DEPLW-1110

SURFACE WATER AMBIENT TOXIC MONITORING PROGRAM

2009

FINAL REPORT

DIVISION OF ENVIRONMENTAL ASSESSMENT
MAINE DEPARTMENT OF ENVIRONMENTAL PROTECTION
AUGUSTA, MAINE 04333

May 2010

TABLE OF CONTENTS

INTRODUCTION

This 2009 Surface Water Ambient Toxic (SWAT) monitoring program final report is organized into an Executive Summary (with introduction and table of contents) and 4 modules, 1) Marine & Estuarine 2) Lakes, 3) Rivers & Streams.

The full report is available on DEP's website at
http://www.maine.gov/dep/blwq/docmonitoring/swat/index.htm

Questions may be directed to authors of each study or to Barry Mower, DEP, SHS 17, Augusta, Maine 04333, tel: 207-287-7777, email: barry.f.mower@Maine.gov

Acknowledgements
Collection of samples was conducted by the principal investigators and technical assistants listed (DEP staff unless otherwise specified).

Chemical analyses were performed by AXYS Analytical Services, Sidney, British Columbia or other laboratories as listed in reports in individual sections.

EXECUTIVE SUMMARY

Maine's Surface Water Ambient Toxics (SWAT) monitoring program was established in 1993 (38 MRSA §420-B) to determine the nature, scope and severity of toxic contamination in the surface waters and fisheries of the State. The authorizing statute states that program must be designed to comprehensively monitor the lakes, rivers and streams and marine and estuarine waters of the State on an ongoing basis. The program must incorporate testing for suspected toxic contamination in biological tissue and sediment, may include testing of the water column and must include biomonitoring and the monitoring of the health of individual organisms that may serve as indicators of toxic contamination. This program must collect data sufficient to support assessment of the risks to human and ecological health posed by the direct and indirect discharge of toxic contaminants.

The Commissioner of the Department of Environmental Protection (DEP) must prepare a 5-year conceptual workplan in addition to annual workplans which are each reviewed by a Technical Advisory Group (TAG), composed of 10 individuals with scientific backgrounds representing various interests and 2 legislators.

The SWAT program is divided into 4 modules, 1) Marine and Estuarine, 2) Lakes, 3) Rivers and Streams, and 4) Special Studies. This annual report follows the outline of the 2009 workplan recommended by the SWAT TAG in a meeting June 26, 2009. Following is a summary of key findings from the 2009 SWAT program for each module.

1. MARINE AND ESTUARINE

- Blue mussel tissue from 42 sites along the Maine coast was analyzed from 2007-2009 for contaminants including metals, mercury, Polycyclic Aromatic Hydrocarbons (PAHs), Polychlorinated Biphenyl (PCBs), and pesticides.
- In 2009, lead in mussel tissue exceeded national 85th percentile concentrations at 5 sites and mercury at 12 sites, which were then considered "elevated." Follow-up sampling in mussel tissue at multiple sites in the Sheepscot River estuary south of Wiscasset in 2009 indicates elevated mercury concentrations.
- Lead concentrations in mussel tissue exceed Maine Center for Disease Control (MCDC) lead fish tissue action levels (FTALs) at 8 of 42 sites (2007-09).
- PAHs in mussel tissue exceeded national 85th percentile concentrations at two sites, which were considered "elevated." One additional site in the Sheepscot River showed elevated concentrations of PAHs when alkylated PAHs were included in the analysis.
- PCB concentrations in mussel tissue at 2 of 8 sites sampled in 2009 exceeded the Gulf of Maine 85th percentile concentration, though no sites exceeded the national 85th percentile concentration (and so were not considered "elevated").
- PCB concentrations in mussel tissue exceed MCDC PCB cancer FTAL at 5 of 42 sites (2007-09).

- Organochlorinated pesticide concentrations in mussel tissue were generally low at Maine sites compared to national data, though 11 of 42 sites showed an elevated level compared to Gulf of Maine data.
- New sampling for organophosphate, triazine, pyrethroid, and organonitrogen pesticides revealed very low concentrations in Maine mussels (non-detects) at all stations sampled.

2. LAKES

- Total PCBs in fish from Androscoggin Lake in Wayne were higher than when last measured in 2000-2001 and exceed the Maine Center for Disease Control and Prevention's (MCDC) Fish Tissue Action Level. Data have been sent to the MCDC for further analysis.

3. RIVERS AND STREAMS

- Thirty-nine stations were assessed for the condition of the benthic macroinvertebrate community. Twenty-nine of the thirty-nine stations attained the aquatic life standards of their assigned class.

- Samples of fish from the Androscoggin, Kennebec, Penobscot, Salmon Falls, St. Croix, and Sebasticook rivers generally exceeded the MCDC's fish tissue action levels (FTAL) for PCBs, used for setting fish consumption advisories, at most stations.

- There are fish consumption advisories for several Aroostook County rivers and streams issued by the MCDC because of residuals of DDT used decades ago. Samples of trout from eight of ten Aroostook County rivers and streams sampled in 2009 significantly exceeded MCDC's FTAL used for setting the advisories.

- Validation of use of a new method of mercury analysis with the University of Maine shows promise of quicker and less expensive monitoring of fish tissue mercury levels, which will allow collection of more data for use in review of Maine's Statewide Fish Consumption Advisory for mercury.

1.0 MARINE MODULE

PRINCIPAL INVESTIGATOR	Jim Stahlnecker
TECHNICAL ASSISTANTS	Joseph Glowa John Reynolds

SPECIAL THANKS	Susanne Meidel Karla Hyde Doug Suitor

1.1

SHELLFISH TISSUE ANALYSIS

1.1 Assessment of Contaminant Levels in Blue Mussels

This work is funded by the Maine Coastal and Inland Surface Oil Clean-up Fund, which is administered by the Bureau of Remediation and Waste Management in the DEP.

1.1.1 Introduction

This report presents and summarizes contaminant data from the collection and analysis of blue mussel (*Mytilus edulis*) tissue collected from 42 sites between 2007 and 2009 along the Maine coast. Blue mussels were taken from 13 sites in 2007 and in 2008, and from 16 sites in 2009. Mussel tissue samples collected in 2007 and 2008 were analyzed for metals, mercury, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and pesticides. Mussel tissue samples were analyzed for metals, mercury, and PAHs at all 16 sites sampled in 2009. In addition to metals, mercury, and PAHS, a subset of 8 of the 16 sites was also analyzed for PCBs and pesticides. In order to provide comparability of results from these 42 samples, blue mussel contaminant levels from the SWAT program are compared to blue mussel contaminant levels in other programs including the Gulfwatch program (Gulf of Maine Council on the Marine Environment) and the Mussel Watch Program (National Oceanographic and Atmospheric Administration). This analysis provides a regional and national context to the Maine SWAT data.

Maine's coastline lies within, and lends its name to, the Gulf of Maine, a diverse and productive ecosystem. The Maine coast and the larger Gulf of Maine provide economic opportunities including commercial fisheries, aquaculture, recreational fisheries, commerce via shipping, and a wide variety of tourism activities. Maine includes the urbanized areas of Portland and Bangor, and has experienced growth and increased development especially in the southwestern portion of the state's coastline in recent years. With increased development, increases in chemical contaminants discharged to the marine environment may occur. Some contaminants can also become magnified as they move up the food chain, bioaccumulating at higher trophic levels and potentially causing impacts on the viability of marine species, ecosystem health, and causing concern about consequences to human health. All these reasons suggest that the monitoring of chemical contaminants is an important component of assessing the health of our marine environment here in Maine.

Blue mussels have been used extensively by the SWAT program (since 1986) and other monitoring programs as an indicator of exposure of marine environments to chemical pollutants. Mussels are ubiquitous and readily collected across the coast of Maine, as well as across the entire Gulf of Maine. Published information about contaminants in mussels provides some historical context and allows comparisons between geographic areas and over time. Since blue mussels are consumed as food by humans, they can be used to understand potential human exposure to contaminants. Mussels are sessile, allowing attribution of their contaminant burdens to the environment where they were collected. Mussels filter large volumes of water as they feed, allowing them to concentrate many chemicals from the water column or sediments suspended in the water column. This allows detection of contaminants in mussel tissue that are sometimes found below detection limits in particulate matter, sediment, or water. It also gives insight into the biologically available portion of contaminants, which may not be readily discerned from background sediment or water concentrations.

1.1.2 Methods

Blue mussel samples have been analyzed for toxics at over 80 distinct locations sampled in the past 23 years. Sampling stations are selected to meet one or more of three goals: Provide spatial coverage of the Maine coast; provide data to determine temporal patterns or trend; and provide more focused results to assess problems documented by earlier sampling and analyses. Early sampling efforts sometimes took a screening approach, included only metals analyses, or sometimes included only one replicate, which provides no information to assess variability of contaminants within site but does limit costs.

Sites sampled in recent years within the context of this report can be divided in three types, based on the goals outlined above that drive the need for information from each site. These types are: Spatial, Temporal, and Follow-up sites. Sites that have never been sampled (or that have not been sampled for a long time), have been sampled for only one analyte type, or have been sampled with no replication are classified as "Spatial" sites. The primary reason for sampling these sites is to provide data required to fill geographic, spatial needs. This gives a better, more complete picture of how contaminants vary across the Maine coastline, and provides screening data that can be used in assessing interest on testing these sites again in the future. Testing sites with low contaminant levels, which can only be determined post-sampling, still provides valuable data on background contaminant levels and provides a context with which to compare more heavily contaminated sites.

"Temporal" sites are sites where there in an interest in obtaining data to provide a temporal look at contaminants through time. These sites will be sampled on an accelerated schedule, with sampling occurring as frequently as biennially. More frequent data collection will provide more closely spaced data through time, which may permit trend analysis when sufficient data is acquired. Relatively few temporal sites will be sampled to minimize costs associated with repeated, higher frequency sampling required at temporal sites.

"Follow-up" sites are those where previous SWAT contaminant levels (or results from another program like Gulfwatch) at the site or nearby indicate that additional sampling and analysis is warranted. Repeat sampling may occur at the same location in an attempt to replicate earlier results, or sampling of additional nearby sites might be used to determine local, fine scale contaminant distribution. Follow-up sites may also occur in the Temporal or Spatial categories as well, based on their historical sampling and data needs at the site.

Blue mussels were collected from 13 sites in 2007 and 2008, and 16 sites in 2009, for a total of 42 sites distributed across the coast of Maine. Thirty of 42 sites had been sampled previously as part of the SWAT program, but had not been visited in between two and twenty-one years (mean of 9 years). Twelve sites had never been sampled previously. Names and locations of all blue mussel collection sites for 2007, 2008, and 2009 are presented in Tables 1.1.2.1 (2007), 1.1.2.2 (2008) and 1.1.2.3 (2009). These tables present sites by name and include municipality, latitude and longitude, and the site selection type: spatial, temporal, or follow-up.

All blue mussel tissues collected in 2007-08 were analyzed for metals, mercury, PAHs, PCBs, and pesticides. In 2009, eight blue mussel tissues were analyzed for metals, mercury, PAHs, PCBs and pesticides, while eight sites in the Sheepscot estuary (follow-up sites) were analyzed for mercury, metals, and PAHs. The eight Sheepscot estuary sites were selected in a follow-up study to determine the spatial distribution of mercury in that system subsequent to obtaining an elevated score for mercury at Clough Point in 2007. Names and locations of eight of the 2009 blue mussel collection sites, which received additional analyses for PCBs and pesticides, are presented by municipality and latitude and longitude in Table 1.1.2.4. The eight follow-up Sheepscot estuary sites analyzed for mercury, metals and PAHs are presented by municipality and latitude and longitude in Table 1.1.2.5. Also included is a ninth reference site from the Damariscotta River, Goose Ledge. Maps of the blue mussel sampling locations are included in Figures 1.1.2.1 through 1.1.2.5 below.

Methodology of field collection, morphometric measurement, and laboratory preparation of mussel samples has been provided in previous SWAT reports and in the Gulfwatch field manual (Sowles, 1997) and will be reviewed here to familiarize the reader with the general approaches used. SWAT mussel sampling is planned and conducted to control as much variability in data collected as possible. Variation in mussel shell size, seasonal timing of collections (subsequent to spawning), location within the intertidal zone, and site location were all minimized to reduce conflicting signals in the contaminant data.

Sampling occurred from mid-October to mid-December and sampling dates are included for specific sites in Table 1.1.2.1 thru 1.1.2.5 In order to characterize the contaminants present in a general area at the sampling station, mussels were collected from four distinct areas (replicates) along the shoreline at each site whenever possible. Gauges were used to sort mussels by shell length in the field and mussels were selected for analysis within a size range of 50-60 mm. For metals analysis, a minimum of 20 mussels were selected from within the target size range from each of the four intra site locations and placed in separate containers. For organics analysis, a minimum of 30 mussels were collected at each intra site location. Replicates were washed in ambient sea water in a mesh or open bucket at the collection site to remove external debris and attached sediments. Mussel replicates were then transported to the laboratory in coolers (supplemented with ice packs in warmer weather). Mussels were not depurated prior to shucking to remove tissue for analysis.

Tissue sample processing was accomplished within 24 hours of field collections at all sites. At the laboratory, individual mussels were measured with calipers for length (anterior umbo to posterior growing edge) to the nearest 0.1 mm. Shell height, width (in mm), and soft tissue wet weight (nearest 0.1 g) were also measured and recorded for ten mussels per 20 mussel replicate. All soft tissue was removed and combined with the soft tissue from the 20 mussels within the same replicate. Total soft tissue wet weights per 20 mussel replicate were recorded. For organics analysis, 30 mussels were utilized.

Tissue composite samples for metals analyses included 20 mussels per composite sample or replicate, with 4 replicates collected per sampling station. Tissue composite samples for organics analyses included 30 mussels per composite sample or replicate, with 4 replicates collected per sampling station. Tissue composites were immediately placed in pre-cleaned glass jars and capped. Jars were pre-labeled and filled jars were stored at -15^{o} C for up to 2-5 months until analysis.

TABLE 1.1.2.1: 2007 SWAT Blue Mussel Sites

Site Name	Municipality	Station Code	West Longitude	North Latitude	Date Sampled	Site Type[1]
Spring Point	South Portland	CBSPSP	-70.2247	43.6512	10/31/2007	S
Middle Fore River	South Portland	CBFRMR	-70.2603	43.6416	11/5/2007	S
East End Beach	Portland	CBEEEE	-70.2408	43.6695	10/31/2007	T
Jewell Island, Punch Bowl	Cumberland	CBJWPB	-70.0888	43.6859	10/22/2007	S
Falmouth Anchorage	Falmouth	CBANAN	-70.2056	43.7314	10/18/2007	S
Harraseeket River	Freeport	CBHRHR	-70.0997	43.8198	10/22/2007	S
Mare Brook, Harpswell Cove	Brunswick, Harpswell	CBMBBH	-69.9438	43.8397	11/5/2007	S
Sheepscot R, Clough Point	Westport Is., Wiscasset	MCSHCP	-69.6557	43.9891	10/31/2007	S
Crockett Pt., Rockland Harbor	Rockland	PBRKCP	-69.1064	44.1058	10/23/2007	S
Rockport Harbor	Rockport	PBRPIH	-69.0741	44.1857	10/23/2007	S
Camden Harbor	Camden	PBCAEH	-69.0586	44.2087	10/18/2007	S
Goose Falls, Cape Rosier	Brooksville	PBCRGF	-68.8091	44.3548	12/17/2007	S
Bar Harbor, Harbor	Bar Harbor	BFBHBA	-68.2077	44.3927	11/1/2007	S

[1] S = Spatial, T = Temporal, F = Follow-up

TABLE 1.1.2.2: 2008 SWAT Blue Mussel Sites

Site Name	Municipality	Station Code	West Longitude	North Latitude	Date Sampled	Site Type[1]
Piscataqua, I-95	Kittery	PQISIS	-70.7798	43.0986	10/9/2008	S
Piscataqua, Back Channel	Kittery	PQBCBC	-70.7233	43.0829	11/12/2008	S
Piscataqua, Pepperell Cove	Kittery	PQPCPC	-70.7027	43.0777	11/5/2008	S
Piscataqua, Fort Foster	Kittery	PQFFFF	-70.6969	43.0646	11/5/2008	S
Perkins Cove, Ogunquit	Ogunquit	SCPCPC	-70.5881	43.2357	10/6/2008	S
Kennebunk River	Kennebunkport	SCKBMT	70.4743	43.3475	10/6/2008	S
Scarborough River	Scarborough	SCSRRR	-70.3441	43.5542	10/23/2008	S
Presumpscot River	Falmouth	CBPRMT	-70.2471	43.6925	11/18/2008	S
Middle Bay, Harpswell	Harpswell	CBMBMB	-70.0537	43.7656	10/21/2008	S
Lincolnville, Ferry Terminal	Lincolnville	PBLNFT	-69.0058	44.2786	10/6/2008	S
Saturday Cove, Northport	Northport	PBNPSC	-68.953	44.338	10/20/2008	S
Belfast Harbor	Belfast	PBBFTD	-68.9987	44.4251	10/21/2008	S
Sears Island, Searsport	Searsport	PBSIWS	-68.8902	44.4468	9/22/2008	S

[1] S = Spatial, T = Temporal, F = Follow-up

TABLE 1.1.2.3: 2009 SWAT Blue Mussel Sites

Site Name	Municipality	Station Code	West Longitude	North Latitude	Date Sampled	Site Type[1]
Inner Fore R.	Portland	CBFRIR	-70.29362	43.64632	9/22/2009	S
East End Beach	Portland	CBEEEE	-70.24065	43.66968	11/10/2009	T
Mill Creek	Falmouth	CBMCMC	-70.21988	43.71997	11/10/2009	T
Long Is.	Long Island	CBLNFT	-70.1608	43.69303	10/27/2009	S
Maquoit Bay	Freeport	CBMBBR	-70.05898	43.80807	9/28/2009	S
Quahog Bay	Harpswell	CBQHQH	-69.92810	43.79535	9/24/2009	S
Phipps Pt.	Woolwich	MCSHPP	-69.72778	43.91532	11/12/2009	F
Maine Yankee	Wiscasset	MCSHMY	-69.69143	43.95048	11/9/2009	F
Berry Is.	Wiscasset	MCSHBI	-69.67922	43.96662	10/9/2009	F
Whittum Is.	Westport	MCSHWT	-69.71227	43.85263	11/12/2009	F, S
Westport Is. (SE)	Westport	MCSHSE	-69.69415	43.89938	10/29/2009	F
Fowles Pt.	Westport	MCSHFP	-69.67245	43.92362	10/26/2009	F
Clough Pt.	Edgecomb	MCSHCP	-69.6643	43.97345	10/29/2009	F
Sheepscot R., Upper R.	Wiscasset	MCSHUR	-69.65142	44.00417	11/12/2009	F
Goose Ledge	Damarsicotta	MCDMGL	-69.54530	44.01500	10/28/2009	F, S
Dennys R.	Dennysville	PMCKDR	-67.20980	44.90690	10/26/2009	S

[1] S = Spatial, T = Temporal, F = Follow-up

Table 1.1.2.4: 2009 SWAT Blue Mussel Sites Analyzed for PCBs and Pesticides

Site Name	Municipality	Station Code	West Longitude	North Latitude	Date Sampled	Site Type[1]
Inner Fore R.	Portland	CBFRIR	-70.29362	43.64632	9/22/2009	S
East End Beach	Portland	CBEEEE	-70.24065	43.66968	11/10/2009	T
Mill Creek	Falmouth	CBMCMC	-70.21988	43.71997	11/10/2009	T
Long Is.	Long Island	CBLNFT	-70.1608	43.69303	10/27/2009	S
Maquoit Bay	Freeport	CBMBBR	-70.05898	43.80807	9/28/2009	S
Quahog Bay	Harpswell	CBQHQH	-69.92810	43.79535	9/24/2009	S
Whittum Is.	Westport	MCSHWT	-69.71227	43.85263	11/12/2009	F, S
Dennys R.	Dennysville	PMCKDR	-67.20980	44.90690	10/26/2009	S

[1] S = Spatial, T = Temporal, F = Follow-up

Table 1.1.2.5: 2009 SWAT Blue Mussel Sites in Sheepscot and Damariscotta Estuaries Analyzed for Metals and PAHs

Site Name	Municipality	Station Code	West Longitude	North Latitude	Date Sampled	Site Type[1]
Phipps Pt.	Woolwich	MCSHPP	-69.72778	43.91532	11/12/2009	F
Maine Yankee	Wiscasset	MCSHMY	-69.69143	43.95048	11/9/2009	F
Berry Is.	Wiscasset	MCSHBI	-69.67922	43.96662	10/9/2009	F
Whittum Is.	Westport	MCSHWT	-69.71227	43.85263	11/12/2009	F, S
Westport Is. (SE)	Westport	MCSHSE	-69.69415	43.89938	10/29/2009	F
Fowles Pt.	Westport	MCSHFP	-69.67245	43.92362	10/26/2009	F
Clough Pt.	Edgecomb	MCSHCP	-69.6643	43.97345	10/29/2009	F
Sheepscot R., Upper R.	Wiscasset	MCSHUR	-69.65142	44.00417	11/12/2009	F
Goose Ledge	Damarsicotta	MCDMGL	-69.54530	44.01500	10/28/2009	F, S

[1] S = Spatial, T = Temporal, F = Follow-up

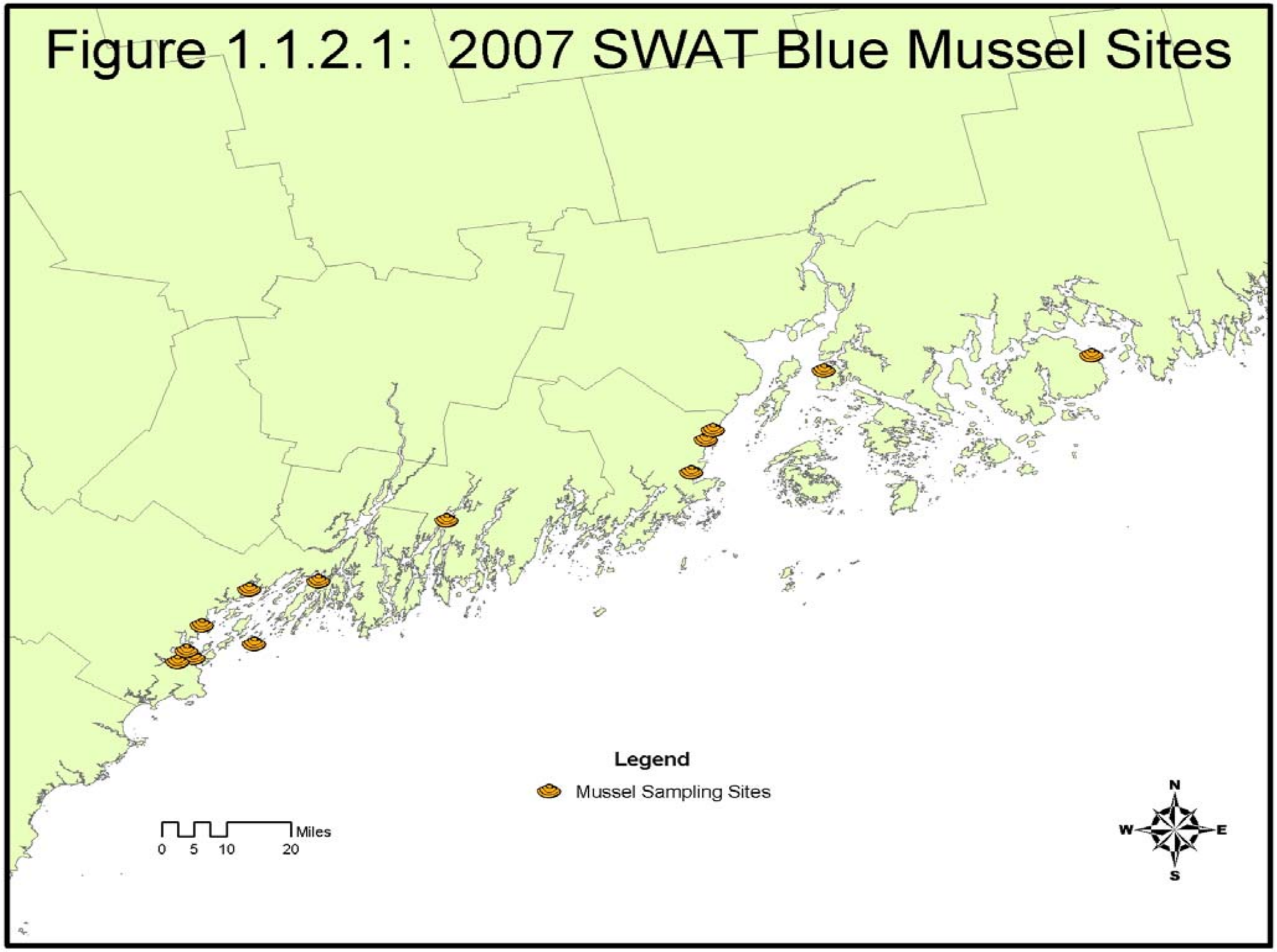


Figure 1.1.2.1: 2007 SWAT Blue Mussel Sites
Legend
Mussel Sampling Sites
Miles
0 5 10 20
N
W
E
S

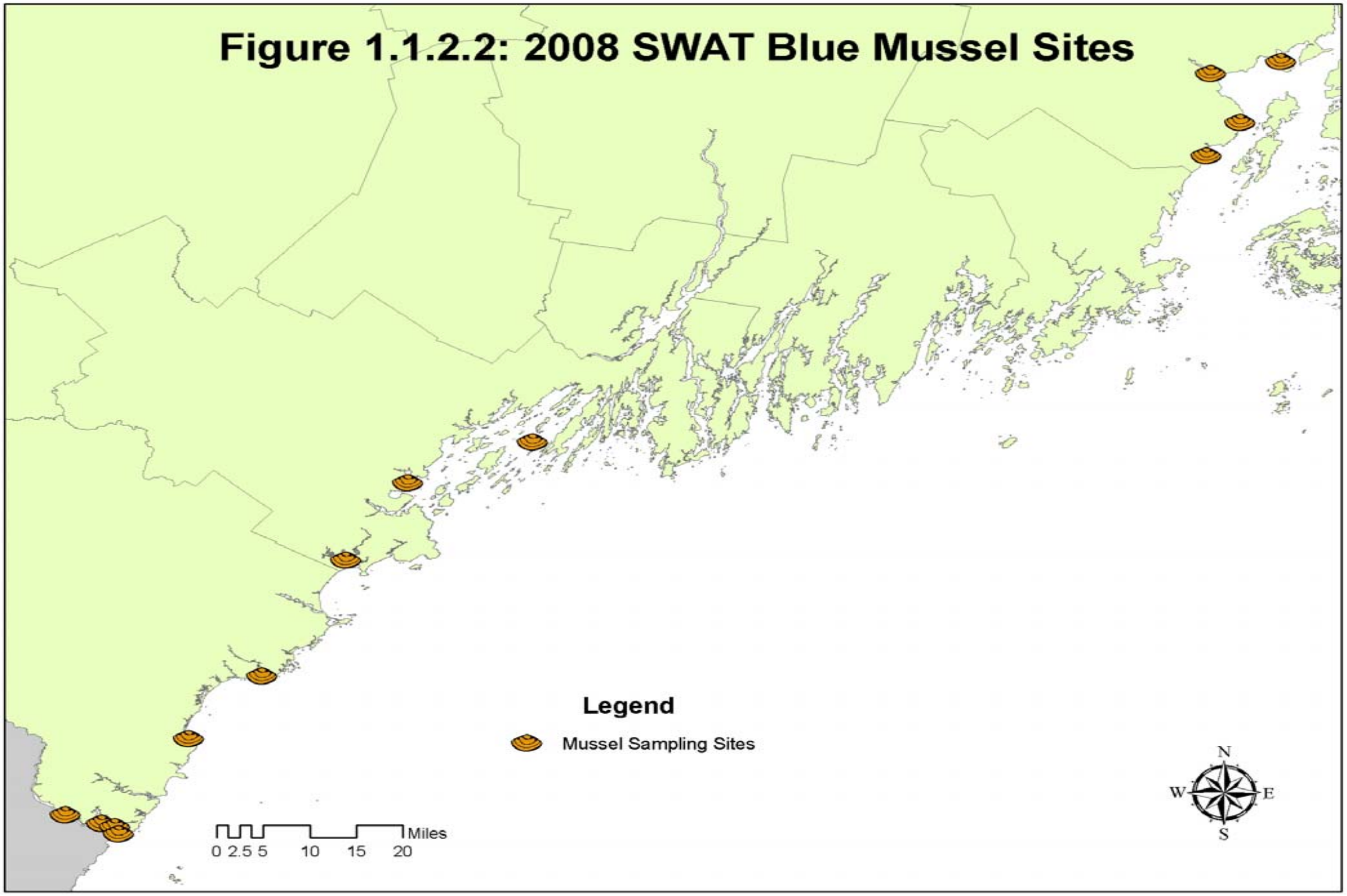
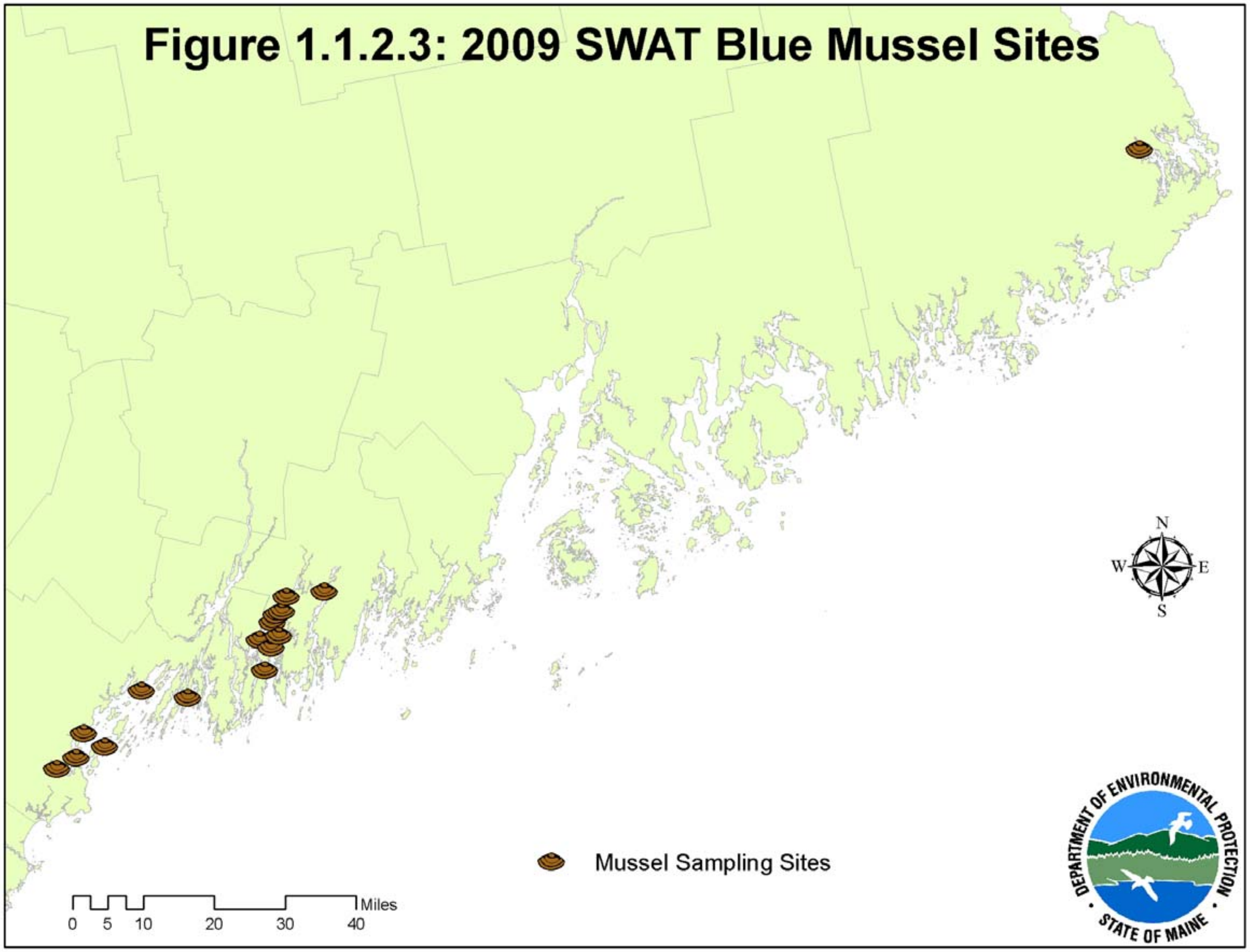


Figure 1.1.2.2: 2008 SWAT Blue Mussel Sites
Legend
Mussel Sampling Sites
Miles
0 2.5 5 10 15 20
N
W
E
S

Figure 1.1.2.3: 2009 SWAT Blue Mussel Sites



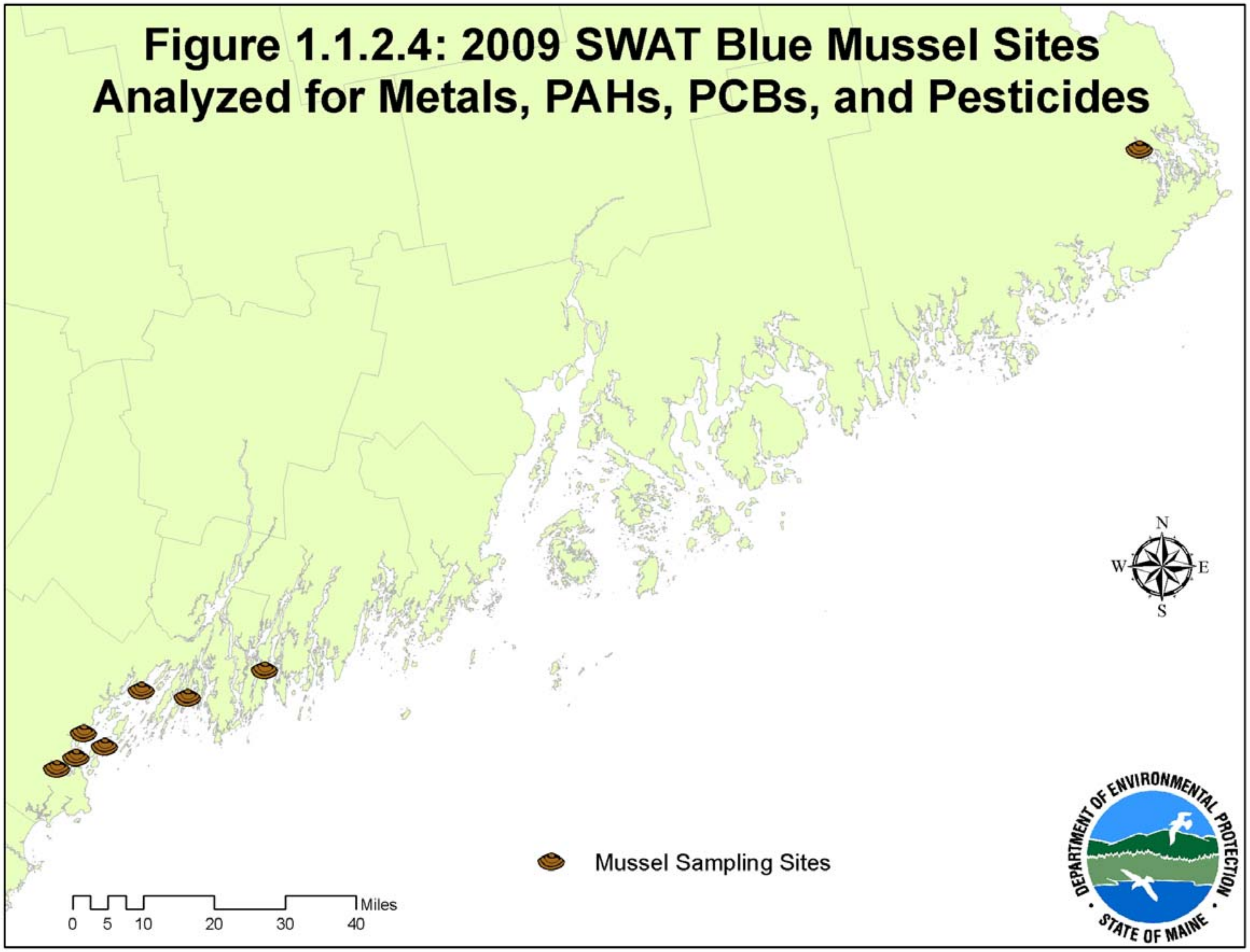


Figure 1.1.2.4: 2009 SWAT Blue Mussel Sites
Analyzed for Metals, PAHs, PCBs, and Pesticides
N
W
E
S
Mussel Sampling Sites
Miles
0 5 10 20 30 40
DEPARTMENT OF ENVIRONMENTAL PROTECTION
STATE OF MAINE

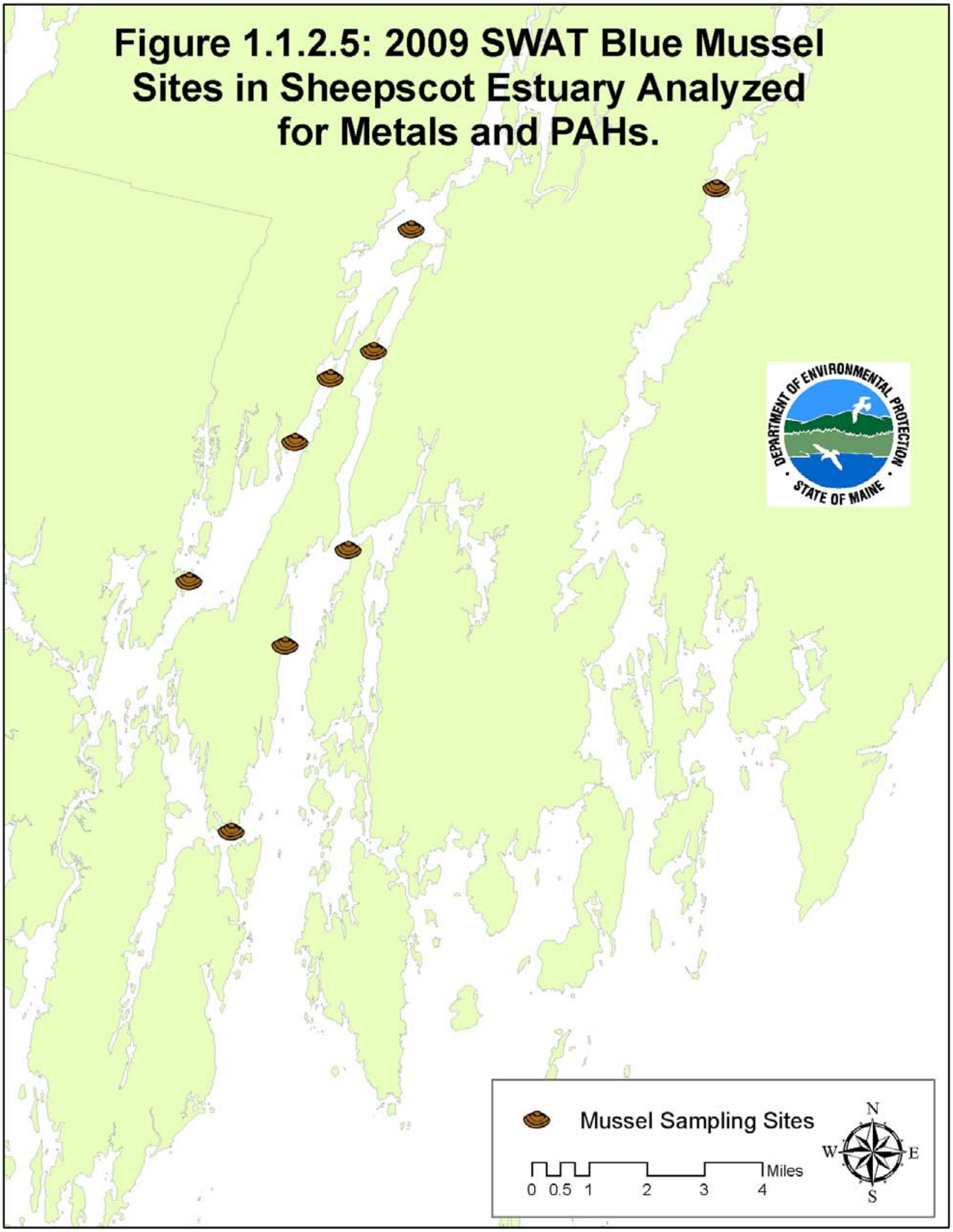


Figure 1.1.2.5: 2009 SWAT Blue Mussel
Sites in Sheepscot Estuary Analyzed
for Metals and PAHs.
DEPARTMENT OF ENVIRONMENTAL PROTECTION
STATE OF MAINE
Mussel Sampling Sites
0 0.5 1 2 3 4
Miles
N
W
E
S

1.1.3 Results

1.1.3.1 Metals

Mussel tissue samples collected in 2009 were analyzed by Battelle Marine Sciences Laboratory, Sequim, WA. The samples were analyzed for 12 metals: Silver (Ag), aluminum (Al), arsenic (Ar), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), mercury (Hg), nickel (Ni), selenium (Se), and zinc (Zn). Selenium results are not presented in this report. The Gulfwatch and NOAA National Status and Trends Mussel Watch programs do not analyze for selenium and so comparable results are not available.

Results were compared to national (NOAA National Status & Trends Mussel Watch (NS&T), see Kimbrough, 2008) and Gulf of Maine (Gulfwatch, see LeBlanc, 2009) blue mussel monitoring program data to place Maine SWAT data set in a national and regional context. From an environmental monitoring perspective, the concentration of an analyte in SWAT mussel tissue was considered elevated when that concentration exceeded the national NS&T 85th percentile. This approach is consistent with the Gulfwatch program (LeBlanc, 2009).

<u>1.1.3.1.1 Silver (Ag)</u>

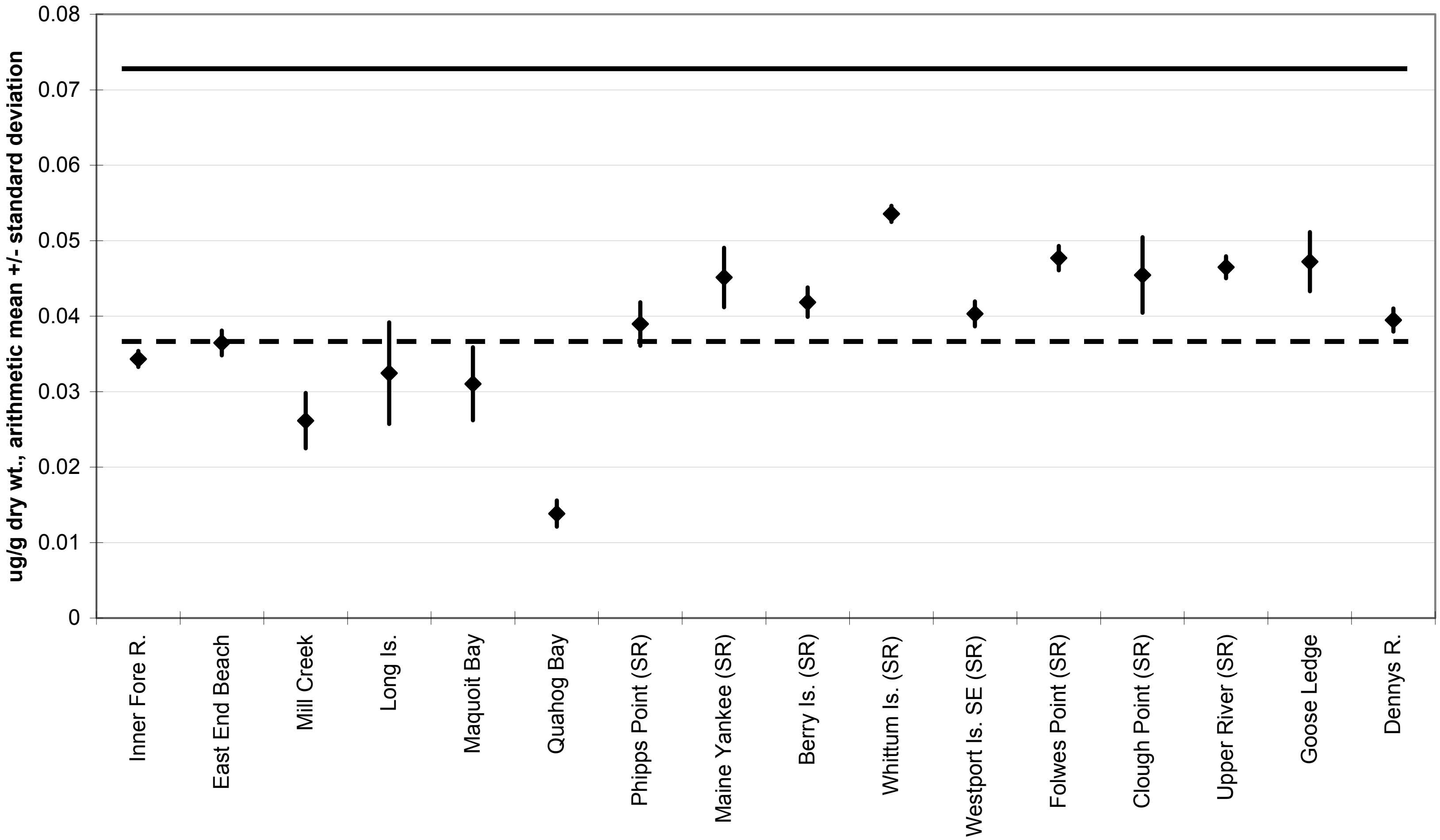
Silver was detected in all 16 sample locations visited in 2009. Silver detected in mussels ranged from a low mean concentration of 0.014 ug/g dry wt. at Quahog Bay, Harpswell to a high mean concentration of 0.054 mg/kg dry wt. at Whittum Island, Sheepscot River (Figure 1.1.3.1.1.1). Silver mean concentrations were above the Gulfwatch median (0.037 ug/g dry wt.), though none of the SWAT mean concentrations approached or exceeded the Gulfwatch 85th percentile (0.073 ug/g dry wt., Figure 1.1.3.1.1.1).

Figure 1.1.3.1.1.2 compares the silver concentrations in 2009 SWAT blue mussel tissue to the NS&T national median and national 85th percentile. Silver mean concentrations at all 16 SWAT sites fell below the NS&T national median and NS&T 85th percentile, hence no sites were considered elevated for silver.

Higher silver concentrations in water and sediments are reported to coincide with municipal sewage discharge (Sanudo-Wilhelmy and Flegal, 1992; Buchholtz ten Brink et al., 1997). Silver concentrations in Maine mussels appear to be relatively low. The highest Gulfwatch values, which came from sites in Neponset River and Sandwich, Massachusetts, exceeded the NS&T median but fell short of the NS&T 85th percentile. Increasing use of silver, including nanosilver, in products makes monitoring silver of interest at present and in the future.

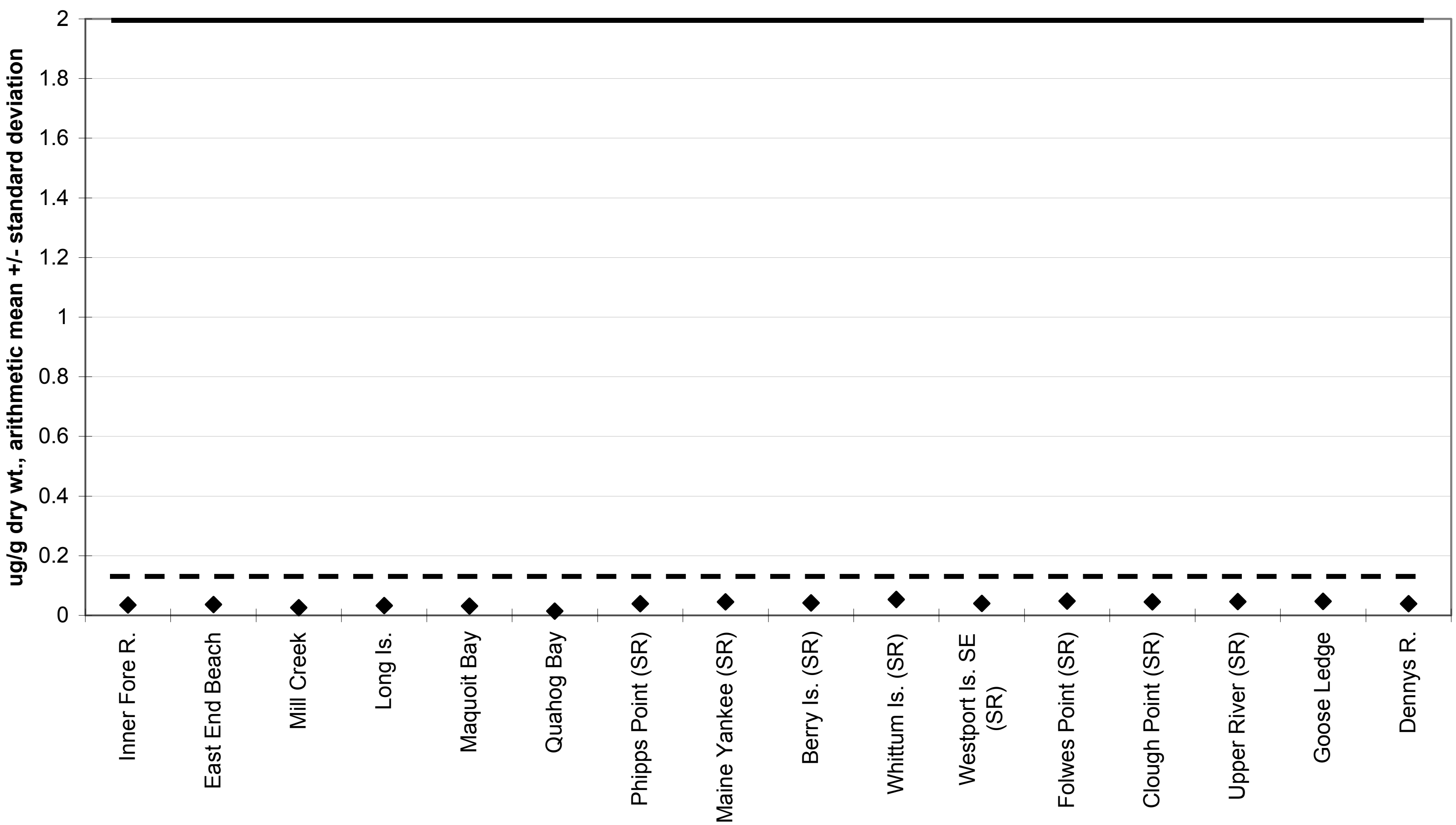
The Maine Center for Disease Control, Bureau of Health (MCDC) silver non-cancer fish tissue action level (FTAL) is 11 ug/g wet wt. (ppm) for noncommercial caught fish. The highest 2009 SWAT blue mussel tissue mean silver concentration, when expressed on a

Figure 1.1.3.1.1.1: Silver in 2009 SWAT Blue Mussels



Dashed line = 2008 Gulfwatch Median; Solid line = 2008 Gulfwatch 85th Percentile.

Figure 1.1.3.1.1.2: Silver in 2009 SWAT Blue Mussels



Dashed line = 2008 National Status and Trends Median; Solid line = 2008 National Status and Trends 85th Percentile.

wet weight basis, is 0.007 ug/g wet wt. at Whittum Island, Sheepscot River. This concentration is well below the 11 ug/g wet wt. FTAL.

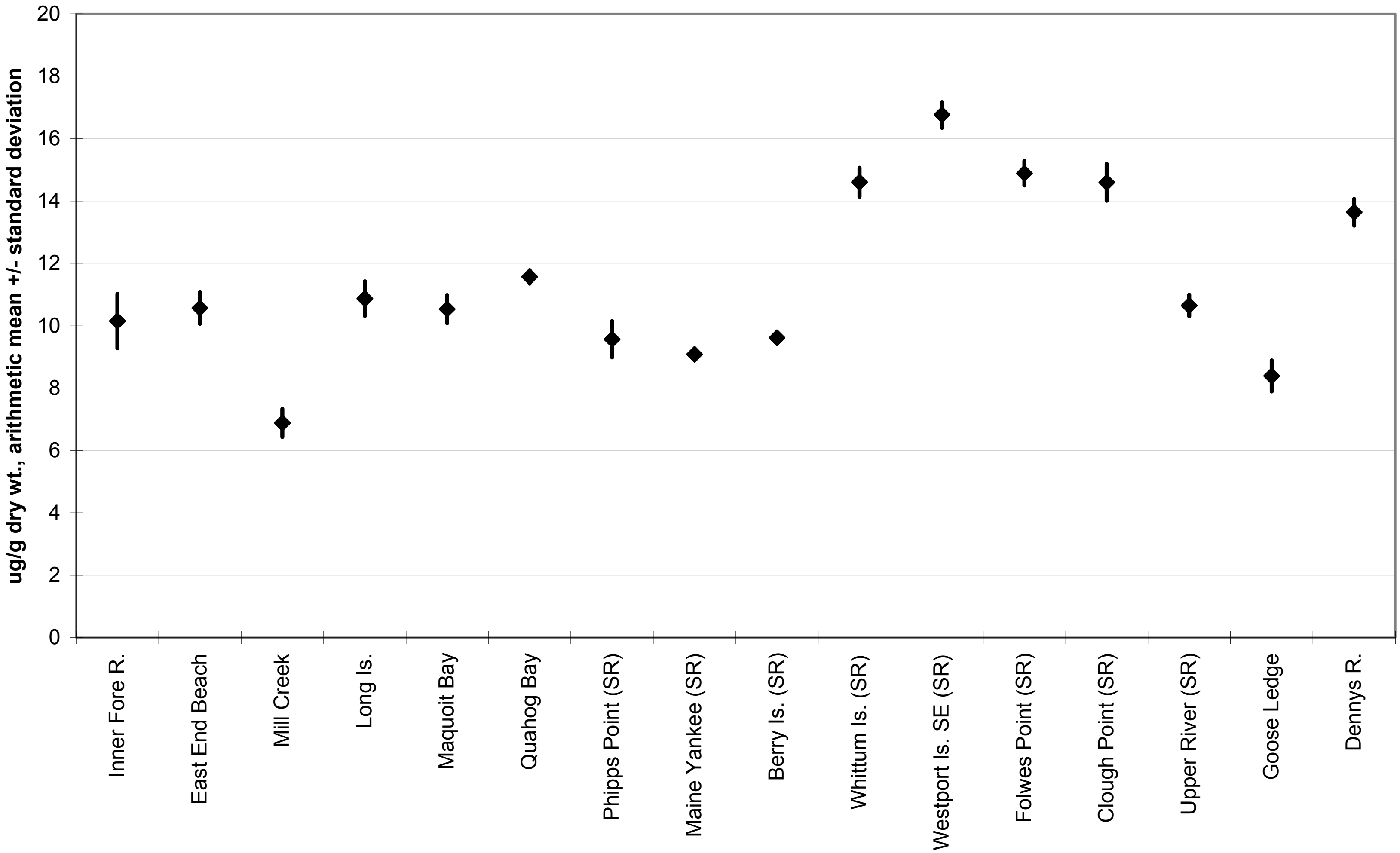
<u>1.1.3.1.2 Arsenic (As)</u>
Arsenic was detected in all 16 sample locations visited in 2009. Arsenic levels detected in mussels ranged from a low mean concentration of 6.88 ug/g dry wt. at Mill Creek, Falmouth to a high mean concentration of 16.76 ug/g dry wt. at Westport Island (Southeast), Sheepscot River (Figure 1.1.3.1.2.1). While Gulfwatch does not monitor arsenic concentrations, they are tracked regionally and nationally by NS&T. In blue mussels, NS&T considers 5-11 parts per million dry wt. (directly comparable to SWAT ug/g data) to be in the lowest of three ranges of arsenic concentration (Kimbrough, 2008). Six of the SWAT sites examined in 2009 show levels above 11 mg/kg dry wt., which places those sites in the lower half of the NS&T mid range (12-22 PPM or ug/g dry wt.) for arsenic. The remaining ten sites fall in the lowest range delineated by NS&T, below 11 ug/g (ppm) dry wt.

Nationally, the primary source for elevated levels of arsenic is crustal rock. Other than natural sources, industrial pollution can contribute arsenic to the environment from preserved wood, semiconductors, pesticides, defoliants, pigments, antifouling paints, and veterinary medicines. Atmospheric sources include smelting, fossil fuel combustion, power generation, and pesticide application (Kimbrough, 2008).

For non-commercially caught finfish, MCDC reports a cancer FTAL of 0.014 ppm and a non-cancer FTAL of 0.6 ppm, both for inorganic arsenic (the most toxic form). Most fish tissue data, including the SWAT blue mussel tissue data, is analyzed for total arsenic, not inorganic arsenic. MCDC uses FDA's 1993 assumption that 10% of total arsenic in finfish is inorganic arsenic. Using this assumption, SWAT blue mussel data were transformed to inorganic arsenic by dividing wet weight concentrations by a factor of 10. 2009 SWAT blue mussel inorganic arsenic concentrations ranged from 0.11 ug/g wet wt. to 0.22 ug/g wet wt. When recent data from all 42 sites sampled from 2007-09, inorganic arsenic concentrations in SWAT blue mussel tissue ranged from a low of 0.11 ug/g wet wt. (Bar Harbor, 2007) to a high of 0.23 ug/g wet wt. (Scarborough R., 2008). All 42 SWAT sites sampled from 2007-09 had blue mussel tissue inorganic arsenic concentrations exceeding the MCDC cancer action level of 0.014 ug/g wet wt. (ppm). None of the 42 sites sampled from 2007-09 exceeded the MCDC non-cancer action level of 0.6 ug/g wet wt. (ppm). The MCDC non-commercially caught finfish FTALs applied here assume an 8 oz. meal eaten by the consumer on a weekly basis. Maine SWAT data indicates that this 8 oz. meal size would translate to approximately 45-50 mussels per meal.

<u>1.1.3.1.3 Cadmium (Cd)</u>
Cadmium was detected in all 16 sample locations visited in 2009. Cadmium levels detected in mussels ranged from a low mean concentration of 0.97 mg/kg dry wt. at Mill Creek, Falmouth to a high mean concentration of 3.49 mg/kg dry wt. at Berry Island,

Figure 1.1.3.1.2.1: Arsenic in 2009 SWAT Blue Mussels



Sheepscot River (Figure 1.1.3.1.3.1). Six sites had concentrations comparable to and below the 2008 Gulfwatch median. The eight Sheepscot River stations and Dennys River, Dennysville exceeded the Gulfwatch median and the Gulfwatch 85th percentile (Figure 1.1.3.1.3.1).

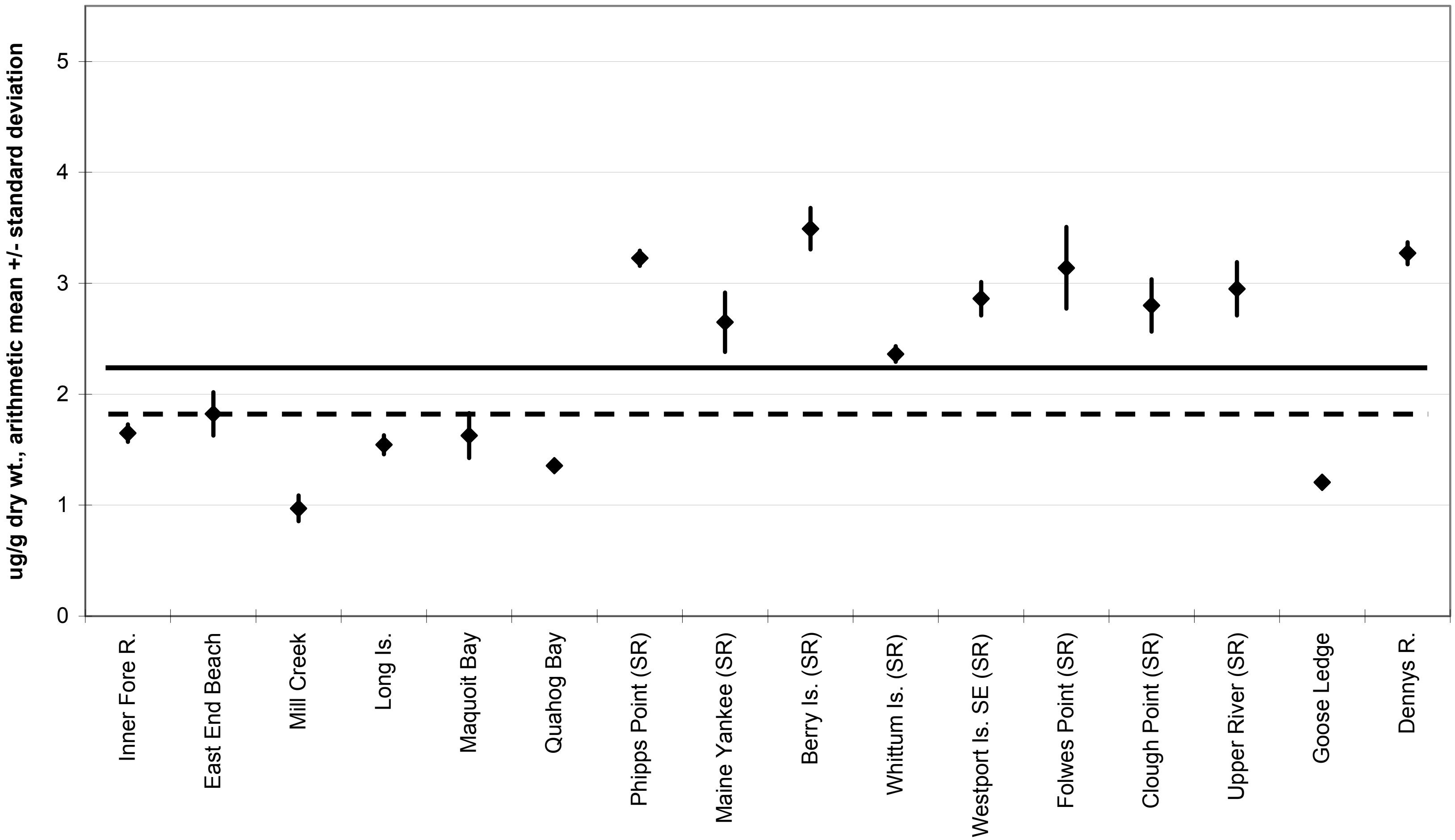
Cadmium concentrations at nine sites exceeded the NS&T national median (Figure 1.1.3.1.3.2) (Kimbrough, 2008). None of the 16 SWAT sites sampled in 2009 had cadmium concentrations exceeding the NS&T national 85th percentile.

Cadmium originates from crustal elements as rocks weather and is transported seaward by rivers, which account for approximately half of worldwide cadmium sources. Cadmium is also released naturally through forest fires and volcanic activity, with anthropogenic sources including manufacturing, fossil fuel combustion, and agriculture. Industrial sources include manufacture of batteries, plating, stabilizers, and nuclear power (Kimbrough, 2008).

Cadmium levels that appear to be relatively higher within the 2009 SWAT sites (eight Sheepscot River sites and Dennys River) may be associated with high sediment ingestion by mussels, and this may well be true as indicated by relatively high levels of iron, aluminum, and nickel in these nine sites. These elements provide a good approximation of ambient sediment intake, scoring high with high sediment ingestion by mussels. Since these three metals results are relatively high in the Sheepscot and Dennys River sites, the cadmium source may be at least partially related to ambient sediment in gut contents. Cadmium in the Sheepscot may also be related to deposition from historical fossil fuel burning, with a coal and then oil fired power plant located on the river, though this plant (Mason Station) is now closed.

