84.7	1	24.2		24.2	24.2	46.8
2009	ES06S	144.6	25.7	14	140.7	67.9	29.1	243.0	3	58.7	14.8	42.6	71.7	57.8
2009	ES15	119.3	15.1	21	58.6	23.5	29.4	146.0	5	43.7	12.4	25.6	60.1	94.2
2009	ES15S	112.1	15.3	20	36.9	9.5	22.7	62.3	4	30.2	8.1	20.6	37.4	85.5
2009	ES13	101.0	7.0	4	43.9	5.2	36.5	47.8	1	45.9		45.9	45.9	96.0
2009	ES13S	113.9	16.9	17	48.1	17.0	28.5	83.1	4	50.8	20.4	32.4	79.4	88.9
2009	ES14N	124.0	31.6	20	40.8	16.8	17.5	80.8	4	38.8	9.1	27.0	46.7	92.0
2009	ES03	141.7	15.9	3	36.2	4.8	31.2	40.8	1	19.1		19.1	19.1	46.8
2009	FP	97.6	23.7	20	34.9	12.9	14.2	70.0	4	24.7	7.8	18.1	34.9	65.0
2009	ES14	99.0		1	42.4	.	42.4	42.4	1	41.6		41.6	41.6	98.1
2009	ES07S	121.7	25.7	7	25.3	3.6	21.5	32.2	1	14.6		14.6	14.6	63.5
2009	ES04W	133.4	18.7	7	40.4	28.5	17.3	101.0	1	24.6		24.6	24.6	53.9
2009	ES10	171.5	67.6	8	74.6	100.9	30.8	323.0	2	42.0	14.1	32.0	52.0	92.4
2009	ES01	132.7	59.1	7	28.9	12.4	15.5	48.4	1	11.1		11.1	11.1	44.6
2010	OB5	96.5	12.3	14	47.8	12.2	23.4	65.8	2	33.0	19.3	19.3	46.6	68.7
2010	OB4	78.5	5.9	6	46.7	12.7	26.5	61.9	1	35.5		35.5	35.5	61.5
2010	OB1E-TR4	115.9	33.2	15	116.1	61.4	23.7	218.0	2	69.2	37.9	42.4	96.0	82.8
2010	OB1S-TR1	101.6	31.9	13	59.9	24.6	23.3	109.0	2	31.1	17.6	18.6	43.5	75.0
2010	ES11N	87.3	15.2	8	54.5	20.0	36.2	93.1	1	87.0		87.0	87.0	93.4
2010	ES02E	95.6	30.6	8	80.6	45.2	42.2	160.0	1	56.7		56.7	56.7	69.1
2010	ES06S	75.8	10.5	13	62.7	15.0	34.9	92.9	2	65.2	9.8	58.2	72.1	86.7
2010	ES15S	114.0	41.9	15	42.7	13.8	19.9	65.7	2	33.0	1.7	31.8	34.2	80.8
2010	ES13	93.0	29.9	4	61.1	14.9	48.0	76.7	1	62.1		62.1	62.1	81.0
2010	ES13S	94.1	22.8	15	45.3	18.4	25.9	83.3	2	24.4	5.1	20.8	28.0	84.6
2010	FP	107.3	63.2	12	41.0	15.3	23.5	75.6	2	31.0	6.1	26.7	35.3	90.1
2010	ES04W	81.7	15.5	15	19.2	6.4	9.7	34.3	2	23.0	5.9	18.8	27.2	83.6

Appendix 14-6a. Lobster summary statistics using raw data for carapace length, and total and methyl Hg concentrations in tail muscle, 2006 and 2008 – 2010. Samples were collected in Penobscot Bay. Sites are listed from north to south, and east to west, within each year.

American lobster year	American lobster site	length mean mm	length SD	n TAIL THg	mean of TAIL THg ng/g ww	SD of TAIL THg ng/g ww	min TAIL THg ng/g ww	max TAIL THg ng/g ww	n TAIL MeHg	mean of TAIL MeHg ng/g ww	SD of TAIL MeHg ng/g ww	min TAIL MeHg ng/g ww	max TAIL MeHg ng/g ww	mean of % TAIL MeHg ng/g ww
2006	Fort Point	80.0	1.0	0					0					
2006	Turner Point	78.1	6.0	5	338	103	172	410	5	254	96	120	351	73.9
2006	Harborside	80.6	7.2	1	319	.	319	319	1	263	.	263	263	82.4
2006	SW Sears Island	79.0	5.6	2	133	16	121	144	2	98	5	94	101	73.9
2008	South Verona	89.2	7.3	10	544	233	288	1,125	0					
2008	Odom Ledge	91.7	5.0	21	344	190	178	1,010	0					
2008	Fort Point	83.3	10.2	11	240	105	134	481	0					
2008	Turner Point	85.8	8.5	35	198	81	68	387	0					
2008	Harborside	89.1	8.0	29	172	81	72	399	0					
2008	Parker Cove	83.3	14.2	11	227	101	55	407	0					
2008	SW Sears Island	82.2	8.5	88	112	43	40	320	0					
2008	Kellys Cove	89.0	8.5	2	88	6	84	92	0					
2009	South Verona	87.6	4.7	5	466	108	359	644	5	446	113	335	625	95.4
2009	Odom Ledge	87.5	9.6	16	235	122	27	454	16	226	116	23	442	95.9
2009	Fort Point	87.5	5.0	12	273	177	51	746	12	255	164	50	706	94.1
2009	Turner Point	87.7	8.6	20	225	119	83	514	20	224	115	76	473	99.7
2009	Harborside	85.4	6.6	20	116	35	65	166	20	113	38	60	169	97.5
2009	Parker Cove	83.6	5.3	20	130	46	63	231	20	123	45	67	237	95.0
2009	SW Sears Island	82.1	9.6	22	120	51	59	250	22	112	50	53	251	92.9
2009	Kellys Cove	84.9	11.7	20	109	47	56	260	20	106	48	48	259	97.2
2010	South Verona	88.3	5.0	12	444	190	157	875	12	459	196	150	906	103.1
2010	Odom Ledge	89.3	7.3	19	266	97	92	526	9	292	107	188	547	98.2
2010	Fort Point	87.2	9.5	21	186	88	50	380	11	202	115	51	422	112.9
2010	Turner Point	87.3	6.4	20	180	84	73	375	10	190	63	95	281	111.5
2010	Harborside	87.7	9.3	20	130	72	46	364	11	151	96	49	377	103.8
2010	Parker Cove	85.8	9.4	20	186	93	63	391	11	216	119	71	420	108.4
2010	SW Sears Island	86.7	8.9	20	114	52	59	250	10	128	64	59	246	97.4
2010	Kellys Cove	84.1	14.8	20	134	90	40	397	11	135	61	46	264	107.9

Appendix 14-7b. Lobster summary statistics using raw data for carapace length, and total and methyl Hg concentrations in claw muscle, 2006 and 2008 – 2010. Samples were collected in Penobscot Bay. Sites are listed from north to south, and east to west, within each year.

American lobster year	American lobster site	length mean mm	length SD	n CLAW THg ng/g ww	mean CLAW THg ng/g ww	SD CLAW THg ng/g ww	min CLAW THg ng/g ww	max CLAW THg ng/g ww	n CLAW MeHg ng/g ww	mean CLAW MeHg ng/g ww	SD CLAW MeHg ng/g ww	min CLAW MeHg ng/g ww	max CLAW MeHg ng/g ww	mean % CLAW MeHg
2006	Fort Point	80.0	1.0	5	179	121	46	296	5	176	119	45	283	99.0
2006	Turner Point	78.1	6.0	62	149	78	26	360	62	126	81	9	452	82.3
2006	Harborside	80.6	7.2	40	85	43	19	222	40	55	29	9	121	65.6
2006	SW Sears Island	79.0	5.6	73	100	93	15	680	73	72	69	14	522	75.6
2008	South Verona	89.2	7.3	10	282	145	84	575	0					
2008	Odom Ledge	91.7	5.0	21	153	84	57	340	0					
2008	Fort Point	83.3	10.2	11	106	67	58	290	0					
2008	Turner Point	85.8	8.5	35	98	61	21	250	0					
2008	Harborside	89.1	8.0	29	85	79	23	387	0					
2008	Parker Cove	83.3	14.2	11	122	79	42	284	0					
2008	SW Sears Island	82.2	8.5	88	46	21	14	118	0					
2008	Kellys Cove	89.0	8.5	2	27	1	26	27	0					
2009	South Verona	87.6	4.7	5	178	96	96	340	5	165	102	81	339	90.8
2009	Odom Ledge	87.5	9.6	16	79	43	39	181	16	77	45	35	188	95.2
2009	Fort Point	87.5	5.0	12	104	35	67	168	12	93	37	44	165	88.6
2009	Turner Point	87.7	8.6	20	85	45	27	171	20	77	44	22	174	89.5
2009	Harborside	85.4	6.6	20	45	12	25	64	20	41	13	20	62	88.8
2009	Parker Cove	83.6	5.3	20	55	22	27	111	20	49	20	20	90	87.9
2009	SW Sears Island	82.1	9.6	22	48	23	23	107	22	44	25	20	112	89.4
2009	Kellys Cove	84.9	11.7	20	48	20	20	98	20	42	19	14	85	86.1
2010	South Verona	88.3	5.0	7	265	126	93	465	6	266	141	97	478	102.6
2010	Odom Ledge	89.3	7.3	9	163	87	58	354	5	169	119	58	351	100.1
2010	Fort Point	87.2	9.5	11	129	67	31	251	5	141	61	46	206	105.0
2010	Turner Point	87.3	6.4	10	117	52	57	195	5	167	58	68	216	108.1
2010	Harborside	87.7	9.3	11	81	31	28	123	5	73	36	26	104	103.0
2010	Parker Cove	85.8	9.4	10	103	64	35	267	5	81	30	36	112	105.2
2010	SW Sears Island	86.7	8.9	10	65	29	18	109	5	53	35	14	99	92.7
2010	Kellys Cove	84.1	14.8	11	59	40	26	171	5	59	15	34	70	106.4

Appendix 14-8c. Lobster summary statistics using raw data for carapace length, and total and methyl Hg concentrations in tomalley (hepatopancreas), wet wt., 2006 and 2008 – 2010. Samples were collected in Penobscot Bay. Sites are listed from north to south, and east to west, within each year.

