DEPLW-1232

SURFACE WATER AMBIENT TOXICS MONITORING PROGRAM

2011

FINAL REPORT

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

June 2012

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INTRODUCTION

This 2011 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 and Estuarine, 2) Lakes, 3) Rivers and Streams, 4) Special Studies.

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

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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.

The assistance of the following members of the SWAT Technical Advisory Group representing various interests, in review and design of the monitoring plan, is greatly appreciated:

Business and Industry: Patrick Gwinn, Integral Consulting Inc.; Mick Kuhns, Tasman Leather Group
Municipal: Janet Robinson, Woodard and Curran Inc.; Janet Abrahamson, Maine Rural Water Association
Conservation: Susan Gallo, Maine Audubon Society; Nick Bennett, Natural Resources Council of Maine
Public Health: Diane Siverman, Maine Center for Disease Control and Prevention; Dan Kusnierz, Penobscot Indian Nation
Academic: Dr. Adria Elskus, School of Biology & Ecology, U Maine and USGS; Dr. Rebecca Van Beneden, Dept. of Biochemistry, MicroBiology, and Molecular Biology, U Maine
Legislators: Senator Thomas Saviello, Energy and Natural Resources; Representative Windol Weaver, Marine Resources

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). The TAG is composed of 10 individuals, made up of 2 each with scientific backgrounds representing five various interests (business, municipal, conservation, public health and academic) 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 2011 workplan recommended by the SWAT TAG in a meeting June 24, 2011. Following is a summary of key findings from the 2011 SWAT program for each module.

1. MARINE AND ESTUARINE

- In 2011, blue mussel tissue from East End Beach, Portland, Mill Creek, Falmouth, Rockland, and Sandy Point, Stockton Springs, was analyzed for contaminants including metals, mercury, Polycyclic Aromatic Hydrocarbons (PAHs), Polychlorinated Biphenyls (PCBs), and organochlorinated pesticides. In 2011, tissue from six additional blue mussel sites in the Sheepscot estuary was analyzed for metals and mercury only.
- In 2011, softshell clam tissue from Fort Point Cove, Stockton Springs, was tested and reported with data from seven other softshell clam sites sampled in 2004-05 and 2010. Clam tissue was analyzed for contaminants including metals, mercury, PAHs, PCBs, and organochlorinated pesticides.
- Lead in mussel tissue exceeded the National Status and Trends (NS&T) Musselwatch 85th percentile concentration at six sites in 2011, resulting in these sites receiving an "elevated" designation. Two of these sites, East End Beach, Portland, and Crockett Point, Rockland, also exceeded the Maine Center for Disease Control's (MCDC) fish tissue action level (FTAL) for lead in finfish. Lead in clam tissue in 2011 at Fort Point Cove, Stockton Springs, fell just below the MCDC FTAL for lead in finfish. Previous clam tissue sampling in 2005 at Fort Point Cove exceeded the MCDC FTAL for lead in finfish.

- Mercury in mussel tissue exceeded the NS&T Musselwatch 85th percentile concentration at all ten sites tested in 2011, which resulted in assignment of an "elevated" classification. Mercury levels in 2011 mussel and clam tissue were below the MCDC methylmercury developmental FTAL for finfish.
- PAH concentrations in mussel and clam tissues did not exceed the NS&T Musselwatch 85th percentile at any site and were not considered to be elevated.
- PCB concentrations in mussel tissue at East End Beach, Portland, and Crockett Point, Rockland exceeded the MCDC cancer FTAL, which is consistent with elevated concentrations detected in 2007 at Crockett Point. PCB concentrations in clam tissue were below the MCDC cancer FTAL.
- Organochlorinated pesticide concentrations in mussel and clam tissue were low at Maine sites compared to national Musselwatch data, and pesticide levels were safely below MCDC FTAL values.
- The U.S. Environmental Protection Agency (EPA), through the 2010 National Coastal Condition Assessment (NCCA), will be analyzing lobster tissues for metals, mercury, PCBs, and organochlorinated pesticides. These data are not yet available from EPA.

2. LAKES

- Fish from 44 lakes were sampled and analyzed for mercury concentrations by a new quicker less expensive method using the Direct Mercury Analyzer 80 at the Sawyer Environmental Research and Chemistry Lab at the University of Maine in Orono. There was no statewide trend for fish from 8 lakes comparing 2011 results with those from the 1990s. Combined with the 2010 results from 26 lakes, there appears to be no statewide change in mercury concentrations in Maine fish in the last 20 years. This is not unexpected given that there have been few efforts to reduce mercury emissions nationally until recently. Given a long history of atmospheric deposition of mercury, it may take a while for reductions in emissions to be measured in reductions in fish. The data were sent to the Maine Center for Disease Control and Prevention (ME-CDC) for use in reviewing the statewide Fish Consumption advisory.

3. RIVERS AND STREAMS

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

- Dioxin concentrations measured in fish from three stations in the Androscoggin River were similar to those of recent years; although lower than levels in the mid 1990s, concentrations still exceed MCDC's Fish Tissue Action Level (FTAL). Dioxin concentrations in fish from Kennebec River at Sidney are below those of previous years and below the FTAL. Dioxin concentrations in Sebasticook Lake are lower than previously, but still exceed the FTAL. Coplanar (dioxin-like)

PCBs added to dioxins resulted in an exceedance of the FTAL for the fish from all rivers sampled.

- Total PCBs exceeded the FTAL in fish from the fish from all rivers sampled.

- A project funded at the University of Maine reported the following. The mummichog, *Fundulus heteroclitus*, is a non-migratory resident fish often used as a sentinel of persistent pollutants in its immediate environment. Mercury concentrations in Penobscot River *F. heteroclitus* populations ranged from 136 – 241 ppb (total Hg wet wt fillet) in juvenile fish from Souadabscook to Old Pier; levels which are 9 – 16 fold higher than those of fish from a reference site in Wells National Estuarine Research Reserve. Mercury levels in Penobscot River mummichog are below those shown to have adverse effects in juvenile/adult fish (> 500 ppb). No concentration gradient was evident in mummichog Hg levels.

4. SPECIAL STUDIES

- A project funded at the University of Maine reported the following. Developing zebrafish use the production of reactive oxygen species as part of their innate immune defense against pathogens. We hypothesized that azoxystrobin, a fungicide that disrupts the production of reactive oxygen species by mitochrondria in fungi, would disrupt the generation of reactive oxygen species in early life stage zebrafish. Our results demonstrate that at environmentally relevant concentrations (10-5000 pptr), azoxystrobin does not alter this aspect of innate immunity in developing zebrafish. In conjunction with our findings that fish exposed to these concentrations developed and hatched normally, we conclude that as a solitary chemical at concentrations reported in US surface waters, azoxystrobin is not likely to pose a threat to fish development or innate immunity.

1.0 MARINE MODULE

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1.1 INTRODUCTION

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 and 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.

1.1.1 Blue Mussels

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 readily be discerned from background sediment or water concentrations.

Blue mussels have been a long term focus of the marine SWAT sampling efforts over the years and were included again in the SWAT program this year. This report presents and summarizes contaminant data from the collection and analysis of blue mussel (*Mytilus edulis*) tissue collected in 2011 from ten sites along the Maine coast. All mussel tissue samples were analyzed for heavy metals (including mercury), and a subset of four sites were analyzed for polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and organochlorinated pesticides. In order to provide comparability of results from these 2011 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 National Status & Trends Mussel Watch Program (National Oceanographic and Atmospheric Administration). This analysis provides a regional and national context to the Maine SWAT data.

1.1.2 Softshell Clams

Like blue mussels, softshell clams (*Mya arenaria*) are consumed as food by humans and can be used to understand potential human exposure to contaminants. Clams are sessile, allowing attribution of their contaminant burdens to the environment where they were collected. Like mussels, clams 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. Softshell clam stations sampled by the SWAT program in recent years have been selected to characterize contaminant concentrations specifically in clam tissue, as opposed to blue mussel tissue which may or may not have been sampled previously in the same general area. Gulfwatch and SWAT softshell clam tissue contaminant data suggest that clams may have very different concentrations of some contaminants than blue mussel tissue taken from the same stations. This is an important point when considering the contaminant concentrations that humans are exposed to when consuming clams. Clam testing is typically driven by human consumption and exposure, and clams are used less in SWAT (or Gulfwatch) as a general environmental monitor or sentinel like the blue mussel.

This report presents and summarizes contaminant data from the collection and analysis of softshell clam tissue collected in 2011 from one site on the Maine coast. Also presented are softshell clam contaminant data from seven additional sites sampled in 2004-05 by the SWAT program. Softshell clam tissue samples were analyzed for metals, mercury, PAHs, PCBs, and organochlorinated pesticides. In order to provide comparability of results from the 2011, 2010, and 2004-05 samples, softshell clam contaminant concentrations from SWAT sampling are compared to contaminant concentrations in the Gulfwatch program to provide regional context.

The Maine Dept. of Marine Resources has asked Maine DEP to sample clams in areas currently closed to shellfish harvest, which usually is due to bacterial contamination that prevents safe consumption of the clams by humans. Some significant clam resources have improving bacterial trends or may be candidates for additional work to reduce bacterial contamination in the vicinity of the resource. Without corresponding contaminant data from clam tissue to document safe human consumption, expenditure of resources to reduce bacterial contaminant sources might be premature if high contaminant concentrations are confirmed. Bacterial source clean up can then be targeted to clam resources that already have been documented as safe for human consumption from a contaminant concentration perspective. Like mussels, testing sites with low contaminant levels, which can only be determined post-sampling, still provides valuable data on background contaminant levels in clams and provides a context with which to compare more heavily contaminated sites.

1.2 METHODS

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

"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 are 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.

1.2.1 Blue Mussels

Blue mussel samples have been analyzed for toxics as part of the SWAT program since 1986, with over 85 distinct locations sampled in the past 26 years. Sampling stations are selected to meet one or more of three goals: 1) Provide spatial coverage of the Maine coast; 2) provide data to determine temporal patterns or trend; and 3) 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 reduce costs.

Blue mussels were collected from ten sites in 2011. Four of the ten mussel sites had been sampled previously as part of the SWAT program. Names and locations of blue mussel collection sites for 2011 are presented in Table 1.2.1.1. This table presents sites by name and includes municipality, latitude and longitude, and the site selection type: spatial, temporal, or follow up. A map of the blue mussel sampling locations is provided in Figure 1.2.1.1.

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.

TABLE 1.2.1.1: 2011 SWAT Blue Mussel Sites

Site Name	Municipality	Station Code	West Longitude	North Latitude	Date Sampled	Site Type1
East End Beach	Portland	CBEEEE	-70.24072	43.66953	10/3/2011	T
Mill Creek	Falmouth	CBMCMC	-70.21979	43.71973	10/4/2011	T
Hockomock Bay	Woolwich	MCSHHB	-69.74232	43.89826	10/6/2011	F, S
Chewonki Neck	Wiscasset	MCSHCW	-69.71891	43.93176	10/6/2011	F, S
Whites Island	Wiscasset	MCSHWI	-69.66814	43.99778	10/5/2011	F, S
Cove Side Way Rd.	Westport	MCSHCS	-69.6934	43.91674	10/21/2011	F, S
Clifford Rd.	Edgecomb	MCSHCL	-69.65208	43.9877	10/6/2011	F, S
Back River	Boothbay	MCSHBR	-69.66409	43.91731	10/21/2011	F, S
Rockland	Rockland	PBRKCP	-69.10409	44.09784	11/7/2011	F
Sandy Point	Stockton Springs	PBSPSP	-68.80639	44.50358	10/5/2011	S

[1] S = Spatial, T = Temporal, F = Follow Up

Sampling occurred from mid-October to mid-November and sampling dates are included for specific sites in Table 1.2.1.1. 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 within a size range of 50-60 mm were selected for analysis. 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 replicate. All soft tissue was removed and combined with the soft tissue from mussels within the same replicate. Total soft tissue wet weights per replicate were recorded. Tissue composites were immediately placed in pre-cleaned glass jars and capped. Jars were pre-labeled and filled jars were stored at -5^{o} C for up to 1 to 2 months until analysis.

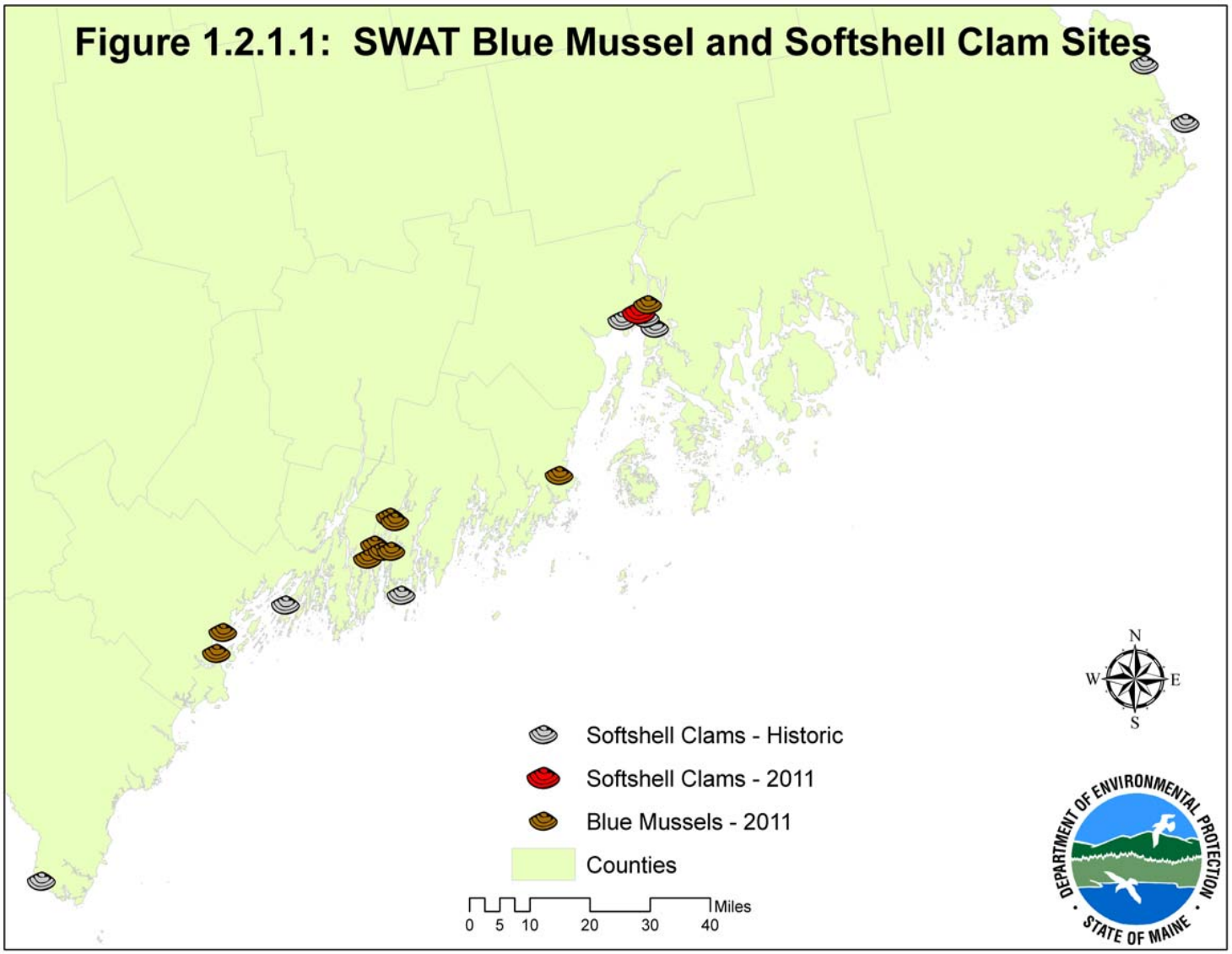


Figure 1.2.1.1: SWAT Blue Mussel and Softshell Clam Sites
Softshell Clams - Historic
Softshell Clams - 2011
Blue Mussels - 2011
Counties
0 5 10 20 30 40
Miles
N
W
E
S
DEPARTMENT OF ENVIRONMENTAL PROTECTION
STATE OF MAINE

Mussel tissues tested for PAHs, PCBs, and organochlorinated pesticides (four sites in 2011) were analyzed by AXYS Analytical Services Ltd., Sidney, British Columbia. Mussel tissue tested for metals samples were analyzed for PAHs using modified EPA Method 8270/1625.

1.2.2 Softshell Clams

Softshell clams were collected at Fort Point Cove, Stockton Springs, the only site sampled successfully for clams in 2011. Softshell clams were slated for collection at two sites in 2011, but only one was successfully collected. Blue mussels were used to generate data at the site where no clams could be collected, Sandy Point in Stockton Springs. Sandy Point had been sampled previously for blue mussels. Fort Point Cove was sampled previously in 2005 and was re-sampled again in 2011 to reassess contaminants at the site in clam tissue. Different geographic areas within Fort Point Cove were sub-sampled in 2011. Previously, in 2005, some contaminants had been elevated at the site and new data were requested by the local shellfish committee and the Maine Dept. of Marine Resources.

In addition to the softshell clam site sampled in 2011 this report includes data from seven softshell clam sites sampled in 2010 and 2004-05. These data are included to provide a broader look at softshell clam contaminant concentrations across the state and to present the 2011 Fort Point Cove data in a statewide context. The data from Fort Point Cove and the seven sites sampled previously are presented in Table 1.2.2.1, and include municipality, and latitude and longitude. The location of the softshell clam sampling stations is presented in Figure 1.2.1.1.

TABLE 1.2.2.1: SWAT Softshell Clam Sites: 2004-05, 2010-11

Site Name	Municipality	Station Code	West Longitude	North Latitude	Date Sampled	Site Type[1]
Mast Cove	Eliot	PQMCMC	-70.8048	43.1210	11/9/2004	S
Navy Pier	Harpswell	CBHWNP	-70.0136	43.7870	11/12/2004	S
Squirrel Island	Southport	MCBBSQ	-69.6290	43.8130	11/8/2004	S
Long Cove	Searsport	PBSTLC	-68.8938	44.4656	12/1/2005	S
Fort Point Cove	Stockton Springs	PBFPFP	-68.8150	44.4717	11/10/2005	S
Fort Point Cove	Stockton Springs	PBFPFP	-68.8372	44.4832	**11/3/2011**	F
Morse Cove	Penobscot/Castine	PBCAMC	-68.7835	44.4478	11/16/2010	S
Harris Cove	Eastport	PMHCHC	-66.9838	44.9171	11/9/2004	S
Mill Cove	Robbinston	PMSCMC	-67.1176	45.0580	11/29/2005	S

[1] S = Spatial, T = Temporal, F = Follow Up

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 any departures from that methodology in softshell clam sampling are noted below.

Sampling typically occurred in mid-November and the specific sampling date is included in Table 1.2.2.1. In order to characterize the contaminants present in a general area at the sampling station, softshell clams were collected from four distinct areas (replicates) along the shoreline at each site whenever possible. Clams at or above the commercial legal length of 2 inches (50.8 mm) were dug from each intra-site location. For metals analysis, a minimum of ten clams 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 20 clams were collected at each intra-site location. Clams in these replicates were washed in ambient sea water in a mesh or open bucket at the collection site to remove external debris and attached sediments. Clam replicates were then transported to the laboratory in coolers (supplemented with ice packs in warmer weather). Clams were not depurated prior to shucking to remove tissue for analysis.

Tissue sample processing was accomplished within 24 hours of field collections. At the laboratory, individual clams were measured with calipers for length (longest shell measurement perpendicular to a line extending from the umbo to the 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 clams. All soft tissue was removed and combined with the soft tissue from the ten clams within the same replicate. Total soft tissue wet weights per ten clam replicate were recorded. For organics analysis, 20 clams were composited into a replicate.

Tissue composite samples for metals analyses included ten clams per composite sample or replicate, and tissue composite samples for organics analyses included 20 clams per composite sample or replicate. For both metals and organics, four replicates were 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 -5^{o} C for up to one to two months until analyses could be completed. Softshell clam tissues tested for PAHs, PCBs, and organochlorinated pesticides in 2010-11 were analyzed by AXYS Analytical Services Ltd., Sidney, British Columbia, while clam tissues tested for metals in these same years were analyzed by Battelle Marine Sciences Laboratory, Sequim, WA. Clam tissues tested in 2004-05 for both the metals and organic contaminants were analyzed by Pace Analytical, Minneapolis, MN.

1.3 RESULTS AND DISCUSSION

1.3.1 Metals

1.3.1.1 Blue Mussels

Mussel tissue samples collected in 2011 were analyzed by Battelle Marine Sciences Laboratory, Sequim, WA. The samples were analyzed for 11 metals: Silver (Ag), aluminum (Al), arsenic (Ar), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), mercury (Hg), nickel (Ni), and zinc (Zn). 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 in a broader geographic context. From an environmental

monitoring perspective, the concentration of an analyte in SWAT mussel tissue was considered elevated when that concentration exceeded the NS&T 85th percentile. This approach is consistent with the Gulfwatch program (LeBlanc, 2009).

1.3.1.1.1 Silver (Ag)

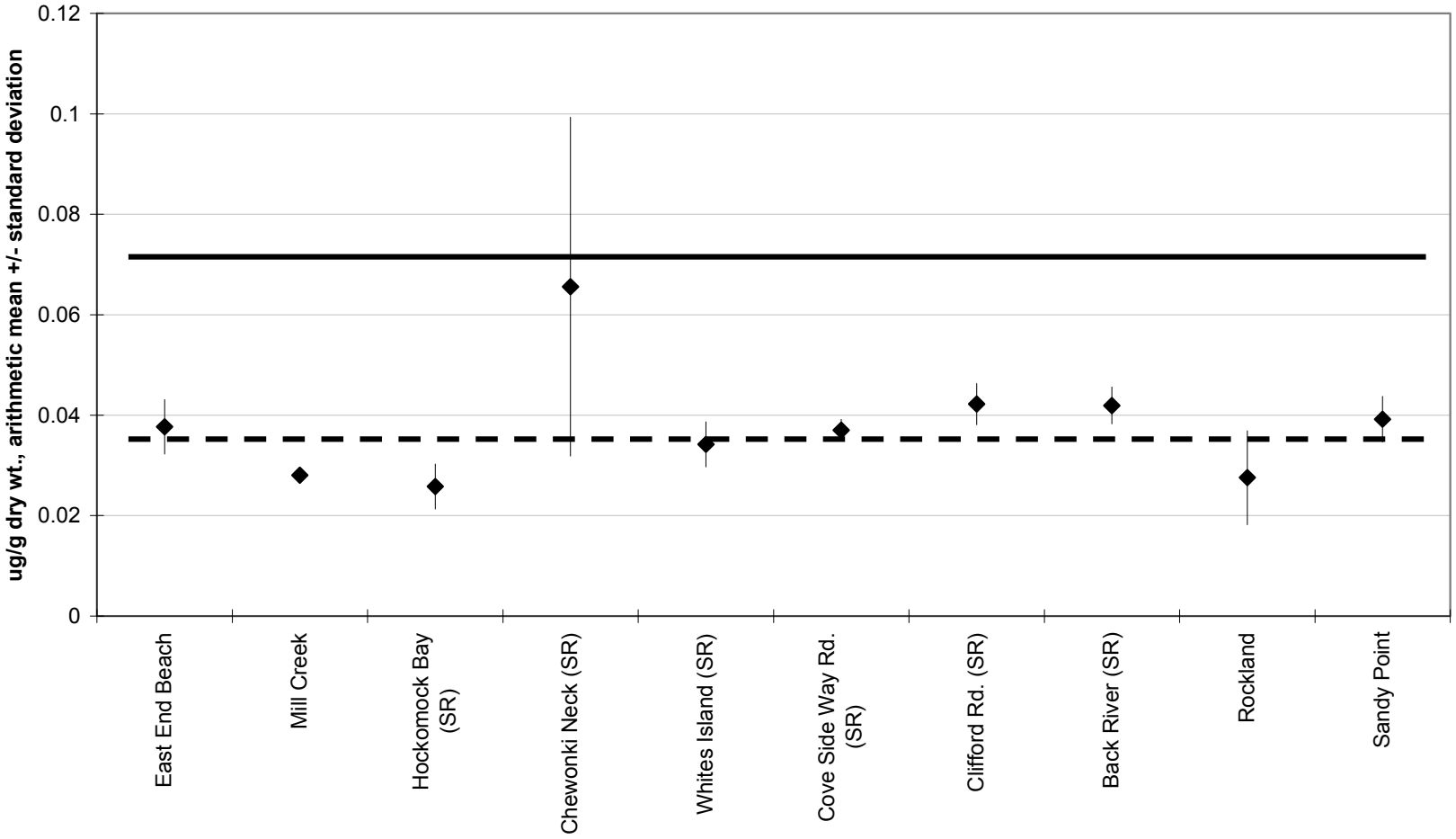
Silver was detected in all ten sample locations visited in 2011. Silver detected in mussels ranged from a low mean concentration of 0.026 ug/g dry wt. at Hockomock Bay, Woolwich, to a high mean concentration of 0.066 ug/g dry wt. at Chewonki Neck, Wiscasset (Figure 1.3.1.1.1.1). Silver mean concentrations in 2011 SWAT mussels were also compared to the Gulfwatch median and 85th percentile concentrations. The mean concentration at six of the ten sites equaled or exceeded the Gulfwatch median (0.037 ug/g dry wt.). None of the SWAT mean concentrations exceeded the Gulfwatch 85th percentile (0.073 ug/g dry wt., Figure 1.3.1.1.1.1).

Figure 1.3.1.1.1.2 compares the silver concentrations in 2011 SWAT blue mussel tissue to the NS&T median and 85th percentile. Silver mean concentrations at all SWAT sites fell below the NS&T median and NS&T 85th percentile, hence no sites were considered elevated for silver.

Higher silver concentrations in water and sediments 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. The increasing use of silver, including nanosilver, in products like paints, caulking, and clothing makes monitoring silver of interest at present and in the future.

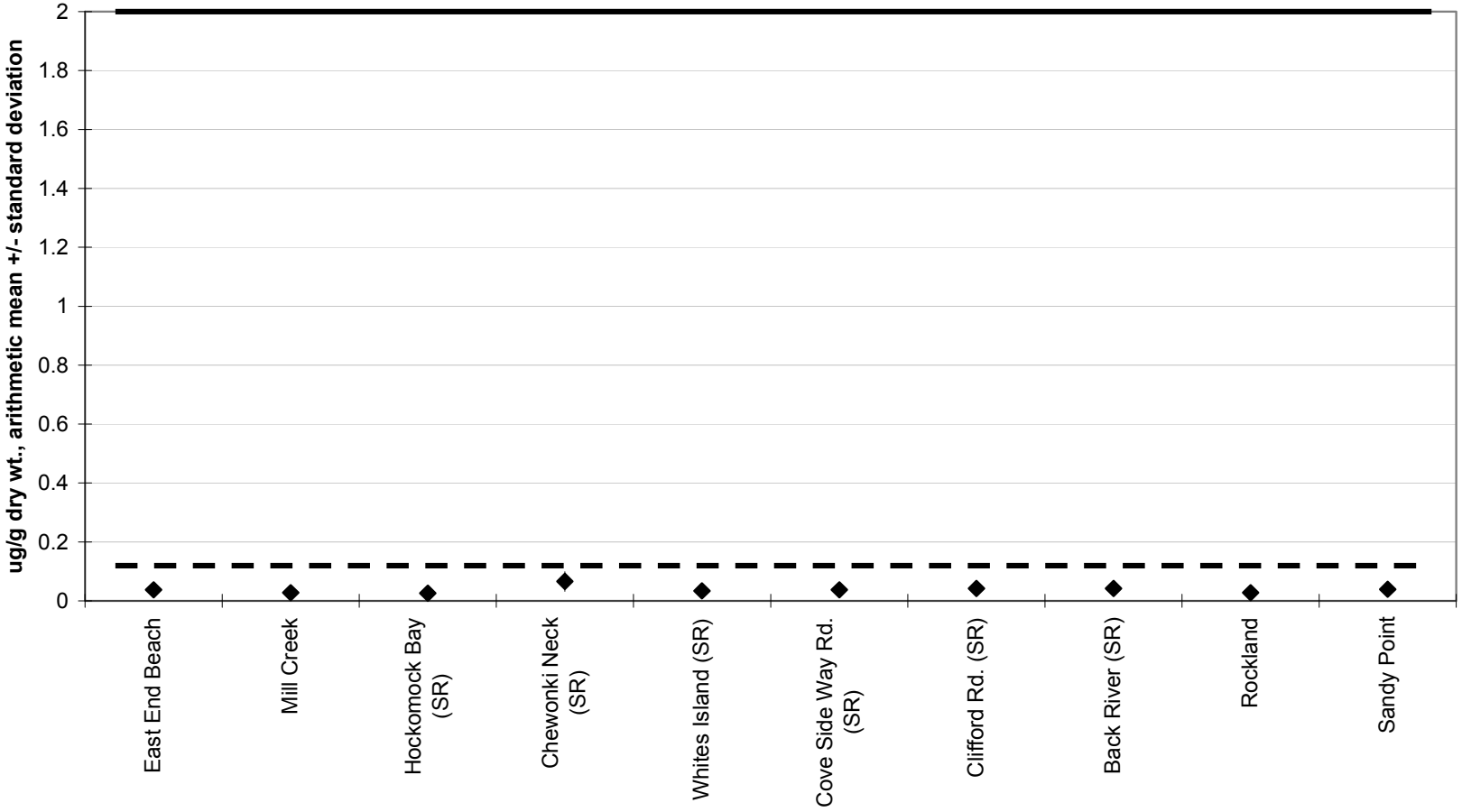
The Maine Center for Disease Control, Bureau of Health (MCDC) silver non-cancer fish tissue action level (FTAL) is 11 ug/g wet wt. (ppm) for non-commercially caught fish. The highest 2011 SWAT blue mussel tissue mean silver concentration, when expressed on a wet weight basis, is 0.007 ug/g wet wt. at Chewonki Neck, Wiscasset. This concentration is three orders of magnitude below the 11 ug/g wet wt. FTAL.

Figure 1.3.1.1.1.1: Silver in SWAT Blue Mussels



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

Figure 1.3.1.1.1.2: Silver in SWAT Blue Mussels



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

1.3.1.1.2 Arsenic (As)

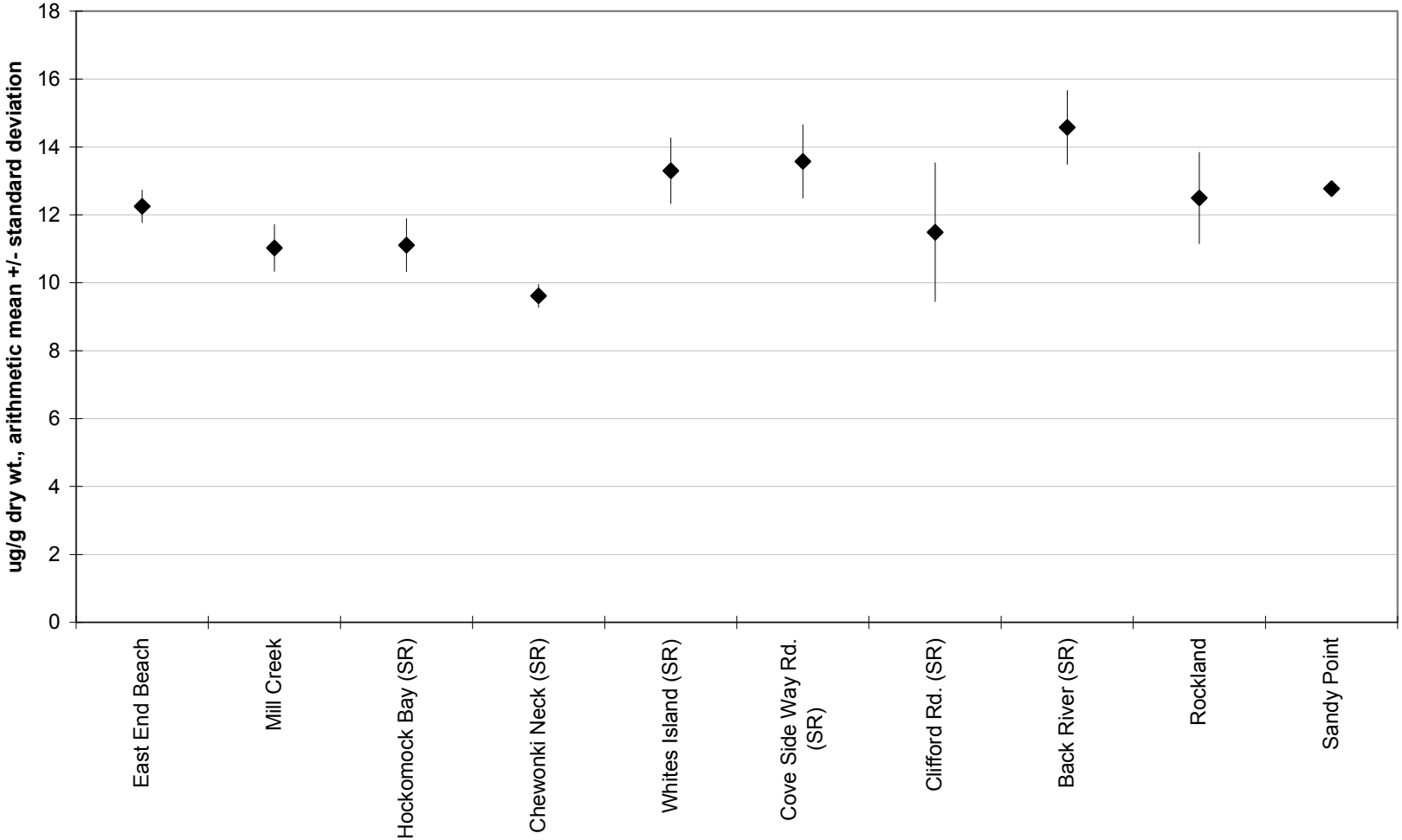
Arsenic was detected in all ten sample locations visited in 2011. Arsenic levels detected in mussels ranged from a low mean concentration of 9.62 ug/g dry wt. at Chewonki Neck, Wiscasset, to a high mean concentration of 14.58 ug/g dry wt. at Back River, Boothbay (Figure 1.3.1.1.2.1). While Gulfwatch 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). Mill Creek, Falmouth, Hockomock Bay, Woolwich, Chewonki Neck, Wiscasset, and Clifford Road, Edgecomb, all had arsenic concentrations which fell into the lowest of three NS&T ranges. The remaining six sites sampled had arsenic concentrations slightly higher than 12 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.

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 and the SWAT blue mussel tissue data are 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. Therefore, 2011 SWAT blue mussel inorganic arsenic concentrations are estimated to range from 0.10 ug/g wet wt. to 0.21 ug/g wet wt. All ten sites exceeded the MCDC cancer FTAL of 0.014 ug/g wet wt. (ppm).

Comparing recent data from all 45 mussel sites sampled from 2007-10, 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 ten sites sampled in 2011 exceeded the MCDC non-cancer action level of 0.6 ug/g wet wt. (ppm) for inorganic arsenic. Similarly, none of the 45 mussel stations sampled from 2007-10 exceeded the MCDC non-cancer FTAL. 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.

Figure 1.3.1.1.2.1: Arsenic in 2011 SWAT Blue Mussels



1.3.1.1.3 Cadmium (Cd)

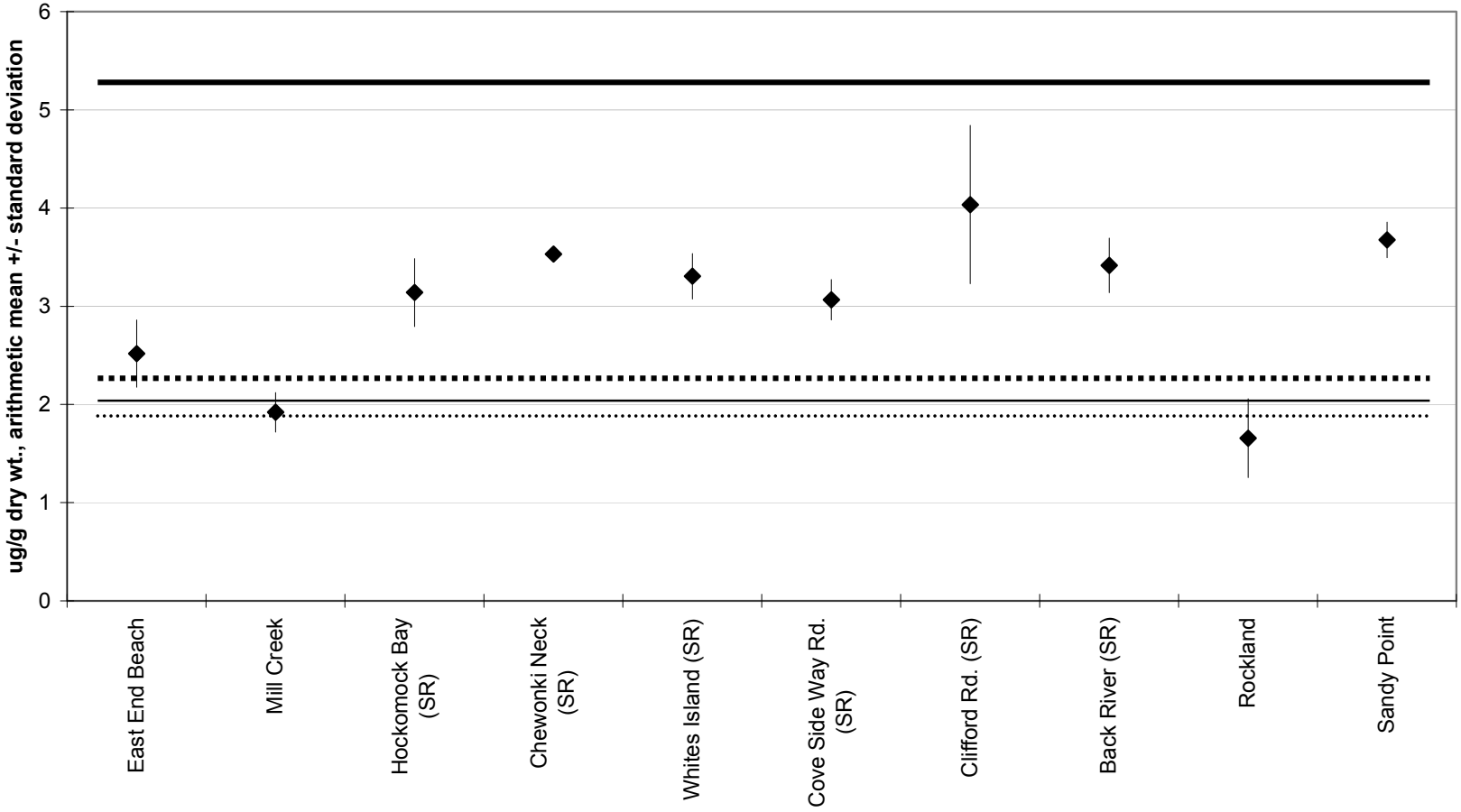
Cadmium was detected in all ten sample locations visited in 2011. Cadmium levels detected in mussels ranged from a low mean concentration of 1.66 ug/g dry wt. at Rockland, to a high mean concentration of 4.04 ug/g dry wt. at Clifford Rd., Edgecomb (Figure 1.3.1.1.3.1). The cadmium concentration at Rockland fell below the 2008 Gulfwatch median, with the concentration at Mill Creek, Falmouth, falling just above the Gulfwatch median. The remaining eight sites exceeded the Gulfwatch median and 85th percentile (Figure 1.3.1.1.3.1).