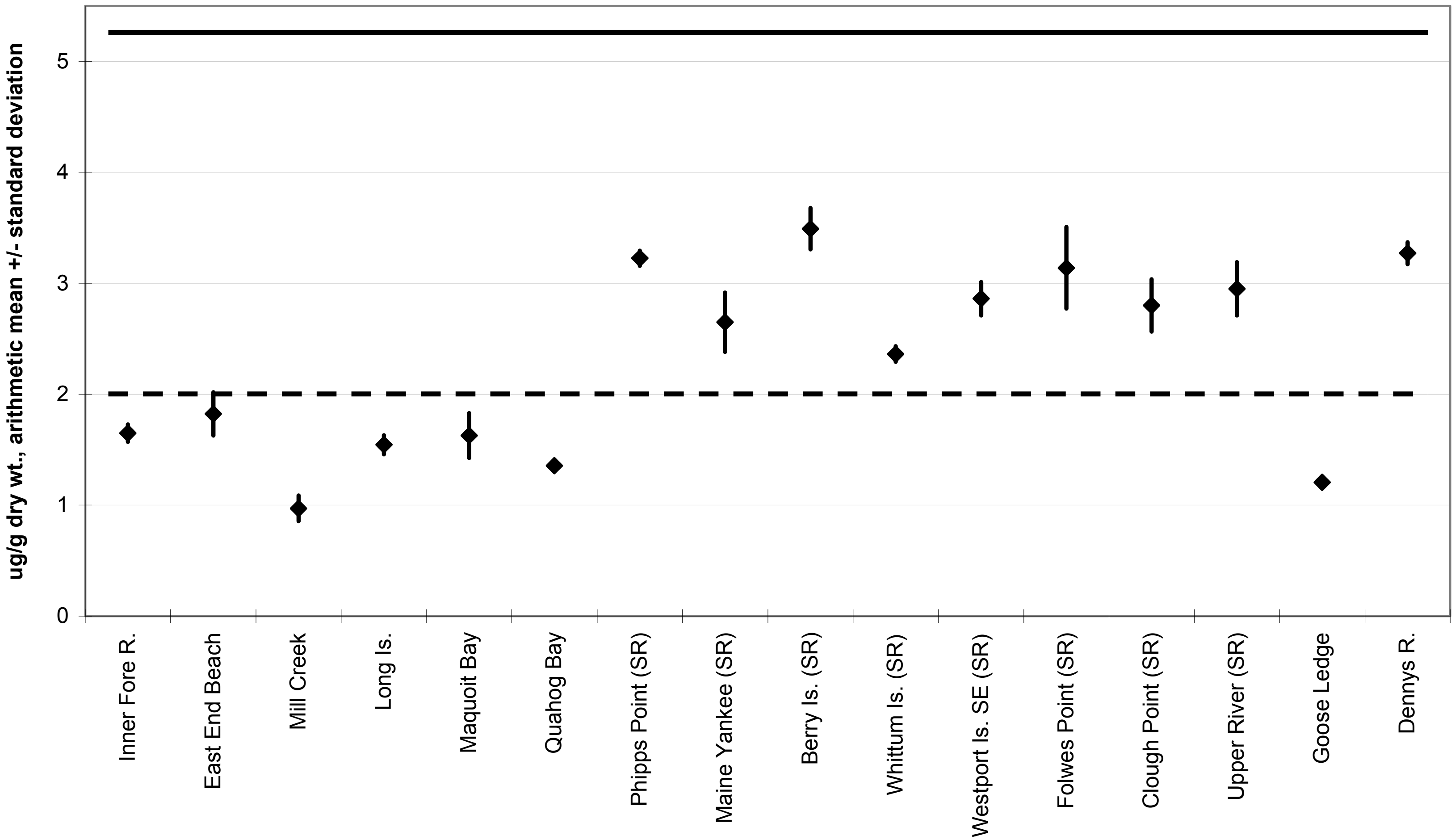
From a human health perspective, the MCDC noncancer FTAL for cadmium in noncommercial caught finfish is 2.2 ug/g wet wt. The FDA action level for clams, oysters, and mussels is 4 ug/g wet wt. (Kimbrough, 2008). The highest scoring 2009 SWAT site, Berry Island, Sheepscot River, had a mean cadmium concentration of 0.49 ug/g wet wt., which was well below the MCDC and FDA action levels.

FIgure 1.1.3.1.3.1: Cadmium in 2009 SWAT Blue Mussels



Dashed line = Gulfwatch Median; Solid line = Gulfwatch 85th Percentile.

FIgure 1.1.3.1.3.2: Cadmium in 2009 SWAT Blue Mussels



Dashed line = National Status and Trends Median; Solid line = National Status and Trends 85th Percentile.

1.1.3.1.4 Chromium (Cr)

Chromium was detected in all 16 SWAT sites sampled in 2009. Chromium levels detected in mussel tissue ranged from a low mean concentration of 1.01 ug/g dry wt. at Mill Creek, Falmouth, to a high mean concentration of 5.27 ug/g dry wt. at Dennys River, Dennysville (Figure 1.1.3.1.4.1). Two Maine SWAT sites had concentrations below the Gulfwatch median, while the remaining 14 sites had chromium concentrations exceeding the Gulfwatch median. Eleven of 16 sites exceeded the Gulfwatch 85th percentile, including Inner Fore River and East End Beach (both in Portland), eight Sheepscot River sites, and Dennys River, Dennysville.

Figure 1.1.3.1.4.2 depicts 2009 SWAT mussel chromium concentrations compared to the NS&T Mussel Watch national median and 85th percentile concentrations. Fifteen of 16 sites fell above the NS&T national median, while seven sites fell above the NS&T national 85th percentile and were considered elevated (Kimbrough, 2008).

Chromium is used extensively in tanning leather and was discharged with untreated tannery effluent during the last two centuries. Chromium persists in the marine environment in sediments near anthropogenic sources.

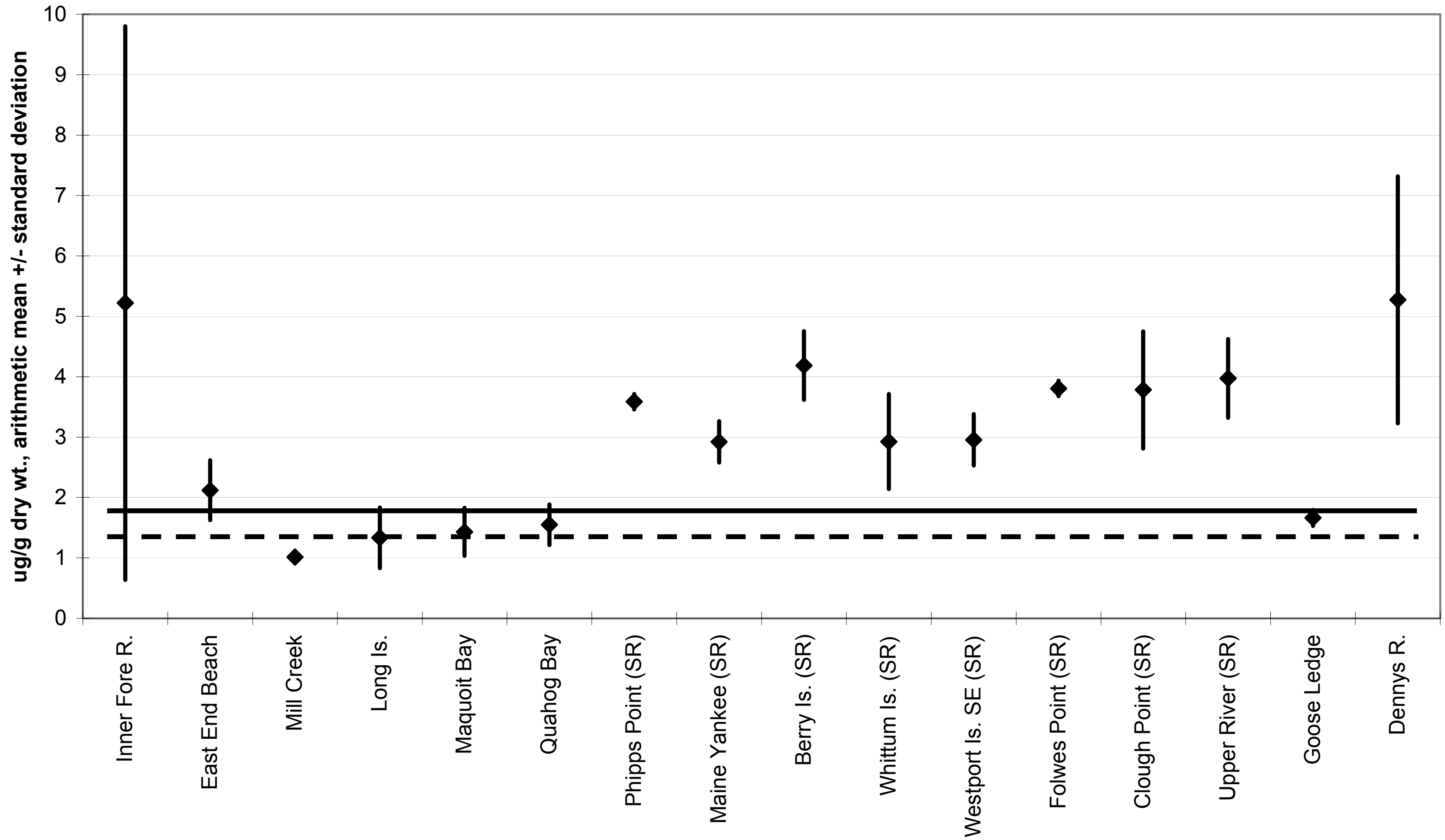
From a human health perspective, the MCDC FTALs (7 ug/g cancer action level and 11 ug/g non-cancer action level) for chromium are based on chromium VI, and are not directly comparable to SWAT results, which are for total chromium.

1.1.3.1.5 Copper (Cu)

Copper was detected in all 16 SWAT mussel sites visited in 2009. Copper levels detected in mussels ranged from a low mean concentration of 4.67 ug/g dry wt. at Maquoit Bay, Freeport to a high mean concentration of 7.72 ug/g dry wt. at Inner Fore River, Portland (Figure 1.1.3.1.5.1). SWAT concentrations were comparable to the Gulfwatch median with the exception of Inner Fore River, Portland, which exceeded the Gulfwatch 85th percentile (LeBlanc, 2009). SWAT copper concentrations in 2009 at all 16 sites fell below the NS&T national median, as well as the national 85th percentile as shown in Figure 1.1.3.1.5.2 (Kimbrough, 2008).

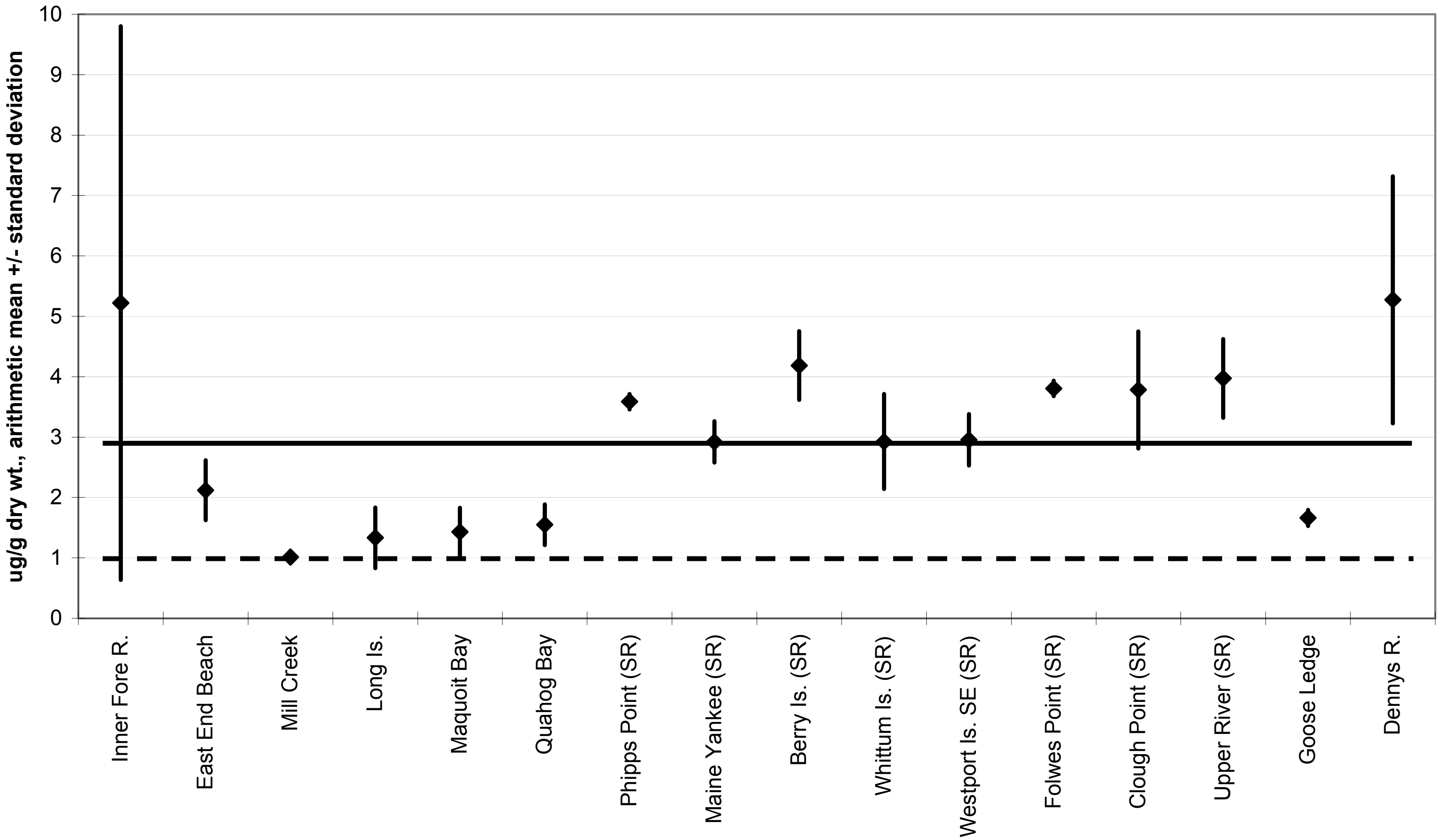
Copper occurs naturally in the environment and is ubiquitous, including the marine environment. Copper, in trace amounts, is considered to be an important nutrient for plant and animal growth. Heightened copper concentrations can occur due to anthropogenic sources, including: Mining, agriculture, sewage sludge, antifouling paint, fungicides, wood preservatives, and brake pads. With the reduction of the use of chromated copper arsenate (CCA) wood preservative due to its phase out by EPA, newer wood preservatives utilizing even higher levels of copper have come into use, including quaternary copper. Similarly, tributyltin marine bottom paint use was reduced in the 1980s, resulting in increased use of copper based antifouling paints while asbestos removal from brake pads has been offset by copper usage in brake pads (Kimbrough, 2008).

Figure 1.1.3.1.4.1: Chromium in 2009 SWAT Blue Mussels



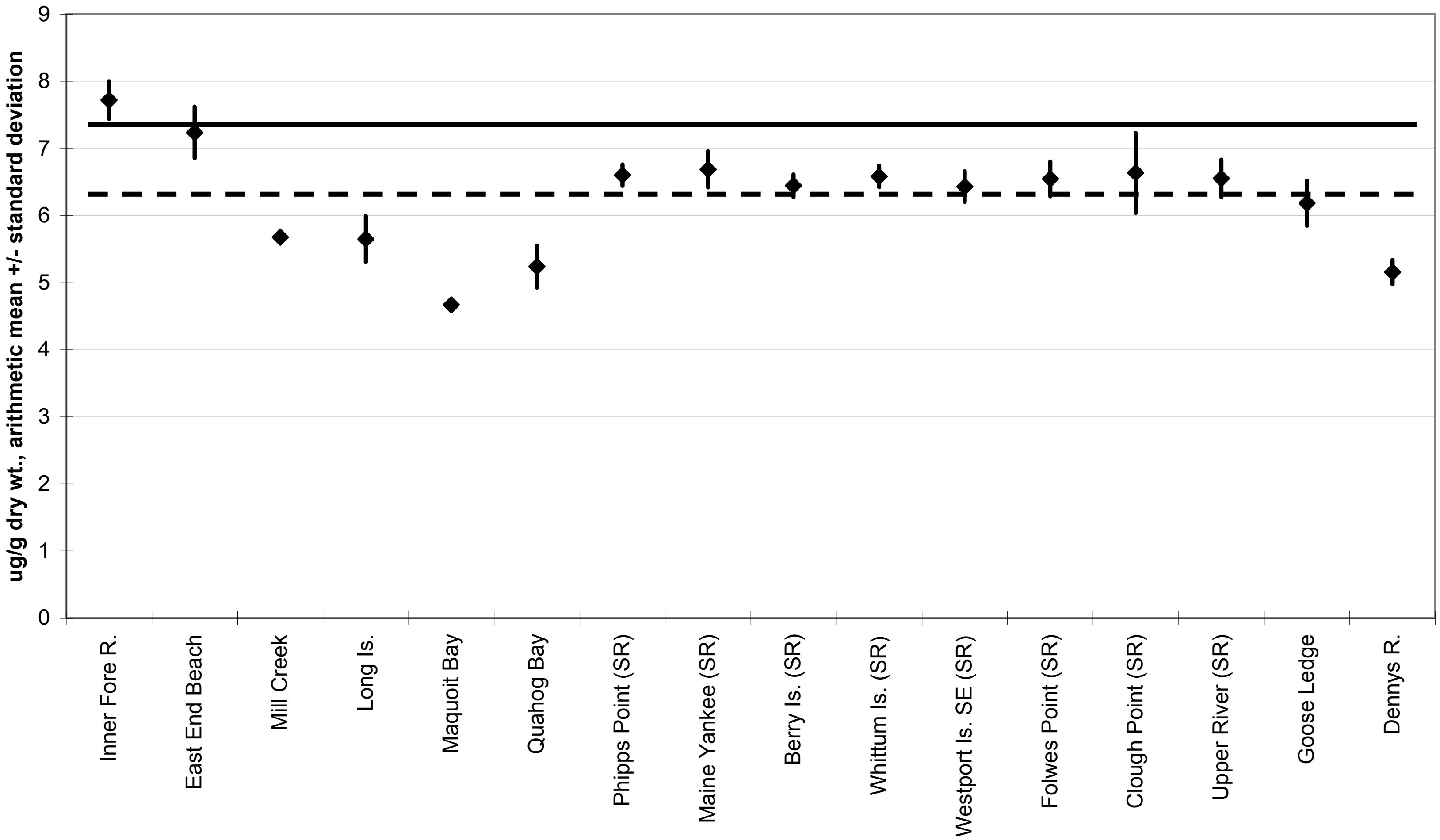
Dashed line = 2008 Gulfwatch Median; Solid line = Gulfwatch 85th Percentile.

Figure 1.1.3.1.4.2: Chromium in 2009 SWAT Blue Mussels



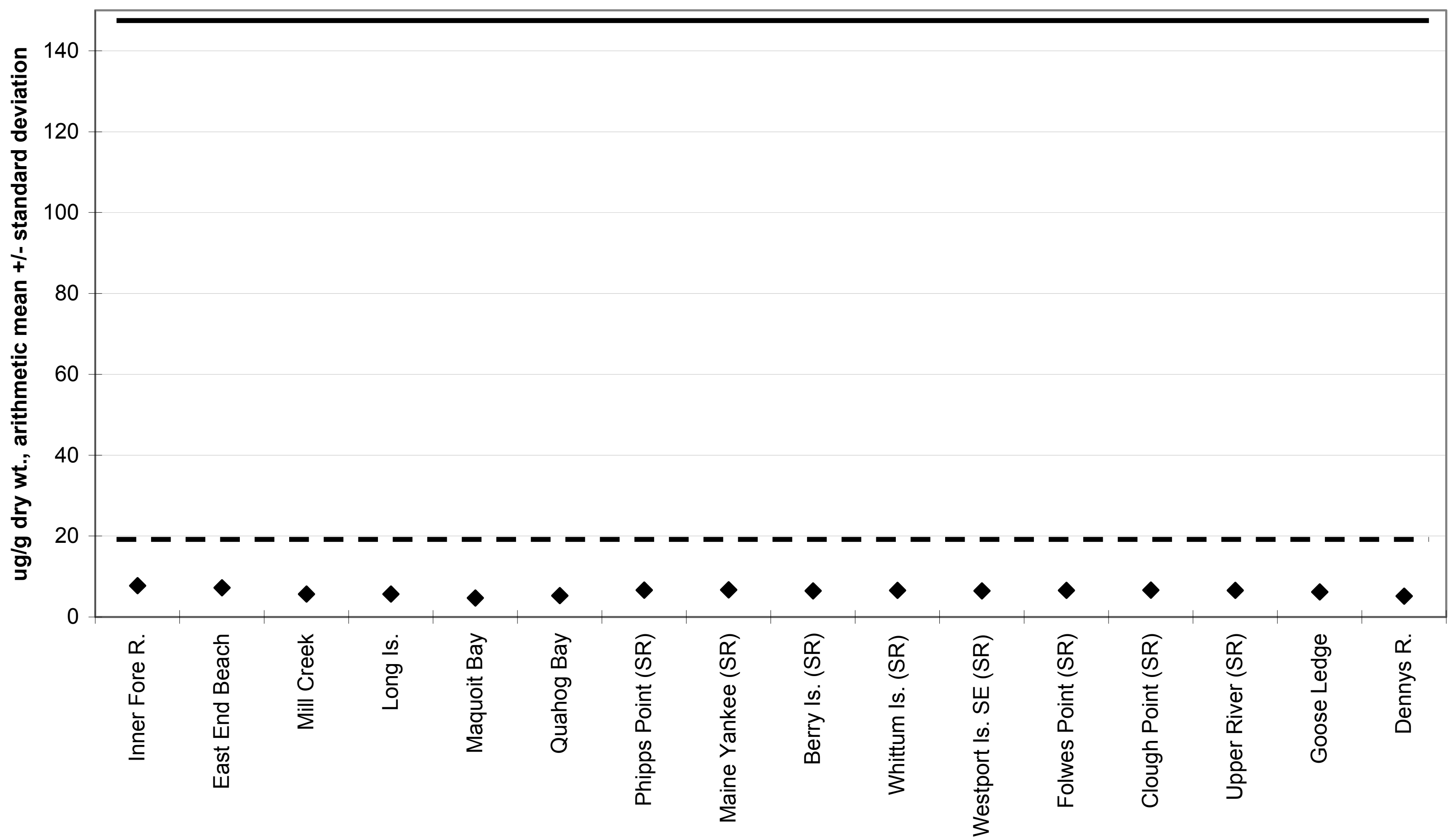
Dashed line = 2008 National Status and Trends Median; Solid line = National Status and Trends 85th Percentile.

Figure 1.1.3.1.5.1: Copper in 2009 SWAT Blue Mussels



Dashed line = Gulfwatch Median; Solid line = Gulfwatch 85th Percentile.

Figure 1.1.3.1.5.2: Copper in 2009 SWAT Blue Mussels



Dashed line = Gulfwatch Median; Solid line = Gulfwatch 85th Percentile.

From a human health perspective, copper is not highly toxic to humans, though there are some chronic effects. There is no recommended FDA safety level for human consumption for copper in fish or shellfish (Kimbrough, 2008), nor does MCDC report a FTAL for copper in non-commercially caught sportfish.

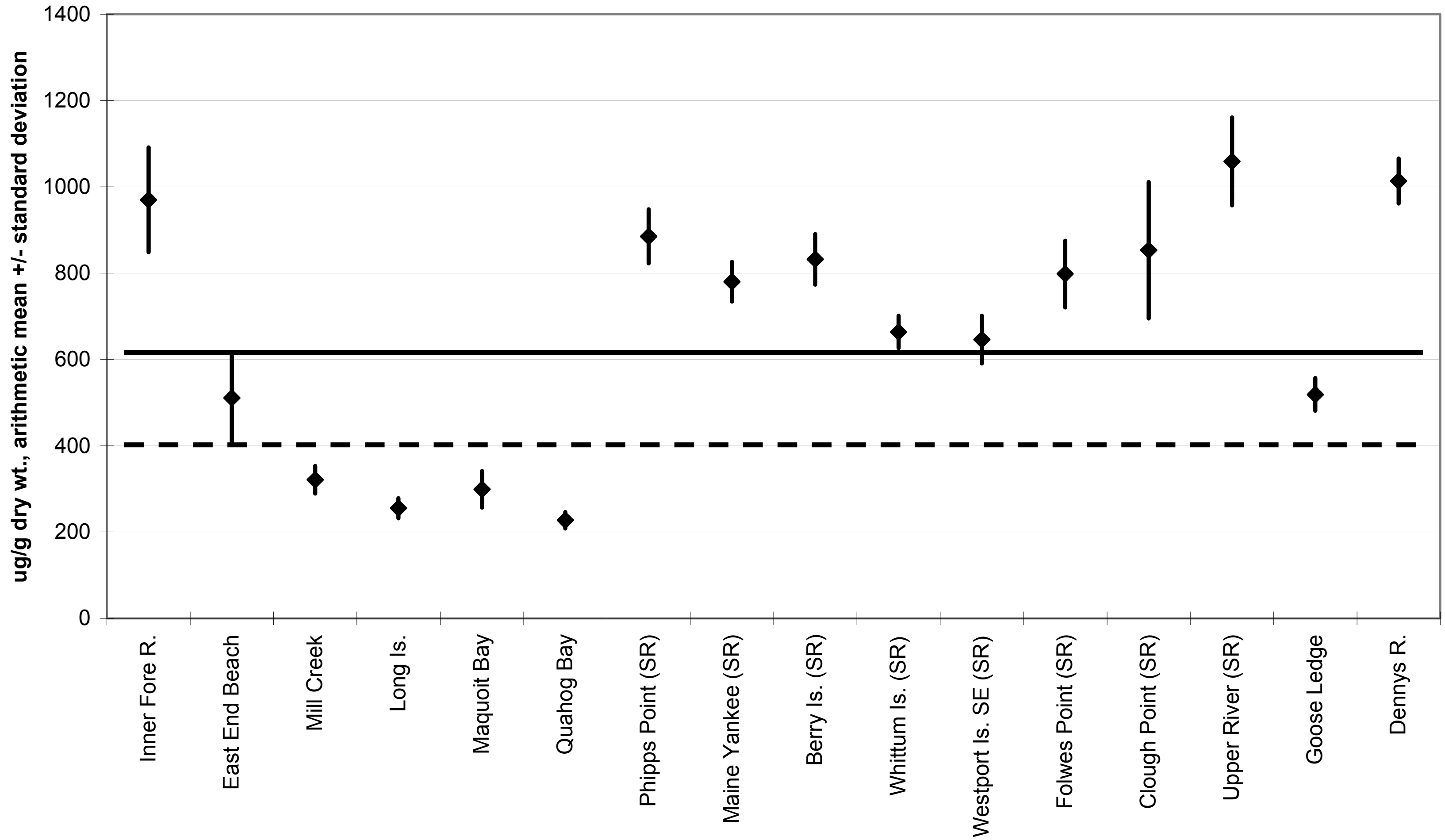
1.1.3.1.6 Iron (Fe) and Aluminum (Al)

Iron was detected in all 16 SWAT blue mussel sites in 2009. Iron concentrations detected in mussels ranged from a low mean concentration of 227 ug/g dry wt. at Quahog Bay, Harpswell to a high mean concentration of 1,059 ug/g dry wt. at Upper River, Sheepscot River as shown in Figure 1.1.3.1.6.1. Iron concentrations at 12 sites exceeded the Gulfwatch median and 10 sites exceeded the Gulfwatch 85th percentile. Figure 1.1.3.1.6.2 shows a comparison of SWAT mean iron concentrations to NS&T national median and 85th percentile iron concentrations. Iron concentrations at 12 sites exceeded the NS&T national median and four sites exceeded the NS&T national 85th percentile.

Aluminum concentrations detected in mussels ranged from a low mean concentration of 107 ug/g dry wt. at Quahog Bay, Harpswell to a high mean concentration of 867 ug/g dry wt. at Clough Point, Sheepscot River (Figure 1.1.3.1.6.3). Aluminum concentrations at 13 sites exceeded the Gulfwatch median concentration, while 10 sites exceeded the Gulfwatch 85th percentile concentration (LeBlanc, 2009). Figure 1.1.3.1.6.4 shows a comparison of SWAT mean aluminum concentrations to NS&T national median and 85th percentile iron concentrations. Mean aluminum concentrations at 15 sites exceeded the NS&T national median and 11 sites exceeded the NS&T national 85th percentile.

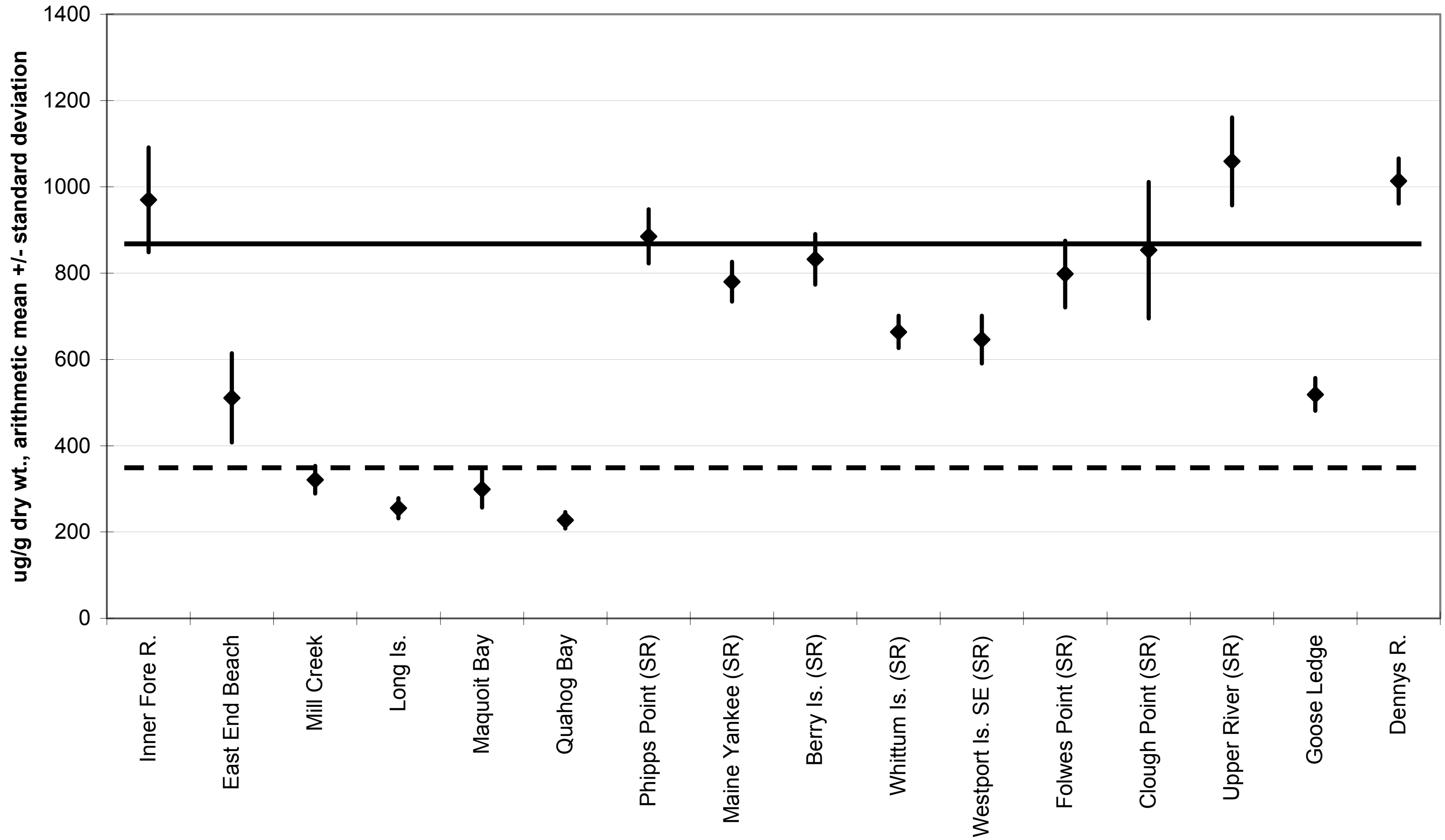
For the 2009 SWAT sites, many sites appeared to have relatively high levels of iron and aluminum, even compared to Gulfwatch results from 2008, the most recent year available (LeBlanc, 2009). Four SWAT sites had lower iron and aluminum concentrations. High iron and aluminum concentrations are usually associated with the intake of high levels of suspended sediments by mussels at sampled sites. This has also been shown with gut depuration experiments conducted as part of Gulfwatch monitoring in previous years, indicating that some of the iron and aluminum is associated with gut contents and not bioaccumulated loads. This theory appears to be consistent with 2009 Maine results, with the highest scoring iron and aluminum sites located in the Sheepscot River system and associated with available finer grained sediments, faster current velocities, and perhaps heightened re-suspension of sediments. Conversely, the lowest scoring sites in 2009 for both iron and aluminum are located in areas with more wave action and exposed shoreline.

Figure 1.1.3.1.6.1: Iron in 2009 SWAT Blue Mussels



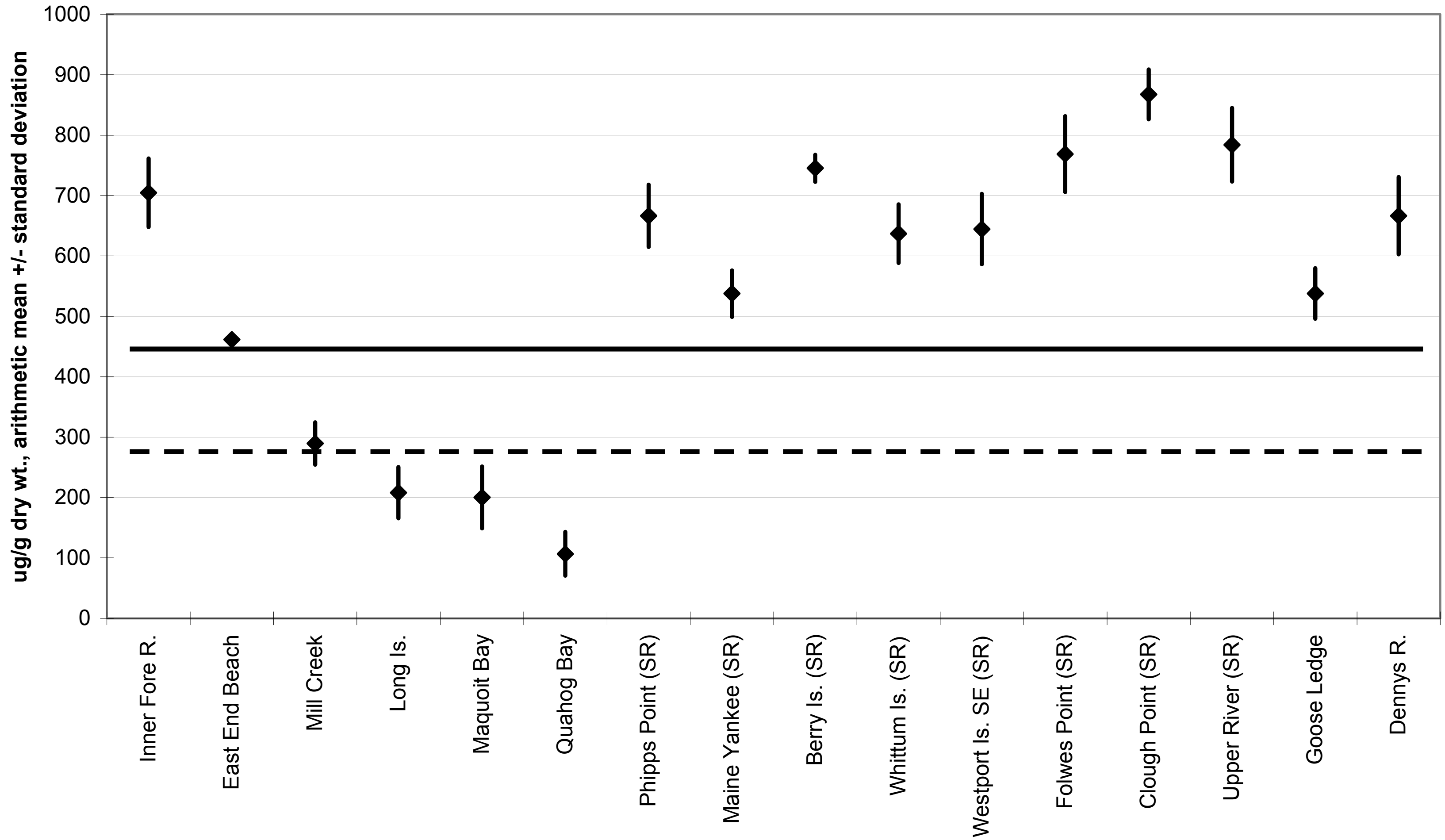
Dashed line = 2008 Gulfwatch Median; Solid line = Gulfwatch 85th Percentile.

Figure 1.1.3.1.6.2: Iron in 2009 SWAT Blue Mussels



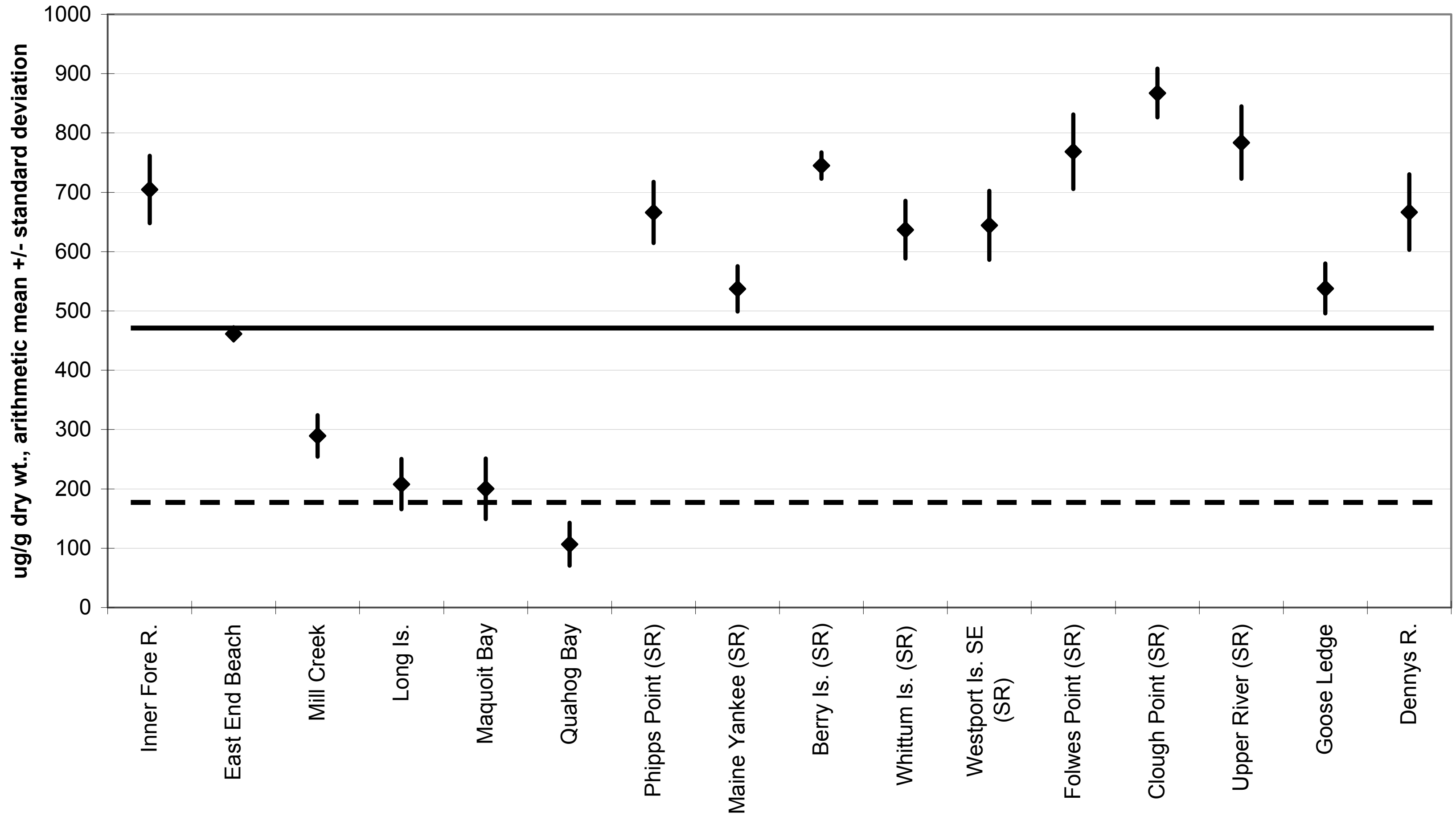
Dashed line = 2008 National Status and Trends Median; Solid line = National Status and Trends 85th Percentile.

Figure 1.1.3.1.6.3: Aluminum in 2009 SWAT Blue Mussels



Dashed line = 2008 Gulfwatch Median; Solid line = 2008 Gulfwatch 85th Percentile.

Figure 1.1.3.1.6.4: Aluminum in 2009 SWAT Blue Mussels



Dashed line = 2008 National Status and Trends Median; Solid line = 2008 National Status and Trends 85th Percentile.

Monitoring for iron and aluminum provides an important reference to gauge sediment intake by mussels, allowing iron and aluminum levels to be referenced if other more toxic metals or contaminants are detected in mussel tissue. If iron and aluminum concentrations are high, it is likely that a fraction of the contaminant load can be traced back to high sediment intake with some contamination coming from sediment in mussels gut contents, rather than bioaccumulated contaminants from mussel tissue.

From a human health perspective, MCDC does not report FTALs for iron and aluminum.

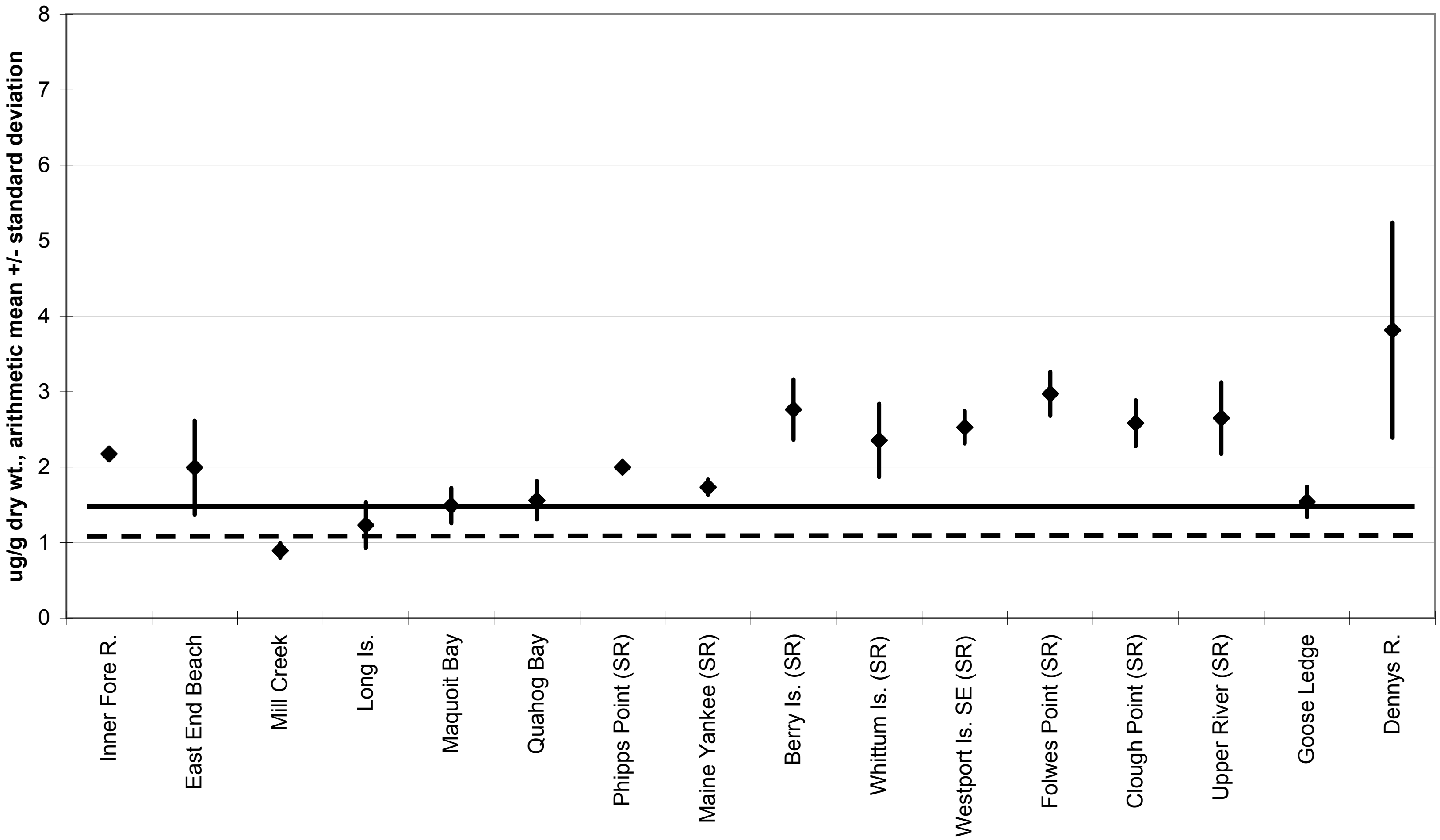
<u>1.1.3.1.7 Nickel (Ni)</u>
Nickel was detected at all 16 SWAT blue mussel sites visited in 2009. Nickel levels detected in mussels ranged from a low mean concentration of 0.90 ug/g dry wt. at Mill Creek, Falmouth to a high mean concentration of 3.81 ug/g dry wt. at Dennys River, Dennysville (Figure 1.1.3.1.7.1). Maine concentrations were generally higher than the Gulfwatch median, with 15 of 16 sites falling above the Gulfwatch 2008 median concentration. Of the 16 SWAT sites, 13 had nickel concentrations which exceeded the Gulfwatch 85^{th} percentile.

Figure 1.1.3.1.7.2 compares 2009 SWAT blue mussel tissue nickel concentrations to NS&T national median and national 85^{th} percentiles to place Maine data into a national context. Maine SWAT sites had nickel concentrations distributed about the national median, with eight sites exceeding the median, six sites below the median, and two sites approximating the national median concentration (Kimbrough, 2008). No 2009 SWAT nickel concentrations exceeded the NS&T national 85^{th} percentile, and so no SWAT sites were considered to be elevated. Higher nickel concentrations are probably associated with sediment ingestion, similar to iron and aluminum concentrations. The higher nickel concentrations in the 2009 SWAT sites were also found at the same sites having higher iron and aluminum concentrations. These sites were Inner Fore River, Portland; the eight Sheepscot River sites; and Dennys River, Dennysville.

Nickel occurs naturally in the environment and is an essential trace element to biological processes. Nickel from soil and weathering of rocks enters rivers and provides the largest source of nickel to coastal waters. Nickel occurs in stainless steel, nickel-cadmium batteries, pigments, computers, wire, coins, and is used in electroplating. Heightened nickel concentrations occur in the Great Lakes and speculation about sources centers on air deposition from a large nickel smelting operation in Ontario, Canada (Kimbrough, 2008).

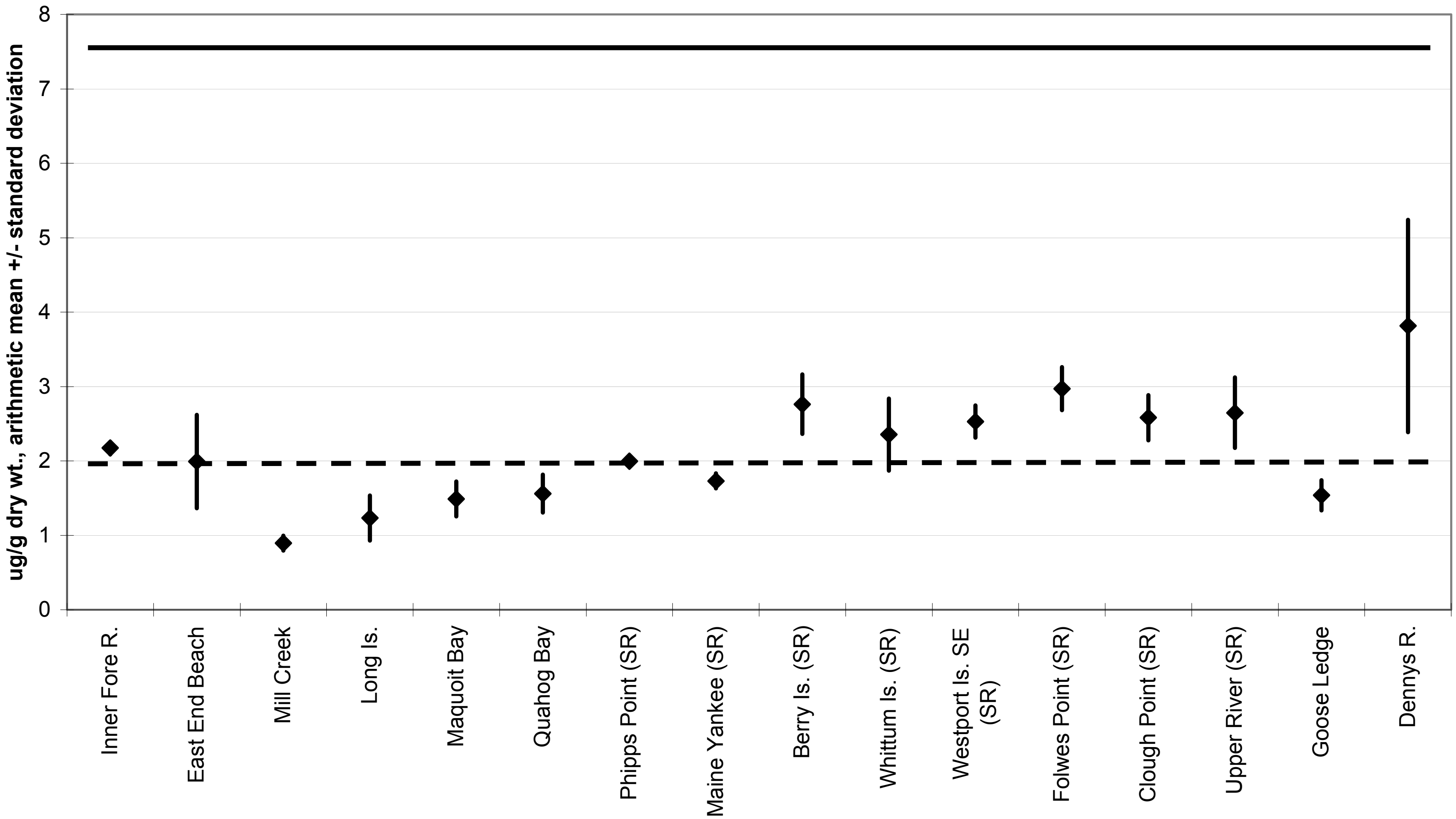
Nickel is not thought to bioaccumulate in the food chain, however nickel can be harmful to humans in large doses, inducing effects including bronchitis and even cancer from long term exposure (Kimbrough, 2008). The MCDC reports a non-cancer FTAL for nickel in non-commercially caught finfish of 43 ug/g wet weight (ppm), which is more conservative than the FDA action level for shellfish of 80 ug/g wet weight (ppm). The maximum mean concentration detected by SWAT in 2009 of 0.32 ug/g wet wt. (ppm) at Dennys River, Dennyville, is two orders of magnitude below the more conservative MCDC action level. MCDC does not report a cancer action level for nickel.

FIGURE 1.1.3.1.7.1: Nickel in 2009 SWAT Blue Mussels



Dashed line = 2008 Gulfwatch Median; Solid line = 2008 Gulfwatch 85th Percentile.

FIGURE 1.1.3.1.7.2: Nickel in 2009 SWAT Blue Mussels



Dashed line = 2008 National Status and Trends Median; Solid line = 2008 National Status and Trends 85th Percentile.

1.1.3.1.8 Lead (Pb)

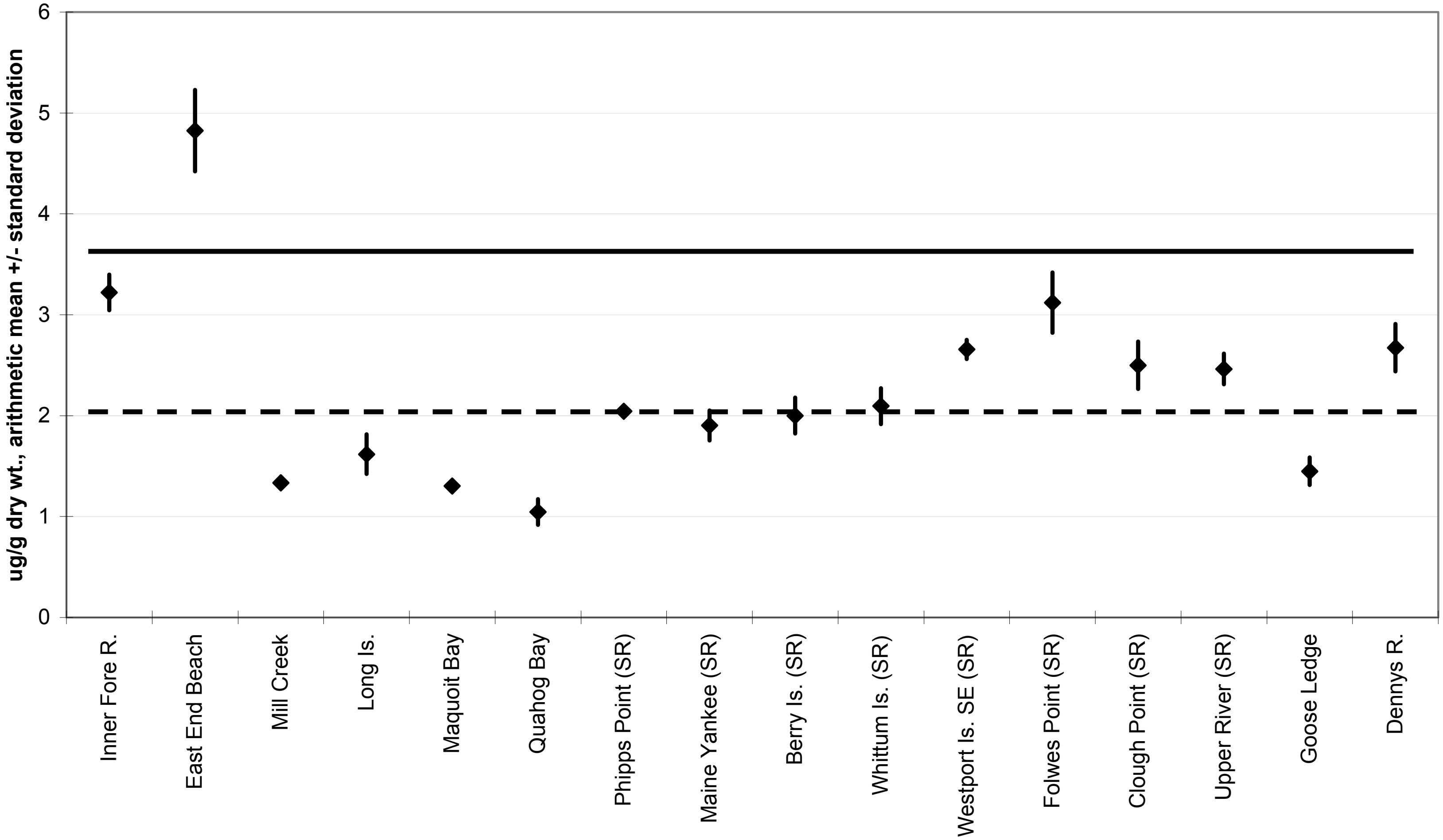
Lead was detected in all 16 SWAT blue mussel sites visited in 2009. Lead levels detected in mussels ranged from a low mean concentration of 1.04 ug/g dry wt. at Quahog Bay, Harpswell to a high mean concentration of 4.83 ug/g dry wt. at East End Beach, Portland (Figure 1.1.3.1.8.1). SWAT blue mussel tissue lead concentrations were well distributed about the Gulfwatch median, with seven sites below, seven sites above, and two sites closely replicating the Gulfwatch median. One SWAT site tested in 2009, East End Beach, Portland, exceeded the Gulfwatch 85th percentile.

Figure 1.1.3.1.8.2 compares 2009 SWAT blue mussel lead tissue concentrations to NS&T national median and national 85th percentiles to place Maine data into a national context. All Maine SWAT sites exceeded the NS&T national median, with five SWAT sites exceeding the NS&T national 85th percentile. These five SWAT sites, which exceeded the national 85th percentile for lead of 2.61 ug/g dry wt. (2008 NS&T data, latest available), are considered elevated in lead based on criteria in the SWAT and Gulfwatch programs. As we noted from a Gulf of Maine perspective, 2009 SWAT lead scores were typical of recent Gulfwatch lead scores, with the exception of East End Beach, Portland. East End Beach is just off the sewage treatment facility for Portland, which is the largest city in Maine. Blue mussel tissue lead levels are generally somewhat higher at many Gulf of Maine sites when compared to the NS&T national median. Maine sites were comparable to Gulf of Maine concentrations (medians of 1.3 to 2.6 ug/g dry wt., 2003-06) from Gulfwatch (Krahforst, 2009) and the more recent 2008 Gulfwatch median of 2.09 ug/g dry wt. (LeBlanc, 2009). Prior samples from Maine sites with elevated lead levels suggest that concentrations are not increasing but have been relatively stable at these sites.

Lead occurs naturally in the earth's crust, however, global lead concentrations in the environmental have increased in the last century due to the use of leaded gasoline. Reduction in lead loading through regulation of leaded gasoline and lead paints has occurred in recent decades. Elevated lead levels in the environment occur due to manufacturing, paints, lead solder, ammunition, plumbing, incineration and burning of fossil fuels. Lead loading in coastal waters is related to wastewater discharge, river runoff, atmospheric deposition, and natural weathering of crustal rock (Kimbrough, 2008).

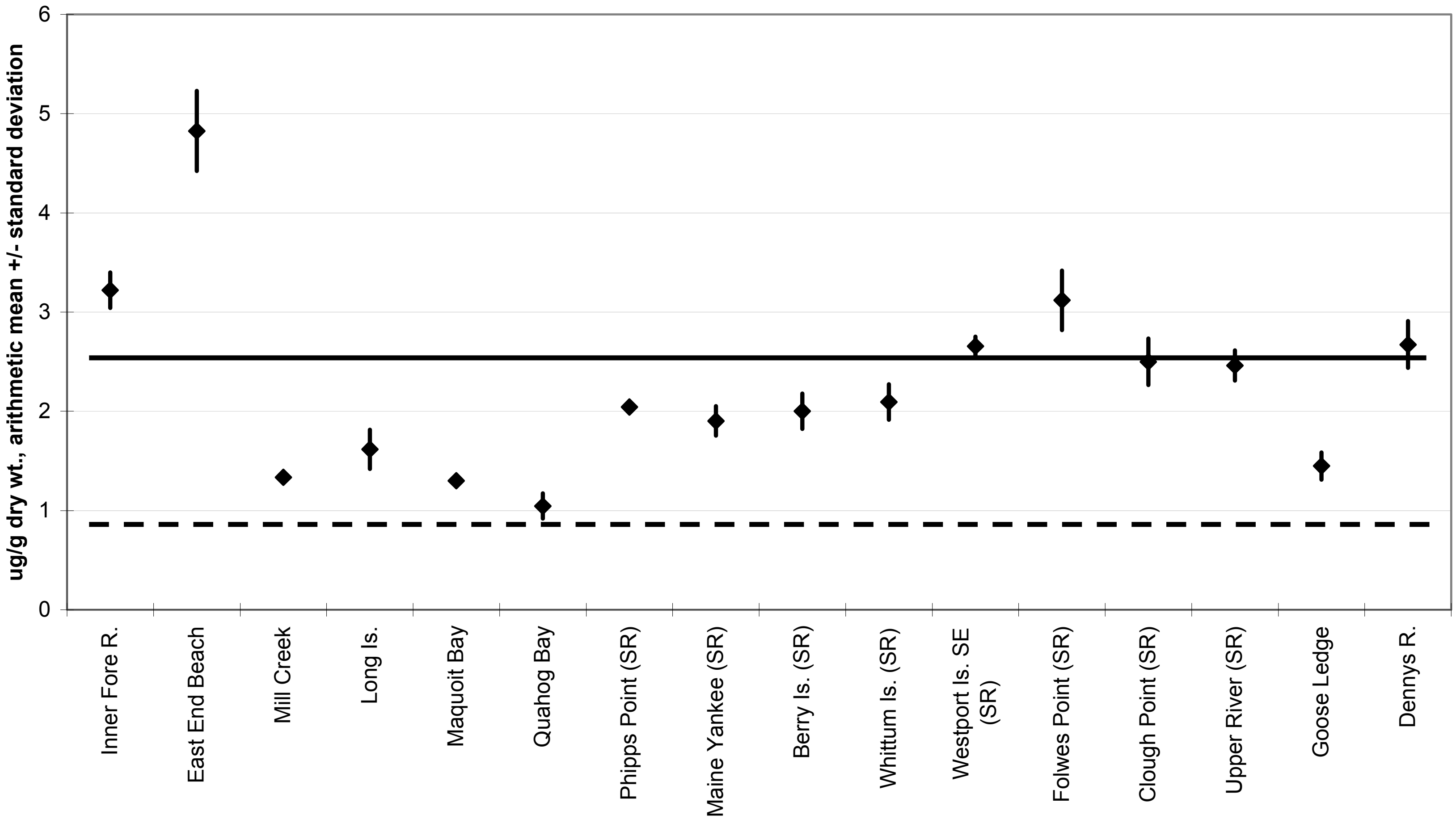
From a human health perspective, the FDA action level for lead in clams, oysters, and mussels is 1.7 ug/g wet wt. (ppm) (Kimbrough, 2008). The more conservative MCDC lead FTAL in non-commercially caught sportfish is 0.6 ug/g wet wt. (ppm), which is based on blood lead concentration model. The highest mean concentration in the 2009 Maine SWAT data, 0.83 ppm (ug/g) wet wt. at East End Beach, Portland, exceeds the MCDC lead FTAL. It is the only 2009 SWAT site that exceeds the MCDC FTAL for lead.

Figure 1.1.3.1.8.1: Lead in 2009 SWAT Blue Mussels



Dashed line = 2008 Gulfwatch Median; Solid line = 2008 Gulfwatch 85th Percentile.

Figure 1.1.3.1.8.2: Lead in 2009 SWAT Blue Mussels



Dashed line = 2008 National Status and Trends Median; Solid line = 2008 National Status and Trends 85th Percentile.

Review of the 2007-09 SWAT blue mussel sampling data from 42 sites indicates that mean lead concentrations at eight sites equaled or exceeded the MCDC lead FTAL, including the 2009 site mentioned previously. Sites equaling or exceeding the MCDC FTAL for lead are:

Spring Point, S. Portland, 2007	0.6 ppm wet wt.
Middle Fore R., Portland, 2007	0.6 ppm wet wt.
East End Beach, Portland, 2007	0.8 ppm wet wt.
Crockett Point, Rockland, 2007	1.1 ppm wet wt.
Camden Harbor, Camden, 2007	0.7 ppm wet wt.
Goose Falls, Brooksville, 2007	1.1 ppm wet wt.
Piscataqua River Back Channel, Kittery, 2008	0.6 ppm wet wt.
East End Beach, Portland, 2009	0.8 ppm wet wt.

The MCDC lead FTAL is based on the consumer eating an 8 oz. meal. Maine SWAT data indicates that an 8 oz. meal would include approximately 45-50 blue mussels of the size tested by the program.