American lobster year	American lobster site	length mean mm	length SD	n TOMALLEY THg ng/g ww	mean TOMALLEY THg ng/g ww	SD TOMALLEY THg ng/g ww	min TOMALLEY THg ng/g ww	max TOMALLEY THg ng/g ww	n TOMALLEY MeHg ng/g ww	mean TOMALLEY MeHg ng/g ww	SD TOMALLEY MeHg ng/g ww	min TOMALLEY MeHg ng/g ww	max TOMALLEY MeHg ng/g ww	mean % TOMALLEY MeHg ng/g ww
2006	Fort Point	80.0	1.0	0					5	176	119	45	283	0.0
2006	Turner Point	78.1	6.0	5	94	10	85	109	62	126	81	9	452	57.7
2006	Harborside	80.6	7.2	1	126	.	126	126	40	55	29	9	121	65.1
2006	SW Sears Island	79.0	5.6	2	105	8	99	111	73	72	69	14	522	46.0
2008	South Verona	89.2	7.3	10	202	66	108	288	0					
2008	Odom Ledge	91.7	5.0	0					0					
2008	Fort Point	83.3	10.2	8	125	44	59	194	0					
2008	Turner Point	85.8	8.5	30	99	36	45	224	0					
2008	Harborside	89.1	8.0	17	75	35	37	156	0					
2008	Parker Cove	83.3	14.2	0					0					
2008	SW Sears Island	82.2	8.5	88	72	22	32	136	0					
2008	Kellys Cove	89.0	8.5	2	58	9	51	64	0					
2009	South Verona	87.6	4.7	5	147	34	113	201	5	165	102	81	339	67.8
2009	Odom Ledge	87.5	9.6	16	88	42	48	207	16	77	45	35	188	50.0
2009	Fort Point	87.5	5.0	12	102	58	56	278	12	93	37	44	165	49.8
2009	Turner Point	87.7	8.6	20	94	33	52	159	20	77	44	22	174	52.8
2009	Harborside	85.4	6.6	20	59	11	40	72	20	41	13	20	62	45.5
2009	Parker Cove	83.6	5.3	20	67	19	38	124	20	49	20	20	90	55.1
2009	SW Sears Island	82.1	9.6	22	69	16	40	105	22	44	25	20	112	37.8
2009	Kellys Cove	84.9	11.7	20	67	26	35	127	20	42	19	14	85	44.1
2010	South Verona	88.3	5.0	2	191	62	147	234	6	266	141	97	478	70.1
2010	Odom Ledge	89.3	7.3	2	164	77	109	218	5	169	119	58	351	47.5
2010	Fort Point	87.2	9.5	3	79	43	49	129	5	141	61	46	206	46.1
2010	Turner Point	87.3	6.4	2	87	11	79	95	5	167	58	68	216	65.4
2010	Harborside	87.7	9.3	2	79	25	61	97	5	73	36	26	104	61.3
2010	Parker Cove	85.8	9.4	2	96	49	61	131	5	81	30	36	112	55.2
2010	SW Sears Island	86.7	8.9	2	117	13	107	126	5	53	35	14	99	21.9
2010	Kellys Cove	84.1	14.8	2	88	31	66	110	5	59	15	34	70	36.4

Appendix 14-9d. Lobster summary statistics using raw data for carapace length, and total and methyl Hg concentrations in tomalley (hepatopancreas), dry wt., 2006 and 2008 – 2010. Samples were collected in Penobscot Bay. Sites are listed from north to south, and east to west, within each year.

American lobster year	American lobster site	length mean mm	length SD	n TOMALLEY THg ng/g dw	mean TOMALLEY THg ng/g dw	SD TOMALLEY THg ng/g dw	min TOMALLEY THg ng/g dw	max TOMALLEY THg ng/g dw	n TOMALLEY MeHg ng/g dw	mean TOMALLEY MeHg ng/g dw	SD TOMALLEY MeHg ng/g dw	min TOMALLEY MeHg ng/g dw	max TOMALLEY MeHg ng/g dw	mean % TOMALLEY MeHg ng/g dw
2006	Fort Point	80.0	1.0	0					0					
2006	Turner Point	78.1	6.0	5	336	99	230	436	5	186	56	149	285	57.7
2006	Harborside	80.6	7.2	1	361	.	361	361	1	237	.	237	237	65.7
2006	SW Sears Island	79.0	5.6	2	353	103	280	426	2	159	21	144	173	46.0
2008	South Verona	89.2	7.3	10	648	248	344	1030	0					
2008	Odom Ledge	91.7	5.0	0					0					
2008	Fort Point	83.3	10.2	8	380	119	176	592	0					
2008	Turner Point	85.8	8.5	30	330	130	130	748	0					
2008	Harborside	89.1	8.0	17	242	82	126	374	0					
2008	Parker Cove	83.3	14.2	0					0					
2008	SW Sears Island	82.2	8.5	88	206	84	87	472	0					
2008	Kellys Cove	89.0	8.5	2	214	83	155	273	0					
2009	South Verona	87.6	4.7	5	411	123	262	548	5	280	88	181	377	67.8
2009	Odom Ledge	87.5	9.6	16	410	194	119	783	16	206	125	67	509	50.0
2009	Fort Point	87.5	5.0	12	482	230	204	786	12	244	178	96	606	49.8
2009	Turner Point	87.7	8.6	20	316	141	133	618	20	175	120	54	535	52.8
2009	Harborside	85.4	6.6	20	180	35	139	265	20	81	31	39	161	45.5
2009	Parker Cove	83.6	5.3	20	218	69	105	371	20	119	46	41	205	55.1
2009	SW Sears Island	82.1	9.6	22	202	74	109	461	22	72	20	37	113	37.9
2009	Kellys Cove	84.9	11.7	20	216	95	115	415	20	96	75	29	368	44.1
2010	South Verona	88.3	5.0	2	747	108	670	823	2	529	148	424	633	70.1
2010	Odom Ledge	89.3	7.3	2	622	395	342	901	2	306	218	152	460	47.7
2010	Fort Point	87.2	9.5	3	288	131	199	439	3	144	109	37	255	46.0
2010	Turner Point	87.3	6.4	2	314	59	272	355	2	205	42	175	234	65.1
2010	Harborside	87.7	9.3	2	255	66	208	301	2	161	71	111	211	61.7
2010	Parker Cove	85.8	9.4	2	270	158	158	381	2	153	99	83	223	55.5
2010	SW Sears Island	86.7	8.9	2	464	137	367	561	2	105	63	60	149	21.5
2010	Kellys Cove	84.1	14.8	2	332	165	215	449	2	116	37	89	142	36.5

Appendix 14-10. Blue mussel summary statistics using raw data for length, and total and methyl Hg concentrations in soft tissue, wet wt., 2006 and 2008 – 2010. Samples were collected in Penobscot Bay. ES = estuarine reach (Penobscot Bay). Sites are listed from north to south, east to west, within each year.

Blue mussel year	Blue mussel site	season	length mean mm	length SD	THg n	THg mean ng/g ww	THg SD	THg min	THg max	MeHg n	MeHg mean ng/g ww	MeHg SD	MeHg min	MeHg max	% MeHg mean
2006	ES15	fall	NA	NA	20	685.4	252.3	376.0	1210.0	20	211.3	74.2	103.0	349.0	31.4
2006	ES13	fall	NA	NA	20	1270.5	283.7	949.0	2070.0	20	491.7	184.1	243.0	858.0	39.8
2006	ES12	fall	NA	NA	20	867.0	183.7	447.0	1240.0	20	365.5	115.8	116.0	555.0	42.0
2006	ES03	fall	NA	NA	19	690.6	323.5	333.0	1440.0	20	250.1	76.4	150.5	427.0	38.9
2006	ES14	fall	NA	NA	20	818.9	281.7	474.0	1500.0	20	189.6	42.3	112.0	289.0	24.8
2006	ES04	fall	NA	NA	20	206.9	67.8	102.0	362.0	20	96.7	29.0	54.0	166.5	47.5
2006	ES10	fall	NA	NA	20	152.5	72.0	81.3	344.0	20	51.6	15.4	31.0	90.0	35.9
2006	ES07	fall	NA	NA	20	118.8	37.9	78.6	184.0	20	41.4	12.0	27.0	66.0	36.1
2006	ES08	fall	NA	NA	20	171.5	49.9	112.0	307.0	20	59.0	22.8	30.5	98.0	35.9
2006	ES01	fall	NA	NA	20	286.7	100.4	159.0	576.0	20	117.8	41.5	57.0	215.0	42.9
2008	ES15	fall	52.3	8.3	30	518.8	169.6	181.0	1060.0	30	171.3	44.2	48.1	254.0	34.2
2008	ES13	fall	56.0	9.6	30	638.8	171.5	390.0	1090.0	30	252.2	54.0	139.0	355.0	40.9
2008	ES12	fall	56.7	8.2	30	459.4	167.5	218.0	1005.0	30	200.9	60.6	105.0	394.0	44.7
2008	ES03	fall	63.1	9.6	30	514.0	168.3	329.0	1050.0	30	200.1	47.5	108.0	292.0	40.3
2008	ES14	fall	68.4	10.4	15	541.2	168.1	216.0	840.0	15	171.1	50.0	69.8	294.0	32.5
2008	ES10	fall	50.2	5.4	15	154.7	48.6	93.9	283.0	0					
2008	ES04	fall	55.2	5.6	15	205.7	89.0	134.0	471.0	0					
2008	ES07	fall	56.7	5.1	15	150.4	47.2	92.8	225.0	0					
2009	ES15	fall	55.5	7.7	39	604.4	176.4	319.0	1020.0	40	280.8	99.1	120.5	665.0	47.8
2009	ES13	fall	57.9	7.6	40	695.8	242.3	311.0	1650.0	40	322.0	103.5	139.0	689.0	47.0
2009	ES03	fall	52.6	6.9	40	409.4	119.0	208.0	649.0	0					
2009	FP	fall	45.3	5.0	20	311.8	67.0	249.0	495.0	20	192.6	40.1	125.5	284.0	62.2
2009	ES10	fall	57.0	8.0	20	105.3	24.3	66.3	157.0	20	50.5	12.7	29.8	77.0	48.4
2009	ES04	fall	54.8	8.5	40	161.4	124.6	70.6	813.0	40	83.9	41.6	40.3	255.0	57.5
2009	ES07	fall	54.3	7.1	20	74.5	13.9	56.5	113.0	20	31.5	5.3	21.3	42.4	43.2
2010	WH7	fall	36.7	3.8	15	413.1	48.0	307.0	496.0	2	170.5	19.1	157.0	184.0	48.4
2010	ES15	fall	52.0	6.3	15	367.3	73.5	244.0	474.0	2	171.5	27.6	152.0	191.0	53.1
2010	ES15	spring	54.8	6.4	20	624.0	133.4	413.0	945.0	20	273.1	50.1	189.0	376.0	44.4
2010	ES13	fall	54.7	6.2	15	428.8	83.2	263.0	567.0	2	230.0	33.9	206.0	254.0	51.8
2010	ES13	spring	56.6	4.4	20	764.8	200.1	489.0	1220.0	20	372.0	86.2	255.0	611.0	49.7
2010	ES03	fall	56.7	7.3	15	311.4	52.0	248.0	434.0	2	165.5	2.1	164.0	167.0	50.1
2010	ES03	spring	62.4	6.0	20	542.7	86.9	393.0	669.0	20	197.2	28.7	132.0	255.5	36.6
2010	FP	fall	64.5	6.6	15	317.1	48.5	260.0	463.0	2	137.3	19.4	123.5	151.0	44.1
2010	ES14	fall	70.6	17.0	15	393.2	159.7	207.0	748.0	2	214.0	58.0	173.0	255.0	55.6
2010	ES10	fall	62.5	5.8	15	224.6	85.9	147.0	509.0	1	99.9	.	99.9	99.9	54.3
2010	ES04	fall	64.8	2.7	15	221.0	28.8	177.0	265.0	2	97.7	0.8	97.1	98.3	47.4
2010	ES04	spring	64.7	5.3	20	202.1	35.9	149.0	299.0	20	82.8	20.2	45.1	122.0	40.7
2010	ES07	fall	61.3	6.1	15	148.6	45.0	91.1	242.0	2	72.8	36.6	47.0	98.7	57.6

Appendix 14-11a. Nelson's sparrow summary statistics using raw data for length, and total and methyl Hg concentrations in blood, 2007 – 2010. Samples were collected in the lower Penobscot River and at coastal reference sites. Sites are listed from north to south, within each year.