Cadmium concentrations at Rockland and Mill Creek, Falmouth, fell below the NS&T median, with the concentrations at the remaining eight sites falling between the NS&T median and 85th percentile (Figure 1.3.1.1.3.1) (Kimbrough, 2008). None of the ten SWAT sites sampled in 2011 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).

From a human health perspective, the MCDC non-cancer FTAL for cadmium in non-commercially caught finfish is 2.2 ug/g wet wt. The FDA action level for clams, oysters, and mussels is 4 ppm wet wt. (Kimbrough, 2008). The highest scoring 2011 SWAT site, Clifford Road, Edgecomb, had a mean cadmium concentration of 0.446 ug/g wet wt., which was well below the MCDC and FDA action levels (20% of the more conservative MCDC non-cancer FTAL).

Figure 1.3.1.1.3.1: Cadmium in 2011 SWAT Blue Mussels



Dotted lines = 2008 Gulfwatch Median and 85th Percentile; Solid lines = 2008 National Status and Trends Median and 85th Percentile.

1.3.1.1.4 Chromium (Cr)

Chromium was detected at all ten sites sampled in 2011. Chromium levels detected in mussel tissue ranged from a low mean concentration of 1.00 ug/g dry wt. at Mill Creek, Falmouth, to a high mean concentration of 2.83 ug/g dry wt. at Whites Island, Wiscasset (Figure 1.3.1.1.4.1). Three SWAT concentrations did not exceed the Gulfwatch median: East End Beach, Portland, Mill Creek, Falmouth, and Rockland. The remaining seven sites exceeded both the Gulfwatch median and 85th percentile (Figure 1.3.1.1.4.1).

Figure 1.3.1.1.4.1 also depicts 2011 SWAT mussel chromium concentrations compared to the NS&T Mussel Watch median and 85th percentile concentrations. Only Mill Creek, Falmouth did not exceed the NS&T median, and the remaining nine SWAT sites had concentrations less than the NS&T national 85th percentile.

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 (Kimbrough, 2008).

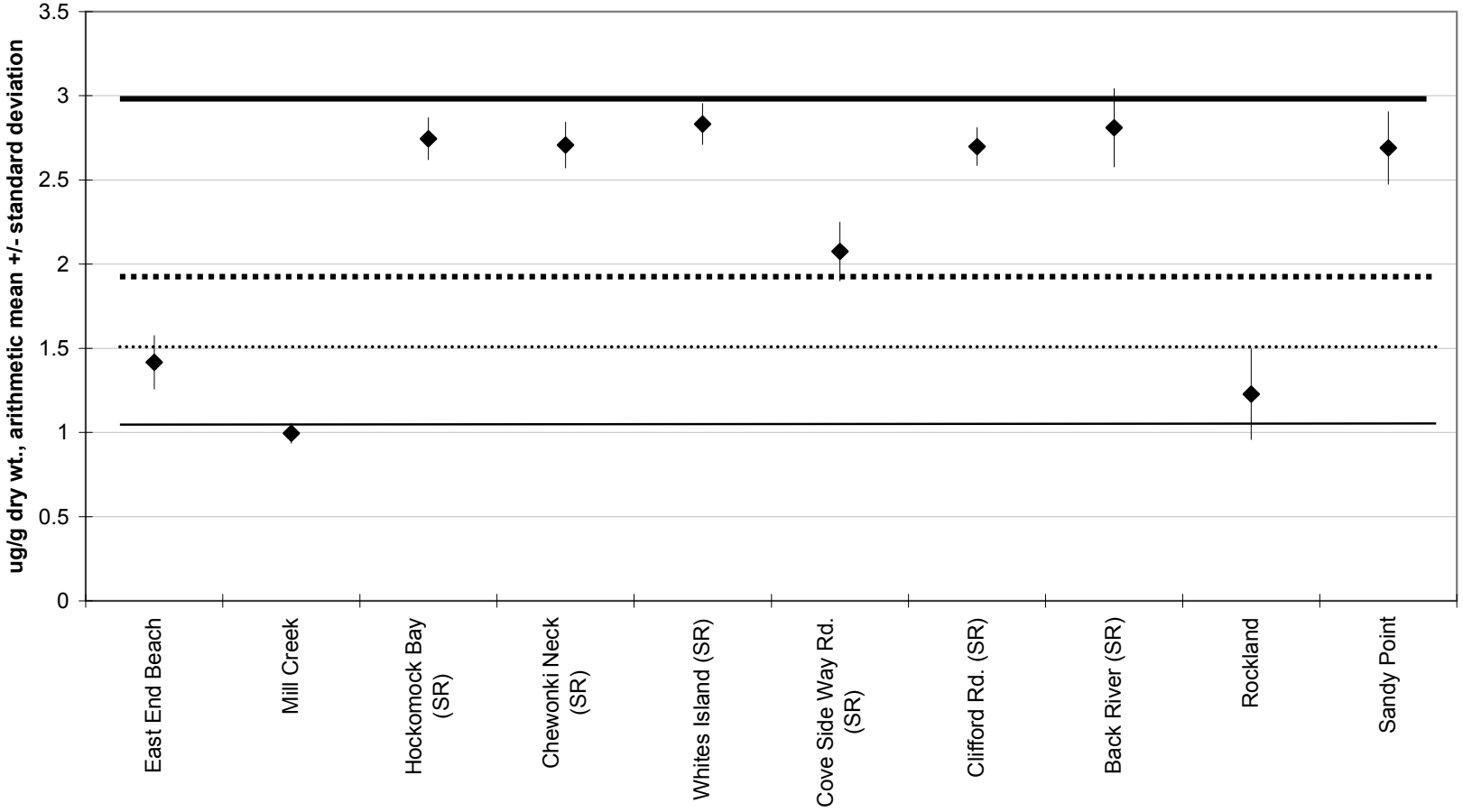
From a human health perspective, the MCDC FTALs (7 ug/g cancer action level and 11 ug/g non-cancer action level) for chromium are based on chromium VI, and are not directly comparable to SWAT results, which measure total chromium.

1.3.1.1.5 Copper (Cu)

Copper was detected in samples taken at all ten SWAT mussel sites visited in 2011. Copper levels detected in mussels ranged from a low mean concentration of 5.95 ug/g dry wt. at Mill Creek, Falmouth, to a high mean concentration of 7.63 ug/g dry wt. at East End Beach, Portland (Figure 1.3.1.1.5.1). Copper concentrations at Mill Creek, Falmouth, and Hockomock Bay, Woolwich, were below the Gulfwatch median, while concentrations at the other eight sites exceeded this value. Only East End Beach, Portland, exceeded the Gulfwatch 85th percentile, although Chewonki Neck, Wiscasset, and Rockland essentially equaled the Gulfwatch 85th percentile (LeBlanc, 2009). SWAT copper concentrations at all ten sites sampled in 2011 fell below the NS&T median, as shown in Figure 1.3.1.1.5.2 (Kimbrough, 2008).

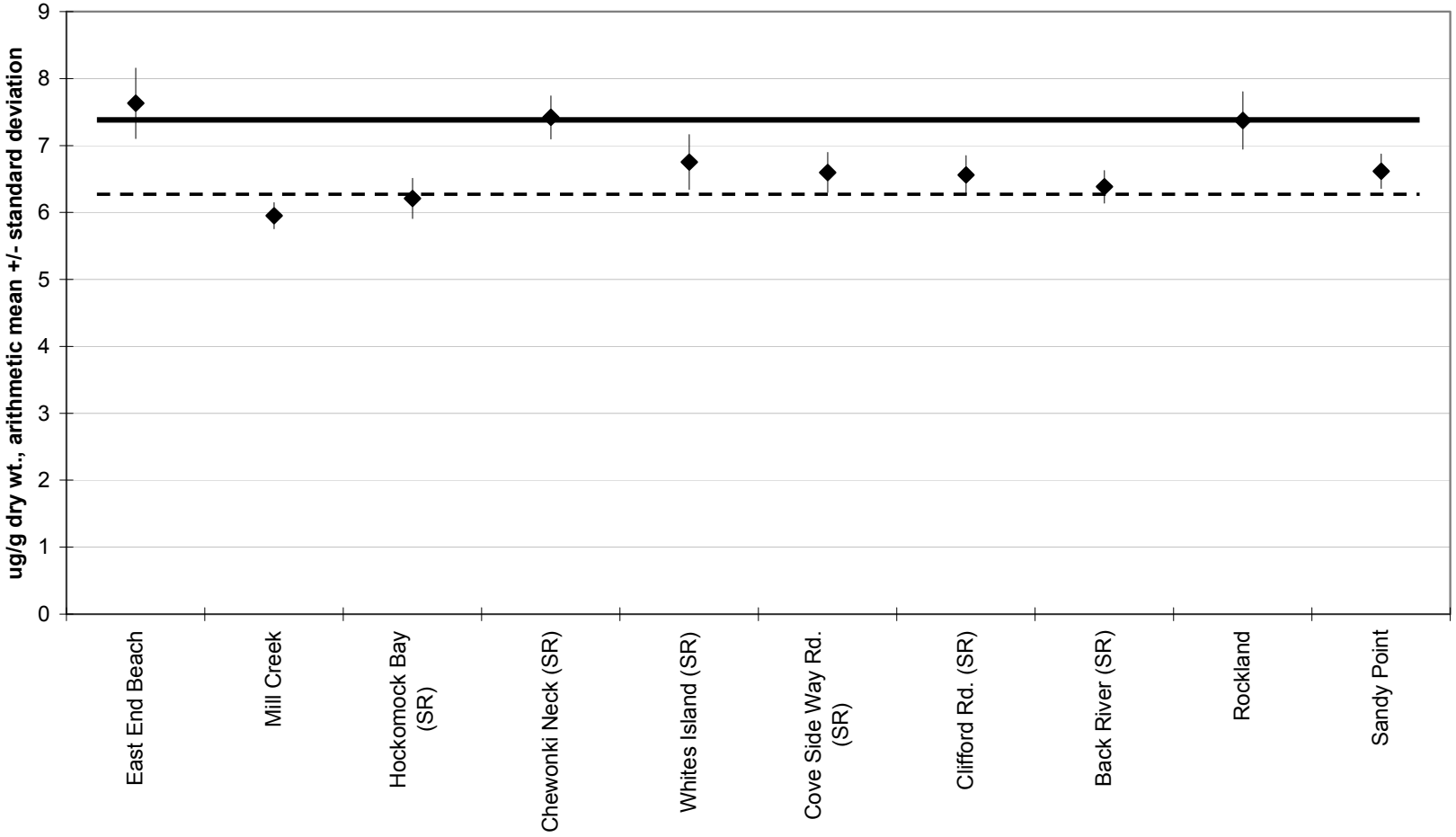
Copper occurs naturally and is ubiquitous throughout the marine environment. Copper, in trace amounts, is considered to be an important nutrient for plant and animal growth. Heightened copper concentrations can occur due to anthropogenic sources, including mining, agriculture, sewage sludge, antifouling paint, fungicides, wood preservatives, and brake pads. With the reduction of the use of chromated copper arsenate (CCA) wood preservative subsequent to being phased 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 1980's, resulting in increased use of copper-based antifouling paints, and asbestos removal from brake pads has been offset by increased copper usage in brake pads (Kimbrough, 2008).

Figure 1.3.1.1.4.1: Chromium in 2011 SWAT Blue Mussels



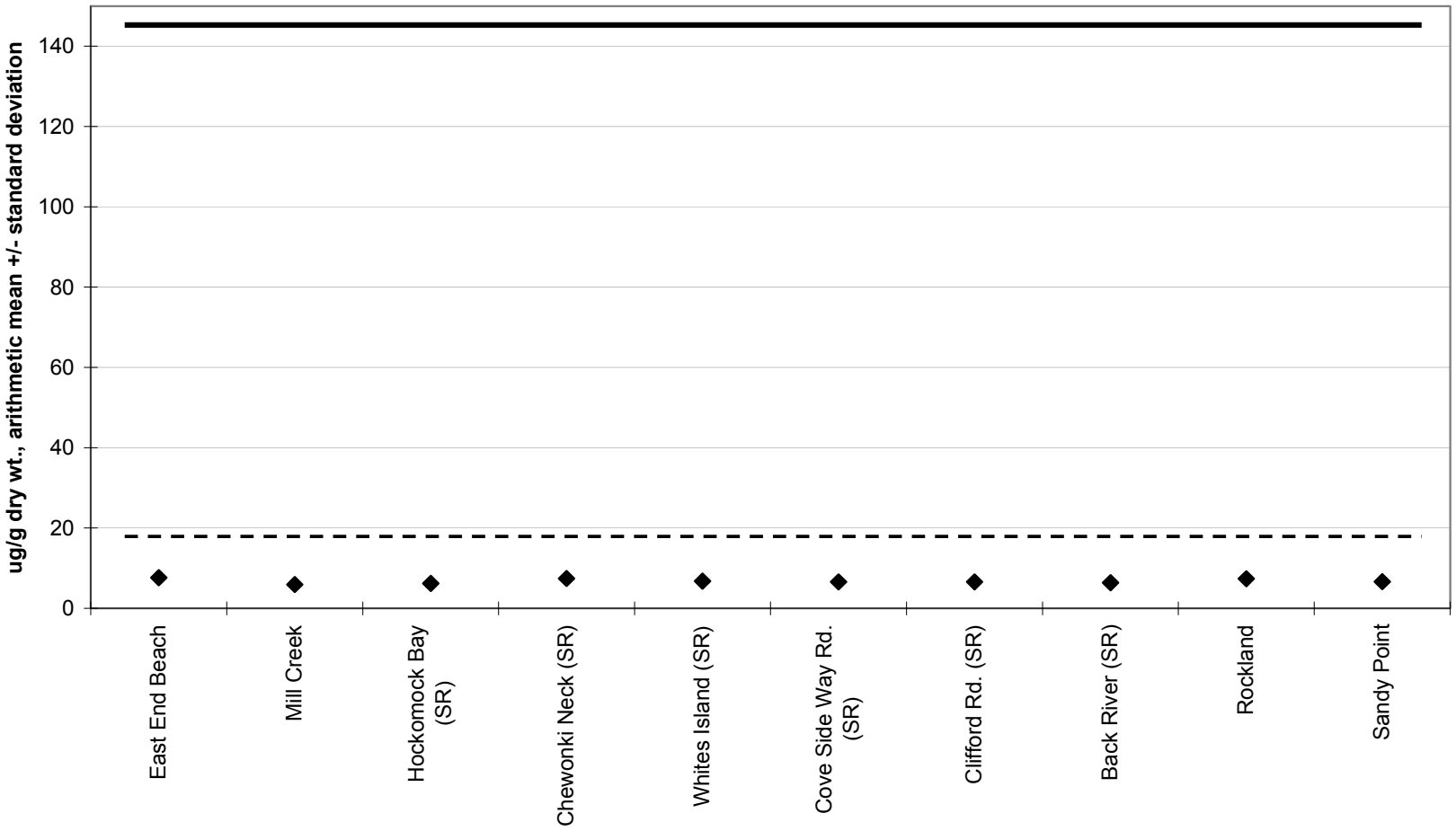
Dotted lines = 2008 Gulfwatch Median and 85th Percentile; Solid lines = 2008 National Status and Trends Median and 85th Percentile.

Figure 1.3.1.1.5.1: Copper in 2011 SWAT Blue Mussels



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

Figure 1.3.1.1.5.2: Copper in 2011 SWAT Blue Mussels



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

1.3.1.1.6 Iron (Fe) and Aluminum (Al)

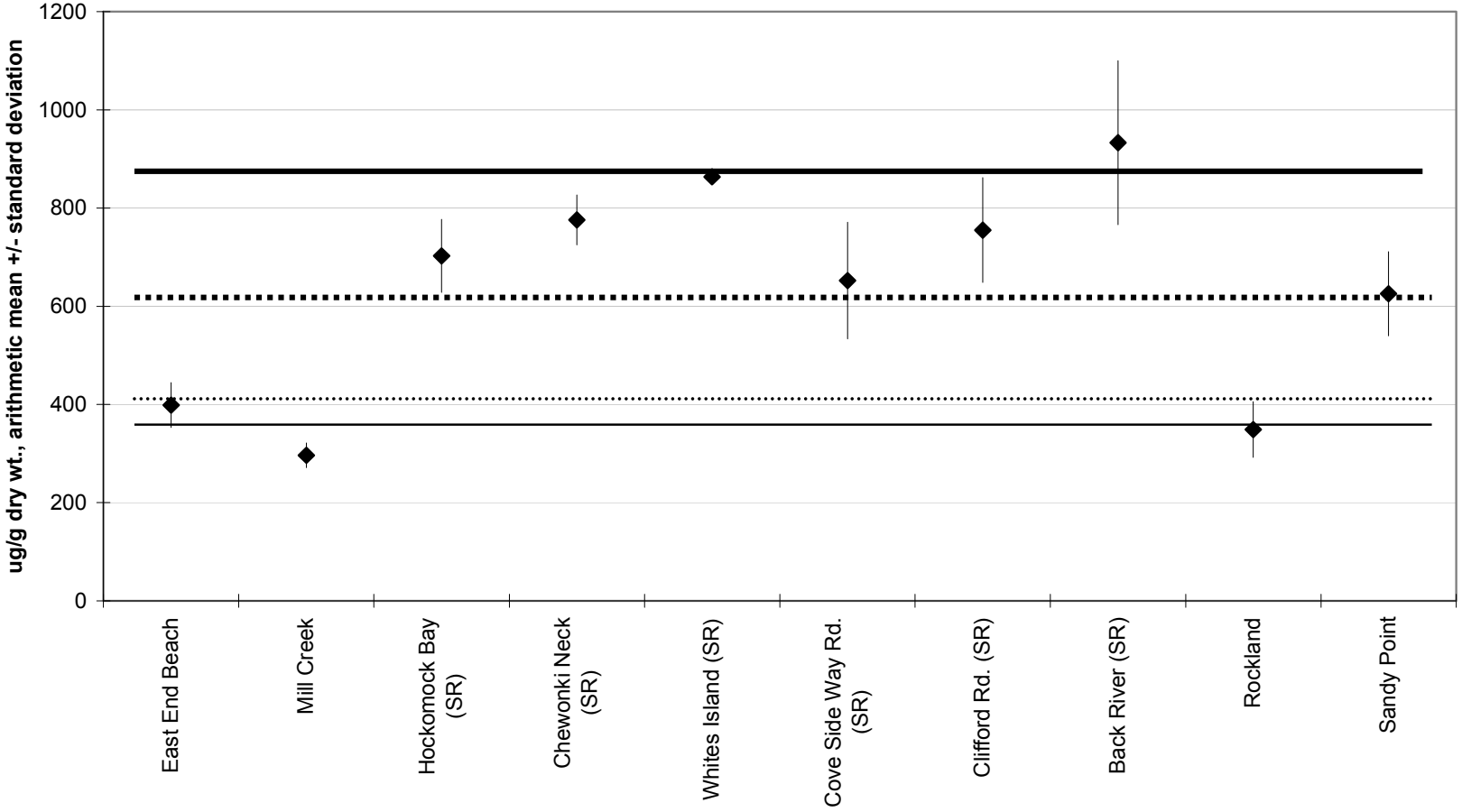
Iron was detected in all ten SWAT blue mussel sites sampled in 2011. Iron concentrations detected in mussels ranged from a low mean concentration of 297 ug/g dry wt. at Mill Creek, Falmouth, to a high mean concentration of 933 ug/g dry wt. at Back River, Boothbay, as shown in Figure 1.3.1.1.6.1. Iron concentrations at three sites were below the Gulfwatch median, East End Beach, Portland, Mill Creek, Falmouth, and Rockland, while the seven remaining sites exceeded the Gulfwatch 85th percentile. Figure 1.3.1.1.6.1 also shows a comparison of SWAT mean iron concentrations to NS&T median and 85th percentile iron concentrations. Iron concentrations at Mill Creek, Falmouth, and Rockland were below the NS&T national median, and only Back River, Boothbay, exceeded the NS&T national 85th percentile.

Aluminum concentrations detected in mussels ranged from a low mean concentration of 165 ug/g dry wt. at Mill Creek, Falmouth, to a high mean concentration of 650 ug/g dry wt. at Back River, Boothbay (Figure 1.3.1.1.6.2). Aluminum concentrations at East End Beach, Portland, Mill Creek, Falmouth, and Rockland were below the Gulfwatch median concentration, while aluminum concentrations at Hockomock Bay, Woolwich, and Chewonki Neck, Wiscasset, were between the Gulfwatch median and 85th percentile concentrations (LeBlanc, 2009). Figure 1.3.1.1.6.2 also shows a comparison of SWAT mean aluminum concentrations to NS&T median and 85th percentile concentrations. The mean aluminum concentration at Mill Creek, Falmouth, was below the NS&T median, while mean concentrations at Whites Island, Wiscasset, Cove Side Way Rd., Westport, Back River, Boothbay, and Sandy Point, Stockton Springs, exceeded the NS&T national 85th percentile.

High iron and aluminum concentrations are usually associated with the intake of high levels of suspended sediments by mussels at sampled sites, with both metals being common components of crustal rocks and coastal sediments. This correlation 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. 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.

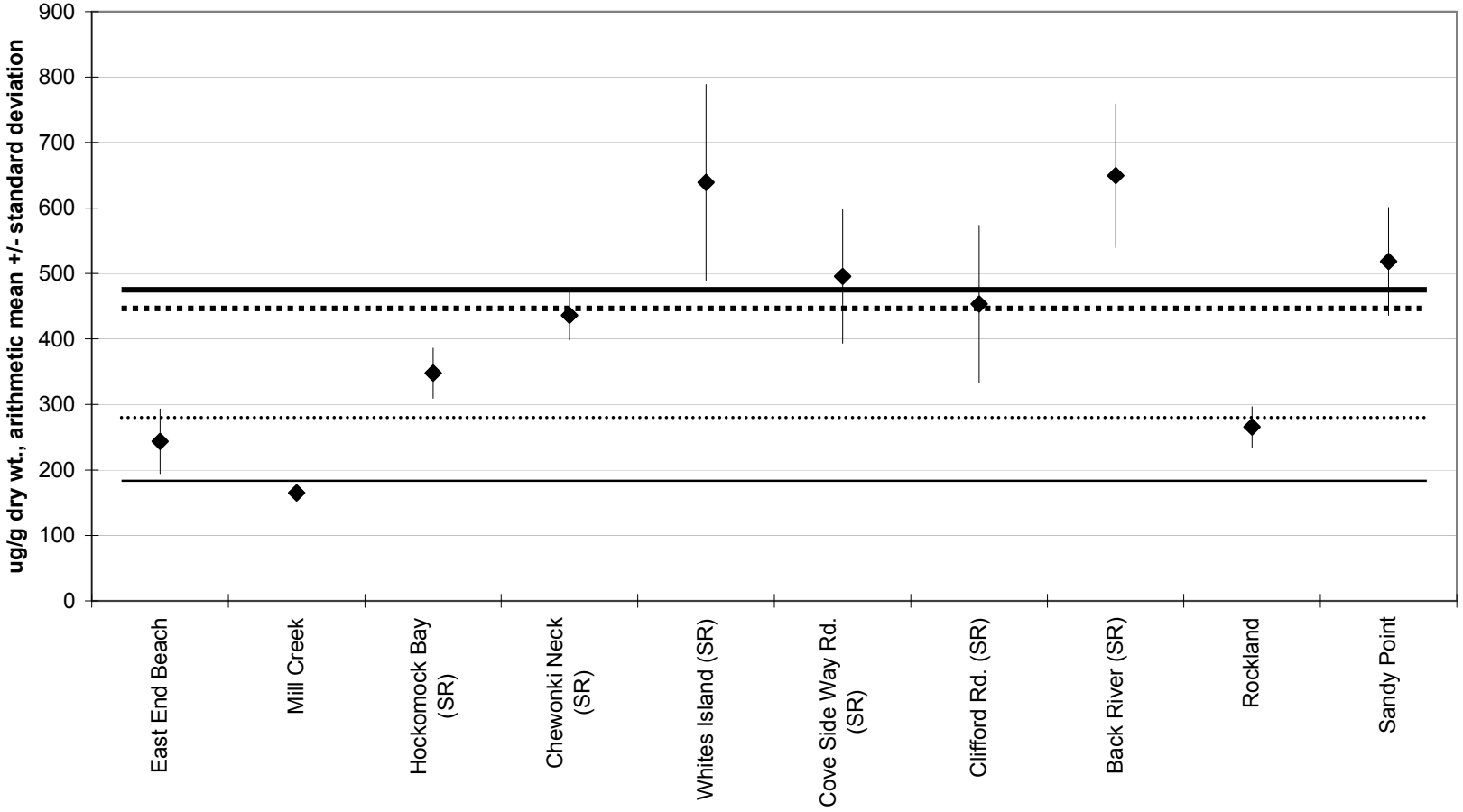
From a human health perspective, MCDC does not report FTALs for iron and aluminum.

Figure 1.3.1.1.6.1: Iron in 2011 SWAT Blue Mussels



Dotted lines = 2008 Gulfwatch Median and 85th Percentile; Solid lines = 2008 National Status and Trends Median and 85th Percentile.

Figure 1.3.1.1.6.2: Aluminum in 2011 SWAT Blue Mussels



Dotted lines = 2008 Gulfwatch Median and 85th Percentile; Solid lines = 2008 National Status and Trends Median and 85th Percentile.

1.3.1.1.7 Nickel (Ni)

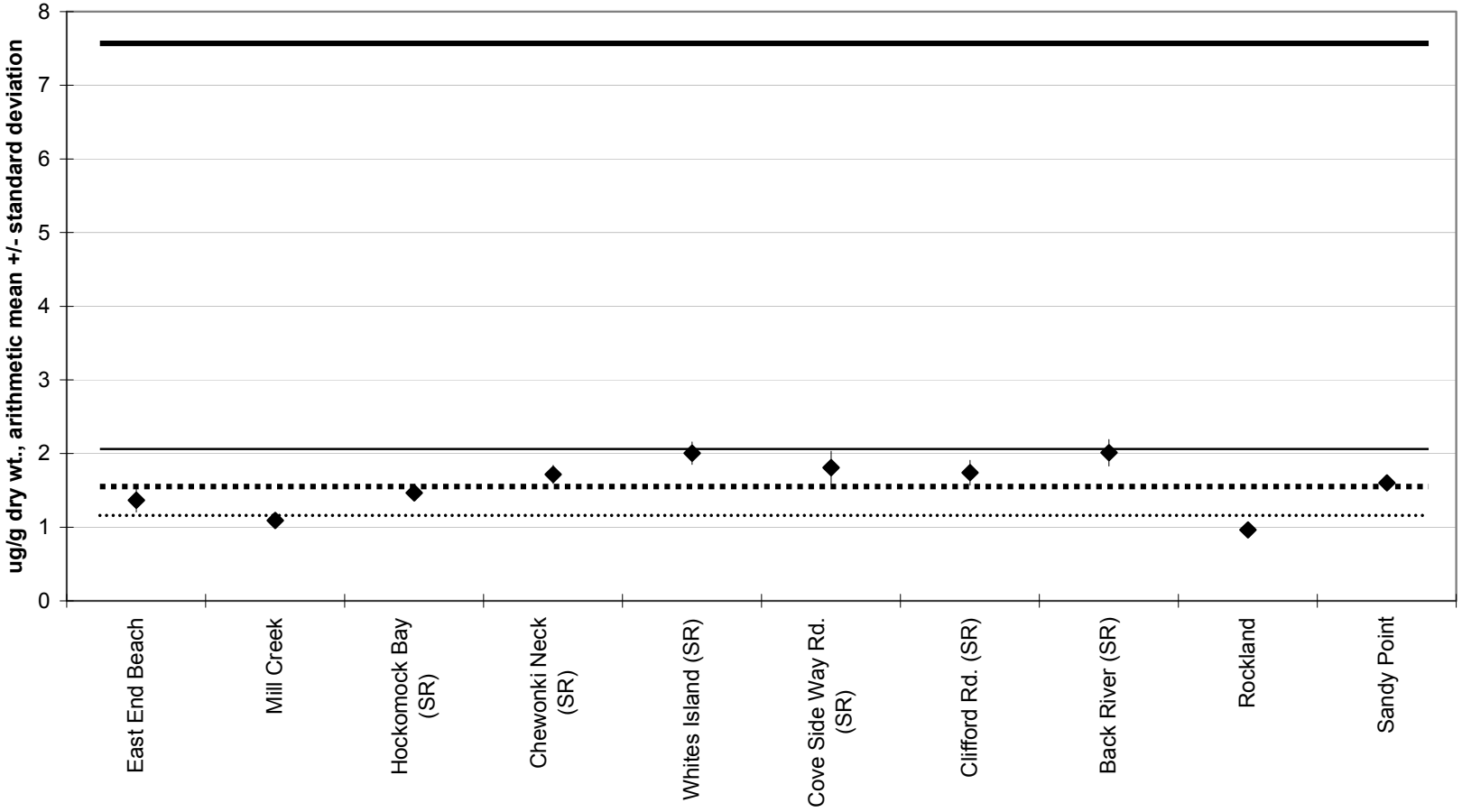
Nickel was detected at all ten SWAT blue mussel sites visited in 2011. Nickel levels detected in mussels ranged from a low mean concentration of 0.96 ug/g dry wt. at Rockland, to a high mean concentration of 2.01 ug/g dry wt. at Whites Island, Wiscasset, and Back River, Boothbay (Figure 1.3.1.1.7.1). Only Mill Creek, Falmouth, and Rockland had nickel concentrations below the Gulfwatch median, while concentrations at End Beach, Portland, and Hockomock Bay, Woolwich, fell between the Gulfwatch median and 85th percentile. The remaining six sites had nickel concentrations exceeding the Gulfwatch 85th percentile (Figure 1.3.1.1.7.1).

Figure 1.3.1.1.7.1 also compares 2011 SWAT blue mussel tissue nickel concentrations to NS&T median and 85th percentiles to place Maine data into a national context. Maine SWAT sites had nickel concentrations distributed about the national median, with only Whites Island, Wiscasset, and Back River, Boothbay, falling just below the national median. No 2011 SWAT nickel concentrations exceeded the NS&T 85th percentile, so no SWAT sites were considered to be elevated for nickel. Higher nickel concentrations are probably associated with sediment ingestion, similar to iron and aluminum concentrations.

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 2011 of 0.285 ug/g wet wt. (ppm) at Back River, Boothbay, is two orders of magnitude below the more conservative MCDC action level. MCDC does not report a cancer action level for nickel.

Figure 1.3.1.1.7.1: Nickel in 2011 SWAT Blue Mussels



Dotted line = 2008 Gulfwatch Median and 85th Percentile; Solid lines = 2008 National Status and Trends Median and 85th Percentile.

1.3.1.1.8 Lead (Pb)

Lead was detected in all ten SWAT blue mussel sites visited in 2011. Lead levels detected in mussels ranged from a low mean concentration of 1.98 ug/g dry wt. at Sandy Point, Stockton Springs, to a high mean concentration of 6.83 ug/g dry wt. at East End Beach, Portland (Figure 1.3.1.1.8.1). Only Sandy Point, Stockton Springs, had a concentration less than the Gulfwatch median, with East End Beach, Portland, Back River, Boothbay, and Rockland falling not only above the median but also above the Gulfwatch 85th percentile.

Figure 1.3.1.1.8.1 also compares 2011 SWAT blue mussel lead tissue concentrations to NS&T median and 85th percentiles to place Maine data into a national context. All ten SWAT sites exceeded the NS&T median. Six of ten SWAT sites exceeded the NS&T 85th percentile for lead (2.61 ug/g dry wt.)(2008 NS&T data, latest available), and are considered elevated based on criteria in the SWAT and Gulfwatch programs. Lead tissue concentrations from prior samples from East End Beach, Portland, Mill Creek, Falmouth, and Rockland were compared to 2011 concentrations (Figures 1.3.1.1.8.2-1.3.1.1.8.4). Lead concentrations at all three sites appear to fluctuate from year to year, which is probably due to patchiness of contamination at each site. More data will be required to demonstrate a consistent trend, but other Maine sites with elevated lead levels sampled in recent years suggest that concentrations are not increasing but have been relatively stable at sites statewide (and Gulf of Maine-wide in the Gulfwatch program).

East End Beach, Portland, is located just outside Portland Harbor and is located adjacent to the outfall of the sewage treatment plant. Another major sewage treatment facility, South Portland, discharges into Portland Harbor/Fore River nearby. Mill Creek, Falmouth, is at the head of a small bay which receives the upland runoff from a strip mall area on Route 1. Crockett Point, Rockland, is located in a busy commercial fishing port, and on a peninsula that has a history of commercial development. Due to the proximity of East End Beach and Mill Creek to coastal development, each has been chosen to be sampled more frequently to enable assessment of trends in contaminants. As a result, repeated sampling at these sites should yield a more complete picture of trends in contaminants, including lead. Some inter-annual variability is to be expected, and contaminant patchiness may also be a factor in the variation in lead levels from year to year. Rockland has been sampled more frequently in recent years to assess other contaminants which have been found in the vicinity of the site, based on mussel tissue concentrations, specifically PCBs.

Lead occurs naturally in the earth's crust, however, global lead concentrations in the environment 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 also 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).

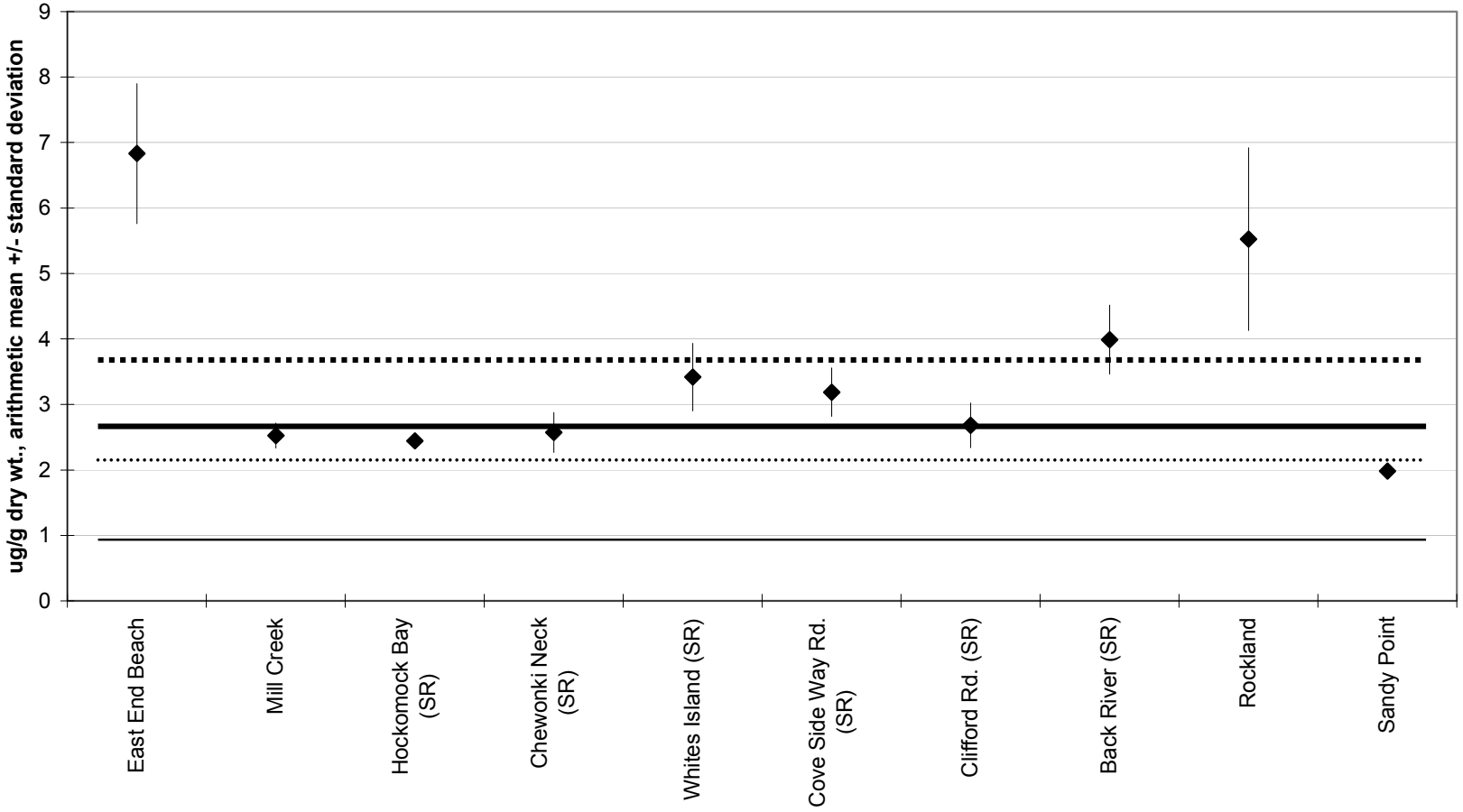
From a human health perspective, the FDA action level for lead in clams, oysters, and mussels is 1.7 ug/g wet wt. (ppm) (Kimbrough, 2008). The more conservative MCDC lead FTAL in non-commercially caught sportfish is 0.6 ug/g wet wt. (ppm), which is based on a blood lead concentration model. The highest mean concentration in the 2011 Maine SWAT data, 1.05 ppm (ug/g) wet wt. at Crockett Point, Rockland, exceeds the MCDC lead FTAL, as does East End Beach, Portland (0.91 ug/g wet wt.). The remaining eight sites sampled in 2011 did not exceed the MCDC FTAL for lead.