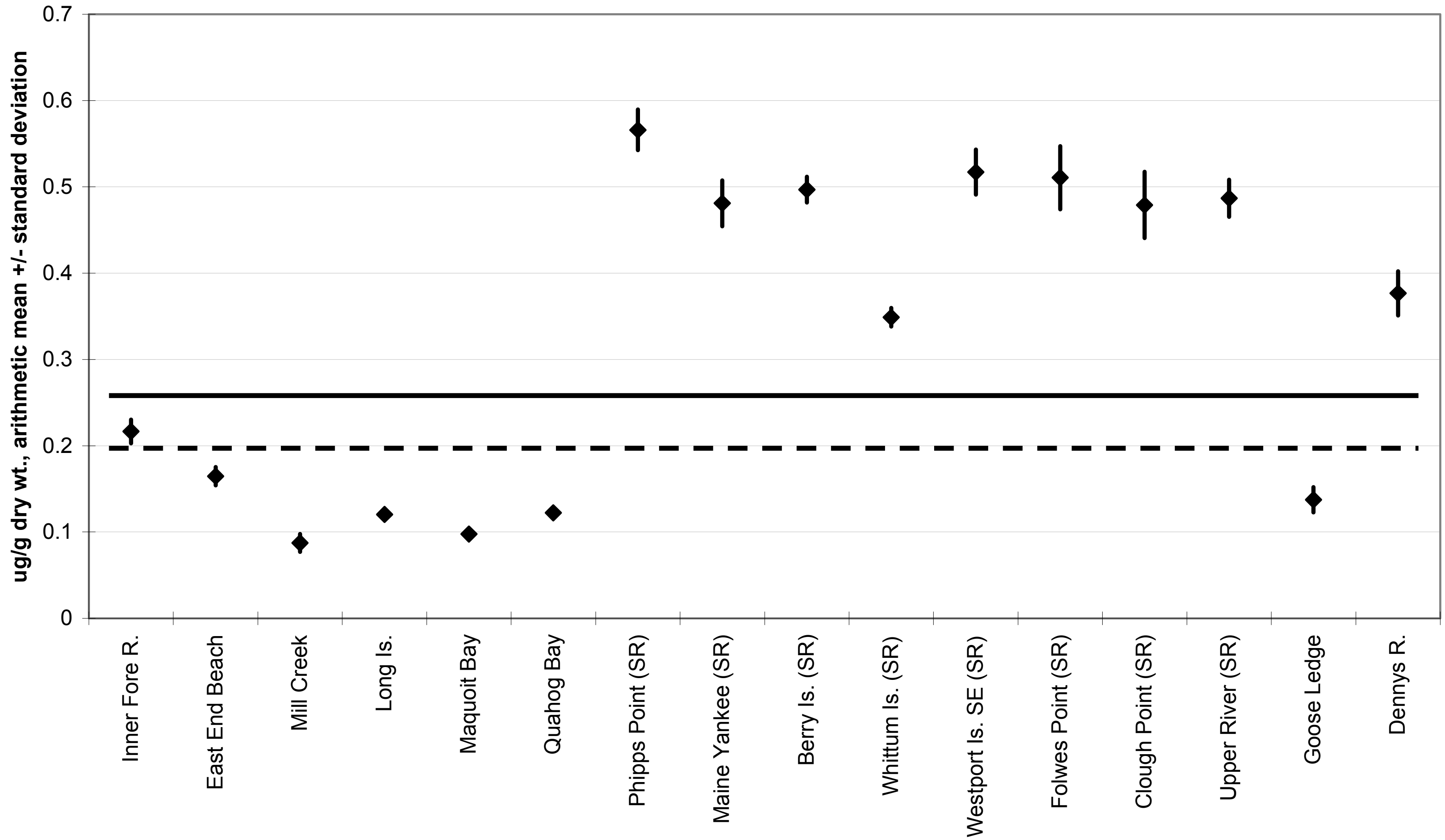
1.1.3.1.9 Mercury (Hg)

Mercury was detected in all 16 blue mussel sample locations visited in 2009. Mercury levels detected in mussels ranged from a low mean concentration of 0.087 µg/g dry wt. at Mill Creek, Falmouth to a high mean concentration of 0.566 µg/g dry wt. at Phipps Point, Woolwich, in the Sheepscot River (Figure 1.1.3.1.9.1). Of the eight SWAT sites located outside the Sheepscot River in 2009, only two exceeded the 2008 Gulfwatch median, with one site (Dennys River, Dennysville) exceeding the Gulfwatch 85^{th} percentile.

Due to a high mercury score at one site in the Sheepscot River in 2007 SWAT sampling, revisiting the Sheepscot was a priority in 2009 specifically to look at mercury levels in a broader geographic area within the Sheepscot Estuary. Mean mercury concentrations in blue mussel tissue at SWAT sites sampled in the Sheepscot in 2009 were higher than other 2009 sampling sites on the whole, with all eight Sheepscot mussel tissue mercury concentrations exceeding both the 2008 Gulfwatch median and 2008 Gulfwatch 85^{th} percentile.

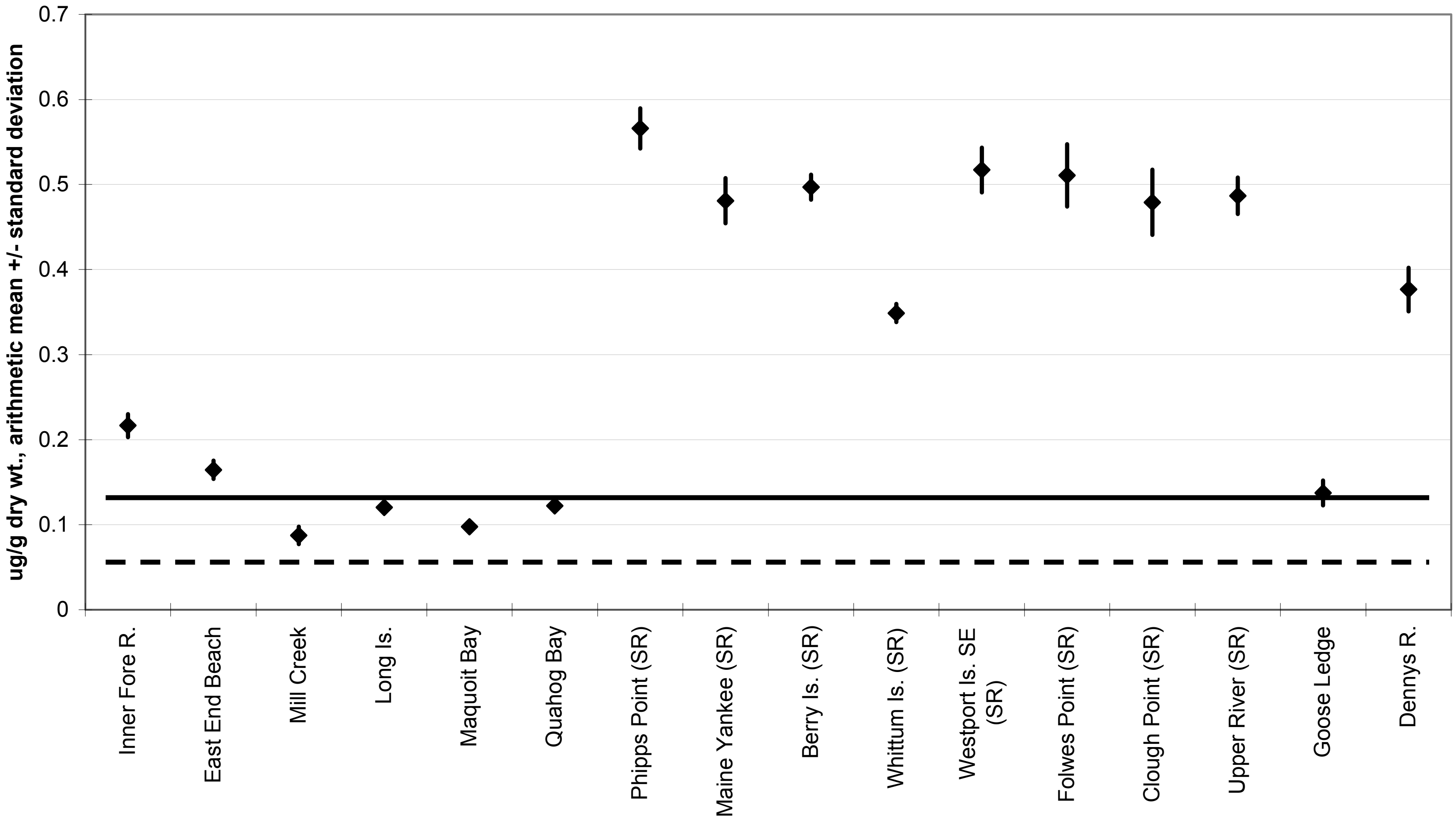
Figure 1.1.3.1.9.2 compares 2009 SWAT blue mussel mercury concentrations to NS&T Mussel Watch national median and 85^{th} percentile values. First, the reader should note that Gulfwatch median and 85^{th} percentile values actually exceed NS&T Mussel Watch median and 85^{th} percentile values, respectively, since the northeastern US has relatively high mercury levels due to air deposition of mercury from a wide range of sources in the US. Maine SWAT mercury values will appear even higher when compared to national values than when compared to regional Gulfwatch values. Figure 1.1.3.1.9.2 demonstrates this, with all 16 2009 SWAT sites exceeding the NS&T Mussel Watch national median, and 12 sites exceeding the NS&T Mussel Watch national 85^{th}

Figure 1.1.3.1.9.1: Mercury in 2009 SWAT Blue Mussels



Dashed line = 2008 Gulfwatch Median; Solid line = 2008 Gulfwatch 85th Percentile.

Figure 1.1.3.1.9.2: Mercury in 2009 SWAT Blue Mussels



Dashed line = 2008 National Status and Trends Median; Solid line = 2008 National Status and Trends 85th Percentile.

percentile. The eight Sheepscot sites might have been expected to be higher than a wider selection of Maine sites, since they were targeted specifically to observe mercury concentrations nearby the 2007 mercury hit at a SWAT site in the Sheepscot.

During previous sampling in the Sheepscot in 2007, SWAT sampled a site listed as Sheepscot River, Clough Point. This tissue concentration (0.443 ug/g dry wt.), which exceeded the then most recent 2006 Gulfwatch 85^{th} percentile (.280 µg/g, dry wt.), prompted larger scale sampling in the Sheepscot in 2009 as noted above. Due to a shortage of suitably sized mussels at Clough Point in 2007, additional mussels were collected as close to the Clough Point site as was possible for the field crew, making the Clough Point site representative of a broader area including Clough Point but also what was sampled in 2009 as Upper River, Sheepscot River. This should be noted by the reader, but mercury concentrations obtained at the two locations separately in 2009 and integrated across the two locations in 2007 (into one Clough Point sample) appear to be quite consistent. In comparison to the 2007 value of 0.443 ug/g dry wt. at Clough Point, the 2009 values (0.479/Clough Pt. and 0.4868/Upper River) are very similar.

Figure 1.1.3.1.9.3 shows the eight blue mussel sites within the Sheepscot estuary sampled in 2009, plus one site (Goose Ledge, Damariscotta River) also sampled in 2009 in the next river estuary to the east. The Goose Ledge, Damariscotta River site has a mean tissue mercury concentration of 0.137 ug/g dry wt., which was within the lower end of 2009 SWAT site concentrations and below the Gulfwatch median, as we saw in Figure 1.1.3.1.9.1. Figure 1.1.3.1.9.3 also shows the relatively higher mean tissue mercury levels in the eight SWAT blue mussel sites within Sheepscot estuary, with the lowest mean tissue concentration within the Sheepscot occurring at the most southerly, or seaward site, Whittum Island (0.349 ug/g dry wt.). The seven Sheepscot sites north of Whittum Island show higher tissue concentrations of mercury, with the northern four showing comparatively moderate levels, and the southern three showing comparatively highest levels. As noted above, the lowest tissue mercury concentration of these nine sites occurs out of the Sheepscot estuary at Goose Ledge on the adjacent Damariscotta River estuary.

Mercury occurs naturally in the environment, however elevated levels are associated with anthropogenic sources. United States sources of mercury to the air include coal fired electrical power generation, incinerators, mining, landfills, and sewage sludge (Kimbrough, 2008). In the Sheepscot estuary environs, there is a historic coal fired electrical power generation station in Wiscasset, Maine, which is located between the two most northerly red dots in the Sheepscot estuary in Figure 1.1.3.1.9.3. This plant was eventually converted to oil, and is now off line. This plant could have contributed to the higher mercury tissue levels observed in the Sheepscot estuary. This hypothesis is not disproved by the moderate tissue level at Whittum Island further south (and within the Sheepscot) and the lowest level out of the Sheepscot estuary and in the Damariscotta, but nearby to the northeast.

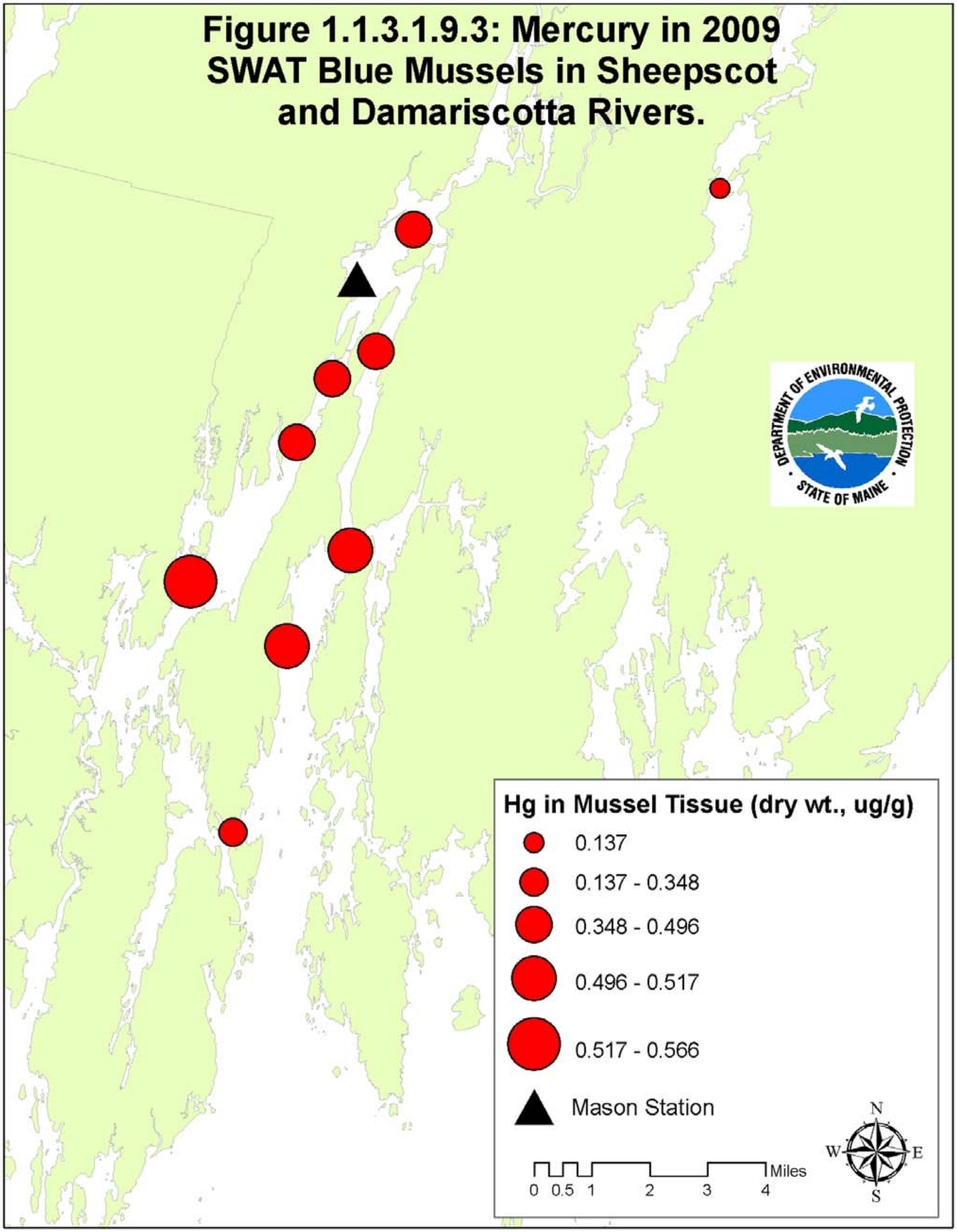


Figure 1.1.3.1.9.3: Mercury in 2009
SWAT Blue Mussels in Sheepscot
and Damariscotta Rivers.
DEPARTMENT OF ENVIRONMENTAL PROTECTION
STATE OF MAINE
Hg in Mussel Tissue (dry wt., ug/g)
0.137
0.137 - 0.348
0.348 - 0.496
0.496 - 0.517
0.517 - 0.566
Mason Station
N
W
E
S
0 0.5 1 2 3 4
Miles

From a human health perspective, the developmental methylmercury FTAL (more protective) used by the MCDC is 0.2 ug/g (ppm) wet wt. for non-commercially caught finfish (fish filet). This FTAL assumes an 8 oz. meal size is consumed weekly. Maine SWAT data uses a total mercury value, which is a more complete measure of mercury than the methylmercury concentration, but includes this more toxic form. Total mercury is therefore a more protective measurement than methylmercury. The highest mean blue mussel total tissue mercury concentration measured in blue mussels in Maine in 2009 was a mean of 0.071 µg/g wet wt. (ppm) at Phipps Point, Woolwich, in the Sheepscot River. This compares favorably with the MCDC methylmercury developmental FTAL of 0.2 ppm, assuming a similar meal size and frequency. To consume approximately 8 oz. of blue mussel tissue the consumer would need to eat approximately 45-50 blue mussels based on the mean mass per mussel collected in the Sheepscot River.

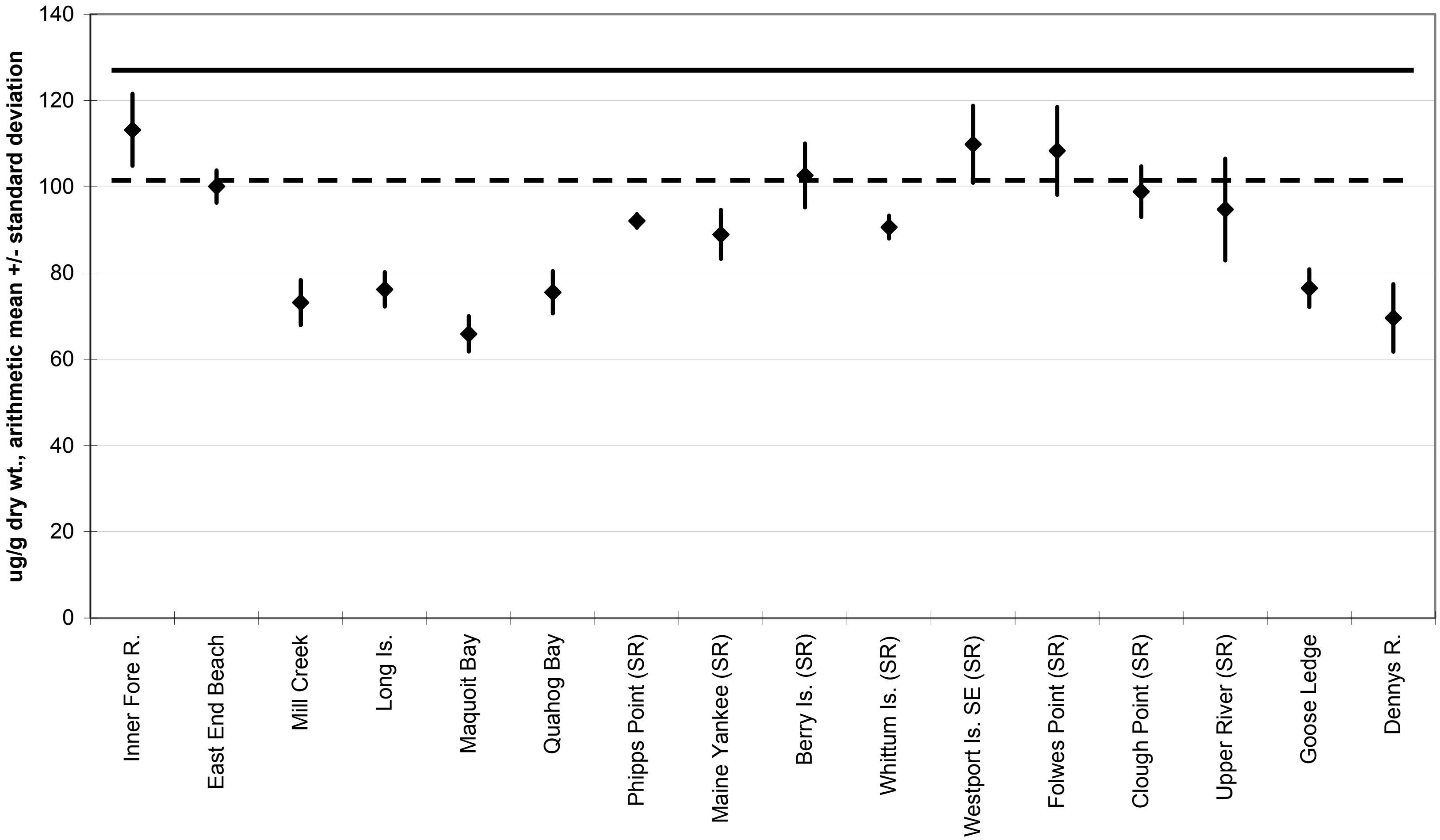
1.1.3.1.10 Zinc (Zn)

Zinc was detected in all 16 sample locations visited in 2009. Zinc levels detected in mussels ranged from a low mean concentration of 65.89 ug/g dry wt. at Maquoit Bay, Harpswell, to a high mean concentration of 113.22 ug/g dry wt. at Inner Fore River, Portland (Figure 1.1.3.1.10.1). SWAT blue mussel tissue zinc concentrations were comparable to the 2008 Gulfwatch median, with 12 sites below the Gulfwatch median and four sites above. No 2009 Maine SWAT sites showed zinc concentrations which exceeded the Gulfwatch 85^{th} percentile.

Figure 1.1.3.1.10.2 shows 2009 Maine SWAT blue mussel zinc concentrations were all below the NS&T Mussel Watch national median, and so it follows that all SWAT concentrations also fell below the NS&T 85^{th} percentile.

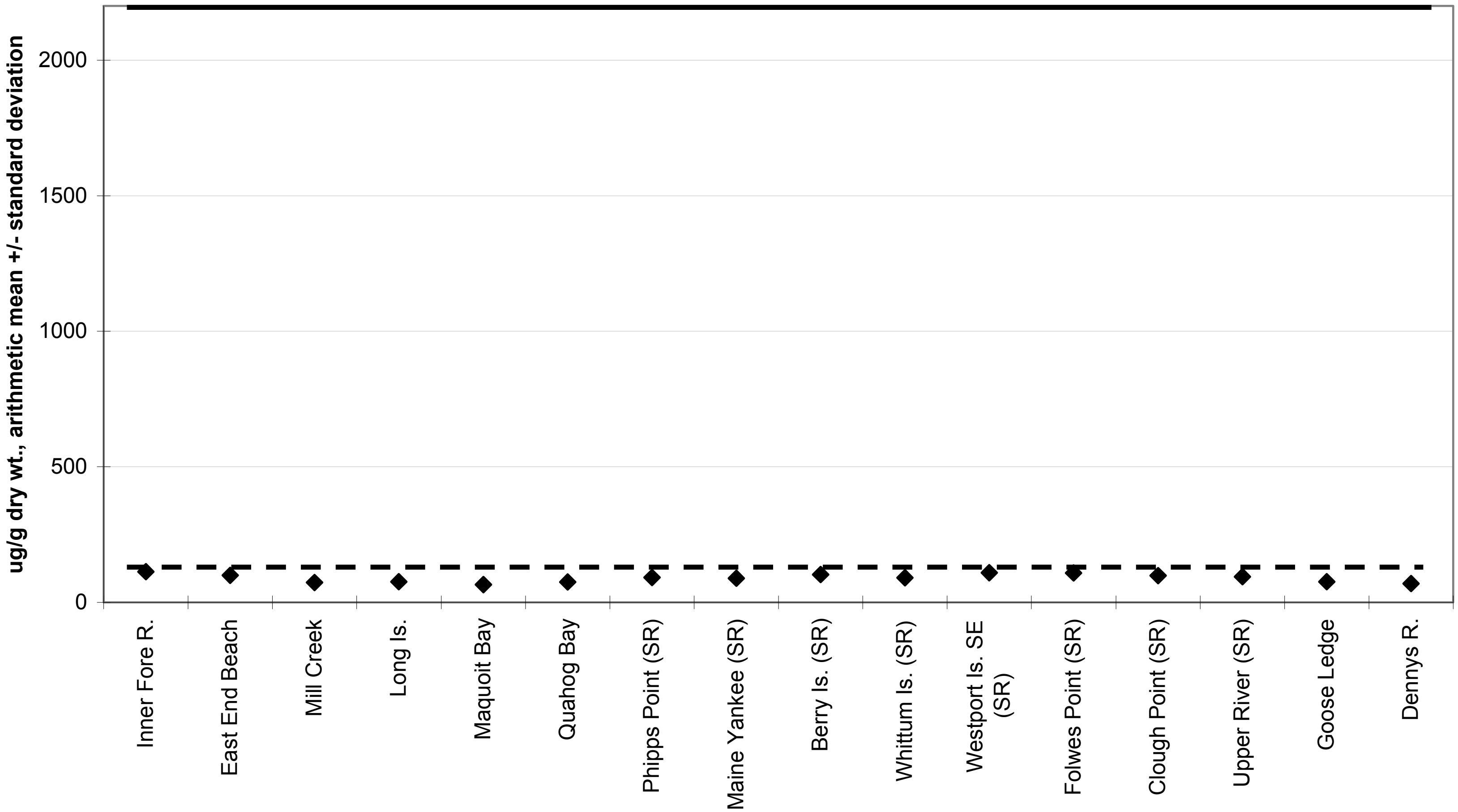
Zinc is a widespread in its distribution but elevated levels primarily originate from a variety of human activities including vehicle tire wear, electroplating and galvanized metals, industrial wastes, and drainage from mining (Kimbrough, 2008). Though an essential nutrient at low levels, higher doses to humans can cause anemia or pancreatic and kidney damage. Since humans do not bioaccumulate zinc, health impacts are normally associated with high doses. From a human health perspective, MCDC reports a non-cancer FTAL for zinc of 648 ug/g wet wt. (ppm), which is higher than any wet wt. concentrations observed in SWAT blue mussel tissue. There is no recommended FDA safety level for zinc in fish (Kimbrough, 2008).

Figure 1.1.3.1.10.1: Zinc in 2009 SWAT Blue Mussels



Dashed line = 2008 Gulwatch Median; Solid line = 2008 Gulfwatch 85th Percentile.

Figure 1.1.3.1.10.2: Zinc in 2009 SWAT Blue Mussels



Dashed line = 2008 National Status and Trends Median; Solid line = 2008 National Status and Trends 85th Percentile.

1.1.3.2 PAHs

Blue mussels were tested for PAHs from 13 sites in 2007, 13 sites in 2008, and 16 sites in 2009. Analysis of PAH blue mussel tissue data results for 2007-08 were not included in the previous SWAT report in 2008 and are included in this report.

Mussel tissue samples collected in 2007, 2008, and 2009 were analyzed by AXYS Analytical Services Ltd., Sidney, British Columbia. Mussel tissue samples were analyzed for PAHs using modified EPA Method 8270/1625. Results were compared to national (NOAA National Status & Trends, see Kimbrough, 2008) and Gulf of Maine (Gulfwatch, see LeBlanc, 2009) blue mussel monitoring program data (when available) in an effort to place Maine SWAT data in a national and regional context.

The National Status and Trends and the Gulfwatch programs utilize a subset of PAHs, summing results from 19, 24 and 40 individual PAHs to construct groups of PAHs, to look at overall PAH concentrations and to compare regional and national concentrations. This report utilizes the Maine SWAT blue mussel tissue PAH data generated by AXYS Analytical, which includes 74 individual and summed alkylated PAHs for 2009. To compare Maine results to the NS&T and Gulfwatch lists of 19 unsubstituted (non-alkylated) PAHs, this report sums 18 unsubstituted (non-alkylated) PAHs from 2009 SWAT data. The difference in one PAH counted is because SWAT results include BENZO[B,J,K]FLUORANTHENES, while the Gulfwatch and National Status and Trends results include both BENZO[B]FLUORANTHENES and BENZO[K]FLUORANTHENES individually. This slight difference is not considered to be important in comparing overall summary concentrations of PAHS for purposes of this report. Though the sum of 18 PAHs in SWAT and 19 PAHs in NS&T/Gulfwatch are not completely identical, they are as close a comparison as is possible. With some caution in data interpretation, this comparison may be used to place Maine SWAT blue mussel tissue PAH concentrations in a Gulf of Maine-wide and national perspective.

SWAT 2007-08 PAH data does not include DIBENZOTHIOPHENE which is included in the Gulfwatch and National Status and Trends summations for 19 PAHs. SWAT PAH data are presented as a sum of 17 PAHs for this reason (and due to the BENZO[B,J,K]FLUORANTHENES discrepancy noted above). However, comparison to similar Gulfwatch and National Status and Trends data is still of interest and deemed appropriate. The summation of 19 PAHs is also useful for comparison to SWAT PAH data sets prior to 2009, as previous SWAT data included only 24 individual PAHs.

With the additional PAHs provided in the SWAT results in 2009, additional comparisons to Gulfwatch and National Status and Trends data sets are possible. Both programs utilize a summation of 24 PAHs, which in addition to the 19 non-alkylated PAHs previously mentioned also includes some alkylated PAHs (C1, C2, C3 Napthalene, and C1-Phenanthrene). Due to the previously outlined difference regarding BENZO[B,J,K]FLUORANTHENES, the SWAT PAH summation used to compare to the Gulfwatch/NS&T summation of 24 PAHs actually contains 23 PAHs for SWAT.

The 2009 SWAT PAH data can also be used to generate a summation to compare to the Gulfwatch/NS&T summation of 40 PAHs, which includes even more alkylated PAHs. The corresponding SWAT data includes 38 PAHs, which is the closest approximation possible. As noted previously, one discrepancy is the BENZO[B,J,K]FLUORANTHENES issue. The second difference in the 40 PAH summation is the absence of C4-Flourenes in the SWAT data set. As a result, the SWAT summation including 38 PAHs, rather than the 40 utilized in the Gulfwatch/NS&T programs. This difference is considered to be relatively minor, and with some caution in interpretation, still allows comparison of SWAT data to regional and national data sets.

SWAT 2009 PAH data includes additional alkylated PAHs as well, with a total of 74 PAHs included. This number has also been totaled and is presented and discussed in this report as "total PAHs." Comparisons to other summations of lesser numbers of PAHs reviewed above are included to illustrate the wider data set provided by the additional level of PAH analysis obtained for SWAT sites in 2009. Alkylated PAHs are typically associated with pyrogenic sources, rather than the more petrogenic sources associated with non-alkylated PAHs.

Table 1.1.3.2.1, "Analyzed PAHs and PAH Summation Calculations" shows comparisons between Gulfwatch/NS&T summation lists, SWAT data sets from 2007-08 and 2009, and details differences between the lists with footnotes and notes in the right column of the table. It details the PAHs included in summations including 19, 24, and 40 PAHs, and includes a complete list of all PAHs for which results were obtained in 2009 (SWAT data, 74 PAHs described above).

Figure 1.1.3.2.1 shows the summation of the 19 non-alkylated PAHs compared to the summation of all 74 PAHs (including many alkylated PAHs) at the 16 blue mussel sites sampled by SWAT in 2009. Both the 19 summed non-alkylated PAHs and the total PAHs vary in a similar manner between sites, but through viewing the figure it is clear that the non-alkylated PAHs make up a small fraction of the total PAHs found at each site. The alkylated PAHs contribute the largest portion to the total PAHs, which is the difference between the two data series illustrated on the graph in the figure. The sum of 19 non-alkylated PAHs varied from 5% (Berry Island, Sheepscot R.) to 37% (Inner Fore R.) of total PAHs (74) across the 16 SWAT sites.

Total PAH concentrations ranged from a low mean concentration of 333 ng/g dry wt. at Goose Ledge, Damariscotta River to a high mean concentration of 3,961 ng/g dry wt. at Inner Fore River (Figure 1.1.3.2.1). Berry Island, Sheepscot River (2,864 ng/g dry wt.) had the second highest total PAH concentrations across the 16 sites sampled. Most sites showed low or intermediate levels of total PAHs.

The mean concentrations for the sum of 19 PAHs ranged from a low mean concentration of 30 ng/g dry wt. at Maquoit Bay to a high mean concentration of 1302 ng/g dry wt. at Inner Fore River (Figure 1.1.3.2.1). Most sites showed low or moderate levels of non-alkylated PAHs, those captured by the sum of 19 PAHs.

TABLE 1.1.3.2.1: Analyzed PAHs and PAH Summation Calculations

	SWAT			Gulfwatch, NS&T, SWAT Summations				
Parameter	2009	2007-08		Sum PAH19	Sum PAH24	Sum PAH40	Not Analyzed by Gulfwatch	Notes (See below list for more notes)
ACENAPHTHENE	x	x		x	x	x		
ACENAPHTHYLENE	x	x		x	x	x		
ANTHRACENE	x	x		x	x	x		
2-METHYLANTHRACENE	x						missing	
BENZ[A]ANTHRACENE	x	x		x	x	x		
DIBENZ(A,H)ANTHRACENE	x	x		x	x	x		
BIPHENYL	x	x		x	x	x		
BENZO[A]PYRENE	x	x		x	x	x		
BENZO(E)PYRENE	x	x		x	x	x		
7-METHYLBENZO[A]PYRENE	x						missing	
CHRYSENE	x	x		x	x	x		
1-METHYLCHRYSENE	x						missing	
5/6-METHYLCHRYSENE	x						missing	
5,9-DIMETHYLCHRYSENE	x						missing	
DIBENZOTHIOPHENE	x	1,2,3		x	x	x		
2,4-DIMETHYLDIBENZOTHIOPHENE	x						missing	
2/3-METHYLDIBENZOTHIOPHENES	x						missing	
FLUORANTHENE	x	x		x	x	x		
BENZO[B,J,K]FLUORANTHENES	x	x		x	x	x		in Gulfwatch list as BENZO[B]FLUORANTHENE and BENZO[K]FLUORANTHENE
3-METHYLFLUORANTHENE/BENZO[A]FLUORENE	x							
FLUORENE	x	x		x	x	x		
2-METHYLFLUORENE	x						missing	
1,7-DIMETHYLFLUORENE	x						missing	

TABLE 1.1.3.2.1: Analyzed PAHs and PAH Summation Calculations (continued)

Parameter	SWAT 2009	2007-08		Gulfwatch, NS&T, SWAT Summations Sum PAH19	Sum PAH24	Sum PAH40	Not Analyzed by Gulfwatch	Notes (See below list for more notes)
NAPHTHALENE	x	x		x	x	x		
1-METHYLNAPHTHALENE	x	x					missing	
2-METHYLNAPHTHALENE	x	x					missing	
1,2-DIMETHYLNAPHTHALENE	x						missing	
2,6-DIMETHYLNAPHTHALENE	x	x					missing	
2,3,5-TRIMETHYLNAPHTHALENE	x	x					missing	
2,3,6-TRIMETHYLNAPHTHALENE	x						missing	
1,4,6,7-TETRAMETHYLNAPHTHALENE	x						missing	
PERYLENE	x	x			x	x		
BENZO[GHI]PERYLENE	x	x		x	x	x		
PHENANTHRENE	x	x		x	x	x		
1-METHYLPHENANTHRENE	x	x					missing	
2-METHYLPHENANTHRENE	x						missing	
3-METHYLPHENANTHRENE	x						missing	
9/4-METHYLPHENANTHRENE	x						missing	
1,7-DIMETHYLPHENANTHRENE	x						missing	
1,8-DIMETHYLPHENANTHRENE	x						missing	
2,6-DIMETHYLPHENANTHRENE	x						missing	
3,6-DIMETHYLPHENANTHRENE	x						missing	
1,2,6-TRIMETHYLPHENANTHRENE	x						missing	
PYRENE	x	x		x	x	x		
INDENO[1,2,3-CD]PYRENE	x	x		x	x	x		

TABLE 1.1.3.2.1: Analyzed PAHs and PAH Summation Calculations (continued)

Parameter	SWAT 2009	SWAT 2007-08		Gulfwatch, NS&T, SWAT Summations Sum PAH19	Sum PAH24	Sum PAH40	Not Analyzed by Gulfwatch	Notes (See below list for more notes)
RETENE	x						missing	
C1-ACENAPHTHENES	x						missing	
C1-BENZO[A]ANTHRACENES/CHRYSENES	x	3				x		in Gulfwatch list as C1-CHRYSENE
C2-BENZO[A]ANTHRACENES/CHRYSENES	x	3				x		in Gulfwatch list as C2-CHRYSENE
C3-BENZO[A]ANTHRACENES/CHRYSENES	x	3				x		in Gulfwatch list as C3-CHRYSENE
C4-BENZO[A]ANTHRACENES/CHRYSENES	x	3				x		in Gulfwatch list as C4-CHRYSENE
C1-BENZOFLUORANTHENES/BENZOPYRENES	x						missing	
C2-BENZOFLUORANTHENES/BENZOPYRENES	x						missing	
C1-BIPHENYLS	x						missing	
C2-BIPHENYLS	x						missing	
C1-DIBENZOTHIOPHENES	x	3				x		
C2-DIBENZOTHIOPHENES	x	3				x		
C3-DIBENZOTHIOPHENES	x	3				x		
C4-DIBENZOTHIOPHENES	x						missing	
C1-FLUORANTHENES/PYRENES	x	3				x		
C2-FLUORANTHENES/PYRENES	x	3				x		
C3-FLUORANTHENES/PYRENES	x						missing	
C4-FLUORANTHENES/PYRENES	x						missing	
C1-FLUORENES	x	3				x		
C2-FLUORENES	x	3				x		
C3-FLUORENES	x	3				x		
C1-NAPHTHALENES	x	2,3			x	x		
C2-NAPHTHALENES	x	2,3			x	x		
C3-NAPHTHALENES	x	2,3			x	x		
C4-NAPHTHALENES	x						missing	

TABLE 1.1.3.2.1: Analyzed PAHs and PAH Summation Calculations (continued)

Parameter	SWAT 2009	SWAT 2007-08		Gulfwatch, NS&T, SWAT Summations Sum PAH19	Sum PAH24	Sum PAH40	Not Analyzed by Gulfwatch	Notes (See below list for more notes)
C1-PHENANTHRENES/ANTHRACENES	x	2,3			x	x		in Gulfwatch list as C1-PHENANTHRENE
C2-PHENANTHRENES/ANTHRACENES	x	3				x		in Gulfwatch list as C2-PHENANTHRENE
C3-PHENANTHRENES/ANTHRACENES	x	3				x		in Gulfwatch list as C3-PHENANTHRENE
C4-PHENANTHRENES/ANTHRACENES	x	3				x		in Gulfwatch list as C4-PHENANTHRENE
C4-FLUORENES		3				x		Not analyzed by SWAT

TABLE 1.1.3.2.1: Analyzed PAHs and PAH Summation Calculations (continued)

	SWAT			Gulfwatch, NS&T, SWAT Summations				
Parameter	2009	2007-08		Sum PAH19	Sum PAH24	Sum PAH40	Not Analyzed by Gulfwatch	Notes (See below list for more notes)

FOOTNOTES:

1 = Not available as used in Gulfwatch Sum 19 PAHs List

2 = Not available as used in Gulfwatch Sum 24 PAHs List

3 = Not available as used in Gulfwatch Sum 40 PAHs List

List of 'Sum PAH19' only has 18 compounds in it because we have BENZO[B]FLUORANTHENES and BENZO[K]FLUORANTHENES listed as one compound, BENZO[B,J,K]FLUORANTHENES; same applies to 'Sum PAH24' which has only 23 compounds

List of 'Sum PAH40' only has 38 compounds in it because we have BENZO[B]FLUORANTHENES and BENZO[K]FLUORANTHENES listed as one compound, BENZO[B,J,K]FLUORANTHENES and we do not have AXYS data fro C-4 FLUORENES (at bottom of above list)
In calculating the various summations, the approach used by SWAT is: Where SWAT has a slight variation from Gulfwatch in analytes, use the closest approximation to the Gulfwatch list as with the BENZO[B,J,K]FLUORANTHENES, the C1/2/3/4-BENZO[A]ANTHRACENES/CHRYSENES and the C1/2/3/4-PHENANTHRENES/ANTHRACENES (see notes column at far right above)

Figure 1.1.3.2.1: Sum of 19 Non-Alkylated PAHs and Sum of Total PAHs at 2009 SWAT Blue Mussel Sites

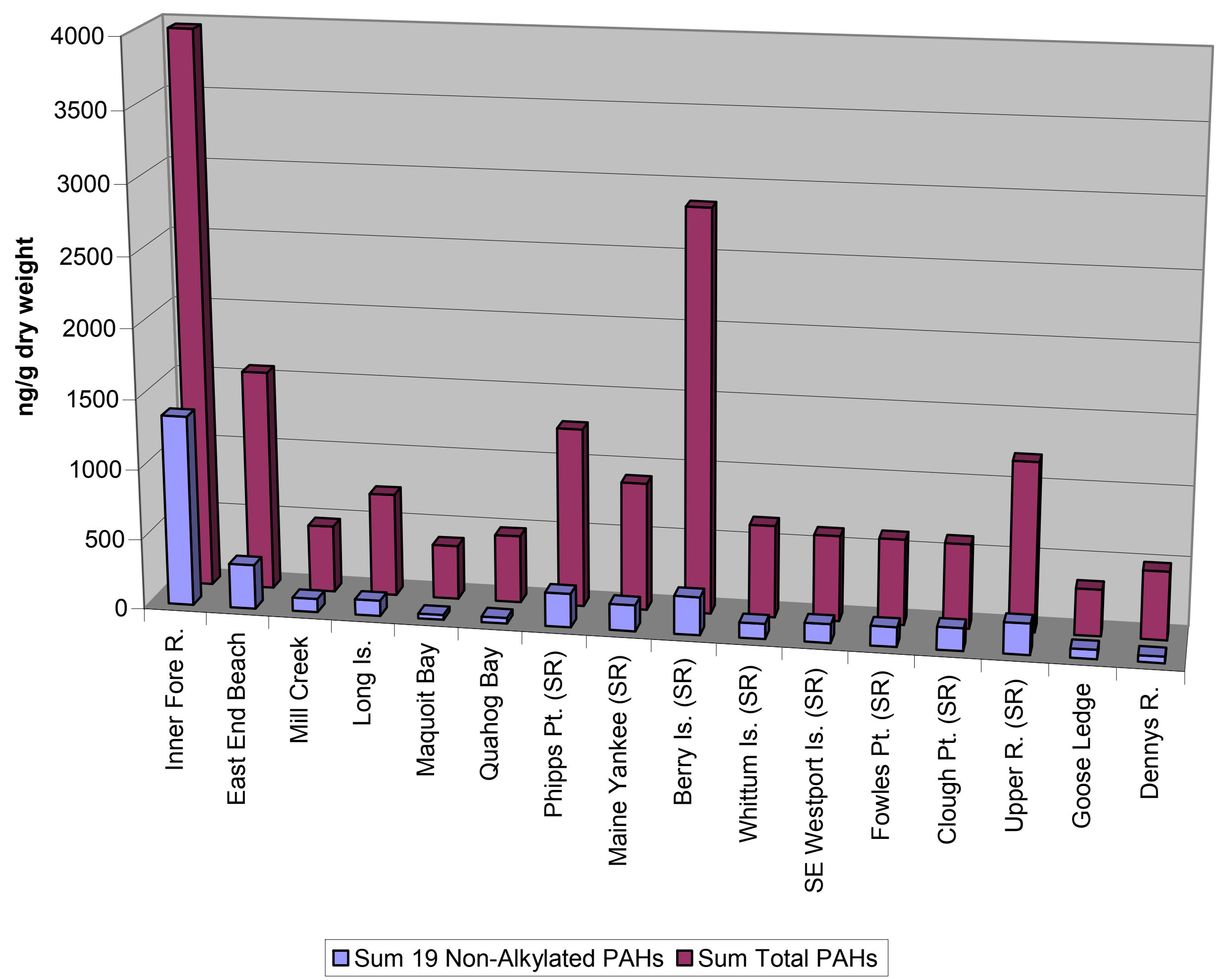


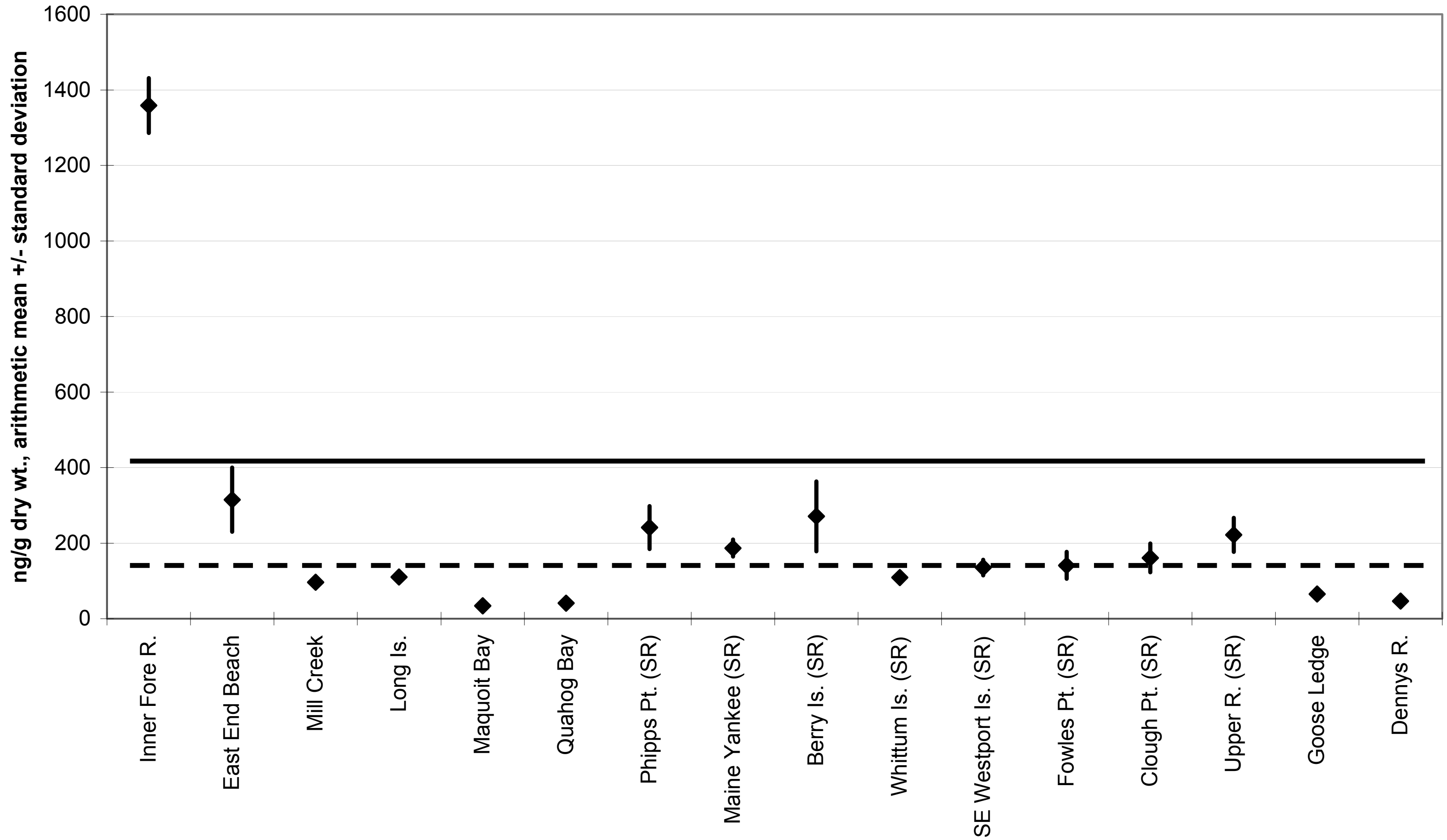
Figure 1.1.3.2.2 presents the sum of 19 PAHs across the SWAT blue mussel sites sampled in 2009, and compares these results with Gulfwatch 2008 median and 85th percentile results. Figure 1.1.3.2.2 depicts the mean concentration across four intra-station replicates as black diamonds, with standard deviation represented by the whiskers extending above and below each diamond. Of the 16 SWAT sites tested in 2009, Inner Fore R., and East End Beach (both in Portland), and Phipps Pt., Maine Yankee, Berry Is., Clough Pt., and Upper River (last five all in Sheepscot R.) are the seven sites that exceeded the Gulfwatch 2008 median of 154 ng/g (dry weight) for 19 summed PAHs. Only one site, Inner Fore River, also exceeded the Gulfwatch 85th percentile of 429 ng/g (dry weight) for 19 summed PAHs. The remaining nine SWAT sites all fell below the Gulfwatch median concentration of 154 ng/g (dry weight) for 19 summed PAHs. Despite the use of 18 summed PAHs (SWAT) to compare to 19 summer PAHs utilized in the Gulfwatch program, the summation of non-alkylated PAHs is useful for putting Maine data into a regional, Gulf of Maine context.

Figure 1.1.3.2.3 compares the sum of 19 non-alkylated PAHs at the 2009 SWAT sites to recent National Status and Trends median and 85th percentile for 19 summed non-alkylated PAHs (2008 data, the most recent available). Of the 16 SWAT sites tested in 2009, Inner Fore R., and East End Beach (Portland), Phipps Pt., Maine Yankee, Berry Is., and Upper River (all four in the Sheepscot River) are the six sites that exceeded the NS&T national 2008 median of 180 ng/g (dry weight) for 19 summed non-alkylated PAHs. Only one 2009 SWAT site (Inner Fore River, Portland)exceeded the NS&T national 85th percentile of 1,104 ng/g (dry weight) for 19 summed PAHs.

The Gulfwatch program also utilized a summation of 24 PAHs in reports, the composition of which is outlined above. SWAT data was converted into this format and when 24 PAHs were summed, 2009 SWAT mean concentrations ranged from 6% (Berry Island, Sheepscot R.) to 41% (Inner Fore R.) of total PAHs (74) across the 16 SWAT sites.

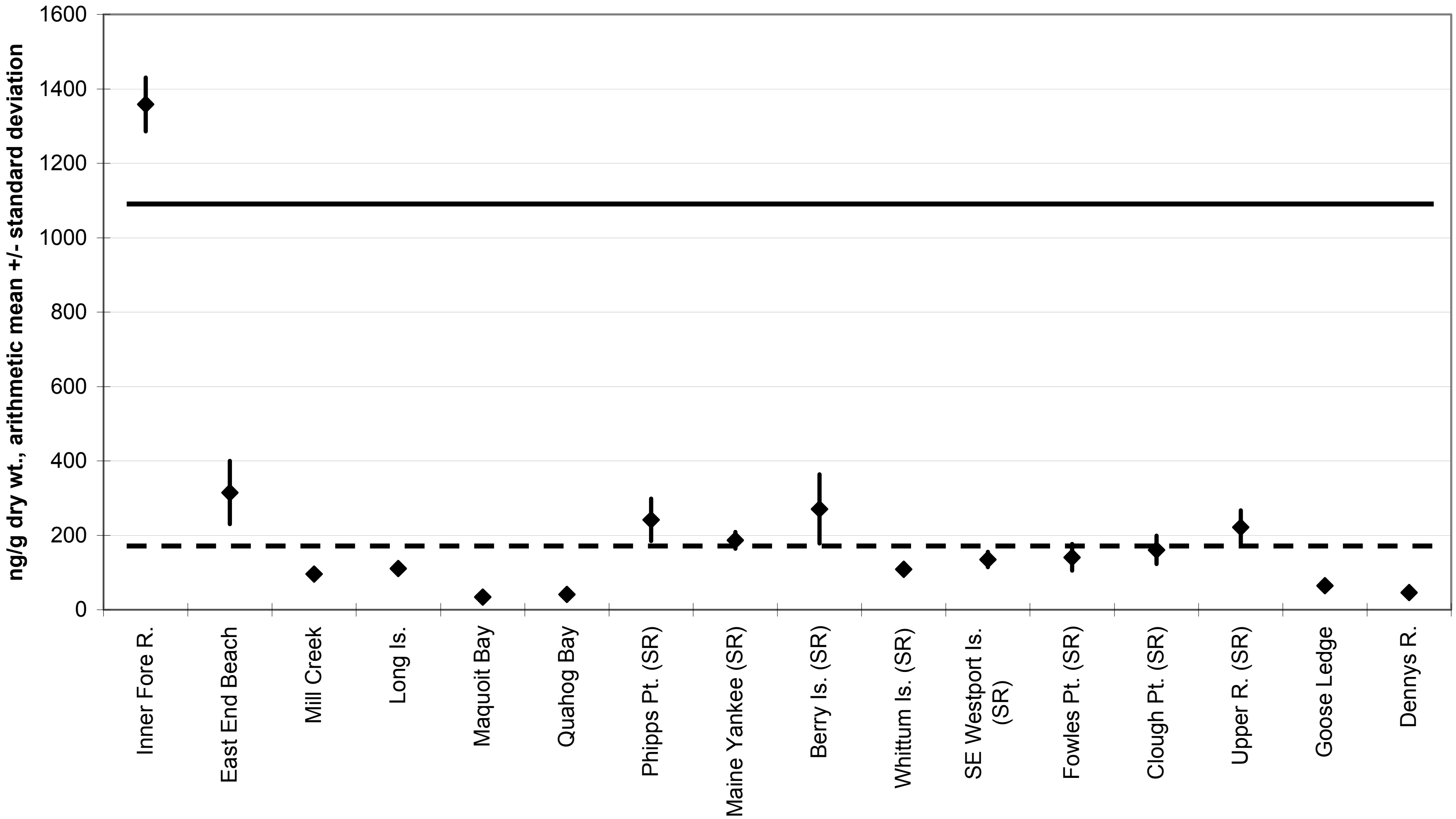
The mean concentrations for the sum of 24 PAHs ranged from a low mean concentration of 55 ng/g dry wt. at Maquoit Bay to a high mean concentration of 1,529 ng/g dry wt. at Inner Fore River (Figure 1.1.3.2.4). Figure 1.1.3.2.4 presents the sum of 24 PAHs across the SWAT blue mussel sites sampled in 2009, and compares these results with Gulfwatch 2008 median and 85th percentile results. Figure 1.1.3.2.4 depicts the mean concentration across four intra-station replicates as black diamonds, with standard deviation represented by the whiskers extending above and below each diamond. Of the 16 SWAT sites tested in 2009, Inner Fore R., and East End Beach (both in Portland), and Phipps Pt., Maine Yankee, Berry Is., and Upper River (last four all in Sheepscot R.) are the six sites that exceeded the Gulfwatch 2008 median of 198 ng/g (dry weight) for 24 summed PAHs. Only one site, Inner Fore River, also exceeded the Gulfwatch 85th percentile of 476 ng/g (dry weight) for 24 summed PAHs. The remaining ten SWAT sites all fell below the Gulfwatch median concentration of 198 ng/g (dry weight) for 24 summed PAHs. Despite

Figure 1.1.3.2.2: Sum of 19 PAHs in 2009 SWAT Blue Mussels



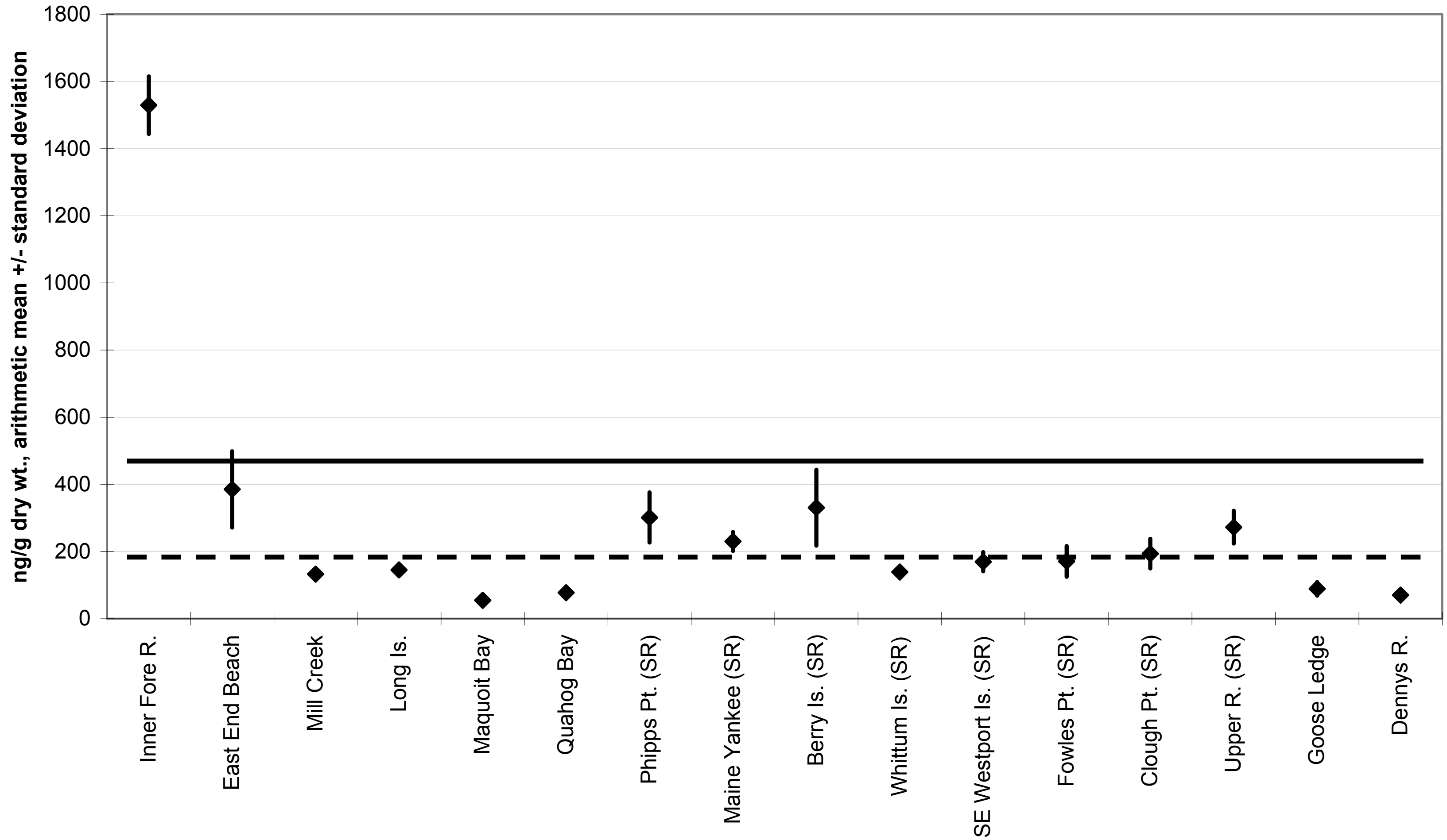
Dashed line = 2008 Gulfwatch Median (Sum 19 PAHs); Solid line = 2008 Gulfwatch 85th Percentile (Sum 19 PAHs).

Figure 1.1.3.2.3: Sum of 19 PAHs in 2009 SWAT Blue Mussels



Dashed line = 2008 National Status and Trends Median (Sum 19 PAHs); Solid line = 2008 National Status and Trends 85th Percentile (Sum 19 PAHs).

Figure 1.1.3.2.4: Sum of 24 PAHs in 2009 SWAT Blue Mussels



Dashed line = 2008 Gulfwatch Median (Sum 24 PAHs); Solid line = 2008 Gulfwatch 85th Percentile (Sum 24 PAHs).

the use of 23 summed PAHs (SWAT) to compare to 24 summed PAHs utilized in the Gulfwatch program, the summation of these PAHs is useful for putting Maine data into a regional, Gulf of Maine context.

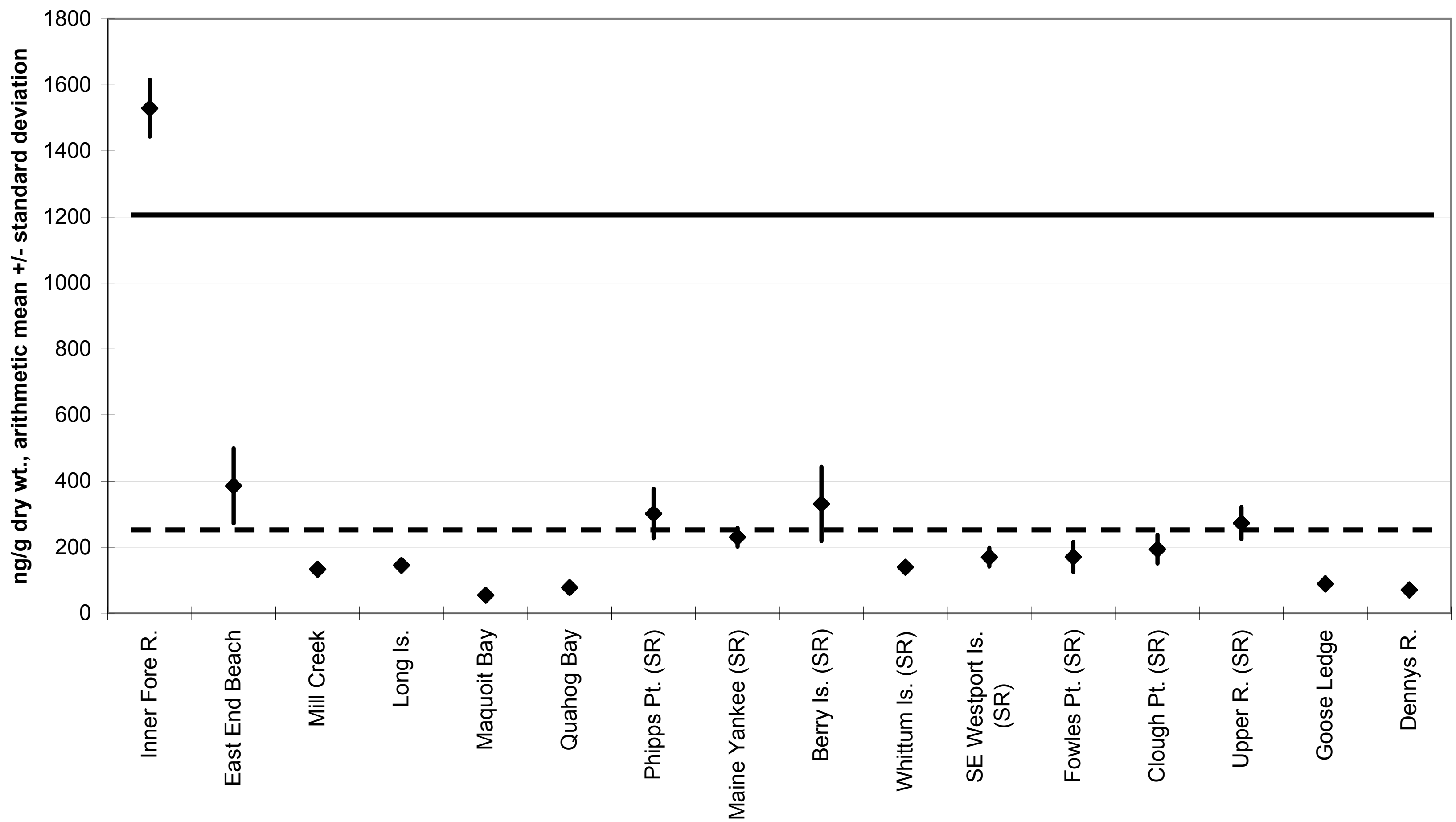
Figure 1.1.3.2.5 compares the sum of 24 PAHs at the 2009 SWAT sites to recent National Status and Trends median and 85th percentile for 24 summed PAHs (2008 data, the most recent available). Of the 16 SWAT sites tested in 2009, Inner Fore R., and East End Beach (Portland), Phipps Pt., Berry Is., and Upper River (all three in the Sheepscot River) are the five sites that exceeded the NS&T national 2008 median of 247 ng/g (dry weight) for 24 summed PAHs. Only one 2009 SWAT site (Inner Fore River, Portland) exceeded the NS&T national 85th percentile of 1,216 ng/g (dry weight) for 24 summed PAHs. As figure 1.1.3.2.5 shows, mean concentrations as most 2009 SWAT sites ranged mostly below or approximately around the NS&T national mean concentration of 247 ng/g, dry wt.