Nelson's sparrow YEAR	Nelson's sparrow SITE	Age class	mean Julian date sampled	SD Julian date	n Blood THg	mean Blood THg µg/g ww	SD Blood THg	min Blood THg	max Blood THg	n Blood MeHg	mean Blood MeHg µg/g ww	SD Blood MeHg	min Blood MeHg	max Blood MeHg	mean % MeHg
2007	MM-Car	AD	7171		0					0					
2007	MM-Northeast	AD	7205	1.2	12	7.96	1.05	6.52	10.31	0					
2007	MM-Southeast	AD	7187	2.6	21	6.09	2.63	0.26	10.85	0					
2007	MM-Jetti	AD	7181	3.1	6	6.24	1.25	4.57	7.94	0					
2007	MM-Southw est	AD	7201	3.3	34	7.58	2.17	2.68	13.49	0					
2007	Parker R NWR	AD	7191		1	1.20	.	1.20	1.20	0					
2007	Rachel Carson NWR	AD	7184	1.9	4	0.43	0.11	0.34	0.54	0					
2007	Scarborough	AD	7216	2.7	5	0.27	0.07	0.21	0.37	0					
2007	MM-Northeast	HY	7206	0.0	2	2.62	0.30	2.40	2.83	0					
2007	MM-Southw est	HY	7205		1	1.97	.	1.97	1.97	0					
2008	W-17-N	AD	8200	0.4	6	4.25	0.37	3.82	4.92	0					
2008	W-17-S	AD	8198	1.0	6	3.51	1.57	0.53	4.82	0					
2008	MM-Car	AD	8190	3.7	8	3.03	0.79	2.07	4.77	0					
2008	MM-Northeast	AD	8223	1.4	17	3.69	1.14	1.16	6.02	6	3.52	0.77	2.33	4.41	96
2008	MM-Southeast	AD	8214	7.2	48	3.78	1.71	0.92	11.70	13	2.97	0.84	1.89	4.33	104
2008	MM-Jetti	AD	8186	0.0	3	5.30	0.23	5.16	5.56	0					
2008	MM-Southw est	AD	8200	7.8	21	5.81	1.49	2.23	9.15	0					
2008	MM-South-174	AD	8185	0.0	6	2.07	0.43	1.48	2.55	0					
2008	Scarborough	AD	8228	1.4	2	0.35	0.22	0.19	0.50	0					
2008	MM-Northeast	HY	8222	1.2	8	1.57	1.12	0.47	3.01	2	1.11	0.81	0.53	1.68	98
2008	MM-Southeast	HY	8216	4.9	2	2.82	0.40	2.54	3.10	0					
2009	W-17-N	AD	9194	0.4	7	4.95	2.42	2.61	9.59	0					
2009	W-17-S	AD	9195	0.0	2	4.61	0.68	4.13	5.09	0					
2009	MM-Car	AD	9182	0.0	3	1.79	0.11	1.70	1.91	0					
2009	MM-Northeast	AD	9191	0.7	31	3.90	1.12	1.37	6.31	0					
2009	MM-Jetti	AD	9168	0.0	5	3.27	0.38	2.83	3.87	0					
2009	MM-Southw est	AD	9165	2.0	11	3.19	1.72	0.49	5.96	0					
2009	MM-South-174	AD	9191	5.4	14	3.87	1.35	1.85	6.27	0					
2009	Bass Harbor	AD	9215	4.9	3	0.55	0.29	0.22	0.78	0					
2009	Tremont	AD	9210	0.0	5	0.73	0.13	0.58	0.92	0					
2009	Rachel Carson NWR	AD	9203	14.4	4	0.49	0.08	0.43	0.60	0					
2009	Scarborough	AD	9217	1.4	10	0.81	0.55	0.39	2.27	0					
2010	W-17-N	AD	10183	0.0	6	5.14	2.14	1.66	7.61	0					
2010	W-17-S	AD	10196	0.0	5	7.12	1.69	5.14	9.00	0					
2010	MM-Car	AD	10190	0.0	4	3.48	0.76	2.36	4.04	0					
2010	MM-Northeast	AD	10189	0.0	8	6.32	1.21	4.95	8.66	0					
2010	MM-Southeast	AD	10197	10.1	26	6.25	2.22	1.53	14.39	0					
2010	MM-Jetti	AD	10182	0.0	2	6.60	0.67	6.12	7.07	0					
2010	MM-South-174	AD	10191	4.3	10	3.79	1.24	2.28	6.02	0					
2010	Spurw ink Marsh	AD	10207	0.0	10	0.51	0.18	0.35	0.84	0					

Appendix 14-12b. Nelson's sparrow summary statistics using raw data for sample date, and total Hg concentrations in feathers, 2007 – 2010. Samples were collected in the lower Penobscot River and at coastal reference sites. Sites are listed from north to south, within each year.

Nelson's sparrow YEAR	Nelson's sparrow SITE	Age class	mean Julian date sampled	SD Julian date	n T6 (tail feather) THg	mean T6 THg µg/g fw	SD T6 THg	min T6 THg	max T6 THg	n S2 (secondary feather) THg	mean S2 THg µg/g fw	SD S2 THg	min S2 THg	max S2 THg	n P1 (primary feather) THg	mean P1 THg µg/g fw	SD P1 THg	min P1 THg	max P1 THg
2007	MM-Car	AD	7171		1	1.75	.	1.75	1.75	0					0				
2007	MM-Northeast	AD	7205	1.2	12	6.83	9.41	0.79	30.21	0					0				
2007	MM-Southeast	AD	7187	2.6	22	2.58	4.02	0.56	20.28	0					0				
2007	MM-Jetti	AD	7181	3.1	6	1.94	0.62	1.23	2.86	0					0				
2007	MM-Southw est	AD	7201	3.3	33	2.09	1.41	0.48	8.72	0					0				
2007	Parker R NWR	AD	7191		0					0					0				
2007	Rachel Carson NWR	AD	7184	1.9	0					0					0				
2007	Scarborough	AD	7216	2.7	0					0					0				
2007	MM-Northeast	HY	7206	0.0	2	38.96	2.63	37.10	40.83	0					0				
2007	MM-Southw est	HY	7205		1	30.20	.	30.20	30.20	0					0				
2008	W-17-N	AD	8200	0.4	6	1.29	0.66	0.82	2.57	0					0				
2008	W-17-S	AD	8198	1.0	5	2.28	1.91	1.04	5.57	0					0				
2008	MM-Car	AD	8190	3.7	6	18.18	6.51	10.70	27.30	1	11.7	.	11.7	11.7	0				
2008	MM-Northeast	AD	8223	1.4	17	1.34	0.58	0.70	2.95	0					0				
2008	MM-Southeast	AD	8214	7.2	45	2.14	2.96	0.56	17.80	3	19.5	2.9	16.2	21.4	0				
2008	MM-Jetti	AD	8186	0.0	0					3	13.3	9.6	3.2	22.4	0				
2008	MM-Southw est	AD	8200	7.8	13	1.82	0.74	0.85	3.13	7	18.8	7.8	2.2	25.4	0				
2008	MM-South-174	AD	8185	0.0	0					6	9.0	4.8	4.4	18.0	0				
2008	Scarborough	AD	8228	1.4	2	0.93	0.31	0.72	1.15	0					0				
2008	MM-Northeast	HY	8222	1.2	7	14.19	9.77	0.29	26.00	0					0				
2008	MM-Southeast	HY	8216	4.9	2	32.90	15.13	22.20	43.60	0					0				
2009	W-17-N	AD	9194	0.4	6	1.06	0.33	0.69	1.53	0					1	4.0	.	4.0	4.0
2009	W-17-S	AD	9195	0.0	2	1.23	0.05	1.19	1.27	0					0				
2009	MM-Car	AD	9182	0.0	3	1.47	0.52	0.87	1.84	0					0				
2009	MM-Northeast	AD	9191	0.7	30	2.36	3.28	0.40	13.99	0					0				
2009	MM-Jetti	AD	9168	0.0	7	1.07	0.40	0.59	1.55	0					7	46.3	33.1	2.9	101.0
2009	MM-Southw est	AD	9165	2.0	9	2.21	1.61	0.73	5.45	0					7	20.6	22.2	2.0	66.2
2009	MM-South-174	AD	9191	5.4	13	1.39	0.67	0.48	2.94	0					0				
2009	Bass Harbor	AD	9215	4.9	3	1.01	0.67	0.35	1.68	0					0				
2009	Tremont	AD	9210	0.0	4	1.89	2.63	0.31	5.82	0					0				
2009	Rachel Carson NWR	AD	9203	14.4	4	0.39	0.11	0.28	0.52	0					0				
2009	Scarborough	AD	9217	1.4	9	0.58	0.22	0.28	0.86	0					0				
2010	W-17-N	AD	10183	0.0	6	1.64	0.54	1.17	2.71	0					6	35.7	25.4	8.8	63.7
2010	W-17-S	AD	10196	0.0	5	1.51	0.34	1.12	2.03	0					5	56.1	21.4	36.7	85.1
2010	MM-Car	AD	10190	0.0	4	1.45	0.53	1.14	2.23	0					4	29.2	13.3	13.3	45.6
2010	MM-Northeast	AD	10189	0.0	8	1.95	0.57	0.92	2.89	0					8	46.9	33.3	2.7	107.9
2010	MM-Southeast	AD	10197	10.1	26	2.21	1.13	0.84	6.40	0					26	61.9	32.4	5.4	136.5
2010	MM-Jetti	AD	10182	0.0	2	1.48	0.05	1.44	1.51	0					2	22.4	13.5	12.8	31.9
2010	MM-South-174	AD	10191	4.3	10	2.09	0.72	1.27	3.72	0					10	50.4	34.0	6.9	101.8
2010	Spurw ink Marsh	AD	10207	0.0	10	0.98	0.27	0.54	1.40	0					10	6.5	2.5	3.5	10.6

Appendix 14-9a. Song sparrow summary statistics using raw data for date sampled, and total Hg concentrations in blood, 2007 – 2008. Samples were collected in the lower Penobscot River and at upstream and coastal reference sites. Sites are listed from north to south, within each year.