Review of the 2007-11 SWAT blue mussel sampling data from 55 sites indicates that mean lead concentrations at seven sites equaled or exceeded the MCDC lead FTAL. Sites sampled in those years equaling or exceeding the MCDC FTAL for lead are:

Spring Point, S. Portland, 2007	0.6 ppm wet wt.
Spring Point, S. Portland, 2010	0.7 ppm wet wt.
Middle Fore R., Portland, 2007	0.6 ppm wet wt.
East End Beach, Portland, 2007	0.8 ppm wet wt.
East End Beach, Portland, 2009	0.8 ppm wet wt.
East End Beach, Portland, 2011	0.9 ppm wet wt.
Crockett Point, Rockland, 2007	1.1 ppm wet wt.
Crockett Point, Rockland, 2010	1.3 ppm wet wt.
Crockett Point, Rockland, 2011	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.

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 SWAT program.

Figure 1.3.1.1.8.1: Lead in 2011 SWAT Blue Mussels



Dotted lines = 2008 Gulfwatch Median and 85th Percentile; Solid lines = 2008 National Status and Trends Median and 85th Percentile.

Figure 1.3.1.1.8.2: Lead Trend in SWAT Blue Mussels - East End Beach, Portland

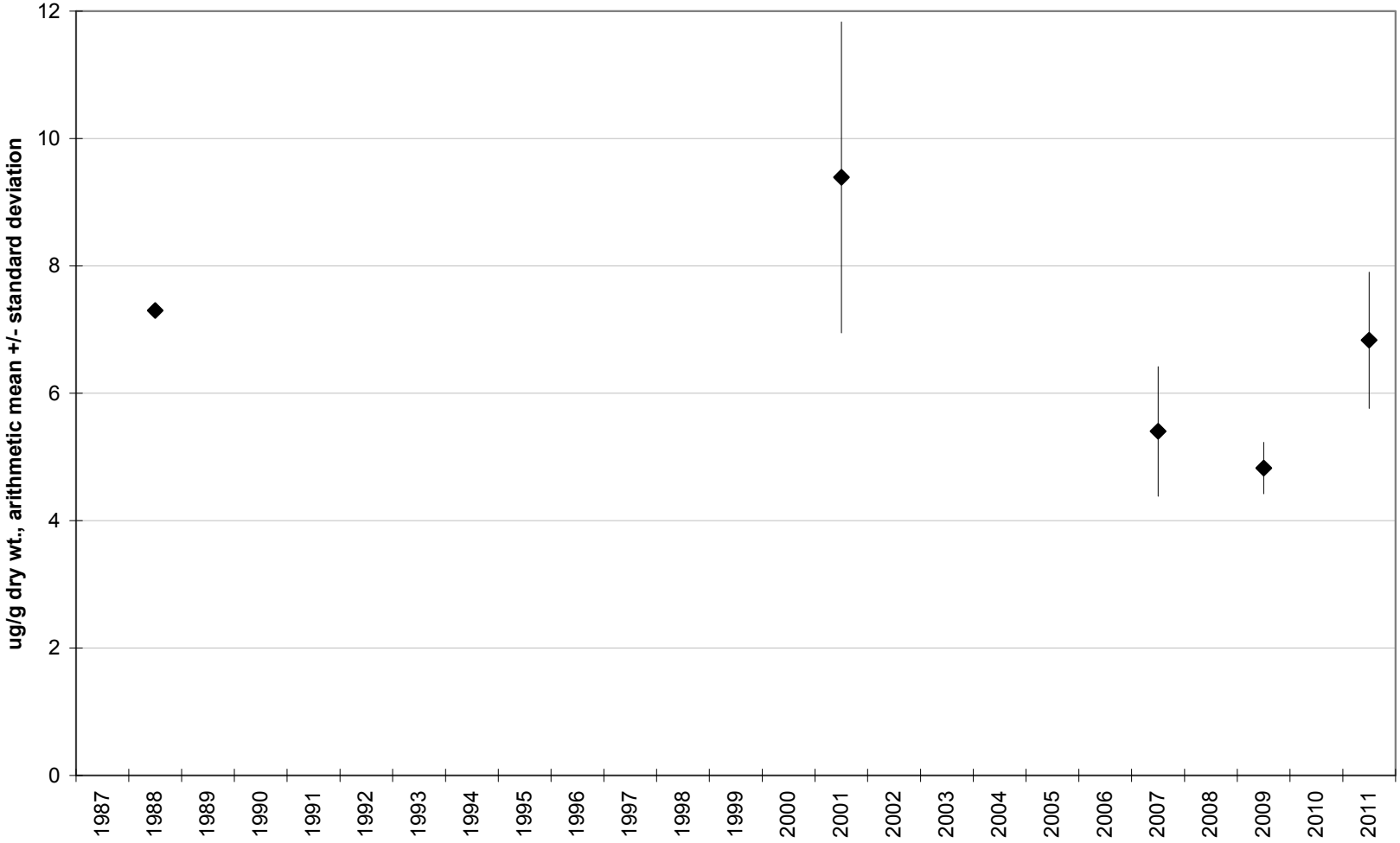


Figure 1.3.1.1.8.3: Lead Trend in SWAT Blue Mussels - Mill Creek, Falmouth

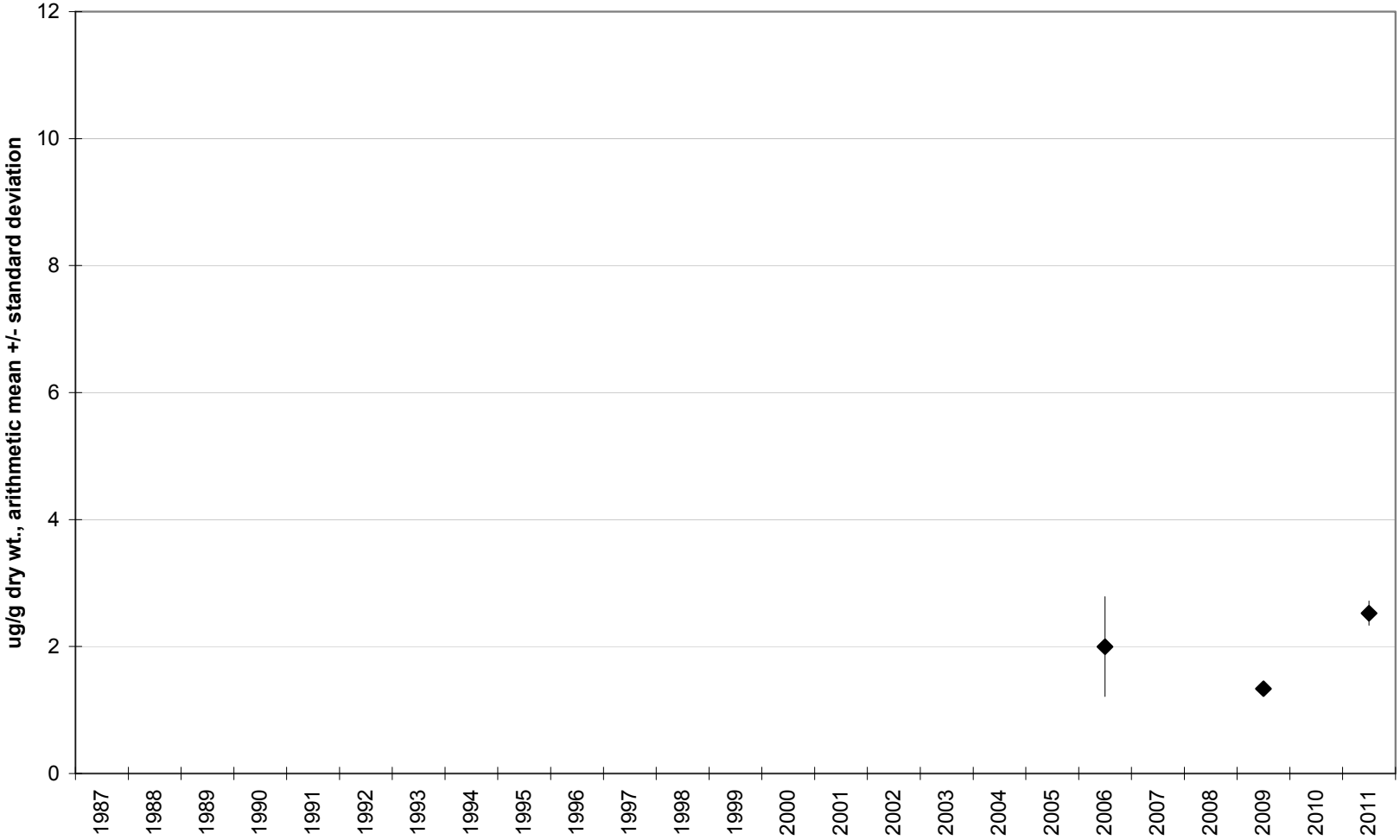
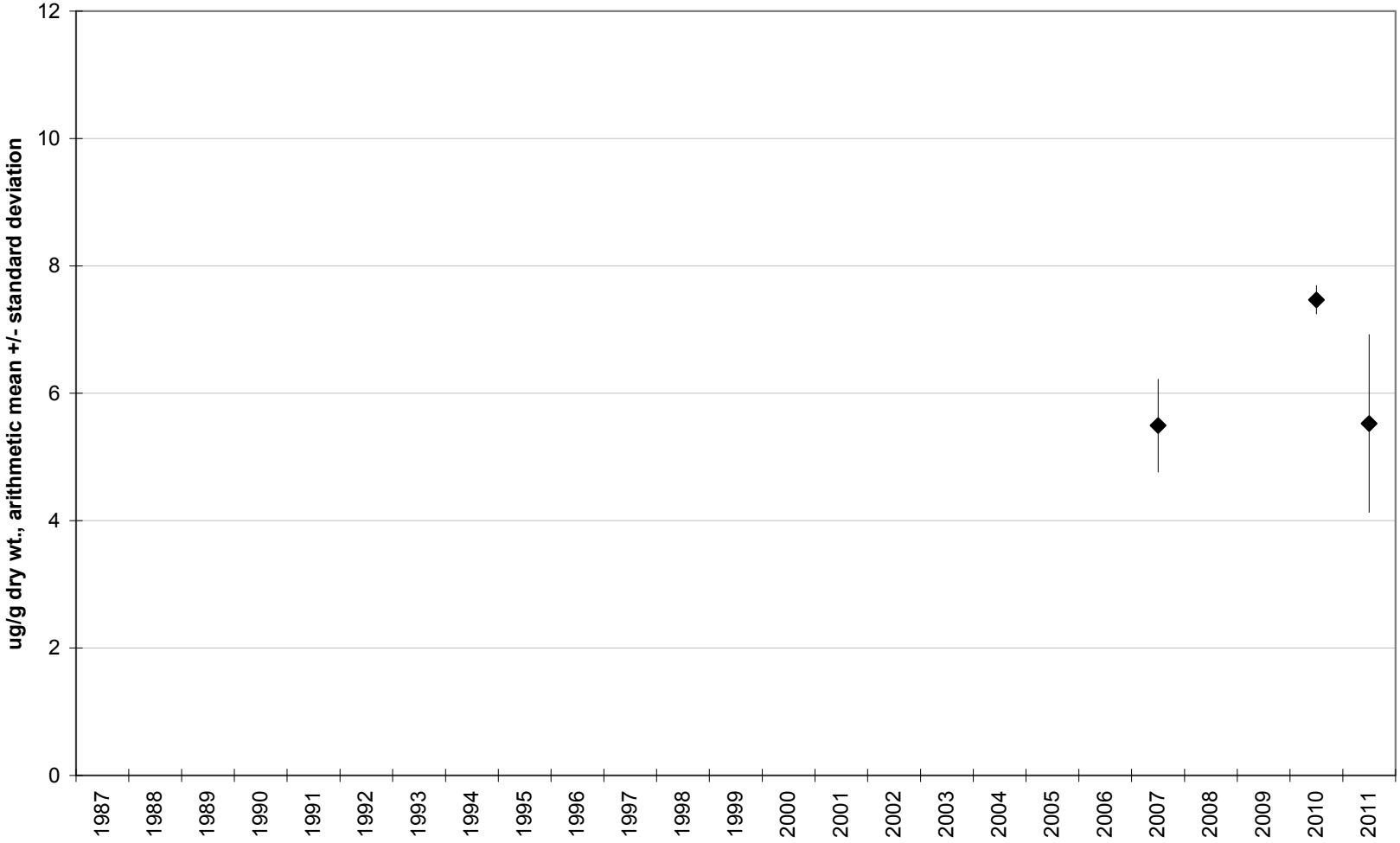


Figure 1.3.1.1.8.4: Lead Trend in SWAT Blue Mussels - Rockland



1.3.1.1.9 Mercury (Hg)

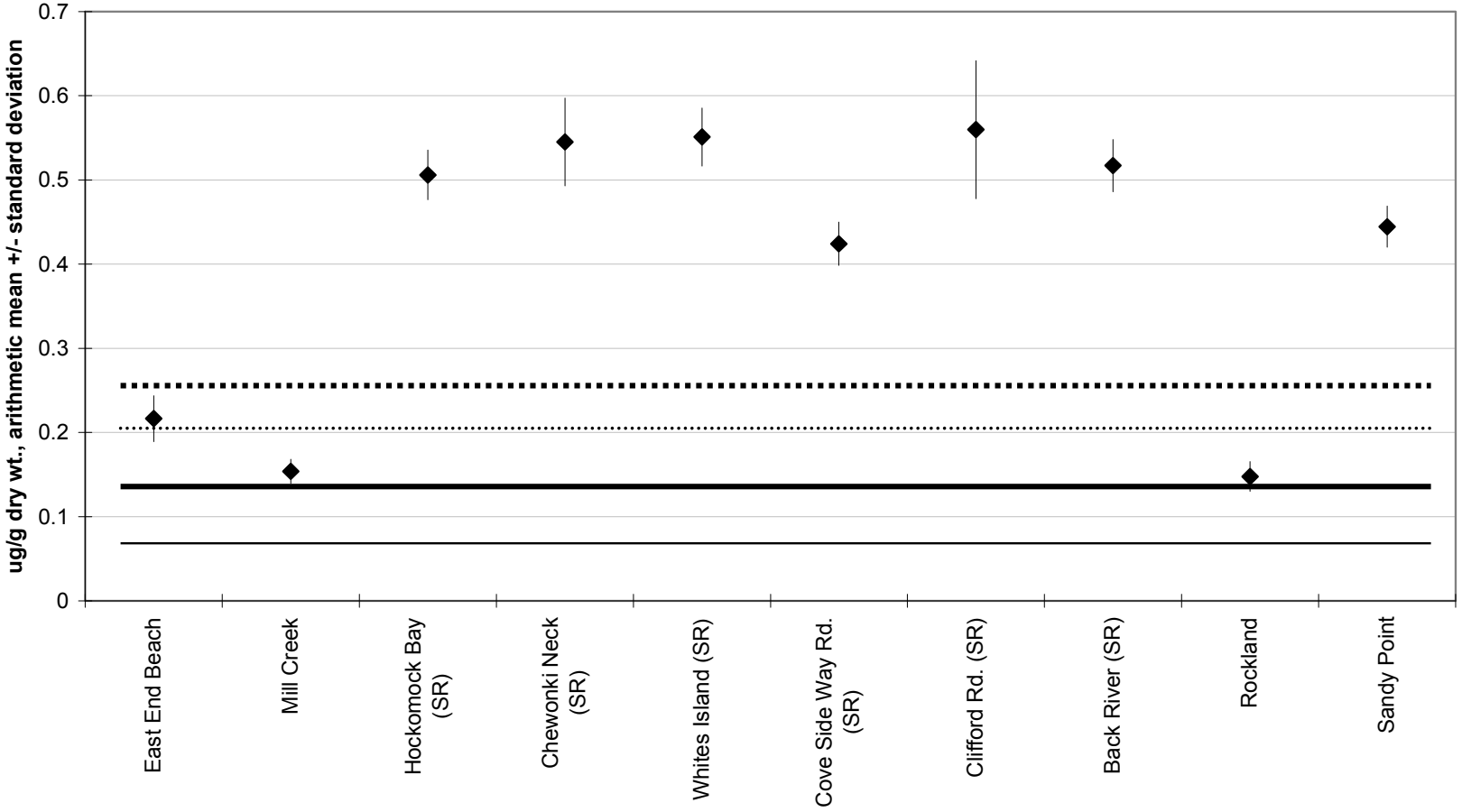
Mercury was detected in all ten blue mussel sample locations visited in 2011. Mercury levels detected in mussels ranged from a low mean concentration of 0.15 µg/g dry wt. at Rockland, to a high mean concentration of 0.56 µg/g dry wt. at Clifford Road, Edgecomb (Figure 1.3.1.1.9.1). Only mercury concentrations at Mill Creek, Falmouth, and Rockland did not exceed the 2008 Gulfwatch median, while East End Beach, Portland, fell between the Gulfwatch median and 85th percentile concentrations. The remaining seven sites all exceeded the Gulfwatch 85th percentile, which were all located in the Sheepscot/Back (six sites) and Penobscot Rivers (one site).1

Figure 1.3.1.1.9.1 also compares 2011 SWAT blue mussel mercury concentrations to NS&T Mussel Watch median and 85th percentile values. The reader should note that Gulfwatch median and 85th percentile values actually exceed NS&T Mussel Watch median and 85th 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 Midwest US. Based on the Gulfwatch and SWAT criteria of "elevated" contaminants being those above the NS&T 85th percentile, all the SWAT sites tested in 2011 would be considered elevated for mercury despite their more typical scores when compared to other northeast US samples from the Gulf of Maine.

Six blue mussel sites sampled in 2011 were within the Sheepscot River estuary, a follow up to eight stations sampled in the same vicinity in 2009. The more intensive sampling in the Sheepscot was initiated subsequent to the detection of higher mercury concentrations in blue mussel tissue in the Wiscasset area in 2008. The follow up stations sampled in 2011 also showed higher mercury concentrations, similar to those detected in 2009, but at additional locations within the Sheepscot estuary. Figure 1.3.1.1.9.2 shows the 2009 and 2011 Sheepscot estuary mercury concentrations in blue mussel tissue in contrast to mercury concentrations from blue mussel tissue from a wide range of sites along the Maine coast sampled from 2007-11. Tissue mercury concentrations in the Sheepscot range from 0.35 to 0.56 ug/g dry wt., with the lowest tissue concentration found at the most southerly site, Whittum Island (2009). Tissue concentrations with the exception of Whittum Island fell between 0.4 to 0.6 ug/g dry wt. Figure 1.3.1.1.9.2 shows that most Maine blue mussel tissue mercury concentrations fall below 0.3 ug/g dry wt., with a few sites having concentrations above 0.3, including the Piscataqua River and Penobscot River (Sandy Point), sites with a documented industrial history.

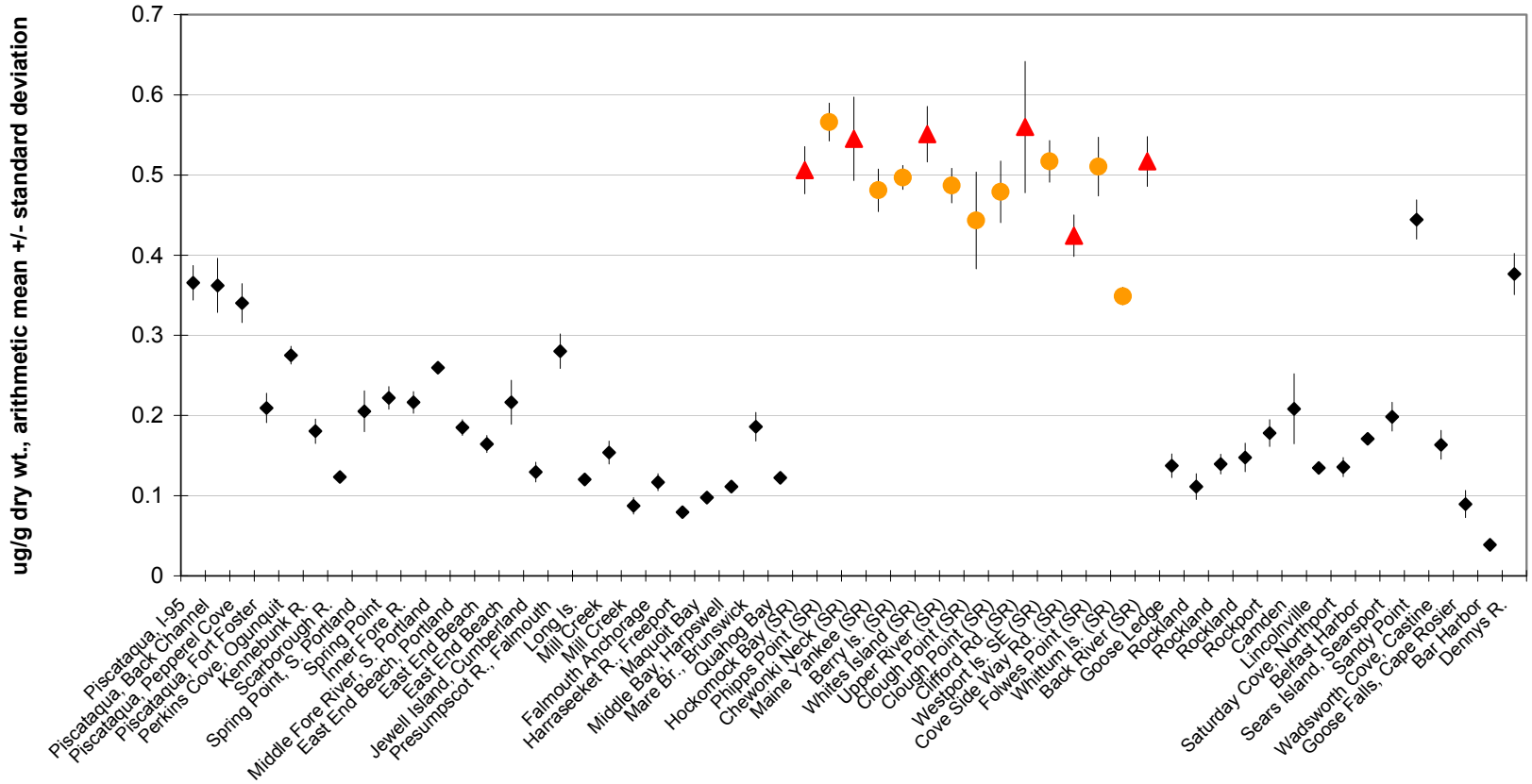
Figure 1.3.1.1.9.3 shows that the lowest concentration found in the Sheepscot, 0.35 ug/g dry wt. at Whittum Island, is the most southerly site shown on the map. In 2009, a control site outside the Sheepscot, just to the east in the Damariscotta River estuary at Goose Ledge, revealed mean mussel tissue concentration of 0.14 ug/g dry wt (Figure 1.3.1.1.9.3). The location of the Mason Station, an historic coal (and subsequently oil) fired electrical power generation station, is also shown.

Figure 1.3.1.1.9.1: Mercury in 2011 SWAT Blue Mussels



Dotted lines = 2008 Gulfwatch Median and 85th Percentile; Solid lines = 2008 National Status and Trends Median and 85th Percentile.

Figure 1.3.1.1.9.2: Mercury in SWAT Blue Mussel Tissue Across the Maine Coast and Sheepscot River Estuary



55 Stations 2007-11 - West to East;
Triangles = 2011 Sheepscot Estuary Sample Points
Circles = 2009 Sheepscot Estuary Sample Points

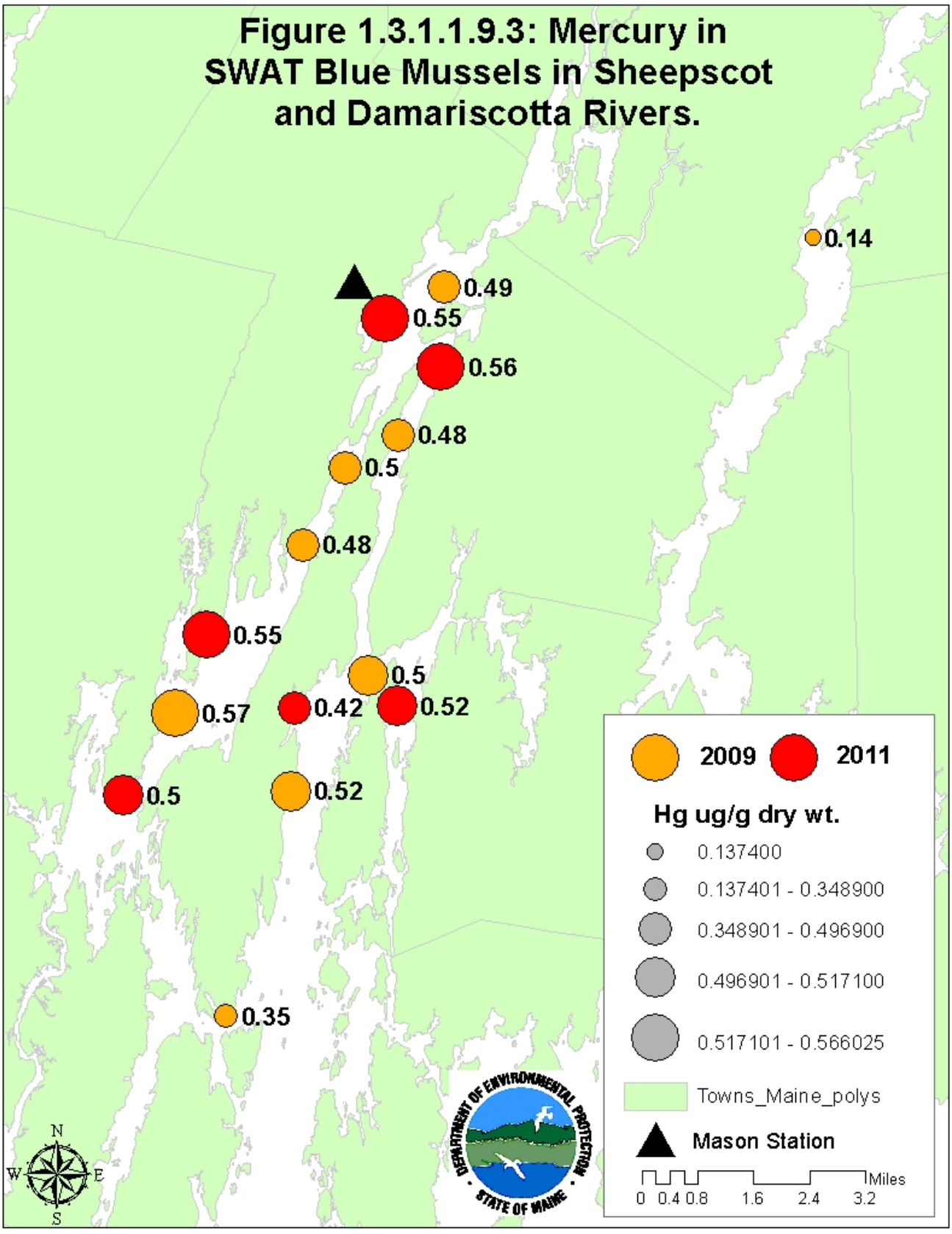


Figure 1.3.1.1.9.3: Mercury in SWAT Blue Mussels in Sheepscot and Damariscotta Rivers.
0.14
0.49
0.55
0.56
0.48
0.5
0.48
0.55
0.5
0.57
0.42
0.52
0.5
0.52
0.35
2009
2011
Hg ug/g dry wt.
0.137400
0.137401 - 0.348900
0.348901 - 0.496900
0.496901 - 0.517100
0.517101 - 0.566025
Towns_Maine_polys
Mason Station
Miles
0 0.4 0.8 1.6 2.4 3.2
N
W
E
S
DEPARTMENT OF ENVIRONMENTAL PROTECTION
STATE OF MAINE

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).

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 alone. The highest mean blue mussel total tissue mercury concentration measured in Maine in 2011 was 0.073 µg/g wet wt. (ppm) at Back River, Boothbay, in the Sheepscot Estuary. 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 by the SWAT program.

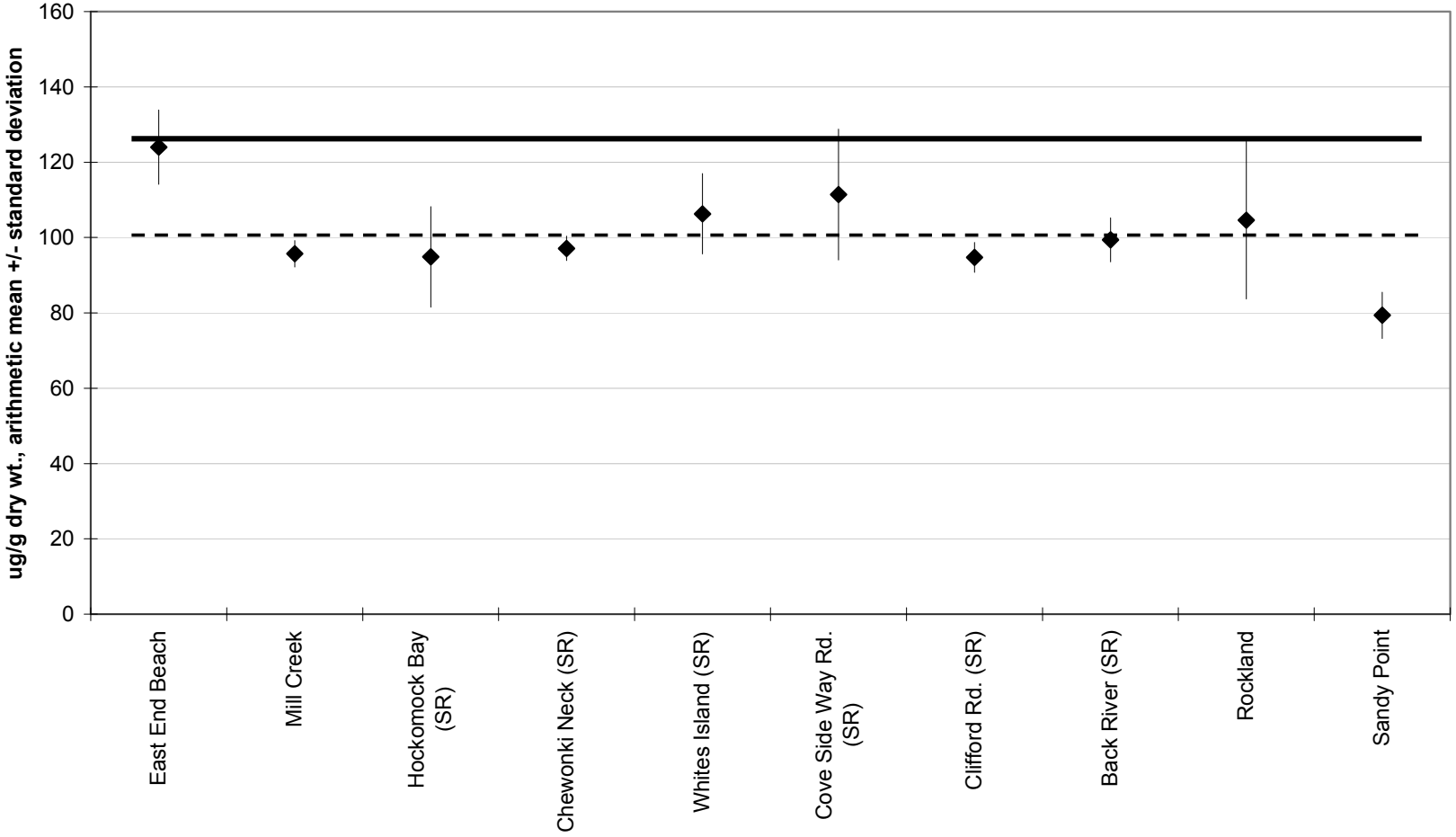
1.3.1.1.10 Zinc (Zn)

Zinc was detected in all ten sample locations visited in 2011. Zinc levels detected in mussels ranged from a low mean concentration of 79.4 ug/g dry wt. at Sandy Point, Stockton Springs, to a high mean concentration of 124.0 ug/g dry wt. at East End Beach, Portland (Figure 1.3.1.1.10.1). The SWAT blue mussel tissue zinc concentrations fell around the 2008 Gulfwatch median, with only East End Beach, Portland, coming close to the Gulfwatch 85th percentile.

Figure 1.3.1.1.10.2 shows 2011 Maine SWAT blue mussel zinc concentrations were all below the NS&T Mussel Watch median, and so it follows that all SWAT concentrations also fell below the NS&T 85th percentile.

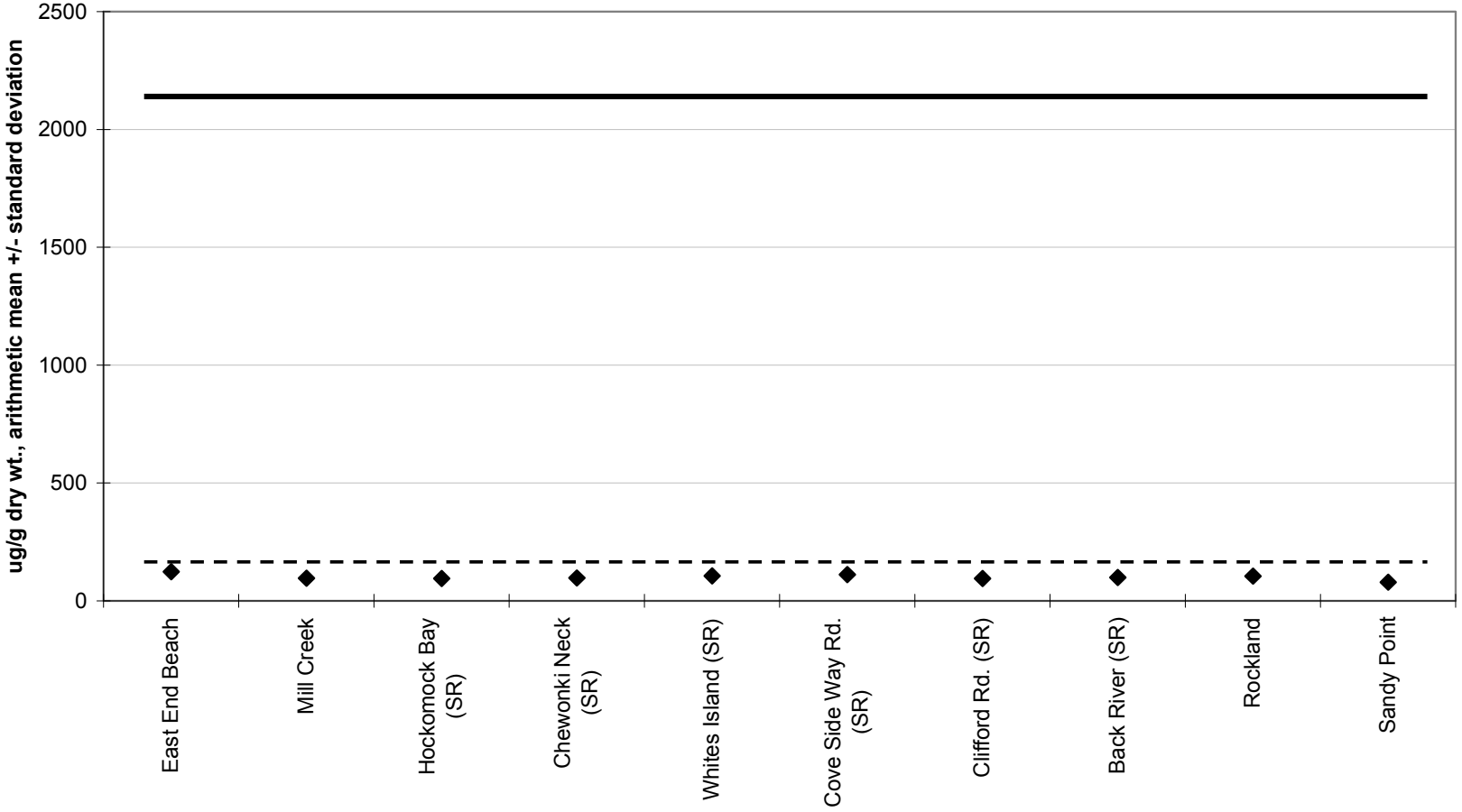
Zinc is widespread in its distribution but elevated levels primarily originate from a variety of human activities including vehicle tire wear, electroplating and galvanized metals, industrial wastes, and drainage from mining (Kimbrough, 2008). Though an essential nutrient at low levels, higher doses 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 much 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 1.3.1.1.10.1: Zinc in 2011 SWAT Blue Mussels



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

Figure 1.3.1.1.10.2: Zinc in 2011 SWAT Blue Mussels



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

1.3.1.2 Softshell Clams

One softshell clam site was sampled in 2011: Fort Point Cove, Stockton Springs. Fort Point Cove was re-sampled in 2011 to follow up on previous toxics sampling completed there in 2005. Results from the 2011 Fort Point Cove softshell clam sampling are compared to previous results from same site and to samples previously collected from seven other clam sites. Softshell clam tissue samples collected in 2010 and 2011 were analyzed by Battelle Marine Sciences Laboratory, Sequim, WA. Clam tissues from 2004-05 were analyzed by Pace Analytical Services, Minneapolis, MN. For purposes of this report, data was compared directly between the two labs. The samples were analyzed for 11 metals: Silver (Ag), aluminum (Al), arsenic (Ar), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), mercury (Hg), nickel (Ni), and zinc (Zn). Results were compared to Gulf of Maine (Gulfwatch, see LeBlanc, 2009) softshell clam data to place Maine SWAT data set in a regional context.