Figure 1.1.3.2.6 shows the summation of 40 PAHs compared to the summation of all 74 PAHs at the 16 blue mussel sites sampled by SWAT in 2009. Both the 40 summed PAHs and the total PAHs vary in a similar manner between sites, but through viewing the figure it is clear that the sum of the 40 PAHs makes up the bulk of the total PAHs found at each site. The sum of 40 PAHs varied from 78% (Goose Ledge, Damariscotta R.) to 88% (Berry Island, Sheepscot R.) of total PAHs (74) across the 16 SWAT sites. The mean concentrations for the sum of 40 PAHs ranged from a low mean concentration of 269 ng/g dry wt. at Goose Ledge, Damariscotta R., to a high mean concentration of 3,309 ng/g dry wt. at Inner Fore River (Figure 1.1.3.2.6).

Figure 1.1.3.2.7 presents the sum of 40 PAHs across the SWAT blue mussel sites sampled in 2009, and compares these results with Gulfwatch 2008 median and 85th percentile results. Figure 1.1.3.2.7 depicts the mean concentration across four intra-station replicates as black diamonds, with standard deviation represented by the whiskers extending above and below each diamond. Of the 16 SWAT sites tested in 2009, all 16 sites exceeded the Gulfwatch 2008 median of 260 ng/g (dry weight) for 40 summed PAHs. Six sites also exceeded the Gulfwatch 85th percentile of 618 ng/g (dry weight) for 40 summed PAHs. The differences between the SWAT list of PAHs and the Gulfwatch list of PAHs available for the sum of 40 PAHs may be part of the reason why the SWAT sum of 40 PAHs is comparably high to the Gulfwatch sum of 40 PAHs. As noted in Table 1.1.3.2.1, SWAT utilizes C1 through C4-Benzo[A]Anthracenes/Chrysenes, where Gulfwatch utilizes C1 through C4-Chrysenes. Similarly, SWAT utilizes C1 through C4-Phananthrenes/Anthracenes, where Gulfwatch utilizes C1 through C4-Phananthrenes. It is likely that the additional summations of C1 through C4-Benzo[A]Anthracenes plus C1 through C4-Anthracenes included in the SWAT data are pushing the SWAT sum of 40 PAHs higher than the exact Gulfwatch equivalents. This can not be avoided due to the makeup of the SWAT data, but should be noted when viewing the comparison in Figure 1.1.3.2.7.

Figure 1.1.3.2.8 compares the sum of 40 PAHs at the 2009 SWAT sites to recent National Status and Trends median and 85th percentile for 40 summed PAHs (2008 data,

Figure 1.1.3.2.5: Sum of 24 PAHs in 2009 SWAT Blue Mussels



Dashed line = 2008 National Status and Trends Median (Sum 24 PAHs); Solid line = 2008 National Status and Trends 85th Percentile (Sum 24 PAHs).

Figure 1.1.3.2.6: Sum of 40 PAHs and Total PAHs at 2009 SWAT Blue Mussel Sites

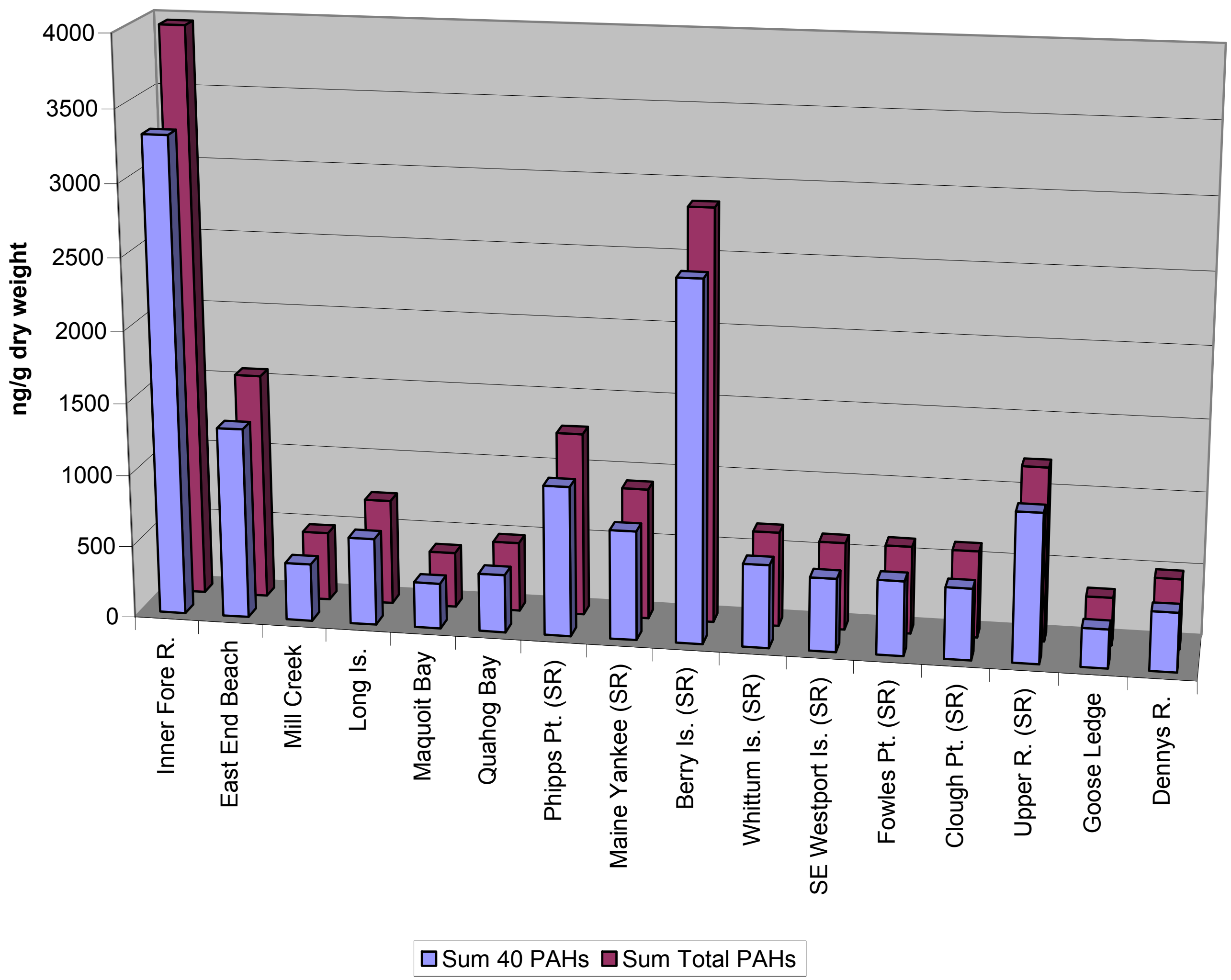
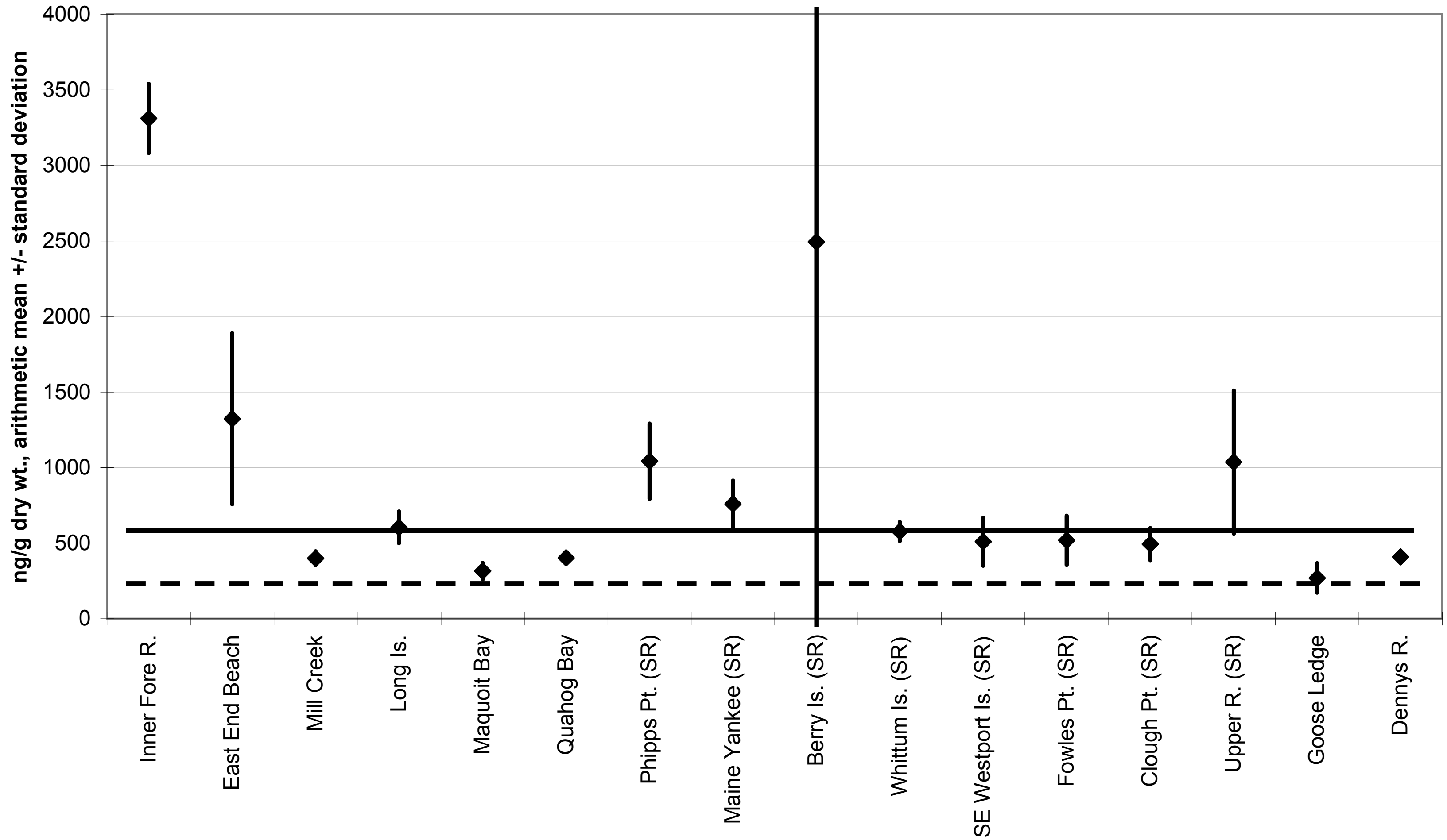
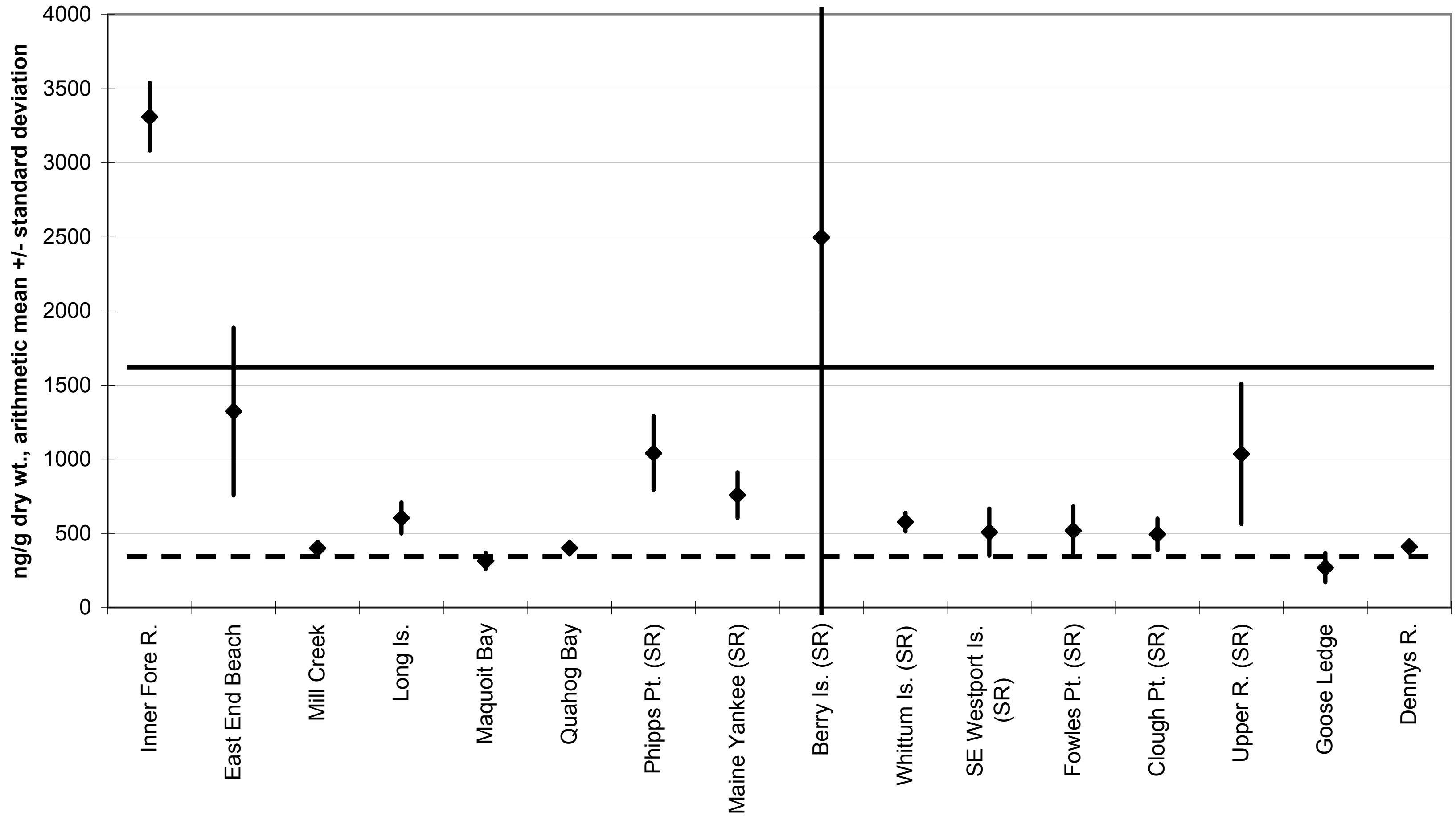


Figure 1.1.3.2.7: Sum of 40 PAHs in 2009 SWAT Blue Mussels



Dashed line = 2008 Gulfwatch Median (Sum 40 PAHs); Solid line = 2008 Gulfwatch 85th Percentile (Sum 40 PAHs).

Figure 1.1.3.2.8: Sum of 40 PAHs in 2009 SWAT Blue Mussels



Dashed line = 2008 National Status and Trends Median (Sum 40 PAHs); Solid line = 2008 National Status and Trends 85th Percentile (Sum 40 PAHs).

the most recent available). Of the 16 SWAT sites tested in 2009, 14 of 16 exceeded the NS&T national 2008 median of 353 ng/g (dry weight) for 40 summed PAHs. Two Sites, Inner Fore River, Portland, and Berry Island, Sheepscot River, exceeded the NS&T national 85th percentile of 1,674 ng/g (dry weight) for 40 summed PAHs.

The differences between the SWAT list of PAHs and the NS&T list of PAHs available for the sum of 40 PAHs may be part of the reason why the SWAT sum of 40 PAHs is comparably high to the NS&T (same as Gulfwatch) sum of 40 PAHs. This is explored in depth in the preceding paragraph. This can not be avoided due to the makeup of the SWAT data, but should be noted when viewing the comparison in Figure 1.1.3.2.8.

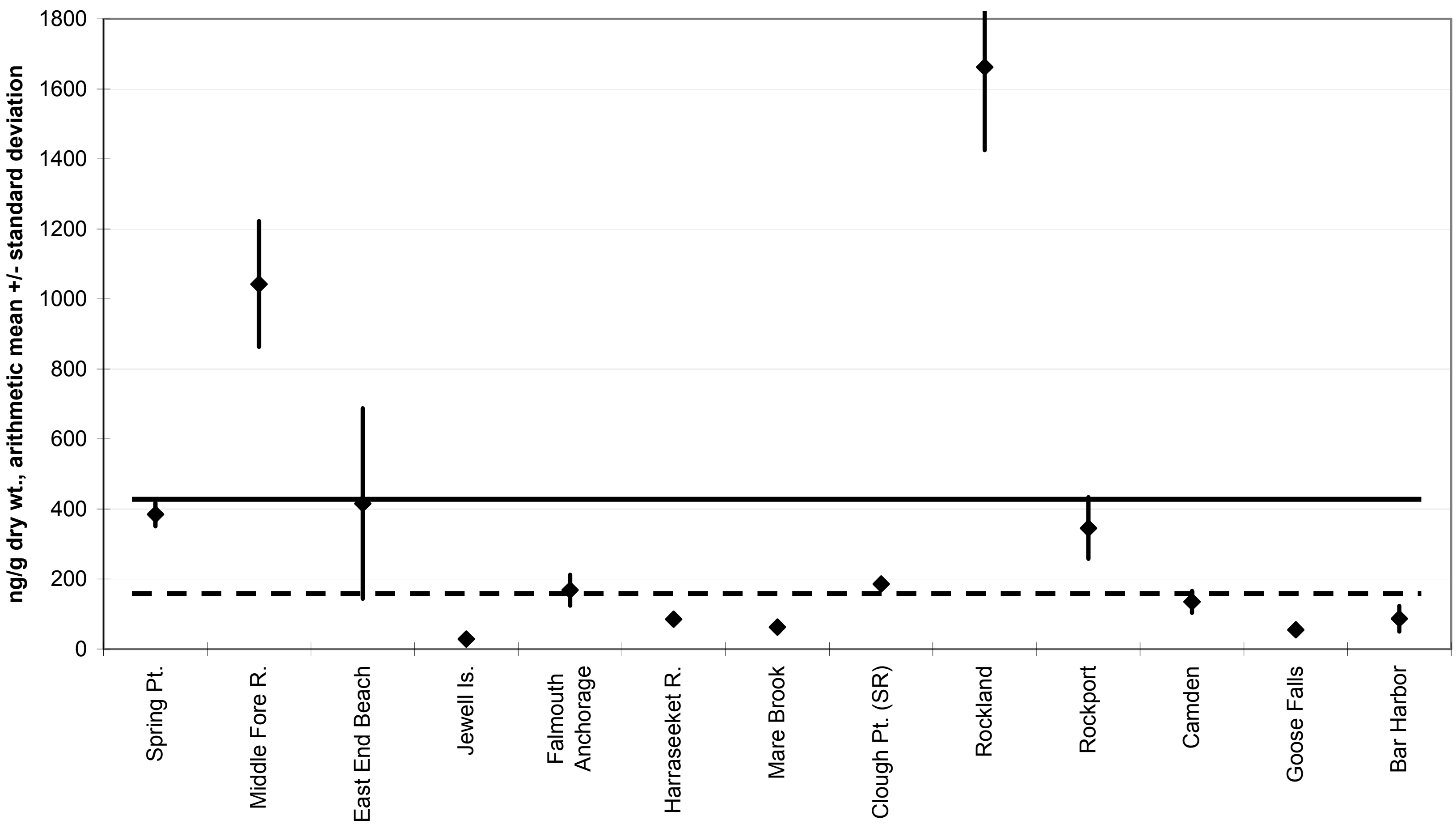
Figure 1.1.3.2.9 presents the sum of 19 PAHs across the SWAT blue mussel sites sampled in 2007, and compares these results with Gulfwatch 2008 median and 85th percentile results. Figure 1.1.3.2.9 depicts the mean concentration across four intra-station replicates as black diamonds, with standard deviation represented by the whiskers extending above and below each diamond. The mean concentrations for the sum of 19 PAHs ranged from a low mean concentration of 28.8 ng/g dry wt. at Jewell Island, Casco Bay to a high mean concentration of 1662 ng/g dry wt. at Rockland Harbor (Figure 1.1.3.2.9). Five of 13 SWAT sites sampled in 2007 exceeded the Gulfwatch mean of 154 ng/g dry wt., while two sites exceeded the Gulfwatch 85th percentile of 429 ng/g dry wt. Most sites showed low or moderate levels of non-alkylated PAHs, those captured by the sum of 19 PAHs.

Figure 1.1.3.2.10 presents the sum of 19 PAHs across the SWAT blue mussel sites sampled in 2007, and compares these results with recent National Status and Trends median and 85th percentile for 19 summed non-alkylated PAHs (2008 data, the most recent available). Of the 16 SWAT sites tested in 2007, six sites exceeded the NS&T national 2008 median of 180 ng/g (dry weight) for 19 summed non-alkylated PAHs. Only one 2007 SWAT site (Rockland Harbor) exceeded the NS&T national 85th percentile of 1,104 ng/g (dry weight) for 19 summed PAHs.

Figure 1.1.3.2.11 presents the sum of 19 PAHs across the SWAT blue mussel sites sampled in 2008, and compares these results with Gulfwatch 2008 median and 85th percentile results. Figure 1.1.3.2.11 depicts the mean concentration across four intra-station replicates as black diamonds, with standard deviation represented by the whiskers extending above and below each diamond. The mean concentrations for the sum of 19 PAHs ranged from a low mean concentration of 43 ng/g dry wt. at Middle Bay, Harpswell to a high mean concentration of 350 ng/g dry wt. at Piscataqua River, I-95 (Figure 1.1.3.2.11). Four of 13 SWAT sites sampled in 2008 exceeded the Gulfwatch mean of 154 ng/g dry wt., while none of the 13 sites sampled exceeded the Gulfwatch 85th percentile of 429 ng/g dry wt. Most sites showed low or moderate levels of non-alkylated PAHs, those captured by the sum of 19 PAHs.

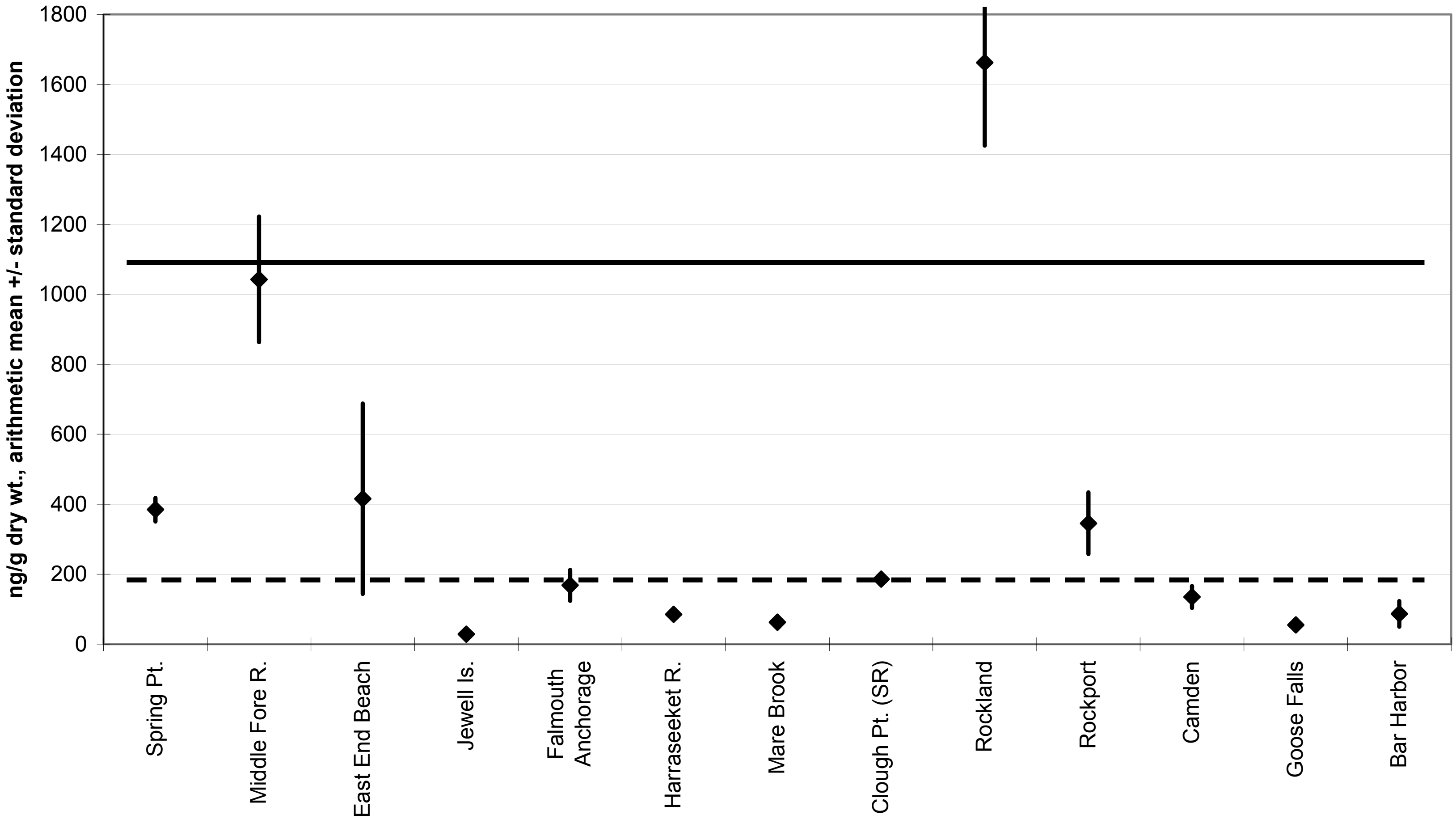
Figure 1.1.3.2.12 presents the sum of 19 PAHs across the SWAT blue mussel sites sampled in 2008, and compares these results with recent National Status and Trends median and 85th percentile for 19 summed non-alkylated PAHs (2008 data, the most

Figure 1.1.3.2.9: Sum of 19 PAHs in 2007 SWAT Blue Mussels



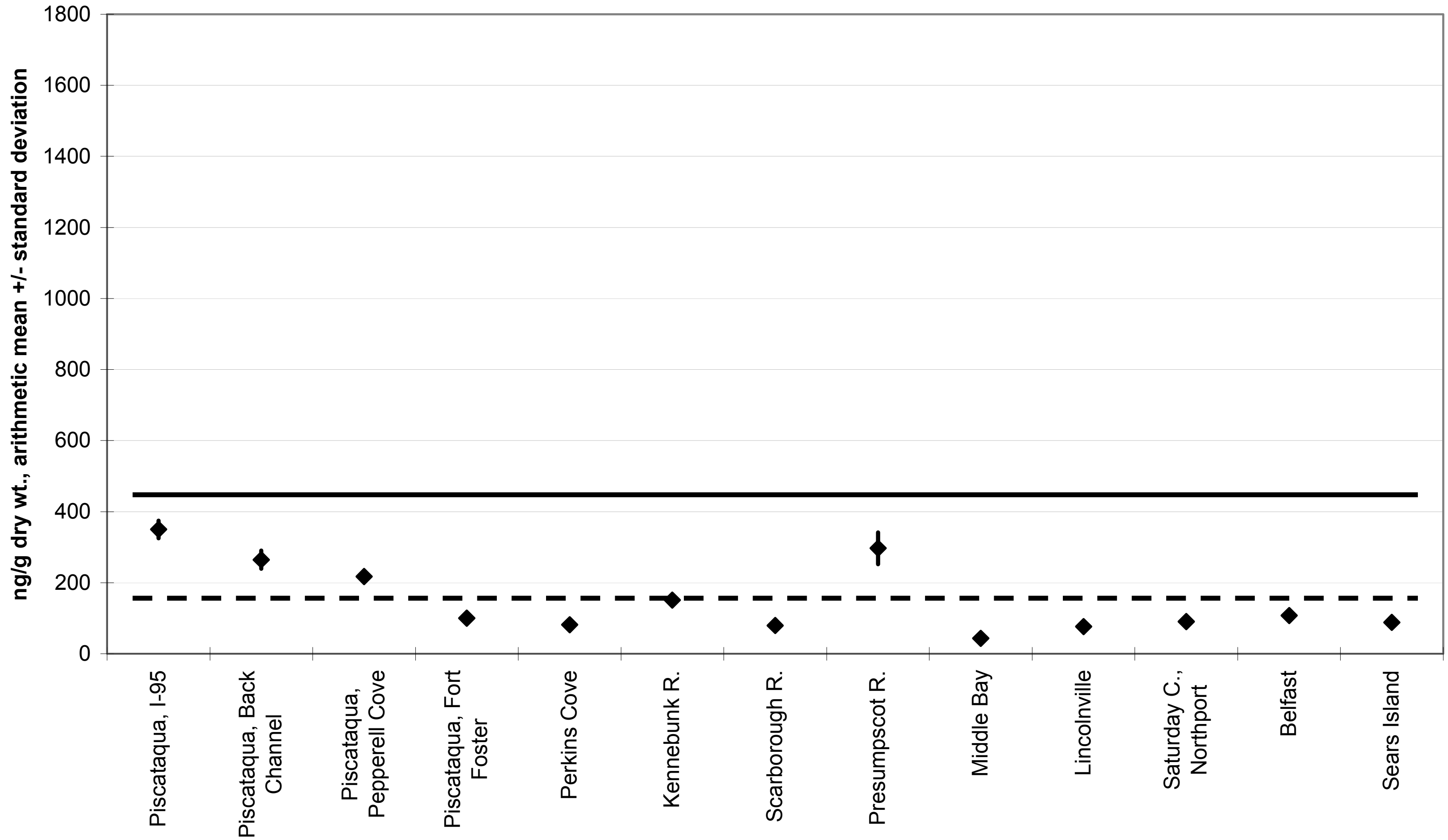
Dashed line = 2008 Gulfwatch Median (Sum 19 PAHs); Solid line = 2008 Gulfwatch 85th Percentile (Sum of 19 PAHs).

Figure 1.1.3.2.10: Sum of 19 PAHs in 2007 SWAT Blue Mussels



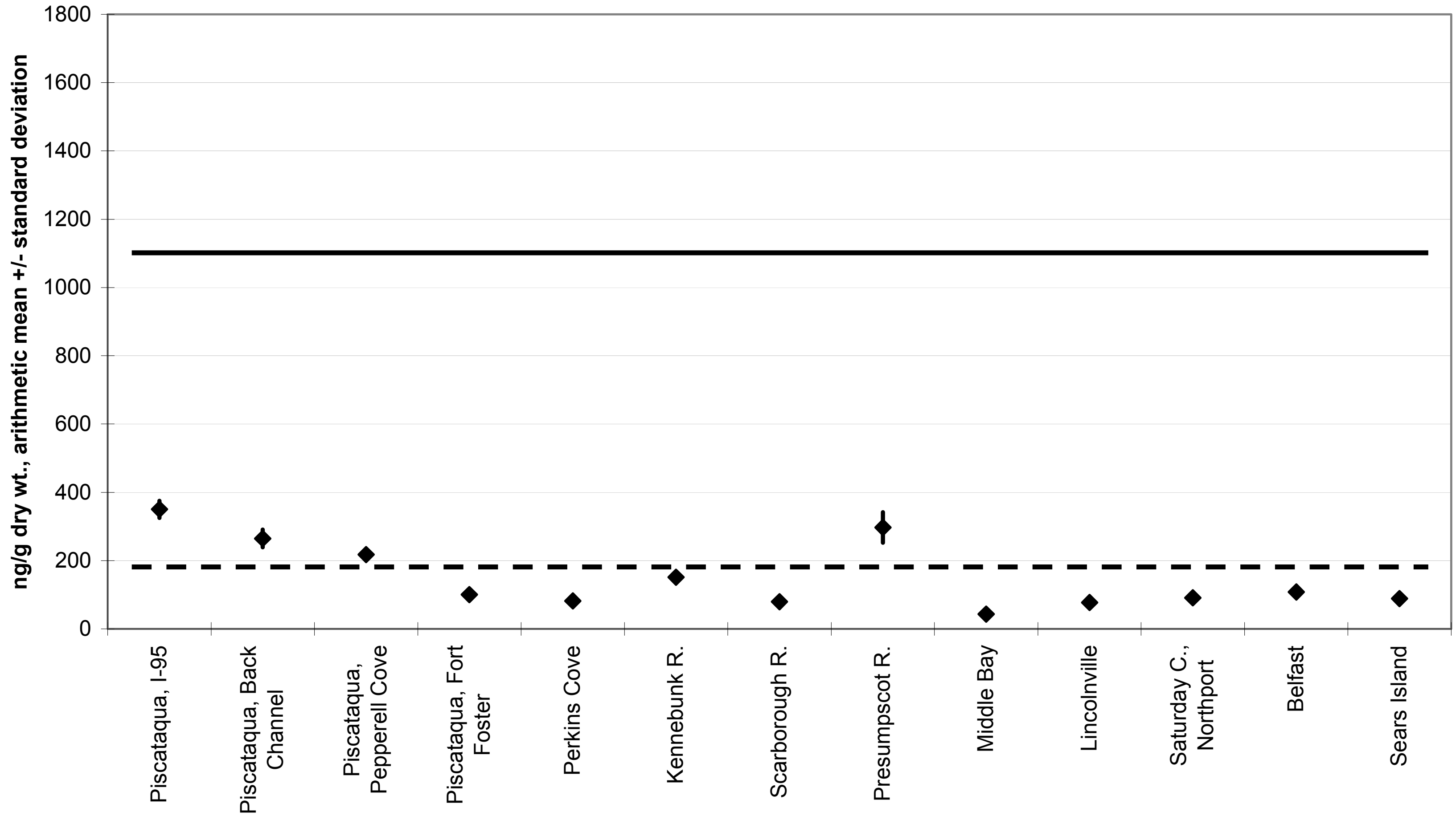
Dashed line = 2008 National Status and Trends Median (Sum 19 PAHs); Solid line = 2008 National Status and Trends 85th Percentile (Sum 19 PAHs).

Figure 1.1.3.2.11: Sum of 19 PAHs in 2008 SWAT Blue Mussels



Dashed line = 2008 Gulfwatch Median (Sum 19 PAHs); Solid line = 2008 Gulfwatch 85th Percentile (Sum 19 PAHs).

Figure 1.1.3.2.12: Sum of 19 PAHs in 2008 SWAT Blue Mussels



Dashed line = 2008 National Status and Trends Median (Sum 19 PAHs); Solid line = 2008 National Status and Trends 85th Percentile (Sum 19 PAHs).

recent available). Of the 16 SWAT sites tested in 2008, four sites exceeded the NS&T national 2008 median of 180 ng/g (dry weight) for 19 summed non-alkylated PAHs. None of the 2008 SWAT sites approached or exceeded the NS&T national 85th percentile of 1,104 ng/g (dry weight) for 19 summed PAHs.

For 2009 SWAT blue mussel sites, Figure 1.1.3.2.13 presents a graphic representation of selected PAHs expressed as a ratio. The equation used to derive the ratio is:

Fluoranthene + Pyrene/Σ(Flouranthene + Pyrene + C2-C4 Alkylphenanthrene)

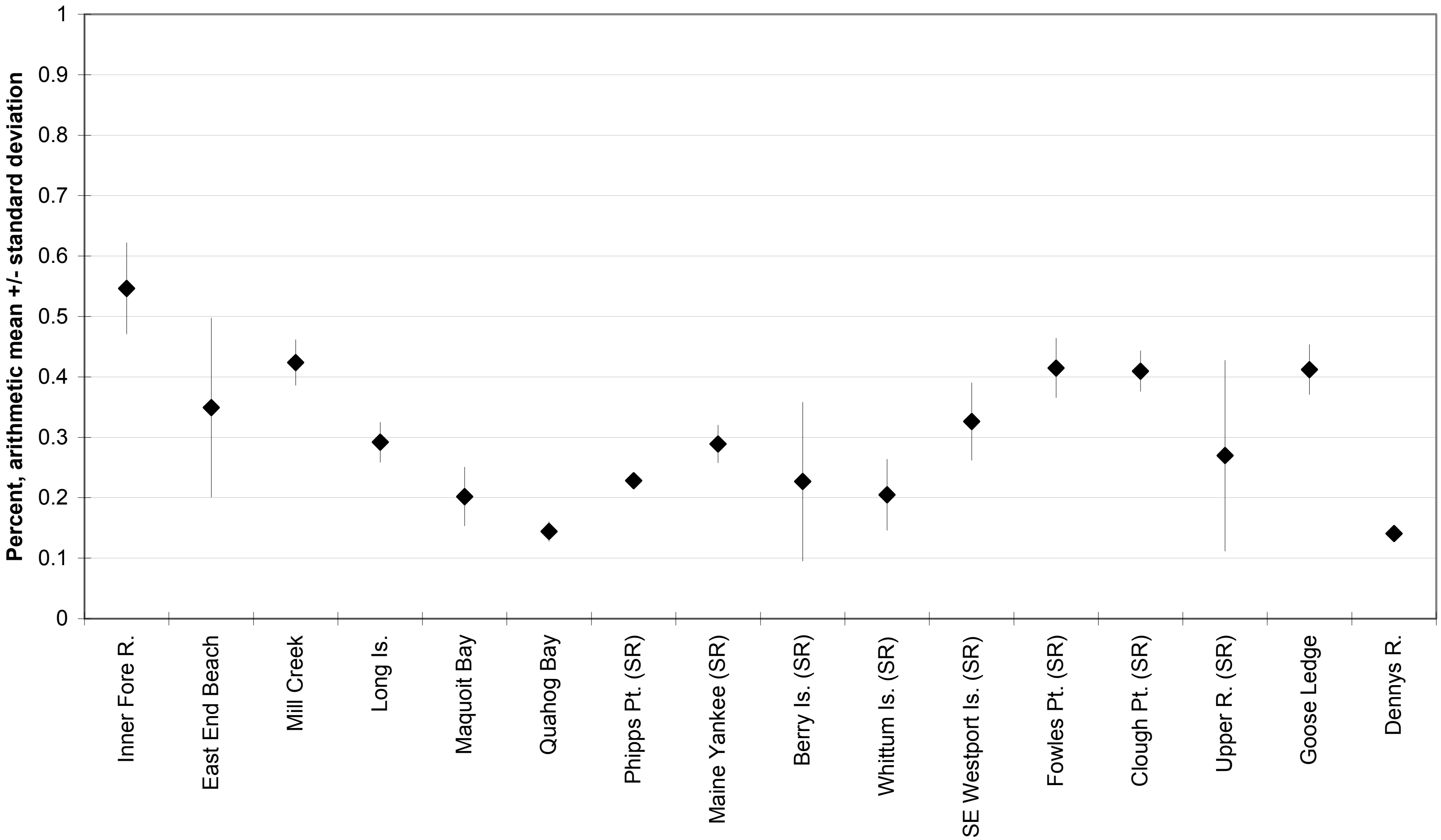
This equation is utilized to show relative concentrations of non-alkylated to alkylated PAHs, which yields a ratio indicating that values <0.1 are interpreted as a petrogenic (unburned fuel or petroleum) source, while values >0.2 are interpreted as a pyrogenic (combusted fuel) source of PAHs.

Of the 16 SWAT blue mussel sites tested in 2009, Quahog Bay and Dennys River had the lowest ratio calculated, both at 0.14. Maquoit Bay and Whittum Island (in the lower Sheepscot River) also had low calculated ratios, at 0.20 and 0.21 respectively. These four sites did not fall below the <0.1 mark, which would indicate a petrogenic source of PAHs. However, these four sites may have lower amounts of alkylated PAHs (in this case, C2-C4 alkylphananthrenes), indicating a lower exposure to combusted fuel sources. Of the remaining 12 sites sampled in 2009, Inner Fore River (0.55) and Mill Creek/Falmouth (0.42) had the highest ratios calculated, which may indicate higher exposure to pyrogenic sources. It is of interest that Fowles Point, and Clough Point (both in the Sheepscot River), and Goose Ledge (Damariscotta River) also had a ratio exceeding 0.4, which appears to indicate relatively higher exposure to pyrogenic sources than lower ratio sites like Quahog Bay or Dennys River.

PAHs occur in elevated concentrations near petroleum manufacturing, creosote use, and wood burning (Kimbrough, 2008). Though there are natural sources, including forest fires and volcanoes, anthropogenic sources, including automobile emissions, home heating, and coal fired power plants, contribute to elevated levels of PAHs. As their name implies, polycyclic aromatic hydrocarbons are made of fused benzene rings, fusion of which may occur during combustion. However, they also occur in coal and oil. PAHs in the environment are primarily from forest fires, coal fired power plants, automobile exhaust, and spilled oil (Kimbrough, 2008).

Toxicities of PAHs vary, with hundreds of compounds making up the pool of PAHs. Toxic responses in aquatic organisms may include reproduction inhibition, mutations, liver abnormalities, and even mortality. Exposure in the marine environment may be from spilled oil, boat exhaust, and runoff from urban areas. From a human health perspective, neither MCDC nor FDA have reported recommended safety levels for PAHs in fish or fish products (Kimbrough, 2008).

Figure 1.1.3.2.13: Flu+Pyr/Sum(FP C2-C4-P) in SWAT 2009 Blue Mussels



0 = Petroleum, 1 = Pyrogenic; Generally Interpreted as >.2 = Pyrogenic, <.1 = Petroleum

1.1.3.3 PCBs

Blue mussels were tested for PCBs from 13 sites in 2007, 13 sites in 2008, and eight sites in 2009. Analysis of PCB blue mussel tissue data results for 2007-08 were not included in the previous SWAT report in 2008 and are included in this report.

Mussel tissue samples collected in 2007, 2008, and 2009 were analyzed by AXYS Analytical Services Ltd., Sidney, British Columbia. Mussel tissue samples were analyzed for 209 PCBs using EPA Method 1668A. Results were compared to national (NOAA National Status & Trends, see Kimbrough, 2008) and Gulf of Maine (Gulfwatch, see LeBlanc, 2009) blue mussel monitoring program data (when available) in an effort to place Maine SWAT data in a national and regional context.

The National Status and Trends and Gulfwatch programs utilize a subset of PCBs, summing scores from 24 peaks on the gas chromatograph trace. Due to the fact that some PCB congeners co-elute, summing these 24 GC peaks actually represents 31 PCB congeners since 7 of the 24 selected peaks actually contain two congeners each. These 31 summed PCB congeners will be called “Gulfwatch PCBs” or “NS&T PCBs” for the purposes of this report. This report utilizes the Maine SWAT blue mussel tissue PCB data generated by AXYS Analytical, which includes all 209 PCB congeners, some of which co-elute and are represented as combinations of PCB congeners. To compare Maine results to the NS&T and Gulfwatch PCBs, this report sums 35 congeners in the Maine SWAT PCB data, with the SWAT 35 congener list including 27 of 31 PCB congeners on the NS&T/Gulfwatch list, while including an additional 6 congeners that are not on the NS&T/Gulfwatch list. This difference is due to the co-elution issue, since some congeners are co-eluting differently or are summed together differently at the various laboratories used. These 35 summed congeners will be called “SWAT PCBs” for the purposes of this report. Table 1.1.3.3.1 shows the list of PCB congeners used by NS&T and Gulfwatch compared to the list of PCB congeners reported by SWAT for comparison to the NS&T and Gulfwatch data. Double numbers in the table represent co-elution or congeners that are quantified together within peaks on the GC output trace. Though the SWAT PCB and NS&T/Gulfwatch PCB congeners included in the summed lists are not completely identical, they are as close a comparison and possible. With some caution in data interpretation, this comparison may be used to place Maine SWAT blue mussel tissue PCB concentrations in a Gulf of Maine-wide and national perspective.

To compare what proportion of the total PCB (209 congeners) the SWAT PCBs represent, figures 1.1.3.3.1, 1.1.3.3.2, and 1.1.3.3.3 show both the total PCBs next to the SWAT PCBs list used for comparison to other data sets in 2007, 2008, and 2009.

2007 - Across all 13 sites sampled in 2007, the SWAT PCBs ranged from 23% to 58% of the total PCBs. The close relationship between total PCB and the SWAT PCBs subset for 2007 can easily be noted when looking at figure 1.1.3.3.1.

Total PCB concentrations ranged from a ranged from a low mean concentration of 9.5 ng/g dry wt. at Bar Harbor to a high mean concentration of 125.9 ng/g dry wt. at Rockland Harbor (Figure 1.1.3.3.1). Middle Fore River had the second highest mean concentration total PCBs in 2007 (Figure 1.1.3.3.1) across the 13 sites sampled. Rockport Harbor, Jewell Island in outer Casco Bay, and Bar Harbor had the lowest levels of total PCBs. The remaining eight sites tested in 2007 show intermediate levels of total PCBs.

2008 – Across all 13 sites sampled in 2008, the SWAT PCBs ranged from 38% to 41% of the total PCBs. The close relationship between total PCB and the SWAT PCBs can easily be noted when looking at figure 1.1.3.3.2.

Total PCB concentrations ranged from a ranged from a low mean concentration of 12.7 ng/g dry wt. at Lincolnville to a high mean concentration of 78.7 ng/g dry wt. at Picataqua River/I-95 (Figure 1.1.3.3.2). Piscataqua River/Back Channel, and Presumpscot River also had high mean concentrations of total PCBs in mussel tissue compared to other sites tested in 2008 (Figure 1.1.3.3.2). Perkins Cove (Ogunquit), and Scarborough River also had low mean concentrations of total PCBs compared to other sites sampled in 2008. The remaining seven sites tested in 2008 show intermediate levels of total PCBs (Figure 1.1.3.3.2)

2009 - To compare what proportion of the total PCB (209 congeners) the SWAT PCBs represent, Figure 1.1.3.3.3 shows both the total PCB totals next to the SWAT PCBs used for comparison to other data sets. Across all eight 2009 sites, the SWAT PCBs ranged from 38% to 42% of the total PCBs. The close relationship between total PCB and the SWAT PCBs subset can be easily noted when looking at the figure.

Total PCB concentrations ranged from a ranged from a low mean concentration of 11.1 ng/g dry wt. at Dennys River, Edmunds Twp., to a high mean concentration of 154 ng/g dry wt. at Inner Fore River, Portland (Figure 1.1.3.3.3). Western sites at the left of Figure 1.1.3.3.3, Inner Fore River and East End Beach (Portland), represent the highest levels of total PCBs found in Maine across the eight sites. Total PCBs in Mill Creek (Falmouth), Long Island (Casco Bay), Maquoit Bay (Freeport), and Quahog Bay (Harpswell) show

TABLE 1.1.3.3.1: Comparison of 35 PCBs Summed for SWAT to 31 PCBs Summed for National Status & Trends and Gulfwatch.

SUM 35 PCBs "SWAT PCBs" List	**SUM 31 PCBs "Gulfwatch, NS&T PCBs" List**
PCB-5	PCB-8/5
PCB-8	PCB-18/15
PCB-15	PCB-29
PCB 18/30	PCB-50
PCB 26/29	PCB-28
PCB 20/28	PCB-52
PCB 50/53	PCB-44
PCB-52	PCB-66/95
PCB-66	PCB-101/90
PCB-77	PCB-87
PCB-90/101/113	PCB-77
PCB-118	PCB-118
PCB-126	PCB-153/132
PCB-132	PCB-105
PCB-153/168	PCB-138
PCB-169	PCB-126
PCB-187	PCB-187
PCB-170	PCB-128
PCB-190	PCB-180
PCB-128/166	PCB-169
PCB-195	PCB-170/190
PCB-208	PCB-195/208
PCB-180/193	PCB-206
PCB-206	PCB-209
PCB-209	
PCB-105	

Unique to SWAT 35 List	Unique to GW and NS&T 31 List
PCB-30	PCB-44
PCB-26	PCB-95
PCB-53	PCB-87
PCB-20	PCB-138
PCB-166	
PCB-193	

Figure 1.1.3.3.1: SWAT PCBs (Sum of 35 PCBs) and Total PCBs at 2007 SWAT Blue Mussel Sites

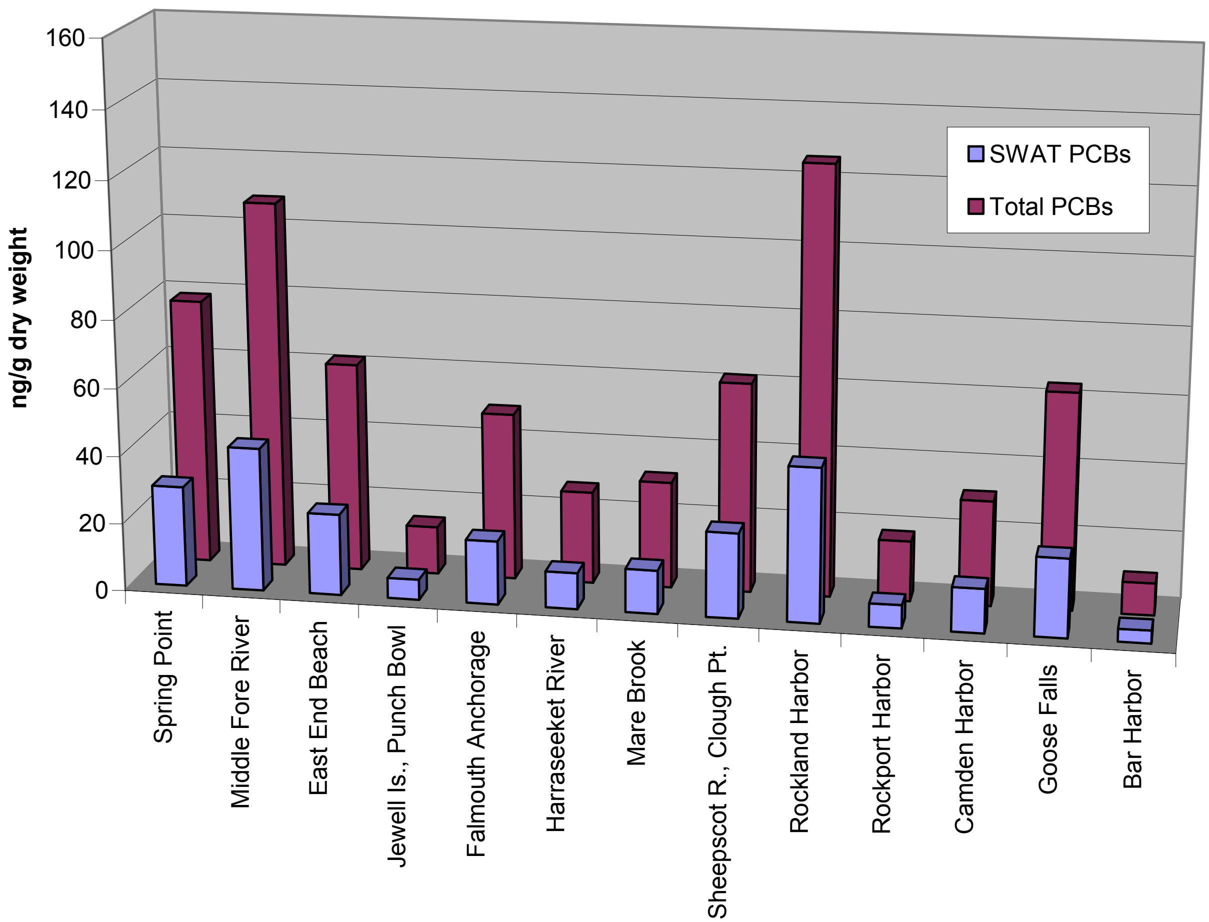


FIgure 1.1.3.3.2: SWAT PCBs (Sum of 35 PCBs) and Total PCBs at 2008 SWAT Blue Mussel Sites

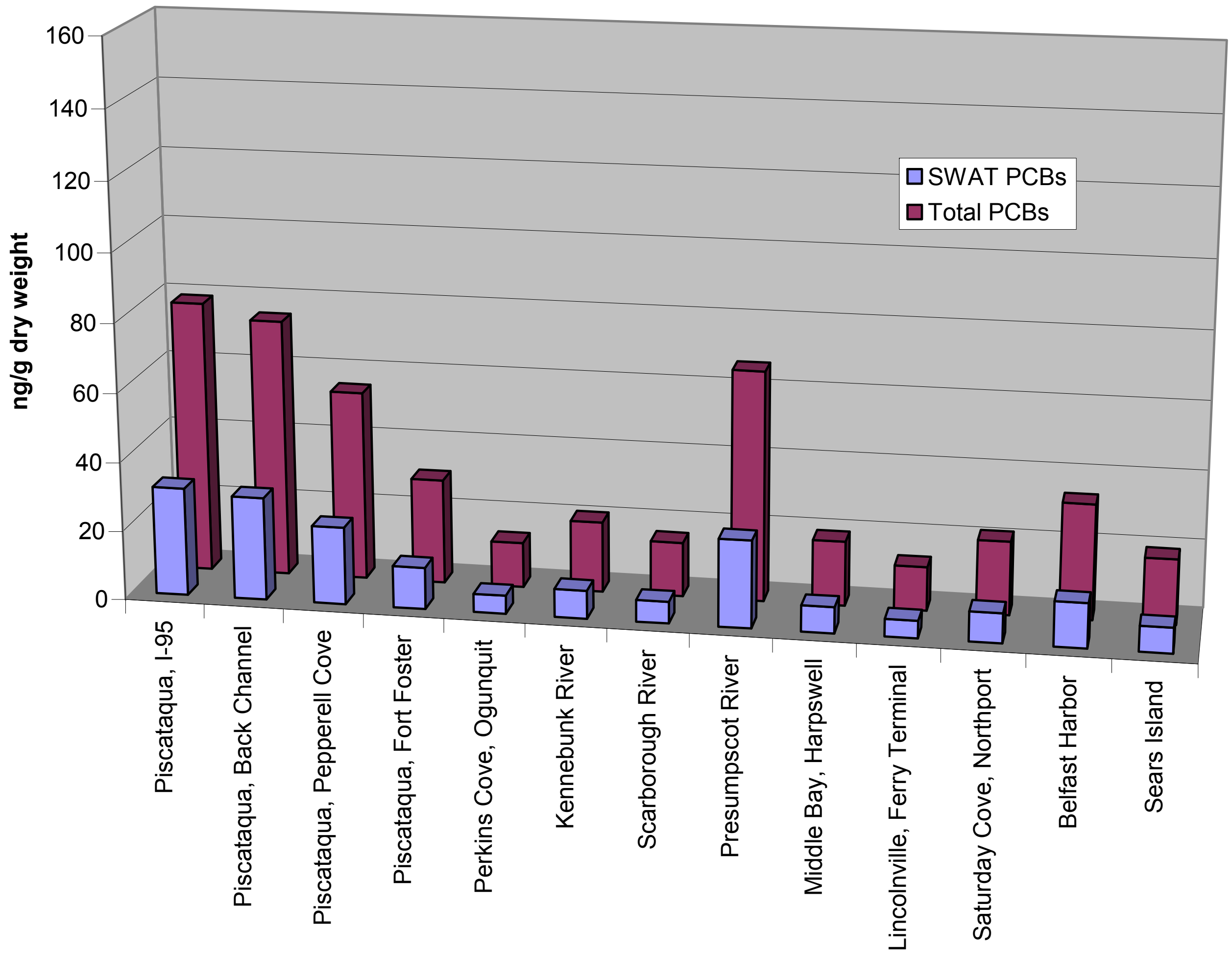
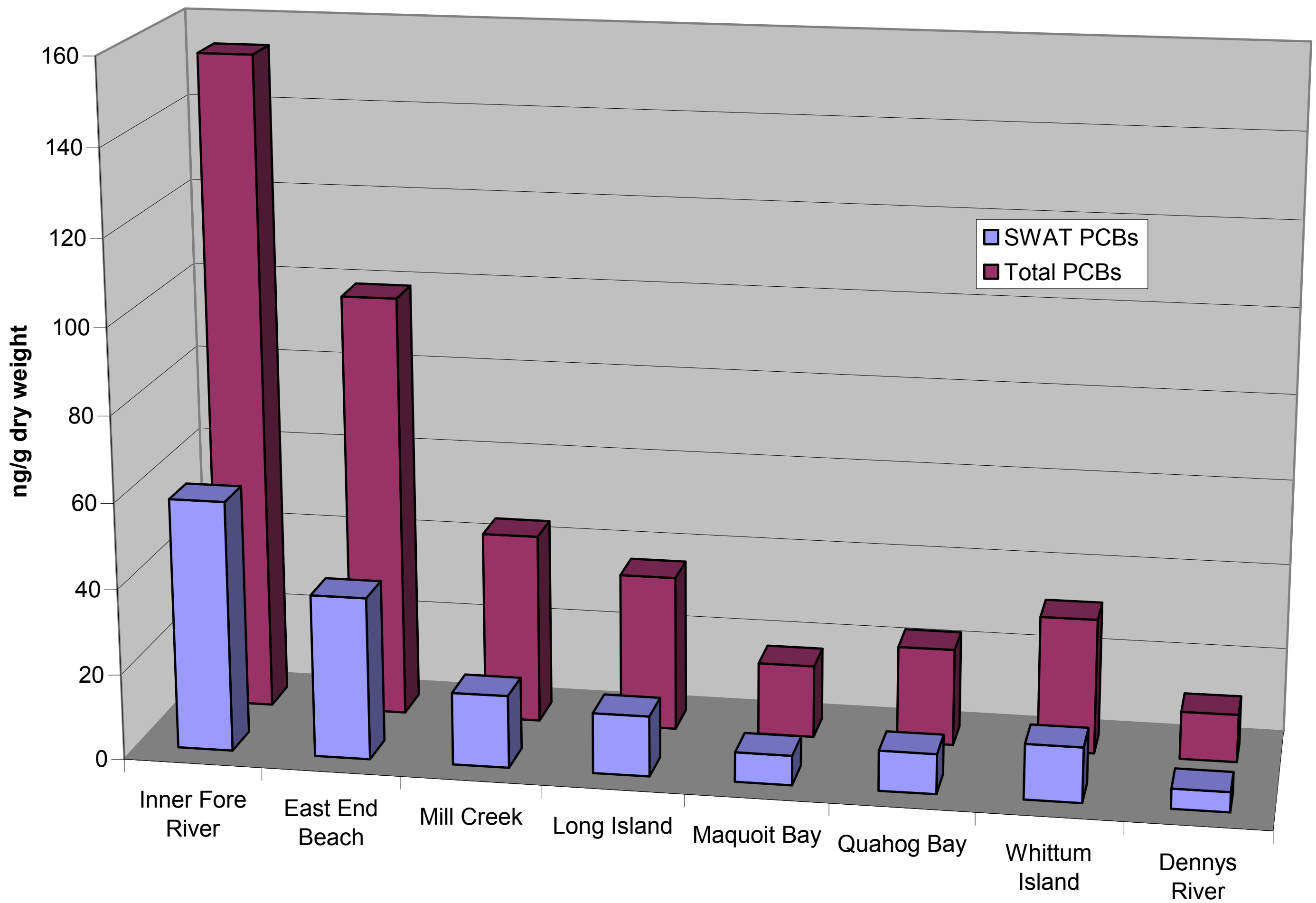


Figure 1.1.3.3.3: SWAT PCBs (Sum of 35 PCBs) and Total PCBs at 2009 SWAT Blue Mussel Sites



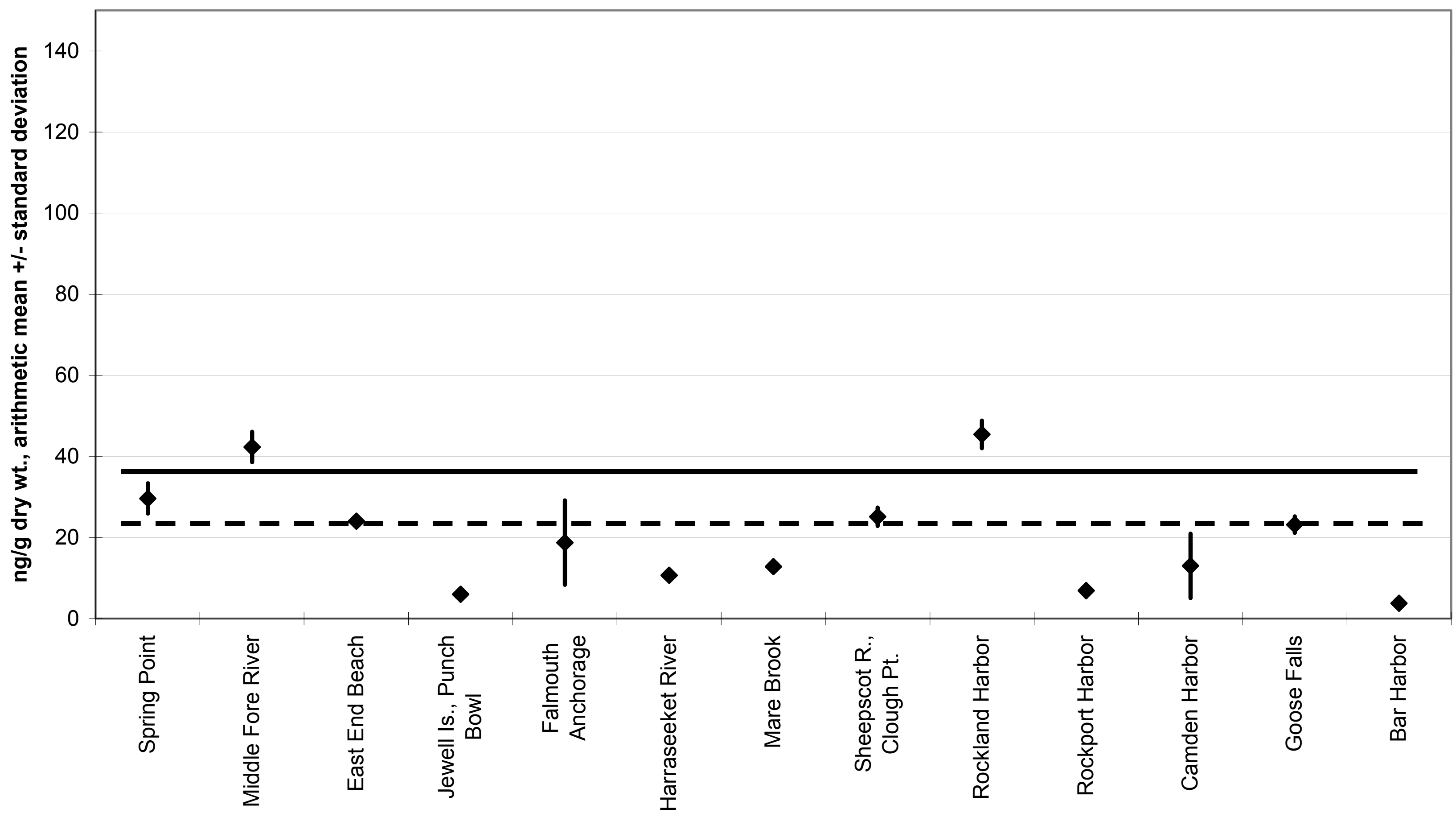
lower levels of total PCBs looking toward the east within Casco Bay. Whittum Island (Westport) in the Sheepscot River estuary shows intermediate levels of PCBs compared to other sites surveyed in 2009. Mussel tissue from Dennys River (Edmunds Twp.) represents the lowest total PCB concentrations among the eight sites tested in 2009.

Figure 1.1.3.3.4 compares the SWAT PCBs at the 2007 SWAT sites to recent Gulfwatch median and 85^{th} percentile for Gulfwatch PCBs (2008 data, the most recent available). Figure 1.1.3.3.4 depicts the mean of scores across four intra-station replicates as black diamonds, with standard deviation represented by the whiskers extending above and below each diamond. Of the 13 SWAT sites tested in 2007, Rockland Harbor, Middle Fore River, Spring Point, and Sheepscot River/Clough Point are the sites that exceeded the Gulfwatch 2008 median of 24.1 ng/g (dry weight) for Gulfwatch PCBs. Two of these sites, Rockland Harbor and Middle Fore River, also exceeded the Gulfwatch 85^{th} percentile of 35.4 ng/g (dry weight) for Gulfwatch PCBs. The remaining nine SWAT sites tested for PCBs in 2007 all fell below the Gulfwatch median concentration of 24.1 ng/g (dry weight) for Gulfwatch PCBs. As noted above, comparison of 35 summed congeners from SWAT (SWAT PCBs) to 31 summed congeners from Gulfwatch (Gulfwatch PCBs) is as close a comparison as is possible due to differences in some PCBs co-eluting in different GC traces across laboratories. Despite these differences, the summation of 35 SWAT congeners is useful for putting Maine data into a regional, Gulf of Maine context.