Song sparrow YEAR	Song sparrow SITE	Age class	mean Julian date sampled	SD Julian date	n Blood THg	mean Blood THg µg/g ww	SD Blood THg	min Blood THg	max Blood THg
2007	Greenbush	AD	7219	0.0	2	0.15	0.08	0.10	0.21
2007	Costigan Boat Launch	AD	7219	0.0	2	0.11	0.07	0.07	0.16
2007	Bald Hill Cove North	AD	7215		1	0.12		0.12	0.12
2007	Bald Hill Cove South	AD	7216	0.0	4	0.10	0.12	0.02	0.28
2007	MM-Northeast	AD	7204	0.0	2	3.55	0.60	3.13	3.97
2007	MM-Southeast	AD	7184		1	1.52		1.52	1.52
2007	MM-Jetti	AD	7205		1	3.41		3.41	3.41
2007	Sandy Point	AD	7208	0.0	3	0.21	0.08	0.13	0.30
2007	Amazon Stream	AD	7211	0.0	3	0.24	0.06	0.19	0.30
2007	Hatch Cove N Castine	AD	7212	0.0	7	0.12	0.05	0.04	0.18
2007	Smith Cove	AD	7212	0.0	4	0.21	0.09	0.10	0.31
2007	Holbrook Sandy Marsh	AD	7212	0.0	3	0.50	0.33	0.25	0.87
2007	Bald Island	AD	7245	0.0	5	0.01	0.01	0.01	0.02
2007	Greenbush	HY	7219	0.0	6	0.13	0.07	0.07	0.26
2007	Bald Hill Cove South	HY	7216	0.0	12	0.08	0.07	0.03	0.28
2007	MM-Southeast	HY	7191	1.3	4	1.58	0.69	0.62	2.27
2007	MM-Jetti Rd	HY	7202	7.9	3	0.19	0.15	0.02	0.29
2007	Amazon Stream	HY	7211	0.0	6	0.15	0.10	0.06	0.28
2007	Hatch Cove N Castine	HY	7212		1	0.04		0.04	0.04
2007	Smith Cove	HY	7212		1	0.04		0.04	0.04
2007	Holbrook Sandy Marsh	HY	7212	0.0	3	0.16	0.08	0.08	0.25
2007	Bald Island	HY	7245	0.0	2	0.03	0.02	0.02	0.04
2008	Orrington-Grant	AD	8211	0.0	2	0.16	0.09	0.09	0.22
2008	Bald Hill Cove North	AD	8211	4.9	7	0.34	0.22	0.06	0.67
2008	W-17-N	AD	8201	0.6	3	0.32	0.26	0.02	0.51
2008	W-17-S	AD	8197	0.0	3	1.73	0.37	1.51	2.16
2008	MM-Car	AD	8184		1	0.83		0.83	0.83
2008	MM-Boat launch	AD	8181	2.1	2	0.29	0.33	0.06	0.53
2008	MM-Southeast	AD	8212		1	2.14		2.14	2.14
2008	MM-Jetti	AD	8183	4.2	2	1.47	1.34	0.52	2.41
2008	MM-South-174	AD	8191		1	0.64		0.64	0.64
2008	Leaches Point-Gross Pt.	AD	8196	0.0	9	0.12	0.13	0.01	0.36
2008	Leaches Point-Orland R	AD	8193	0.0	4	0.42	0.26	0.13	0.68
2008	Orland R	AD	8212	0.0	2	0.24	0.07	0.19	0.29
2008	Bald Hill Cove North	HY	8218		1	0.03		0.03	0.03
2008	W-17-N	HY	8201	0.4	6	0.72	0.32	0.29	1.23
2008	W-17-S	HY	8199	0.9	5	0.67	0.41	0.15	1.19
2008	MM-Northeast	HY	8224	0.0	3	1.25	0.14	1.12	1.40
2008	MM-Southeast	HY	8214	1.8	5	0.20	0.26	0.04	0.66
2008	MM-Southw est	HY	8203		1	0.15		0.15	0.15
2008	Leaches Point-Gross Pt.	HY	8196		1	0.07		0.07	0.07
2008	Leaches Point-Orland R.	HY	8193	0.0	2	0.35	0.14	0.25	0.45
2008	Orland R	HY	8212	0.0	3	0.30	0.22	0.09	0.52

Appendix 14-9b. Song sparrow summary statistics using raw data for date sampled, and total Hg concentrations in blood, 2009 - 2010. Samples were collected in the lower Penobscot River and at upstream and coastal reference sites. Sites are listed from north to south, within each year.

Song sparrow YEAR	Song sparrow SITE	Age class	mean Julian date sampled	SD Julian date	n Blood THg	mean Blood THg µg/g ww	SD Blood THg	min Blood THg	max Blood THg
2009	Bald Hill Cove North	AD	9212	0.0	2	0.11	0.02	0.10	0.13
2009	W-17-N	AD	9195	0.5	6	1.84	0.97	0.83	3.45
2009	W-17-S	AD	9195	0.0	2	1.86	0.61	1.44	2.29
2009	MM-Jetti	AD	9168		1	2.19		2.19	2.19
2009	MM-Southwest	AD	9162	0.0	2	0.55	0.29	0.34	0.75
2009	MM-South-174	AD	9196		1	0.03		0.03	0.03
2009	Leaches Point-Gross Pt.	AD	9175	0.0	2	0.06	0.03	0.05	0.08
2009	Leaches Point-LP Rd.	AD	9177	0.0	2	0.18	0.05	0.15	0.22
2009	Leaches Point-Orland R.	AD	9176	0.0	4	0.19	0.07	0.10	0.25
2009	MDI	AD	9218		1	0.24		0.24	0.24
2009	Bald Hill Cove North	HY	9212	0.0	2	0.23	0.25	0.05	0.40
2009	W-17-N	HY	9194	0.6	3	0.83	0.87	0.32	1.84
2009	MM-Northeast	HY	9191		1	0.67		0.67	0.67
2009	Leaches Point-LP Rd.	HY	9177		1	0.02		0.02	0.02
2009	Leaches Point-Orland R.	HY	9176		1	0.10		0.10	0.10
2009	MDI	HY	9218		1	0.14		0.14	0.14
2009	Tremont	HY	9210		1	0.02		0.02	0.02
2010	Greenbush	AD	10215	0.0	5	0.09	0.06	0.04	0.19
2010	Orrington-Grant	AD	10202	0.0	3	0.12	0.10	0.02	0.21
2010	Bald Hill Point	AD	10204	0.0	3	0.07	0.02	0.05	0.08
2010	Bald Hill Cove South	AD	10200	0.0	3	0.48	0.21	0.25	0.65
2010	W-17-N	AD	10209	8.2	5	0.93	0.78	0.14	1.98
2010	W-17-S	AD	10196		1	3.26		3.26	3.26
2010	MM-Southeast	AD	10208	0.0	2	0.70	0.10	0.63	0.77
2010	MM-Jetti	AD	10189	9.2	2	0.91	0.00	0.91	0.91
2010	MM-Southwest	AD	10210		1	0.83		0.83	0.83
2010	MM-South-174	AD	10175	0.0	2	1.85	1.56	0.75	2.95
2010	Leaches Point-Orland R.	AD	10201	0.0	2	0.43	0.38	0.16	0.70
2010	Greenbush	HY	10215	0.0	4	0.10	0.08	0.02	0.21
2010	Bald Hill Point	HY	10204	0.0	3	0.16	0.21	0.03	0.40
2010	Bald Hill Cove South	HY	10200		1	0.03		0.03	0.03
2010	W-17-N	HY	10203	0.0	5	0.38	0.51	0.08	1.29
2010	W-17-S	HY	10223	0.0	3	0.10	0.13	0.02	0.25
2010	MM-South-174	HY	10211		1	0.19		0.19	0.19
2010	Spurwink Marsh	HY	10207	0.0	4	0.05	0.01	0.04	0.05
2010	Greenbush	U	10215		1	0.11		0.11	0.11

Appendix 14-9c. Song sparrow summary statistics using raw data for date sampled, and total Hg concentrations in feathers, 2007 – 2008. Samples were collected in the lower Penobscot River and at upstream and coastal reference sites. Sites are listed from north to south, within each year.

Song sparrow YEAR	Song sparrow SITE	Age class	mean Julian date sampled	SD Julian date	n T6 (tail feather) THg	mean T6 THg µg/g fw	SD T6 THg	min T6 THg	max T6 THg	n S2 (secondary feather) THg	mean S2 THg µg/g fw	SD S2 THg	min S2 THg	max S2 THg	n P1 (primary feather) THg	mean P1 THg µg/g fw	SD P1 THg	min P1 THg	max P1 THg
2007	Greenbush	AD	7219	0.0	2	1.39	1.10	0.61	2.16	0					0				
2007	Costigan Boat Launch	AD	7219	0.0	2	0.71	0.31	0.49	0.93	0					0				
2007	Bald Hill Cove North	AD	7215		1	1.56		1.56	1.56	0					0				
2007	Bald Hill Cove South	AD	7216	0.0	4	1.67	1.72	0.11	3.62	0					0				
2007	MM-Northeast	AD	7204	0.0	2	12.26	5.92	8.07	16.44	0					0				
2007	MM-Southeast	AD	7184		1	12.98		12.98	12.98	0					0				
2007	MM-Jetti	AD	7205		1	9.00		9.00	9.00	0					0				
2007	Sandy Point	AD	7208	0.0	3	0.75	0.60	0.23	1.41	0					0				
2007	Amazon Stream	AD	7211	0.0	3	1.57	0.75	0.91	2.38	0					0				
2007	Hatch Cove N Castine	AD	7212	0.0	7	0.62	0.39	0.11	1.27	0					0				
2007	Smith Cove	AD	7212	0.0	4	0.66	0.44	0.20	1.21	0					0				
2007	Holbrook Sandy Marsh	AD	7212	0.0	3	2.59	0.30	2.37	2.93	0					0				
2007	Bald Island	AD	7245	0.0	0					0					0				
2007	Greenbush	HY	7219	0.0	6	3.77	1.65	0.94	5.74	0					0				
2007	Bald Hill Cove South	HY	7216	0.0	12	1.22	1.46	0.51	5.76	0					0				
2007	MM-Southeast	HY	7191	1.3	4	18.70	4.14	14.84	22.55	0					0				
2007	MM-Jetti Rd	HY	7202	7.9	3	2.22	2.24	0.45	4.74	0					0				
2007	Amazon Stream	HY	7211	0.0	6	2.14	1.36	0.70	3.95	0					0				
2007	Hatch Cove N Castine	HY	7212		1	0.33		0.33	0.33	0					0				
2007	Smith Cove	HY	7212		1	0.59		0.59	0.59	0					0				
2007	Holbrook Sandy Marsh	HY	7212	0.0	3	1.25	0.70	0.47	1.81	0					0				
2007	Bald Island	HY	7245	0.0	0					0					0				
2008	Orrington-Grant	AD	8211	0.0	2	0.44	0.20	0.30	0.58	0					0				
2008	Bald Hill Cove North	AD	8211	4.9	6	0.45	0.32	0.21	0.98	1	0.56	.	0.56	0.56	0				
2008	W-17-N	AD	8201	0.6	3	0.45	0.36	0.16	0.85	0					0				
2008	W-17-S	AD	8197	0.0	3	2.94	3.94	0.17	7.45	0					0				
2008	MM-Car	AD	8184		0					1	0.43	.	0.43	0.43	0				
2008	MM-Boat launch	AD	8181	2.1	0					2	2.03	2.31	0.39	3.66	0				
2008	MM-Southeast	AD	8212		1	6.77		6.77	6.77	0					0				
2008	MM-Jetti	AD	8183	4.2	0					2	0.26	0.18	0.13	0.39	0				
2008	MM-South-174	AD	8191		1	0.25		0.25	0.25	0					0				
2008	Leaches Point-Gross Pt.	AD	8196	0.0	9	0.47	0.45	0.12	1.44	0					0				
2008	Leaches Point-Orland R	AD	8193	0.0	4	0.49	0.22	0.18	0.69	0					0				
2008	Orland R	AD	8212	0.0	2	2.10	2.76	0.14	4.05	0					0				
2008	Bald Hill Cove North	HY	8218		1	1.12		1.12	1.12	0					0				
2008	W-17-N	HY	8201	0.4	5	4.81	3.96	0.38	9.59	0					0				
2008	W-17-S	HY	8199	0.9	5	2.57	1.96	0.50	4.72	0					0				
2008	MM-Northeast	HY	8224	0.0	3	14.10	7.90	7.76	22.95	0					0				
2008	MM-Southeast	HY	8214	1.8	5	0.64	0.16	0.47	0.79	0					0				
2008	MM-Southwest	HY	8203		1	1.63		1.63	1.63	0					0				
2008	Leaches Point-Gross Pt.	HY	8196		1	0.60		0.60	0.60	0					0				
2008	Leaches Point-Orland R.	HY	8193	0.0	1	0.74		0.74	0.74	0					0				
2008	Orland R	HY	8212	0.0	2	1.46	0.59	1.04	1.87	0					0				

Appendix 14-9d. Song sparrow summary statistics using raw data for date sampled, and total Hg concentrations in feathers, 2009 - 2010. Samples were collected in the lower Penobscot River and at upstream and coastal reference sites. Sites are listed from north to south, within each year.