1.3.1.2.1 Silver (Ag)

Silver was detected in all eight sample locations visited. Silver detected in clams ranged from a low mean concentration of 0.13 ug/g dry wt. at Harris Cove, Eastport, to a high mean concentration of 2.08 ug/g dry wt. at Mast Cove, Eliot (Figure 1.3.1.2.1.1). Silver mean concentrations in SWAT softshell clams were also compared to the Gulfwatch median concentration for four sites sampled in 2008 (two in Maine and two in New Hampshire). The mean concentration at Mast Cove, Eliot, exceeded the Gulfwatch median (1.32 ug/g dry wt.). The silver concentration in clam tissue in Fort Point Cove appeared to be slightly higher in 2011 than in 2005, which may be an artifact of intra-site spatial variability or year to year variability.

Higher silver concentrations in water and sediments coincide with municipal sewage discharge (Sanudo-Wilhelmy and Flegal, 1992; Buchholtz ten Brink et al., 1997). Silver concentrations in Maine softshell clams appear to be relatively low. The highest Gulfwatch values, which came from the two NH sites, were just over 2 ug/g dry wt. which is very similar to the Mast Cove, Eliot, SWAT site tissue concentration. The increasing use of silver, including nanosilver, in products such as clothing, paints, and caulks, 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 non-commercially caught fish. The highest SWAT softshell clam tissue mean silver concentration, when expressed on a wet weight basis, is 0.32 ug/g wet wt. at Mast Cove, Eliot. This concentration is over an order of magnitude below the 11 ug/g wet wt. FTAL, assuming the same meal size is applied.

1.3.1.2.2 Arsenic (As)

Arsenic was detected at Fort Point Cove, Stockton Springs (2011), and at Morse Cove, Castine (2010), which were the only softshell clam sites where tissue was tested for arsenic. The mean arsenic concentration in Fort Point Cove (2011) clams was 13.34 ug/g dry wt. and the mean arsenic concentration in Morse Cove (2010) clams was 9.97 ug/g dry wt. While Gulfwatch does not monitor arsenic in blue mussels or softshell clams in

the Gulf of Maine, arsenic in mussels and oysters is 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). The mean arsenic concentration in softshell clams at Morse Cove fell into this range, while the mean arsenic concentration at Fort Point Cove fell into the lower end of the middle range of NS&T arsenic concentrations (Kimbrough, 2008). The NS&T ranges are based on mussels/oysters. However, it is of interest to give a point of comparison for Maine clam data.

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, are 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 softshell clam data were transformed to inorganic arsenic by dividing wet weight concentrations by a factor of 10. Therefore, the Fort Point Cove (2011) clam inorganic arsenic mean concentration is estimated to be 0.22 ug/g wet wt., which exceeds the MCDC cancer FTAL of 0.014 ugg/g wet wt. (ppm). The Morse Cove (2010) clam inorganic arsenic mean concentration is estimated to be 0.16 ug/g wet wt., which exceeds the MCDC cancer FTAL of 0.014 ug/g wet wt. (ppm). Note that all blue mussel sites sampled since arsenic data has been recorded as part of the SWAT program also exceed the MCDC cancer FTAL. The Fort Point Cove and Morse Cove estimated mean inorganic arsenic concentrations do not exceed the MCDC non-cancer action level of 0.6 ug/g wet wt. (ppm) for inorganic arsenic. MCDC non-commercially caught finfish FTALs applied here assume an 8 oz. meal eaten by the consumer on a weekly basis.

1.3.1.2.3 Cadmium (Cd)

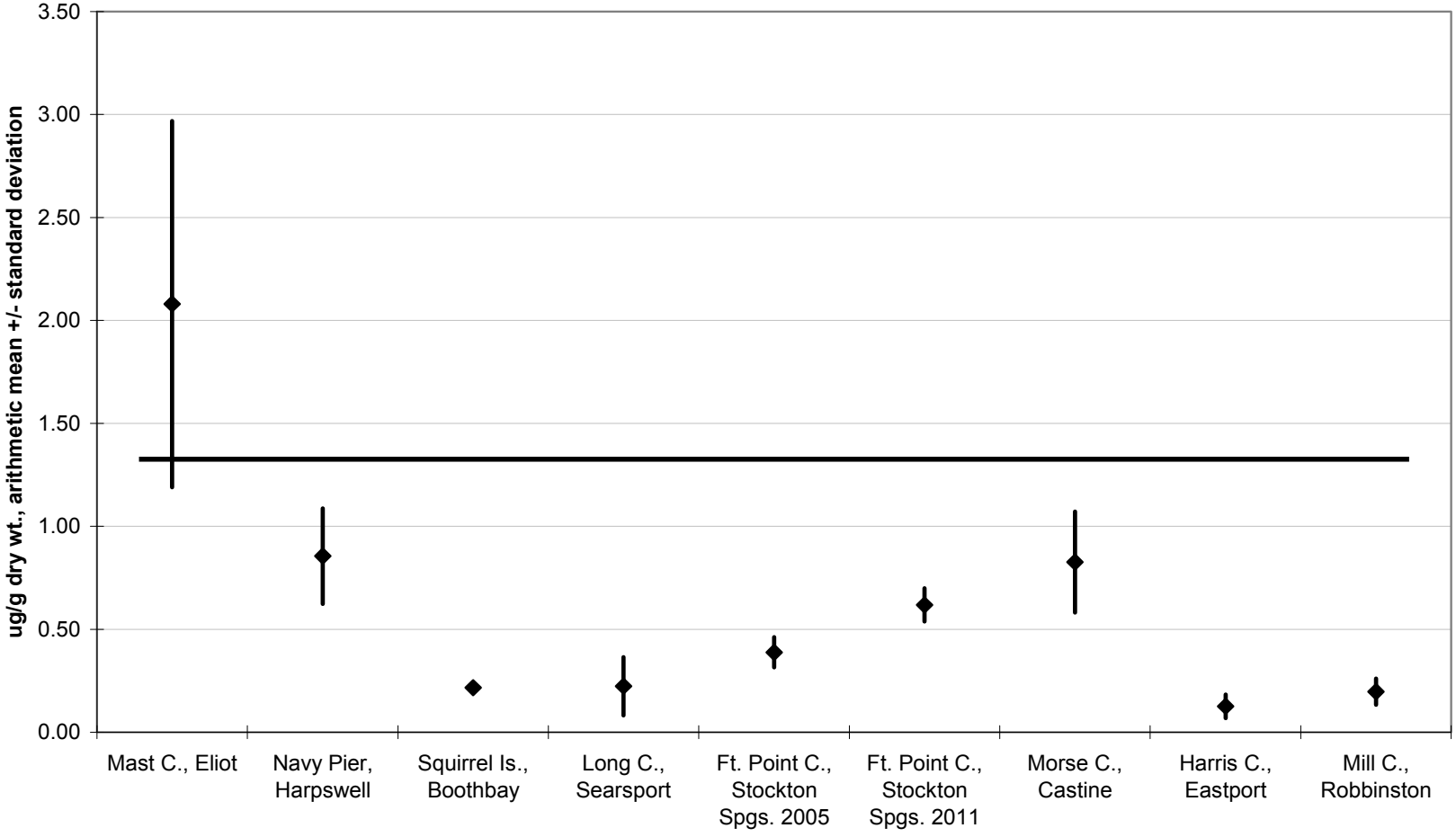
Cadmium was detected in tissue from all eight clam locations visited. Cadmium levels detected in softshell clams ranged from a low mean concentration of 0.31 ug/g dry wt. at Squirrel Island, Southport, to a high mean concentration of 0.77 ug/g dry wt. at Mill Cove, Robbinston (Figure 1.3.1.2.3.1). Only Mill Cove, Robbinston, and Navy Pier, Harpswell, approached the 2008 Gulfwatch median, with all eight sites falling below that median. Fort Point Cove cadmium concentrations appeared to be slightly lower in the 2011 clam tissues than the previously sampled 2005 tissues.

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).

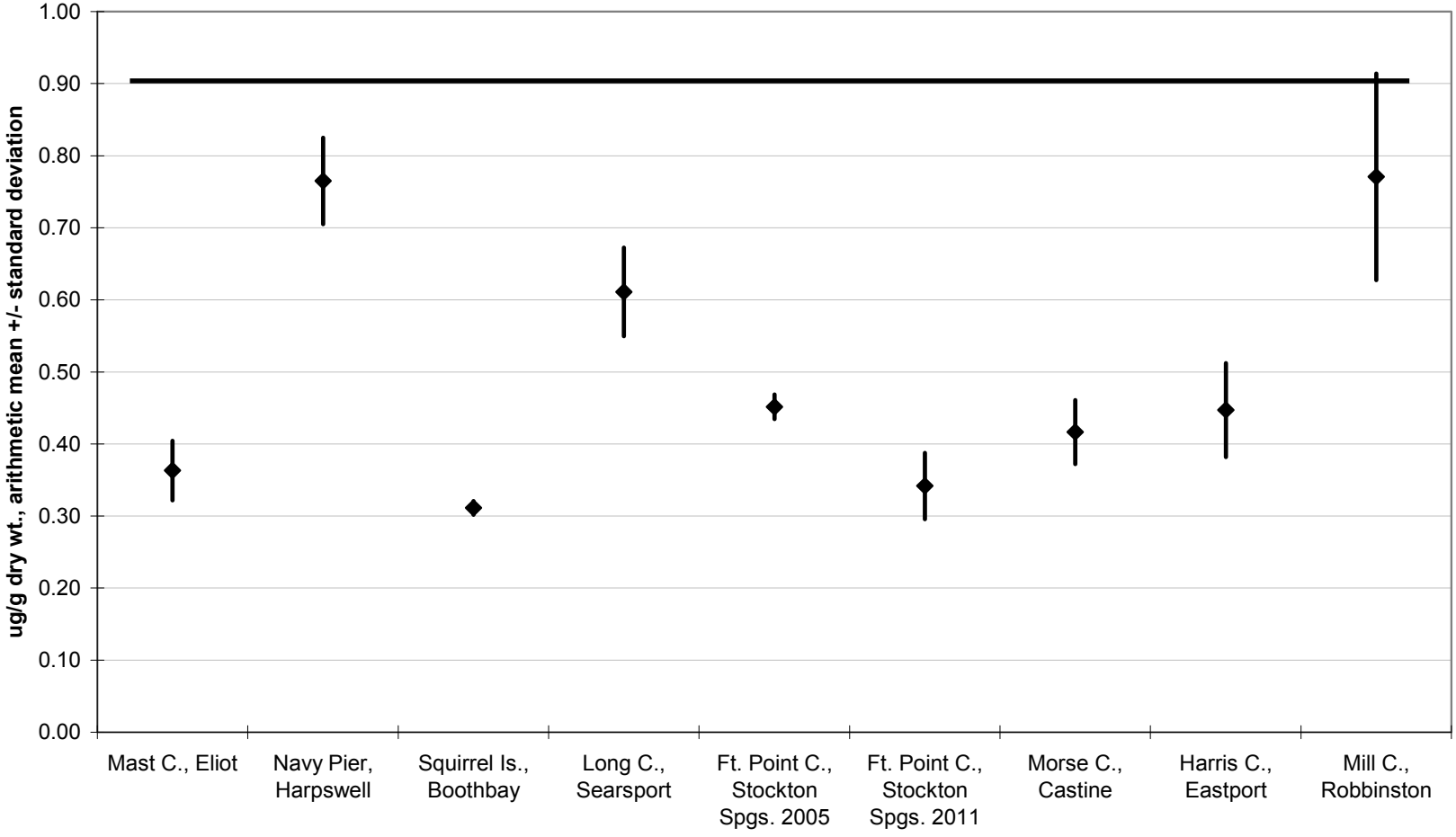
From a human health perspective, the MCDC non-cancer FTAL for cadmium in non-commercially caught finfish is 2.2 ug/g wet wt. The FDA action level for clams, oysters, and mussels is 4 ppm wet wt. (Kimbrough, 2008). The highest scoring SWAT clam site, Mill Cove, Robbinston, had a mean cadmium concentration of 0.088 ug/g wet wt., which was well below the MCDC and FDA action levels (4% of the more conservative MCDC non-cancer FTAL).

Figure 1.3.1.2.1.1: Silver in SWAT Softshell Clams



Solid line = Gulfwatch 2008 Mean (four Softshell Clam Sites in NH, ME)

Figure 1.3.1.2.3.1: Cadmium in SWAT Softshell Clams



Solid line = Gulfwatch 2008 Mean (four Softshell Clam Sites in NH, ME)

1.3.1.2.4 Chromium (Cr)

Chromium was detected at all eight sites sampled. Chromium levels detected in clam tissue ranged from a low mean concentration of 3.67 ug/g dry wt. at Long Cove, Searsport, to a high mean concentration of 13.32 ug/g dry wt. at Mast Cove, Eliot (Figure 1.3.1.2.4.1). Figure 1.3.1.2.4.1 depicts SWAT softshell clam chromium concentrations compared to the Gulfwatch 2008 median concentration for four sites (two each in ME and NH). All clam sites but one, Long Cove, Searsport, fell above the Gulfwatch 2008 median. The Fort Point Cove, Stockton Springs, clam tissue chromium concentration was essentially the same as the Gulfwatch 2008 median, while chromium concentrations appeared to be slightly lower in Fort Point Cove samples in 2011, falling below the Gulfwatch 2008 median..

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 (Kimbrough, 2008).

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.

1.3.1.2.5 Copper (Cu)

Copper was detected in samples taken at all eight SWAT softshell clam sites visited. Copper levels detected in clam tissue ranged from a low mean concentration of 7.31 ug/g dry wt. at Long Cove, Searsport, to a high mean concentration of 13.07 ug/g dry wt. at Mast Cove, Eliot (Figure 1.3.1.2.5.1). Copper concentrations in clam tissue at all eight sites fell below the 2008 Gulfwatch median (LeBlanc, 2009). The copper concentration at Fort Point Cove appears to have increased slightly in the 2011 clams compared to the 2005 clams.

Copper occurs naturally and is ubiquitous throughout 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 subsequent to being phased out by EPA regulations, 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, and asbestos removal from brake pads has been offset by increased copper usage in brake pads (Kimbrough, 2008).

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.

Figure 1.3.1.2.4.1: Chromium in SWAT Softshell Clams

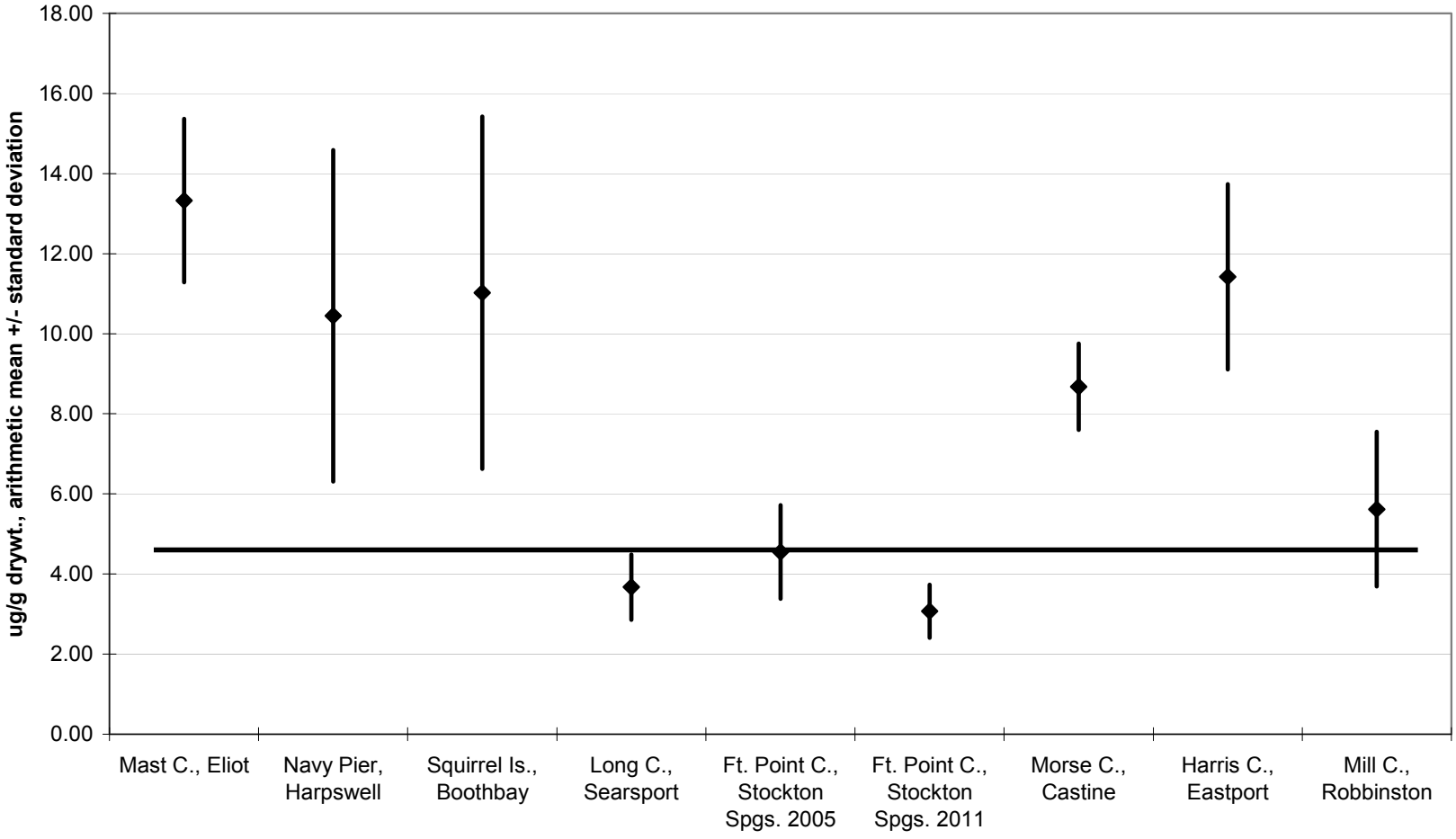
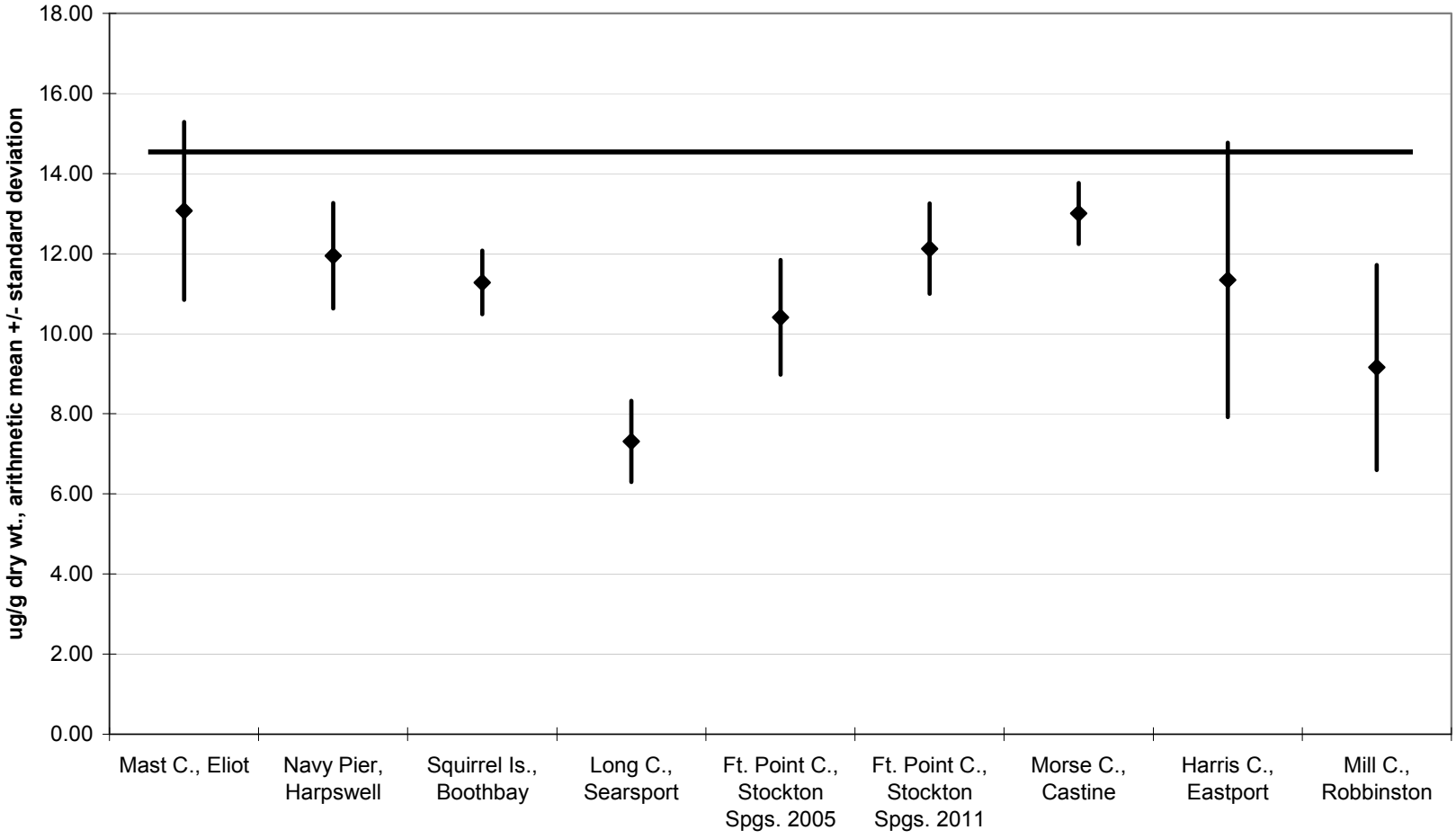


Figure 1.3.1.2.5.1: Copper in SWAT Softshell Clams



1.3.1.2.6 Iron (Fe) and Aluminum (Al)

Iron was detected in all eight SWAT softshell clam sites. Iron concentrations detected in clam tissue ranged from a low mean concentration of 1,370 ug/g dry wt. at Squirrel Island, Boothbay, to a high mean concentration of 4,712 ug/g dry wt. at Mast Cove, Eliot as shown in Figure 1.3.1.2.6.1. No SWAT sites had clam tissue iron concentrations that exceeded the 2008 Gulfwatch median (Figure 1.3.1.2.6.1). Iron concentrations in Fort Point Cove clams in 2011 appeared to be similar or slightly lower than in 2005.

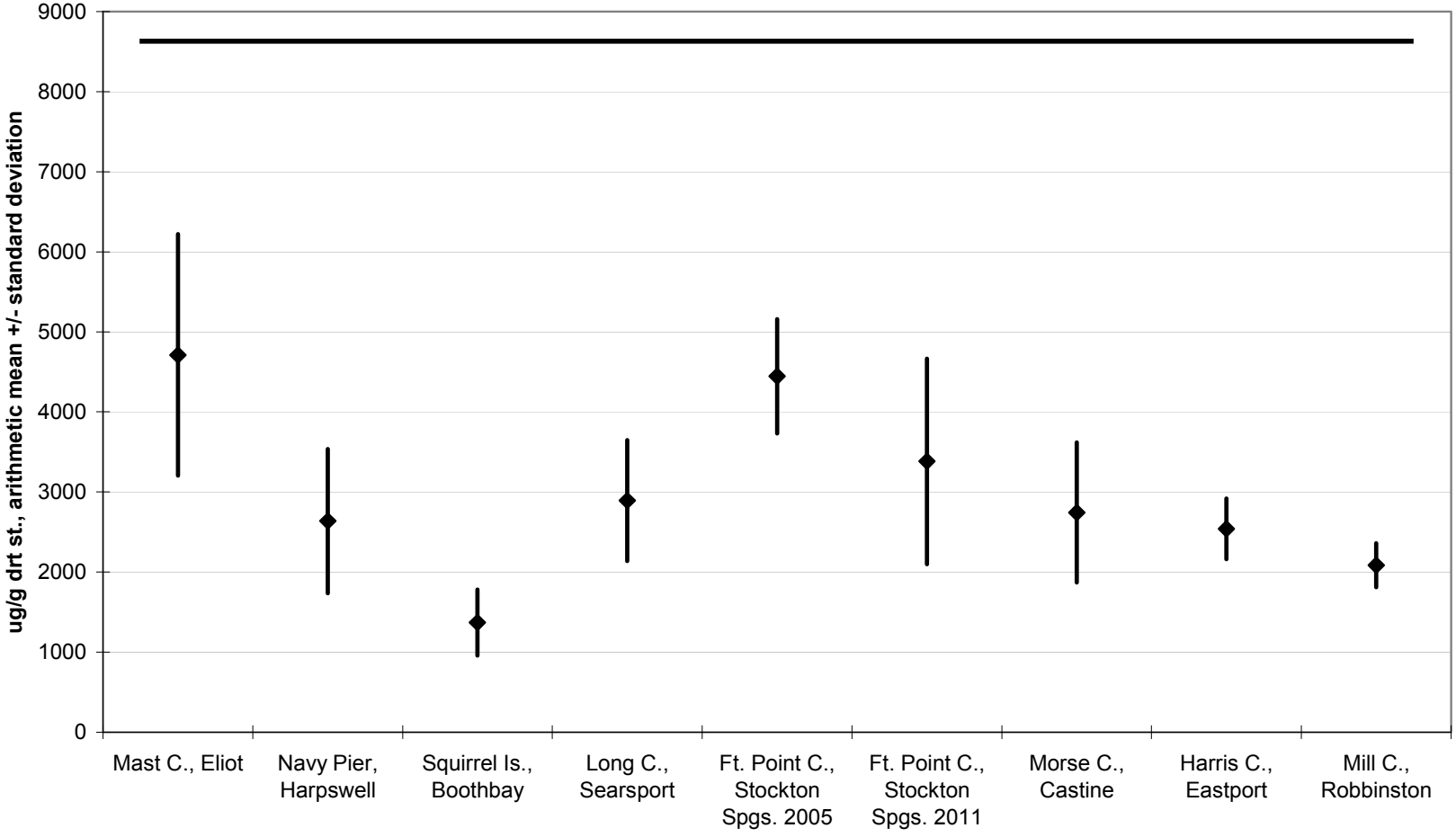
Aluminum concentrations detected in clams ranged from a low mean concentration of 563 ug/g dry wt. at Squirrel Island, Boothbay, to a high mean concentration of 1,623 ug/g dry wt. at Morse Cove, Castine (Figure 1.3.1.2.6.2). None of the clam tissue from the eight sites had aluminum concentrations exceeding the 2008 Gulfwatch mean concentration. Aluminum concentrations in Fort Point Cove clams in 2011 appeared to be similar or slightly higher than in 2005.

High iron and aluminum concentrations are usually associated with the intake of high levels of suspended sediments by mussels and clams at sampled sites, with the iron and aluminum being abundant crustal elements and therefore abundant in sediments. This correlation 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. Sediment loading in clam gut contents may be quite a bit higher than mussel gut loading, thus affecting aluminum and iron levels disproportionately in clam tissue concentrations since no depuration occurs prior to tissue removal.

Monitoring for iron and aluminum provides an important reference to gauge sediment intake by clams, allowing iron and aluminum levels to be referenced if other more toxic metals or contaminants are detected in 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 clam gut contents, rather than bioaccumulated contaminants from mussel tissue.

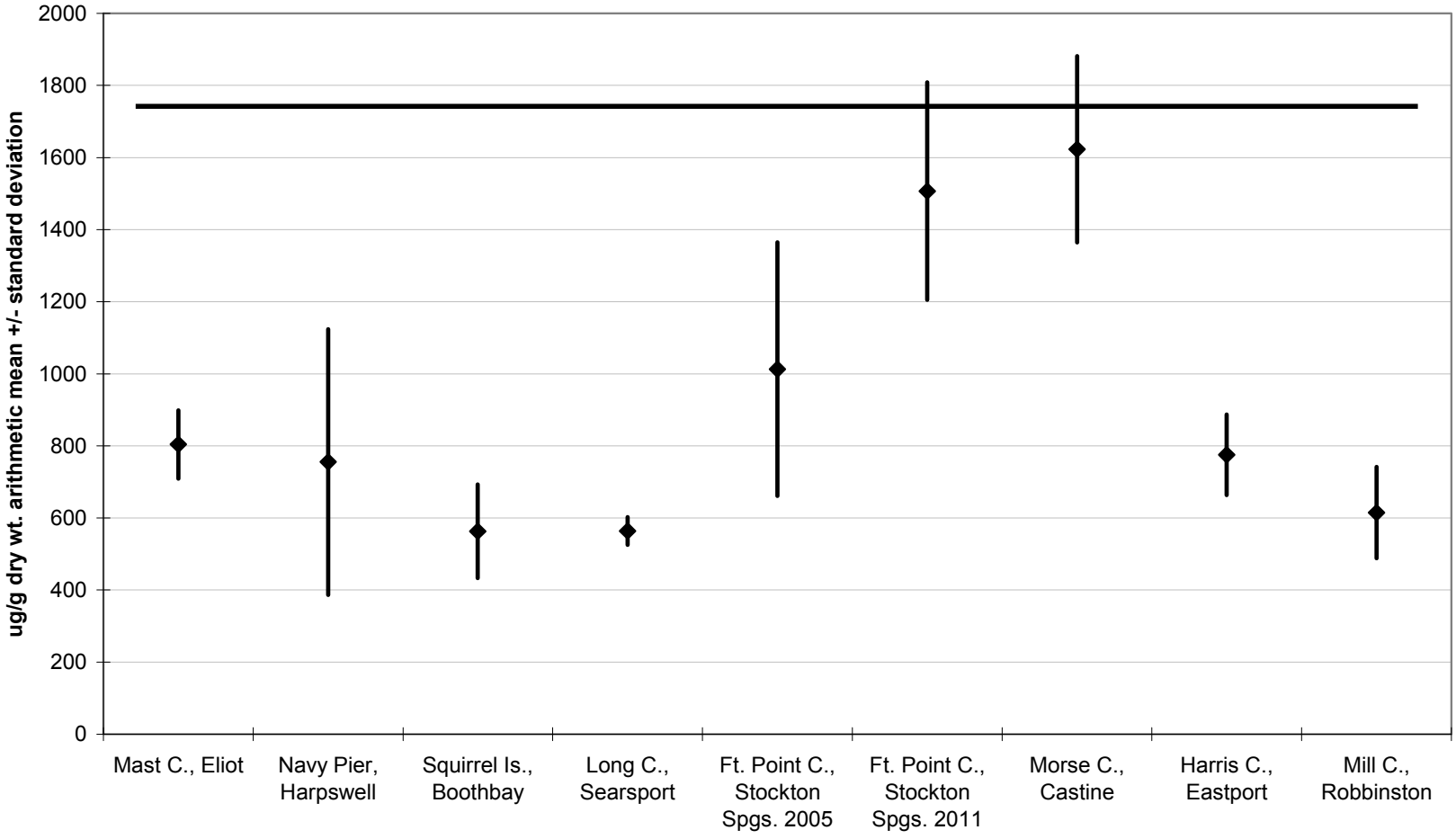
From a human health perspective, MCDC does not report FTALs for iron and aluminum.

Figure 1.3.1.2.6.1: Iron in SWAT Softshell Clams



Solid line = Gulfwatch 2008 Mean (four Softshell Clam Sites in NH, ME)

Figure 1.3.1.2.6.2: Aluminum in SWAT Softshell Clams



1.3.1.2.7 Nickel (Ni)

Nickel was detected in clam tissue at all eight SWAT softshell clam sites visited. Nickel levels detected in mussels ranged from a low mean concentration of 3.01 ug/g dry wt. at Long Cove, Searsport, to a high mean concentration of 9.68 ug/g dry wt. at Mast Cove, Eliot (Figure 1.3.1.2.7.1). Maine concentrations were all higher than the 2008 Gulfwatch clam median except for the 2011 Fort Point Cove concentration, which appeared to be somewhat lower than the 2005 concentration.

Higher nickel concentrations are probably associated with sediment ingestion, similar to iron and aluminum concentrations. The highest nickel concentration in the SWAT clam sites (Mast Cove, Eliot) was also found at the same site having the highest iron concentration indicating sediment in the clam gut may be a contributing factor to nickel concentration in the samples.

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 clam tissue is 1.5 ug/g wet wt. (ppm) at Mast Cove, Eliot, is an order of magnitude below the more conservative MCDC action level. MCDC does not report a cancer action level for nickel.

1.3.1.2.8 Lead (Pb)

Lead was detected in all eight SWAT softshell clam sites visited. Lead levels detected in clams ranged from a low mean concentration of 1.39 ug/g dry wt. at Navy Pier, Harpswell, to a high mean concentration of 5.45 ug/g dry wt. at Harris Cove, Eastport (Figure 1.3.1.2.8.1). Mean lead clam tissue concentrations at all eight SWAT sites fell below the 2008 Gulfwatch median. Lead concentrations at Fort Point Cove appeared to be slightly lower in 2011 than in 2005.

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

Figure 1.3.1.2.7.1: Nickel in SWAT Softshell Clams

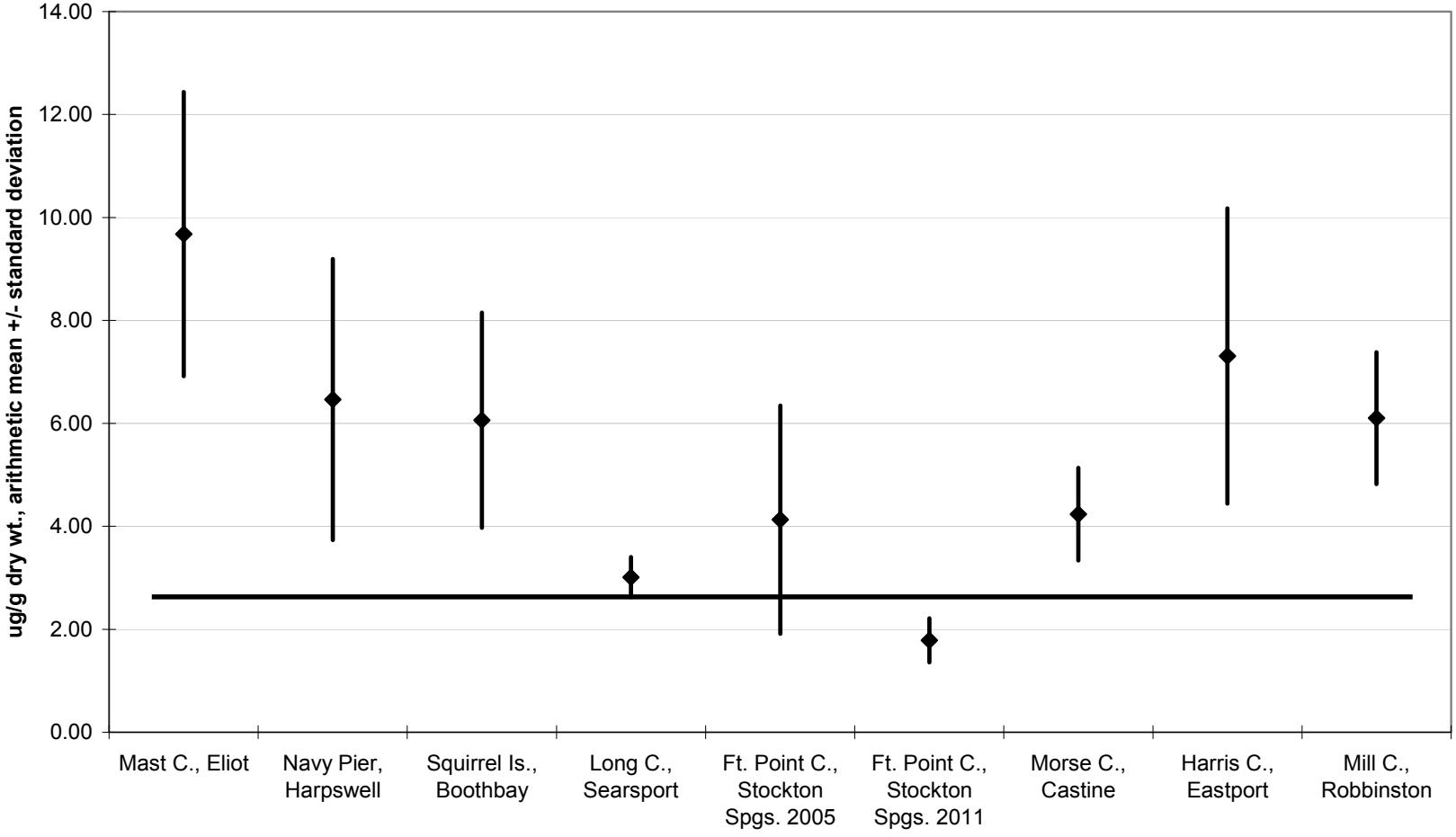
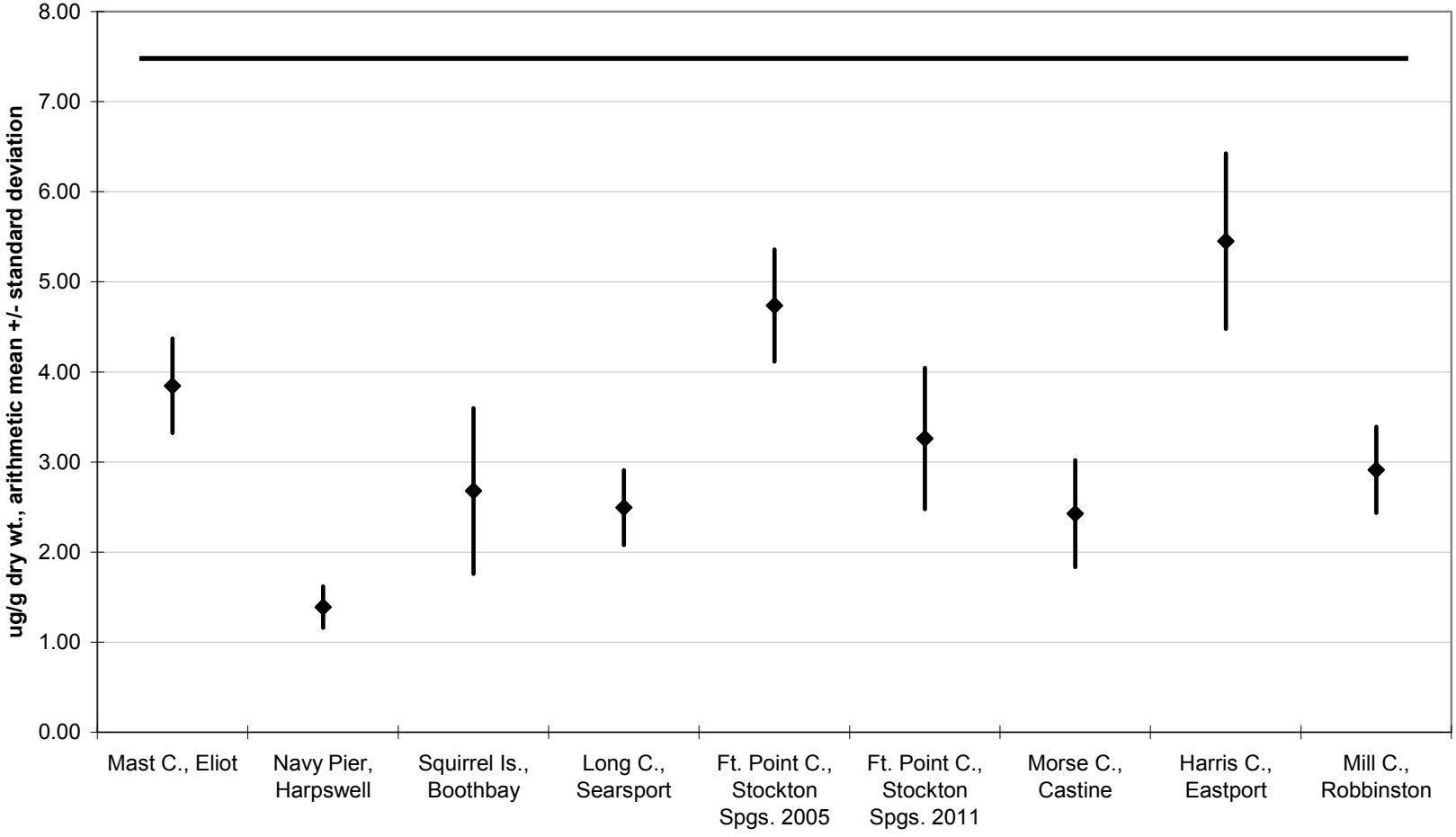


Figure 1.3.1.2.8.1: Lead in SWAT Softshell Clams



Solid line = Gulfwatch 2008 Mean (four Softshell Clam Sites in NH, ME)

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 a blood lead concentration model. The highest mean concentration in the Maine SWAT softshell clam data, 0.765 ppm (ug/g) wet wt. at Harris Cove, Eastport, exceeds the MCDC lead FTAL, as does Fort Point Cove, Searsport, in 2005 (0.647 ug/g wet wt.). Mast Cove, Eliot, (0.597 ug/g wet wt.) is at the MCDC lead FTAL. The other five SWAT softshell clam sites fell below the more conservative MCDC lead FTAL, as did the 2011 Fort Point Cove clam tissue sample (0.52 ug/g wet wt.). One replicate of four at Fort Point Cove in 2011 scored 0.65 ug/g wet wt. indicating considerable variability in the lead tissue concentrations, with some falling on either side of the MCDC lead FTAL.