Figure 1.1.3.3.5 compares the SWAT PCBs at the 2007 SWAT sites to recent National Status and Trends (NS&T) median and 85^{th} percentile for NS&T PCBs (2008 data, the most recent available). Of the 13 SWAT sites tested in 2007, Rockland Harbor, Middle Fore River (Portland), and Spring Point (S. Portland) are the only sites that exceeded the NS&T 2008 national median, 29.2 ng/g (dry weight), for NS&T PCBs. No 2007 SWAT sites exceeded the NS&T national 85^{th} percentile, 141 ng/g (dry weight), for NS&T PCBs. The 2008 NS&T national 85^{th} percentile was approximately 3 X higher than the highest scoring PCB site tested by SWAT in Maine in 2007, Rockland Harbor (45.4 ng/g, dry weight).

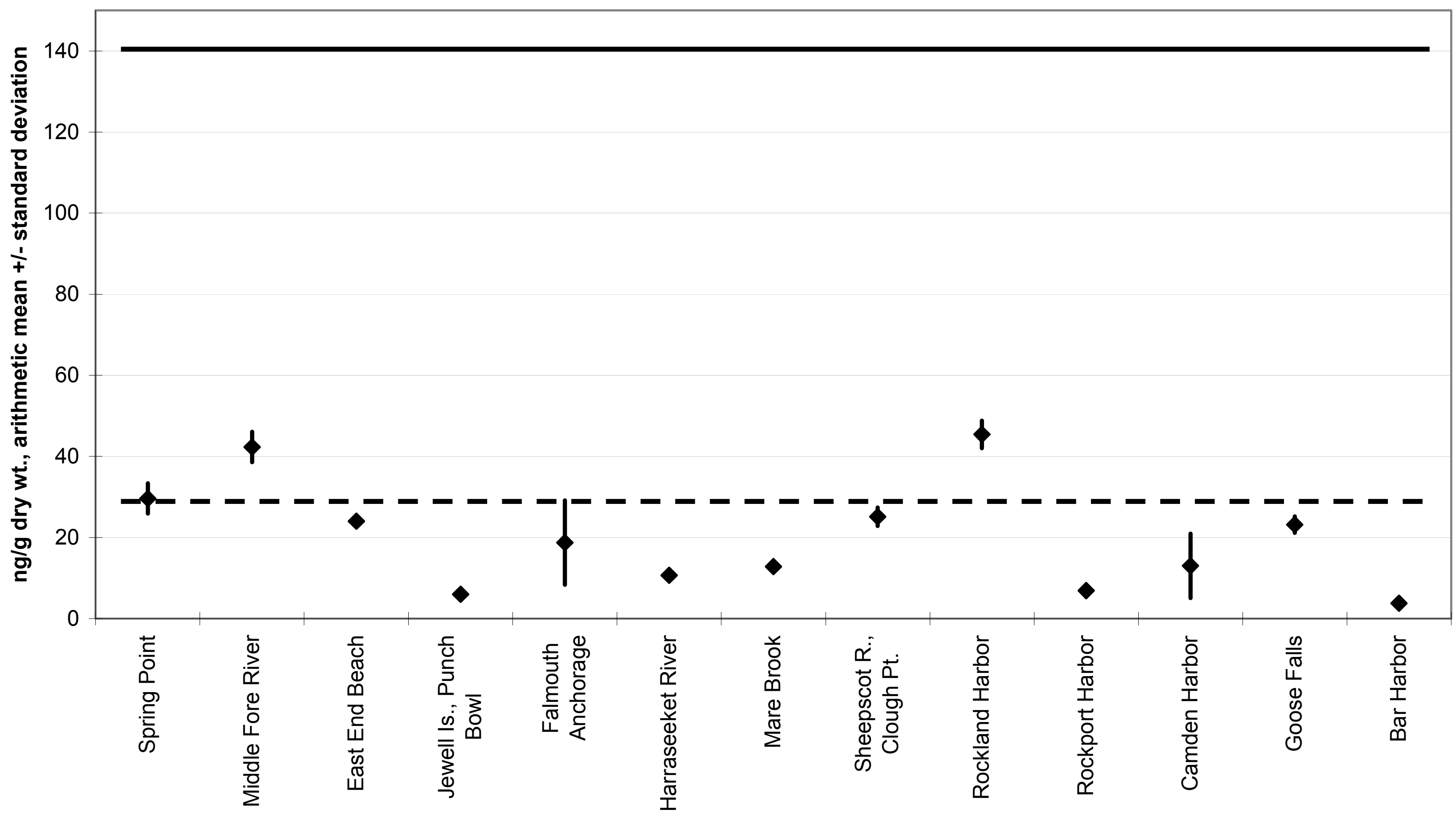
Figure 1.1.3.3.6 compares the SWAT PCBs at the 2008 SWAT sites to recent Gulfwatch median and 85^{th} percentile for Gulfwatch PCBs (2008 data, the most recent available). Figure 1.1.3.3.6 depicts the mean of scores across four intra-station replicates as black diamonds, with standard deviation represented by the whiskers extending above and below each diamond. Of the 13 SWAT sites tested in 2008, Piscataqua River/I-95, Piscataqua River/Back Channel, and Presumpscot River are the sites that exceeded the Gulfwatch 2008 median, 24.1 ng/g (dry weight), for Gulfwatch PCBs. None of the sites sampled in 2008 exceeded the Gulfwatch 85^{th} percentile, 35.4 ng/g (dry weight), for Gulfwatch PCBs. The remaining 10 SWAT sites tested for PCBs in 2008 all fell below the Gulfwatch median concentration, 24.1 ng/g (dry weight), for Gulfwatch PCBs.

Figure 1.1.3.3.4: SWAT PCBs (Sum of 35 PCBs) in 2007 SWAT Blue Mussels



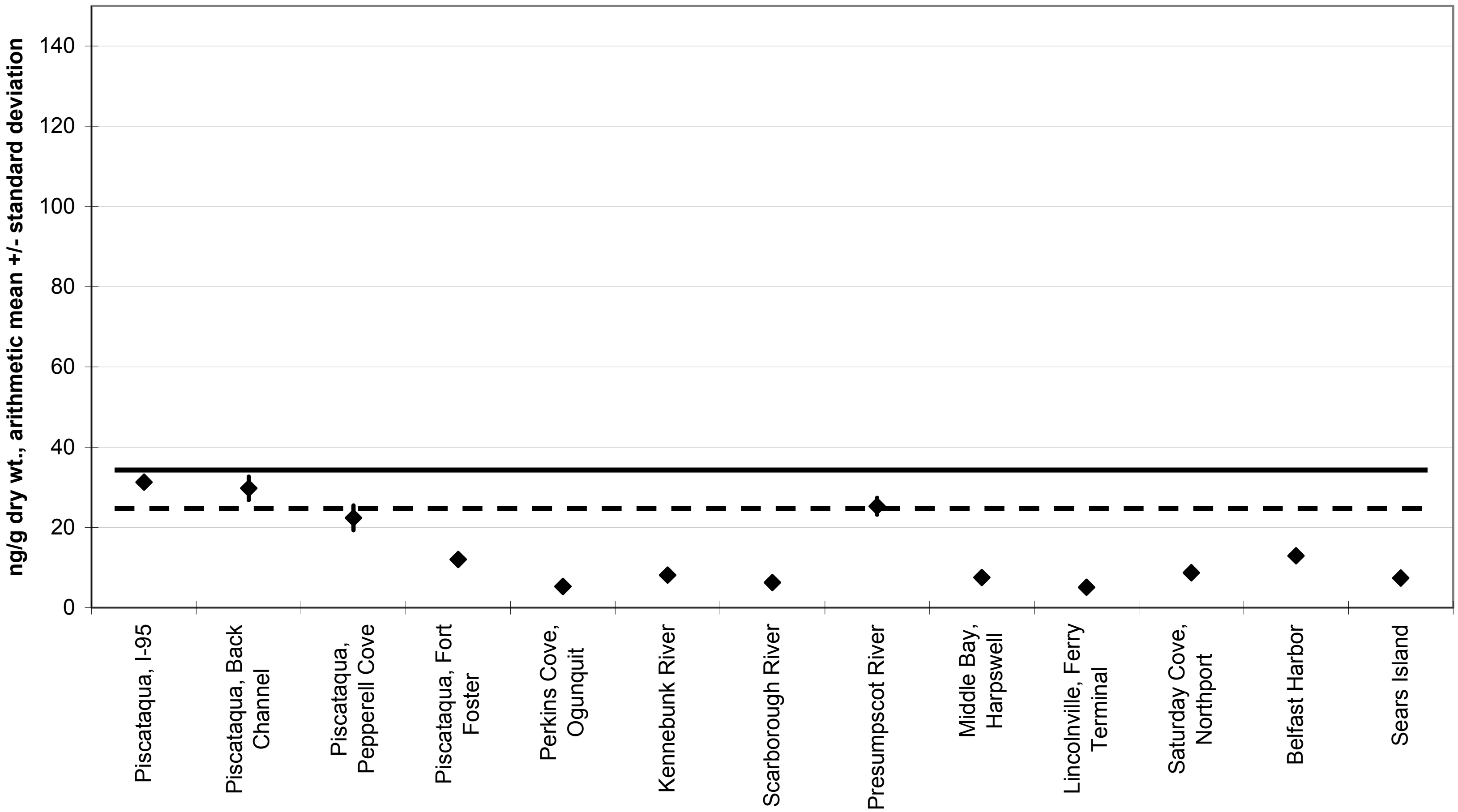
Dashed line = 2008 Gulfwatch Median (Gulfwatch PCBs, Sum 31); Solid line = 2008 Gulfwatch 85th Percentile (Gulfwatch PCBs, sum 31).

Figure 1.1.3.3.5: SWAT PCBs (Sum of 35 PCBs) for 2007 SWAT Blue Mussels



Dashed line = 2008 NS&T National Median (NS&T PCBs, Sum 31); Solid line = NS&T National 85th Percentile (NS&T PCBs, Sum 31).

Figure 1.1.3.3.6: SWAT PCBs (Sum of 35 PCBs) in 2008 SWAT Blue Mussels



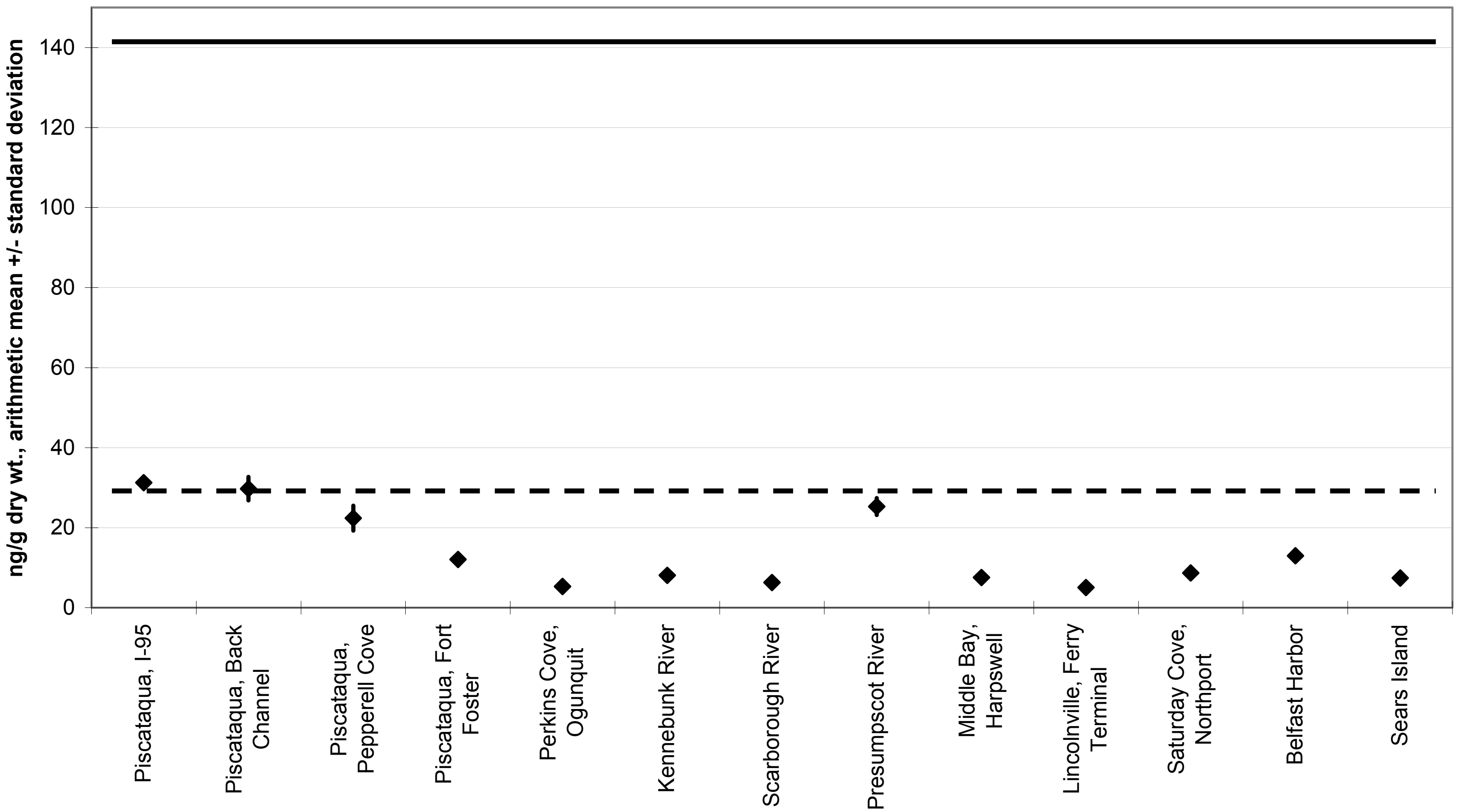
Dashed line = 2008 Gulfwatch Median (Gulfwatch PCBs, Sum 31); Solid line = 2008 Gulfwatch 85th Percentile (Gulfwatch PCBs, Sum 31).

Figure 1.1.3.3.7 compares the sum of SWAT PCBs at the 2008 SWAT sites to recent NS&T median and 85^{th} percentile for NS&T PCBs (2008 data, the most recent available). Of the 13 SWAT sites tested in 2008, Piscataqua River/I-95 and Piscataqua River/Back Channel are the only sites that exceeded the NS&T national 2008 median, 29.2 ng/g (dry weight), for NS&T PCBs. No 2008 SWAT sites exceeded the NS&T national 85^{th} percentile, 141 ng/g (dry weight), for NS&T PCBs. The 2008 NS&T national 85^{th} percentile was approximately 4.5 X higher than the highest scoring PCB site tested by SWAT in Maine in 2008, Piscataqua River/I-95 (31.3 ng/g, dry weight).

Figure 1.1.3.3.8 compares the SWAT PCBs at the 2009 SWAT sites to recent Gulfwatch median and 85^{th} percentile for Gulfwatch PCBs (2008 data, the most recent available). The figure depicts means of scores across four intra-station replicates as black diamonds, with standard deviation represented by the whiskers extending above and below each diamond. Of the eight SWAT sites tested in 2009, Inner Fore River and East End Beach (both in Portland) are the only sites that exceeded the Gulfwatch 2008 median, 24.1 ng/g (dry weight), for Gulfwatch PCBs. These same two sites also exceeded the Gulfwatch 85^{th} percentile, 35.4 ng/g (dry weight), for Gulfwatch PCBs. The remaining six SWAT sites tested for PCBs in 2009 all fell below the Gulfwatch median concentration of 24.1 ng/g (dry weight) for Gulfwatch PCBs. Variation among intra-station replicates is highest where PCB concentrations are highest, at Inner Fore River and East End Beach, Portland.

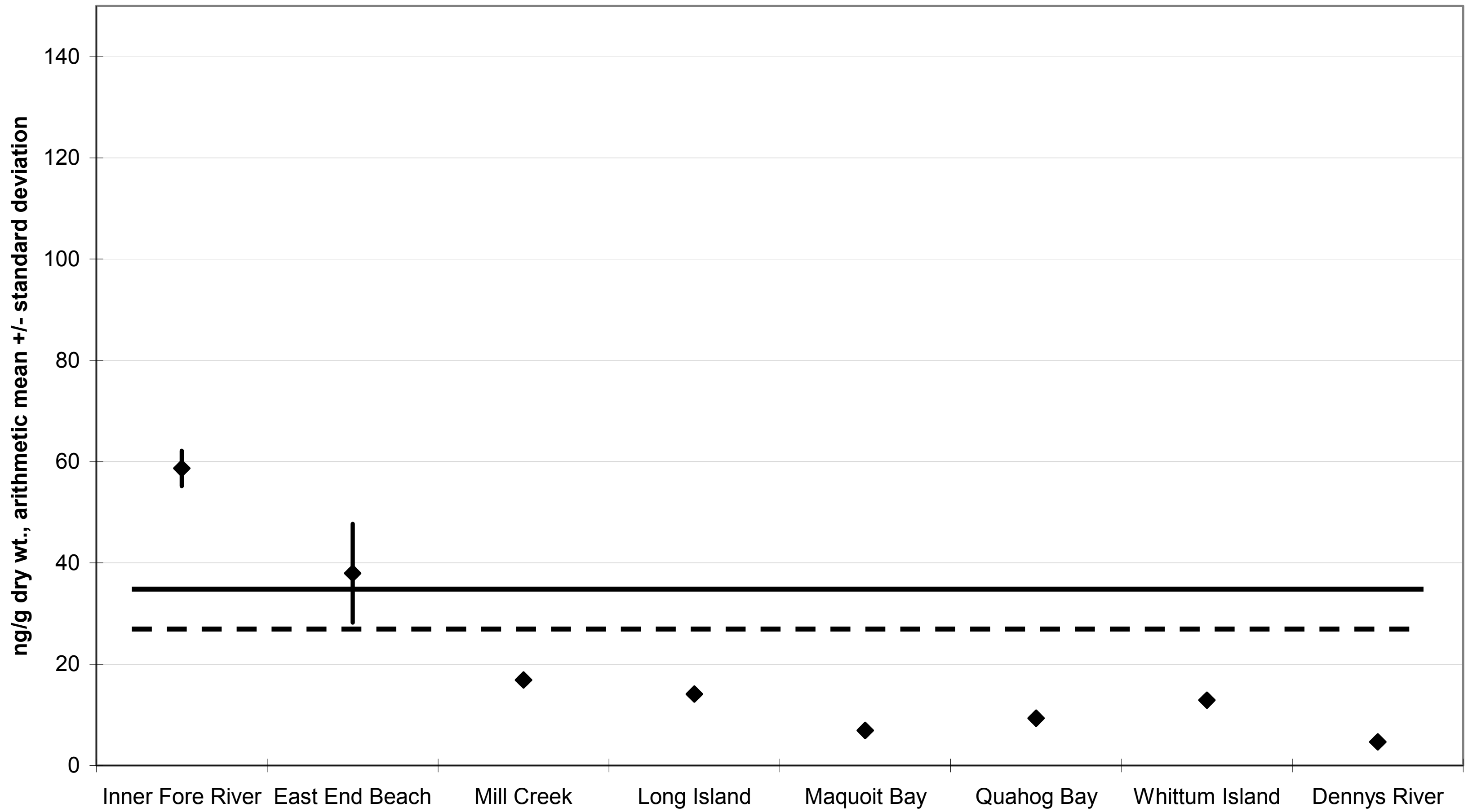
Figure 1.1.3.3.9 compares the sum of SWAT PCBs at the 2009 SWAT sites to recent NS&T median and 85^{th} percentile for NS&T PCBs (2008 data, the most recent available). Of the eight SWAT sites tested in 2009, Inner Fore River and East End Beach (both in Portland) are the only sites that exceeded the NS&T national 2008 median, 29.2 ng/g (dry weight), for NS&T PCBs. No 2009 SWAT sites exceeded the NS&T national 85^{th} percentile, 141 ng/g (dry weight), for NS&T PCBs. The 2008 NS&T national 85^{th} percentile was approximately 2.4 X higher than the highest scoring PCB site tested by SWAT in Maine in 2009, the Inner Fore River (58.7 ng/g dry weight). Some areas in southern New England have higher level of PCBs than Maine waters but are still relatively cleaner than the lower Hudson River/Raritan Bay system, which is heavily contaminated from PCBs moving downriver from the upper Hudson (Kimbrough, 2008).

Figure 1.1.3.3.7: SWAT PCBs (Sum of 35 PCBs) in 2008 SWAT Blue Mussels



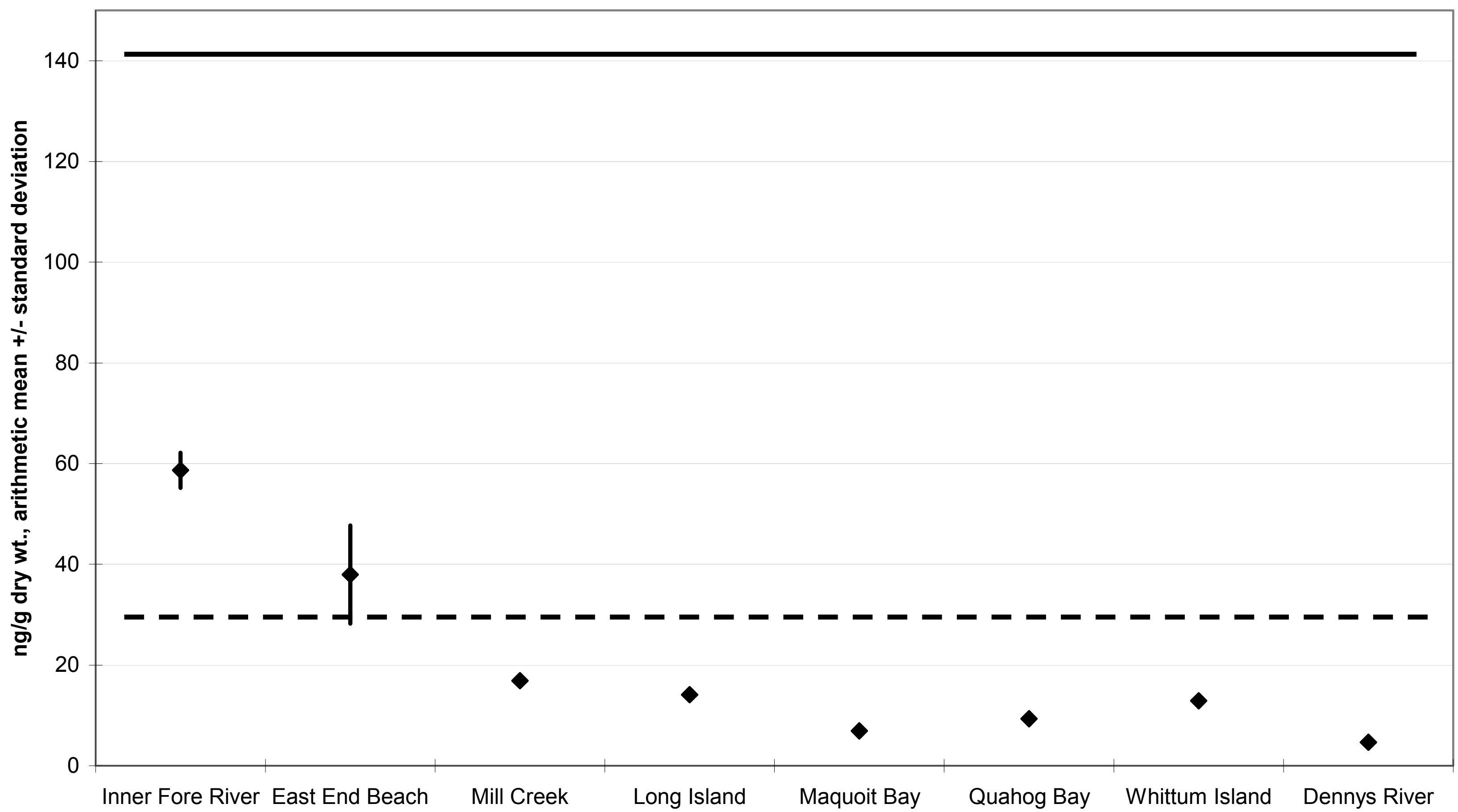
Dashed line = 2008 NS&T National Median (NS&T PCBs, Sum 31); Solid line = 2008 NS&T National 85th Percentile (NS&T PCBs, Sum 31).

Figure 1.1.3.3.8: SWAT PCBs (Sum of 35 PCBs) in 2009 SWAT Mussels



Dashed line = 2008 Gulfwatch Median (Gulfwatch PCBs, Sum 31); Solid line = 2008 Gulfwatch 85th Percentile (Gulfwatch PCBs, Sum 31).

Figure 1.1.3.3.9: SWAT PCBs (Sum of 35 PCBs) for 2009 SWAT Blue Mussels



Dashed line = 2008 NS&T National Median (NS&T PCBs, Sum 31); Solid line = NS&T National 85th Percentile (NS&T PCBs, Sum 31).

PCBs (polychlorinated biphenyls) are synthetic organic compounds that consist of biphenyl with varying numbers of chlorine atoms. PCBs were manufactured from 1929 to 1977, though they were regulated in 1971 and new uses were banned in 1976. PCBs were used in electrical transformers and capacitors, and in lubricants and hydraulic fluids. They were also included in paints, adhesives, plasticizers, and flame retardants. Manufacturing of PCBs for flame retardants and lubricants was stopped in 1977. Current uses are electrical equipment and transformers (Kimbrough, 2008).

From a human health perspective, the MCDC cancer FTAL for total PCBs for non-commercially caught finfish is 11 ng/g wet wt. (ppb), while the MCDC non-cancer FTAL for total PCBs is 43 ng/g wet wt. (ppb). Of the 42 SWAT blue mussel sites samples from 2007-09, five sites had total PCB mean tissue concentrations equal to or exceeding the MCDC cancer FTAL of 11 ng/g wet wt. Sites exceeding the cancer FTAL include:

Middle Fore River, Portland, 2007	16 ng/g wet wt.
Crockett Point, Rockland, 2007	23 ng/g wet wt.
Goose Falls, Brooksville, 2007	11 ng/g wet wt.
Inner Fore River, Portland, 2009	21 ng/g wet wt.
East End Beach, Portland, 2009	14 ng/g wet wt.

None of the 42 SWAT blue mussel sites sampled had total PCB concentrations approaching the MCDC non-cancer FTAL of 43 ng/g wet wt.

When East End Beach site was tested previously in 2007, the mean concentration at the site was 9 ng/g wet wt., indicating some inter-annual variability in total PCB concentration. This variability may be a result of patchiness and heterogeneity within site, or differences between sampling years.

1.1.3.4 Pesticides

Blue mussels were tested for pesticides from 13 sites in 2007, 13 sites in 2008, and eight sites in 2009. Analysis of pesticides blue mussel tissue data results for 2007-08 were not included in the previous SWAT report in 2008 and are included in this report.

Mussel tissue samples collected in 2007, 2008, and 2009 were analyzed by AXYS Analytical Services Ltd., Sidney, British Columbia. Mussel tissue samples were analyzed for organochlorinates (modified EPA Method 8081/EPA 1625) using GC/MS, and organphosphates, triazines, pyrethroids, and organonitrogens (EPA Method 1699) using HRGC/HRMS. Organochlorinated pesticide results were compared to national (NOAA National Status & Trends, see Kimbrough, 2008) and Gulf of Maine (Gulfwatch, see LeBlanc, 2009) blue mussel monitoring program data (when available) in an effort to place Maine SWAT data in a national and regional context.

The National Status and Trends and Gulfwatch programs utilize a summation of 21 organochlorinated pesticides to look at general pesticide concentrations. SWAT pesticide laboratory results include these 21 organochlorinated pesticides and several more. Table 1.1.3.4.1 shows the Gulfwatch list of 21 organochlorinated pesticides (also used by National Status and Trends Mussel Watch Program) and also shows additional pesticides included in SWAT results. To allow direct comparison to Gulfwatch and NS&T results summing 21 organochlorinated pesticides, SWAT data were summed for the same 21 organochlorinated pesticides. In addition, SWAT pesticide analysis also included additional pesticides, as outlined in Table 1.1.3.4.1, including organophosphates, triazines, pyrethroids, and organonitrogens. Analyses for most of these additional pesticides were first performed in 2009, as outlined in the Table 1.1.3.4.1.

To allow comparison to other National Status and Trends Mussel Watch program work, summations of SWAT data were completed for: DDDs, DDEs, and DDTs; chlordanes; and dieldrins. Methodology was consistent with that used by Mussel Watch in constructing their summations of these pesticide compound groups. Use of these summations assists in putting Maine SWAT data into a national context.

ΣDDTs

The summation of DDDs, DDEs, and DDTs, (six compounds total, called ΣDDTs in this report) is presented in Figure 1.1.3.4.1 (2007), Figure 1.1.3.4.2 (2008), and Figure 1.1.3.4.3 (2009). ΣDDTs ranged from a low mean concentration of 2.7 ng/g dry wt. at Jewell Island, Casco Bay (2007) to a high mean concentration of 25.7 ng/g dry wt. at Long Island, in Casco Bay (2009). The National Status and Trends Mussel Watch considers ΣDDTs scores between 0 and 112 ng/g dry wt. in blue mussel tissue to be "low" (groupings include low, moderate, and high) on a national scale, with all 34 SWAT sites sampled from 2007-09 falling in the low category of that range.

ΣDDTs are in the low range in blue mussels throughout the northeast, with higher scores occurring in oysters in the Gulf of Mexico and in mussels on the southwest coast of California. Highest concentrations are generally found near historic DDT manufacturing plants. DDT was banned in the US in 1972, after widespread use as a pesticide. DDT is persistent in the environment and also is hydrophobic, leading to DDT bioaccumulating in organisms. DDT concentrations in shellfish are decreasing across US sampling stations (Kimbrough, 2008).

Table 1.1.3.4.1: Comparison of Pesticides Analyzed in Gulfwatch and SWAT Programs

	Gulfwatch Chlorinated Pesticides (Sum 21)	SWAT Chlorinated Pesticides	
		2009	2007-08
<u>**Organochlorines**</u>			
ALDRIN	x	x	X
ALPHA-BHC	x	x	X
BETA-BHC		x	X
DELTA-BHC		x	X
GAMMA-BHC (LINDANE)	x	x	X
CAPTAN		x	
ALPHA-CHLORDANE (cis-CHLORDANE)	x	x	X
GAMMA-CHLORDANE	x	x	X
CHLOROTHALONIL		x	
DACTHAL		x	
2,4'-DDD	x	x	x
4,4'-DDD	x	x	x
2,4'-DDE	x	x	x
4,4'-DDE	x	x	x
2,4'-DDT	x	x	x
4,4'-DDT	x	x	x
DIELDRIN	x	x	x
ENDOSULFAN I (α-ENDOSULFAN)	x	x	x
ENDOSULFAN II (β-ENDOSULFAN)	x	x	x
ENDOSULFAN SULFATE		x	x
ENDRIN	x	x	x
ENDRIN KETONE		x	x
HEPTACHLOR	x	x	x
HEPTACHLOR EPOXIDE	x	x	x
HEXACHLOROBENZENE	x	x	x
METHOXYCHLOR	x	x	x
MIREX	x	x	x
CIS-NONACHLOR		x	
TRANS-NONACHLOR	x	x	x
OCTACHLOROSTYRENE		x	
OXYCHLORDANE		x	
PERTHANE		x	
QUINTOZENE		x	
TECNAZENE		x	
	21	34	25

Table 1.1.3.4.1: Comparison of Pesticides Analyzed in Gulfwatch and SWAT Programs
(continued)

	Gulfwatch Chlorinated Pesticides (Sum 21)	SWAT Chlorinated Pesticides	
		2009	2007-08
Organophosphates			
AZINPHOS-METHYL		x	
CHLORPYRIPHOS		x	
CHLORPYRIPHOS-METHYL		x	
CHLORPYRIPHOS-OXON		x	
DIAZINON		x	
DIAZINON-OXON		x	
DISULFOTON		x	
DISULFOTON SULFONE		x	
FENITROTHION		x	
FONOFOS		x	
MALATHION		x	
METHAMIDOPHOS		x	
PARATHION-ETHYL		x	
PARATHION-METHYL		x	
PHORATE		x, NQ	
PHOSMET		x	
PIRIMIPHOS-METHYL		x	
		17	
Triazines			
AMETRYN		x	
ATRAZINE		x	
CYANAZINE		x	
DESETHYLATRAZINE		x	
HEXAZINONE		x	
METRIBUZIN		x	
SIMAZINE		x	
		7	
Pyrethroids			
CYPERMETHRIN		x	
PERMETHRIN		x	
		2	

Table 1.1.3.4.1: Comparison of Pesticides Analyzed in Gulfwatch and SWAT Programs

(continued)	Gulfwatch Chlorinated Pesticides (Sum 21)	SWAT Chlorinated Pesticides	
		2009	**2007-08**
Organonitrogens			
ALACHLOR		x	
BUTRALIN		x	
BUTYLATE		x	
DIMETHENAMID		x	
ETHALFLURALIN		x	
FLUFENACET		x	
FLUTRIAFOL		x	
LINURON		x	
METHOPRENE		x	
METOLACHLOR		x	
PENDIMETHALIN		x	
TEBUCONAZOL		x	
TRIALLATE		x	
TRIFLURALIN		x	
		14	
	sum = 21	74	25

Figure 1.1.3.4.1: Sum of DDDs, DDEs, DDTs in 2007 SWAT Blue Mussels

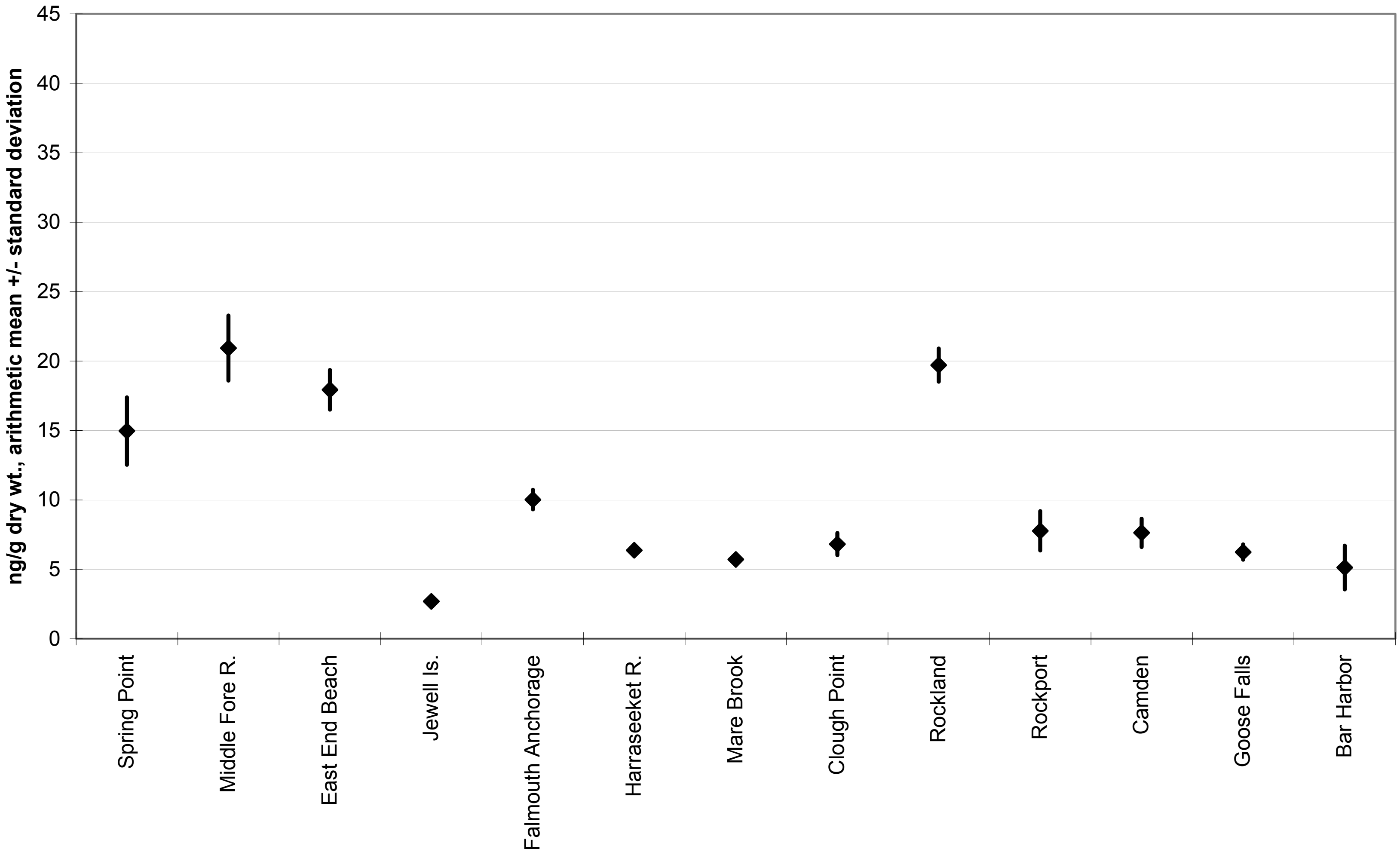


Figure 1.1.3.4.2: Sum of DDDs, DDEs, DDTs in 2008 SWAT Blue Mussels

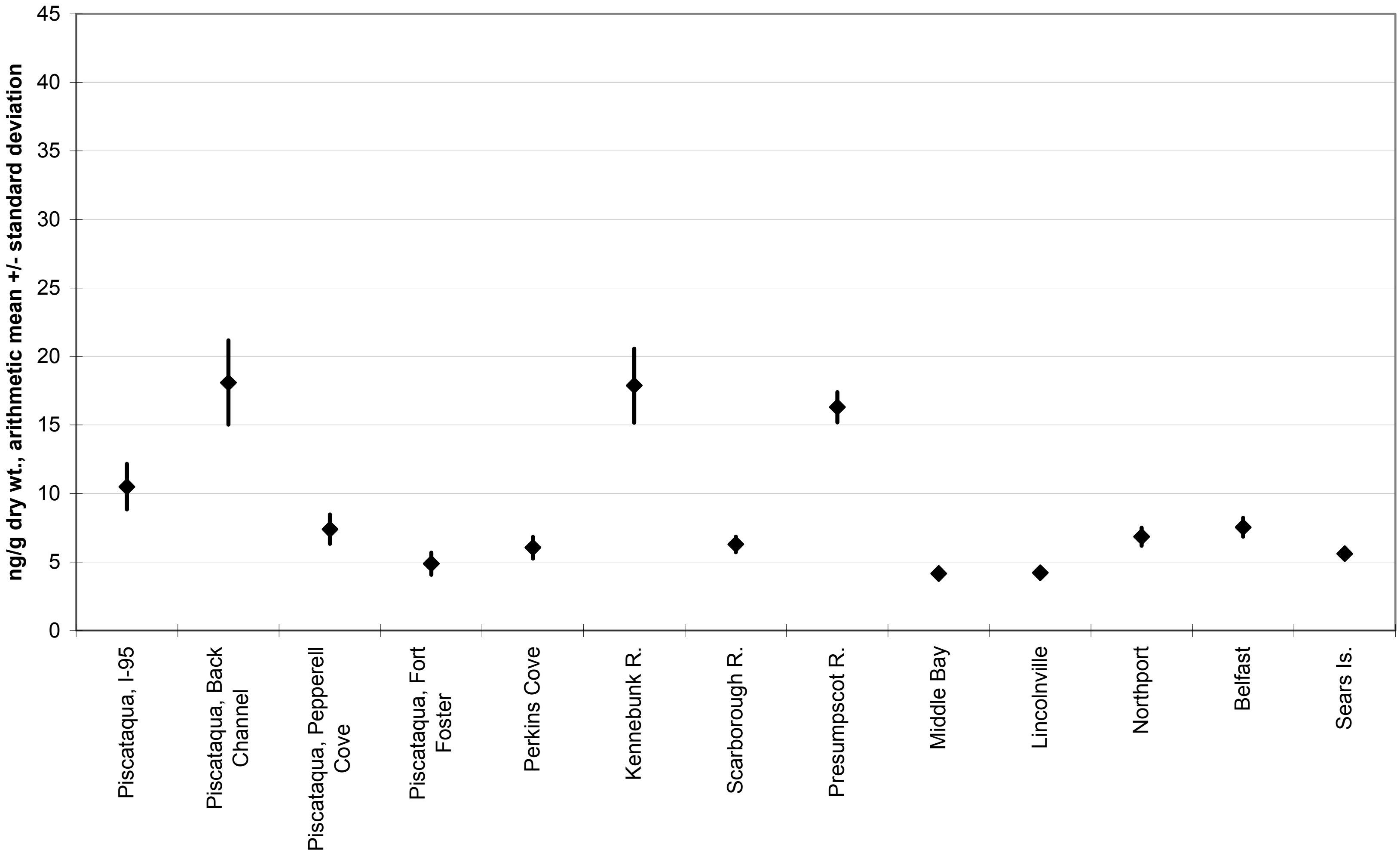
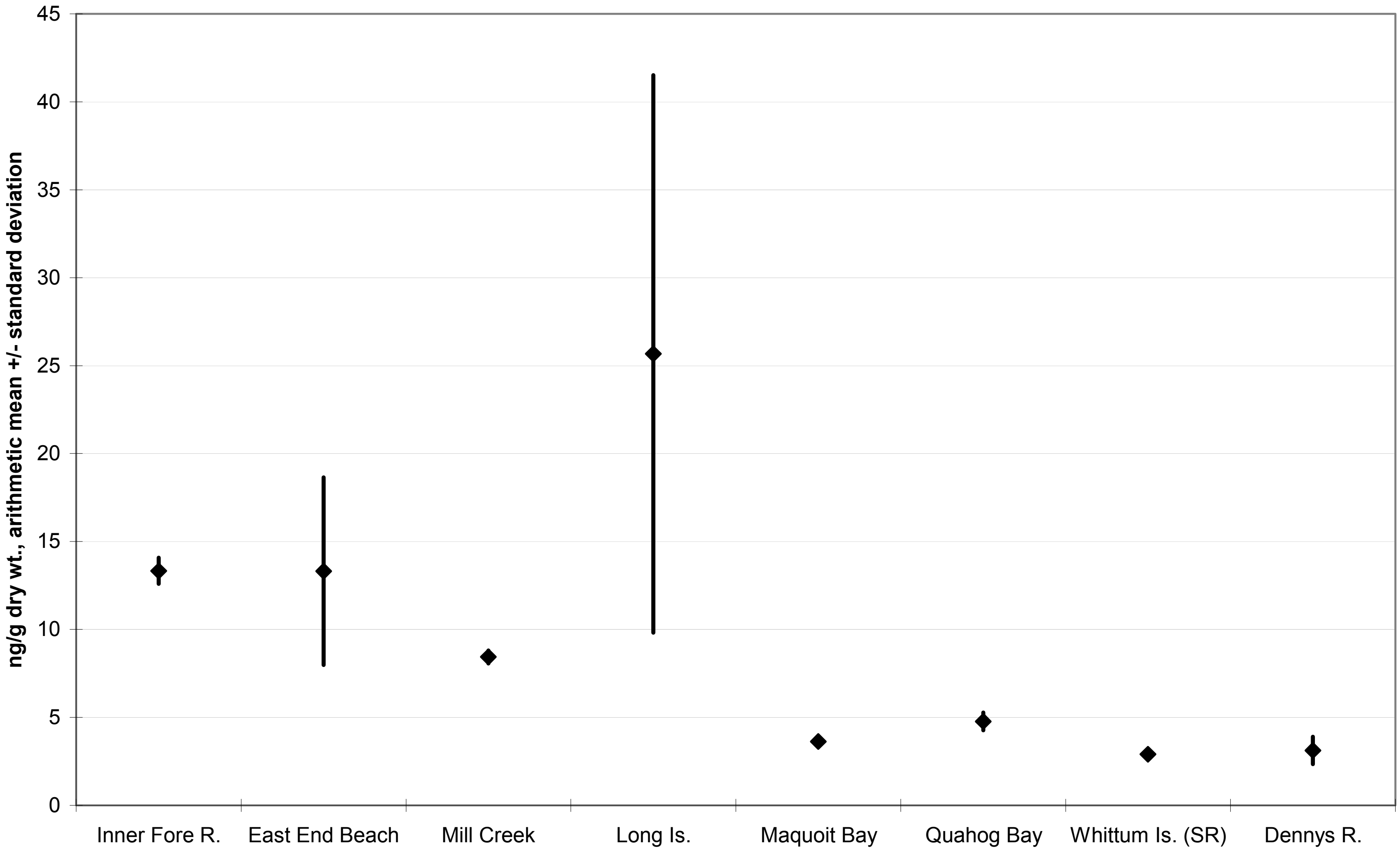


Figure 1.1.3.4.3: Sum of DDDs, DDEs, DDTs in 2009 SWAT Blue Mussels



From a human health perspective, MCDC reports a cancer DDT FTAL of 64 ng/g wet wt. (ppb) and a non-cancer DDT FTAL of 1,080 ng/g wet wt. The MCDC DDT FTALs are based on the summation of DDDs, DDEs, and DDTs, (six compounds total, called ΣDDTs in this report), except that they are expressed on a wet tissue weight basis rather than a dry weight basis used in the SWAT monitoring segments of this report. When converted to wet weight, the highest 2009 SWAT blue mussel tissue DDT concentration was 4.4 ng/g wet wt., which is 6.9% of the more conservative MCDC cancer FTAL of 64 ng/g wet wt.

ΣChlordanes

The summation of alpha-chlordane, heptachlor, trans-nonachlor, and heptachlor epoxide (four compounds total, called ΣChlordanes in this report) was determined from SWAT data and is presented in Figure 1.1.3.4.4 (2007), Figure 1.1.3.4.5 (2008), and Figure 1.1.3.4.6 (2009). ΣChlordanes ranged from a low mean concentration of 0.4 ng/g dry wt. at Whittum Island, Sheepscot River (2009) to a high mean concentration of 4.3 ng/g dry wt. at Presumpscot River (2008). NS&T considers ΣChlordanes scores between 0 and 8 ng/g dry wt. in blue mussel tissue to be “low” (groupings include low, moderate, and high) on a national scale. All 34 SWAT sites sampled from 2007-09 fall in the lower half of that low category (Kimbrough, 2008).

ΣChlordanes are in the low range in blue mussels throughout much of the northeast US, with a few exceptions in urbanized areas like Boston or New York City. Highest concentrations are generally found near areas of historic agricultural use or in urban areas from termite control applications (Kimbrough, 2008). Chlordane, one of the cyclodiene organic pesticides, is a mixture of more than fifty compounds, but is predominantly made up of alpha- and gamma-chlordane, heptachlor, and nonachlor. The NS&T and our SWAT summation capture three of these compounds, plus one transformation product (heptachlor epoxide). Chlordane was used from roughly 1948 through 1983 in agriculture, when it was banned. Chlordane was also the primary insecticide for termite control under ground. All uses were banned in 1988 (Kimbrough, 2008). NS&T Mussel Watch reported that Chlordane was one of the most ubiquitous contaminants measured by that program. ΣChlordanes concentrations in shellfish are decreasing across US sampling stations (Kimbrough, 2008).

The MCDC reports a cancer and non-cancer FTALs for chlordane/nonachlor (summation of alpha-chlordane, gamma-chlordane, and trans-nonachlor) and heptachlor epoxide. MCDC reports a cancer FTAL of 17 ng/g wet wt. and a non-cancer FTAL of 130 ng/g wet wt. for chlordane/nonachlor. The 2009 SWAT blue mussel tissue data, when summed in the same manner, shows the highest mean concentration recorded to be 0.42 ng/g wet wt., which is 2.5% of the 17 ng/g cancer FTAL. MCDC reports a cancer FTAL of 2.4 ng/g wet wt. and a non-cancer FTAL 28 ng/g wet wt. for heptachlor epoxide. The highest mean value for heptachlor epoxide in 2009 SWAT blue mussel tissue was 0.044 ng/g wet wt., which is 1.9% of the 2.4 ng/g wet wt. cancer FTAL.

Figure 1.1.3.4.4: Sum of Chlordanes in 2007 SWAT Blue Mussels

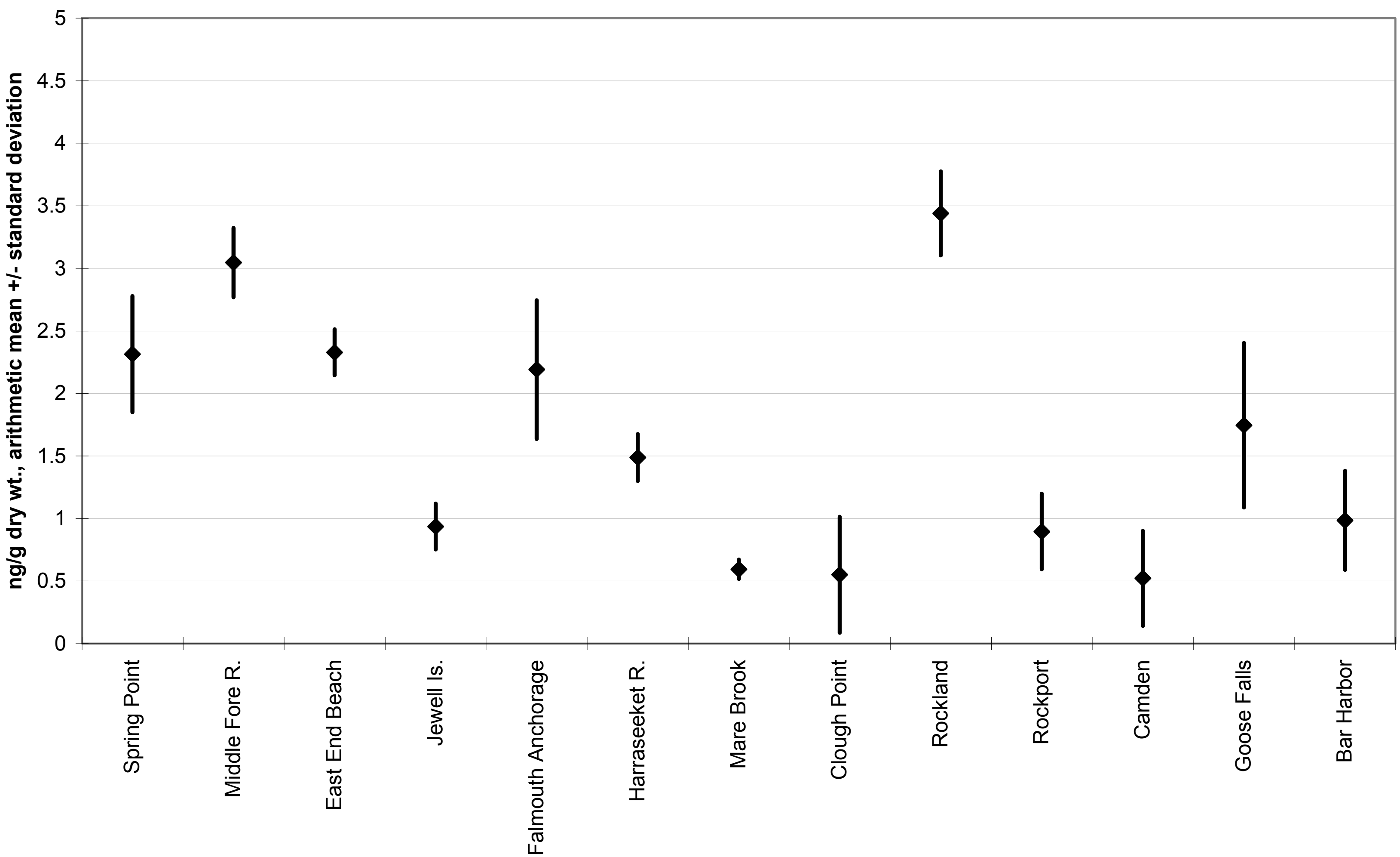


Figure 1.1.3.4.5: Sum of Chlordanes in 2008 SWAT Blue Mussels

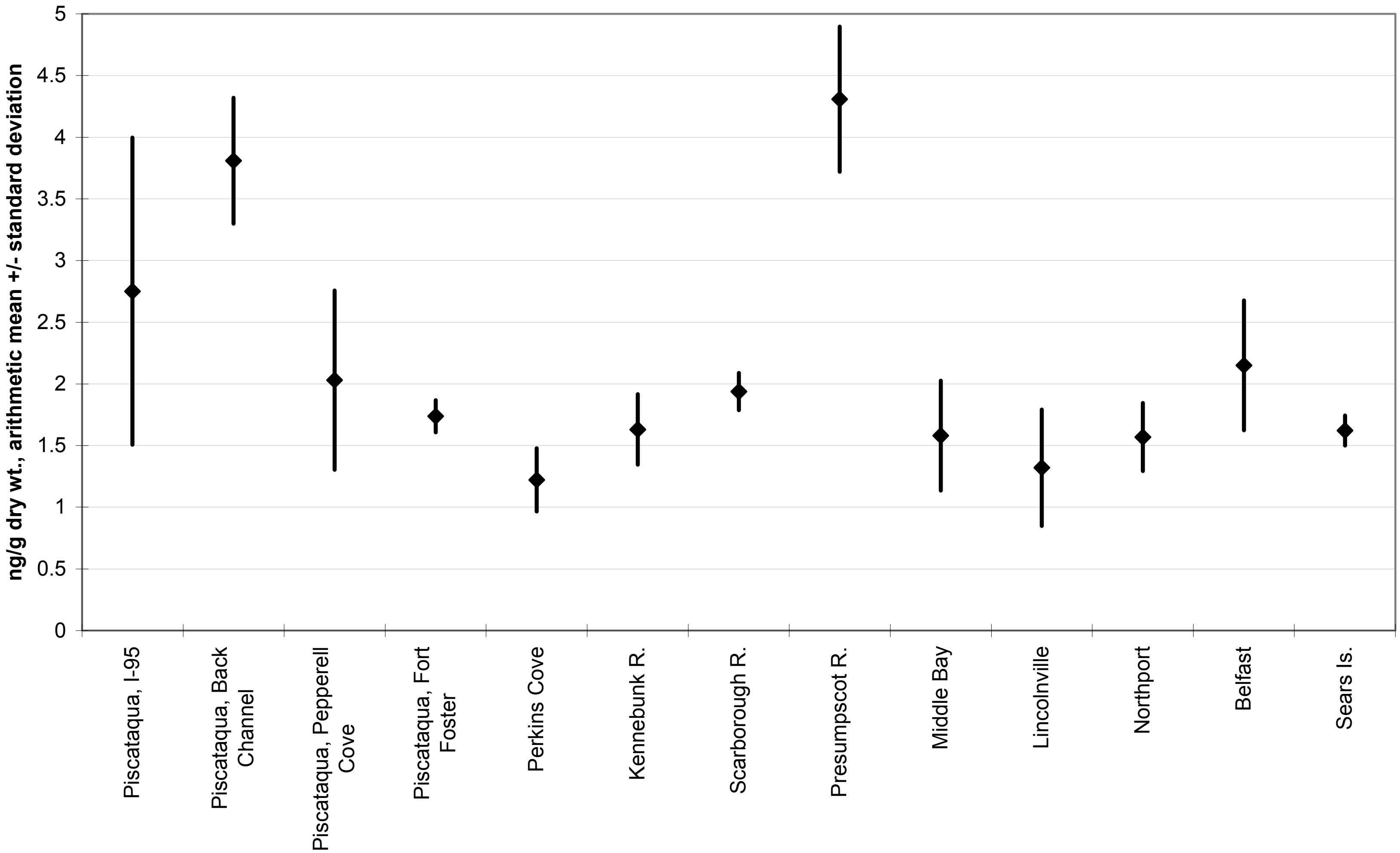
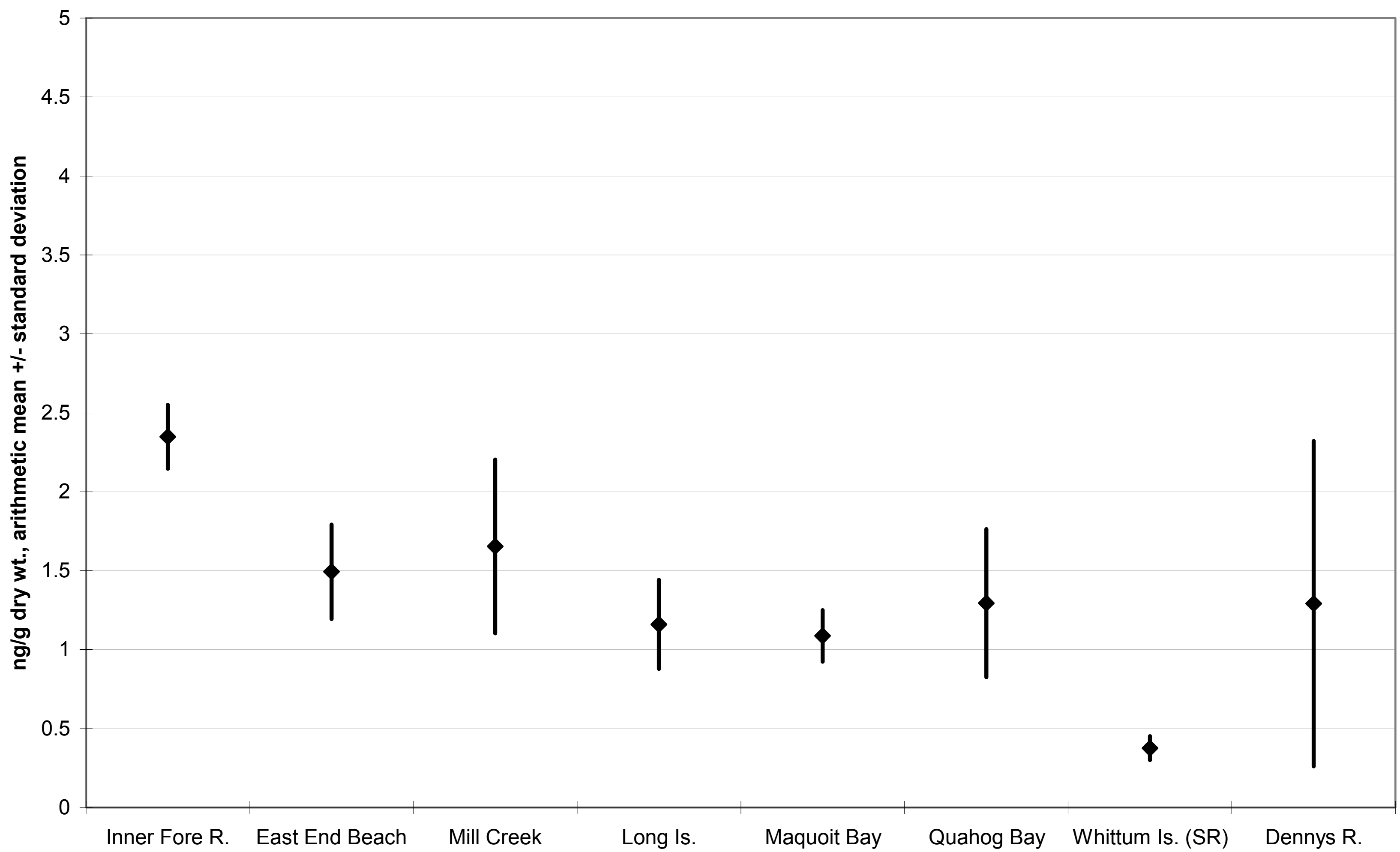


Figure 1.1.3.4.6: Sum of Chlordanes in 2009 SWAT Blue Mussels



ΣDieldrins

The summation of aldrin and dieldrin (two compounds total, called ΣDieldrins in this report) was determined from SWAT data and is presented in Figure 1.1.3.4.7 (2007), Figure 1.1.3.4.8 (2008), and Figure 1.1.3.4.9 (2009). ΣDieldrins ranged from a low mean concentration of 0.29 ng/g dry wt. at Whittum Island, Sheepscot River (2009), to a high mean concentration of 2.5 ng/g dry wt. at Piscataqua River, Back Channel (2008). National Status and Trends Mussel Watch considers ΣDieldrins scores between 0 and 8 ng/g dry wt. in blue mussel tissue to be "low" (groupings include low, moderate, and high) on a national scale, with all 34 of the 2007-09 SWAT sites falling in the lower half of the low category (Kimbrough, 2008).

ΣDieldrins are in the low range in blue mussels throughout most of the northeast US. Nationally, the highest concentrations are generally found near areas of historic pesticide use and manufacturing (Kimbrough, 2008). Dieldrin and aldrin were used as insecticides through the 1960s for the control of termites and on crops. All uses were suspended in 1970, but use as a termite insecticide was allowed again from 1972 through 1989, when use was again cancelled. Aldrin and dieldrin are carcinogenic in animals, and are thought to be in humans (Kimbrough, 2008).

From a human health perspective, MCDC reports cancer and non-cancer FTALs for dieldrin and separately for aldrin. MCDC reports a cancer FTAL of 1.4 ng/g wet wt. and a non-cancer FTAL of 108 ng/g wet wt. for dieldrin. The highest dieldrin mean concentration in blue mussel tissue in 2009 SWAT data was 0.16 ng/g wet wt., which is 11.4% of the MCDC cancer FTAL. MCDC reports a cancer FTAL of 1.3 ng/g wet wt. and a non-cancer FTAL of 65 ng/g wet wt. for aldrin. The highest aldrin mean concentration in blue mussel tissue in 2009 SWAT data was 0.0055 ng/g wet wt., which is 0.4% of the MCDC cancer FTAL.