Song sparrow YEAR	Song sparrow SITE	Age class	mean Julian date sampled	SD Julian date	n T6 (tail feather) THg	mean T6 THg µg/g fw	SD T6 THg	min T6 THg	max T6 THg	n S2 (secondary feather) THg	mean S2 THg µg/g fw	SD S2 THg	min S2 THg	max S2 THg	n P1 (primary feather) THg	mean P1 THg µg/g fw	SD P1 THg	min P1 THg	max P1 THg
2009	Bald Hill Cove North	AD	9212	0.0	2	1.67	1.26	0.78	2.56	0					0				
2009	W-17-N	AD	9195	0.5	6	2.52	1.87	0.55	4.79	0					0				
2009	W-17-S	AD	9195	0.0	2	0.16	0.04	0.13	0.19	0					0				
2009	MM-Jetti	AD	9168		1	0.31		0.31	0.31	0					0				
2009	MM-Southwest	AD	9162	0.0	2	2.51	3.27	0.19	4.82	0					0				
2009	MM-South-174	AD	9196		1	0.36		0.36	0.36	0					0				
2009	Leaches Point-Gross Pt.	AD	9175	0.0	2	0.61	0.49	0.26	0.95	0					0				
2009	Leaches Point-LP Rd.	AD	9177	0.0	1	0.29		0.29	0.29	0					0				
2009	Leaches Point-Orland R.	AD	9176	0.0	4	0.77	0.69	0.28	1.77	0					0				
2009	MDI	AD	9218		1	0.53		0.53	0.53	0					0				
2009	Bald Hill Cove North	HY	9212	0.0	2	1.00	0.55	0.61	1.39	0					0				
2009	W-17-N	HY	9194	0.6	3	6.94	10.88	0.57	19.50	0					0				
2009	MM-Northeast	HY	9191		1	21.40		21.40	21.40	0					0				
2009	Leaches Point-LP Rd.	HY	9177		1	0.27		0.27	0.27	0					0				
2009	Leaches Point-Orland R.	HY	9176		1	0.64		0.64	0.64	0					0				
2009	MDI?	HY	9218		1	2.03		2.03	2.03	0					0				
2009	Tremont	HY	9210		1	1.67		1.67	1.67	0					0				
2010	Greenbush	AD	10215	0.0	4	0.40	0.30	0.17	0.84	0					3	2.65	0.13	2.54	2.80
2010	Orrington-Grant	AD	10202	0.0	3	2.41	2.67	0.46	5.45	0					3	0.98	0.51	0.61	1.57
2010	Bald Hill Point	AD	10204	0.0	3	0.20	0.09	0.13	0.30	0					3	0.61	0.19	0.47	0.82
2010	Bald Hill Cove South	AD	10200	0.0	4	0.94	0.59	0.24	1.51	0					4	1.65	1.45	0.38	3.15
2010	W-17-N	AD	10209	8.2	5	1.14	1.59	0.20	3.96	0					5	2.94	2.85	0.57	7.62
2010	W-17-S	AD	10196		1	0.75		0.75	0.75	0					1	7.60		7.60	7.60
2010	MM-Southeast	AD	10208	0.0	3	3.69	5.37	0.41	9.89	0					3	7.52	11.77	0.30	21.10
2010	MM-Jetti	AD	10189	9.2	2	15.39	13.77	5.65	25.13	0					2	7.83	8.96	1.49	14.16
2010	MM-Southwest	AD	10210		1	11.67		11.67	11.67	0					1	23.42		23.42	23.42
2010	MM-South-174	AD	10175	0.0	2	2.91	3.83	0.20	5.62	0					2	10.00	6.07	5.70	14.29
2010	Leaches Point-Orland R.	AD	10201	0.0	2	2.81	0.39	2.53	3.08	0					2	8.99	2.26	7.39	10.58
2010	Greenbush	HY	10215	0.0	4	2.49	0.74	1.75	3.37	0					4	2.45	1.09	1.01	3.58
2010	Bald Hill Point	HY	10204	0.0	3	0.72	0.36	0.40	1.11	0					3	0.45	0.19	0.24	0.60
2010	Bald Hill Cove South	HY	10200		1	0.34	.	0.34	0.34	0					1	0.65		0.65	0.65
2010	W-17-N	HY	10203	0.0	5	5.37	6.76	0.77	17.10	0					5	4.02	4.64	0.67	11.99
2010	W-17-S	HY	10223	0.0	3	2.56	3.04	0.56	6.06	0					3	2.44	3.18	0.51	6.11
2010	MM-South-174	HY	10211		1	0.74	.	0.74	0.74	0					1	0.52		0.52	0.52
2010	Spurwink Marsh	HY	10207	0.0	4	0.75	0.28	0.44	1.00	0					4	0.54	0.20	0.28	0.78
2010	Greenbush	U	10215		1	0.93	.	0.93	0.93	0					0				

Appendix 14-13a. Swamp sparrow summary statistics using raw data for sample date, and total Hg concentrations in blood, 2007 – 2010. Samples were collected in the lower Penobscot River and at upstream and coastal reference sites. Sites are listed from north to south, within each year.

Swamp sparrow YEAR	Swamp sparrow SITE	Age class	mean Julian date sampled	SD Julian date	n Blood THg	mean Blood THg µg/g ww	SD Blood THg	min Blood THg	max Blood THg
2007	Passadumkeag	AD	7219	0.0	3	0.59	0.64	0.10	1.31
2007	MM-Jetti	AD	7181	8.3	4	1.38	0.51	0.76	1.91
2007	MM-Northeast	AD	7206	0.0	2	1.66	0.42	1.37	1.96
2007	MM-Southeast	AD	7190	1.6	9	2.63	1.09	1.50	4.64
2007	MM-Southwest	AD	7180	0.6	3	3.54	0.25	3.36	3.82
2007	MM-South-174	AD	7182	0.0	4	2.35	1.33	0.90	3.59
2007	Passadumkeag	HY	7219	0.0	2	0.33	0.12	0.24	0.41
2007	Greenbush	HY	7219	0.0	7	0.18	0.17	0.05	0.53
2007	Costigan boat launch	HY	7219		1	0.39	.	0.39	0.39
2007	Bald Hill Cove North	HY	7215	0.0	2	0.48	0.20	0.34	0.62
2007	Bald Hill Cove South	HY	7216		1	0.14	.	0.14	0.14
2007	MM-Northeast	HY	7206		1	2.91	.	2.91	2.91
2007	MM-Southwest	HY	7201	1.4	1	2.01	.	2.01	2.01
2007	Amazon Stream	HY	7211		1	0.41	.	0.41	0.41
2007	Hatch Cove	HY	7212	0.0	2	0.51	0.50	0.16	0.87
2008	W-17-N	AD	8201	0.4	8	1.33	0.47	0.61	1.90
2008	W-17-S	AD	8199	0.0	2	1.70	0.21	1.55	1.84
2008	MM-Car	AD	8192	0.0	2	0.91	0.37	0.65	1.17
2008	MM-Jetti	AD	8179	6.6	4	1.09	0.13	0.91	1.20
2008	MM-Southeast	AD	8200	24.5	4	1.49	0.45	0.99	2.08
2008	MM-Southwest	AD	8192	20.8	5	2.64	1.47	0.29	4.34
2008	MM-South-174	AD	8176	11.4	3	1.40	0.66	0.67	1.96
2008	W-17-S	HY	8200	0.7	2	1.00	0.55	0.61	1.39
2008	MM-Northeast	HY	8223	0.6	3	1.01	0.12	0.88	1.11
2008	MM-Southeast	HY	8214	1.8	6	0.93	0.71	0.22	2.11
2008	MM-Southwest	HY	8204	2.3	4	1.87	1.00	0.39	2.53
2009	W-17-N	AD	9194	0.0	3	1.63	0.80	0.98	2.53
2009	MM-Car	AD	9183	0.7	2	0.46	0.17	0.34	0.58
2009	MM-Jetti	AD	9168	0.0	3	2.25	0.96	1.45	3.32
2009	MM-Southwest	AD	9166	0.0	4	3.21	0.28	2.91	3.56
2009	MM-South-174	AD	9195	4.2	7	1.11	0.45	0.63	1.83
2009	Leaches Point-LP Rd.	AD	9179	1.7	3	0.59	0.29	0.27	0.85
2009	Bass Harbor	AD	9217		1	1.19	.	1.19	1.19
2009	W-17-N	HY	9194		1	0.53	.	0.53	0.53
2009	MM-Jetti	HY	9188		1	0.52	.	0.52	0.52
2009	MM-Northeast	HY	9192	0.7	2	0.71	0.03	0.70	0.73
2009	MM-South-174	HY	9194	4.0	4	0.75	0.34	0.39	1.11
2010	Greenbush	AD	10215		1	0.06	.	0.06	0.06
2010	W-17-N	AD	10214	0.0	2	1.18	0.03	1.16	1.20
2010	MM-Jetti	AD	10182		1	1.82	.	1.82	1.82
2010	MM-Southwest	AD	10179	13.2	6	4.45	0.72	3.18	5.24
2010	MM-South-174	AD	10184	12.0	3	1.20	0.58	0.63	1.79
2010	Spurwink Marsh	AD	10207	0.0	2	0.25	0.06	0.21	0.29
2010	Greenbush	HY	10215	0.0	4	0.09	0.04	0.05	0.13
2010	W-17-N	HY	10209	7.4	7	0.70	0.26	0.40	1.15
2010	W-17-S	HY	10213	9.4	5	0.89	0.18	0.66	1.05
2010	Spurwink Marsh	HY	10207	0.0	4	0.25	0.08	0.16	0.35

Appendix 14-14b. Swamp sparrow summary statistics using raw data for sample date, and total Hg concentrations in feathers, 2007 – 2010. Samples were collected in the lower Penobscot River and at upstream and coastal reference sites. Sites are listed from north to south, within each year.