The MCDC FTAL is based on the consumer eating an 8 oz. meal. Maine SWAT data indicates that an 8 oz. meal would include approximately 21 softshell clams of the size tested by the SWAT program.

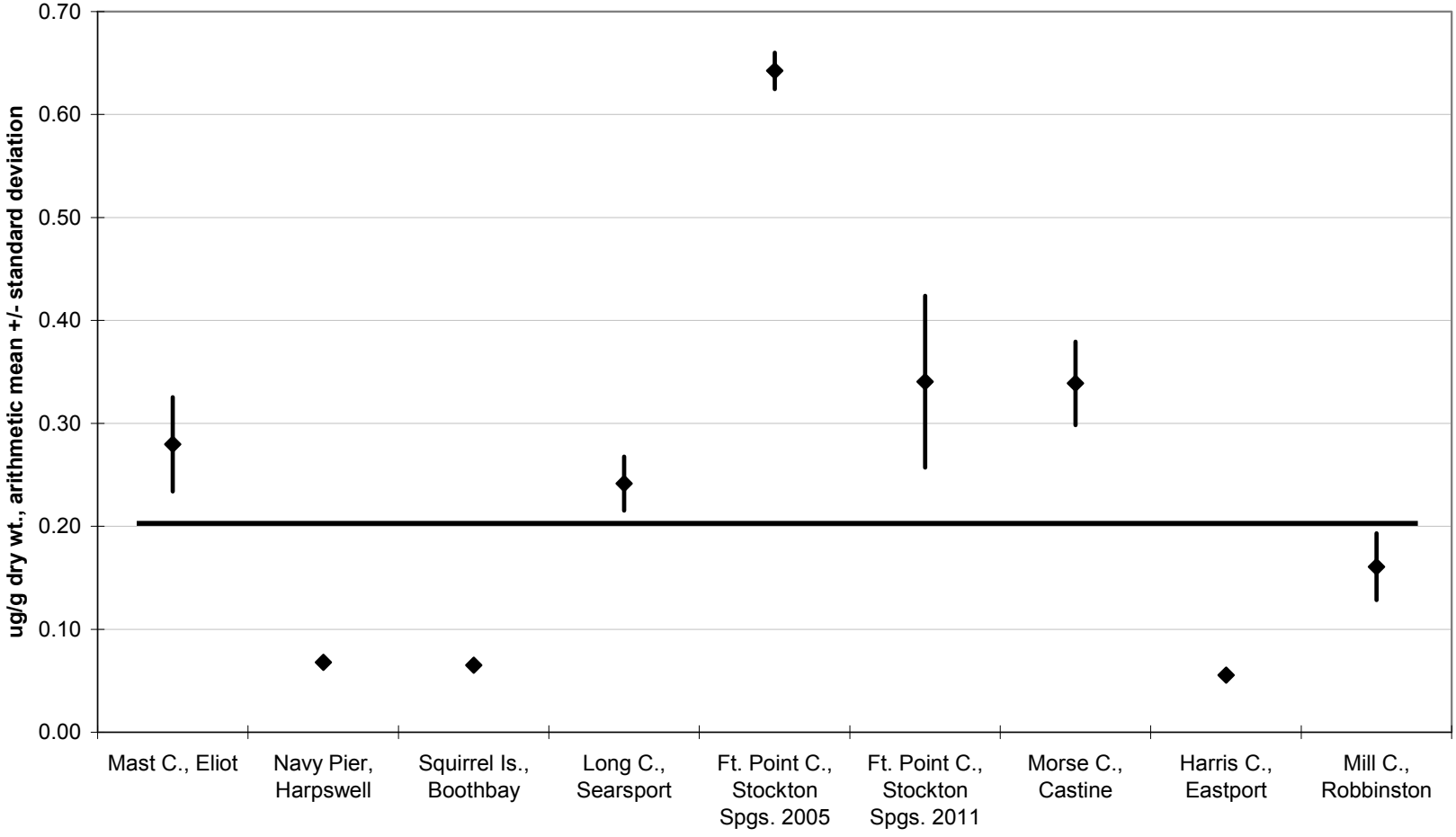
1.3.1.2.9 Mercury (Hg)

Mercury was detected in all eight softshell clam sample locations visited. Mercury levels detected in clams ranged from a low mean concentration of 0.06 µg/g dry wt. at Harris Cove, Eastport, to a high mean concentration of 0.64 µg/g dry wt. at Fort Point Cove, Stockton Springs, 2005 (Figure 1.3.1.2.9.1). High mercury concentrations in a variety of matrices have been documented in the Penobscot and are likely associated with the Holtrachem site. Four sites had clam tissue concentrations that exceeded the 2008 Gulfwatch mean: Mast Cove, Eliot; Long Cove, Searsport; Fort Point Cove (in both 2005 and 2011), Stockton Springs; and Morse Cove, Castine (Figure 1.3.1.2.9.1).

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).

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 alone. The highest mean softshell clam total tissue mercury concentration measured by SWAT in this Maine data set was 0.088 µg/g wet wt. (ppm) at Fort Point Cove, Stockton Springs in 2005 (note 2011 concentration appears to be somewhat lower, which may be due to patchiness of contaminants and sampling variability or inter-annual variability). The 2005 concentration compares favorably with the MCDC methylmercury developmental FTAL of 0.2 ppm, assuming a similar meal size and frequency. To consume approximately 8

Figure 1.3.1.2.9.1: Mercury in SWAT Softshell Clams



Solid line = Gulfwatch 2008 Mean (four Softshell Clam Sites in NH, ME)

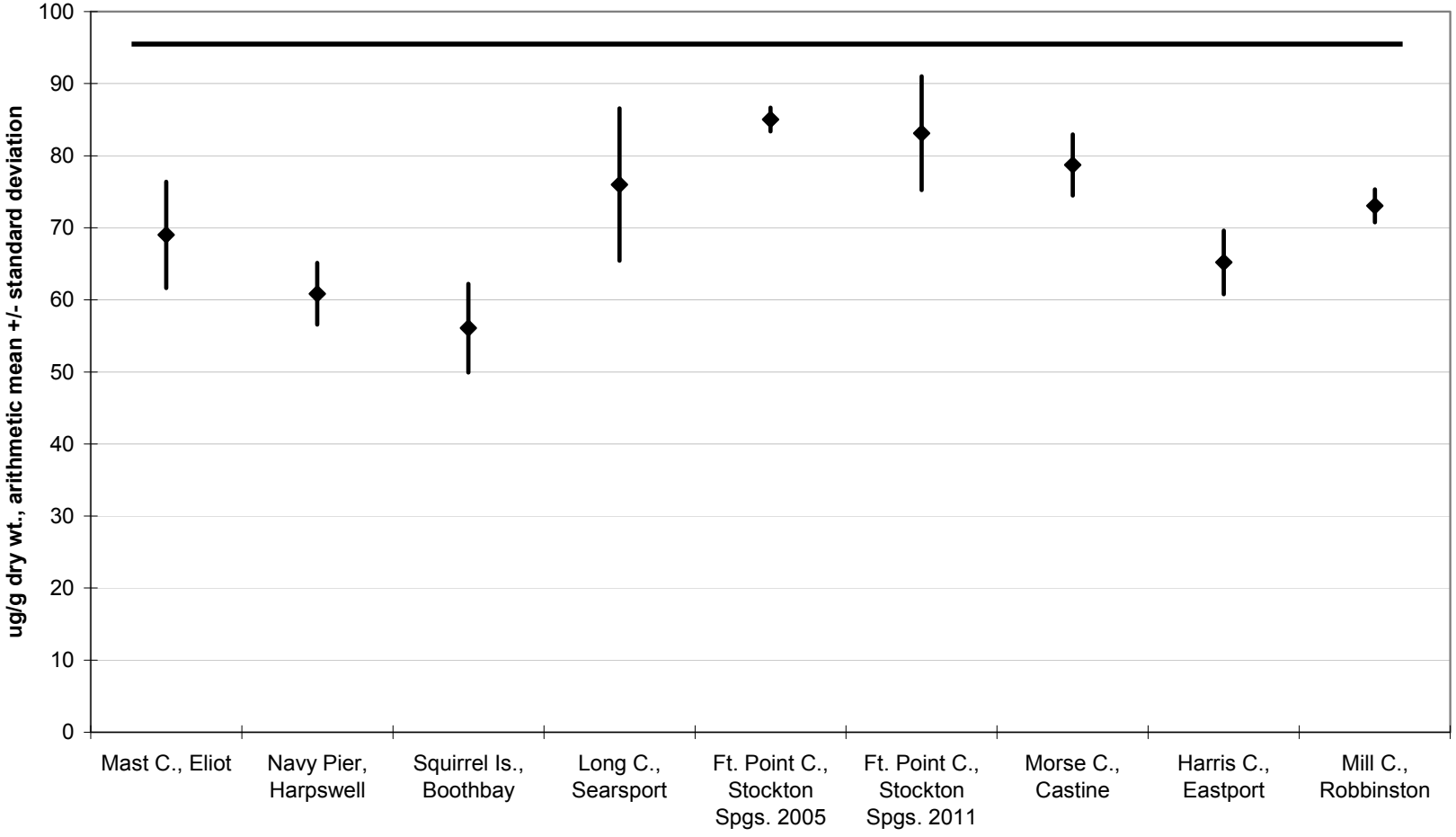
oz. of blue mussel tissue the consumer would need to eat approximately 21 softshell clams based on the mean mass per clam collected by the SWAT program.

1.3.1.2.10 Zinc (Zn)

Zinc was detected in all eight clam sample locations. Zinc levels detected in clams ranged from a low mean concentration of 56.1 ug/g dry wt. at Squirrel Island, Boothbay, to a high mean concentration of 85.0 ug/g dry wt. at Fort Point Cove, Stockton Springs in 2005 (Figure 1.3.1.2.10.1). Zinc concentrations appeared to be very similar at Fort Point Cove in 2005 and 2011. All eight of the SWAT clam sites had zinc tissue concentrations that fell below the 2008 Gulfwatch median.

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 more than an order of magnitude higher than any wet wt. concentrations observed in SWAT clam tissue. There is no recommended FDA safety level for zinc in fish (Kimbrough, 2008).

Figure 1.3.1.2.10.1: Zinc in SWAT Softshell Clams



Solid line = Gulfwatch 2008 Mean (four Softshell Clam Sites in NH, ME)

1.3.2 PAHs

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).

1.3.2.1 Blue Mussels

When available, 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, respectively.

The NS&T and the Gulfwatch programs utilize a subset of PAHs, summing results from 19, 24 and 40 individual PAHs to construct groups of PAHs to assess overall PAH concentrations and to compare regional and national concentrations. Smaller subsets of PAHs were utilized historically as a substitute for more complete sets as a cost saving measure. This report utilizes the Maine SWAT blue mussel tissue PAH data generated by AXYS Analytical, which includes 74 individual and summed alkylated PAHs. 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 2011 SWAT data. The difference in one PAH counted is because SWAT results include BENZO[B,J,K]FLUORANTHENES, while the Gulfwatch and NS&T 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. 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. 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.

Both the Gulfwatch and NS&T 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 2011 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. 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 includes 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 2011 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 recent years, including 2010. Alkylated PAHs are typically associated with pyrogenic sources, rather than the more petrogenic sources associated with non-alkylated PAHs.

Table 1.3.2.1.1, "Analyzed PAHs and PAH Summation Calculations" shows comparisons between Gulfwatch/NS&T summation lists and SWAT summation lists, 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 2011 (SWAT data, 74 PAHs described above).

Figure 1.3.2.1.1 shows the summation of the 19 non-alkylated PAHs compared to the summation of all 74 PAHs (including many alkylated PAHs) at the four blue mussel sites sampled by SWAT in 2011. 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 13% (Sandy Point, Stockton Springs) to 22% (East End Beach, Portland) of total PAHs (74) across the four SWAT sites.

Total PAH concentrations ranged from a low mean concentration of 572 ng/g dry wt. at Mill Creek, Falmouth, to a high mean concentration of 1,362 ng/g dry wt. at East End Beach, Portland (Figure 1.3.2.1.1). Rockland had the second highest mean total PAH concentration of the four sites sampled in 2011 (1,219 ng/g dry wt.). The sum of 19 non-alkylated PAHs varied from a concentration of 95 ng/g dry wt. at Mill Creek, Falmouth, to a high mean concentration of 304 ng/g dry wt. at East End Beach, Portland.

TABLE 1.3.2.1.1: Analyzed PAHs and PAH Summation Calculations

	SWAT		Gulfwatch, NS&T, SWAT Summations				
Parameter	2010-11	2004-05	ΣPAH19	ΣPAH24	ΣPAH40	Not Analyzed	Notes (See below list for more notes)
						by Gulfwatch	
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		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		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 1.3.2.1.1: Analyzed PAHs and PAH Summation Calculations (continued)

	SWAT		Gulfwatch, NS&T, SWAT Summations				
Parameter	2010-11	2004-05	ΣPAH19	ΣPAH24	ΣPAH40	Not Analyzed	Notes (See below list for more notes)
						by Gulfwatch	
NAPHTHALENE	x	x	x	x	x		
1-METHYLNAPHTHALENE	x					missing	
2-METHYLNAPHTHALENE	x					missing	
1,2-DIMETHYLNAPHTHALENE	x					missing	
2,6-DIMETHYLNAPHTHALENE	x					missing	
2,3,5-TRIMETHYLNAPHTHALENE	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					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 1.3.2.1.1: Analyzed PAHs and PAH Summation Calculations (continued)

	SWAT		Gulfwatch, NS&T, SWAT Summations				
Parameter	2010-11	2004-05	ΣPAH19	ΣPAH24	ΣPAH40	Not Analyzed	Notes (See below list for more notes)
						by Gulfwatch	
RETENE	x					missing	
C1-ACENAPHTHENES	x					missing	
C1-BENZO[A]ANTHRACENES/CHRYSENES	x				x		in Gulfwatch list as C1-CHRYSENE
C2-BENZO[A]ANTHRACENES/CHRYSENES	x				x		in Gulfwatch list as C2-CHRYSENE
C3-BENZO[A]ANTHRACENES/CHRYSENES	x				x		in Gulfwatch list as C3-CHRYSENE
C4-BENZO[A]ANTHRACENES/CHRYSENES	x				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				x		
C2-DIBENZOTHIOPHENES	x				x		
C3-DIBENZOTHIOPHENES	x				x		
C4-DIBENZOTHIOPHENES	x					missing	
C1-FLUORANTHENES/PYRENES	x				x		
C2-FLUORANTHENES/PYRENES	x				x		
C3-FLUORANTHENES/PYRENES	x					missing	
C4-FLUORANTHENES/PYRENES	x					missing	
C1-FLUORENES	x				x		
C2-FLUORENES	x				x		
C3-FLUORENES	x				x		
C1-NAPHTHALENES	x			x	x		
C2-NAPHTHALENES	x			x	x		
C3-NAPHTHALENES	x			x	x		
C4-NAPHTHALENES	x					missing	

TABLE 1.3.2.1.1: Analyzed PAHs and PAH Summation Calculations (continued)

	SWAT		Gulfwatch, NS&T, SWAT Summations				
Parameter	2010-11	2004-05	ΣPAH19	ΣPAH24	ΣPAH40	Not Analyzed	Notes (See below list for more notes)
						by Gulfwatch	
C1-PHENANTHRENES/ANTHRACENES	x			x	x		in Gulfwatch list as C1-PHENANTHRENE
C2-PHENANTHRENES/ANTHRACENES	x				x		in Gulfwatch list as C2-PHENANTHRENE
C3-PHENANTHRENES/ANTHRACENES	x				x		in Gulfwatch list as C3-PHENANTHRENE
C4-PHENANTHRENES/ANTHRACENES	x				x		in Gulfwatch list as C4-PHENANTHRENE
C4-FLUORENES					x		Not analyzed by SWAT

FOOTNOTES:

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 SWAT/AXYS data for 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

Figure 1.3.2.1.1: Sum of 19 PAHs and Total PAHs at 2011 SWAT Blue Mussel Sites

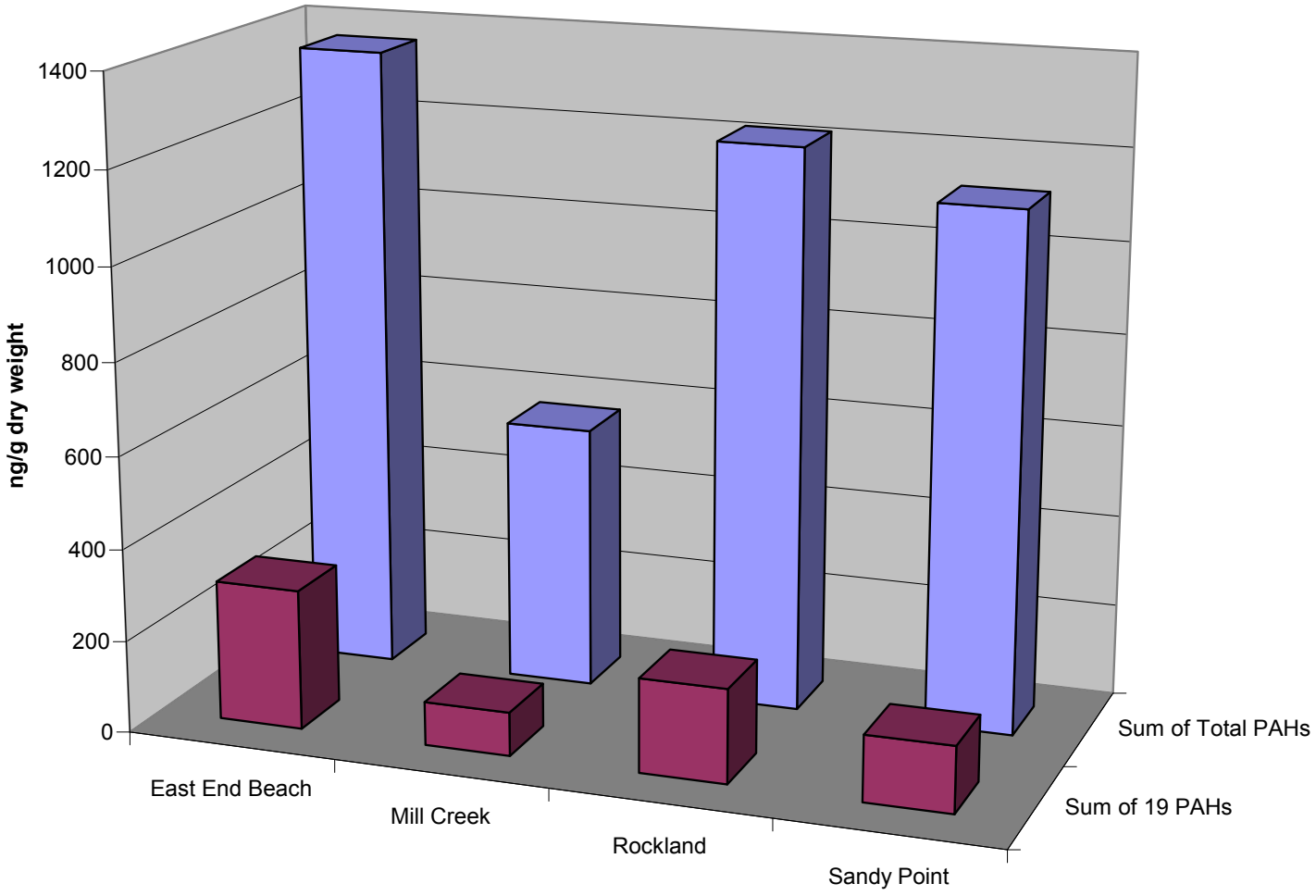


Figure 1.3.2.1.2 presents the sum of 19 PAHs across the SWAT blue mussel sites sampled in 2011, and compares these results with Gulfwatch 2008 median and 85th percentile results. Of the four SWAT sites tested in 2011, East End Beach, Portland, and Rockland exceeded the Gulfwatch 2008 median of 154 ng/g (dry weight) for 19 summed PAHs. No sites exceeded the Gulfwatch 85th percentile of 429 ng/g (dry weight) for 19 summed PAHs. Despite the use of 18 summed PAHs (SWAT) to compare to 19 summed 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.

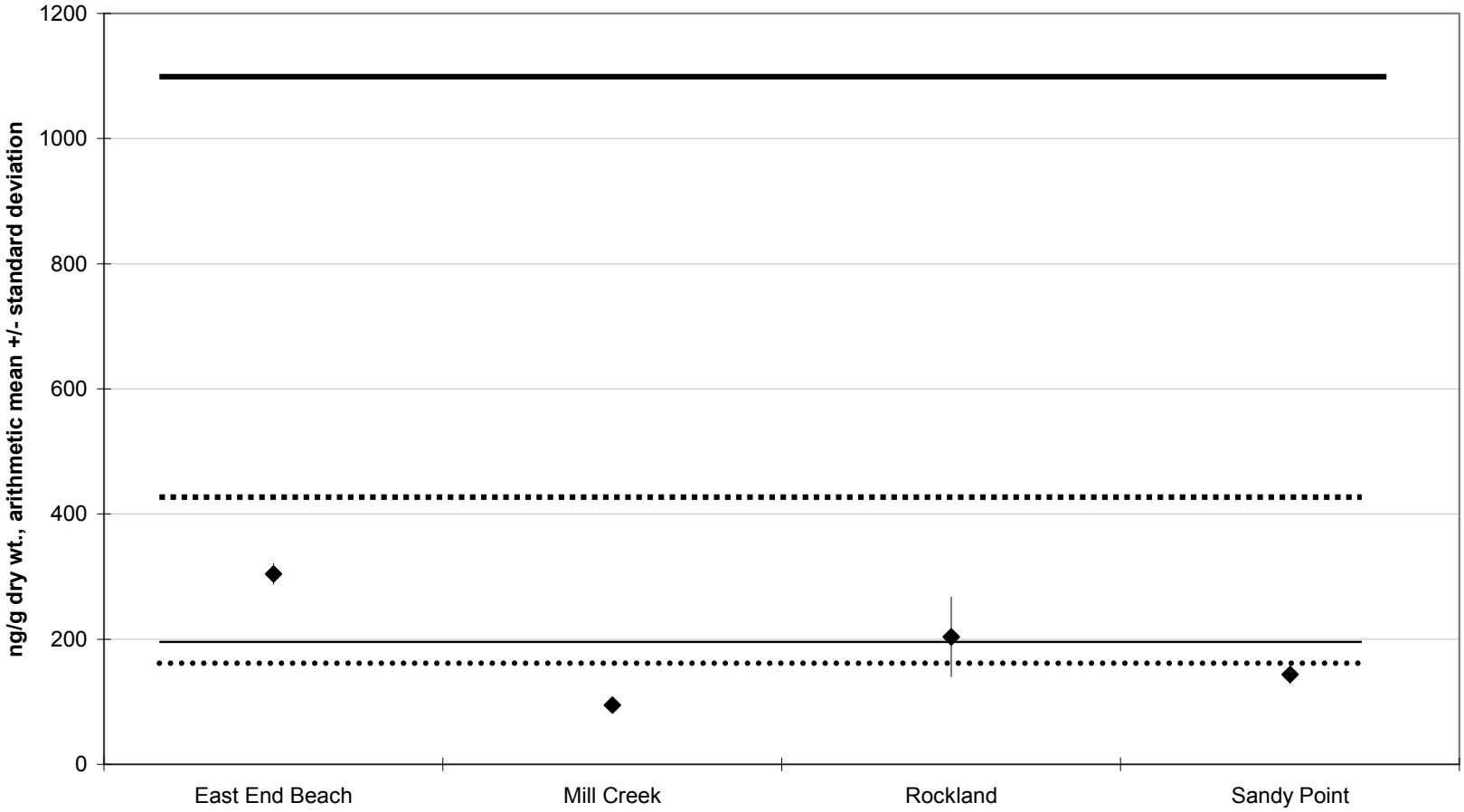
Figure 1.3.2.1.2 also compares the sum of 19 non-alkylated PAHs at the 2011 SWAT blue mussel sites to recent NS&T median and 85th percentile for 19 summed non-alkylated PAHs (2008 data, the most recent available). Of the four SWAT sites tested in 2010, East End Beach, Portland, and Rockland exceeded the 2008 NS&T median of 180 ng/g (dry weight) for 19 summed non-alkylated PAHs. None of the four SWAT mussel sites approached or exceeded the NS&T 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 were converted into this format and when 24 PAHs were summed, 2011 SWAT mean concentrations ranged from 17% (Sandy Point, Stockton Springs) to 27% (East End Beach, Portland) of total PAHs (74) across the four SWAT mussel sites.

The mean concentrations for the sum of 24 PAHs ranged from a low mean concentration of 195 ng/g dry wt. at Sandy Point, Stockton Springs, to a high mean concentration of 373 ng/g dry wt. at East End Beach, Portland (Figure 1.3.2.1.3). Figure 1.3.2.1.4 presents the sum of 24 PAHs across the SWAT blue mussel sites sampled in 2011, and compares these results with Gulfwatch 2008 median and 85th percentile results. Of the four SWAT sites tested in 2011, East End Beach, Portland, and Rockland are the two sites that exceeded the Gulfwatch 2008 median of 198 ng/g (dry weight) for 24 summed PAHs. None of the 2011 sites exceeded the Gulfwatch 85th percentile of 476 ng/g (dry weight) for 24 summed PAHs. Despite 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 1.3.2.1.4 also compares the sum of 24 PAHs at the 2011 SWAT sites to recent NS&T median and 85th percentile for 24 summed PAHs (2008 data, the most recent available). Of the four SWAT sites tested in 2011, East End Beach, Portland, and Rockland exceeded the NS&T 2008 median of 247 ng/g (dry weight) for 24 summed PAHs. None of the 2011 SWAT sites approached or exceeded the NS&T 85th percentile of 1,216 ng/g (dry weight) for 24 summed PAHs.

Figure 1.3.2.1.2: Sum of 19 PAHs in 2011 SWAT Blue Mussels



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

Figure 1.3.2.1.3: Sum of 24 PAHs and Total PAHs at 2011 SWAT Blue Mussel Sites

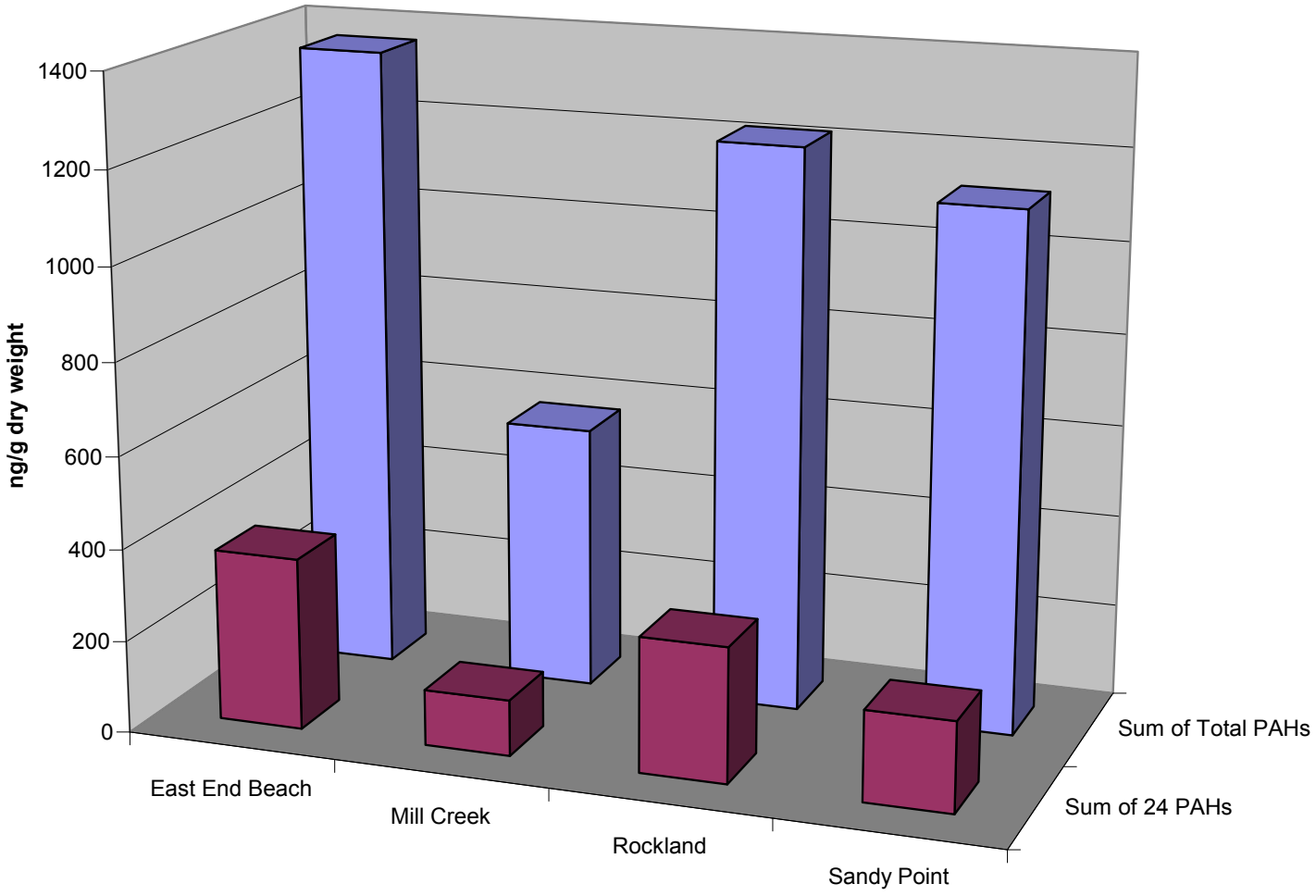
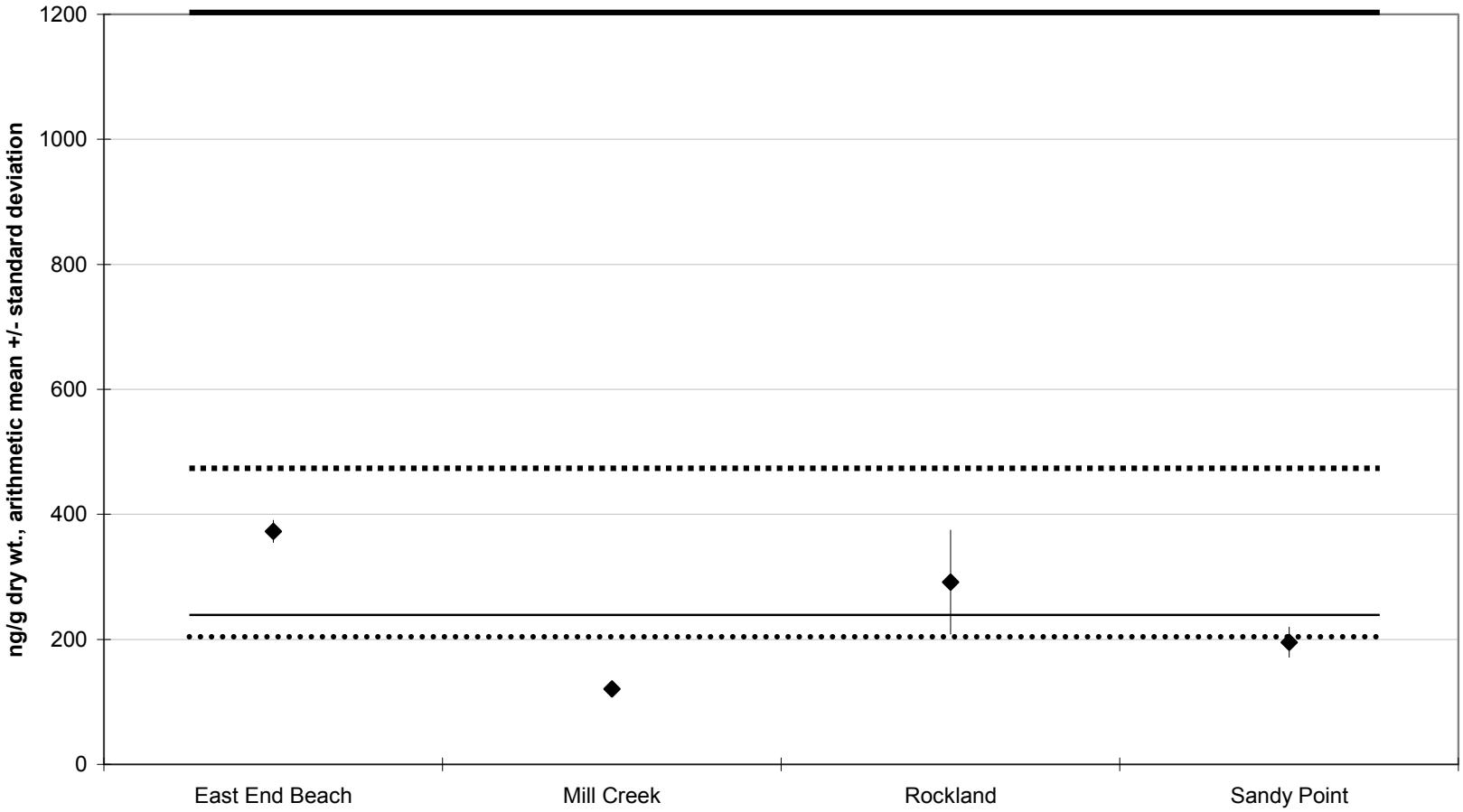


Figure 1.3.2.1.4: Sum of 24 PAHs in 2011 SWAT Blue Mussels



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

Figure 1.3.2.1.5 shows the summation of 40 PAHs compared to the summation of all 74 PAHs at the four blue mussel sites sampled by SWAT in 2011. 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 77% (Rockland) to 81% (East End Beach, Portland) of total PAHs (74) across the four SWAT sites. The mean concentrations for the sum of 40 PAHs ranged from a low mean concentration of 458 ng/g dry wt. at Mill Creek, Falmouth, to a high mean concentration of 1,101 ng/g dry wt. at East End Beach, Portland (Figure 1.3.2.1.5).

Figure 1.3.2.1.6 presents the sum of 40 PAHs across the SWAT blue mussel sites sampled in 2011, and compares these results with Gulfwatch 2008 median and 85th percentile results. Of the four SWAT sites tested in 2011, all exceeded the Gulfwatch 2008 median of 260 ng/g (dry weight) for 40 summed PAHs. Three 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 1.3.2.1.1, 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 result cannot be avoided due to the composition of the SWAT data, but should be noted when viewing the comparison in Figure 1.3.2.1.6.