Figure 1.1.3.4.7: Sum of Dieldrins in 2007 SWAT Blue Mussels

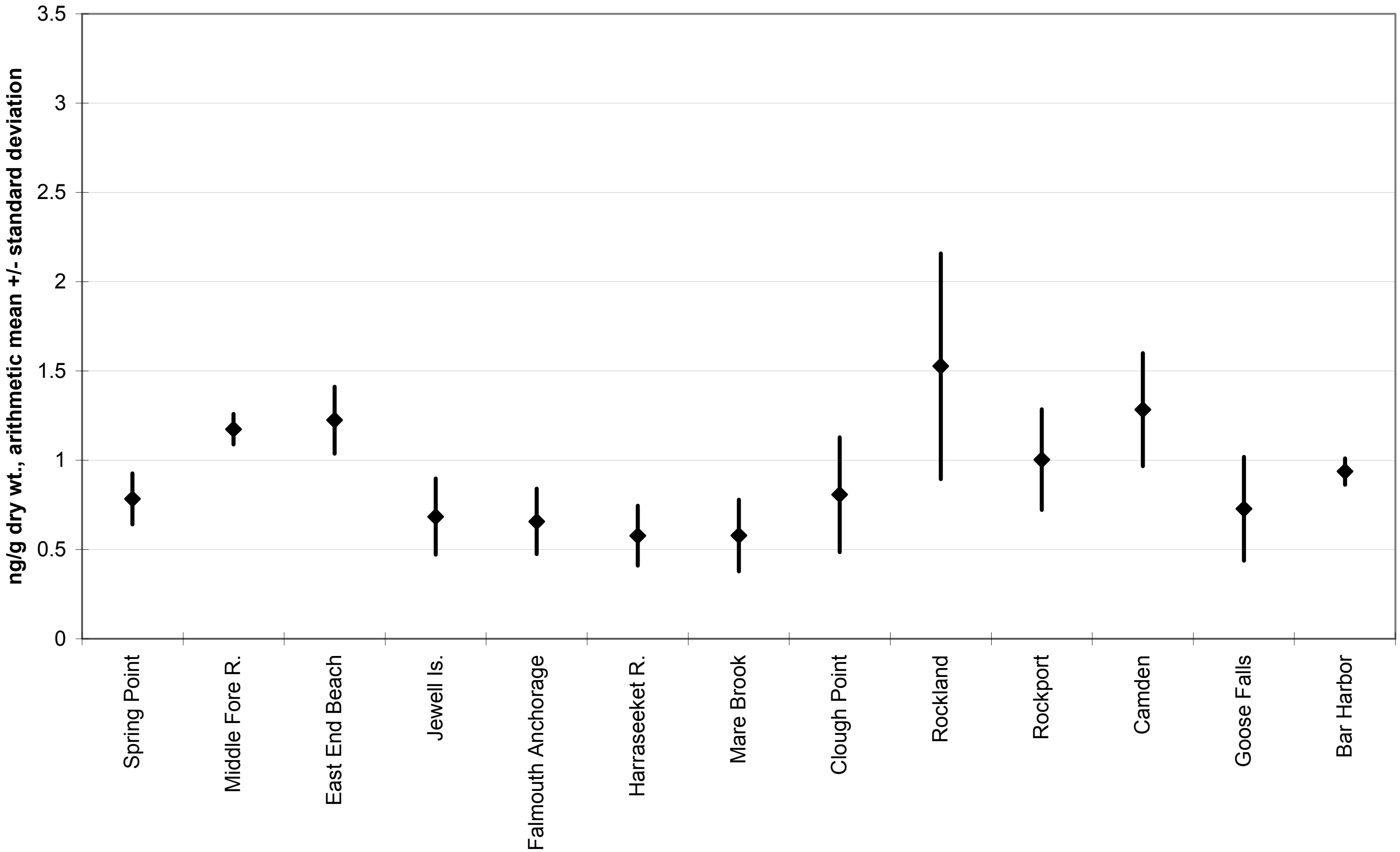


Figure 1.1.3.4.8: Sum of Dieldrins in 2008 SWAT Blue Mussels

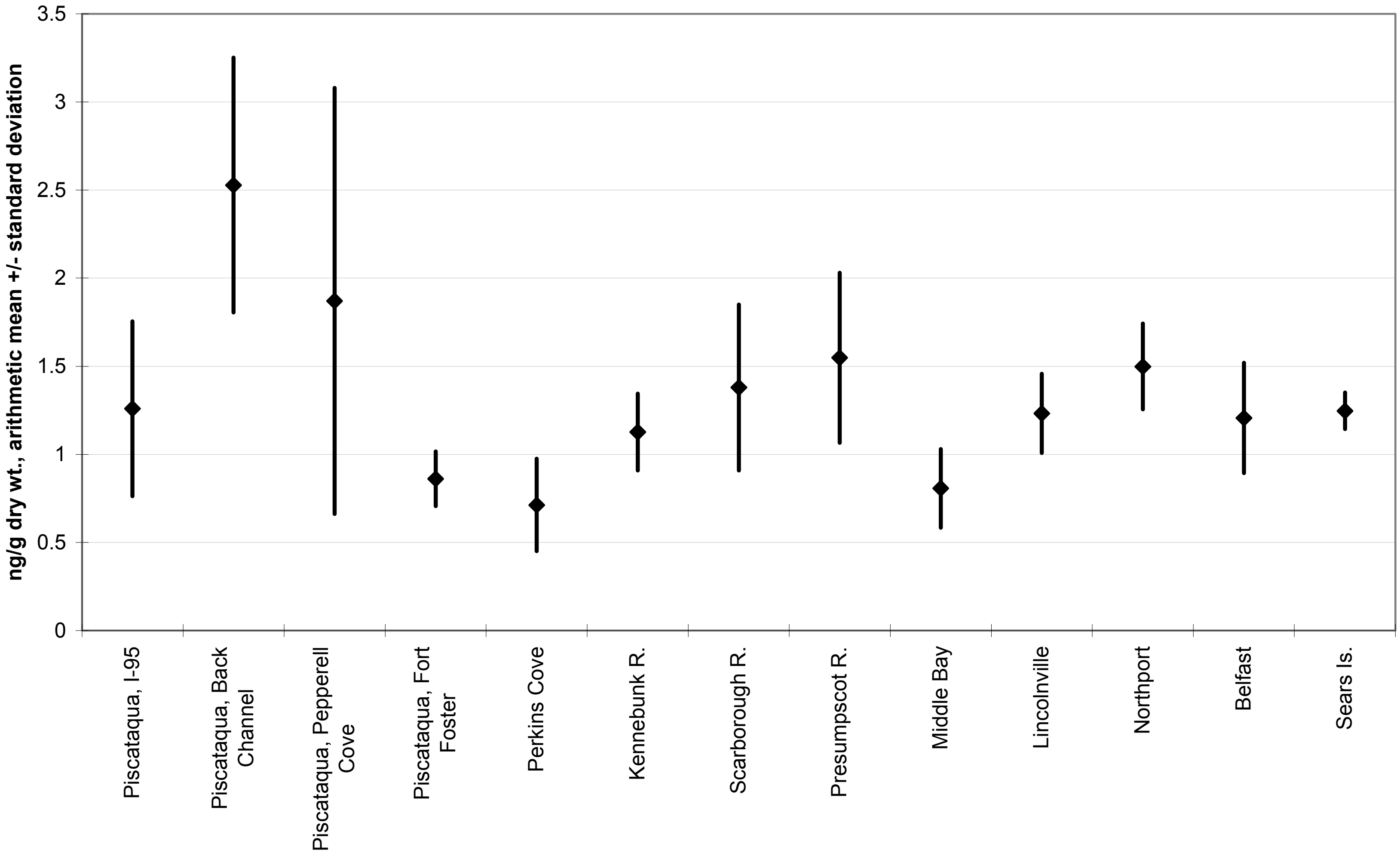
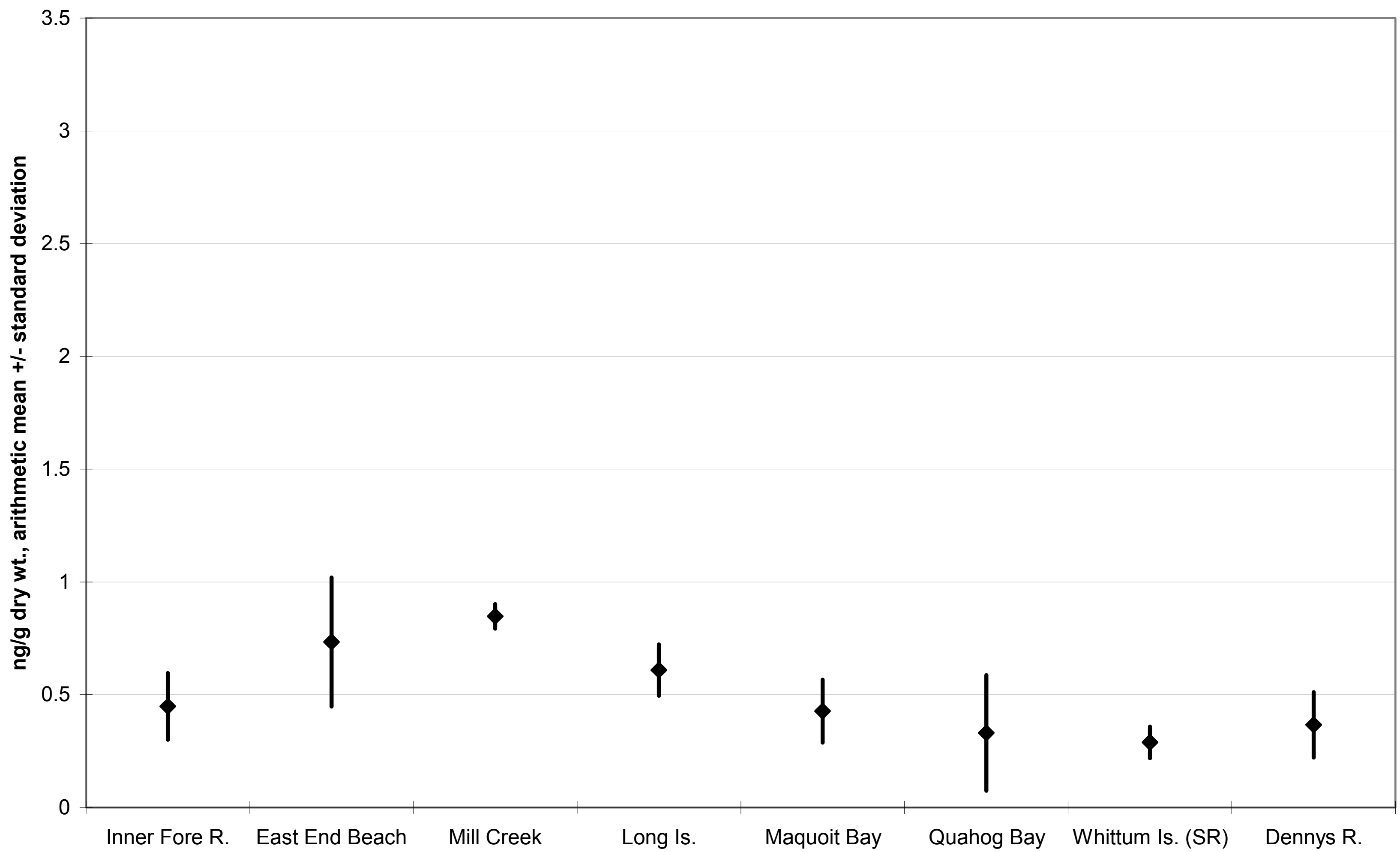


Figure 1.1.3.4.9: Sum of Dieldrins in 2009 SWAT Blue Mussels



Σ21 Organochlorine Pesticides

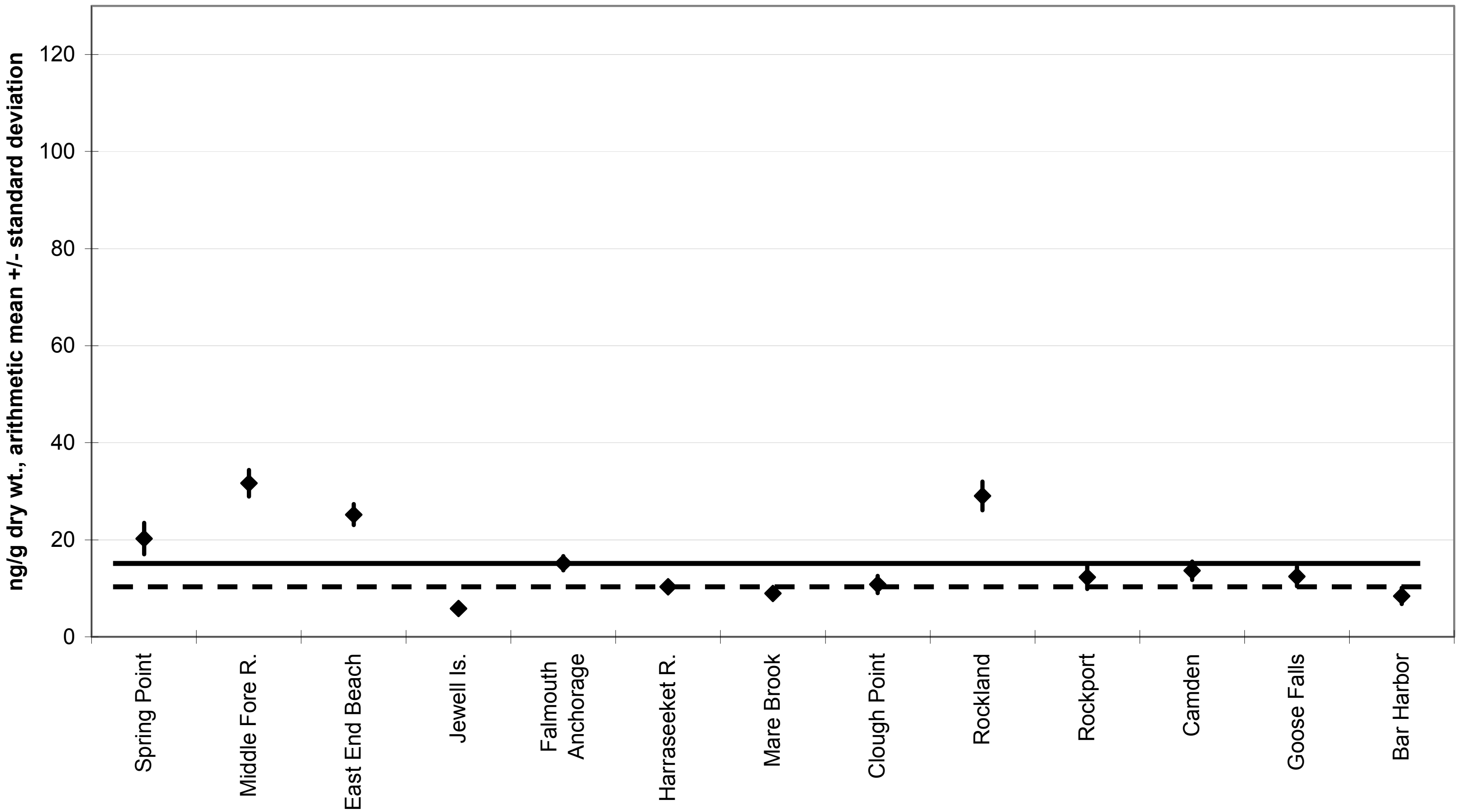
2007 – The summation of 21 organochlorine pesticides (as noted in Table 1.1.3.4.1) was determined from SWAT data and is presented in Figure 1.1.3.4.10 (21 compounds total, called Σ21 Pesticides in this report). Σ21 Pesticides ranged from a low mean concentration of 5.8 ng/g dry wt. at Jewell Island, Casco Bay, to a high mean concentration of 31.7 ng/g dry wt. at Middle Fore River, Portland. Σ21 Pesticides ranged evenly across this spread at the remaining 11 of the 13 sites tested. Figure 1.1.3.4.10 compares the sum of Σ21 Pesticides at the 2007 SWAT sites to recent Gulfwatch median and 85th percentile for Σ21 Pesticides (2008 data, the most recent available). Of the 13 SWAT sites tested in 2007, 10 of 13 sites exceeded the Gulfwatch 2008 median, 9.9 ng/g (dry weight) for Σ21 Pesticides. Five sites sampled in 2007 exceeded the Gulfwatch 85th percentile, 14.3 ng/g (dry weight), for Σ21 Pesticides. The remaining eight SWAT sites tested for Σ21 Pesticides all fell below the Gulfwatch 85th percentile concentration for Σ21 Pesticides.

Figure 1.1.3.4.11 compares the sum of Σ21 Pesticides at the 2007 SWAT sites to recent NS&T Mussel Watch median and 85th percentile for Σ21 Pesticides (2008 data, the most recent available). Of the 13 SWAT sites tested in 2007, 3 of 13 sites exceeded the NS&T 2008 median, 22.9 ng/g (dry weight), for Σ21 Pesticides. None of the 13 sites sampled in 2007 approached or exceeded the NS&T 85th percentile of 128 ng/g (dry weight) for Σ21 Pesticides. SWAT sites were mostly below the 2008 NS&T median concentration.

2008 – The summation of 21 organochlorine pesticides (as noted in Table 1.1.3.4.1) was determined from SWAT data and is presented in Figure 1.1.3.4.12 (21 compounds total, called Σ21 Pesticides in this report). Σ21 Pesticides ranged from a low mean concentration of 8.6 ng/g dry wt. at Lincolnville to a high mean concentration of 26.9 ng/g dry wt. at Back Channel, Piscataqua River. Σ21 Pesticides ranged evenly across this spread at the remaining 11 of the 13 sites tested. Figure 1.1.3.4.12 compares the sum of Σ21 Pesticides at the 2008 SWAT sites to recent Gulfwatch median and 85th percentile for Σ21 Pesticides (2008 data, the most recent available). Of the 13 SWAT sites tested in 2008, 11 of 13 sites exceeded the Gulfwatch 2008 median, 9.9 ng/g (dry weight), for Σ21 Pesticides. Five sites sampled in 2008 exceeded the Gulfwatch 85th percentile, 14.3 ng/g (dry weight), for Σ21 Pesticides. The remaining eight SWAT sites tested for Σ21 Pesticides all fell below the Gulfwatch 85th percentile concentration for Σ21 Pesticides.

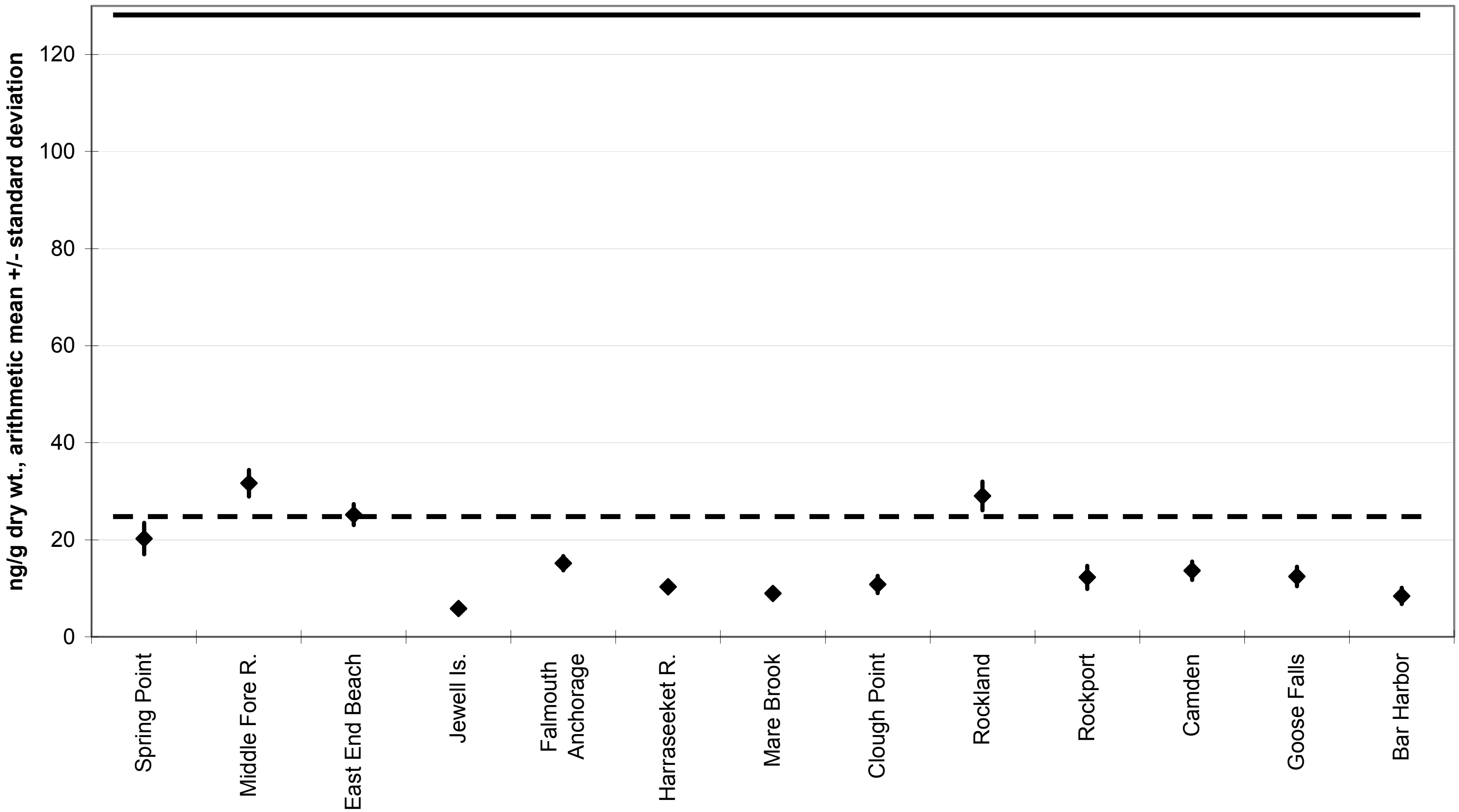
Figure 1.1.3.4.13 compares the sum of Σ21 Pesticides at the 2008 SWAT sites to recent NS&T Mussel Watch median and 85th percentile for Σ21 Pesticides (2008 data, the most recent available). Of the 13 SWAT sites tested in 2008, 3 of 13 sites exceeded the NS&T 2008 median, 22.9 ng/g (dry weight)for Σ21 Pesticides. None of the 13 sites sampled in 2008 approached or exceeded the NS&T 85th percentile of 128 ng/g (dry weight) for Σ21 Pesticides. SWAT sites were mostly below the 2008 NS&T median concentration.

Figure 1.1.3.4.10: Sum of 21 Chlorinated Pesticides in 2007 SWAT Blue Mussels



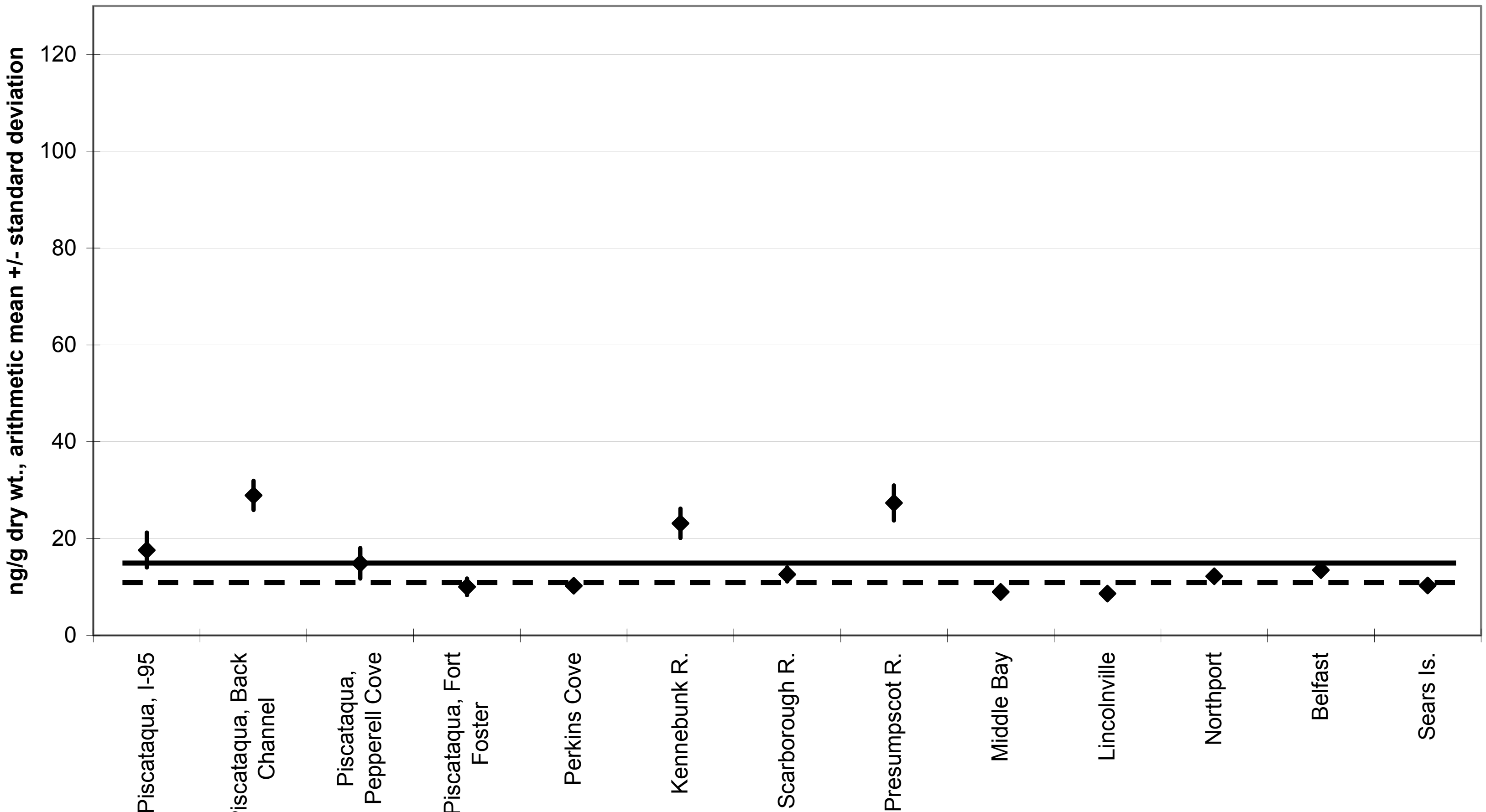
Dashed line = 2008 Gulfwatch Median (Sum 21 Chlorinated Pesticides); Solid line = 2008 Gulfwatch 85th Percentile (Sum 21 Chlorinated Pesticides).

Figure 1.1.3.4.11 Sum of 21 Chlorinated Pesticides in 2007 SWAT Blue Mussels



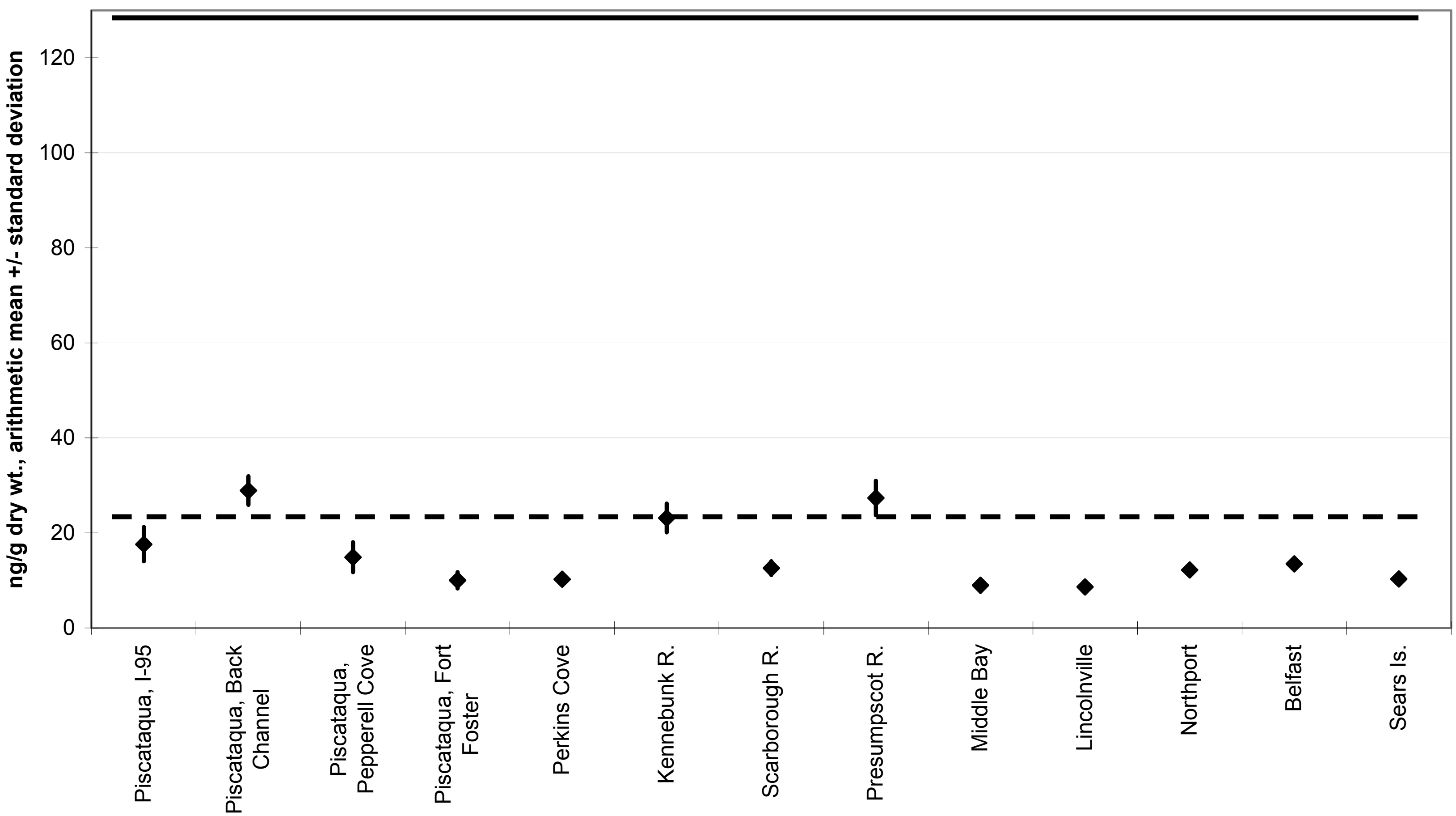
Dashed line = 2008 National Status and Trends Median (Sum 21 Chlorinated Pesticides); Solid line = 2008 National Status and Trends 85th Percentile (Sum 21 Chlorinated Pesticides).

FIgure 1.1.3.4.12: Sum of 21 Chlorinated Pesticides in 2008 SWAT Blue Mussels



Dashed line = 2008 Gulfwatch Median (Sum 21 Chlorinated Pestcides); Solid line = 2008 Gulfwatch 85th Percentile (Sum 21 Chlorinated Pesticides).

FIgure 1.1.3.4.13: Sum of 21 Chlorinated Pesticides in 2008 SWAT Blue Mussels



Dashed line = 2008 National Status and Trends Median (Sum 21 Chlorinated Pestcides); Solid line = 2008 National Status and Trends 85th Percentile (Sum 21 Chlorinated Pesticides).

2009 - The summation of 21 organochlorine pesticides (as noted in Table 1.1.3.4.1) was determined from SWAT data and is presented in Figure 1.1.3.4.14 (21 compounds total, called Σ21 Pesticides in this report). Σ21 Pesticides ranged from a low mean concentration of 6.4 ng/g dry wt. at Whittum Island, Sheepscot River, to a high mean concentration of 30.5 ng/g dry wt. at Long Island, Casco Bay. Σ21 Pesticides ranged evenly across this spread at the remaining 6 of the 8 sites tested. Figure 1.1.3.4.14 compares the sum of Σ21 Pesticides at the 2009 SWAT sites to recent Gulfwatch median and 85^{th} percentile for Σ21 Pesticides (2008 data, the most recent available). Of the 8 SWAT sites tested in 2009, five sites exceeded the Gulfwatch 2008 median, 9.9 ng/g (dry weight), for Σ21 Pesticides. Three sites sampled in 2009 exceeded the Gulfwatch 85^{th} percentile, 14.3 ng/g (dry weight), for Σ21 Pesticides. The remaining five SWAT sites tested for Σ21 Pesticides all fell below the Gulfwatch 85^{th} percentile concentration for Σ21 Pesticides.

Figure 1.1.3.4.15 compares the sum of Σ21 Pesticides at the 2009 SWAT sites to recent NS&T Mussel Watch median and 85^{th} percentile for Σ21 Pesticides (2008 data, the most recent available). Of the eight SWAT sites tested in 2009, one exceeded the NS&T 2008 median, 22.9 ng/g (dry weight), for Σ21 Pesticides. None of the eight sites sampled in 2009 approached or exceeded the NS&T 85^{th} percentile of 128 ng/g (dry weight) for Σ21 Pesticides. SWAT sites were mostly below the 2008 NS&T median concentration.

From a human health perspective, the MCDC reports cancer and/or non-cancer FTALs for several individual chlorinated pesticides which fall under the heading of the Σ21 Pesticides discussed above. To compare the FTALs to SWAT data, the individual pesticide data has been expressed on wet weight basis and matched to the corresponding MCDC FTAL(s).

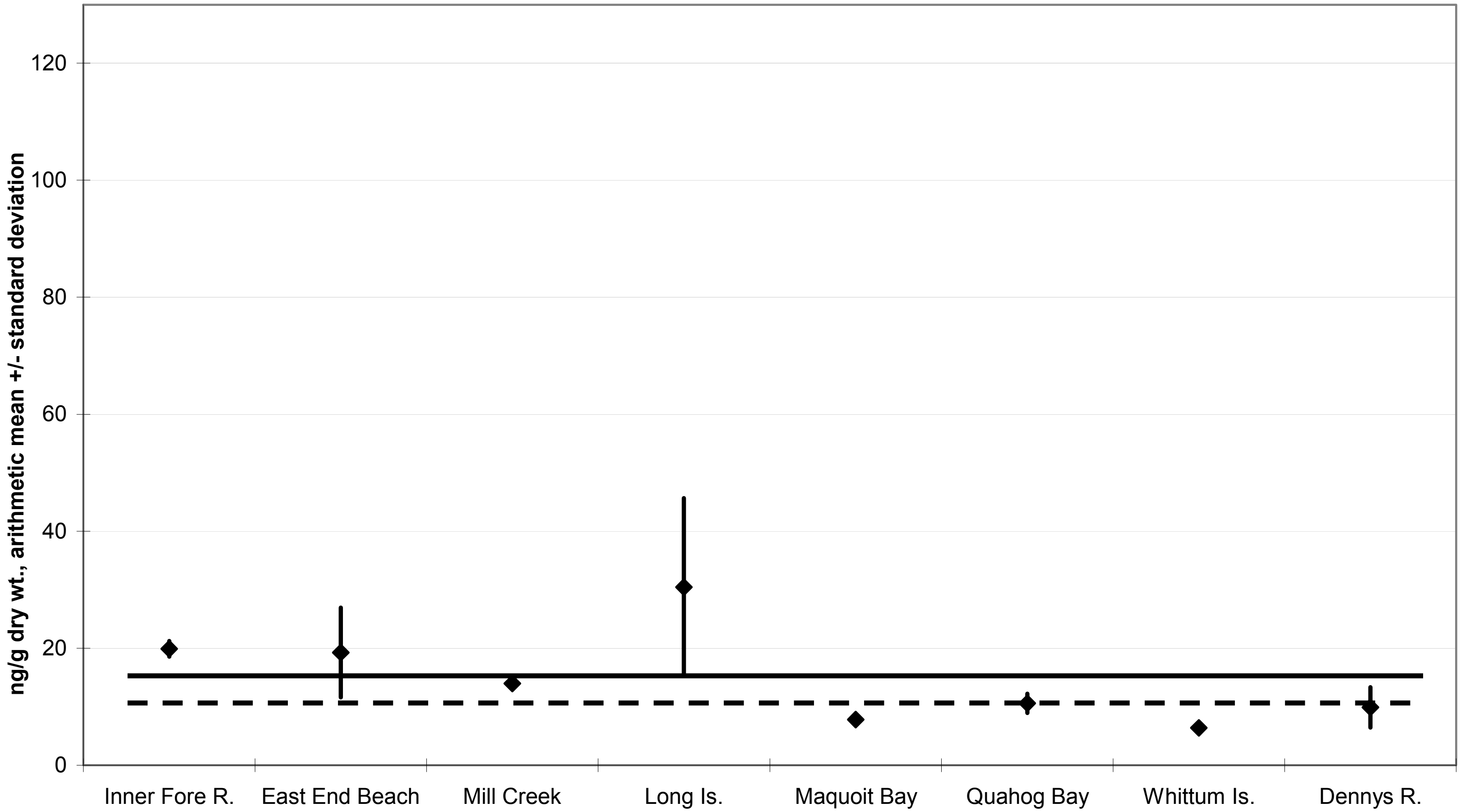
For hexachlorobenzene, MCDC reports a cancer FTAL of 14 ng/g wet wt. and a non-cancer FTAL of 1,728 ng/g wet wt. The highest mean hexachlorobenzene concentration in blue mussel tissue detected by SWAT in 2009 was 0.039 ng/g wet wt., which is 0.3% of the more protective MCDC cancer FTAL.

For heptachlor, MCDC reports a cancer FTAL of 5 ng/g wet wt. and a non-cancer FTAL of 1,080 ng/g wet wt. The highest mean heptachlor concentration in blue mussel tissue detected by SWAT in 2009 was 0.0072 ng/g wet wt., which was 0.1% of the more protective MCDC cancer FTAL.

For mirex, MCDC reports a non-cancer FTAL of 432 ng/g wet wt. MCDC does not report a cancer FTAL for mirex. The highest mean mirex concentration in blue mussel tissue detected by SWAT in 2009 was 0.0093 ng/g wet wt., which was 0.002% of the MCDC non-cancer FTAL.

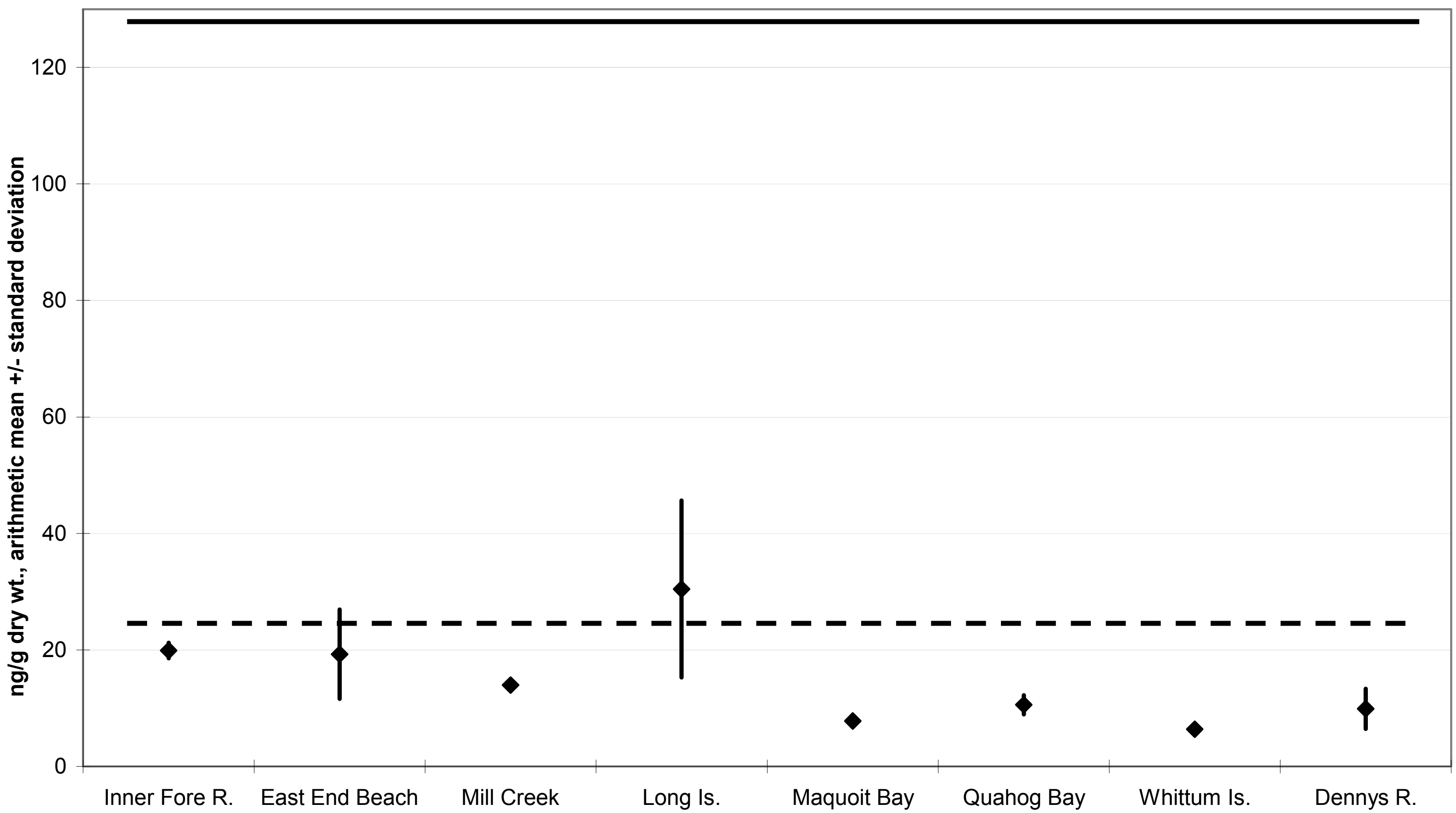
For lindane, MCDC reports a cancer FTAL of 17 ng/g wet wt. and a non-cancer FTAL of 648 ng/g wet wt. The highest mean lindane concentration in blue mussel tissue detected

Figure 1.1.3.4.14: Sum of 21 Chlorinated Pesticides at 2009 SWAT Blue Mussel Sites



Dashed line = 2008 Gulfwatch Median (Sum 21 Chlorinated Pesticides); Solid line = 2008 Gulfwatch 85th Percentile (Sum 21 Chlorinated Pesticides).

Figure 1.1.3.4.15: Sum of 21 Chlorinated Pesticides at 2009 SWAT Blue Mussel Sites



Dashed line = 2008 National Status and Trends Median (Sum 21 Chlorinated Pesticides); Solid line = 2008 National Status and Trends 85th Percentile (Sum 21 Chlorinated Pesticides).

by SWAT in 2009 was 0.017 ng/g wet wt., which was 0.1% of the more protective MCDC cancer FTAL.

For endosulfan (summation of endosulfan I and II), MCDC reports a non-cancer FTAL of 12,963 ng/g wet wt. MCDC does not report a cancer FTAL for endosulfan. The highest mean endosulfan concentration in blue mussel tissue detected by SWAT in 2009 was 0.30 ng/g wet wt., which was 0.002% of the MCDC non-cancer FTAL.

As outlined at the beginning of the pesticides section of this report, in 2009 SWAT blue mussel samples were analyzed for a variety of additional pesticides beyond the traditional Gulfwatch and NS&T suite of organochlorinated pesticides. DEP staff and the SWAT Technical Advisory Group are interested in obtaining data for analytes which previously have not received attention in Maine SWAT work, and pesticides beyond the organochlorinated pesticides sampled for previously fit this description. As noted in Table 1.1.3.4.1, previously unanalyzed, "newer" pesticides for which analyses were performed in 2009 included organophosphates, triazines, pyrethroids, and organonitrogens. Across all eight sites tested for pesticides in 2009, results were almost exclusively non-detects at the various sample specific detection limits (which varied by pesticide analyte and by individual replicate sampled). Within the organonitrogen group of pesticides, one "detect" was encountered for one replicate of four at two different sites for two different pesticides within the organonitrogen group. These results are not of interest for discussion since the three other replicates at each site showed nondetects and mean results across four replicates would involve nondetects dominating the results.

1.1.3.5 References

Buchholtz ten Brink, M., F.T. Manheim, J.C. Hathaway, S.H. Jones, L.G. Ward, P.F. Larsen, B.W. Tripp and G.T. Wallace. 1997. Gulf of Maine contaminated Sediment Database: Draft Final Report. Regional Marine Research Program for the Gulf of Maine, Orono, ME.

Kimbrough, K. L., W. E. Johnson, G. G. Lauenstein, J. D. Christensen and D. A. Apeti. 2008. An Assessment of Two Decades of Contaminant Monitoring in the Nation's Coastal Zone. Silver Spring, MD. NOAA Technical Memorandum NOS NCCOS 74. 105 pp.

Krahforst, C., B. Arter, J Aube, C. Bourbonnaise-Boyce, G. Brun, G. Harding, P. Hennigar, D. Page, S. Jones, S. Shaw, J. Stahlnecker, J. Schwartz, D. Taylor, B. Thorpe, P. Vass, P. Wells. 2009. Gulfwatch 2006 Data Report: Sixteenth Year of the Gulf of Maine Environmental Monitoring Program. Gulf of Maine Council on the Marine Environment.

LeBlanc, Lawrence A., Christian Krahforst, Jamie Aube, Cynthia Bourbonnaise-Boyce, Guy Brun, Gareth Harding, Peter Hennigar, David Page, Stephen Jones, Susan Shaw, James Stahlnecker, Jack Schwartz, Darrell Taylor, Bruce Thorpe, Peter Vass, and Peter Wells. 2009. Gulfwatch 2008 Data Report: Eighteenth Year of the Gulf of Maine Environmental Monitoring Program. Gulf of Maine Council on the Marine Environment.

Neff, J.M., Stout S.A., Gunster D.G. 2005. Ecological risk assessment of PAHs in sediments. Identifying sources and toxicity. Integrated Environmental Assessment and Management 1:22-33.

Sanudo-Wilhemy, S.A. and A.R. Flegal, 1992. Anthropogenic Silver in Southern California Bight: A New Tracer of Sewage in Coastal Waters. Environ. Sci. Technol. 26:2147-2151.

Sowles, J., R. Crawford, P. Hennigar, et al., 1997. Gulfwatch Project Standard Procedures: Field and Laboratory, Gulfwatch Implementation Period 1993-2001. Gulf of Maine Council on the Marine Environment.

2.0 LAKES MODULE

PRINCIPAL INVESTIGATOR	Barry Mower
TECHNICAL ASSISTANTS	John Reynolds Joseph Glowa

2.1 ANDROSCOGGIN LAKE CONTAMINANTS IN FISH

Total PCB levels above the FTAL have been documented in bass and white perch from Androscoggin Lake in years past but no recent total PCB data were available for white sucker from the lake. In 2009, the Maine Center for Disease Control and Prevention (MCDC) requested sampling of both bass and white sucker from Androscoggin Lake to confirm historical levels in bass and provide representative sampling for white sucker. Consequently, a total of ten smallmouth bass and ten white sucker were collected from Androscoggin Lake in Wayne during July 2009 and combined into two composites of five fish each of each species. Each composite was analyzed for total PCBs (TPCB) by summation of congeners, for mercury, percent moisture and percent lipid.

Results of TPCB analysis showed that in 2009 concentrations in both smallmouth bass and white sucker appear higher than when last measured in 2001 and 2000 respectively, but the small sample size (n=2) precludes meaningful statistical analysis to know whether differences are real or a result of natural variation (Table 2.1). Concentrations were similar to those in Gulf Island Pond (GIP) into which the lake drains. Concentrations in both species exceeded the MCDC's Fish Tissue Action Level (FTAL) of 11 ng/g. The data have been sent to MCDC for evaluation of the need for modification of the current fish consumption advisory..

Table 2.1. Mean total PCBs (ng/g) in fish from Androscoggin Lake (max value where n=2 or 95th upper confidence level where n>2)

Year	Species	Androscoggin L ALW
1998	SMB	3.1
2001	SMB	15.5
2009	SMB	25 (25)
1998	WHP	5
2001	WHP	22
2002	WHP	41
2008	WHP	18 (23)
1998	WHS	5
2000	WHS	11.8
2009	WHS	32 (44)

SMB = smallmouth bass, WHP = white perch, WHS = white sucker

3.0 RIVERS AND STREAMS MODULE

3.1

AMBIENT BIOLOGICAL MONITORING

3.1 AMBIENT BIOLOGICAL MONITORING

3.1.1 Background

As part of the SWAT program, DEP's Biological Monitoring Unit evaluates benthic macroinvertebrate communities of Maine streams and rivers to determine if they are impaired by toxic contamination. For reasons of comparability, a small number of unimpaired reference sites are also evaluated. Benthic macroinvertebrates are animals without backbones that can be seen with the naked eye and live on the stream bottom, such as mayflies, stoneflies, caddisflies, crayfish, snails, and leeches. In 2009, we evaluated the condition of 39 sample locations, primarily in the St. John River basin.

The Biological Monitoring Unit uses a multivariate statistical model to analyze a benthic macroinvertebrate sample and predict if a waterbody is attaining the biological criteria associated with its statutory class. If a waterbody does not meet minimum state aquatic life criteria, Class C, then the model class is predicted as Non-Attainment (NA). Classes AA and A are treated the same in the model. Final decisions on aquatic life attainment of a waterbody are made accounting for factors that may allow adjustments to the model outcome. This is called the final determination.

Table 3.1.1 summarizes the results of biological monitoring activities for the 2009 SWAT Program, sorted by waterbody name. Column headings of Table 3.1.1 are described below:

- *Station* – Since waterbodies are sometimes sampled in more than one location, each sampling location is assigned a unique "Station" number.
- *Log* – Each sample event is assigned a unique "Log" number.
- *Issue* – Issues are potential sources of pollution.
- *Statutory Class* – The state legislature has assigned a statutory class, either AA, A, B, or C, to every Maine stream and river. Class AA and A waterbodies shall support a "natural" biological community. Class B waterbodies shall not display "detrimental changes in the resident biological community". Class C waterbodies shall "maintain the structure and function of the resident biological community".
- *Final determination* – The final decision on aquatic life attainment of a waterbody; this decision accounts for factors that may allow adjustments to the model outcome.
- *Attains Class* – "Y" is given if the final determination is equal to or exceeds the Statutory Class. A Class B stream, for example, would receive a "Y" if its Final determination was either A or B. "N" is given if a stream does not attain its Statutory Class. A Class B stream, for example, would receive an "N" if its final determination was either C or NA.
- *Probable Cause* – The probable cause column lists potential stressors to benthic macroinvertebrate communities, based on best professional judgment. In some cases, a probable cause may not be related to toxic pollution but instead to poor habitat conditions.

Data reports for each sampling event, known as Aquatic Life Classification Attainment Reports, are available in electronic format with the web version of this report. Supporting water chemistry data are given in Table 3.1.2. Water temperature data are given in Figure 3.1.1. For more information about the Biological Monitoring Unit, please e-mail us at biome@maine.gov or visit our web site: http://www.state.me.us/dep/blwq/docmonitoring/biomonitoring/index.htm. The Data and Maps page of this website provides access to station information and available data via Google Earth.

3.1.2 Results Summary

- Thirty-nine stations were assessed for the condition of the benthic macroinvertebrate community.
- Twenty-nine of the thirty-nine stations attained the aquatic life standards of their assigned class.

Table 3.1.1 - 2009 SWAT Benthic Macroinvertebrate Biomonitoring Results

Waterbody	Town	Station	Log	Issue[1]	Statutory Class/ Final Determina-tion	Attains Class?	Probable Cause[1]
Aroostook River	Ashland	929	1856	NPS	AA / A	Y	
Aroostook River	Presque Isle	594	1857	NPS	B / A	Y	
Aroostook River	Presque Isle	595	1858	Municipal/ NPS	C / A	Y	
Aroostook River	Caribou	370	1859	Municipal/ NPS	C / A	Y	
Capisic Brook	Portland	931	1835	Urban NPS	C / NA	N	Urban runoff/ toxics
Capisic Brook	Portland	932	1836	Urban NPS	C / NA	N	Urban runoff/ toxics
Capisic Brook	Portland	934	1838	Urban NPS	C / NA	N	Urban runoff/ toxics
Capisic Brook	Portland	257	1839	Urban NPS	C / NA	N	Urban runoff/ toxics
Capisic Brook- Unnamed Tributary	Portland	933	1837	Urban NPS	C / NA	N	Urban runoff/ toxics
Caribou Stream	Caribou	935	1861	Urban NPS	B / A	Y	
Coloney Brook	Ft. Fairfield	733	1871	Agricultural NPS	B / C	N	Agricultural NPS
Dickey Brook	T17 R05 WELS	688	1852	Agricultural NPS	B / B	Y	
Dudley Brook	Castle Hill	928	1867	Agricultural NPS	B / A	Y	
Dudley Brook	Chapman	215	1868	Agricultural NPS	B / A	Y	
Everett Brook	Ft. Fairfield	924	1872	Agricultural NPS	B / B	Y	
Fish River	Ft. Kent	371	1844	NPS	B / B	Y	
Gardner Brook	Wade	689	1860	Forestry NPS	B / A	Y	

[1] NPS, non-point source pollution; BPJ, Best Professional Judgment.

Table 3.1.1 - 2009 SWAT Benthic Macroinvertebrate Biomonitoring Results (cont.)

Waterbody	Town	Station	Log	Issue	Statutory Class/ Final Determina-tion	Attains Class?	Probable Cause[1]
Getchell Brook	Easton	925	1843	Agricultural NPS	B / A	Y	
Kennedy Brook	Presque Isle	646	1870	Urban NPS	B / B	Y	
Little Madawaska River	Connor TWP	730	1864	Reference	A / A	Y	
Little Madawaska River	Caribou	731	1865	Municipal/ NPS	B / A	Y	
Merrit Brook	Presque Isle	742	1866	NPS	B / NA	N	Agricultural NPS
North Fork McLean Brook	St. Agatha	922	1850	Agricultural NPS	B / C	N	Agricultural NPS
Perley Brook	Ft. Kent	727	1851	NPS	B / A	Y	
Prestile Stream	Easton	734	1840	Agricultural NPS	A / B	N	Agricultural NPS
Prestile Stream	Westfield	690	1841	Agricultural NPS	A / A	Y	
Prestile Stream	Blaine	3	1842	Agricultural NPS/Municipal	B / C	N	Enrichment
River de Chute	Easton	926	1846	Agricultural NPS	B / A	Y	
Salmon Brook	Perham	376	1862	Reference	B / A	Y	
Salmon Brook	Washburn	377	1863	Municipal/NPS	B / A	Y	
Sheepscot River	Whitefield	74	1875	Long Term Monitoring	AA / A	Y	
St. John River	Ft. Kent	8	1847	Reference	A / A	Y	
St. John River	Frenchville	921	1848	Municipal	B / A	Y	
St. John River	Madawaska	368	1849	Industrial	C / C	Y	
Unnamed (Skanky) Stream	Presque Isle	743	1855	Agricultural NPS	B / B	Y	
Violette Stream	Van Buren	923	1853	Reference	B / A	Y	
Violette Stream	Van Buren	729	1854	NPS	B / A	Y	
West Branch Sheepscot River	China	268	1876	Long Term Monitoring	AA / A	Y	
Whitney Brook	Bridgewater	749	1845	NPS	B / A	Y	

[1] NPS, non-point source pollution; BPJ, Best Professional Judgment.

3.1.3 Attainment History of Sampling Stations prior to 2009

- Aroostook River (Station 594) attained class in 2001.
- Aroostook River (Station 595) attained class in 2001.
- Aroostook River (Station 370) attained class in 1999.
- Capisic Brook (Station 257) attained class in 1995. It failed to attain class in 1996, 1999, and 2003.
- Colony Brook (Station 733) attained class in 2004.
- Dickey Brook (Station 688) attained class in 2003.
- Dudley Brook (Station 215) failed to attain class in 1994 and 1999.
- Fish River (Station 371) attained class in 1999.
- Gardner Brook (Station 689) attained class in 2004.
- Kennedy Brook (Station 646) attained class in 2002 and 2004.
- Little Madawaska River (Station 731) attained class in 2004.
- Merrit Brook (Station 742) failed to attain class in 2004.
- Prestile Stream (Station 734) failed to attain class in 1999 and 2004.
- Prestile Stream (Station 690) failed to attain class in 2004.
- Prestile Stream (Station 3) failed to attain class in 1983. It attained class in 1994 and 1998.
- Salmon Brook (Station 376) attained class in 1999.
- Salmon Brook (Station 377) attained class in 1999.
- Sheepscot River (Station 74) attained class in 1985, 1987, 1988, 1989, 1990, 1987-1990, 1992, 1995, 1996, 1998, 1999 - 2008. It failed to attain class in 1984, 1986, 1991, 1993, 1994, and 1997.
- St. John River (Station 8) attained class in 1983, 1985, 1994, and 1999.
- St. John River (Station 368) attained class in 1999.
- Unnamed (Skanky) Stream (Station 743) failed to attain class in 2004.
- Violette Stream (Station 729) attained class in 2004.
- West Branch Sheepscot River (Station 268) attained class in 1996-1999, 2001, 2002, 2005, and 2007. It failed to attain class in 2000, 2003, 2004, 2006 and 2008.
- Whitney Brook (Station 749) attained class in 2004.

Table 3.1.2 - 2009 SWAT Water Chemistry Data

Samples were analyzed by the Health & Environmental Testing Laboratory, Augusta, ME. Please note that data for dissolved oxygen, specific conductance and pH (where available) are shown in the Aquatic Life Classification Attainment Report (pdf format) for each log number.

Waterbody	Log	Sampling Date	DOC	NH_3-N	TKN	NO_2-NO_3-N	SRP	Total P	TSS	TDS
			mg/L	mg/L	mg/L	mg/L	ug/L	mg/L	mg/L	mg/L
Aroostook River	1856	7/23/09	6.8		0.2	0.01	1	0.011		
Aroostook River	1857	7/22/09	6.2		0.4	0.03	1	0.015		
Aroostook River	1858	7/22/09	6.4		0.3	0.15	2	0.022		
Aroostook River	1859	7/22/09	7.9		0.4	0.23	1	0.015		
Capisic Brook	1835	8/11/09	15	0.29	1.5	1.2	8		62	240
Capisic Brook	1836	8/11/09	5.4	0.19	1.1	1.4	4		54	340
Capisic Brook	1838	8/11/09	9.1	0.24	1.1	0.91	5		29	580
Capisic Brook	1839	8/11/09	6.2	0.01	0.8	1.1	6		36	390
Capisic Brook - Unnamed Tributary	1837	8/11/09	15	0.52	1.3	0.62	6		8	820
Caribou Stream	1861	7/22/09	5		0.4	0.2	2	0.018		
Coloney Brook	1871	7/23/09	4.7		0.4	1.3	41	0.060		
Dickey Brook	1852	7/21/09	11		~ 0.6	0.09	7	0.062		
Dudley Brook	1867	7/23/09	8.3		0.4	0.29	4	0.017		
Dudley Brook	1868	7/23/09	7		0.3	0.42	3	0.017		
Everett Brook	1872	7/23/09	3.3		0.4	0.56	18	0.070		
Fish River	1844	7/21/09	5		0.3	0.04	1	0.009		
Gardner Brook	1860	7/22/09	9		~ 0.3	0.04	2	0.015		
Getchell Brook	1843	7/22/09	2.4		0.2	1.1	16	0.035		
Kennedy Brook	1870	7/23/09	3.1		0.3	2.3	37	0.057		
Little Madawaska River	1864	7/22/09	8.5		0.4	0.03	1	0.014		
Little Madawaska River	1865	7/22/09	8.3		~ 0.4	0.18	2	0.016		
Merritt Brook	1866	7/22/09	5		0.3	1.3	18	0.053		
North Fork Mclean Brook	1850	7/21/09	3.3		0.3	1.6	12	0.042		

DOC = dissolved organic carbon, NH_3-N = ammonia-nitrogen, TKN = total Kjeldahl-nitrogen, NO_2-NO_3-N = nitrite-nitrate-nitrogen, SRP = soluble reactive phosphorus (ortho-phosphate), Total P = total phosphorus, TSS = total suspended solids, and TDS = total dissolved solids.

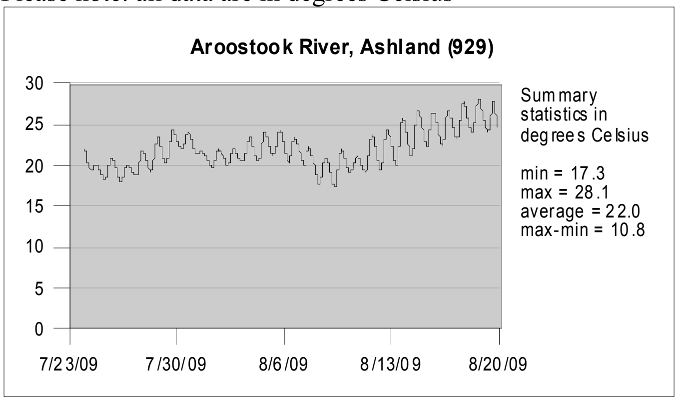
Table 3.1.2 - 2009 SWAT Water Chemistry Data (cont.)