Swamp sparrow YEAR	Swamp sparrow SITE	Age class	mean Julian date sampled	SD Julian date	n T6 (tail feather) THg	mean T6 THg µg/g fw	SD T6 THg	min T6 THg	max T6 THg	n S2 (secondary feather) THg	mean S2 THg µg/g fw	SD S2 THg	min S2 THg	max S2 THg	n P1 (primary feather) THg	mean P1 THg µg/g fw	SD P1 THg	min P1 THg	max P1 THg
2007	Passadumkeag	AD	7219	0.0	3	9.90	10.34	2.97	21.79	0					0				
2007	MM-Jetti Rd.	AD	7181	8.3	4	7.18	4.25	0.95	10.54	0					0				
2007	MM-Northeast	AD	7206	0.0	2	10.48	1.27	9.58	11.38	0					0				
2007	MM-Southeast	AD	7190	1.6	9	6.45	5.26	0.77	15.30	0					0				
2007	MM-Southw est	AD	7180	0.6	3	7.71	2.44	5.68	10.42	0					0				
2007	MM-South-174	AD	7182	0.0	3	5.99	2.46	4.43	8.83	0					0				
2007	Passadumkeag	HY	7219	0.0	2	6.71	3.59	4.17	9.24	0					0				
2007	Greenbush	HY	7219	0.0	7	6.03	2.78	1.77	9.11	0					0				
2007	Costigan boat launch	HY	7219		1	13.40	.	13.40	13.40	0					0				
2007	Bald Hill Cove North	HY	7215	0.0	2	6.77	0.92	6.12	7.42	0					0				
2007	Bald Hill Cove South	HY	7216		1	3.30	.	3.30	3.30	0					0				
2007	MM-Northeast	HY	7206		0					0					0				
2007	MM-Southw est	HY	7201	1.4	1	15.93	.	15.93	15.93	0					0				
2007	Amazon Stream	HY	7211		1	4.81	.	4.81	4.81	0					0				
2007	Hatch Cove	HY	7212	0.0	2	4.98	2.04	3.54	6.42	0					0				
2008	W-17-N	AD	8201	0.4	8	5.62	4.39	1.32	11.50	0					0				
2008	W-17-S	AD	8199	0.0	2	3.40	4.09	0.51	6.29	0					0				
2008	MM-Car dealer	AD	8192	0.0	2	7.16	5.58	3.21	11.10	0					0				
2008	MM-Jetti Rd.	AD	8179	6.6	0					4	7.23	3.03	3.12	10.30	0				
2008	MM-Southeast	AD	8200	24.5	3	8.66	3.46	6.10	12.60	1	7.82	.	7.82	7.82	0				
2008	MM-Southw est	AD	8192	20.8	3	11.77	2.04	9.42	13.00	2	8.39	2.71	6.47	10.30	0				
2008	MM-South-174	AD	8176	11.4	0					4	6.22	4.92	1.34	13.00	0				
2008	W-17-S	HY	8200	0.7	1	8.85	.	8.85	8.85	0					0				
2008	MM-Northeast	HY	8223	0.6	3	10.92	9.65	1.76	21.00	0					0				
2008	MM-Southeast	HY	8214	1.8	6	5.42	2.70	2.04	8.33	0					0				
2008	MM-Southw est	HY	8204	2.3	2	12.18	11.06	4.36	20.00	0					0				
2009	W-17-N	AD	9194	0.0	3	6.44	3.17	4.61	10.10	0					1	5.75	.	5.75	5.75
2009	MM-Car dealer	AD	9183	0.7	2	7.89	0.88	7.26	8.51	0					1	33.70	.	33.70	33.70
2009	MM-Jetti Rd.	AD	9168	0.0	3	6.45	8.57	0.71	16.30	0					2	14.69	14.72	4.28	25.10
2009	MM-Southw est	AD	9166	0.0	4	16.63	8.37	6.30	26.40	0					0				
2009	MM-South-174	AD	9195	4.2	5	4.36	1.29	2.52	5.79	0					0				
2009	Leaches Point-LP Rd.	AD	9179	1.7	2	0.99	0.73	0.47	1.50	0					3	2.22	0.96	1.42	3.28
2009	Bass Harbor	AD	9217		1	2.52	.	2.52	2.52	0					0				
2009	W-17-N	HY	9194		1	4.43	.	4.43	4.43	0					0				
2009	MM-Jetti Rd.	HY	9188		0					0					0				
2009	MM-Northeast	HY	9192	0.7	2	10.80	2.41	9.09	12.50	0					0				
2009	MM-South-174	HY	9194	4.0	3	4.05	2.22	1.49	5.41	0					0				
2010	Greenbush	AD	10215		1	2.82	.	2.82	2.82	0					1	1.54	.	1.54	1.54
2010	W-17-N	AD	10214	0.0	2	3.92	0.23	3.76	4.08	0					2	7.20	1.22	6.33	8.06
2010	MM-Jetti	AD	10182		1	20.95	.	20.95	20.95	0					1	5.37	.	5.37	5.37
2010	MM-Southw est	AD	10179	13.2	6	11.50	14.27	1.21	39.70	0					6	8.77	9.40	1.35	26.71
2010	MM-South-174	AD	10184	12.0	2	1.47	0.76	0.93	2.00	0					3	7.78	6.00	0.85	11.27
2010	Spurw ink Marsh	AD	10207	0.0	1	4.57	.	4.57	4.57	0					2	3.68	2.97	1.58	5.78
2010	Greenbush	HY	10215	0.0	3	4.59	2.20	2.40	6.79	0					4	3.52	1.57	1.75	5.42
2010	W-17-N	HY	10209	7.4	7	3.38	1.02	1.97	5.34	0					7	2.90	1.04	1.61	4.82
2010	W-17-S	HY	10213	9.4	4	4.97	2.38	2.67	8.29	0					5	4.03	2.09	2.20	7.29
2010	Spurw ink Marsh	HY	10207	0.0	4	1.93	1.50	1.06	4.18	0					4	1.51	1.20	0.83	3.31

Appendix 14-15a. Red-winged blackbird summary statistics using raw data for sample date, and total Hg concentrations in blood, 2007 – 2010. Samples were collected in the lower Penobscot River and at coastal reference sites. Sites are listed from north to south, within each year.

Red-winged blackbird YEAR	Red-winged blackbird SITE	Age class	mean Julian date sampled	SD Julian date	n Blood THg	mean Blood THg µg/g ww	SD Blood THg	min Blood THg	max Blood THg
2007	MM-Northeast	AD	7188	1.0	3	7.89	4.83	4.71	13.44
2007	MM-Southwest	AD	7193	9.3	10	5.73	3.87	0.42	11.86
2007	MM-South-174	AD	7194	0.8	13	2.37	2.17	0.19	6.51
2007	MM-Southwest	HY	7199	2.1	7	2.86	1.99	1.18	7.02
2007	MM-South-174	HY	7194	0.0	2	0.52	0.04	0.49	0.54
2008	MM-Treat Point	AD	8172	0.0	2	3.28	0.13	3.19	3.37
2008	MM-Car	AD	8182	7.6	5	3.05	2.60	0.23	5.79
2008	MM-Southeast	AD	8210	0.7	2	1.01	1.01	0.29	1.72
2008	MM-Southwest	AD	8199	10.3	20	4.70	3.40	0.26	11.30
2008	MM-South-174	AD	8169	9.4	5	1.08	1.68	0.14	4.06
2008	MM-Southeast	HY	8210	0.7	10	0.90	0.87	0.11	2.88
2008	MM-Southwest	HY	8205	2.2	12	0.73	0.57	0.17	2.33
2008	MM-South-174	HY	8191		1	0.33		0.33	0.33
2009	W-17-N	AD	9194		1	4.25		4.25	4.25
2009	MM-Car	AD	9169		1	0.73		0.73	0.73
2009	MM-Northeast	AD	9203	10.4	3	4.42	2.42	2.05	6.90
2009	MM-Southeast	AD	9207	0.9	5	5.86	3.06	0.99	9.21
2009	MM-Southwest	AD	9194	20.5	17	4.39	3.26	0.45	10.17
2009	MM-South-174	AD	9192	7.1	6	2.00	1.72	0.20	4.73
2009	W-17-N	HY	9201	16.1	5	2.22	1.72	0.53	4.18
2009	MM-Car	HY	9161		1	1.43		1.43	1.43
2009	MM-Northeast	HY	9203	8.9	11	1.32	2.39	0.15	8.43
2009	MM-Southeast	HY	9209	1.4	14	0.94	1.19	0.08	3.63
2009	MM-Southwest	HY	9205	4.3	11	0.89	0.67	0.10	2.03
2009	MM-South-174	HY	9201	0.6	4	0.32	0.20	0.10	0.54
2010	W-17-N	AD	10183	0.0	3	3.01	0.87	2.02	3.66
2010	MM-Northeast	AD	10189	0.0	2	9.65	1.34	8.70	10.60
2010	MM-Jetti	AD	10182	0.0	2	8.33	2.33	6.68	9.98
2010	MM-Southwest	AD	10187	9.0	4	7.78	5.03	0.25	10.70
2010	MM-South-174	AD	10188	9.8	7	0.87	0.59	0.31	1.86
2010	Spurwink Marsh	AD	10207	0.0	2	0.20	0.08	0.14	0.25
2010	W-17-N	HY	10183		1	2.29		2.29	2.29
2010	MM-Car	HY	10190	0.0	4	1.49	0.59	0.74	2.01
2010	MM-Jetti	HY	10182		1	1.77		1.77	1.77
2010	MM-Southwest	HY	10199	9.2	3	0.92	0.95	0.30	2.02
2010	MM-South-174	HY	10197	0.0	4	0.59	0.20	0.30	0.77
2010	Spurwink Marsh	HY	10207	0.0	3	0.16	0.18	0.02	0.36

Appendix 14-16b. Red-winged blackbird summary statistics using raw data for sample date, and total Hg concentrations in feathers, 2007 – 2010. Samples were collected in the lower Penobscot River and at coastal reference sites. Sites are listed from north to south, within each year.