Figure 1.3.2.1.6 also compares the sum of 40 PAHs at the 2011 SWAT sites to recent NS&T median and 85th percentile for 40 summed PAHs (2008 data, the most recent available). Of the four SWAT sites tested in 2011, all exceeded the NS&T 2008 median of 353 ng/g (dry weight) for 40 summed PAHs. None of the four sites exceeded the NS&T 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 contribute significantly to the relatively higher concentrations apparent in three of the SWAT sites when compared to the NS&T (same as Gulfwatch) sum of 40 PAHs. These differences are explored in depth in the preceding paragraph. This result cannot be avoided due to the composition of the SWAT data, but should be noted when viewing the comparison in Figure 1.3.2.1.6.

Figure 1.3.2.1.5: Sum of 40 PAHs and Total PAHs at 2011 SWAT Blue Mussel Sites

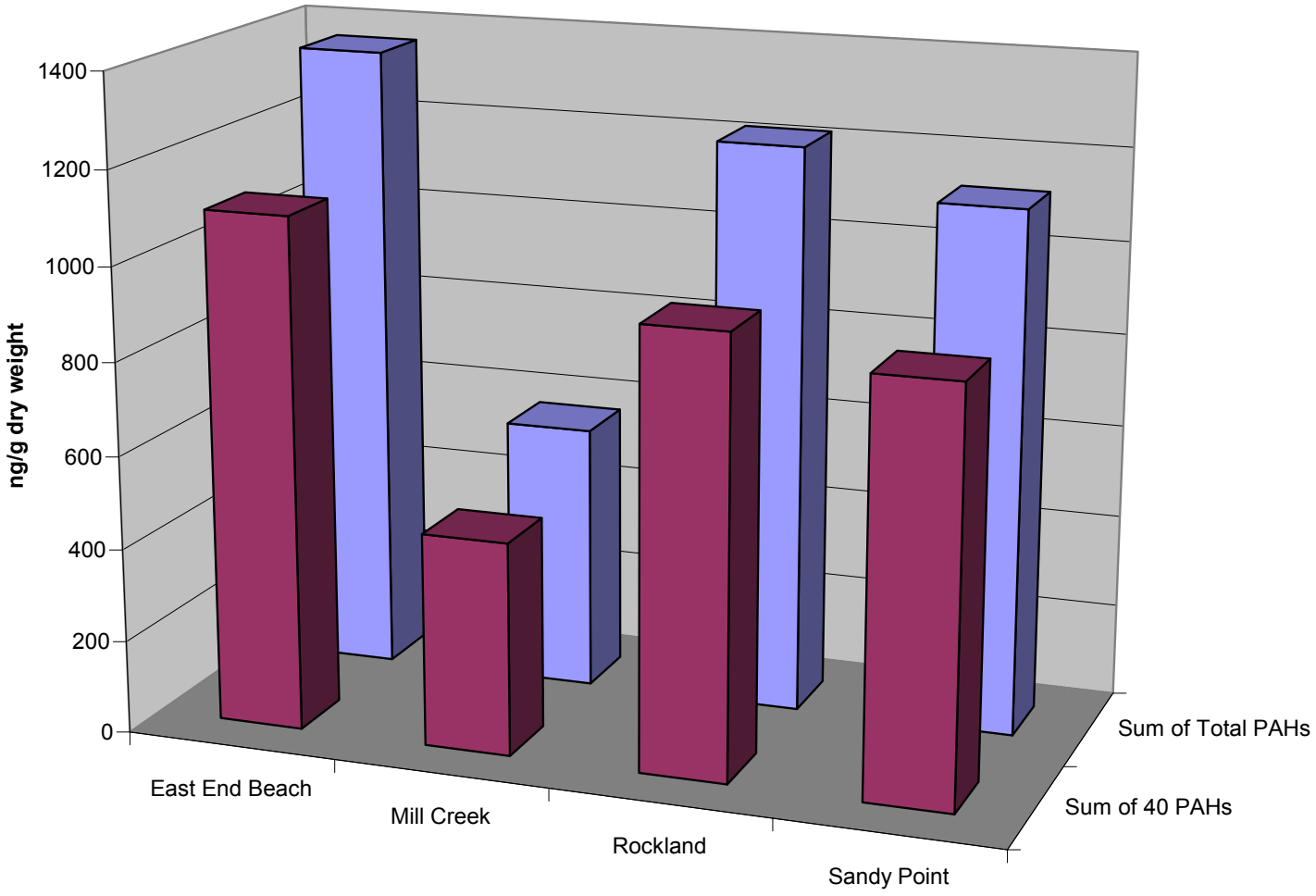
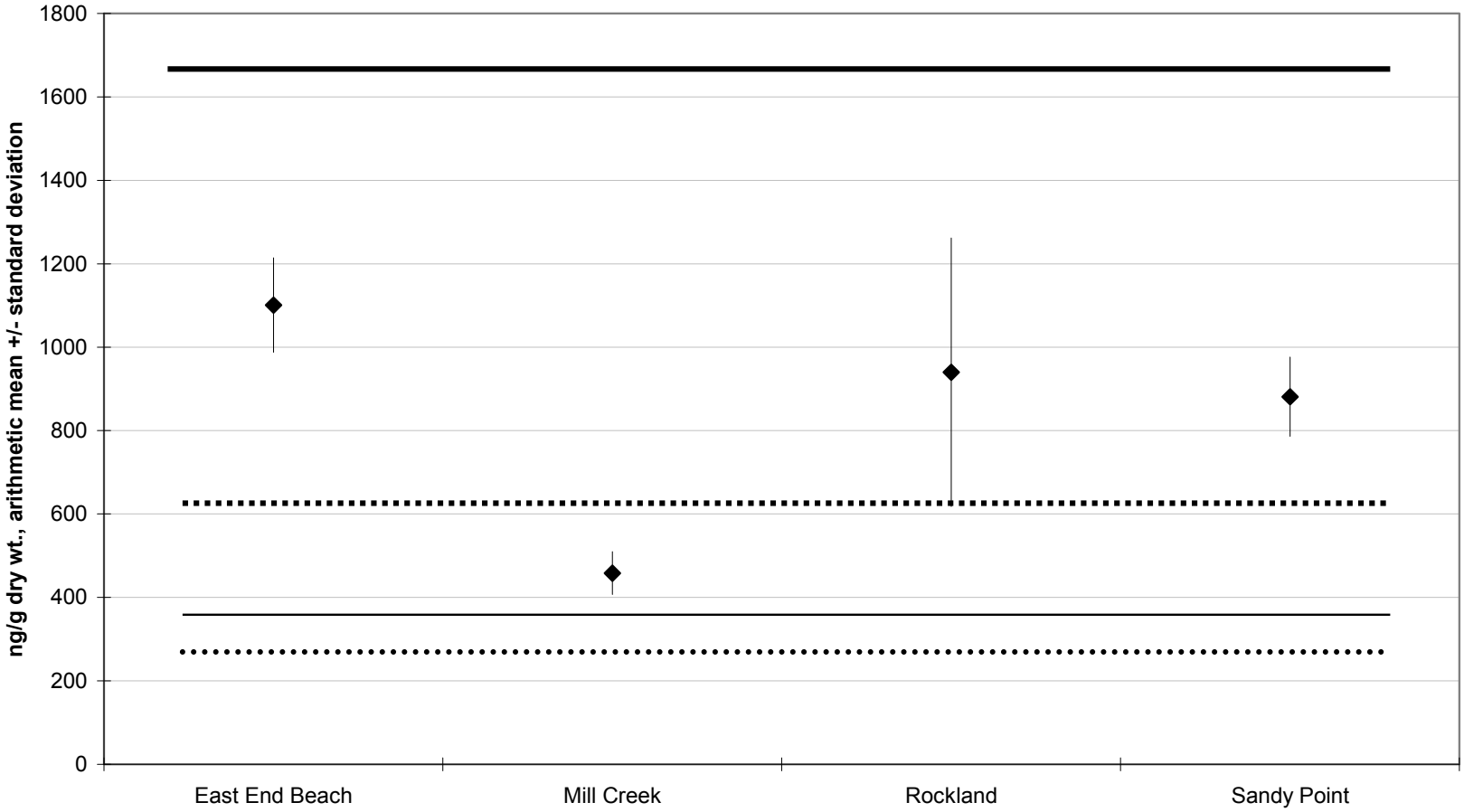


Figure 1.3.2.1.6: Sum of 40 PAHs in 2011 SWAT Blue Mussels



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

For 2011 SWAT blue mussel sites, Figure 1.3.2.1.7 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 four SWAT blue mussel sites tested in 2011, Sandy Point, Stockton Springs, had the lowest ratio calculated, 0.15. Even this lowest ratio site did not fall below the <0.1 mark, which would indicate a petrogenic source of PAHs. Sandy Point was the only blue mussel tissue site that had a ratio <0.2, indicating that proportionately there is not a very strong pyrogenic component to the PAHs there. Sandy Point is much further removed from urban sources of combusted fuels than the East End Beach, Portland, Mill Creek, Falmouth, and even the smaller urban Rockland area. The higher ratio in the two greater Portland sites may be attributed to the urbanized upland area (Portland and Route 1, Falmouth) with associated impervious surfaces and combusted hydrocarbon runoff) or to ship and boat emissions.

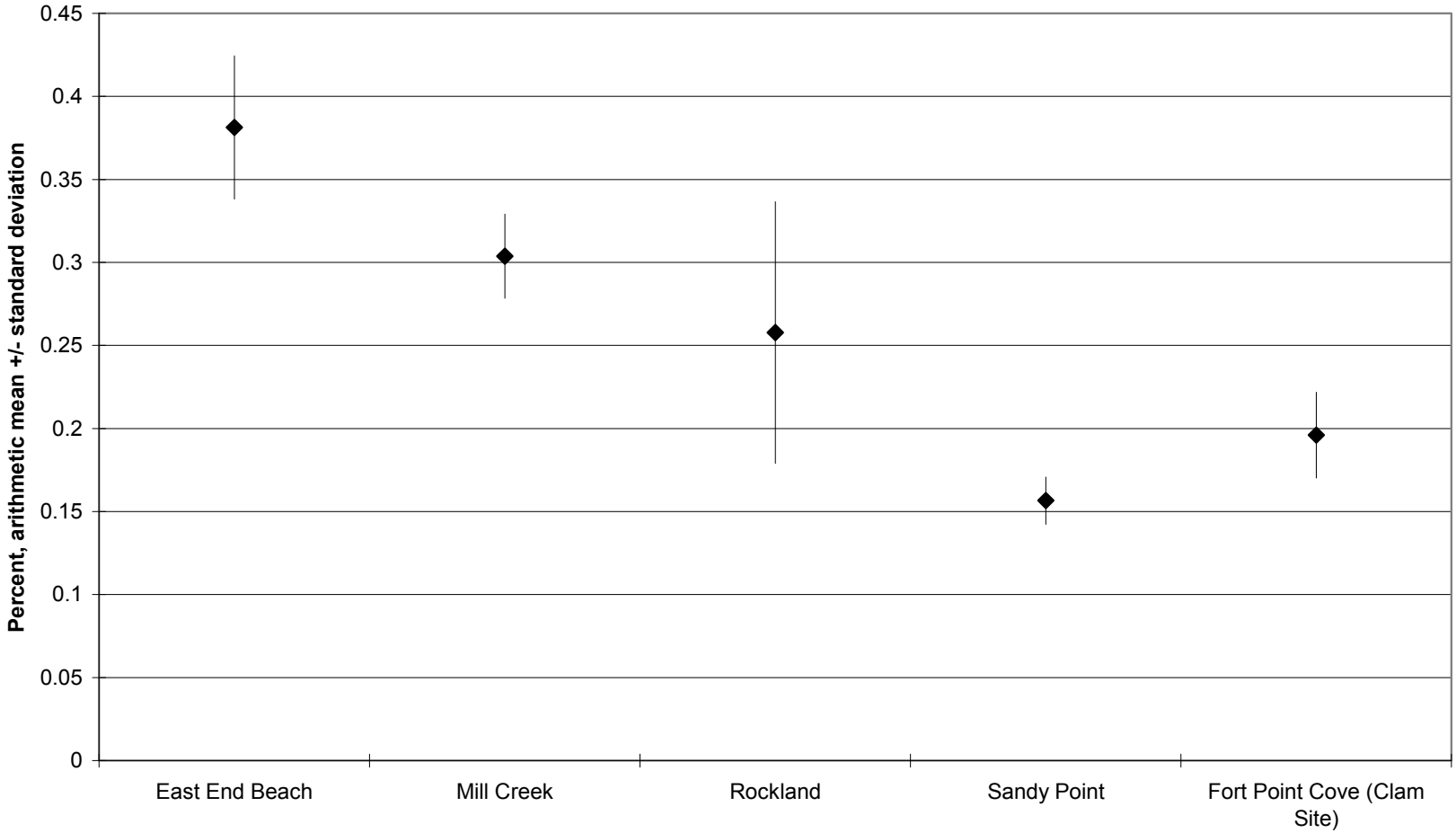
Toxicities of PAHs vary, with hundreds of compounds making up the pool of PAHs. Toxic responses in aquatic organisms may include reproduction inhibition, mutations, liver abnormalities, and even mortality. Exposure in the marine environment may be from spilled oil, boat exhaust, and runoff from urban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

1.3.2.2 Softshell Clams

Results were compared to national (NOAA National Status & Trends, see Kimbrough, 2008) shellfish data and Gulf of Maine (Gulfwatch, see LeBlanc, 2009) softshell clam data (when available) in an effort to place Maine SWAT data in a national and regional context, respectively. Differences in individual PAHs obtained from different laboratories and different years are described in depth in the previous section 1.3.2.1, Blue Mussels. The same approach was utilized to develop lists of PAHs in clam tissues presented in this section. Comparisons were made to NS&T and Gulfwatch programs when data sets were available and to place Maine SWAT data in wider geographic context.

Table 1.3.2.1.1, "Analyzed PAHs and PAH Summation Calculations" which also was presented in the previous Section 1.3.2.1, shows comparisons between Gulfwatch/NS&T summation lists and SWAT summation lists, and details differences between the lists with footnotes and notes in the right column of the table. Table 1.3.2.1.1 details the PAHs included in summations and includes a complete list of all PAHs for which results were obtained in the different years sampled.

Figure 1.3.2.1.7: Flu+Pyr/Sum(FP C2-C4-P) in SWAT 2011 Blue Mussels and Softshell Clams



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

Figure 1.3.2.2.1 shows the summation of the 19 non-alkylated PAHs at the eight SWAT clam sites (Fort Point Cove, Stockton Springs, re-sampled in 2011). Sum of 19 non-alkylated PAHs ranged from a low mean concentration of 88 ng/g dry wt. at Long Cove, Searsport, to a high mean concentration of 319 ng/g dry wt. at Morse Cove, Castine. No SWAT clam sites exceeded the 2008 Gulfwatch mean concentration for the sum of 19 non-alkylated PAHs, which was calculated for four sites (two in NH and two in ME). Re-sampling at Fort Point Cove, Stockton Springs, in 2011 appears to show a lower PAH concentration than when the site was previously sampled in 2005, with the mean concentration in mussel tissue dropping from 248 to 140 ng/g dry wt. This may be a real trend, due to patchiness of the PAHs on site, or related to inter-annual variability.

Due to the lesser number of PAHs for which lab analysis was conducted in 2004-05, no summations for 24 or 40 PAHs are available for clam tissues collected in these years. Due to the larger number of PAHs from lab analysis in 2010-2011, all summations were constructed for Morse Cove, Castine (see 2010 SWAT Report), and Fort Point Cove, Stockton Springs, which was re-sampled in 2011. Figure 1.3.2.2.2 includes summations for 19 non-alkylated PAHs, as well as summations of 24, 40, and total PAHs. The sum of 40 PAHs concentration in Fort Point Cove clam tissue exceeded the 2008 Gulfwatch median (four sites, two in NH and two in ME), though the summations of 19 and 24 PAHs did not exceed the mean. PAHs summed from clam tissue from Morse Cove, Penobscot/Castine exhibited the same pattern in 2010. This may indicate a component of alkylated PAHs at Fort Point Cove that is contributing to the higher summation concentration as more alkylated PAHs are included in broader summations. No summation of total PAHs is available for Gulfwatch data, so no mean can be calculated to present in Figure 1.3.2.2.2.

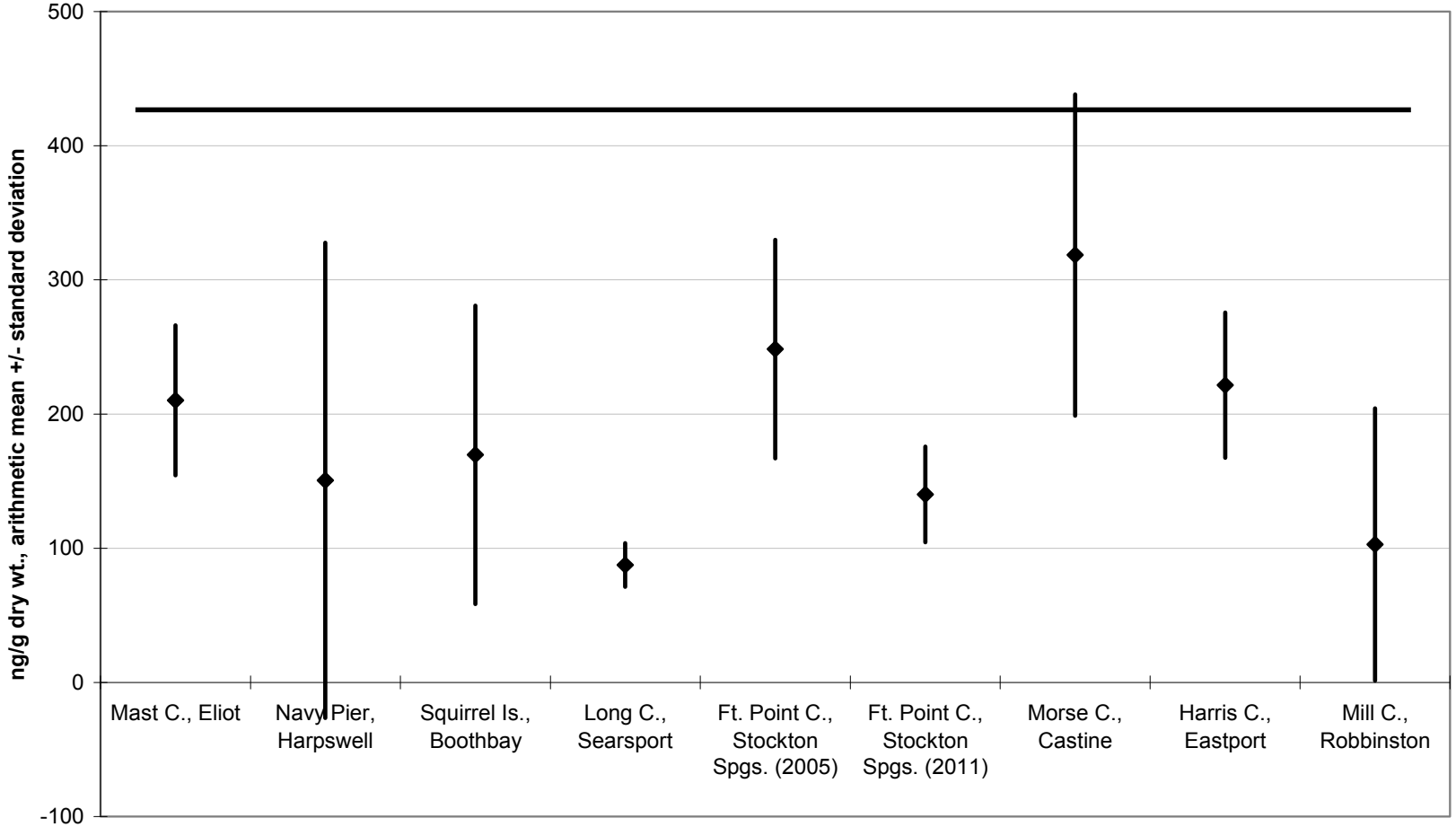
Only PAH results from Morse Cove, Castine (see 2010 SWAT report) and Fort Point Cove, Stockton Springs (2011), included the PAHs necessary to calculate the ratio used previously to explore non-alkylated to alkylated PAHs. Sites sampled in 2004-05 were not analyzed for all necessary PAHs to complete this ratio calculation. 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.

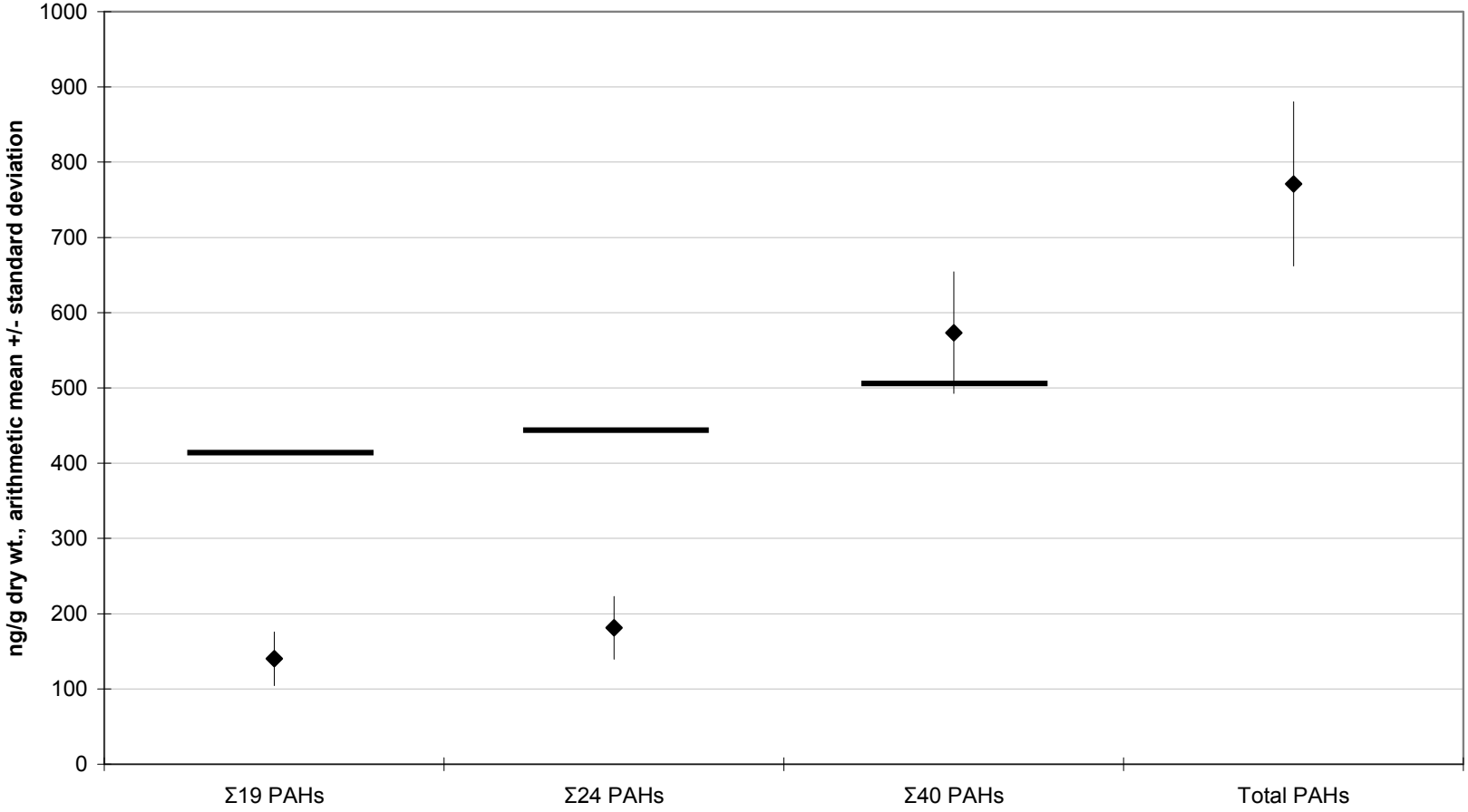
Since clams were sampled only at Fort Point Cove, Stockton Springs, in 2011, the calculated ratio has been included in Figure 1.3.2.1.7, which also depicts the calculated ratios for the blue mussel sites sampled in 2011 and is in the previous section of the report, section 1.3.2.1. Fort Point Cove, Stockton Springs, appears to have neither a predominantly pyrogenic nor predominantly petrogenic ratio, falling just below the >0.2 level (Figure 1.3.2.1.7).

Figure 1.3.2.2.1: Sum of 19 PAHs in SWAT Softshell Clams



Solid line = Gulfwatch 2008 Mean (four Softshell Clam Sites in NH, ME)

Figure 1.3.2.2.2: PAHs in Fort Point Cove, Stockton Springs, Softshell Clams



Solid lines = Gulfwatch 2008 Means for Σ19 PAHs, Σ24 PAHs, and Σ40 PAHs (four Softshell Clam Sites in NH, ME; no total PAH mean is available for Gulfwatch).

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).

1.3.3 PCBs

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).

1.3.3.1 Blue Mussels

This report utilizes the Maine SWAT blue mussel tissue PCB data generated by AXYS Analytical, which includes 209 PCB congeners, some of which co-elute and are represented as combinations of PCB congeners. Co-elution refers to congeners that are collected together and then not separated during the detection/quantitation process on the gas chromatograph (GC) trace. The NS&T and Gulfwatch programs utilize a subset of PCBs, summing scores from 24 peaks on the gas chromatograph (GC) trace. The sum of these 24 GC peaks actually represents 31 PCB congeners since 7 of the 24 selected peaks contain two congeners each. These 31 summed PCB congeners will be called "Gulfwatch PCBs" or "NS&T PCBs" for the purposes of this report.

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 1.3.3.1.1 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 as 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.

TABLE 1.3.3.1.1: 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	

To compare what proportion of the total PCBs (209 congeners) the SWAT PCBs represent, Figure 1.3.3.1.1 shows the total PCBs next to the SWAT PCBs list used for comparison to other data sets like Gulfwatch and NS&T Musselwatch. Comparing the four mussel sites sampled in 2011, the SWAT PCBs ranged from 18.6% to 19.9% of the total PCBs. The close relationship between total PCBs and the 2011 SWAT PCBs subset can easily be noted. Total PCB concentrations ranged from a low mean concentration of

67.9 ng/g dry wt. at Mill Cove, Falmouth, to a high mean concentration of 117.8 ng/g dry wt. at Rockland (Figure 1.3.3.1.1). East End Beach, Portland, mussel tissue had a total PCB concentration slightly less than Rockland, with a mean of 115.7 ng/g dry wt., and Sandy Point, Stockton Springs, had a mean total PCB concentration of 88.5 ng/g dry wt. (Figure 1.3.3.1.1).

Figure 1.3.3.1.2 compares the SWAT PCBs at the 2011 SWAT mussel sites to recent Gulfwatch median and 85th percentile for 2008 PCB data, the most recent available. None of the four 2011 SWAT mussel sites exceeded the Gulfwatch 2008 median of 24.1 ng/g (dry weight), and consequently, none of the sites tested in 2011 exceeded the Gulfwatch 85th percentile of 35.4 ng/g (dry weight) for Gulfwatch PCBs.

Figure 1.3.3.1.2 also compares the SWAT PCBs at the 2011 SWAT sites to recent NS&T (NS&T) median and 85th percentile 2008 PCB data, the most recent available. None of the four SWAT sites exceeded the NS&T 2008 median, 29.2 ng/g (dry weight), and so none exceeded the NS&T national 85th percentile, 141 ng/g (dry weight). The 2008 NS&T 85th percentile was approximately 6 X higher than the highest scoring PCB site tested by SWAT in Maine in 2011, East End Beach, Portland (22.5 ng/g, dry weight). Some areas in southern New England have higher levels 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).

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 four SWAT blue mussel sites sampled in 2011, two sites had total PCB mean tissue concentrations exceeding the MCDC cancer FTAL of 11 ng/g wet wt. These sites are:

East End Beach, Portland	13 ng/g wet wt.
Rockland, 2011	22 ng/g wet wt.

Sandy Point, Stockton Springs, had a total PCB mean tissue concentration of 10.9 ng/g wet wt., essentially the same as the MCDC cancer FTAL of 11 ng/g wet wt. None of the four SWAT blue mussel sites sampled had total PCB concentrations approaching the MCDC non-cancer FTAL of 43 ng/g wet wt.

When Crockett Point, Rockland, was tested previously in 2007 and 2010, the mean concentrations at the site were 23 and 15 ng/g wet wt., respectively, indicating some inter-annual variability in total PCB concentration. This variability may be a result of patchiness and heterogeneity within the sampled site or differences between sampling years. Sampling conducted in 2011 utilized a wider area within the western section of Rockland Harbor and Crockett Point to avoid restriction of sample collection to only one portion of Crockett Point as done previously in 2007 and 2010. In 2011, mussels were collected in four spatial subsamples to characterize this area, with the first two collected on a different section of Crockett Point than the area previously sampled in 2007 and

Figure 1.3.3.1.1: SWAT PCBs (Sum of 35 PCBs) and Total PCBs at 2011 SWAT Blue Mussel Sites

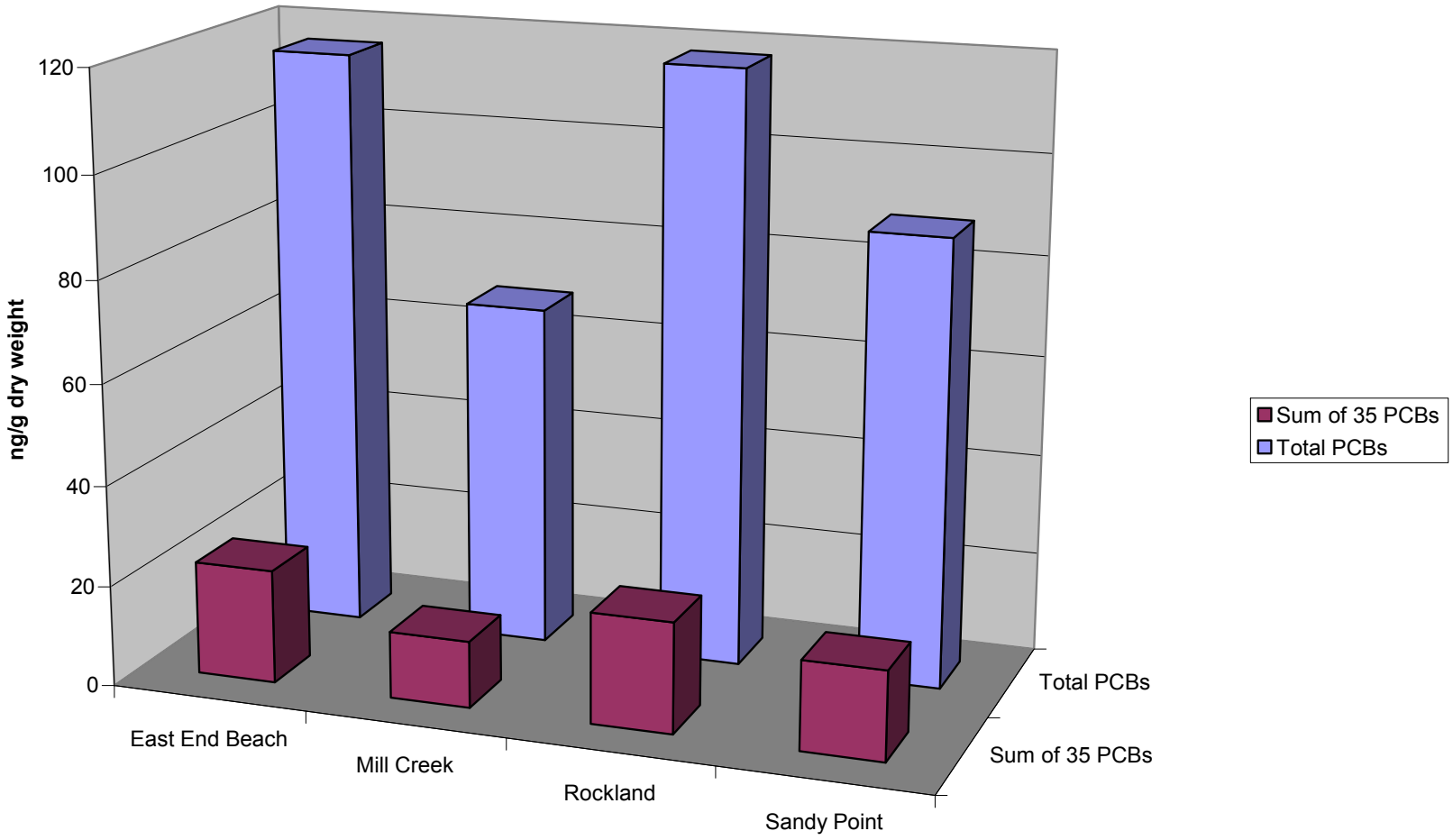
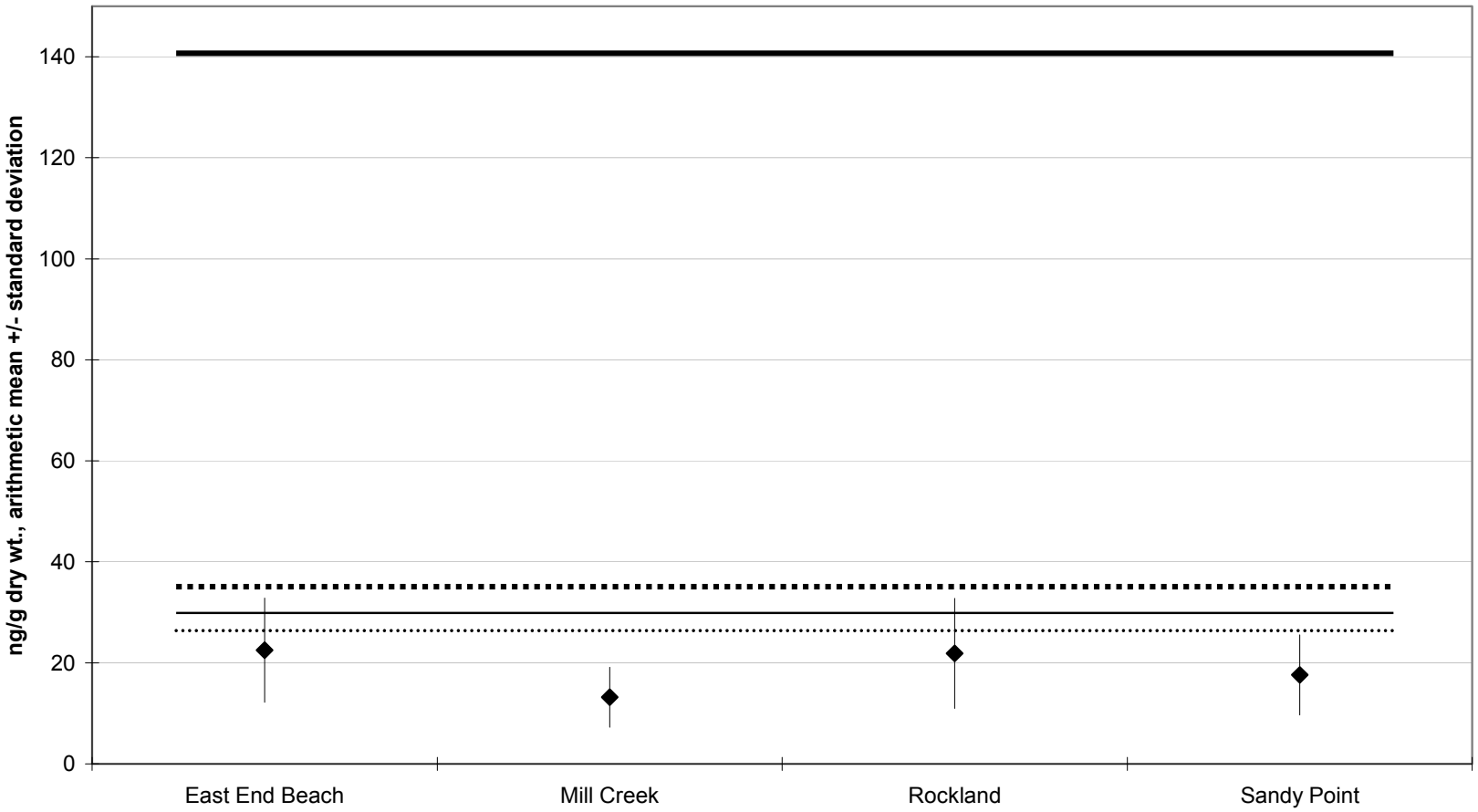


Figure 1.3.3.1.2: SWAT PCBs (Sum of 35 PCBs) in 2011 SWAT Blue Mussels



Dashed lines = 2008 Gulfwatch Median adn 85th Percentile (Gulfwatch PCBs, Sum 31); Solid lines = 2008 National Status and Trends Median and 85th Percentile (Sum 31).

2010. The third was collected just south of Crockett Point and the fourth was collected to the north of Crocket Point.

Rockland, 2011 (mean)	22 ng/g wet wt.
Composed of:	
Sample 1, Crockett Pt.	15 ng/g wet wt.
Sample 2, Crockett Pt.	21 ng/g wet wt.
Sample 3, South of Crockett Pt.	29 ng/g wet wt.
Sample 4, North of Crockett Pt.	20 ng/g wet wt.

Historic means:	
Crockett Point, Rockland, 2010	15 ng/g wet wt.
Crockett Point, Rockland, 2007	23 ng/g wet wt.

The 2011 results indicate that the heightened PCBs are not confined to a localized area of Crockett Point (unresolved by the narrower 2007 and 2010 sampling data). It appears that a somewhat larger area in western Rockland harbor shows heightened total PCBs in blue mussel tissue, such that all of the four subsamples collected in 2011 show total PCB wet wt. concentrations above the MCDC cancer FTAL of 11 ng/g wet wt. None of the four SWAT blue mussel 2011 Rockland subsamples had total PCB concentrations approaching the MCDC non-cancer FTAL of 43 ng/g wet wt.