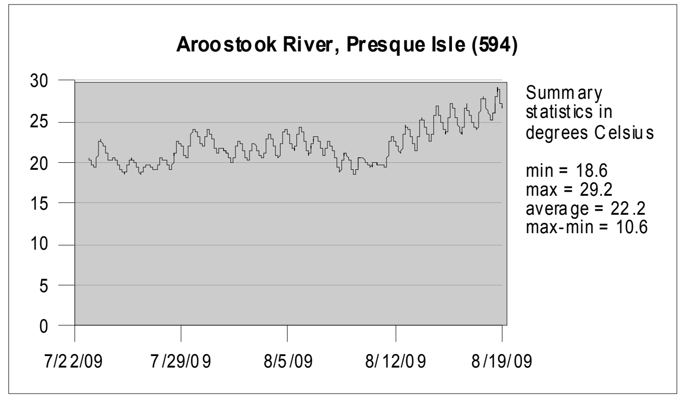
Waterbody	Log	Sampling Date	DOC	NH_3-N	TKN	NO_2-NO_3-N	SRP	Total P	TSS	TDS
			mg/L	mg/L	mg/L	mg/L	ug/L	mg/L	mg/L	mg/L
Perley Brook	1851	7/21/09	4.0		~0.3	0.35	6	0.021		
Prestile Stream	1840	7/22/09	5.8		0.7	0.11	48	0.120		
Prestile Stream	1841	7/20/09	4.5		<0.1	0.44	18	0.041		
Prestile Stream	1842	7/20/09	4.4		<0.1	0.25	5	0.026		
River De Chute	1846	7/23/09	3.6		0.2	0.18	3	0.018		
Salmon Brook	1862	7/22/09	11		~0.5	0.03	1	0.016		
Salmon Brook	1863	7/22/09	7.1		0.3	0.18	2	0.016		
Sheepscot River	1875	8/3/09	6.6		0.3	0.02	2	0.018		
St John River	1847	7/21/09	10		~0.4	0.04	1	0.015		
St John River	1848	7/21/09	8.5		~0.3	0.03	1	0.013		
St John River	1849	7/21/09	8.9		~0.4	0.05	5	0.023		
Unnamed (Skanky) Stream (Presque Isle)	1855	7/22/09	4.6		0.3	0.23	16	0.038		
Violette Stream	1853	7/21/09	9.6		~0.4	0.03	1	0.017		
Violette Stream	1854	7/21/09	8.5		~0.3	0.05	1	0.017		
West Branch Sheepscot River	1876	8/3/09	5.9		0.4	0.02	2	0.016		
Whitney Brook	1845	7/20/09	5.2		<0.1	0.10	1	0.010		

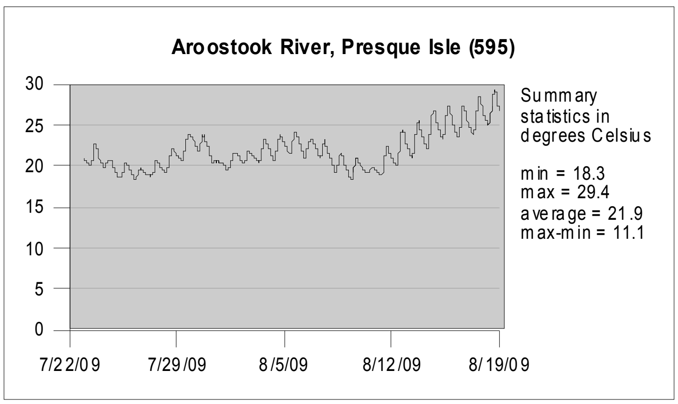
DOC = dissolved organic carbon, NH_3-N = ammonia-nitrogen, TKN = total Kjeldahl-nitrogen, NO_2-NO_3-N = nitrite-nitrate-nitrogen, SRP = soluble reactive phosphorus (ortho-phosphate), Total P = total phosphorus, TSS = total suspended solids, and TDS = total dissolved solids

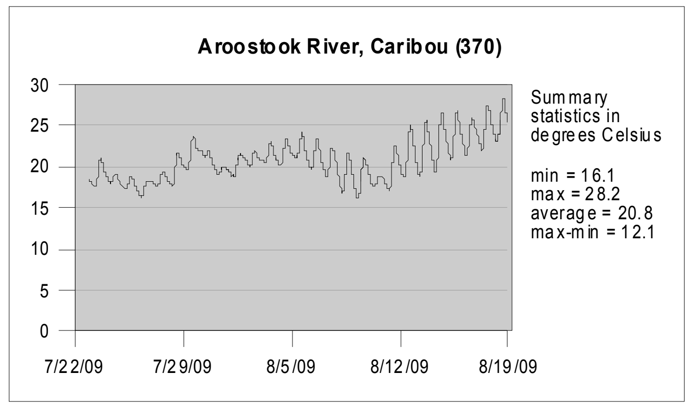
Figure 3.1.1 – 2009 In-Stream Temperature Data

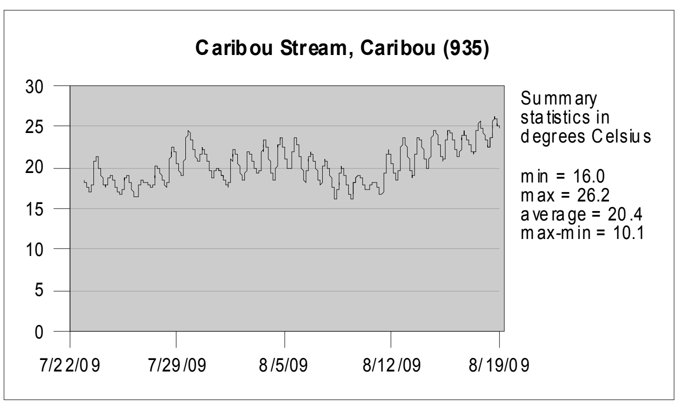
Please note: all data are in degrees Celsius

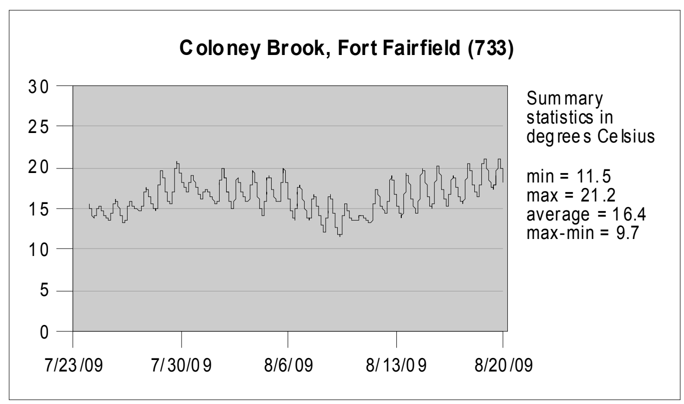


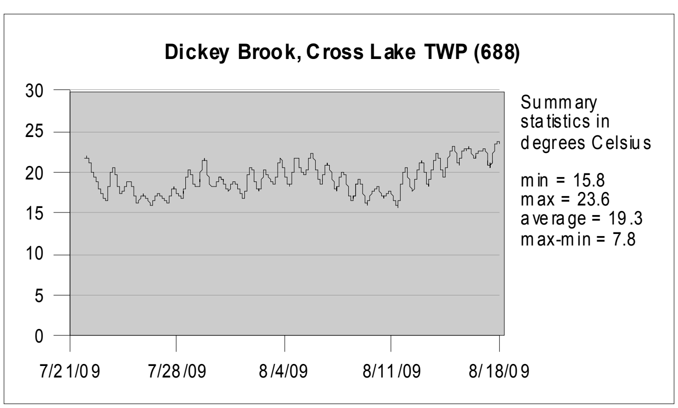












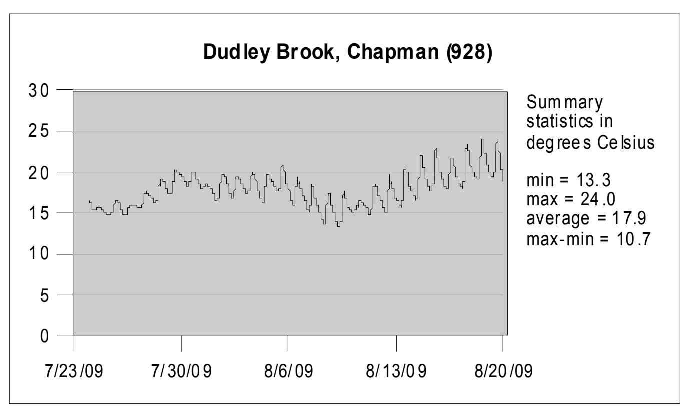
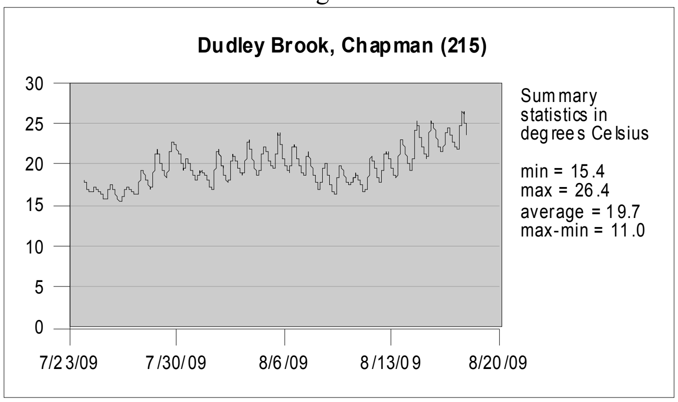
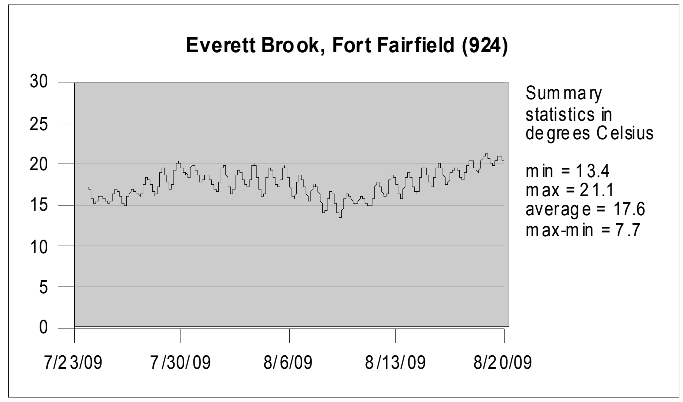
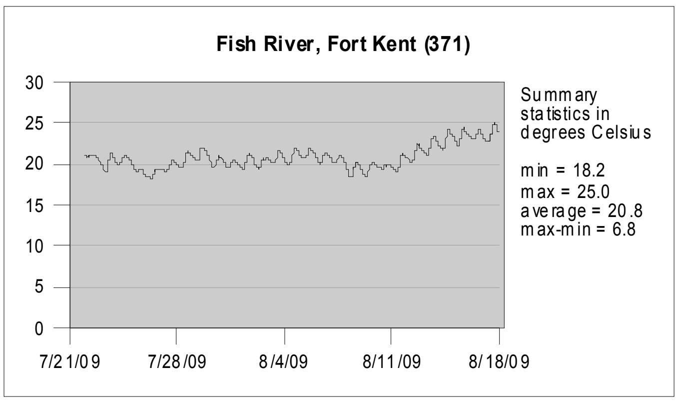


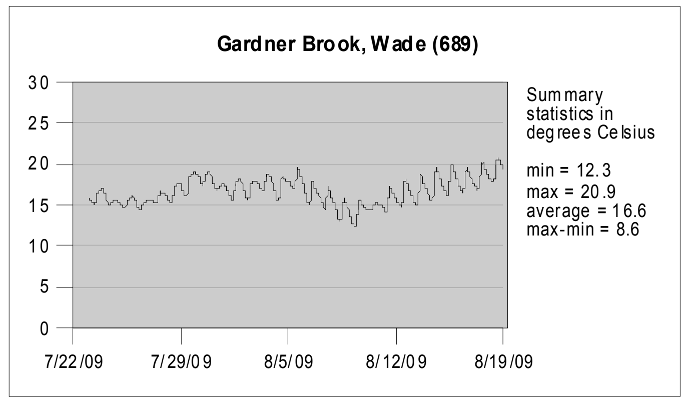
Figure 3.1.1 – 2009 In-Stream Temperature Data (cont.)

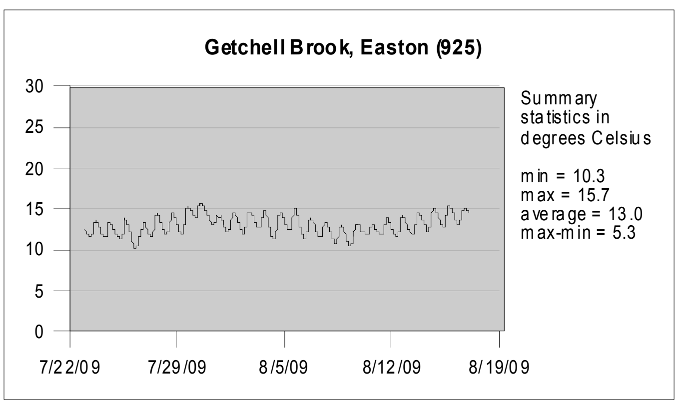
Please note: all data are in degrees Celsius

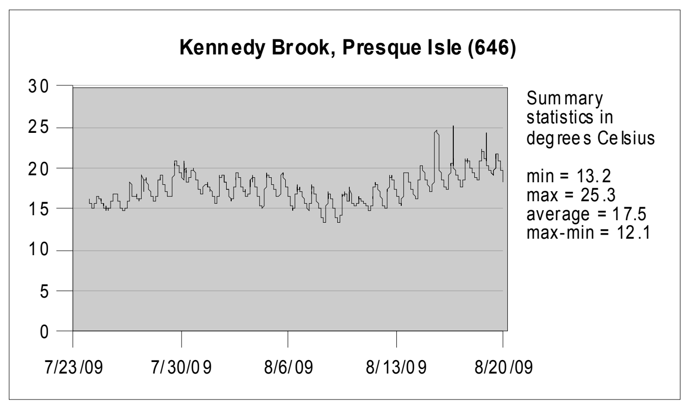


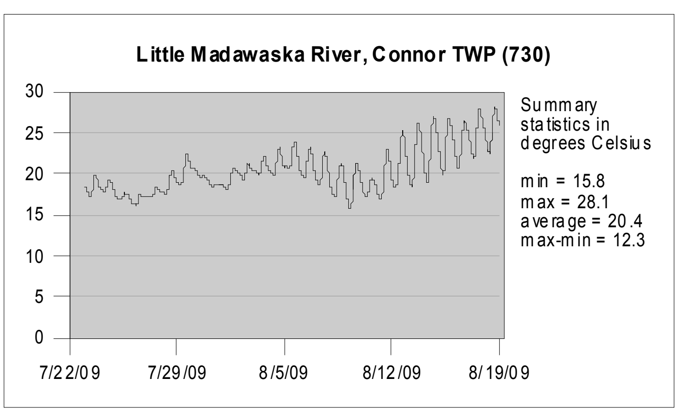












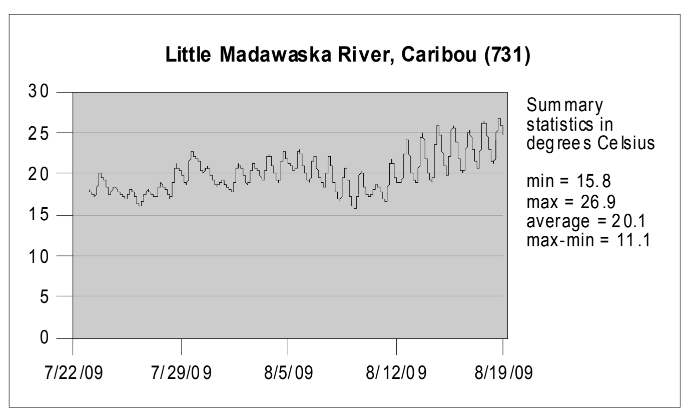
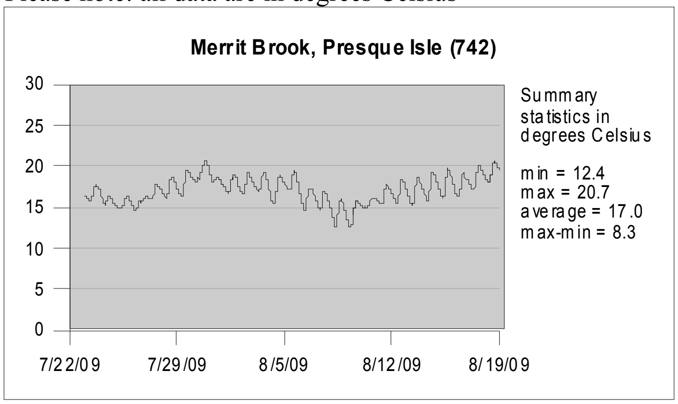
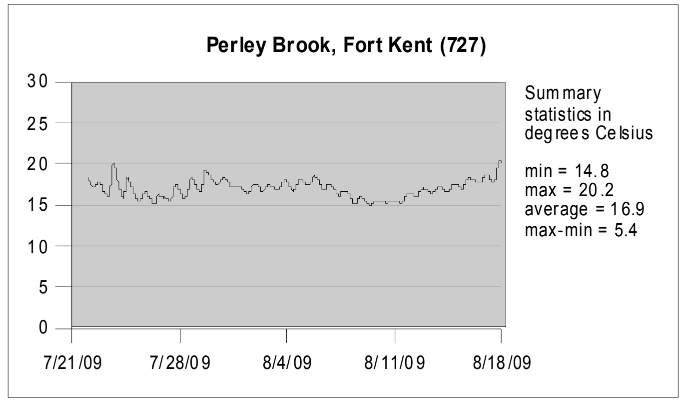
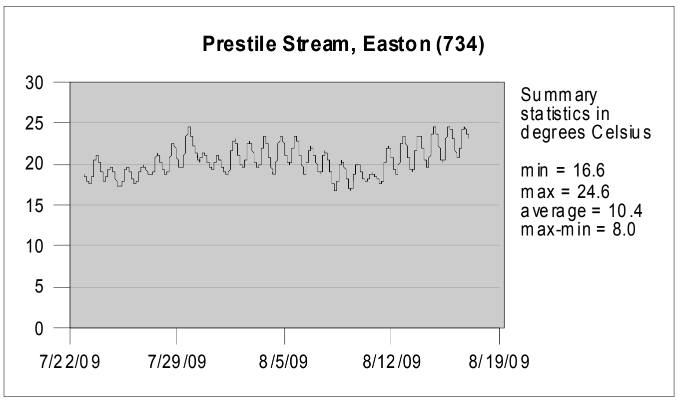
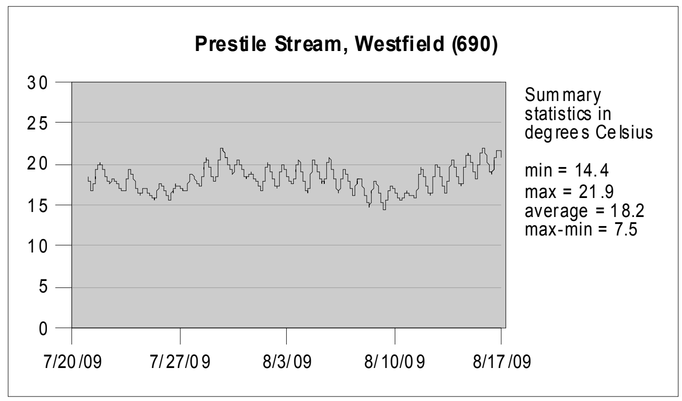


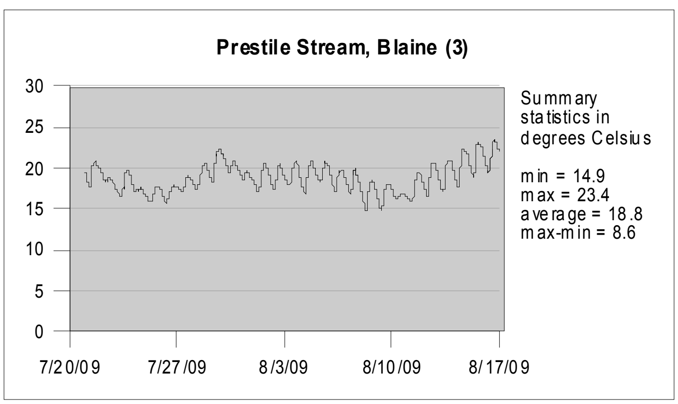
Figure 3.1.1 – 2009 In-Stream Temperature Data (cont.)
Please note: all data are in degrees Celsius

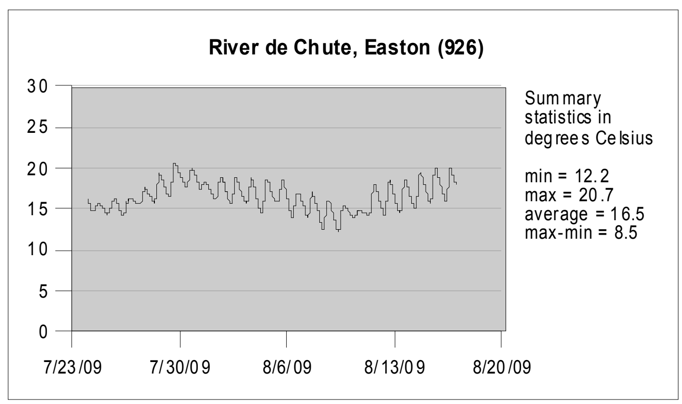


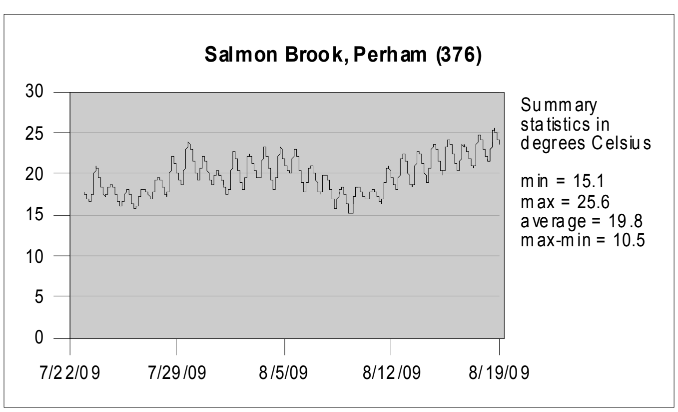












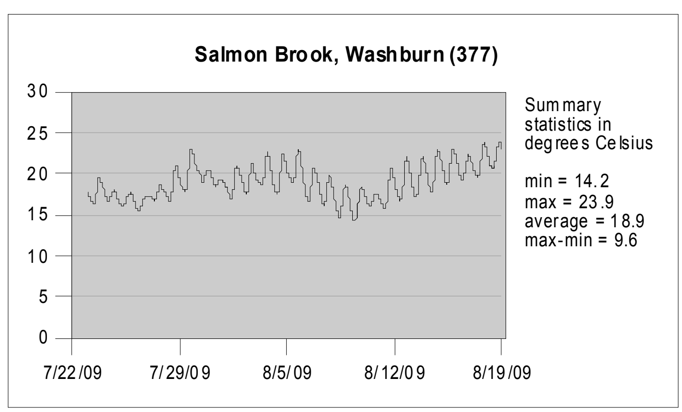
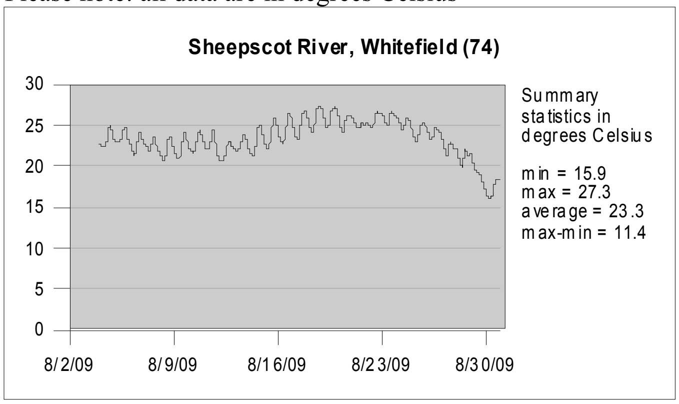
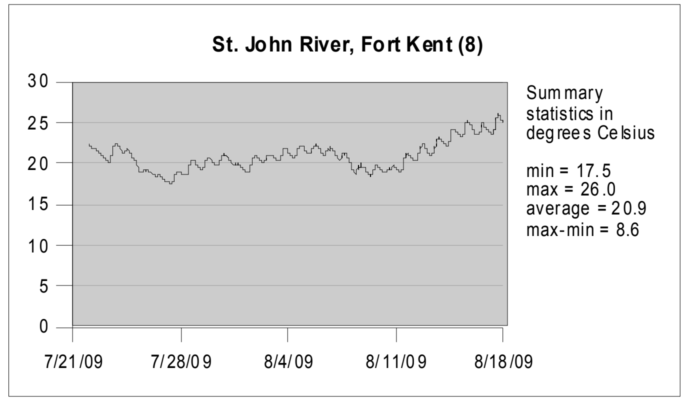
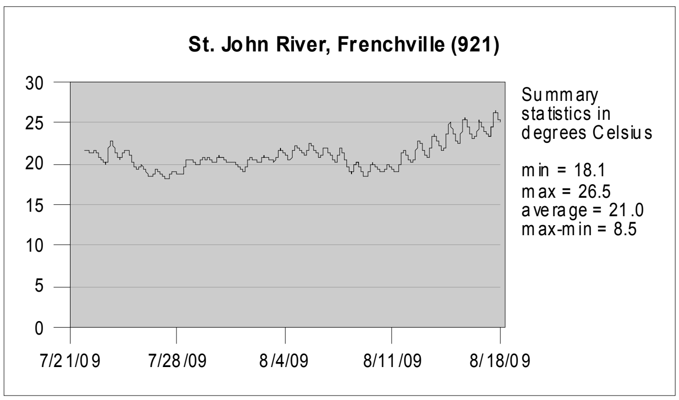


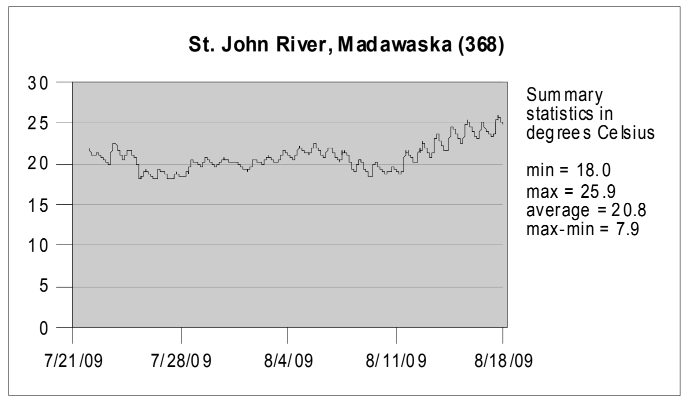
Figure 3.1.1 – 2009 In-Stream Temperature Data (cont.)

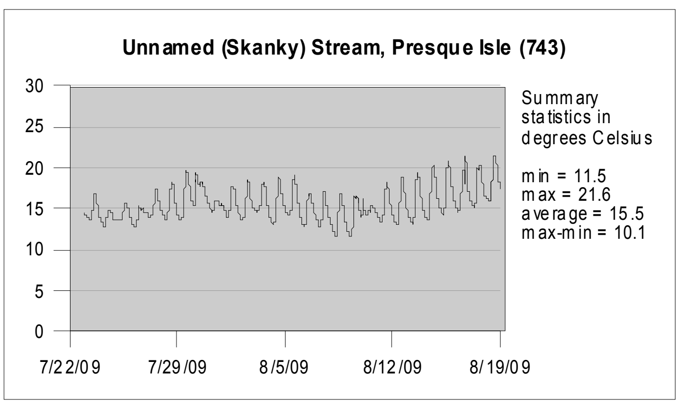
Please note: all data are in degrees Celsius

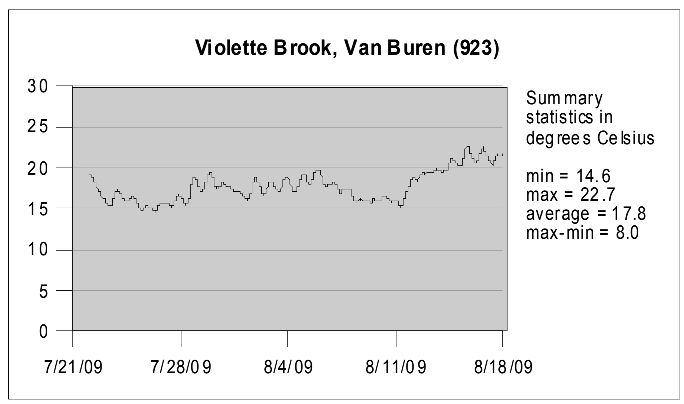


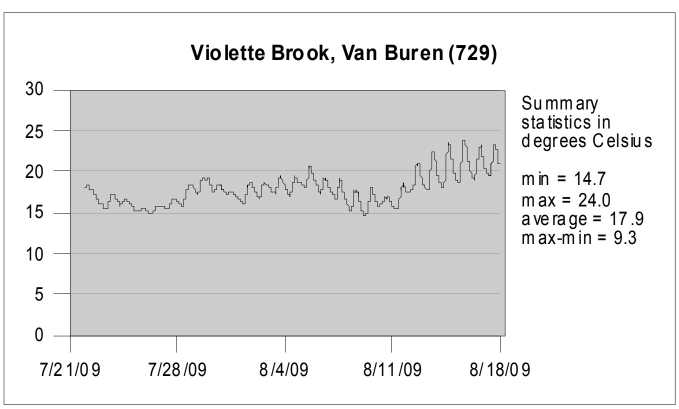












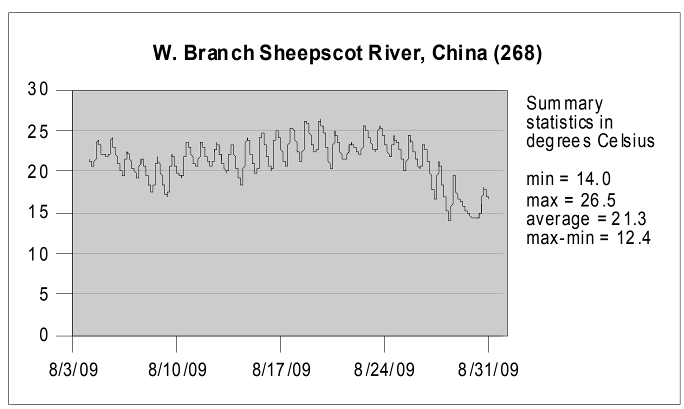
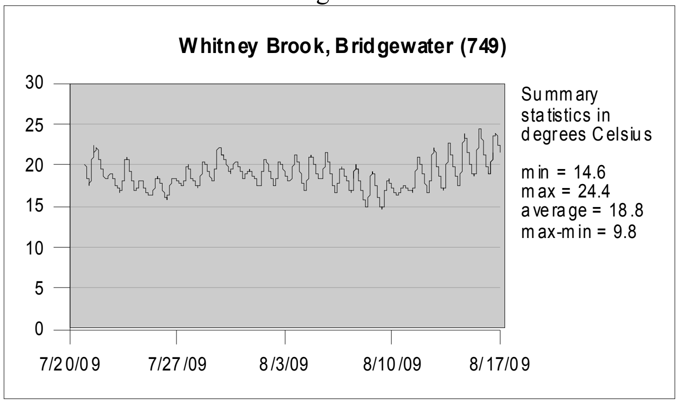


Figure 3.1.1 – 2009 In-Stream Temperature Data (cont.)

Please note: all data are in degrees Celsius



3.2

FISH CONSUMPTION ADVISORIES

3.2 FISH CONSUMPTION ADVISORIES

Based on a review of the fish sampling data conducted through 2008, dioxin, coplanar PCB and total TEQ concentrations have decreased significantly over the last 10 to 15 years. Total PCBs and DDT are the contaminants of primary concern for most of the continued fish consumption advisories that are more restrictive than the statewide mercury advisory.. The data set for total PCBs is sparse in terms of locations and fish species sampled over recent years, however. Available data indicate levels significantly above the PCB fish tissue action level (FTAL) of 11 ppb at many locations and in multiple species of fish. As for DDT, four of the five new locations tested in 2008 indicate concentrations above the FTAL of 64 ppb, suggesting that DDT may be affecting a significant number of rivers and streams in Aroostook County. Therefore, in 2009 the Maine Center for Disease Control and Prevention (MCDC) requested monitoring of fish to obtain a representative sampling of total PCB data for bass, trout and white sucker in the major rivers, and DDT data in brook trout from additional rivers and streams in Aroostook County. Mercury data were also requested at a small number of locations to provide tissue with what is expected to be a range of mercury levels for continued validation studies with the use of small biopsy samples and analysis with the direct mercury analyzer (DMA 80) housed at the Sawyer Environmental Chemistry and Research lab at the University of Maine in Orono. Due to the deepening state budget deficit and resulting continuing cuts in the SWAT budget, MCDC limited their requests compared to those from previous years. All data for contaminants in fish in this report are based on wet weight.

Dioxins and CoPlanar PCBs

There was no monitoring for dioxins in 2009 for the first time since 1986 because concentrations in fish have significantly decreased and are not changing much from year to year. Sampling is expected to resume in 2010. The results of previous monitoring have been published in the 2008 Dioxin Monitoring Program report at http://www.maine.gov/dep/blwq/docmonitoring/dioxin/index.htm

Coplanar (dioxin-like) PCBs were routinely monitored in past years in all samples analyzed for dioxins that required detection limits lower than those used for measurement of total PCBs. New congener specific analysis for total PCBs gives suitably low detection limits such that the coplanar PCBs can be measured. Nevertheless, without dioxin analysis, coplanar toxic equivalents are not calculated in this report.

Total PCBs

According to MCDC, total PCBs now appear to be a limiting factor for revision of the fish consumption advice for the major rivers, which is more restrictive than the advice based on state-wide mercury concentrations in game fish. Because total PCBs, in general, are higher in white sucker than game fish, white sucker data were also requested to determine whether separate advice for white sucker, more restrictive than for other game fish, is required.

A total of ten game fish and 10 white sucker were successfully collected at most stations and combined into two composites of five fish of each species for total PCB (TPCB) analysis. Results show that TPCB concentrations varied among species, stations, and years. Generally results are similar among years, but there is some variability. Most concentrations exceeded MCDC's fish tissue action level (FTAL = 11 ng/g). Recent results are considered to be more representative than earlier results.

Androscoggin River: Monitoring of trout at Gilead for total PCBs was conducted due to elevated levels in brown trout in 2000 and rainbow trout in 2008. Results show that concentrations in rainbow trout in 2009 remained elevated above the FTAL (11 ng/g) similar to those of 2008 and of brown trout from 2000 (Table 3.2.1).

Table 3.2.1. Mean total PCBs (ng/g) in fish from the Androscoggin River
(max value where n=2, 95th upper confidence level on the mean where n>2)

Year	Species	Gilead AGL	Rumford Pt ARP	Rumford ARF	Riley ARY	Jay ARJ	Livermore/Jay ALV	Livermore Fls ALF	Auburn GIP AGI	Lisbon ALS
2000	BNT	85								
1998	RBT	11								
2000	RBT	28								
2008	RBT	75 (86)								
2009	RBT	63 (73)								
1994	SMB			97		42	49		114	98
1998	SMB		4 (4)	9 (12)	7 (8)		15 (19)		20 (26)	27 (30)
2000	SMB		10 (11)	21 (27)	15 (17)		38 (42)	27 (32)	29 (36)	52 (60)
2001	SMB									
2002	SMB		101	22	18		18		22	17
2003	SMB						22	19		
2008	SMB								30 (35)	
2009	SMB		51 (65)			31 (34)			21 (24)	
1998	WHP									
2001	WHP									
2002	WHP									
2008	WHP									
1994	WHS			80		129	39		114	145
1996	WHS						31	58		
1998	WHS		17	21	24		33			
2000	WHS						48	42		
2001	WHS									
2008	WHS								80 (85)	
2009	WHS	61(65)	36(46)				71 (91)	40 (45)	31 (38)	

BNT = brown trout, RBT = rainbow trout, SMB = smallmouth bass, WHP = white perch, WHS = white sucker

Ten smallmouth bass from Rumford Point, Jay, and Auburn were also collected and combined into two composites of five fish each for total PCB analysis, to confirm whether or not total PCB levels remain in excess of the FTAL as in historical data. Concentrations in bass from Rumford Point were intermediate to those from previous years while the concentrations in bass at Jay were similar to that of the previous time measured. Concentrations in bass at Gulf Island Pond (GIP) in Auburn were similar to those from previous years since 1994. Samples of smallmouth bass exceeded the FTAL at all three stations by varying amounts.

Historical white sucker data were more limited and often showed higher concentrations than did bass since sucker have a higher fat (lipid) content which concentrates the PCBs. Lipid normalization of PCB values is appropriate when making comparisons between stations, years, or species, but PCBs based on wet weight is more valid when comparing against the FTAL, which was the primary purpose here. Ten white sucker were collected from Gilead, Rumford Point, and Auburn and combined into two composites of five fish each. There were no previous PCB data at Gilead. Concentrations of PCBs at Rumford Point were higher than previously while those at GIP were lower than previous levels.

Sixteen smallmouth bass and sixteen white sucker were also collected in an impoundment at Livermore/Jay and in a riverine reach at Livermore Falls and combined into four composites of four fish each as part of monitoring for a hydroelectric power project to determine whether the accumulation of contaminated sediments behind the dam resulted in increased bioaccumulation in fish. Results showed no difference in mercury concentrations in smallmouth bass or in PCB concentrations in white sucker between stations, and therefore no measurable effect of the dam.

Kennebec River: Monitoring of trout at Fairfield was recommended by MCDC for total PCBs for comparison to previously collected data (2003) which show levels slightly in excess of the FTAL. Monitoring of smallmouth bass at Fairfield, Sidney, and Augusta for PCBs was recommended to confirm levels less than the FTAL at Fairfield and Sydney, and greater than the FTAL at Augusta. For white sucker, total PCB data at Fairfield, Sydney and Augusta were recommended, based on historical detections in excess of the FTAL. Ten fish of each species were collected at each station and combined into two composites of five fish each for PCB analysis.

The 2009 results show that PCBs remain low in brown trout and smallmouth bass at Fairfield as in the most recent past (Table 3.2.2). PCB levels in white sucker were lower than past levels, similar to those in trout and bass, all of which were below the FTAL. Concentrations in smallmouth bass at Sidney exceeded the FTAL as has occurred occasionally in the past while concentrations in white sucker were much higher than previous levels and higher than those in bass. All 2009 PCB concentrations in fish at Sidney exceeded the FTAL. PCB levels in smallmouth bass at Augusta were greatly elevated over the FTAL, similar to the most recent levels. Concentrations in white sucker were similar to those in bass, but lower than in previous years. These results document the continuing contamination of the fish in the Kennebec at Augusta.

Table 3.2.2. Mean total PCBs (ng/g) in fish from the Kennebec River
(max value where n=2, 95th upper confidence level on the mean where n>2)

Year	Species	Norridgewock KNW	Skowhegan KSK	Fairfield KFF	Sidney KSD	Augusta KAG	Hallowell KRH	Gardiner KGD	Richmond KRD
1994	BNT			300					
1997	BNT			93 (107)		54.6 (70.9)			
1999	BNT					55 (71)			
2000	BNT	3			34 (45)				
2002	BNT	8		10					
2007	BNT	10 (14)		10 (14)					
2009	BNT			7 (7)					
2002	EEL								377
2005	RBS								46 (64)
2007	RBS						60 (83)		
2009	RBS							18 (20)	
1994	SMB			5	9	604			
1997	SMB	4	4 (5)	4 (5)	6 (7)	342 (357)			
1999	SMB					263 (323)		179 (227)	166
2000	SMB				32 (42)				
2002	SMB	2		2	20	111		47.5	
2006	SMB				8 (10)	83 (142)		51 (75)	
2007	SMB							52 (70)	44 (64)
2009	SMB			3 (4)	17 (22)	85 (100)			
1994	WHS			17	23	1354			
1996	WHS					850			
1997	WHS	7		54	12	831			
1999	WHS					708			
2009	WHS			5 (5)	46 (64)	91 (101)			

BNT = brown trout, EEL = American eel, RBS = rainbow smelt, SMB = smallmouth bass, WHS = white sucker

Penobscot River: Limited historic total PCB data are available for the Penobscot River. However, available data have documented total PCB levels exceeding the FTAL in white sucker at several stations. Consequently ten smallmouth bass and ten white sucker were collected from Woodville, South Lincoln, and Veazie to confirm previously low concentrations in smallmouth bass and elevated levels in white sucker and combined into two composites of five fish each.

Results show that concentrations in smallmouth bass at all three stations remain at or below the FTAL as in previous years (Table 3.2.3). Concentrations in white sucker are similar among all three stations and are elevated above the FTAL. Concentrations at Woodville are similar to that of 1996 and 2008. Concentrations at South Lincoln are similar to that of 2008 but lower than that of 1994, while the concentration at Veazie is lower than that of 1994.

Table 3.2.3. Mean total PCBs (ng/g) in fish from the Penobscot River
(max value where n=2, 95th upper confidence level on the mean where n>2)

Year	Species	Grindstone PBG	Woodville PBW	Mattawamkeag PBM	S Lincoln PBL	Costigan PBC	Veazie PBV	Bangor PBB	Bucksport PBP
2000	ATS						19		
1996	EEL							37	
2000	EEL							253	
2002	EEL							98	
2007	RBS								27 (27)
1994	SMB				9		10		
1996	SMB	5	6						
2008	SMB		9		7 (8)				
2009	SMB		7 (10)		6 (9)		8 (12)		
1994	WHS				95		65		
1996	WHS	7	18						
2008	WHS		29 (30)		29 (49)				
2009	WHS		33 (35)		22 (26)		31 (32)		

ATS = Atlantic salmon, EEL = American eel, RBS = rainbow smelt, SMB = smallmouth bass, WHS = white sucker

Presumpscot River: No recent total PCB data were available for the Presumpscot River so sampling was conducted at 3 stations in 2009. Ten smallmouth bass and ten white sucker at Gorham and Westbrook were combined into two composites of five fish each to determine whether total PCB levels currently exceed the FTAL. The results show that the FTAL was exceeded for both species at both Gorham and Westbrook (Table 3.2.4). At Westbrook, concentrations in bass were higher than when last measured in 1994 but concentrations in sucker were lower than in 1994. In 2009 concentrations in Gorham were higher than those previously at Windham. The Gorham station was an impoundment that extends from urban Westbrook upstream to Gorham, whereas the Windham station is in a more rural area.

Table 3.2.4. Mean total PCBs (ng/g) in fish from the Presumpscot River
(max value where n=2, 95th upper confidence level on the mean where n>2)

Year	Species	Windham PWD	Gorham PBO	Westbrook PWB
1994	SMB	8		8
2009	SMB		41 (48)	26 (27)
1994	WHS	25		128
2009	WHS		40 (44)	41 (42)

SMB = smallmouth bass, WHS = white sucker

Salmon Falls River: Total PCBs in bass and white sucker at South Berwick and white perch at Northeast Pond (Lebanon) exceed the FTAL by up to 10-fold in years past. In 2009 ten largemouth bass and ten white sucker were collected at Northeast Pond and South Berwick and combined into 2 composites of five fish each to provide more recent data for Northeast Pond and additional data for S. Berwick. PCBs in largemouth bass from Northeast Pond were lower than those in largemouth bass from Spaulding Pond, just downstream, in 2006 and just above the FTAL (Table 3.2.5). Concentrations in largemouth bass from South Berwick were similar to those in previous years, well above the FTAL. Concentrations in white sucker at Northeast Pond were just above the FTAL. Concentrations in white sucker at S. Berwick were lower than those in the 1990s but still well above the FTAL.

Table 3.2.5. Mean total PCBs (ng/g) in fish from the Salmon Falls River
(max value where n=2, 95th upper confidence level on the mean where n>2)

Year	Species	Acton SFA	Northeast P SFN	Spaulding P SFP	Berwick SFB	S. Berwick SFS
1994	SMB					91
1995		5 LMB				30 SMB
1997	SMB	5 (6)				75
2000	SMB					83 (100)
2002	SMB					110
2006	LMB			26 (49)		33 (44)
2007	LMB					47 (61)
2008	LMB					47 (59)
2009	LMB		12 (14)			42 (48)
1997	CHP					47 (53)
2002	WHP		23			
1994	WHS					576
1997	WHS					185
2008	WHS					115 (150)
2009	WHS		15 (16)			105 (113)

CHP = chain pickerel, LMB = largemouth bass, SMB = smallmouth bass, WHP = white perch, WHS = white sucker

St. Croix: PCB concentrations in smallmouth bass were significantly different at Baring in 1997 and 2008 and there were data for white sucker only for 1997 (Table 3.2.6). In 2009 ten smallmouth bass and ten white sucker were collected from Woodland and Baring and combined into two composites of five fish each. The results showed that PCB levels were similar to previous levels in both species at Woodland. At Baring, while the concentration in smallmouth bass was similar to that of 2008, the concentration in white sucker was higher than previously measured (1997). Concentrations exceeded the FTAL in both species at Baring.

Table 3.2.6. Mean total PCBs (ng/g) in fish from the Saint Croix River
(max value where n=2, 95th upper confidence level on the mean where n>2)

Year	Species	Woodland SCW	Baring SCB
1997	SMB	6	7
2008	SMB	1 (2)	22 (42)
2009	SMB	5 (6)	27 (31)
1997	WHS	12	23
2008	WHS		
2009	WHS	12 (15)	51 (55)

SMB = smallmouth bass, WHS = white sucker

Sebasticook River: No recent total PCB data were available for the Sebasticook River. Total PCB data were recommended by the MCDC for collection in both bass and white sucker at representative locations (e.g., Burnham, Palmyra and Newport) to determine whether total PCB levels exceed the FTAL. These data were recommended for collection prior to changing the fish consumption advice for this river. The results showed that the concentration of PCBs in largemouth bass on the East Branch of the Sebasticook River at Newport were higher than previously measured and exceeded the FTAL (Table 3.2.7). This station is below a former Superfund site which has since been remediated. While the target contaminants were not PCBs, the source was a textile mill which used many chemical products over the years. Concentrations of PCBs in largemouth bass and white sucker from the West Branch of the Sebasticook River at Palmyra were low in both species, similar to historical data. This was surprising since the station is below a tannery which has used multiple chemicals over the years. PCB levels in both species at Burnham, however, were higher in 2009 than previously and exceeded the FTAL. This station is on the main stem below the confluence of the East and West branches and received further discharges from a dairy and several municipal sewage treatment plants.

Table 3.2.7. Mean total PCBs (ng/g) in fish from the Sebasticook River
(max value where n=2, 95th upper confidence level on the mean where n>2)

Year	Species	E Br Newport SEN	W Br Palmyra SWP	Burnham SBN	Winslow
1994	SMB		9		
1997	LMB	3	4	3	6
2009	LMB	31 (36)	4 (5)	39 (41) SMB	
1997	WHP	4			
1997	WHS		6	7	14
2009	WHS		7 (8)	70 (77)	

LMB = largemouth bass, SMB = smallmouth bass, WHP = white perch, WHS = white sucker

DDT in Aroostook County Rivers and Streams

Data collected in 2000 showed significant decreases in total DDT (∑ DDD + DDE +DDT) levels in fish from some rivers but not in others. In 2008, fish samples were collected at the Meduxnekeag River in Houlton to determine whether levels overall have decreased in this river or if elevated levels of DDT and its metabolites are confined to the main branch of the river, since levels were low in the south branch at Hodgdon (25 ppb) in 2007 and in the North Branch at Bridgewater (5 ppb) in 2000. Data collection was also recommended at other popular fishing areas that had not been previously sampled.

The 95% upper confidence level (UCL) on the mean at Houlton in 2008 (72 ppb) exceeds the FTAL; however, this value exceeds the maximum detected concentration of 63 ppb, which is slightly below the FTAL of 64 ppb. Five new locations were sampled in 2008 and demonstrated DDT levels above the FTAL in 4 of the 5 locations tested: Clark Brook in Presque Isle (96 ppb); Hammond Brook in Hamlin (234 ppb); Libby Brook in Ft. Fairfield (106 ppb); and Limestone Stream in Limestone (229 ppb). Only Violette Stream in Van Buren (28 ppb) demonstrated levels less than the FTAL. In addition, sampling results obtained in 2007 indicated DDT levels in excess of the FTAL in Everett Brook (Ft. Fairfield) and Prestile Brook (Caribou). Therefore, in 2009 MCDC requested the following:

- One more year of sampling at Houlton to determine the variability in the levels of DDT and its metabolites and whether the advisory can be lifted for the Meduxnekeag River.
- A second year of sampling in the 4 rivers/streams sampled in 2008 that exceeded the FTAL to confirm DDT impacts and to determine whether these surface water bodies should be added to the list of advisories.
- Confirmation of the 2007 results in excess of the FTAL in Everett Brook (Ft. Fairfield) and Prestile Brook (Caribou) to determine whether these surface water bodies should to be added to the list of advisories.
- Sampling of 5 additional popular fishing locations (based on advice from IF&W) not previously sampled to aide in determining the areal extent of elevated DDT levels in Aroostook County rivers and streams.

In 2009 ten brook trout were collected from nine rivers and streams and combined into two composites of five fish each. Seven brook trout were collected from the Meduxnekeag River near Lowry Bridge at Houlton and combined into one composite of four fish and one composite of three fish.

In 2009 concentrations in all streams sampled exceeded MCDC's FTAL for DDT (64 ng/g) although exceedances for Clark Brook and the Meduxnekeag River were marginal (Table 3.2.8). Although there is considerable variation from year to year, the results generally show total DDT concentrations similar to those of previous years. Exceptions included Everett Brook and Libby Brook in Fort Fairfield and Limestone Stream in Limestone, which were higher than when previously sampled, and Hammond Brook in Hamlin where concentrations in 2009 were lower than in 2008.

Table 3.2.8 Mean total DDT (DDD+DDE+DDT) in brook trout from Aroostook Co. Rivers and Streams, ng/g (max value, n = 2)

STREAM	YEAR→ SPECIES→ Town ↓	1995 BKT	1995 BNT	1996 BKT	1997 BKT	2000 BKT	2003 BKT	2007 BKT	2008 BKT	2009 BKT
Aroostook R	Caribou				35					
Beaver Bk	Portage					13			21	
Caribou Str	Caribou					3				
Clark Bk	Presque Isle								96	67 (73)
Dickey Bk	Cross Lake									248 (273)
Everett Bk	Ft. Fairfield					242		196		402 (448)
Hammond Bk	Hamlin								234	80 (127)
Hockenhull Bk	Ft Fairfield					3				
Libby Bk	Ft Fairfield								106	355 (481)
Limestone Str	Limestone								229	362 (415)
Meduxnekeag R N	Bridgewater					5				
Meduxnekeag R S	Hodgdon							25		
Meduxnekeag R	Houlton	82	98						45	68 (78)
Otter Bk	Caribou									108 (156)
Presque Str N Br	Mapleton	142				44		65		
Presque Isle Str	Mapleton					3				
Prestile Str	Mars Hill			260				88		
Prestile Bk	Caribou						170	140		157 (203)
Prestile Str	Westfield					96				
Riviere De Chute	Easton									116 (129)
Salmon Bk	Washburn					38				
Violette Str	Van Buren								28	

BKT = brook trout, BNT = brown trout

MERCURY METHOD DEVELOPMENT

A promising new method allows use of non-lethal sampling by taking small (< 1 g) biopsies of tissue for analysis using a Milestone Direct Mercury Analyzer (DMA80). The use of the DMA 80 also allows quicker and less expensive analysis of fish and other environmental samples. The US Environmental Protection Agency and several states are beginning to use this new technology. To investigate the potential for use of this new method in Maine, in 2008 a small sub-sample of filet were taken from the ten smallmouth bass and ten white suckers from the Androscoggin River, known to have significant levels in fish, and sent to the University of Maine's Sawyer Environmental Research Chemistry Lab (SERCL) that houses a DMA 80 purchased by DEP for use by researchers statewide, for mercury analysis. The results were similar for sucker between the two labs, but the results for bass were outside the acceptable range. There is an issue of comparability to more traditional methods such as the method used by AXYS (EPA Method 1631, CVAAS, cold vapor atomic fluorescence atomic spectroscopy) primarily due to greater dehydration of the small biopsy samples which can skew results based on wet weight.

Consequently, in 2009, additional samples were taken with comparisons between the two labs to be made on a dry weight basis. Fish with a range of anticipated mercury levels are recommended by MCDC for analysis to aide in DMA 80 method validation. Seven brook trout from the Meduxnekeag River (one of the DDT river sampling stations expected to be low in mercury), ten smallmouth bass from Gulf Island Pond in Auburn on the Androscoggin River (likely to be high in mercury based on 2008 data) and rainbow trout from Gilead on the Androscoggin River (likely to be intermediate in mercury) were collected to provide the range of concentrations required for method development and validation. Biopsies and small (1-2g) plugs were taken from each fish for analysis by the DMA 80, while the remainder of the fish was sent to the commercial lab for analysis of filets by EPA Method 1631 CVAAS.

There was no significant difference in mean wet or dry weight mercury concentrations between the biopsies and small plugs analyzed by SERCL for any of the species or stations, although there was significant differences (relative percent difference >30%) for some individual fish (Table 3.2.9). That there was more variation between biopsy and small plug results for the dry weight mercury values was likely due to different drying procedures, which may have resulted in incomplete drying of one or both types of samples. There was good correspondence between AXYS and SERCL for the samples taken from the rainbow trout on the Androscoggin and the brook trout on the Meduxnekeag, both of which had relatively low concentrations. There was a larger difference for the small-mouth bass on the Androscoggin and the [which?], which have higher concentrations, but the difference was not significant.

From these data, it appears that biopsies or small plugs analyzed on the DMA80 at SERCL gave relatively comparable results to those from the standard filet analysis at AXYS. The key is to carefully dry the biopsy or plug samples completely and report both wet and dry weight based results.

Concentrations of mercury in rainbow trout from the Androscoggin River at Gilead and smallmouth bass at Gulf Island Pond were generally similar to those from previous years (Table 3.2.10).

Table 3.2.9. Mercury concentrations (ug/g) in filets and biopsies of fish analyzed by two labs, 2009

ID	SERCL FILET ww	SERCL BIOPSY ww	SERCL RPD ww	SERCL FILET dw	SERCL BIOPSY dw	SERCL RPD dw	AXYS FILET ww	SERCL/AXYS FILET RPD	SERCL/AXYS BIOPSY RPD
AGL RBT 1	0.10	0.09	12.0	0.40	0.30	27.7	0.100	-0.1	-12.1
AGL RBT 2	0.06	0.14	-71.8	0.32	0.25	23.8	0.0605	5.5	76.5
AGL RBT 3	0.13	0.10	23.3	0.51	0.36	34.6	0.108	18.1	-5.3
AGL RBT 4	0.13	0.11	13.7	0.51	0.41	21.3	0.109	14.0	0.3
AGL RBT 5	0.25	0.18	33.2	1.11	0.73	41.3	0.177	35.7	2.5
AGL RBT 6	0.31	0.24	23.8	1.51	1.03	37.7	0.234	28.3	4.6
AGL RBT 7	0.13	0.12	11.7	0.55	0.42	26.3	0.112	14.7	2.9
AGL RBT 8	0.17	0.16	7.5	0.73	0.63	14.3	0.150	11.9	4.5
AGL RBT 9	0.14	0.12	14.9	0.56	0.45	22.1	0.110	23.2	8.3
AGL RBT 10	0.11	0.10	3.9	0.45	0.36	20.2	0.0961	12.0	8.1
MEAN	**0.15**	**0.14**	**7.2**	**0.66**	**0.49**	**26.9**	**0.13**	**16.3**	**9.0**
S.D.	**0.07**	**0.05**	**29.1**	**0.37**	**0.24**	**8.5**	**0.05**	**10.6**	**24.5**
S.E.	**0.02**	**0.01**	**9.2**	**0.12**	**0.07**	**2.7**	**0.02**	**3.3**	**7.7**
AGI SMB 1	1.28	1.18	8.5	6.36	5.28	18.5	0.974	27.2	18.8
AGI SMB 2	0.71	0.67	6.2	3.17	2.86	10.2	0.598	17.4	11.1
AGI SMB 3	0.74	0.75	-0.4	3.32	2.49	28.6	0.679	8.9	9.3
AGI SMB 4	1.08	1.03	5.0	4.94	4.40	11.5	0.874	21.3	16.3
AGI SMB 5	1.79	2.09	-15.4	7.56	6.65	12.9	1.44	21.6	36.7
AGI SMB 6	0.65	0.83	-23.5	2.97	2.62	12.4	0.565	14.4	37.6
AGI SMB 7	0.76	0.70	8.6	3.57	3.04	16.1	0.630	18.9	10.3
AGI SMB 8	0.73	0.58	22.5	3.41	2.40	34.6	0.616	16.7	-5.9
AGI SMB 9	0.63	0.66	-5.0	2.87	2.51	13.3			
AGI SMB 10	0.58	0.64	-10.5	2.72	1.90	35.8	0.472	20.4	30.8
AGI SMB 11	0.69	0.62	11.1	3.01	2.55	16.5	0.546	23.6	12.5
MEAN	**0.88**	**0.89**	**0.7**	**3.99**	**3.34**	**19.1**	**0.74**	**19.0**	**17.8**
S.D.	**0.37**	**0.44**	**13.3**	**1.61**	**1.47**	**9.4**	**0.29**	**5.1**	**13.7**
S.E.	**0.11**	**0.13**	**4.0**	**0.48**	**0.44**	**2.8**	**0.09**	**1.5**	**4.1**
MXW BKT 1	0.06	0.08	-19.6	0.23	0.27	-17.0	0.0632	2.6	22.1
MXW BKT 2	0.06	0.05	10.9	0.22	0.19	11.1	0.0615	-3.4	-14.2
MXW BKT 3	0.09	0.10	-19.7	0.31	0.28	9.1	0.0830	2.9	22.6
MXW BKT 4	0.06	0.09	-43.0	0.17	0.29	-49.6	0.0637	-9.7	33.6
MXW BKT 5	0.05	0.09	-60.4	0.18	0.33	-61.6	0.0566	-11.9	49.4
MXW BKT 6	0.07	0.07	-0.5	0.24	0.23	5.9	0.0752	-1.0	-0.5
MXW BKT 7	0.11	0.12	-14.7	0.33	0.39	-16.7	0.110	-4.4	10.4
MEAN	**0.07**	**0.09**	**-21.0**	**0.24**	**0.28**	**-17.0**	**0.07**	**-3.6**	**17.6**
S.D.	**0.02**	**0.02**	**24.2**	**0.06**	**0.06**	**29.0**	**0.02**	**5.7**	**21.2**
S.E.	**0.01**	**0.00**	**5.4**	**0.02**	**0.01**	**6.5**	**0.01**	**2.2**	**8.0**

AGL = Androscoggin River at Gilead, RBT = rainbow trout
AGI = Androscoggin River at Gulf Island Pond, SMB = smallmouth bass
MXW = Meduxnekeag River at Houlton, BKT = brook trout
RPD = relative percent difference

Table 3.2.10. Mercury concentrations in Androscoggin River fish, 1998-2008

Waterbody & Location	Station Code	Species Code	1998 ppm	2000 ppm	2001 ppm	2002 ppm	2008 ppm	2009 ppm
Androscoggin R.								
Gilead	AGL	RBT	0.09				0.14	0.13
Rumford Point	ARP	SMB	0.52			0.39		
Rumford	ARF	SMB	0.60			0.36		
Riley	ARY	SMB	0.84			0.72		
Livermore Falls	ALV	SMB	0.68	0.56		0.80		
Auburn	AGI	SMB	0.83			1.09	1.26	0.74
		WHS					0.30	
Lisbon	ALS	SMB	0.61			0.61		
Androscoggin L	ALW	PKL			0.71			
		SMB	0.70					
		WHP	0.85				0.79	
		WHS	0.18					

3.3

CUMULATIVE EFFECTS DRIVEN ASSESSMENT OF FISH POPULATIONS

CUMULATIVE EFFECTS ASSESSMENT OF FISH POPULATIONS

INTRODUCTION

The US Clean Water Act (CWA) and Maine statutes set an ultimate goal that point source discharges be eliminated where appropriate and an interim goal that all waters be fishable and swimmable. Maine Water Quality Standards further require that all freshwaters be 'suitable for the designated uses of …fishing and ….as habitat for fish and other aquatic life' and be 'of sufficient quality to support …indigenous species of fish'. EPA and DEP interpret 'fishing' to mean that not only do fish have to be present, but also healthy and safe to eat in unlimited quantities. And in order to provide 'habitat… to support a species', water quality must ensure that the population is sustainable, by allowing adequate survival, growth, and reproduction.

In the past, most SWAT studies of fish have focused on measuring the effects of particular persistent, toxic, and bioaccumulative (PBT) contaminants (or what are also termed "stressors") on human consumers, i.e. assessment of attainment of the designated use 'fishing', with some consideration of impacts to wildlife consumers as well. Direct effects on fish populations have been measured or estimated by other DEP programs able to detect only relatively severe impacts on survival, growth, and reproduction. Several studies (Adams et al, 1992; Kavlock et al, 1996; Munkittrick et al, 1998; Rolland et al, 1997) have measured other more subtle effects on development, immune system function, and reproduction not normally seen in more typical stressor-based testing regimes historically used by DEP. These more subtle effects may be a result of long term or cumulative exposure to relatively low levels of contaminants. These responses to pollutant challenge are often within the same magnitude as natural variation and therefore difficult to measure with the methods that are currently used. Many new techniques, such as an effects-driven cumulative effects assessment (CEA) of fish populations have been developed to measure some of these effects.

A CEA measures indicators of survival, growth, and reproduction. Age structure and mean age are measured as indicators of survival. Indicators of growth and reproduction include measures of energy expenditure and storage. Energy expenditure measures include size and size at age as indicators of growth while gonad size normalized to body size (gonadosomatic index, GSI), fecundity, and egg size as indicators of reproductive potential. Energy storage measures include condition factor (K) as an indicator of growth and liver size normalized to body size (liversomatic index, LSI) and lipid storage as indicators of both growth and reproductive potential (Munkittrick et al, 2000). Response patterns of all indicators provide an integrative assessment of overall performance that may reflect different types of stresses, such as exploitation, food limitation, recruitment failure, niche shift, metabolic disruption (Munkittrick et al, 2000). Levels of circulating sex steroids are also often used as biomarkers of reproductive potential, which, along with survival, are considered an index of potential population trends.

With the assistance of Environment Canada (EC), DEP conducted CEAs of fish populations on the St John River in 1999-2001 that indicated probable impacts to fish populations and identified a previously unknown source of pollution (a poultry processing plant) in Canada that negatively affected fish populations in the river. In 2000, similar studies of the North Branch of Presque Isle

Stream and Prestile Stream in Maine, where high concentrations of DDT, a known endocrine disruptor, have been previously found, indicated potential population level effects by a significant reduction in gonad size in both streams compared to two reference streams with much lower DDT levels in fish. Although a population estimate of brook trout in Prestile Stream found an abundance of trout, it is not known whether negative effects were mitigated by the high natural productivity of this limestone stream and anthropogenic nutrient enrichment as there is no suitable reference stream in the area with limestone and without DDT.

To undertake a CEA for Maine's major industrial rivers, it was decided to evaluate the most impacted river, and if no negative impacts were measured, not to study the other rivers. The Androscoggin River was chosen to study first because it had more (3) large pulp and paper mills for its size than the other major rivers and has historically had the poorest water quality. CEAs of white sucker populations in the Gulf Island Pond on the Androscoggin River from 2001-2003 did not show the evidence of endocrine disruption and metabolic redistribution found in a preliminary study in 1994. This result is likely due to the change in technology to elemental chlorine free (ECF) bleaching and improved waste treatment in the 3 upstream bleached kraft pulp and paper mills in the intervening years. Nor was there any evidence of endocrine disruption at any location below any of the mills in the rest of the river. There was, however, evidence of increased eutrophication that correlated with increased nutrient levels downstream of the mills and host municipalities (DEP, 2004).

Similar studies were conducted on the Kennebec and Penobscot rivers from 2004-2006. No consistent evidence of endocrine disruption was found despite a few isolated signals with white suckers and caged freshwater mussels. The major response was one of eutrophication, more so for the Penobscot than the Kennebec. Detailed results are reported in the 2004-2006 SWAT reports at http://www.maine.gov/dep/blwq/docmonitoring/swat/index.htm .

Many studies have also documented effects of heavy metals, PAHs, sewage, and pulp and paper mill waste on fish immune systems (Voccia et al,1994; Holliday et al, 1998; Secombes et al, 1992; Ahmad et al, 1998). We have measured the spleen somatic index (SSI) and kidney somatic index (KSI) from white suckers from the Androscoggin River from 2002-2003, the Kennebec River in 2004, and Penobscot River in 2005 as rough indicators of immune system effects. There were significant decreases in SSI below the 2 most upstream mills on the Androscoggin for one or both sexes in 2002 and 2003, indicating potential immune system stress. Similarly, SSI was decreased below the SAPPI Somerset bleached kraft mill on the Kennebec River in 2004 not inconsistent with the possible decreased immune system capacity found by Hannum in head kidneys (SWAT, 2004), although the mechanism is unclear since head kidney size (KSI) in our study was no different between sites above and below the mills for either sex on either river. There was no such difference in 2006. Both SSI and KSI, measured on both species from the Penobscot River in 2005 and 2006, showed a marginal reduction in SSI below the mill in 2005 and a significant increase in 2006. The results of the SSI are therefore not consistent from year to year at either river. Additional study with more sophisticated assays are needed.

Another method of determining the impact of stressors on fish populations is through studies of fish communities. For the last several years, Chris Yoder (Midwest Biodiversity Institute) and Brandon Kulik (Kleinschmidt Associates) have been conducting fish assemblage studies on large rivers in

Maine and the rest of New England, for the purpose of developing an Index of Biological Integrity of fish communities, under an EPA grant in consultation with Maine DEP and the Department of Inland Fisheries and Wildlife, In their 2006 study of the Presumpscot River field observations noted reduced catch rates of fish in the Presumpscot River below Westbrook compared to the river above the city.

Consequently, it was decided that further investigation was necessary and in 2007, 2008, and 2009, CEAs were conducted on the Presumpscot River. The SD Warren pulp mill in Westbrook closed in 1999, leaving the paper mill and city of Westbrook as the major dischargers into the river. The Presumpscot River much is smaller than the Androscoggin, Kennebec, and Penobscot recently studied and consequently wastewater is a larger proportion of the Presumpscot River than the other 3 rivers previously studied, and more likely to have an effect on fish populations. As reported in the 2007 SWAT report, at the downstream stations, GSI and K were elevated consistent with nutrient enrichment and general observations of eutrophication due to the two discharges and urban runoff. Also, field data from 2007 indicated that catch rates were lower and there were fewer (3) males captured below Westbrook. One possible explanation for such unusual responses was a suggestion by mill personnel that the habitat at the sampling stations above Westbrook at PWD and below at PWB are different, with the latter being more influenced by marine clay deposits than the former. Consequently, the study was repeated in 2008 and 2009 with an additional station (PGO), in the area sampled by Chris Yoder immediately upstream of the Saccarappa dam in Westbrook near the Gorham town line, which was more similar in habitat to the station below Westbrook (PWB).

METHODS

In September 2009, white suckers were collected from the Presumpscot River at Windham (PWD) and in the Saccarappa impoundment near the Gorham/Westbrook town line (PGO) above the discharges from the SD Warren paper mill and municipal wastewater treatment plant in the city of Westbrook and at Westbrook (PWB) below the discharges. Previous studies in Canada have determined that a sample size of 20 is sufficient to reduce the variance enough to detect a difference of ~25% in the variables measured between stations. Therefore, the target was to collect 20 males and 20 females from each station.

Fish were collected by gill net. Because the 3 males captured at PWB in 2007 had been smaller than those upstream at PWD, there was a possibility that mesh size of the net was the factor in different catch rates. Consequently, in 2008, additional nets with smaller mesh were used at all stations which increased the catch rate. In 2007 400 feet of 2 inch bar mesh nylon gill net was used, whereas in 2008 an additional 600 feet of 1.5 inch bar mesh nylon gill net was also used.

Blood, liver, and gonad samples were collected and analyzed in 2007 and 2008; in 2009 samples were collected and archived rather than analyzed due to limited funds.

Blood samples were collected from live fish immobilized in a foam cradle, into heparinized Vacutainers and placed on ice for transport to the lab the same day. The fish were then killed with a blow to the head. The operculum was collected for aging. Livers were dissected out and weighed, for calculation of LSI, and then frozen in liquid nitrogen. Gonads were dissected out and weighed for calculation of GSI and a small sample ~1 cm square was taken and placed in 10% buffered formalin for storage. Head kidney in suckers and spleen in both species were dissected out and weighed for calculation of KSI and SSI respectively.

Later the same day in the lab, the samples were placed in proper storage to await analyses. Plasma was collected from the blood samples after centrifugation in the lab and then frozen at –20 ° C for radioimmunoassay (RIA) analysis for circulating sex steroids (testosterone T, 11 ketotestosterone 11-KT, and estradiol E2) following the method of McMaster, et al. (1992) and F following the method of Jardine (1996). Liver samples were stored at –80 ° C for MFO (CYP1A) analysis as outlined by Munkittrick et al (1992). Gonad samples remained in formalin for further analyses. Histological samples of gonads were prepared and examined for the presence of testis-ova as outlined in Gray and Metcalf (1997) or analysis of gonadal staging (McMaster, 2001). All laboratory analyses were performed at Environment Canada's National Water Research Institute in Burlington, Ontario, Canada. Samples for aging were stored at –20 ° C until prepared and read in the DEP lab in Augusta, Maine.