Red-winged blackbird YEAR	Red-winged blackbird SITE	Age class	mean Julian date sampled	SD Julian date	n T6 (tail feather) THg	mean T6 THg µg/g fw	SD T6 THg	min T6 THg	max T6 THg	n S2 (secondary feather) THg	mean S2 THg µg/g fw	SD S2 THg	min S2 THg	max S2 THg	n P1 (primary feather) THg	mean P1 THg µg/g fw	SD P1 THg	min P1 THg	max P1 THg
2007	MM-Northeast	AD	7188	1.0	3	11.28	16.02	1.13	29.75	0					0				
2007	MM-Southwest	AD	7193	9.3	10	1.47	1.40	0.16	4.92	0					0				
2007	MM-South-174	AD	7194	0.8	13	3.72	10.57	0.20	38.87	0					0				
2007	MM-Southwest	HY	7199	2.1	7	15.96	12.50	2.62	34.05	0					0				
2007	MM-South-174	HY	7194	0.0	2	3.03	0.33	2.79	3.26	0					0				
2008	MM-Treat Point	AD	8172	0.0	0					2	1.65	0.23	1.48	1.81	0				
2008	MM-Car	AD	8182	7.6	1	5.46	.	5.46	5.46	4	2.33	2.93	0.19	6.41	0				
2008	MM-Southeast	AD	8210	0.7	2	3.73	3.16	1.49	5.96	0					0				
2008	MM-Southwest	AD	8199	10.3	16	1.38	1.30	0.16	4.88	4	4.33	3.38	0.21	7.81	0				
2008	MM-South-174	AD	8169	9.4	0					5	0.89	0.65	0.38	1.97	0				
2008	MM-Southeast	HY	8210	0.7	10	7.19	7.94	0.54	23.90	0					0				
2008	MM-Southwest	HY	8205	2.2	11	5.12	4.81	2.27	19.10	0					0				
2008	MM-South-174	HY	8191		0					1	1.89	.	1.89	1.89	0				
2009	W-17-N	AD	9194		1	0.89	.	0.89	0.89	0					0				
2009	MM-Car	AD	9169		1	0.33	.	0.33	0.33	0					0				
2009	MM-Northeast	AD	9203	10.4	3	0.57	0.39	0.26	1.01	0					0				
2009	MM-Southeast	AD	9207	0.9	5	1.78	1.18	0.45	2.71	0					0				
2009	MM-Southwest	AD	9194	20.5	15	1.14	1.01	0.15	3.18	0					0				
2009	MM-South-174	AD	9192	7.1	6	0.54	0.52	0.24	1.59	0					0				
2009	W-17-N	HY	9201	16.1	5	17.26	15.32	0.58	33.90	0					0				
2009	MM-Car	HY	9161		1	5.04	.	5.04	5.04	0					0				
2009	MM-Northeast	HY	9203	8.9	12	2.58	1.49	0.15	4.78	0					0				
2009	MM-Southeast	HY	9209	1.4	14	2.91	1.68	0.35	5.88	0					0				
2009	MM-Southwest	HY	9205	4.3	11	6.05	4.31	2.03	15.00	0					0				
2009	MM-South-174	HY	9201	0.6	4	2.67	2.27	0.51	5.13	0					0				
2010	W-17-N	AD	10183	0.0	3	0.54	0.41	0.16	0.98	0					3	8.28	5.66	1.83	12.40
2010	MM-Northeast	AD	10189	0.0	2	2.41	1.24	1.54	3.29	0					2	28.85	4.04	26.00	31.71
2010	MM-Jetti	AD	10182	0.0	2	0.37	0.07	0.32	0.42	0					2	3.14	1.03	2.41	3.87
2010	MM-Southwest	AD	10187	9.0	4	0.76	0.79	0.12	1.86	0					4	22.52	26.15	1.31	55.75
2010	MM-South-174	AD	10188	9.8	6	0.46	0.49	0.09	1.39	0					7	4.54	4.72	0.92	13.30
2010	Spurwink Marsh	AD	10207	0.0	2	1.27	1.63	0.12	2.42	0					1	1.46		1.46	1.46
2010	W-17-N	HY	10183		1	32.05	.	32.05	32.05	0					1	26.90		26.90	26.90
2010	MM-Car	HY	10190	0.0	4	14.95	5.59	9.13	21.08	0					4	13.84	9.32	5.01	24.30
2010	MM-Jetti	HY	10182		1	26.15	.	26.15	26.15	0					1	17.33		17.33	17.33
2010	MM-Southwest	HY	10199	9.2	3	12.40	12.48	4.74	26.80	0					3	9.44	12.10	1.80	23.40
2010	MM-South-174	HY	10197	0.0	2	2.67	2.59	0.84	4.51	0					4	5.46	4.43	0.81	10.37
2010	Spurwink Marsh	HY	10207	0.0	2	1.89	1.72	0.67	3.10	0					3	1.20	1.19	0.33	2.56

Appendix 14-17. Virginia rail summary statistics using raw data for length, and total concentrations in blood and feathers, 2007 – 2010. Samples were collected in the lower Penobscot River and at coastal reference sites. Sites are listed from north to south, within each year.

Virginia rail YEAR	Virginia rail SITE	Age class	mean Julian date sampled	SD Julian date	n Blood THg	mean Blood THg µg/g ww	SD Blood THg	min Blood THg	max Blood THg	n T6 (tail feather) THg	mean T6 THg µg/g fw	SD T6 THg	min T6 THg	max T6 THg	n P1 (primary feather) THg	mean P1 THg µg/g fw	SD P1 THg	min P1 THg	max P1 THg
2007	MM-Car	AD	7173	2.1	2	1.68	0.16	1.56	1.79	2	12.63	1.16	11.81	13.45	0				
2007	MM-w oods	AD	7151		1	0.61		0.61	0.61	1	30.86		30.86	30.86	0				
2007	MM-Northeast	AD	7206		1	4.19		4.19	4.19	1	13.60		13.60	13.60	0				
2007	MM-Jetti	AD	7164	17.7	2	1.25	0.09	1.18	1.31	1	1.83		1.83	1.83	0				
2007	MM-Southw est	AD	7185	15.8	4	3.51	1.17	2.21	4.61	4	32.27	17.93	18.88	58.70	0				
2007	MM-South-174	AD	7150	0.0	3	0.44	0.31	0.15	0.76	3	19.28	22.36	4.09	44.95	0				
2007	Scarborough	AD	7144		2	0.14	0.06	0.09	0.18	2	1.28	0.67	0.81	1.75	0				
2007	MM-Southw est	HY	7203	3.8	5	1.39	0.25	1.07	1.66	3	49.18	7.37	43.31	57.45	0				
2008	W-17-S	AD	8199	0.6	3	1.03	0.11	0.94	1.15	1	13.35		13.35	13.35	0				
2008	MM-Car	AD	8157		1	0.91		0.91	0.91	0					0				
2008	MM-Southeast	AD	8219	0.7	2	1.55	0.37	1.28	1.81	2	30.30	0.57	29.90	30.70	0				
2008	MM-Jetti	AD	8161		1	0.36		0.36	0.36	0					0				
2008	MM-Southw est	AD	8176	27.3	5	2.06	0.51	1.36	2.76	1	11.90		11.90	11.90	0				
2008	Leech's Point-LP Rd	AD	8177		1	0.76		0.76	0.76	0					0				
2008	Scarborough	AD	8162		1	0.23		0.23	0.23	1	0.65		0.65	0.65	0				
2008	MM-Car dealer	HY	8182		1	0.58		0.58	0.58	0					0				
2008	MM-Northeast	HY	8223	0.6	3	0.84	0.13	0.70	0.96	1	15.60		15.60	15.60	0				
2008	MM-Southeast	HY	8213	0.7	2	1.05	0.09	0.99	1.11	2	17.70	2.55	15.90	19.50	0				
2008	MM-Southw est	HY	8203		1	1.30		1.30	1.30	1	25.80		25.80	25.80	0				
2009	W-17-N	AD	9173		1	2.91		2.91	2.91	1	20.30		20.30	20.30	0				
2009	MM-Treat Pt.	AD	9186	0.0	4	2.17	1.18	1.19	3.71	4	19.17	14.41	2.97	35.70	0				
2009	MM-Car	AD	9171		1	1.82		1.82	1.82	1	25.90		25.90	25.90	0				
2009	MM-Northeast	AD	9182		1	1.59		1.59	1.59	1	25.40		25.40	25.40	0				
2009	MM-Southeast	AD	9182	3.4	4	3.19	0.95	2.09	4.40	4	33.58	18.74	10.10	51.40	0				
2009	MM-Jetti	AD	9173	3.0	4	2.87	1.64	0.85	4.76	4	18.42	12.54	1.56	31.60	0				
2009	MM-Southw est	AD	9172	5.8	7	3.09	2.08	1.36	7.19	8	19.31	9.45	4.10	30.20	0				
2009	MM-South-174	AD	9169	6.7	3	1.30	0.15	1.15	1.44	3	29.73	19.42	14.50	51.60	0				
2009	Scarborough	AD	9197	8.4	7	0.16	0.06	0.10	0.27	7	2.75	2.08	1.22	7.04	0				
2009	MM-Southeast	HY	9210	0.0	2	1.61	0.08	1.55	1.66	0					0				
2010	Fields Pond	AD	10193	0.0	2	0.41	0.06	0.36	0.45	2	6.72	1.90	5.38	8.06	2	6.2	1.7	4.9	7.4
2010	MM-Car	AD	10174		1	2.04		2.04	2.04	1	35.55		35.55	35.55	1	41.2		41.2	41.2
2010	MM-Southeast	AD	10170	3.5	2	3.89	0.92	3.24	4.54	2	18.85	20.40	4.42	33.27	2	38.4	5.9	34.2	42.6
2010	MM-Jetti	AD	10167	1.5	3	2.13	0.84	1.24	2.90	3	25.41	15.08	15.91	42.80	3	28.2	13.7	16.9	43.4
2010	MM-Southw est	AD	10170	10.1	4	2.78	1.32	1.22	4.32	4	17.97	23.25	5.52	52.80	4	32.7	18.5	8.9	53.9

Appendix 14-18. Double-crested cormorant summary statistics using raw data for total and methyl Hg concentrations in eggs, 2007 – 2010. Samples were collected in Penobscot Bay and at coastal reference sites. Sites are listed from north to south, within each year.

Double-crested cormorants YEAR	Double-crested cormorants SITE	mean Julian date sampled	SD Julian date	n Egg THg	mean Egg THg µg/g ww	SD Egg THg	min Egg THg	max Egg THg	mean Egg THg µg/g dw	SD Egg THg	min Egg THg	max Egg THg	n Egg MeHg	mean Egg MeHg µg/g ww	SD Egg MeHg	min Egg MeHg	max Egg MeHg	mean % MeHg	Development stage mean
2006	Castine Harbor	6228		1	0.49	.	0.49	0.49	3.51	.	3.51	3.51	0						3.0
2006	East Goose Rock	6199	5.1	17	0.34	0.06	0.18	0.44	2.03	0.42	1.04	2.78	0						0.8
2006	Fort Point	6194	0.0	2	0.88	0.01	0.88	0.89	5.23	0.07	5.18	5.28	0						0.0
2006	Robinson Rock	6194	0.0	10	0.19	0.09	0.11	0.37	1.19	0.57	0.63	2.39	0						2.0
2006	Thrumcap Island	6194	0.0	10	0.36	0.11	0.14	0.51	1.94	0.77	0.84	3.03	0						1.1
2007	Castine Harbor	7158	0.0	13	0.29	0.10	0.17	0.47	1.69	0.56	1.04	2.55	0						0.0
2007	East Goose Rock	7169	0.0	12	0.34	0.14	0.16	0.68	1.99	0.83	0.97	3.98	0						0.0
2007	Flat Island	7164	0.0	12	0.29	0.08	0.19	0.48	1.71	0.41	1.14	2.73	0						0.0
2007	Fort Point	7166		1	0.59	.	0.59	0.59	3.75	.	3.75	3.75	0						0.0
2007	Green Island Ledge	7178	6.3	18	0.25	0.08	0.14	0.44	1.57	0.52	0.85	2.58	0						0.0
2007	Luce Cove	7156	7.0	4	0.68	0.07	0.63	0.79	4.26	0.44	3.98	4.91	0						0.0
2007	Robinson Rock	7169	0.0	12	0.35	0.15	0.19	0.69	2.04	0.85	1.14	3.99	0						0.0
2007	Sandy Point	7152	0.0	12	0.35	0.14	0.23	0.66	2.01	0.79	1.27	3.82	0						0.0
2007	Spoon Ledge	7182	0.0	7	0.29	0.05	0.23	0.35	1.71	0.32	1.38	2.10	0						0.0
2007	Stockton Old Pier	7178	0.0	2	0.34	0.07	0.29	0.39	1.92	0.36	1.66	2.17	0						0.0
2007	Thrumcap Island	7170	0.0	12	0.34	0.07	0.22	0.47	1.98	0.44	1.29	2.73	0						0.0
2008	Flat Island	8158		1	0.18	.	0.18	0.18	1.06	.	1.06	1.06	0						0.0
2008	Sandy Point	8161	0.0	12	0.37	0.14	0.27	0.79	2.23	0.79	1.55	4.52	0						1.3
2008	Stockton Old Pier	8154	0.0	12	0.32	0.08	0.25	0.48	1.88	0.41	1.52	2.69	0						1.0
2009	Castine Harbor	9155	0.5	12	0.22	0.07	0.13	0.31	1.37	0.41	0.84	1.94	2	0.18	0.05	0.15	0.22	97.48	2.3
2009	Flat Island	9141	0.0	2	0.26	0.21	0.11	0.41	1.64	1.36	0.68	2.60	2	0.24	0.19	0.10	0.37	89.15	0.0
2009	Sandy Point	9132	0.0	20	0.29	0.10	0.17	0.56	1.81	0.65	1.05	3.55	2	0.31	0.01	0.30	0.32	96.40	0.6
2009	Stockton Old Pier	9132	0.0	12	0.24	0.08	0.11	0.35	1.48	0.49	0.68	2.06	2	0.23	0.06	0.18	0.27	93.91	0.0
2009	Thrumcap Island	9154	0.0	20	0.20	0.05	0.10	0.30	1.21	0.29	0.58	1.87	2	0.15	0.04	0.12	0.18	98.01	1.1
2010	Luce Cove	10166	0.0	3	0.65	0.02	0.64	0.67	3.97	0.10	3.86	4.06	0						0.0
2010	Sandy Point	10142	16.7	34	0.39	0.13	0.17	0.59	2.42	0.79	1.09	3.69	0						0.9
2010	Thrumcap Island	10150	3.8	22	0.23	0.08	0.04	0.41	1.36	0.48	0.33	2.51	0						1.7