1.3.3.2 Softshell Clams

Softshell clams were tested for 209 PCBs from one site in 2011, Fort Point Cove, Stockton Springs, and results compared to Gulf of Maine (Gulfwatch, see LeBlanc, 2009) softshell clam monitoring program data in an effort to place Maine SWAT data in a national and regional context. Summations of PCBs constructed for comparisons were previously discussed in Section 1.3.3.1 in the blue mussel PCB section. The same approach was utilized to construct clam PCB summations.

Table 1.3.3.1.1 shows the list of PCB congeners used by Gulfwatch compared to the list of PCB congeners reported by SWAT. 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 as possible. With some caution in data interpretation, this comparison may be used to place Maine SWAT softshell clams blue mussel tissue PCB concentrations in a Gulf of Maine-wide perspective.

To compare what proportion of the total PCBs (209 congeners) the SWAT PCBs represent, Figure 1.3.3.2.1 shows both the total PCBs next to the SWAT PCBs list used for comparison to Gulfwatch. Comparing Fort Point Cove, Stockton Springs (sampled in 2011), to the three other clam sites sampled for PCBs in recent years, the SWAT PCBs ranged from 18% to 53% of the total PCBs. Total PCB concentrations ranged from a low mean concentration of 3.5 ng/g dry wt. at Mill Cove, Robbinston, to a high mean concentration of 31.7 ng/g dry wt. at Fort Point Cove, Stockton Springs (Figure 1.3.3.2.1).

Mill Cove, Robbinston, and Long Cove, Stockton Springs, were sampled in 2005, and analyzed at a different lab than the Morse Cove, Castine, (2010) and Fort Point Cove, Stockton Springs, (2011) clam tissue. The two early sites had much higher detection limits than those generated by the newer lab (Axys Analytical) that worked up the 2010-11 samples. In order to prevent the non-detects at Mill and Long Coves driving up the summations if non-detects were assigned a value of half the detection limit at the much higher detection limits used at the time of their analysis, all non-detects were assigned a value of zero for this figure and subsequent PCB analysis of the clam samples.

Figure 1.3.3.2.2 compares the SWAT PCBs at the four recently sampled SWAT clam sites to a recent Gulfwatch clam site sampled in 2008 (the most recent available). All four SWAT clam site sums of 35 PCBs fell below the one Gulfwatch site mean. As noted above, comparison of 35 summed congeners from SWAT PCBs to 31 summed congeners from Gulfwatch PCBs is as close a comparison as possible due to differences in some PCBs co-eluting in different GC traces across laboratories. Gulfwatch non-detects were valued as half-detects, which will elevate the sum of 35 PCBs at North Mill Pond, NH, to some extent over the SWAT summations taken at non-detect valued at zero. Detection limits at the Gulfwatch site were lower than the older 2005 SWAT PCB analysis. Despite these differences, the summation of 35 SWAT congeners is useful for putting Maine data into a regional, Gulf of Maine context.

Summations of 35 PCBs at the SWAT clam sites all fall below recent NS&T (NS&T) median (29.2 ng/g, dry weight) and 85th percentile (141 ng/g, dry weight) for NS&T PCBs (2008 data, the most recent available). The 2008 NS&T national 85th percentile was approximately 25 times higher than the Fort Point Cove, Stockton Springs, clam PCB site tested by SWAT in 2011.

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 four SWAT clam sites sampled, the highest mean tissue concentration for total PCBs on a wet weight basis was 2.6 ng/g at Morse Cove, Castine (2010), which was approximately one fourth of the MCDC cancer FTAL of 11 ng/g wet wt. The mean tissue concentration for total PCBs on a wet weight basis was 5.0 ng/g at Fort Point Cove, Stockton Springs (2011), which was less than half of the MCDC cancer FTAL of 11 ng/g wet wt.

Figure 1.3.3.2.1: Sum of 35 and Sum of Total PCBs in SWAT Softshell Clams

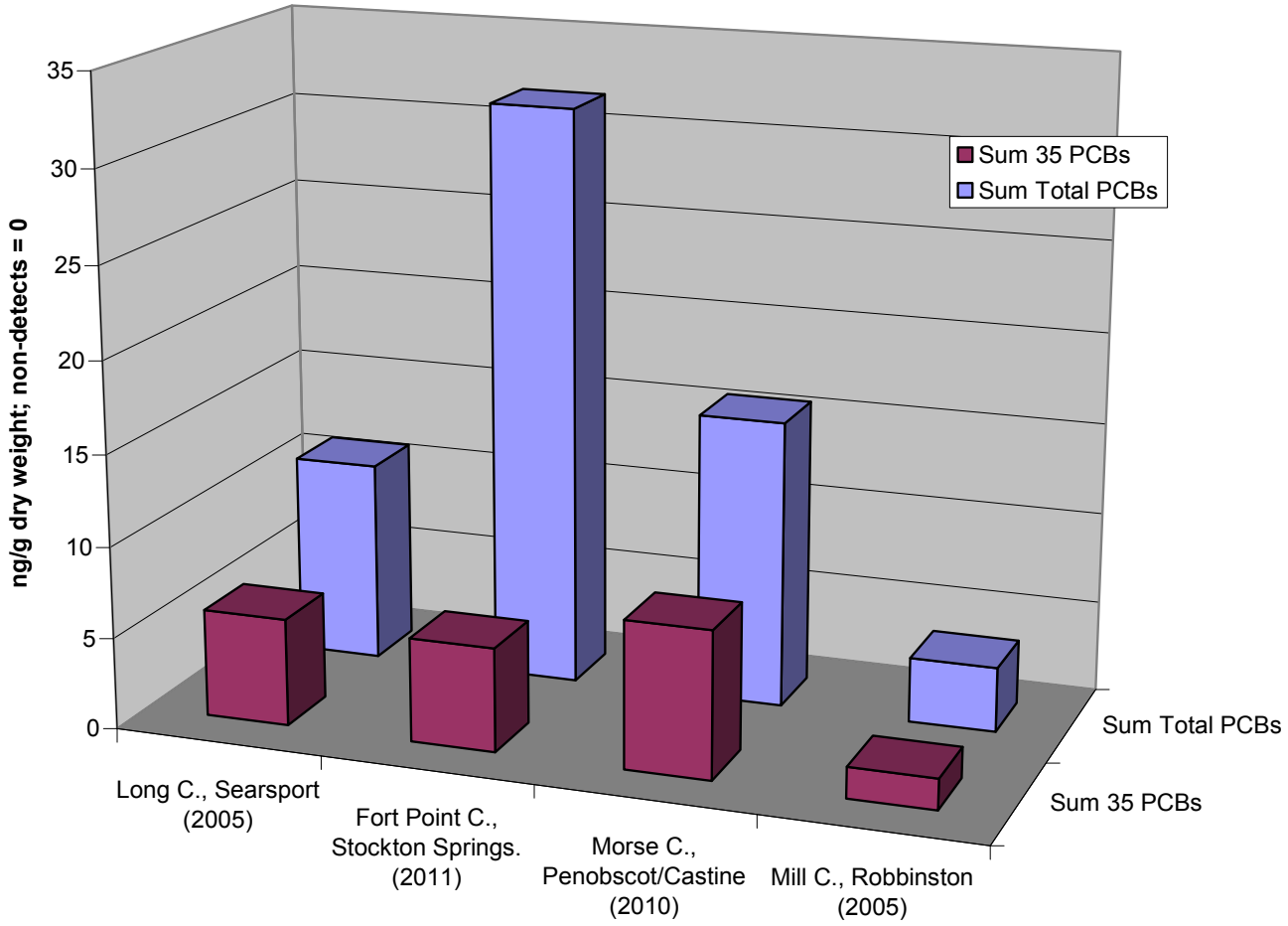
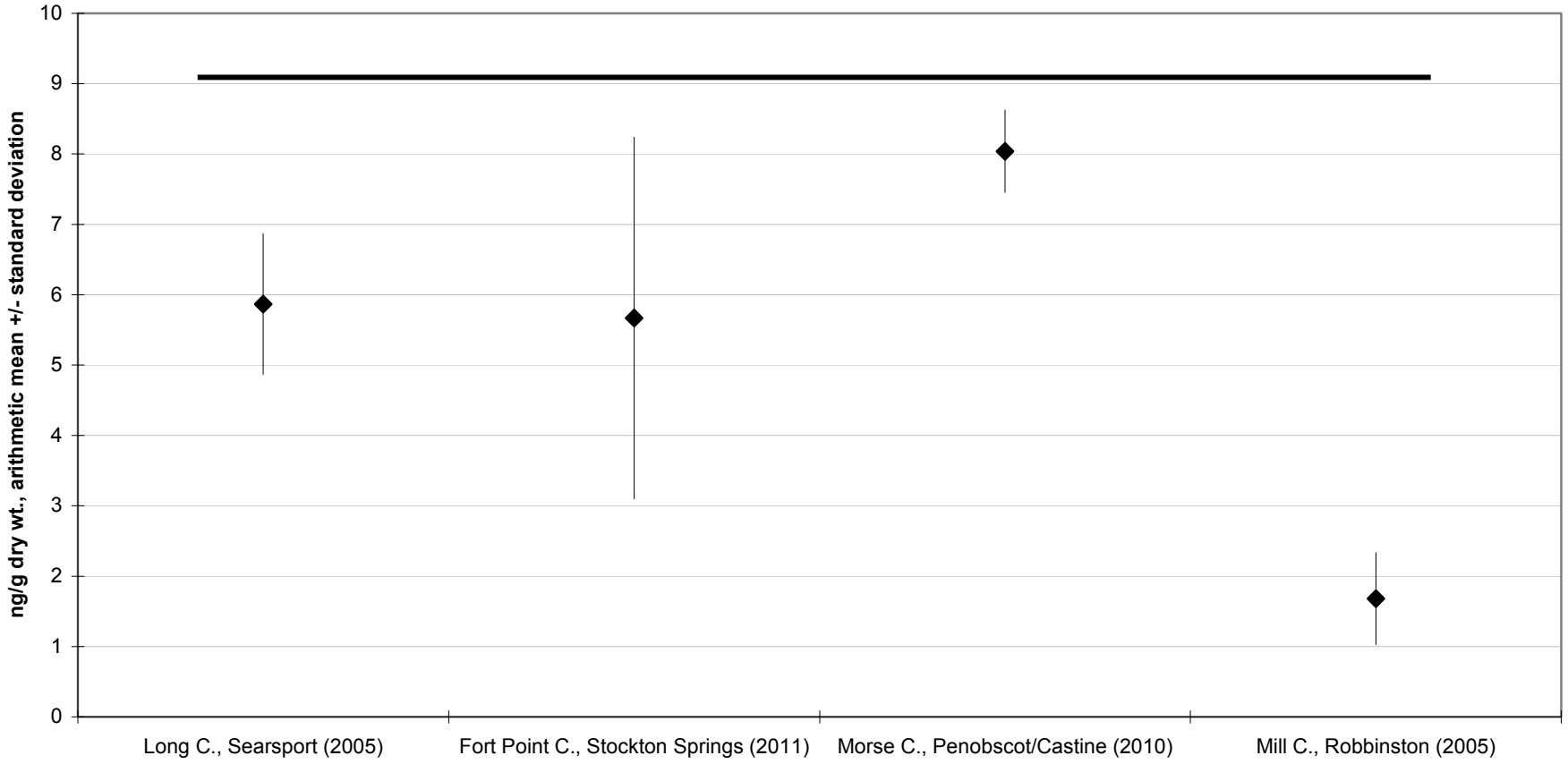


Figure 1.3.3.2.2: SWAT PCBs (Sum 35 PCBs) in SWAT Softshell Clams



Solid line = Gulfwatch 2008 softshell clam site at North Mill Pond, NH; three other 2008 Gulfwatch softshell clam sites had 0 Summed PCB concentrations (sum 31 Gulfwatch PCBs).

1.3.4 Pesticides

1.3.4.1 Blue Mussels

Blue mussels were tested for pesticides from four sites in 2011. Organochlorinated pesticide results were compared to national (NOAA NS&T, 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, respectively. To allow comparison to other NS&T 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 summations of these pesticide compound groups. Use of these summations assists in putting Maine SWAT data into a national context.

The NS&T 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 1.3.4.1.1 shows the Gulfwatch list of 21 organochlorinated pesticides (also used by NS&T Mussel Watch Program) and as well 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.

Table 1.3.4.1.1: Pesticides Utilized in SWAT Blue Mussel and Softshell Clam Analysis

	Gulfwatch Chlorinated Pesticides	SWAT 2010, 2011	SWAT 2005
Organochlorines			
ALDRIN	x	x	x
ALPHA-BHC	x	x	
BETA-BHC		x	
DELTA-BHC		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	
ENDRIN	x	x	x

ENDRIN KETONE		x	
HEPTACHLOR	x	x	x
HEPTACHLOR EPOXIDE	x	x	x
HEXACHLOROBENZENE	x	x	x
METHOXYCHLOR	x	x	
MIREX	x	x	x
CIS-NONACHLOR		x	
TRANS-NONACHLOR	x	x	x
OCTACHLOROSTYRENE		x	
OXYCHLORDANE		x	
PERTHANE		x	
QUINTOZENE		x	
TECNAZENE		x	
ENDRIN ALDEHYDE			
	21	34	19

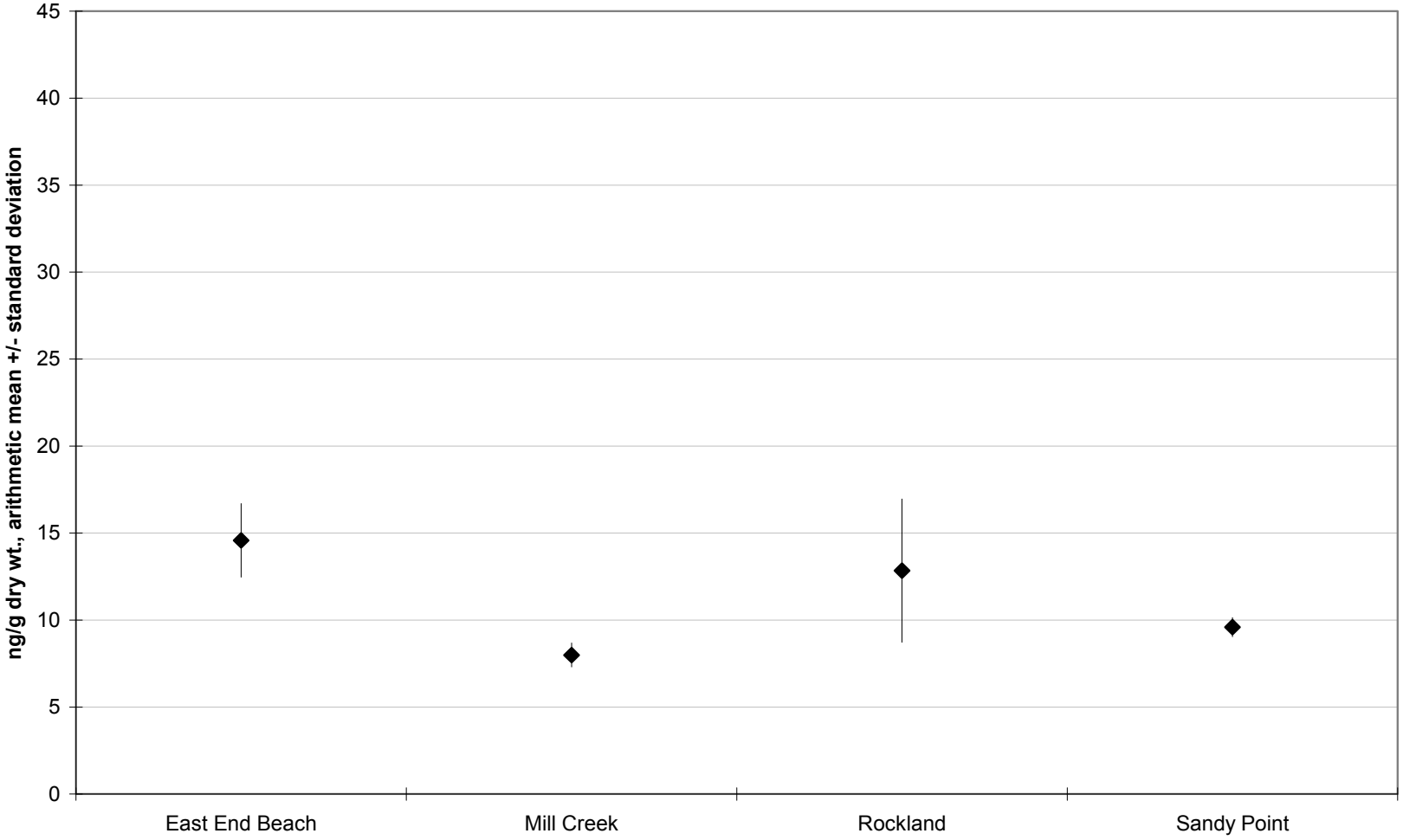
1.3.4.1.1 ΣDDTs

The summation of DDDs, DDEs, and DDTs, (six compounds total, called ΣDDTs in this report) is presented in Figure 1.3.4.1.1.1 for the four 2011 SWAT mussel sites. ΣDDTs ranged from a low mean concentration of 8.0 ng/g dry wt. at Mill Creek, Falmouth, to a high mean concentration of 14.6 ng/g dry wt. at East End Beach, Portland. The NS&T 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 four SWAT sites sampled in 2011 falling in the low category of that range. This is consistent with all mussel sites sampled Maine coast-wide over the past four years, with all falling into the low end of the low NS&T grouping.

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).

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 2011 SWAT blue mussel tissue DDT concentration was 1.6 ng/g wet wt., which is 2.5% of the more conservative MCDC cancer FTAL of 64 ng/g wet wt.

Figure 1.3.4.1.1.1: Sum of DDDs, DDEs, and DDTs in 2011 SWAT Blue Mussels



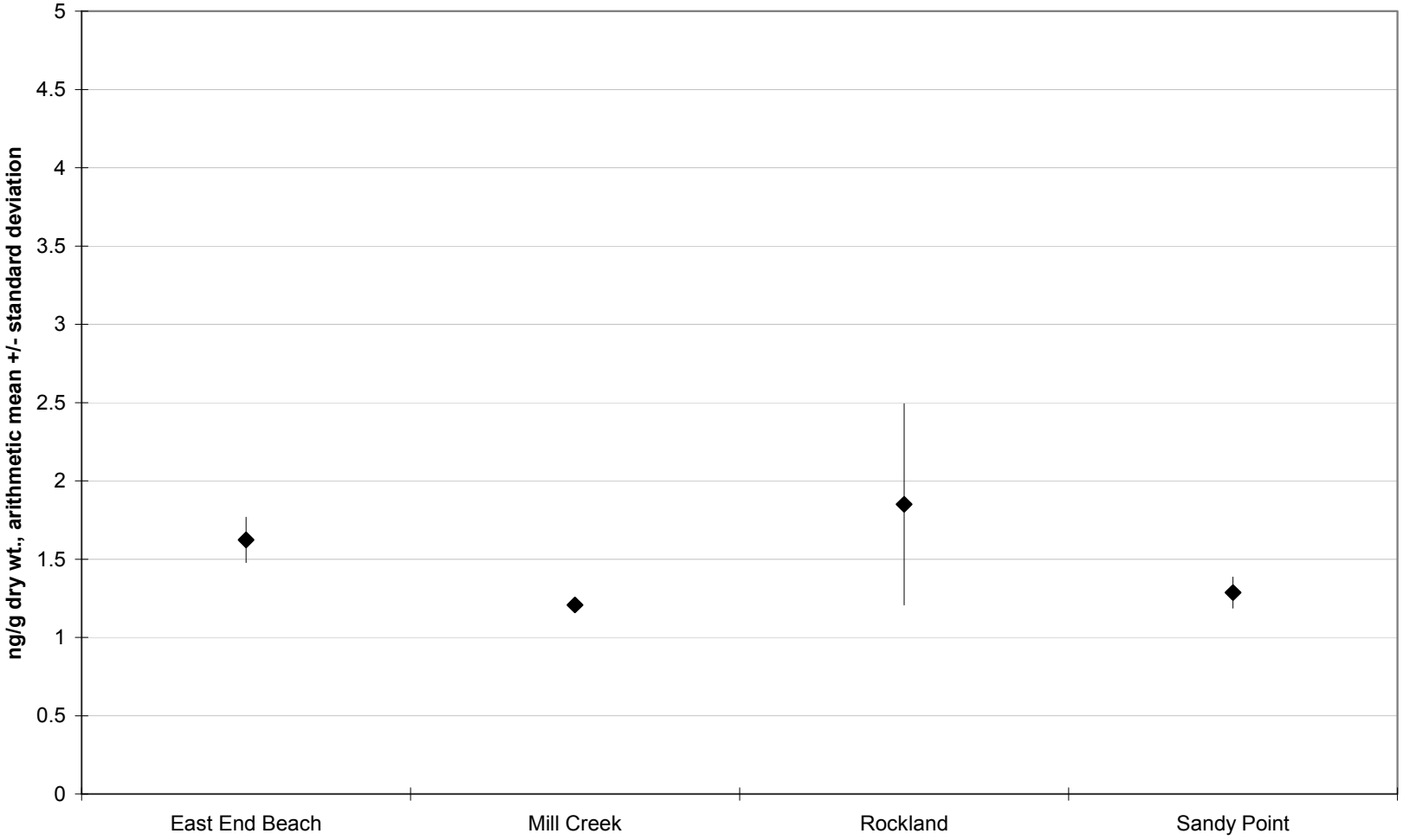
1.3.4.1.2 ΣChlordanes

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 1.3.4.1.2.1. ΣChlordanes ranged from a low mean concentration of 1.2 ng/g dry wt. at Mill Creek, Falmouth, to a high mean concentration of 1.9 ng/g dry wt. at Rockland. 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 sites sampled in 2011 fall in the lowest quarter 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 2011 SWAT blue mussel tissue data, when summed in the same manner, shows the highest mean concentration recorded to be 0.35 ng/g wet wt., which is 2.1% 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 2011 SWAT blue mussel tissue was 0.027 ng/g wet wt., which is 1.1% of the 2.4 ng/g wet wt. cancer FTAL.

Figure 1.3.4.1.2.1: Sum of Chlordanes in 2011 SWAT Blue Mussels



1.3.4.1.3 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 1.3.4.1.3.1. ΣDieldrins ranged from a low mean concentration of 0.45 ng/g dry wt. at Mill Creek, Falmouth, to a high mean concentration of 0.92 ng/g dry wt. at Rockland. NS&T 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 of the 2011 SWAT sites falling in the bottom 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 2011 SWAT data was 0.17 ng/g wet wt., which is 9.4% 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 2011 SWAT data was 0.043 ng/g wet wt., which is 3.3% of the MCDC cancer FTAL.

1.3.4.1.4 Σ21 Organochlorines

The summation of 21 organochlorine pesticides (as noted in Table 1.3.4.1.1) was determined from SWAT data and is presented in Figure 1.3.4.1.4.1 (21 compounds total, called Σ21 Pesticides in this report). Σ21 Pesticides ranged from a low mean concentration of 11.1 ng/g dry wt. at Mill Creek, Falmouth, to a high mean concentration of 19.1 ng/g dry wt. at East End Beach, Portland. Figure 1.3.4.1.4.1 compares the sum of Σ21 Pesticides at the 2011 SWAT sites to recent Gulfwatch median and 85th percentile for Σ21 Pesticides (2008 data, the most recent available). All four of the 2011 SWAT sites exceeded the Gulfwatch 2008 median, 9.9 ng/g (dry weight) for Σ21 Pesticides. Two sites exceeded the Gulfwatch 85th percentile, 14.3 ng/g (dry weight), for Σ21 Pesticides (East End Beach, Portland, and Rockland).

Figure 1.3.4.1.4.1 also compares the sum of Σ21 Pesticides at the 2011 SWAT sites to recent NS&T Mussel Watch median and 85th percentile for Σ21 Pesticides (2008 data, the most recent available). None of the four SWAT sites tested exceeded the NS&T 2008 median, 22.9 ng/g (dry weight), for Σ21 Pesticides, or the NS&T 85th percentile of 128 ng/g (dry weight) for Σ21 Pesticides.

Figure 1.3.4.1.3.1: Sum of Dieldrins in 2011 SWAT Blue Mussels

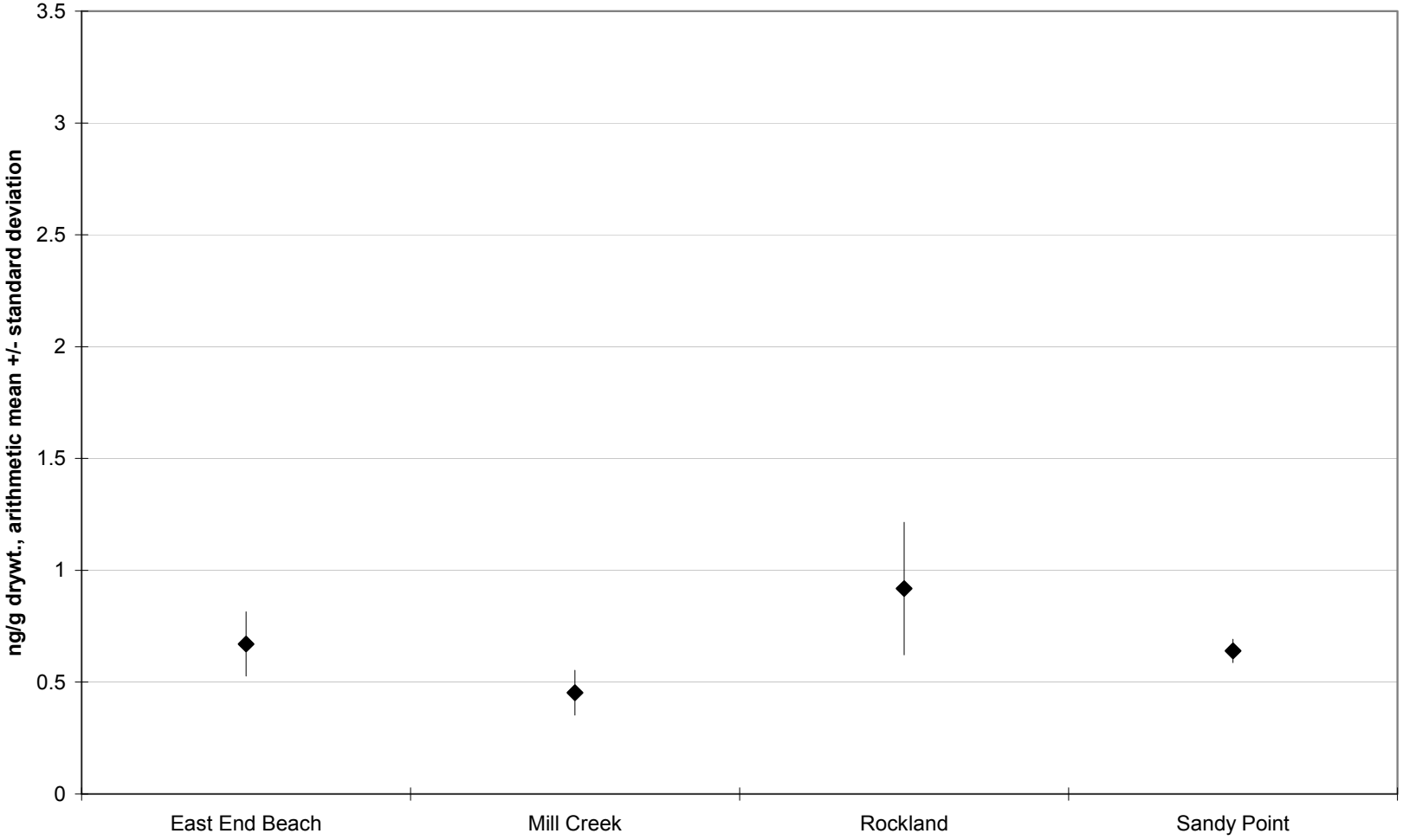
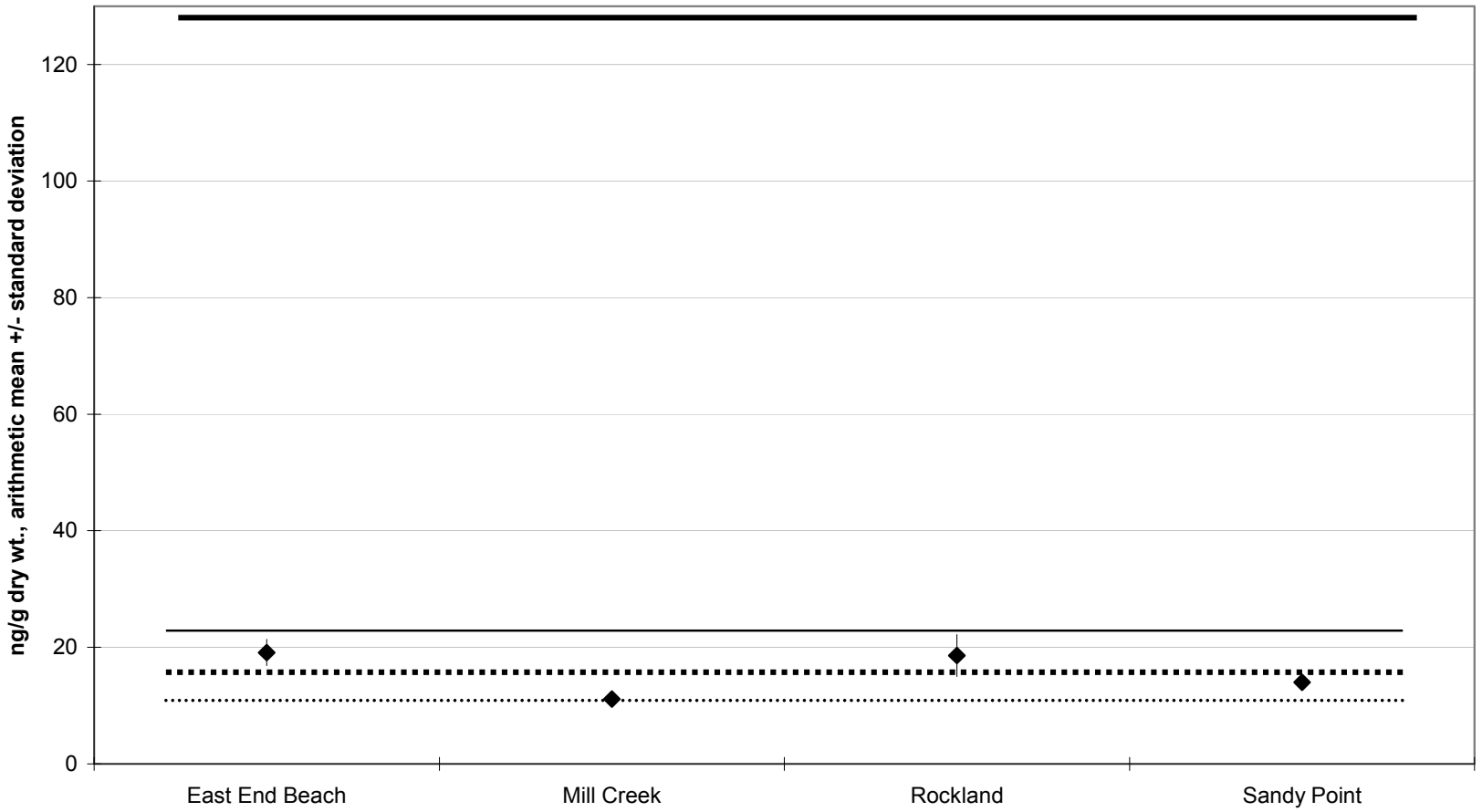


Figure 1.3.4.1.4.1: Sum of Chlorinated Pesticides in 2011 SWAT Blue Mussels



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

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.

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 2011 was 0.057 ng/g wet wt., which is 0.4% 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 2011 was 0.155 ng/g wet wt., which was 3.1% 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 2011 was 0.180 ng/g wet wt., which was 0.04% 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 by SWAT in 2011 was 0.244 ng/g wet wt., which was 1.4% 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 2011 was 0.093 ng/g wet wt., which was 0.0007% of the MCDC non-cancer FTAL.

1.3.4.2 Softshell Clams

Softshell clam tissue was sampled from Fort Point Cove, Stockton Springs (2011), Morse Cove, Castine (2010), and Long Cove, Searsport; Fort Point Cove, Stockton Springs; and Mill Cove, Robbinston (2005) and analyzed for pesticides. Organochlorinated pesticide results were compared to national (NOAA NS&T, 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, respectively. To allow comparison to other NS&T 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 summations of these pesticide compound groups. Use of these summations assists in putting Maine SWAT data into a national context.

The summations of 21 organochlorinated pesticides utilized by the NS&T and Gulfwatch programs were discussed previously in Section 1.3.4.1, and Table 1.3.4.1.1 in that section

shows the Gulfwatch list of 21 organochlorinated pesticides (also used by NS&T Mussel Watch Program) and 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.

1.3.4.2.1 ΣDDTs

The summation of DDDs, DDEs, and DDTs, (six compounds total, called ΣDDTs in this report) is presented in Figure 1.3.4.2.1.1 for the four SWAT softshell clam sites, including the re-sampling of Fort Point Cove, Stockton Springs, in 2011. ΣDDTs ranged from a low mean concentration of 4.1 ng/g dry wt. at Mill Cove, Robbinston, to a high mean concentration of 5.2 ng/g dry wt. at Long Cove, Searsport. ΣDDTs at Fort Point Cove appears to have decreased slightly or remained steady from 2005 to 2011 (5.1 to 4.6 ng/g dry wt.). The NS&T 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 four SWAT clam sites falling in the low category of that range.

ΣDDTs are also 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).

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 SWAT softshell clam tissue DDT concentration was 0.70 ng/g wet wt., which is 1.1% of the more conservative MCDC cancer FTAL of 64 ng/g wet wt.

1.3.4.2.2 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 1.3.4.2.2.1. ΣChlordanes ranged from a low mean concentration of 0.8 ng/g dry wt. at Fort Point Cove, Stockton Springs (2011), to a high mean concentration of 3.1 ng/g dry wt. at Mill Cove, Robbinston. 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 four SWAT clam sites sampled fall in the lower half of that low category (Kimbrough, 2008). Chlordanes are discussed in more detail in the previous Section 1.3.4.1.2, including their geographic distribution, composition, historic usage, and recent trends.