RESULTS

A suite of biomarkers (MFO-mixed function oxidase enzymes, circulating sex steroids, and vitellogenin) and population indices (age, length at age, condition factor, gonad size, gamete development, intersex, and liver size) were measured to assess the effect of certain discharges in Westbrook on the fitness of white sucker populations in the Presumpscot river in 2007-2009. In addition catch per unit effort was calculated as an index of population density. Results were interpreted against the background water quality data collected in 2008.

Water Quality

As part of an intensive water quality survey for gathering data for development of a water quality model, in 2008 water samples were collected for 3 consecutive days in August at a number of stations (Table 3.3.1). The data document nutrient enrichment and the river visibly shows signs of eutrophication below Westbrook that was also observed in 2007. The cause is the discharge from the Westbrook Sewage Treatment Plant, SD Warren paper mill, and urban runoff. The river is relatively clear with little enrichment (low phosphorus concentrations in mg/l) at PWD. There is some nutrient enrichment from urban runoff from part of Westbrook at PGO, just above the Saccarappa Dam, as shown by increased phosphorus concentration just downstream at PR1. The increase in phosphorus concentration (mg/l) from PR1 to PR2 shows the effect of the discharge from the Westbrook Sewage Treatment Plant, while the increase in total phosphorus concentration (mg/l) from PR2 to PR3 documents the effect of the SD Warren Paper mill. There also were small increases in total phosphorus below the confluence of tributaries, i.e. Mill Stream and the East and West Branches of the Piscataqua River. These limited data were collected during a dry weather period which might minimize the effect of urban runoff and the tributaries. Nevertheless, the data clearly document the nutrient enrichment effect of the discharges.

Table 3.3.1. Water quality of the Presumpscot River 2008

STATION	FLOW[1]	BOD[1]	NITROGEN[2]	NITROGEN[3]	PHOSPHORUS[2]	PHOSPHORUS[3]
	1000 m3/d	kg/d	ug/l	kg/d	ug/l	kg/d
PWD			230		5	
PGO						
PR1			250		9	
WESTBROOK STP	13.0	117	16967	220	3700	48
PR2			355		39	
SAPPI	19.2	124	2503	48	437	8.4
PWB PR3			447		53	
PWB PR4			350		43	
Mill Stream	17.1		650		82	1.2
PWB PR5			350		48	
PWB PR6			390		53	
Piscataqua R	66		940		26	1.5
PR8			437		61	

discharges or tributaries to the river

[1] mean monthly for 2007-2008

[2] mean August 2,4,5, 2008

[3] mean monthly flow 2007-2008 X August 2008 nitrogen/phosphorus concentrations X conversion factor.

Mixed Function Oxidase

Mixed function oxidase enzymes (MFO, P450, CYP1A) function in the liver and other tissues of vertebrates to detoxify the body of toxic substances. MFOs are induced by certain xenobiotic substances, such as dioxins, PCBs, and PAHs and therefore serve as an indicator of exposure to certain discharges such as pulp and paper mill effluents. MFO were measured in white sucker only in 2007 and 2008. MFO were different between PWD and PWB in 2007 for males (Figure 3.3.1a). But the sample size was small (n=3) at PWB and the results may not be well representative of the population. There was no difference between stations in 2008 for either sex (Figure 3.3.1b). Regardless, there was no consistent response between years.

Figure 3.3.1a. Mean MFO levels in white sucker from the Presumpscot River above (PWD) and below (PWB) Westbrook, 2007. (letters = significant difference from upstream station, p<0.05)

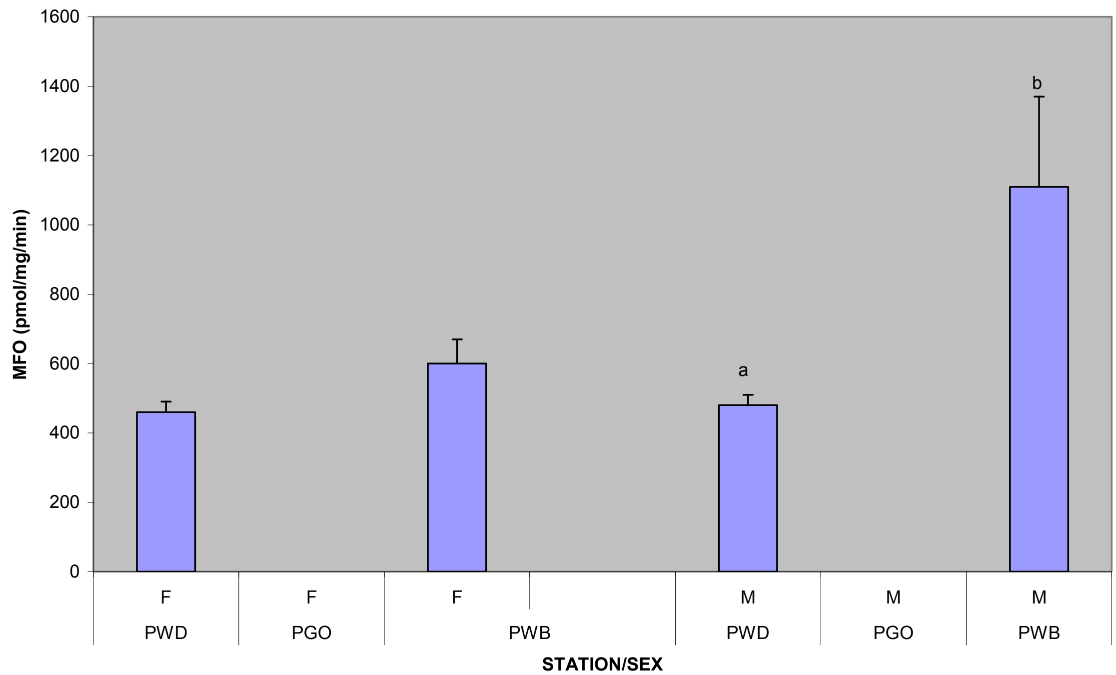
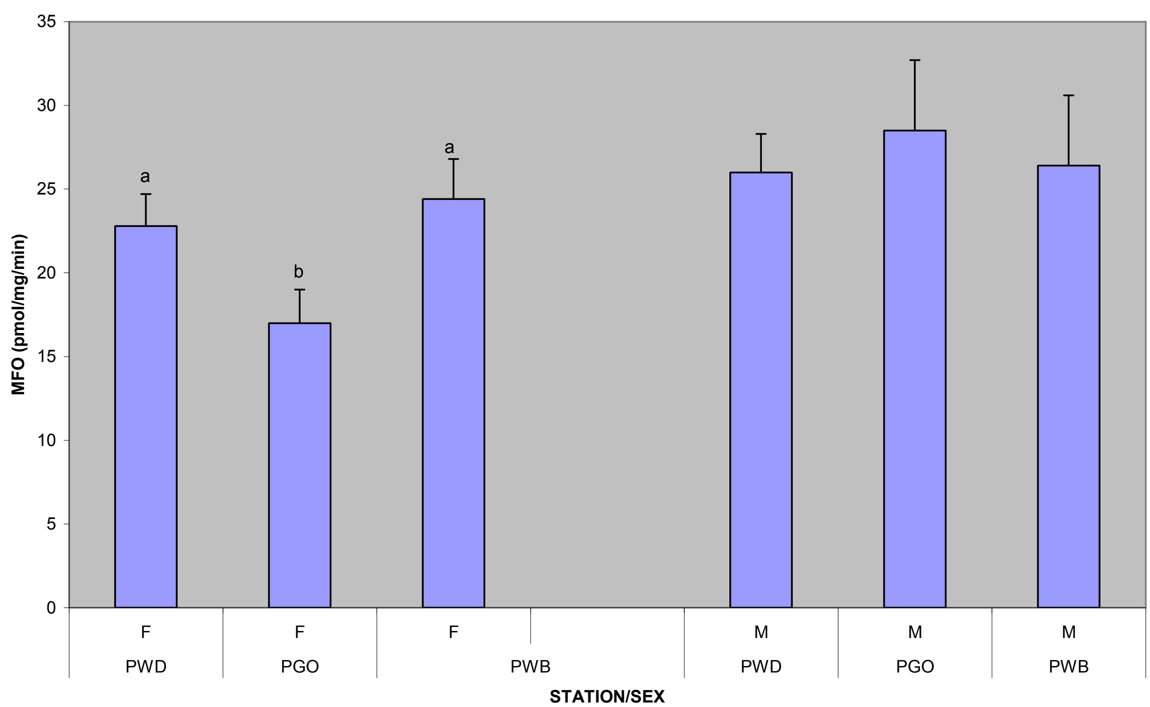


Figure 3.3.1b. Mean levels of MFO in white sucker from the Presumpscot River above (PWD, PGO) and below (PWB) Westbrook, 2008. (letters = siginificant differences from upstream station, p<0.05)



Circulating Sex Steroids

There are some other effects of discharges from sewage treatment plants and pulp and paper mills on fish reproduction Responses may be measured as altered neuroendocrine responses, such as levels of circulating sex steroids (Munkittrick et al. 2000). The mechanism for some of these responses in fish is disruption in functioning of the hypothalamic-pituitary-gonadal (HPG) axis of fish (Kime, 1999). As a result of this kind of dysfunction there have often been changes in levels of the circulating sex steroids testosterone (T), 11-keto-testosterone (11-KT), and/or estradiol (E2) in fish exposed to these and other industrial effluents (McMaster et al. 2005; Kovacs et al. 2005; West et al. 2006).

Results show that concentrations of testosterone (T) and estradiol (E2) were significantly lower in female white sucker at PWB below Westbrook compared to PGO immediately above Westbrook in 2008, but there was no difference in 2007 (Figure 3.3.2). In males, concentrations of T were lower at PWB below Westbrook than one or both stations above Westbrook for both 2007 and 2008, while 11-keto-testosterone (11-KT) was lower at PWB in 2008 (Figure 3.3.3). Steroids were not measured in 2009.

Figure 3.3.2. Mean levels of circulating sex steroids (testosterone-T and estradiol-E2) in female white sucker from the Presumpscot River above (PWD, PGO) and below (PWB) Westbrook, 2007 & 2008). (different letters = significant differences at $p<0.05$)

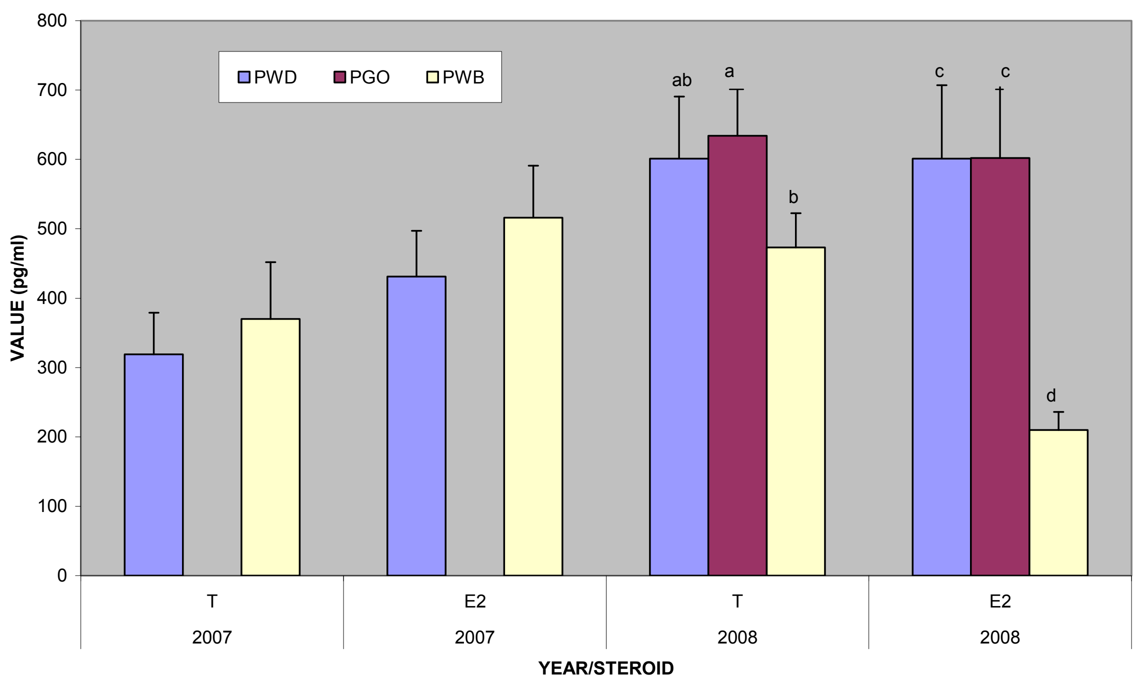
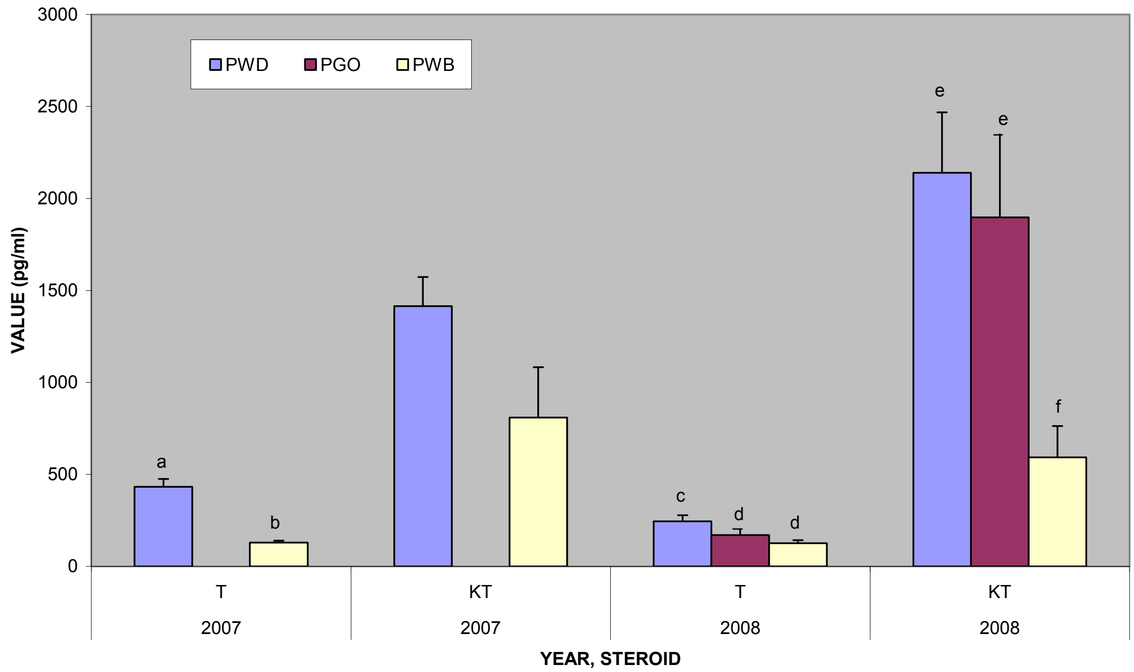


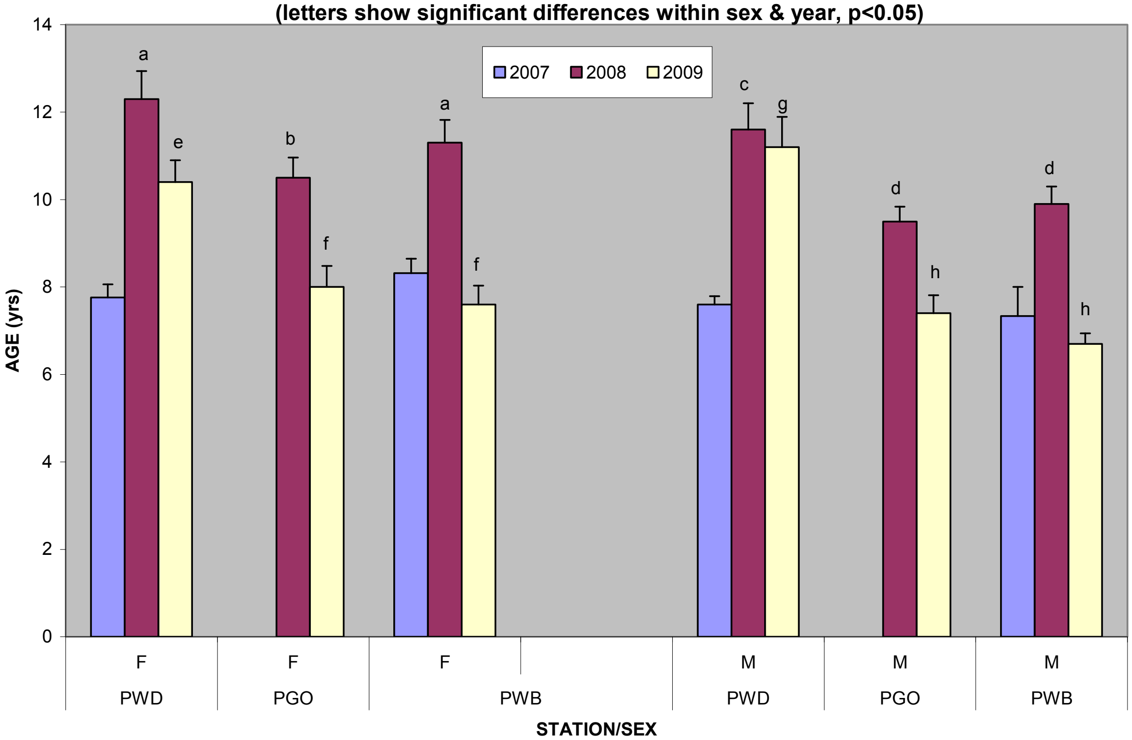
Figure 3.3.3. Mean levels of circulating sex steroids (testosterone-T and 11-ketotestosterone-KT) in male white sucker from the Presumpscot River above (PWD, PGO) and below (PWD) Westbrook, 2007 & 2008 (letters = significant differences by steroid p<0.05)



Age

Differences in mean age of white sucker among the sample stations was not consistent among the years (Figure 3.3.4). There was no difference between stations in 2007 for either sex, but females were younger at PGO in 2008 and at both PGO and PWB in 2009. Males were younger at PGO and PWB than at the upstream station PWD for both 2008 and 2009. Comparisons among the years are not appropriate, given the difference in net mesh size between the first and next two years.

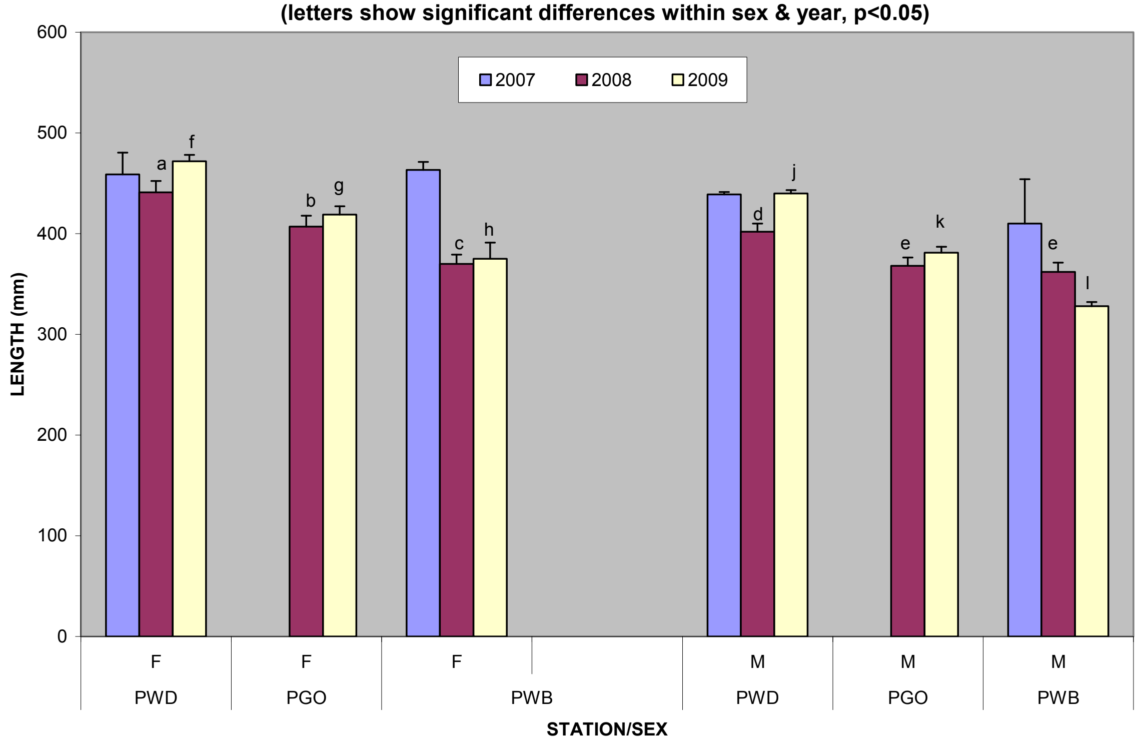
Figure 3.3.4. Mean age of white sucker from the Presumpscot River above (PWD, PGO) and below (PWB) Westbrook, 2007-2009 (letters show significant differences within sex & year, p<0.05)



Length

There was no difference in length adjusted for age between stations for either sex in 2007 (Figure 3.3.5). The fish at PWB (mean = 410 mm) appeared to be shorter than those at PWD (mean = 439 mm) but the difference was not significant perhaps due to a small (n=3) sample size and high variance. In both 2008 and 2009, fish were progressively shorter from the upstream station at PWD to each successive downstream station, PGO to PWB. These results are contrary to the expected greater length below PWD due to increased nutrient enrichment and eutrophication at PGO and PWB shown in Table 3.3.1. Comparison among years is inappropriate given the difference in net mesh size among the years.

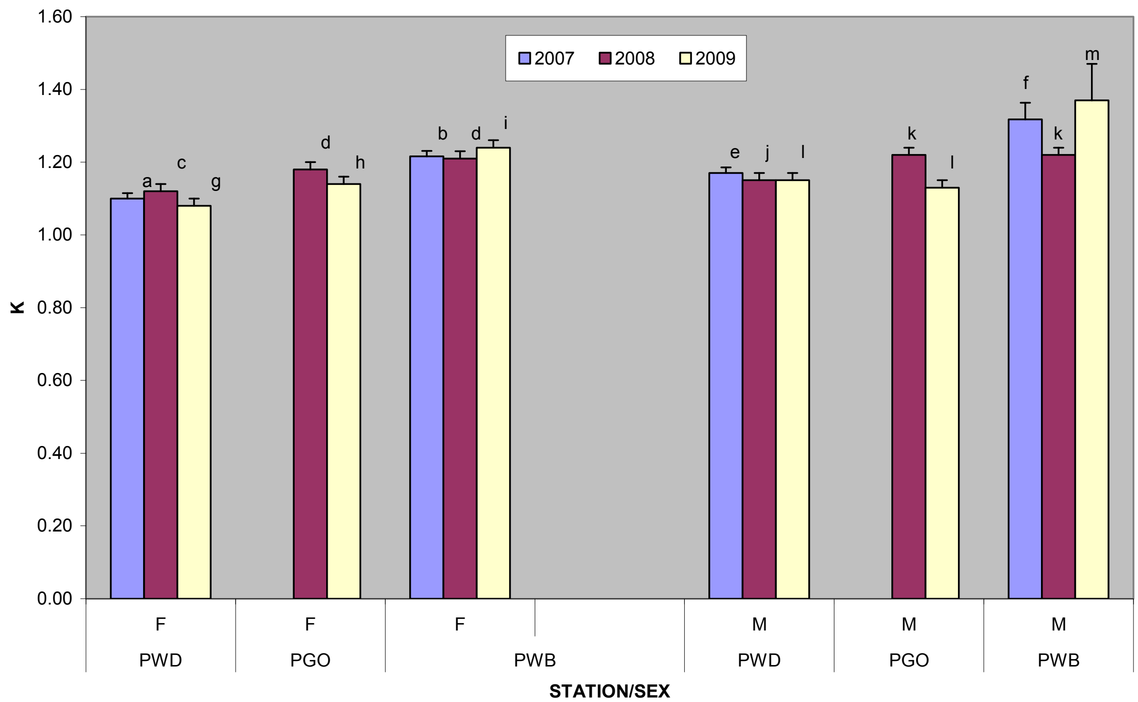
Figure 3.3.5. Mean length of white sucker from the Presumpscot River above (PWD, PGO) and below (PWB) Westbrook, 2007-2009 (letters show significant differences within sex & year, p<0.05)



Condition Factor

Mean condition factor (K) was greater below Westbrook at PWB than above Westbrook at PWB for both sexes for all three years (Figure 3.3.6). Mean K at PGO was intermediate that of the other two stations for females, but not for males. These results generally mirror nutrient levels shown in Table 3.3.1 but are opposite to the trend seen with growth in length. Comparison among years is inappropriate given the difference in net mesh size among the years.

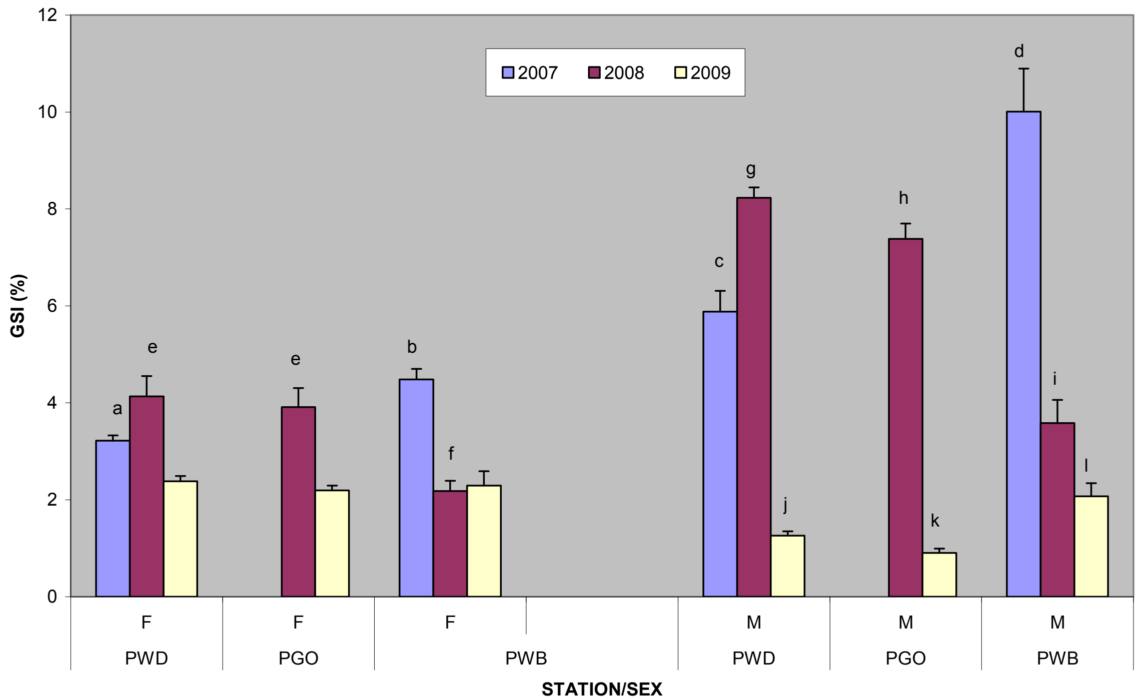
Figure 3.3.6. Mean condition factor (K) of white sucker from the Presumpscot River above (PWD, PGO) and below (PWB) Westbrook, 2007-2009 (letters show significant differences within sex & year, p<0.05)



GSI

Mean GSI was higher at PWB than at PWD for both sexes in 2007 and for males in 2009. GSI was lower at PWB for both sexes in 2008. (Figure 3.3.7). Due to the increased nutrient enrichment downstream, GSI would be expected to increase at PWB. If there was an endocrine disruption, GSI would be expected to decrease at PWB. There is no consistent response among the years

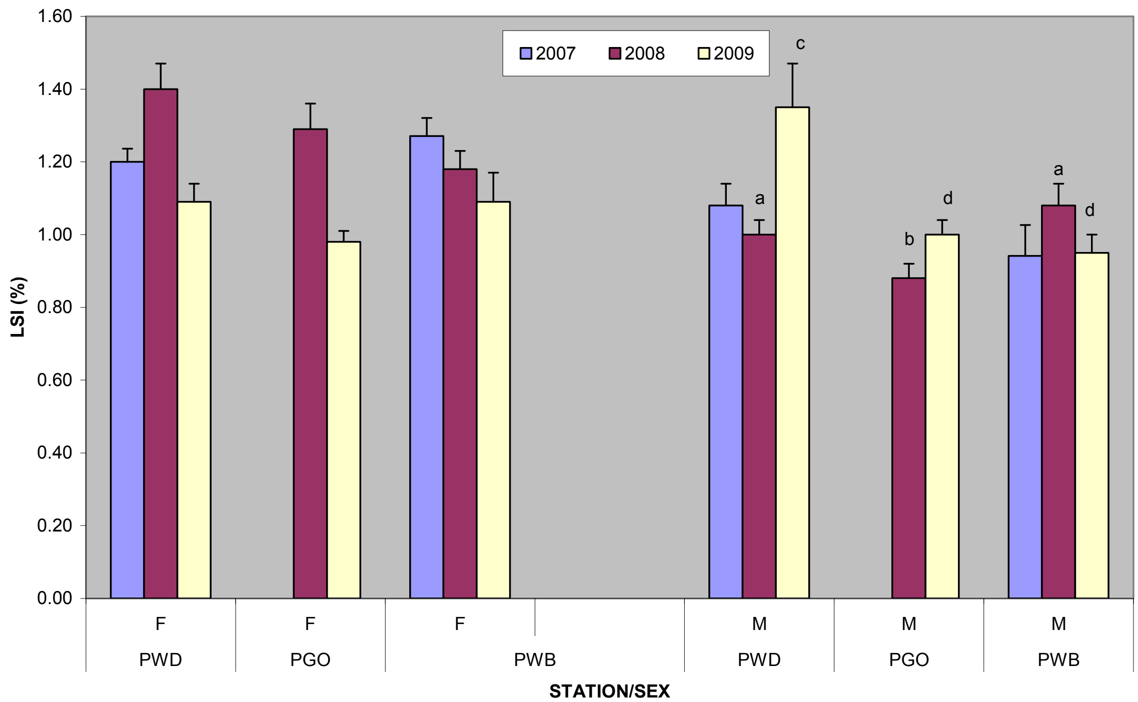
Figure 3.3.7. Mean GSI in white sucker from the Presumpscot River above (PWD, PGO) and below (PWB) Westbrook, 2007-2009 (letters show significant differences within sex & year, p<0.05)



Liver Size

Due to increased nutrient enrichment, the expectation was that LSI would be greater at PWB than upstream stations. There was, however, no year when LSI was greater at PWB than upstream stations (Figure 3.3.8). In fact there was no difference among the stations for males in any year. GSI at PWB was different than that at PWD only in 2009 when it was lower at PWB.
This was unexpected since LSI usually responds similarly to K, and increases in eutrophic waters, such as occurs below Westbrook.

Figure 3.3.8. Mean LSI in white sucker from the Presumpscot River above (PWD, PGO) and below (PWB) Westbrook, 2007-2009. (letters show significant differences within sex and year, $p<0.05$)



Immune system

Kidney size and spleen size, both crude indicators of immune system dysfunction, showed no little difference among stations. The few differences were variable among the years. There is no clear indication of immune system dysfunction.

Gonad Development

Studies of fish exposed to municipal sewage treatment plant effluents and to pulp and paper mill effluents have documented numerous negative impacts on reproduction. Some studies have documented altered secondary sex characteristics (Rickwood et al. 2006), such as masculinization of females or bias towards males (Noggle et al. 2004), and feminization of males (Parrott and Wood, 2004). Effects on the reproductive endpoint include increased atresia of oocytes (Sepulveda et al. 2001), reduced egg size (Martel et al. 2004), and fecundity (Parrot and Wood, 2004) or deformities of embryos and reduced recruitment (Karas et al. 1991).

Development of eggs and sperm in the gonads of fish have been shown to be affected by exposure to some contaminants. Delay in gonadal development has resulted in reduced egg size and fecundity in fish exposed to discharges with implications on populations. In fish gonads, male and female germ cells may be classified into stages of development. In the ovary, as oogonia develop into oocytes and then ova, the oocytes are typically classified into previtellogenic, endovitellogenic, and vitellogenic oocytes depending on the amount of vitellogenin contained as well as other features (Blazer et al. 2002). In the testes, the development of spermatogonia progresses from spermatocytes to spermatids, and finally to spermatozoa in succession (Wolf et al. 2004).

A gonadal staging study comparing the developmental stage of the male and female germ cells in white sucker collected at PWD and PWB was conducted by Environmental Canada. Results showed that there was no significant difference in percentage of previtellogenic, endovitellogenic, and vitellogenic oocytes between stations for either year when measured (Figure 3.3.9). Mean size of vitellogenic oocytes was no different between stations in 2008; mean size was significantly reduced in successive stations downstream in 2008 (Figure 3.3.10). Gonadal development of male sperm cells was not significantly (p=0.104) different between stations in 2007 (Figure 3.3.11), but sample size of male suckers was limited (n=3). In 2008,there was, however, a significant earlier development of spermatozoa in male sucker at the most upstream station at Windham, which was surprising, since the productivity of the aquatic environment is lower there compared to downstream stations as shown by water quality measurements. There was no difference in sperm development between PGO and PWB, immediately above and below Westbrook, respectively,

Figure 3.3.9. Mean percentage of previtellogenic (P), endovitellogenic (E), & vitellogenic (V) oocytes from female white sucker from the Presumpscot River above (PWD, PGO) and below (PWB) Westbrook, 2007 & 2008

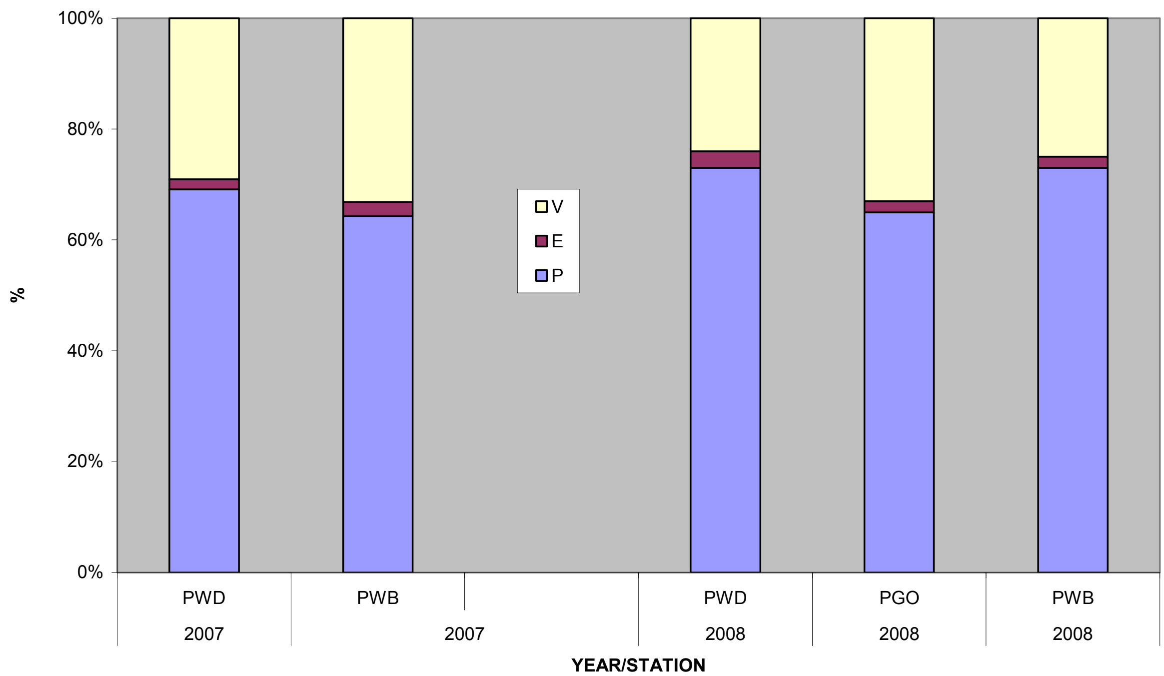


Figure 3.3.10. Mean size (µm2) of vitellogenic oocytes in female white sucker from the Presumpscot River above (PWD, PGO) & below (PWB) Westbrook, 2007 & 2008 (different letters show significant differences within years)

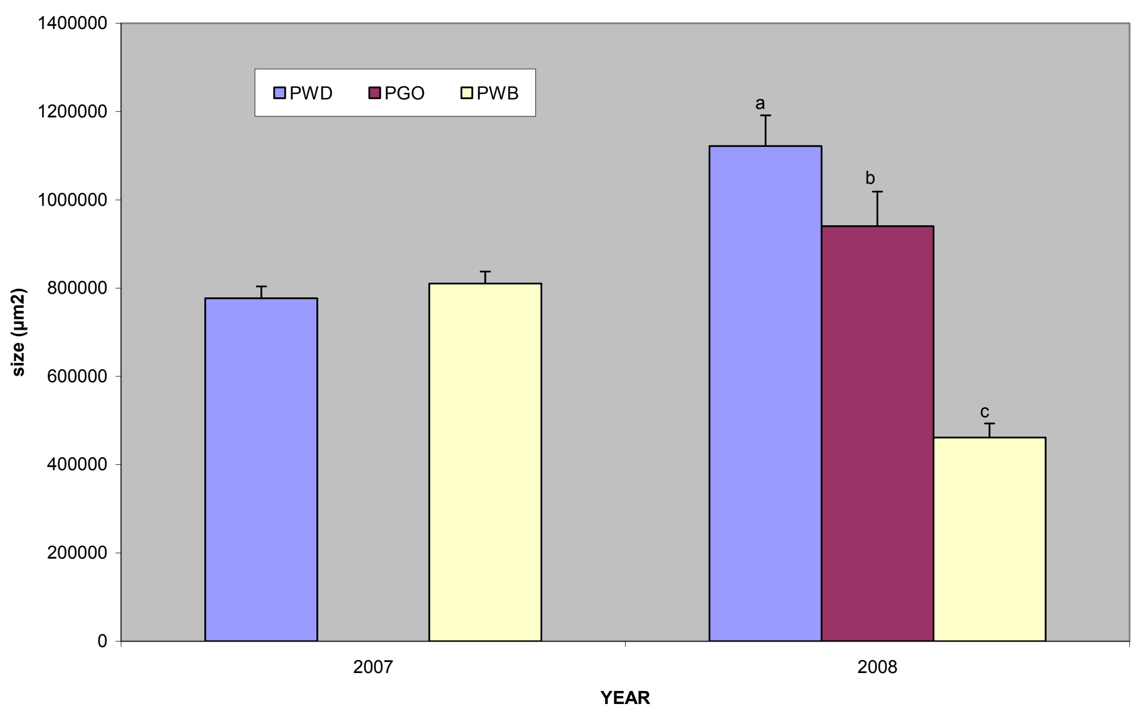
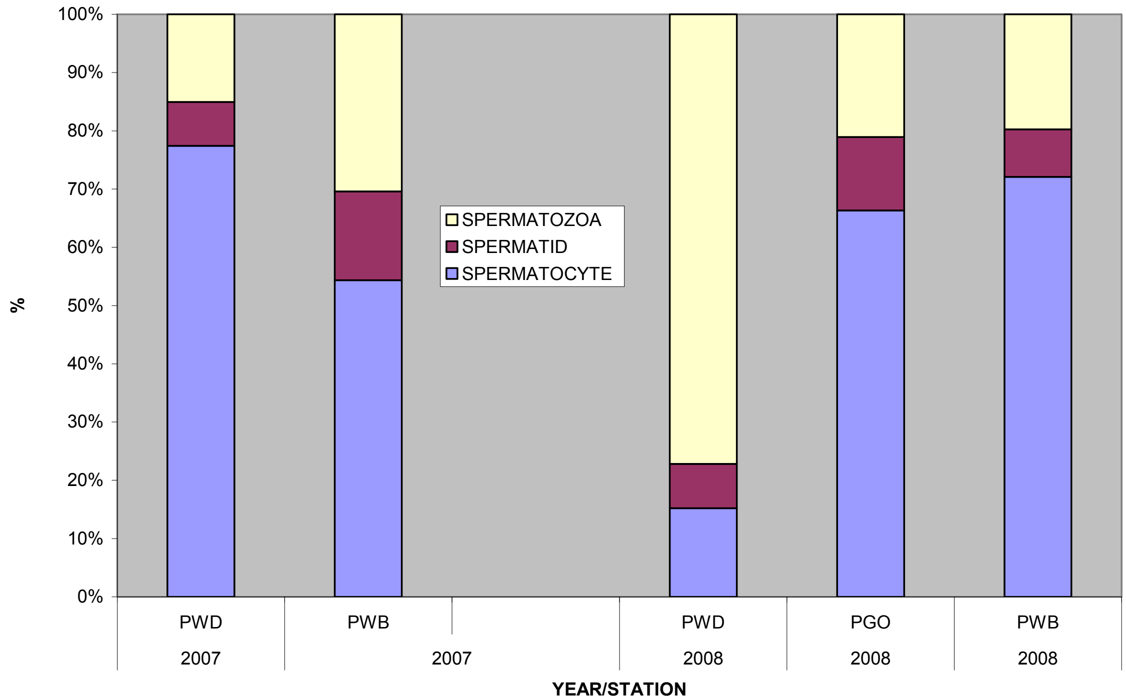


Figure 3.3.11. Mean percentage of spermatocytes, spermatids, spermatozoa in male white sucker testes from the Presumpscot River above (PWD, PGO) & below (PWB) Westbrook, 2007 & 2008



Vitellogenin and Intersex

Vitellogenin (VTG) is a protein normally synthesized in the liver of female fish in response to endogenous estrogens, and is then transported via the blood to the developing oocyte in the ovary where is functions as a precursor to egg yolk protein. Males normally have very little if any measurable VTG. Finding measurable levels of VTG in males or abnormally high levels in females is used as a biomarker for exposure to environmental estrogens. Exposure of males to estrogenic substances has resulted in increased levels of circulating sex steroids, precocious maturation, reduced testicular development and fertility, feminization, i.e. intersex or development of ova in the testes, reduced spawning and hatching and survival, altered growth and development (Jobling and Tyler, 2003). Exposure of females to environmental estrogens has resulted in masculinization, ovarian atresia, inhibition of the ovarian duct, increased levels of circulating sex steroids, precocious maturation, reduced spawning and hatching and survival, altered growth and development. Studies in Canada, England, and the United States have found elevated levels of VTG below sewage treatment plants (Folmar et al. 1996; Sumpter, 2005) and pulp and paper mills (Hewitt et al. 2008).

Measurement of VTG in plasma of white suckers from the Presumpscot River above (PWD, PGO) and below (PWB) the Westbrook sewage treatment plant discharge and SD Warren paper mill discharge showed measurable levels of VTG in females (Figure 3.3.12). There was only trace amounts in males as expected (Figure 3.3.10). VTG was significantly elevated in females at PWB in both years compared to upstream stations, although considerably lower in 2008 than in 2007. The increase in 2007 was consistent with the increase in GSI but GSI actually decreased at PWB in 2008 (Figure 3.3.6). The increase in VTG may be a result of increased nutrition shown by condition factor (weight to length) which was greater at PWB than at PWD in both years as a result of increased eutrophication due to the two discharges. There was no significant difference between stations for males (Figure 3.3.13), signaling that endocrine disruption was an unlikely factor in this river. Sample size was small (n=3) at the downstream station in 2007, but sample size (n=17) was adequate in 2008, when the conclusion is the same. No intersex was observed in male gonads.

Figure 3.3.12. Vitellogenin (VTG) in female white sucker plasma from the Presumpscot River above (PWD, PGO) and below (PWB) Westbrook, 2007-2008 (different letters show significant differences within years)

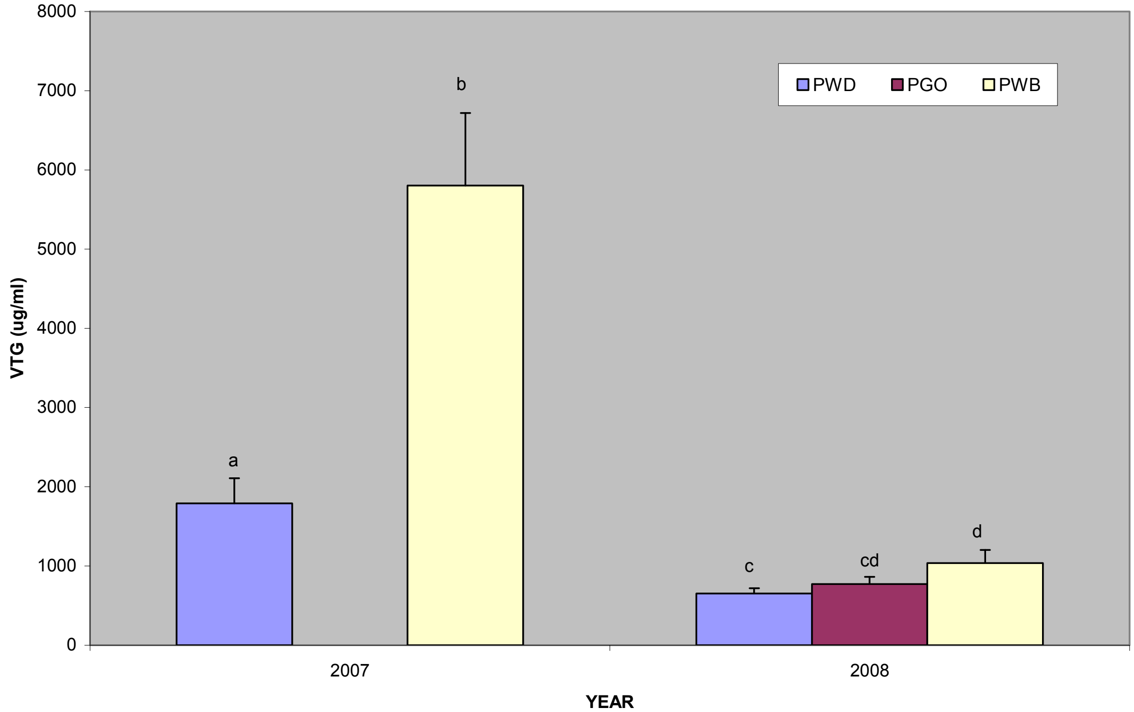
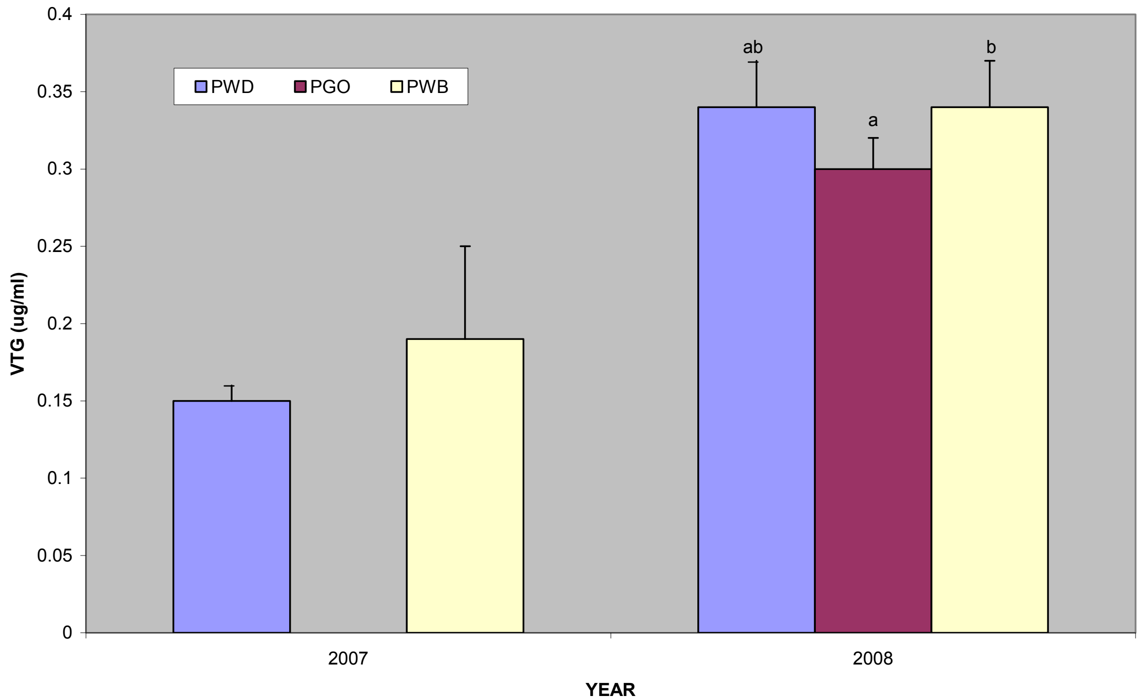


Figure 3.3.13. Mean vitellogenin (VTG) concentrations in male white sucker from the Presumpscot River above (PWD, PGO) and below (PWD) Westbrook, 2007 & 2008 (different letters show significant differences within years)



Catch Rates (catch per unit effort, CPUE)

In 2009, the target collection of 20 live females and 20 live males was achieved at the two stations above Westbrook in 1-2 days. Below Westbrook, only 18 live females and 9 males were collected in 6 days. The apparent lower density, as determined by catch rates (CPUE), below Westbrook is similar to that observed in 2007 (Table 3.3.2). The validity of comparing among years is limited by use of different net sizes in different years.

Table 3.3.2. Catch rates (CPUE) of white sucker from the Presumpscot River above (PWD, PGO) and below (PWB) Westbrook, 2007-2009

STATION	SEX	2007 CPUE #/d/1000ft	2008 CPUE #/d/1000ft	2009 CPUE #/d/1000ft
PWD	F	28	15	9
PGO	F		28	14
PWB	F	6	17	3
PWD	M	19	16	6
PGO	M		14	10
PWB	M	1	14	1

CONCLUSIONS

Although there were individual responses for one or both sexes in one or more years indicating endocrine disruption below Westbrook compared to stations upstream, the overall pattern (alternate hypothesis Ha) of endocrine disruption was not evident in any year (Table 3.3.3).

Table 3.3.3. Responses of white sucker in the Presumpscot River above (PWD, PGO) and below (PWB) Westbrook, 2007-2009.

STATION	SPECIES	sex	AGE	LENGTH	GSI	K	LSI	KSI	SSI
Ha:			+	+	-	+	+	+	+
2007									
PWD	WHS	F							
PWB	WHS	F	0	0	+	+	0	0	0
PWD	WHS	M							
PWB	WHS	M	0	0	+	0	0	0	0
2008									
PWD	WHS	F							
PGO	WHS	F	-	-	0	+	0	+	0
PWB	WHS	F	0	-	-	0	0	0	-
PWD/PWB	WHS	F	0	-	-	+	0	0	0
PWD	WHS	M							
PGO	WHS	M	-	-	-	+	-	0	0
PWB	WHS	M	0	0	-	0	+	0	0
PWD/PWB	WHS	M	-	-	-	+	0	0	0
2009									
PWD	WHS	F							
PGO	WHS	F	-	-	0	+	0	0	-
PWB	WHS	F	0	-	0	-	0	+	0
PWD/PWB	WHS	F	-	-	0	+	0	+	-
PWD	WHS	M							
PGO	WHS	M	-	-	-	0	-	0	-
PWB	WHS	M	0	-	+	+	0	0	-
PWD/PWB	WHS	M	-	-	+	+	-	0	-

+ - 0 = significantly greater, lesser or no different from station above

Reduced GSI, indicative of disruption of the reproductive system, was lower at PWB only in 2008. Elevated GSI, K, and LSI, indicative of nutrient enrichment, was not evident at PWB for any year, although K was elevated at PWB from PWD for females in 2007 and both sexes in 2008 and 2009. Often the increase in K occurred at PGO, where nutrient levels were elevated from those at PWD, likely due to urban runoff. Other measures of reproductive fitness, such as gamete development and vitellogenin, showed no clear pattern of endocrine disruption. There was no evidence of intersex observed in gonads of males at any station.

Although comparison among years is difficult because of different gear size, growth rates, as determined by length (adjusted for age), were lower below Westbrook than upstream for 2008 and 2009 (Table 3.3.2). This is contrary to expectations, given the eutrophication of the river at and below Westbrook due to urban runoff and the discharges from the Westbrook sewage treatment plant and SD Warren paper mill. Catch rates of both female and male white sucker appeared much lower below Westbrook than the two stations upstream for both 2007 and 2009. Catch rate comparisons among the years are considered rough estimates, given different gear sizes and flow conditions among the years.

A 2006-2007 study of fish communities in the Presumpscot River found reduced species richness, abundance, biomass downstream of Westbrook (Yoder et al. 2009). Habitat was assessed using a Qualitative Habitat Evaluation Index (QHEI) as modified for application to large, non-wadeable rivers. The QHEI was poorest (lowest) in the reach below Westbrook (at DEP station PWB), although the QHEI upstream at PWD was not much higher. To a large extent, the difference in QHEI was due to a greater amount of silt cover at PWB than at PWD. Although percent erodible soils was similar at the two stations, the higher siltation at PWB was likely due to lower gradient and possible channel modifications. Any channel modifications are possibly a result of the effect of increased runoff from impervious areas in developed Westbrook on erodible stream banks. An interim Maine IBI (index of biological integrity) also indicated reduced fitness of fish populations downstream of Westbrook that was potentially “more indicative of pollution impacts than of habitat alone”.

Whole effluent toxicity (WET) tests from both the Westbrook Sewage Treatment Plant and SD Warren Paper mill do not show the effluents to be toxic at the critical receiving water concentrations, but WET tests typically detect only relatively gross effects. And there is a possibility of toxic effects from urban runoff from the highly developed city of Westbrook.

There is no consistent evidence of endocrine disruption in white sucker in the Presumpscot River below Westbrook. Although water quality data document nutrient enrichment and visual observations and some fish responses suggest eutrophication of the river below Westbrook, the response of fish populations is not completely typical of a eutrophic ecosystem. Growth rates, abundance, diversity, and an index of biological integrity appear to be lower below Westbrook. The causes may be natural differences in habitat exacerbated by past or present discharges of sediments or other pollutants from municipal and industrial activities and urban runoff from Westbrook.

REFERENCES

Adams, S.M., W.D. Crumby, M.S.Greeley Jr., L.R. Shugart, and C.F. Saylor, 1992. Responses of Fish Populations and Communities to Pulp Mill Effluents: A Holistic Assessment. Ecotoxicology and Environmental Safety 24:347-360.

Ahmad, T.M., M. Athar, N.Z. Khan, and S. Raisuddin, 1998. Responses of circulating fish phagocytes to paper mill effluent exposure. Bull. Environ. Contam. Toxicol. 61: 746-753.

Blazer, V.S., 2002. Histopathological assessment of gonadal tissue in wild fishes. Fish Physiology and Biochemistry 26:85-101.

DEP, 2004. Surface Waters Ambient Toxics Monitoring Program Final Report, 2002-2003, Maine Department of Environmental Protection, Augusta, Maine, December 2004.

Gray, MA and CD Metcalf, 1997. Induction of testis-ova in Japanese medaka (Oryzias latipes) exposed to p-nonylphenol. Env. Toxicol. Chem. 16(4):1082-1086.

Folmar, L, ND Denslow, V Rao, M Chow, DA Crain, J Enblom, J Marcino, and L J Guillette Jr, 1996. Vitellogenin induction and reduced serum testosterone concentrations in feral male carp captured near a major metropolitan sewage treatment plant. Env Health Perspectives 104(10):1096-1101.

Hewitt LM, Kovacs TG, Dube MG, MacLatchy DL, Martel PH, McMaster ME, Paice MG, Parrott JL, Van den Heuvel,Michael R., Van der Kraak,Glen J. 2008. Altered reproduction in fish exposed to pulp and paper mill effluents: Roles of individual compounds and mill operating conditions. Environ Toxicol Chem 27(3):682-97.

Jardine, JJ, GJ Van Der Kraak, and KR Munkittrick, 1996. Impact of capture, handling, confinement, and a three day recovery period on general indicators of stress and reproductive steroids in white sucker exposed to bleached kraft mill effluent. Ecotoxicol. Environ. Safe 33:287-298.

Jobling, S and CR Tyler, 2003. Endocrine disruption in wild freshwater fish. Pure Appl. Chem. 75 (11-12): 2219-2234.

Holliday, S.D., S.A. Smith, E.G. Besteman, A.S.M.I. Deyab, R.M. Gogal, T. Hrubec, J.L. Robertson, and S.A. Ahmed, 1998. Benzoapyrene-induced hypocellularity of the pronephros in tilapia (Oreochromis niloticus) is accompanied by alterations in stromal and parenchymal cells and by enhanced cell apoptosis. Vet. Immunology and Immunopthology 64(1):69-82.

Karas, P, E Neuman, and O Sandstrom, 1991. Effects of a pulp mill effluent on the population dynamics of a perch, *Perca fluviatilis*. Can. J. Fish. Aquat. Sci. 48:28-34.

Kavlock, R.J., G.P. Daston, C. DeRosa, P. Fennes-Crisp, L. E. Gray, S. Kaattari, G. Lucier, M. Luster,M.J. Mac, C. Maczka, R. Miller, J. Moore, R. Rolland, G. Scott, D.M. Sheehan, T. Sinks, and H.A. Tilson, 1996. Research needs for the risk assessment of health and environmental effects of endocrine disruptors: A report of the US EPA sponsored workshop. Env. Health Perspectives 104 supp 715

Kime, DE, 1999. A strategy for assessing the effects of xenobiotics on fish reproduction. The Science of the Total Environment 225:3-11.

Kovacs, T.G., P. Martel, M. Ricci, J. Michaud, and R. Voss, 2005. Further insights into the potential of pulp and paper mill effluents to affect fish reproduction. J. Toxicol. Environ. Health 68:1621-1641.

Martel, P, T. Kovacs, and R. Voss, 2004. Survey of pulp and paper mill effluents for their potential to affect fish reproduction. In Borton, D.L , T.J. Hall, R.P. Fisher, and J.F. Thomas (eds) Proceedings of the 5th International Conference on Fate and Effects of Pulp and Paper Mill Effluents, Seattle, Washington, USA, June 1-4, 2003. pp 78-91. DEStech Publications Inc., Lancaster, PA, USA

McMaster, M, GJ Van Der Kraak, and KR Munkittrick, 1996. An epidemiological evaluation of the biochemical basis for steroid hormonal depressions in fish exposed to industrial wastes. J. Great Lakes Res. 22(2):153-171.

McMaster, ME, KR Munkittrick, and GJ Van Der Kraak, 1992. Protocol for measuring circulating levels of gonadal sex steroids in fish. Can. Tech. Rept. Fish. Aquat. Sci. 1836.

McMaster, M, 2001. National Water Research Institute, Canada Center for Inland Waters, Environment Canada, Burlington, Ontario. Personal communication.

McMaster, M.E., L. Mark Hewitt, Gerald R. Tetreault, Tamara Janoscik, Chad Boyko, Lisa Peters, Joanne L. Parrot, Glen J. Van Der Kraak, Cam B. Portt, Kevin J. Kroll, and Nancy Denslow, 2005. Detailed endocrine assessments of wild fish in the Northern River Basins, Alberta, in comparison to EEM monitored endpoints. Wat. Qual. Res. J. Canada 40(3):299-314.

Munkittrick, KR, GJ Van Der Kraak, ME McMaster, and CB Portt, 1992. Response of hepatic MFO activity and plasma sex steroids to secondary treatment of bleached kraft pulp mill effluent and mill shutdowns. Env. Toxicol. Chem. 11:1427-1439.

Munkittrick, K.A., M.E. McMaster, L.H. McCarthy, M.R. Servos, and G.J. Van Der Kraak, 1998. An overview of recent studies on the potential of pulp-mill effluents to alter reproductive parameters in fish. J. of Toxicology and Environmental Health, Part B, 1:347-371.

Munkittrick, K.A., M.E. McMaster, G. Van Der Kraak, C. Portt, W. N. Gibbons, A. Farwell, and M. Gray, 2000. Development of methods for effects driven cumulative effects assessment using fish populations: Moose River project. Technical Publication, SETAC Press, Pensacola, Fla. 236 pp.

Noggle, J.J., B. P. Quinn, J. T. Smith, D. S. Ruessler, M. S. Sepulveda,T. S. Gross, and S. E. Holm, 2004. Paper Mill Process Modifications Reduce Biological Effects on Largemouth Bass and Eastern *Gambusia.* In Borton, D.L , T.J. Hall, R.P. Fisher, and J.F. Thomas (eds) Proceedings of the 5th International Conference on Fate and Effects of Pulp and Paper Mill Effluents, Seattle, Washington, USA, June 1-4, 2003. pp14-24. DEStech Publications Inc., Lancaster, PA, USA.

Parrott, J.L. and C.S. Wood, 2004. Changes in Growth, Sex Characteristics and Reproduction of Fathead Minnows Exposed for a Life-Cycle to Bleached Sulphite Mill Effluent. In Borton, D.L, T.J. Hall, R.P. Fisher, and J.F. Thomas (eds) Proceedings of the 5th International Conference on Fate and Effects of Pulp and Paper Mill Effluents, Seattle, Washington, USA, June 1-4, 2003. pp 92-109. DEStech Publications Inc., Lancaster, PA, USA

Rickwood, C.J., M.G. Dube, L.M.Hewitt, T.G. Kovacs, J.L. Parrott, and D.L. MacLatchy, 2006. Use of paired fathead minnow (Pimephales promelas) reproductive test. Part 1: Assessing biological effects of final bleached kraft pulp mill effluent using a mobile bioassay trailer system. Environ. Toxicol. Chem. 25(7):1836-1846.

Rolland, R.M., M. Gilbertson, and R.E. Peterson editors, 1997. Chemically Induced Alterations in Functional Development and Reproduction of Fishes. Proceedings from a session at the 1995 Wingspread Conference Center, 21-23 July 1995, Racine Wi. Published by the Society of Environmental Toxicology and Chemistry (SETAC), Pensacola, Florida.

Secombes, C.J., T.C. Fletcher, A. White, M.J. Costello, R. Stagg, and D.F. Houlihan, 1992. Effects of sewage sludge on immune responses in the dab, Limanda limanda L. Aquatic Toxicology 23:217-230.

Sepulveda MS; Ruessler DS; Denslow ND; Holm SE; Schoeb TR; Gross TS, 2001. Assessment of reproductive effects in largemouth bass (*Micropterus salmoides*) exposed to bleached/unbleached kraft mill effluents. Arch Environ Contam Toxicol. 41(4):475-82.

Sumpter, J.P., 2005. Endocrine disrupters in the aquatic environment: An overview. Acta. Hydrochim. Hydrobiol. 33(1):9-16.

Voccia, I., K. Krzystyniak, M. Dunier, and M. Fournier, 1994. In vitro mercury-related cytotoxicity and functional impairment of the immune cells of rainbow trout (Oncorhynchus mykiss). Aqu. Tox. 29(1-2):37-48.

West, D.W, N. Ling, B.J. Hicks, L.A. Tremblay, N.D. Kim, and M.R. van den Heuvel, 2006. Cumulative impacts assessment along a large river, using brown bullhead catfish (*Ameiurus nebulosus*) populations. Environ. Toxicol. Chem. 25(7):1868-80.

Wolf, J.C., D.R. Dietrich, U. Freiderich, J. Caunter, and A.R. Brown, 2004. Qualitative and quantitative histomorphologic assessment of fathead minnow Pimephales promelas gonads as an endpoint for evaluating endocrine-active compounds: a pilot study. Toxicologic Pathology 32:600-612.

Yoder, C. O., L.E. Hersa, and E.T. Rankin, 2009. Fish Assemblage and habitat assessment of the Presumpscot River. MBI Technical Report MBI 2008-12-6, Midwest Biodiversity Institute, Columbus, OH. 142 pp.