Appendix 14-19. American black duck summary statistics using raw data for total and methyl Hg concentrations in blood, muscle, and feathers, 2010 – 2012. Samples were collected in the lower Penobscot River and at coastal reference sites. Sites are listed from north to south, within each winter season.

American black duck Winter Year	American black duck Site	Month	n Muscle THg	mean Muscle THg µg/g ww	SD Muscle THg	min Muscle THg	max Muscle THg	n Muscle MeHg	mean Muscle MeHg µg/g ww	SD Muscle MeHg	min Muscle MeHg	max Muscle MeHg	mean % MeHg
2010-11	MM-SW-Mink Hole	December	2	0.763	0.022	0.747	0.778	2	0.80	0.01	0.79	0.81	104.8
2010-11	MM-Treat Point	December	3	0.745	0.106	0.625	0.823	3	0.76	0.11	0.66	0.87	101.7
2010-11	ES13-Verona	January	1	0.642		0.642	0.642	1	0.69		0.69	0.69	106.7
2010-11	MM-Treat Point	January	5	0.803	0.614	0.166	1.620	5	0.83	0.66	0.16	1.76	101.0
2010-11	Meadow Pt Lamoine	January	0					0					
2011-12	MM-SW-Mink Hole	December	1	0.771		0.771	0.771	0					
2011-12	MM-Treat Point	December	5	0.824	0.237	0.546	1.136	1	0.53		0.53	0.53	96.5
2011-12	ES13-Verona	January	0					0					
2011-12	Jordan R Trenton	January	0					0					
2011-12	MM-Treat Point	January	0					0					
2011-12	MM-Treat Point	October	6	0.234	0.178	0.052	0.487	1	0.05		0.05	0.05	83.3
2011-12	W17	October	2	0.262	0.197	0.123	0.401	0					

American black duck Winter Year	American black duck Site	Month	n Blood THg	mean Blood THg µg/g ww	SD Blood THg	min Blood THg	max Blood THg	n Blood MeHg	mean Blood MeHg µg/g ww	mean % MeHg	n P1 (primary feather) THg	mean P1 THg µg/g fw	SD P1 THg	min P1 THg	max P1 THg
2010-11	MM-SW-Mink Hole	December	0					0			1	3.12	.	3.12	3.12
2010-11	MM-Treat Point	December	0					0			3	2.31	1.60	1.20	4.15
2010-11	ES13-Verona	January	3	0.49	0.43	0.19	0.98	0			3	2.03	2.11	0.31	4.38
2010-11	MM-Treat Point	January	8	0.81	0.52	0.14	1.72	0			9	1.94	1.16	0.18	3.83
2010-11	Meadow Pt Lamoine	January	8	0.08	0.02	0.06	0.13	0			8	2.30	1.19	1.34	4.79
2011-12	MM-SW-Mink Hole	December	0					0							
2011-12	MM-Treat Point	December	0					0							
2011-12	ES13-Verona	January	8	0.14	0.03	0.10	0.19	1	0.09	81.4					
2011-12	Jordan R Trenton	January	6	0.11	0.03	0.07	0.16	1	0.10	80.5					
2011-12	MM-Treat Point	January	8	0.74	0.60	0.20	1.92	1	1.47	76.5					
2011-12	MM-Treat Point	October	0					0							
2011-12	W17	October	1	0.26	.	0.26	0.26	0							

Appendix 14-20. Bat summary statistics using raw data for total Hg concentrations in blood and fur, 2008. Samples were collected in the lower Penobscot River and at coastal reference sites. Sites are listed from north to south.

Bat Species	Bat site	Bat Age	Bat Sex	mean Julian date	SD Julian date	n Blood THg	mean Blood THg µg/g ww	SD Blood THg	min Blood THg	max Blood THg	n Fur THg	mean Fur THg µg/g fw	SD Fur THg	min Fur THg	max Fur THg
Little brown bat	HoltraChem	A	F	8227	4.5	4	0.59	0.26	0.22	0.83	4	39.45	27.84	15.20	79.55
Little brown bat	HoltraChem	A	M	8228	4.6	2	0.48	0.15	0.37	0.59	3	9.23	10.99	0.52	21.58
Little brown bat	Bald Hill Cove	A	F	8215	2.8	19	0.22	0.06	0.14	0.36	19	24.06	5.51	12.10	33.49
Little brown bat	Bald Hill Cove	A	M	8217	4.9	2	0.26	0.04	0.23	0.29	2	18.94	19.01	5.49	32.38
Little brown bat	East Mendall	A	F	8210	0.5	8	0.13	0.04	0.08	0.19	8	27.32	15.79	9.95	54.52
Little brown bat	East Mendall	A	M	8211	0.7	2	0.19	0.08	0.14	0.25	2	20.57	6.37	16.06	25.07
Little brown bat	West Mendall	A	F	8215	0.0	3	0.16	0.05	0.11	0.21	3	14.52	6.41	7.24	19.32
Little brown bat	West Mendall	A	M	8219	4.9	2	0.13	0.06	0.09	0.18	2	18.79	6.55	14.16	23.42
Little brown bat	Verona	A	F	8224	2.8	10	0.15	0.06	0.04	0.22	10	13.31	6.15	6.11	26.32
Little brown bat	Verona	A	M	8224	0.7	2	0.23	0.00	0.23	0.23	2	11.81	6.14	7.46	16.15
Little brown bat	Orland	A	F	8226	4.2	7	0.15	0.05	0.11	0.26	7	7.28	4.80	2.66	14.06
Little brown bat	Orland	A	M	8232		1	0.13		0.13	0.13	1	3.68		3.68	3.68
Little brown bat	Scarborough	A	F	8233		1	0.03		0.03	0.03	1	2.36		2.36	2.36
Little brown bat	HoltraChem	J	M	8225		1	0.75		0.75	0.75	1	3.72		3.72	3.72
Little brown bat	Bald Hill Cove	J	M	8214		1	0.27		0.27	0.27	1	4.68		4.68	4.68
Little brown bat	East Mendall	J	F	8210	0.4	5	0.14	0.05	0.08	0.21	5	7.65	8.08	1.18	21.32
Little brown bat	East Mendall	J	M	8211	0.0	2	0.12	0.03	0.10	0.14	2	5.86	4.60	2.61	9.11
Little brown bat	West Mendall	J	F	8215	0.0	2	0.15	0.12	0.06	0.24	2	4.44	3.83	1.73	7.14
Little brown bat	West Mendall	J	M	8219	4.9	2	0.14	0.05	0.11	0.18	2	14.43	18.35	1.45	27.40
Little brown bat	Mt. Waldo	J	F	8218	.	1	0.14		0.14	0.14	1	4.48		4.48	4.48
Little brown bat	Mt. Waldo	J	M	8218	.	1	0.10		0.10	0.10	1	3.29		3.29	3.29
Little brown bat	Verona	J	F	8229	4.6	3	0.24	0.10	0.13	0.30	3	6.21	3.94	3.88	10.75
Little brown bat	Verona	J	M	8228	5.7	2	0.13	0.02	0.11	0.14	2	4.89	4.31	1.84	7.94
Little brown bat	Orland	J	F	8224	0.6	3	0.24	0.13	0.15	0.39	3	3.20	1.06	1.99	3.96
Little brown bat	Orland	J	M	8225	3.8	5	0.12	0.04	0.08	0.18	5	2.50	0.91	1.65	3.62
Little brown bat	Scarborough	J	F	8233	0.0	7	0.05	0.02	0.02	0.10	7	3.64	2.88	0.72	8.02
Little brown bat	Scarborough	J	M	8233	0.5	5	0.07	0.04	0.03	0.12	5	6.24	7.44	0.96	18.82
Northern long-eared bat	HoltraChem	A	F	8225		1	0.20		0.20	0.20	1	37.96		37.96	37.96
Northern long-eared bat	East Mendall	A	F	8210		1	0.06		0.06	0.06	1	8.58		8.58	8.58
Northern long-eared bat	East Mendall	A	M	8211	0.0	6	0.18	0.19	0.04	0.55	6	9.98	5.36	4.76	19.89
Northern long-eared bat	Verona	A	F	8224	0.7	2	0.10	0.01	0.09	0.11	2	13.59	1.89	12.25	14.92
Northern long-eared bat	Verona	A	M	8223		1	0.12		0.12	0.12	1	12.17		12.17	12.17
Northern long-eared bat	Scarborough	A	M	8234		1	0.06		0.06	0.06	1	6.49		6.49	6.49
Northern long-eared bat	East Mendall	J	M	8211	0.7	2	0.07	0.00	0.07	0.07	2	4.18	4.23	1.19	7.17
Northern long-eared bat	Verona	J	F	8224		1	0.14		0.14	0.14	1	2.74		2.74	2.74
Northern long-eared bat	Scarborough	J	F	8234	0.0	7	0.09	0.03	0.05	0.15	7	5.01	5.57	1.20	17.03
Northern long-eared bat	Scarborough	J	M	8234	0.0	8	0.11	0.07	0.05	0.27	8	6.77	5.67	2.23	18.24
Big brown bat	East Mendall	A	F	8210		1	0.23		0.23	0.23	1	38.92		38.92	38.92
Big brown bat	East Mendall	J	F	8210		1	0.16		0.16	0.16	1	4.25		4.25	4.25
Eastern red bat	East Mendall	J	M	8210		1	0.00		0.00	0.00	1	0.78		0.78	0.78
Eastern red bat	Scarborough	J	F	8233		1	0.05		0.05	0.05	1	1.47		1.47	1.47