Figure 1.3.4.2.1.1: Sum of DDDs, DDEs, and DDTs in SWAT Softshell Clams

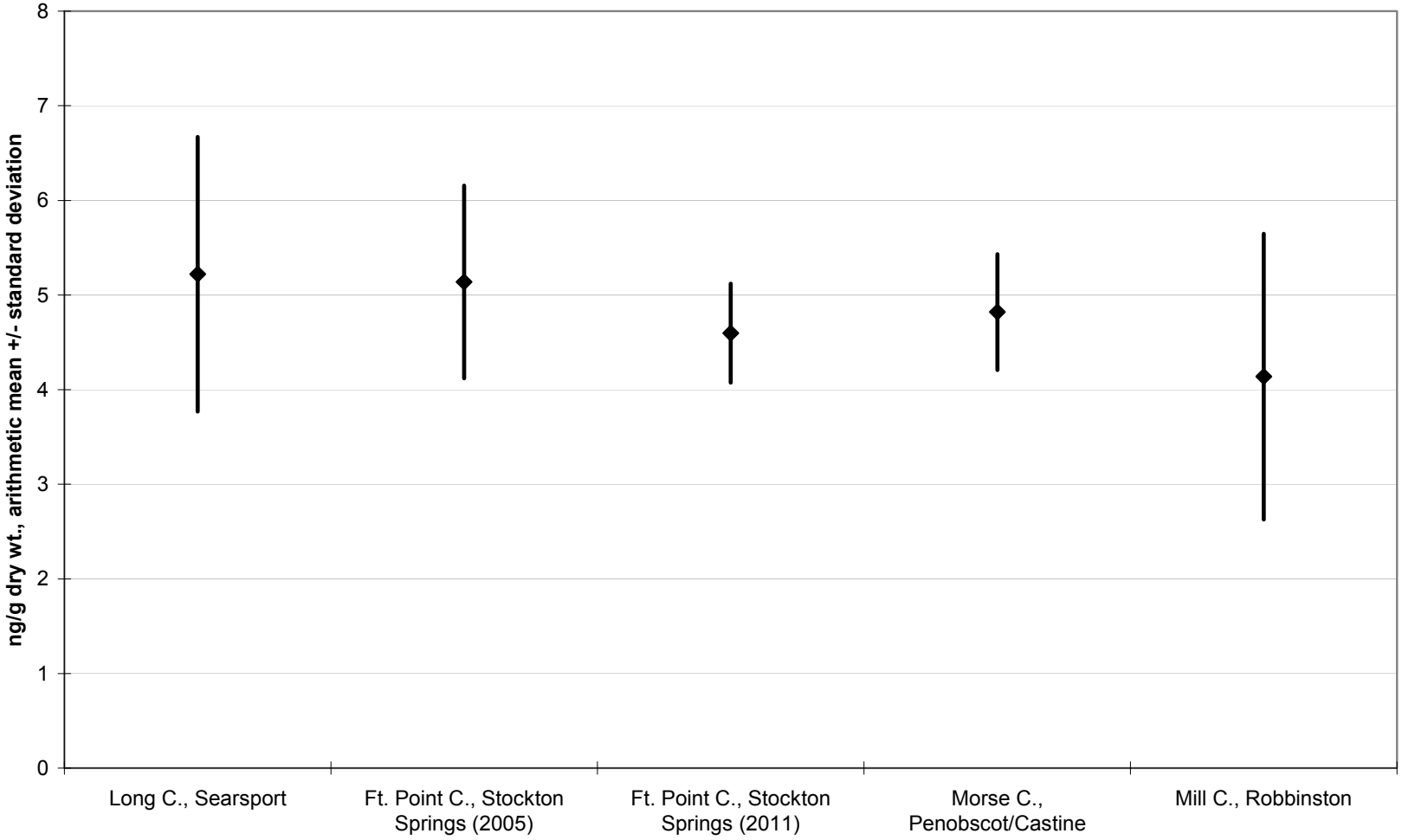
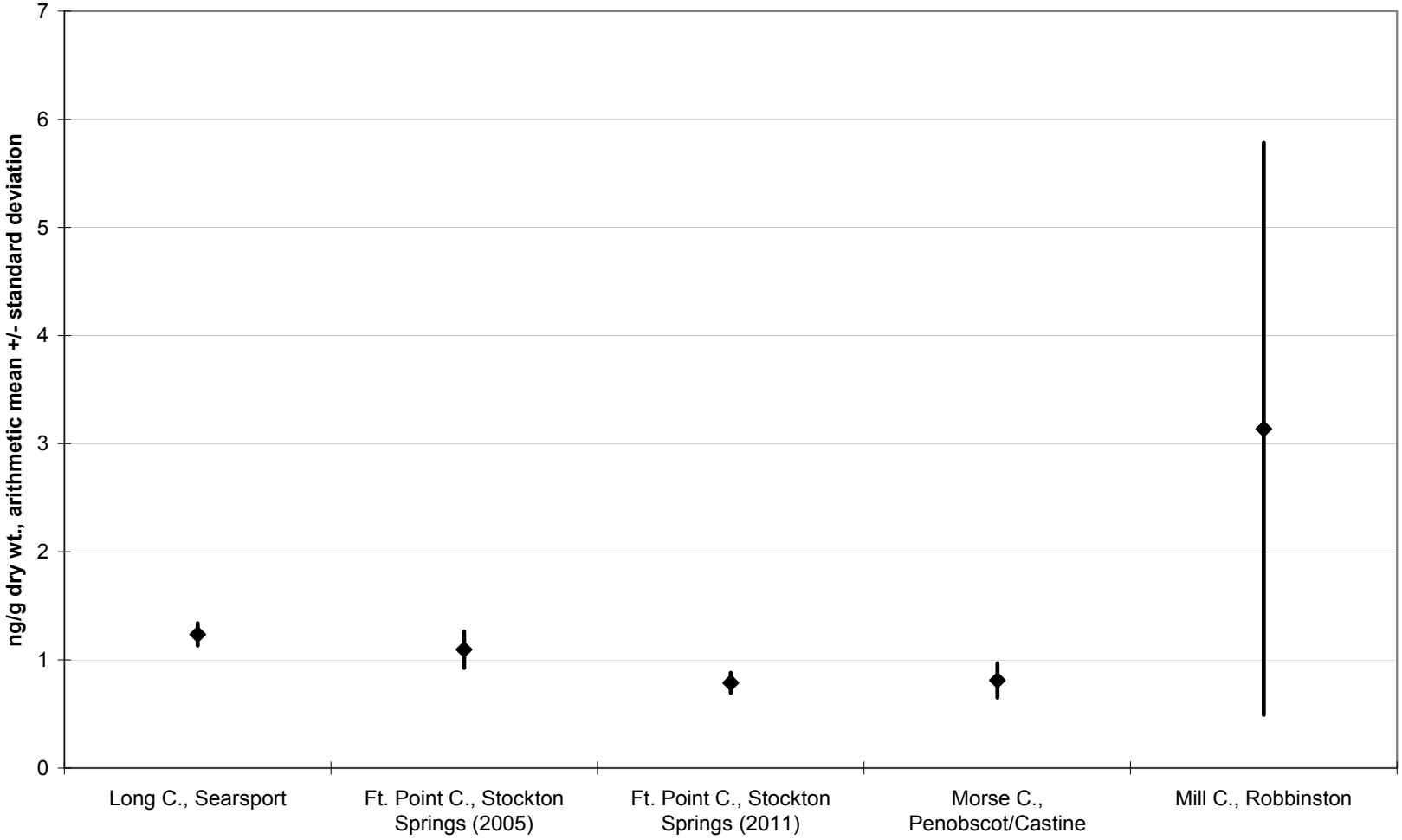


Figure 1.3.4.2.2.1: Sum of Chlordanes in SWAT Softshell Clams



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 SWAT clam tissue data, when summed in the same manner, shows the highest mean concentration recorded at a site to be 0.24 ng/g wet wt., which is 1.4% 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 SWAT clam tissue was 0.165 ng/g wet wt., which is 6.5% of the 2.4 ng/g wet wt. cancer FTAL.

1.3.4.2.3 ΣDieldrins

The summation of aldrin and dieldrin (two compounds total, called ΣDieldrins in this report) was determined from SWAT clam tissue data and is presented in Figure 1.3.4.2.3.1. ΣDieldrins ranged from a low mean concentration of 0.40 ng/g dry wt. at Morse Cove, Castine, to a high mean concentration of 0.61 ng/g dry wt. at Mill Cove, Robbinston. NS&T 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 three of the 2010 SWAT softshell clam sites falling in the bottom of the low category (Kimbrough, 2008). The geographic distribution, historic usage, and recent trends in dieldrins are discussed in Section 1.3.4.1.3 in relation to blue mussels.

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 SWAT softshell clam tissue was 0.073 ng/g wet wt., which is 5.2% 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 data was 0.028 ng/g wet wt., which is 2% of the MCDC cancer FTAL.

1.3.4.2.4 Σ21 Organochlorines

The summation of 21 organochlorine pesticides (as noted in Table 1.3.4.1.1) was determined from SWAT softshell clam data and is presented in Figure 1.3.4.2.4.1 (21 compounds total, called Σ21 Pesticides in this report). Σ21 Pesticides ranged from a low mean concentration of 7.65 ng/g dry wt. at Morse Cove, Castine, to a high mean concentration of 13.71 ng/g dry wt. at Fort Point Cove, Stockton Springs (2005). Figure 1.3.4.2.4.1 compares the sum of Σ21 Pesticides at the SWAT clam sites to a recent Gulfwatch median at four clam sites (2008 data, the most recent available). All five of the SWAT mean concentrations exceeded the Gulfwatch 2008 median, 4.2 ng/g (dry weight) for Σ21 Pesticides. No Gulfwatch 85th percentile was calculated since only four Gulfwatch clam sites comprised the entire 2008 data set. Of note is the highest scoring Gulfwatch clam site, with Σ21 Pesticides of 12.0 ng/g (dry weight) at North Mill Pond, NH, which was quite similar to the highest Maine SWAT clam site.

Of the five SWAT clam mean concentrations, none exceeded the NS&T 2008 median, 22.9 ng/g (dry weight), for Σ21 Pesticides in shellfish, and consequently none of the

SWAT sites exceeded the NS&T 85th percentile of 128 ng/g (dry weight) for Σ21 Pesticides.

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.

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 softshell clam tissue detected by SWAT was 0.89 ng/g wet wt., which is 6.4% 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 SWAT clam tissue was 0.22 ng/g wet wt., which was 4.4% 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 SWAT clam tissue was 0.066 ng/g wet wt., which was 0.02% of the MCDC non-cancer FTAL. All mirex results from clam tissue analyzed yielded non-detects at the detection limits utilized by the two labs.

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 SWAT clam tissue was 0.16 ng/g wet wt., which was 0.9% 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 SWAT clam tissue was 0.083 ng/g wet wt., which was 0.0006% of the MCDC non-cancer FTAL. All endosulfan results from clam tissue analyzed yielded non-detects at the detection limits utilized by the two labs.

Figure 1.3.4.2.3.1: Sum of Dieldrins in SWAT Softshell Clams

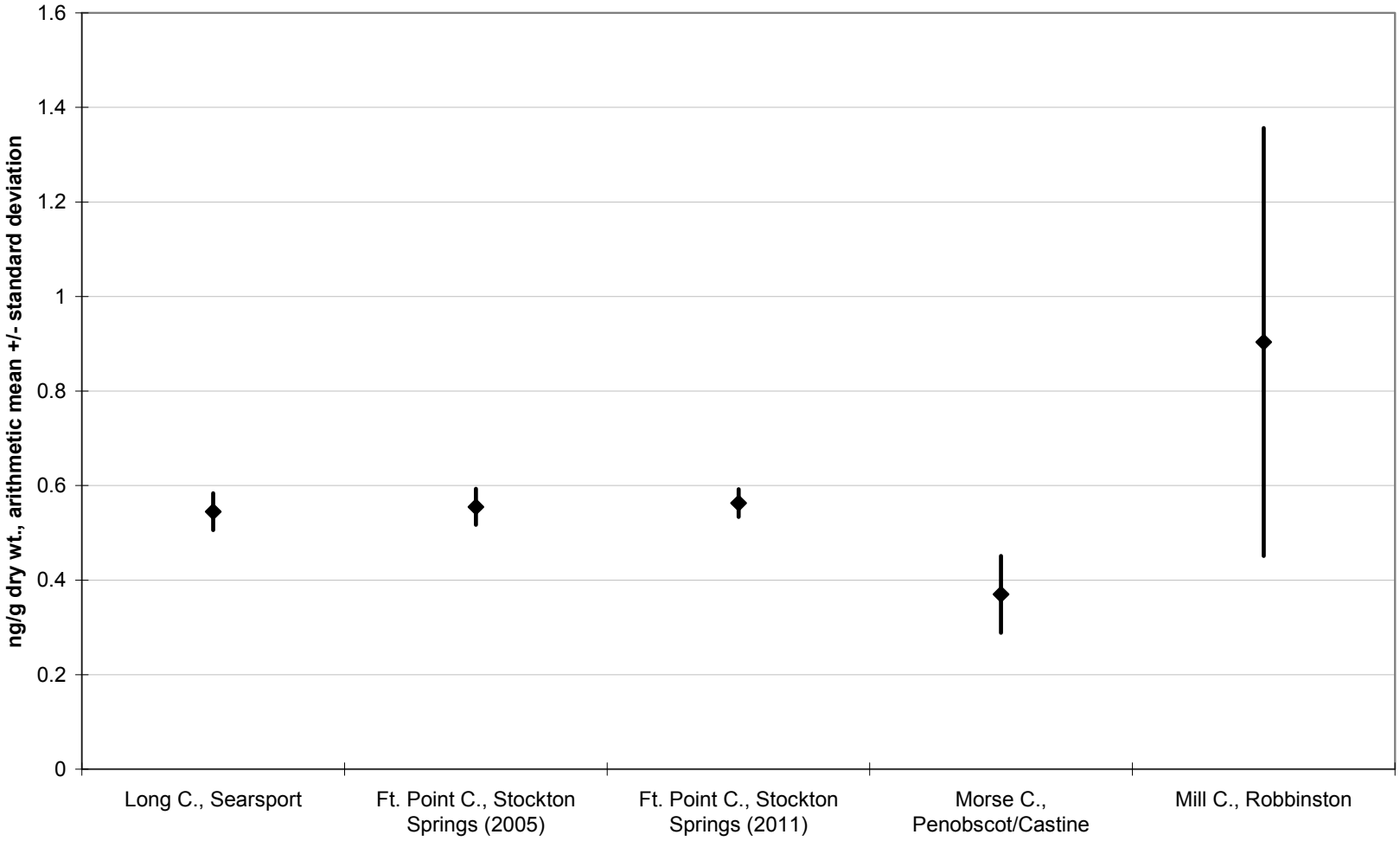
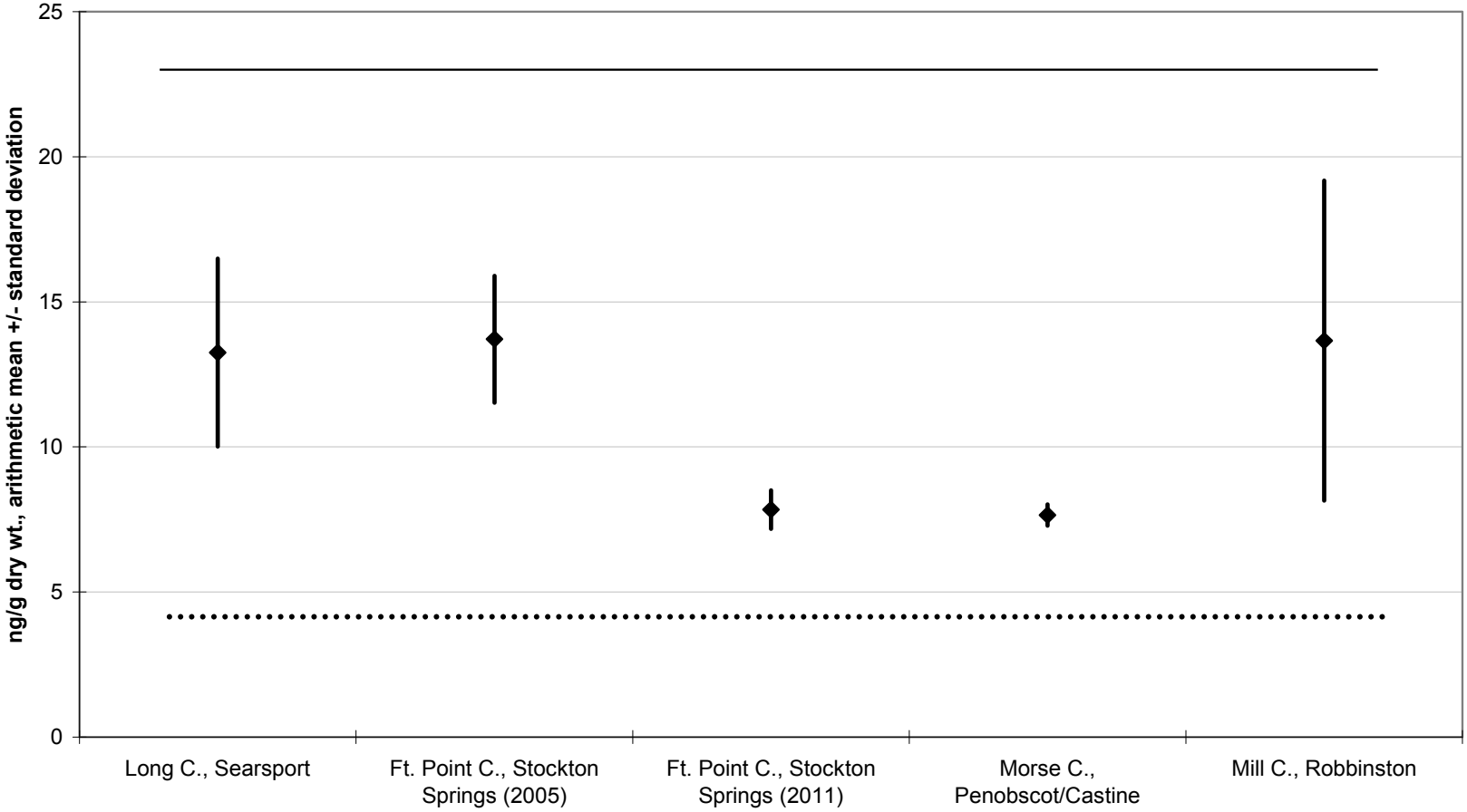


Figure 1.3.4.2.4.1: Sum of 21 Chlorinated Pesticides in SWAT Softshell Clams



Dotted line = Gulfwatch 2008 Mean (four Softshell Clam Sites in NH, ME); Solid line = National Status and Trends 2008 Median (NS&T 85th percentile not shown = 128 ng/g dry wt.).

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2.0 LAKES MODULE

2.1 MERCURY IN LAKE FISH

2.1.1 Introduction

As the second year of a two year program, in 2011 fish were to be collected from 50 plus Maine lakes to meet the objectives of the Maine Center for Disease Control and Prevention (ME-CDC) and DEP. Lakes and species to be sampled were selected so that all samples would be useful for both agencies.

As requested by ME-CDC, sampling for the year was geared primarily toward filling data gaps identified in the sampling network and establishing a current baseline data set for mercury. Data were also requested from as many of the lakes sampled previously such that current mercury levels can also be compared to historical mercury levels from similar locations in an attempt to determine any trending in the data sets.

Also, in collaboration with researchers at the University of Maine, DEP targeted fish from certain types of lakes to try to determine factors that influence mercury accumulation in fish. From the literature the most important factors that may affect mercury concentrations in fish seem to be drivers of lake trophic status (i.e., nitrogen, phosphorus, iron, aluminum, pH), lake mercury concentrations, and watershed characteristics. From the list of REMAP lakes and other lakes with mercury concentrations in fish from 10 years ago or longer, DEP selected lakes whose characteristics included combinations of the range of variables that are correlated with these factors. Maximum depth, average dissolved organic carbon (DOC), and epilimnetic total phosphorus (TP) concentrations were trisected yielding 27 possible combinations. Some of these factor combinations did not have representation in the existing dataset of 216 lakes for which there were filet mercury, DOC and TP data, so other white perch lakes which had DOC and TP data were targeted. From the resulting set of 443 lakes, 102 lakes were selected to be sampled over the two year period and prioritized according to fish tissue sampling history. Due to limited staff time for sampling, half of the lakes were targeted in 2010 with the rest targeted for 2011. Lakes having white perch were of particular interest because this species is the most common one for which we have data and was the species with the highest mercury concentrations in the REMAP Study of Fish Contamination in Maine Lakes from the early 1990's.

From each lake, 10 fish were to be collected. Species included the species previously collected if possible and white perch, black bass, chain pickerel, lake trout, or yellow perch in order of preference. These were the species having the highest mercury concentration in the REMAP data set and are, for the most part, game fish caught and eaten by Maine anglers. A possible exception is yellow perch, which are not consumed by many anglers, but are common, are consumed by common loons and other piscivorous birds, and have been used in ecological risk analysis in Maine and the rest of New England. Water quality and sediment data were collected by DEP's lakes staff during the August 'baseline' period.

Studies from 2008 to 2010 showed that the analysis of biopsy samples of fish tissue for mercury by the Direct Mercury Analyzer (DMA80) housed at the Sawyer Environmental Research and Chemistry Lab (SERCL) at the University of Maine provided data as accurate and precise as analysis of filets by commercial laboratories using standard methods. The benefits of biopsy

sample analysis at SERCL include lower cost, ability to work with a Maine lab, and potentially non-lethal sampling of the fish in the future.

2.1.2. Methods

Fish were captured by gill nets and angling. Gill net sets were short as possible (usually checked every hour or so) to ensure capture of live fish and avoid oversampling of the lake. To avoid a potential bias due to desiccation, fish were captured and kept in a plastic bag on ice in a cooler until transfer to the lab where the biopsy samples were taken at the end of the day or fish stored in a refrigerator until biopsy samples were collected the next morning. The biopsy samples were then frozen in 2 ml cryovials. At the lab a subsample of the contents of the cryovial was weighed and transferred to the DMA 80 quartz sample boat for analysis. Biopsy samples were analyzed at SERCL by the DMA80 using Method 7473.

2.1.3. Results

In 2011, we were unsuccessful in collecting any or enough fish from some lakes. A total of 46 samples of 10 fish from a total of 44 lakes (for all but 2 lakes where N<4 and N>13) were collected. White perch were collected from all 44 lakes, and smallmouth bass were also collected from 2 lakes. Mean concentrations in white perch from the lakes ranged from 0.13 ug/g to 1.42 ug/g (Figure 2.1). Fish from all but one lake (Chickawaukie Pond) exceeded the ME-CDC's Fish Tissue Action Level (FTAL = 0.2 ug/g) for mercury. There were 10 lakes with previous data from the 1990s. For Highland Lake and Toddy Pond, there were not enough data from the 1990s for statistical comparisons with 2011 data, leaving 8 lakes with enough data to make statistical comparisons. Given that mercury concentrations in fish vary with size and age, comparisons in mercury concentrations were made using ANCOVA with length as the covariate. The results show that there were 3 lakes where concentrations were significantly higher in 2011 than in the 1990s, 2 lakes where concentrations were lower, and 2 lakes where there was no difference. These results are similar to those of 2010, where concentrations were higher in fish from 16 lakes and lower in 10 lakes than concentrations in the 1990s. Consequently, there appears to be no statewide trend during the last 20 years.

Comparison of concentrations in white perch from 2011 with concentrations in other species from the 1990s demonstrates differences among species (Figure 2.1). Concentrations were often relatively similar in multiple species, corroborating a lake's status as a high, medium, or low mercury lake.

The data are sent to ME-CDC for use in evaluation of the statewide fish consumption advisory.

Table 2.1. Mercury concentrations in fish from Maine lakes, 2011 and 1990s.

LAKES	MIDAS	SPECIES	HG ug/g 2011	HG ug/g 1990s	% 2011-1990s	SIGDIF 2011-1990s	SPECIES 1990s	HG ug/g 1990s
BASKAHEGAN L	1078	WHP	0.88				SMB	0.78
BISCAY P	5710	WHP	0.81				BNT	0.28
BISCAY P	5710						SPK	0.39
BRACKETT L	1068	WHP	0.75					
BRACKETT L	1068	SMB	0.45	0.31	45	+		
CENTER P	760	WHP	0.53					
CHICKAWAUKIE P	4822	WHP	0.13					
COCHNEWAGON P	3814	WHP	0.39					
COLD STREAM P	2146	WHP	0.61					
CRESCENT L	3696	WHP	0.53					
DEXTER P	3830	WHP	0.34					
ECHO L	5814	WHP	0.65	0.83	-22	-	LKT	0.50
ECHO L	5814						SMB	0.57
EAST GRAND L	1070	WHP	0.33					
FISH P	4802	WHP	0.59					
FLANDER P	4388	WHP	0.67					
GASSABIAS L	4782	WHP	1.42					
HIGHLAND L (Bridgton)	3454	WHP	0.51	0.10	410		BNT	0.24
HIGHLAND L (Bridgton)	3454						LMB	0.23
HIGHLAND L (Bridgton)	3454						SMB	0.35
HOBBS P	4806	WHP	0.30					
JO-MARY L (UPPER)	243	WHP	0.71					
L GEORGE	2608	WHP	1.22	0.34	259	+		
LONG L (Bridgton)	5780	WHP	0.58					
MEGUNTICOOK L	4852	WHP	0.69					
MESSALONSKEE L	5280	WHP	0.24	0.42	-43	-		
MILLINOCKET L	2020	WHP	0.47	0.61	-23	0	LKT	0.56
MOLUNKUS L	3038	WHP	1.03					
MOLUNKUS L	3038	SMB	0.54	1.22	-56	0		
MUSQUASH L (EAST)	1088	WHP	1.24					
NEQUASSET L	5222	WHP	0.58				BNT	0.46
NORTH P (ROME)	5344	WHP	0.53					
NORTH P (Warren)	5690	WHP	0.79					
OSSIPEE L (LITTLE)	5024	WHP	0.25				BKT	0.02
OSSIPEE L (LITTLE)	5024						LKT	0.54
PARKER P	3388	WHP	0.44					
PARKS P	4272	WHP	1.26					
PLEASANT RIVER L	1210	WHP	0.85					
PUSHAW L	80	WHP	0.29					
PUSHAW P (LITTLE)	2156	WHP	0.37					
SANDY P (Freedom)	5174	WHP	0.54	0.22	145	+	LMB	0.35
SILVER (MATTAKEUNK) L	2242	WHP	0.25					
SPEDNIK L	121	WHP	0.29					
TODDY P	5490	WHP	0.76	0.47	62		LMB	0.58
TODDY P	5490						SMB	1.10
UNITY P	5172	WHP	0.41	0.33	24	0		
WASHINGTON P	4894	WHP	0.39					
WEBB L	3672	WHP	0.57					
WESSERUNSETT L	70	WHP	0.45					
WILSON P	3682	WHP	0.72					
WILSON P (LOWER)	342	WHP	0.50					
WILSON P (UPPER)	410	WHP	0.56					

SIGDIF = length adjusted signifcant difference, p<0.05; 2011 compared to 1990s; '+' = higher, '-' = lower, '0' = no difference

3.0 RIVERS AND STREAMS MODULE

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 potentially 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 2011, we evaluated the condition of 39 sample locations, primarily in the Penobscot and Downeast 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 (DEP Rule Chapter 579). 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 2011 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.
- *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. An 'NA' (Non-attainment) indicates that the sample did not meet the minimum Class C criteria. An 'I' (Indeterminate) indicates that a final decision could not be made based on the aquatic community collected.
- *Attains Class* – "Yes" is given if the final determination is equal to or exceeds the Statutory Class. A Class B stream, for example, would receive a "Yes" if its Final determination was either A or B. "No" is given if a stream does not attain its Statutory Class. A Class B stream, for example, would receive a "No" 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 other factors.

Field and water chemistry data for each sampling event (where available) are given in Table 3.1.2 and 3.1.3, respectively. The data from tables 3.1.1 to 3.1.3 is also summarized in reports for each

sampling event, known as Aquatic Life Classification Attainment Reports, which are available in electronic format with the web version of this report. Continuous water temperature data are given in Figure 3.1.1. The attainment history of sampling stations prior to 2011, where available, is given in Table 3.1.4.

For more information about the Biological Monitoring Unit, please e-mail us at biome@maine.gov or visit our web site: http://www.maine.gov/dep/water/monitoring/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

The Biological Monitoring Unit concentrated its sampling in 2011 in the Penobscot and Downeast region. Thirty-nine stations were sampled under the SWAT Program (Table 3.1.1).

All stations have been analyzed for aquatic life attainment with twenty-six stations in attainment of their statutory class. Seven stations exceeded their assigned class. So far no licensing / relicensing issues have been found in waterbodies sampled below municipalities or industries. The streams that did not attain their statutory class were located on small urban, residential, and rural systems; summaries on these streams are found below.

Birch Stream – Bangor Station 312
Birch Stream is located below Bangor International Airport and the Airport Mall and much of the headwaters of the stream have been altered through the years. The stream did not attain the minimum Class C criteria for aquatic life. The macroinvertebrate community consisted of a low number of organisms with Total Mean Abundance and Generic Richness barely meeting minimum criteria. Sensitive taxa were present in very low numbers. Specific conductance and total dissolved solids were high and indicative of an urban system (Table 3.1.2 and 3.1.3). Deicer continues to impact the benthic community as well as an altered hydrology which has affected the habitat and stream bank stability. The stream bottom condition has improved as a result of efforts to contain the deicer. Sewage fungus was not present in 2010 or 2011. The stream has been listed on our 303(d) list and is a designated TMDL stream; it has not attained class since first being sampled in 1997 (Table 3.1.4).

Card Brook – Ellsworth Stations 814 and 815
Card Brook is a small Class B stream originating above Ellsworth and flowing southwest before entering the Union River. There is a large wetland complex above Route 3 that is a major part of the watershed. Station 814, which is located upstream of Route 3, did not meet the minimum Class C aquatic life criteria. The station is above most of the urban area in Ellsworth but is still impacted by development in the watershed. The specific conductance at station 814 is fairly high and dissolved oxygen (DO) readings in the stream were below 6 mg/l (Table 3.1.2). The low dissolved oxygen is probably a reflection of the wetland complex upstream of Route 3. There were very few sensitive organisms present in the community with the dominant taxa consisting of collector-filterers from the families *Chironomidae* and *Hydropsychidae*. Station 815, located below Route 230, met the Class C aquatic life criteria. The benthic community was very similar to the upstream station. Sensitive taxa were in low abundance and collector-filterers were the dominant organisms.

Specific conductance increased at the lower station but dissolved oxygen (DO) recovered from the low value upstream (Table 3.1.2). There was significant erosion on the right bank of the stream indicating storm water surges in the system which is probably limiting the community.

Carleton Stream – Blue Hill Station 526

Carleton Stream is a second order stream that flows through a former copper mine that has been mitigated. Station 526 is located below Second Pond and the former mining site and is located just above First Pond. This section of the stream is classified as Class C. The benthic macroinvertebrate community did not meet the Class C aquatic life criteria. The number of sensitive organisms was very low as was Generic Diversity. The three most dominant taxa made up 90% of the community. These three organisms were collector filterers. The community may be affected by the ponds, beaver activity, and wetland system upstream. The specific conductance and pH were in the normal range and did not indicate impact from the mining location (Table 3.1.2).

Great Falls Branch – Deblois Station 504

Great Falls Branch is a Class AA stream downstream of Route 193 in Deblois. Jasper Wyman & Son transports blueberry waste products to a site above Route 193 for storage. Leachate flowing from the storage pile eventually discharged into the Great Falls Branch. The leachate consisted of unprocessed waste berries, leaves, and twigs. The aquatic community below Route 193 in Deblois did not meet the minimum Class C aquatic life criteria. The aquatic community indicated a low abundance and very low diversity. There were only a few sensitive organisms present. Sensitive taxa such as stoneflies and mayflies should be present in good numbers in a Class A system. Polypedilum (a tolerant midge) and Nyctiophylax (a low DO tolerant caddisfly) made up 65% of the community. The dissolved oxygen (DO) at retrieval was 3.1 mg/l and pH had dropped to 4.31 (Table 3.1.2). Soluble Reactive Phosphorus (SRP) was measured at 480 ppb (Table 3.1.3). Corrective action was initiated in late August 2011.

Penjajawoc Stream – Bangor Stations 511, 314, and 315

Penjajawoc Stream is a Class B stream flowing southeast through the Bangor Mall and crossing Route 2 before entering the Penobscot River. Station 511 is below a large wetland area and above Stillwater Avenue. Station 314 is directly below the I-95 crossing and Station 315 is located above Route 2. The stream enters the Penobscot River directly below Route 2. Specific conductance was high at all stations but increased below I-95 (Table 3.1.2) to a high of 844 microS/cm. Total Dissolved Solids (TDS) were also very high at Station 314 (Table 3.1.3). All three Stations met the Class C aquatic life criteria. There were very few sensitive organisms found in the samples but the Generic Richness was fairly high. There was a replacement of sensitive organisms in the system by more tolerant taxa which maintained the structure and function of the community. The taxa replacement was enough to meet the Class C aquatic life criteria. Twenty-five per cent of the upstream community (Station 511) consisted of organic tolerant Isopods. This is probably indicative of the transition area directly below the wetland. The benthic community below I-95 (Station 314) showed some enrichment. The Total Mean Abundance was over 1000 organisms per sampler. Over 50% of the community was made up of filter feeders. The stream has been sampled extensively since 1997 (Table 3.1.4).

Shaw Brook – Herman Station 480

Shaw Brook is a small Class B stream originating near the Bangor Airport and flowing south through an industrial park area in Herman. Station 480 is located below Odlin Road in Herman. The stream did not meet the Class C aquatic life criteria. Total mean abundance was very low and did not meet the minimum provisions to run through the attainment model. The majority of organisms collected were tolerant midges. The system is highly altered with a great deal of siltation occurring in the stream. The dissolved oxygen (DO) in the stream at sampler placement was 5 mg/l (Table 3.1.2). In addition, Shaw Brook did not meet aquatic life criteria in 2001 and 2006 (Table 3.1.4).

Silver Lake Outlet Stream – Bucksport Station 285

Silver Lake Outlet Stream is a first order stream which originates at the outlet of Silver Lake and flows through Bucksport to the Penobscot River. The flow at the outlet of Silver Lake is regulated by a dam. The stream is classified as a Class B waterbody. The benthic macroinvertebrate community sampled did not meet the Class B aquatic life criteria. The community did meet the Class C aquatic life criteria. There were a high number of organisms in the sample and the number of different types of organisms was also adequate. However, there were very few sensitive organisms present. The relative abundance of the midge family *Chironomidae* made up almost 40% of the sample. The riparian area adjacent to the stream in this heavy residential area is very poor with Japanese Knotweed the dominant plant at the station location. In addition, dissolved oxygen (DO) readings taken at sampler placement and retrieval indicated that dissolved oxygen in the stream was low (Table 3.1.2).

Sucker Brook – Bangor, Hampden Stations 624 and 971

Sucker Brook is a small Class B stream originating near the Bangor Airport and flowing southeast through a highly developed area, through Hampden, and finally into the Penobscot River. The specific conductance of the stream is very high indicating urban runoff (Table 3.1.2). Station 624 located in Hampden did not attain Class C aquatic life criteria in 2002 and 2004 (Table 3.1.4). Station 971 located in Bangor was sampled for the first time. Both stations failed to attain Class C aquatic life criteria. The number of sensitive organisms collected at both stations was very low and the five dominant taxa at both stations were made up of tolerant organisms whose abundance consisted of 80% of the sampled community. The stream habitat was also degraded at both stations.

Table 3.1.1. 2011 SWAT Benthic Macroinvertebrate Biomonitoring Results

Waterbody	Town	Station	Log	Potential sources of pollution[1]	Statutory Class/ Final Determina-tion	Attains Class?[2]	Probable Cause
Allen Stream	Exeter	308	2040	Agricultural NPS	B / B	Yes	
Babel Brook	Ebeemee TWP	305	2052	Reference	A / A	Yes	
Birch Stream	Bangor	312	2033	Urban NPS / Airport	B / NA	No	Urban Runoff / Airport
Card Brook	Ellsworth	814	2028	Urban NPS	B / NA	No	Habitat / Urban Runoff
Card Brook	Ellsworth	815	2029	Urban NPS	B / NA	No	Urban Runoff / Habitat
Carleton Stream	Blue Hill	526	2047	In-Place Contamination	C / NA	No	In-Place Contaminat ion / Habitat
Cove Brook	Winterport	813	2038	NPS	AA / A	Yes	
Crooked Brook	Corinth	510	2041	Agricultural NPS	B / A	Yes	
East Branch Penobscot River	T3 R7 WELS	823	2064	Reference	AA / A	Yes	
East Machias River	Crawford	494	2056	Reference	AA / A	Yes	
Eaton Brook	Brewer	973	2032	NPS	B / B	Yes	
French Stream	Exeter	505	2039	Agricultural NPS	B / A	Yes	
Great Falls Branch	Deblois	504	2060	Agricultural NPS	AA / NA	No	Blueberry Waste
Kenduskeag Stream	Corinth	508	2042	Agricultural NPS	B / A	Yes	
Kenduskeag Stream	Bangor	829	2027	Urban NPS	C / B	Yes	
Millinocket Stream	Millinocket	287	2063	NPS	B / A	Yes	
Mopang Stream	T30 MD BPP	501	2055	Reference	AA / A	Yes	
Narraguagus River	Cherryfield	81	2058	Agricultural NPS	B / A	Yes	
Narraguagus River	Deblois	111	2057	Agricultural NPS	AA / A	Yes	
Narraguagus River	Beddington	112	2054	Reference	AA / A	Yes	

[1] NPS = non-point source pollution.
[2] This field is completed only for stations for which sampling results have been obtained as of the time of this report

Table 3.1.1. 2011 SWAT Benthic Macroinvertebrate Biomonitoring Results (continued)

Waterbody	Town	Station	Log	Potential sources of pollution[1]	Statutory Class/ Final Determina-tion	Attains Class?[2]	Probable Cause
Penjajawoc Stream	Bangor	314	2024	Urban NPS	B / C	No	Urban Runoff / Habitat
Penjajawoc Stream	Bangor	315	2025	Urban NPS	B / C	No	Urban Runoff / Habitat
Penjajawoc Stream	Bangor	511	2026	Urban NPS	B / C	No	Urban Runoff / Habitat
Penobscot River	Orono	62	2023	Municipal / Industrial	B / A	Yes	
Piscataquis River	Abbot	83	2051	Reference	A / A	Yes	
Piscataquis River	Dover-Foxcroft	152	2050	Municipal / Agricultural	B / B	Yes	
Seboeis River	T6 R7 WELS	737	2065	Reference	AA / A	Yes	
Seboeis Stream	Howland	665	2045	NPS	A /A	Yes	
Sedgeunkedunk Stream	Orrington	972	2031	NPS	B / B	Yes	
Shaw Brook	Hermon	480	2036	Urban NPS	B / NA	No	Urban Runoff / Habitat
Sheepscot River	Whitefield	74	2020	Long Term Monitoring	AA / A	Yes	
Silver Lake Outlet Stream	Bucksport	285	2046	Urban NPS / Flow Regulation	B / C	No	Habitat / Residential / Flow Regulation
Souadabscook Stream	Hampden	291	2037	Landfill	AA / A	Yes	
Sucker Brook	Hampden	624	2034	Urban / Agricultural NPS	B / NA	No	Urban runoff / Habitat
Sucker Brook	Bangor	971	2035	Urban NPS / Airport	B / NA	No	Urban Runoff / Habitat
Tunk Stream	T10 SD	159	2030	Reference	B / B	Yes	
West Branch Narraguagus River	Cherryfield	502	2059	Agricultural NPS	AA / B	No	Very high water. Resample
West Branch Sheepscot River	China	268	2022	Long Term Monitoring	AA / A	Yes	
West Seboeis Stream	T4 R9 NWP	818	2053	Reference	A / A	Yes	

[1] NPS = non-point source pollution.
[2] This field is completed only for stations for which sampling results have been obtained as of the time of this report.

Table 3.1.2. 2011 SWAT Field Data

Measurements were obtained using handheld electronic meters.

Site	Station	Log	Sampler Deployment					Sampler Retrieval				
			Date	Temp	DO	SPC	pH	Date	Temp	DO	SPC	pH
				Deg C	mg/L	uS/cm	STU		Dec C	mg/L	uS/cm	STU
Allen Stream	308	2040	7/14/11	22.6	7.3	167	7.36	8/16/11	18.9	7.3	171	7.03
Babel Brook	305	2052	7/21/11	18.7	8.3	21	6.67	8/23/11	17.3	8.8	12	6.97
Birch Stream	312	2033	7/12/11	22.5	7.5	340	7.51	8/11/11	19.1	8.2	367	8.08
Card Brook	814	2028	7/11/11	23.9	5.7	192	6.16	8/10/11	18.7	5.3	226	6.43
Card Brook	815	2029	7/11/11	21.8	8.1	241	7.22	8/10/11	18.7	8.4	284	7.53
Carleton Stream	526	2047	7/19/11	25.3	7.8	52	6.55	8/18/11	20.8	8.2	51	6.70
Cove Brook	813	2038	7/13/11	19.5	8.4	119	7.50	8/15/11	18.6	8.6	182	8.18
Crooked Brook	510	2041	7/14/11	21.9	8.0	129	7.37	8/16/11	20.0	7.8	140	7.72
East Branch Penobscot River	823	2064	7/28/11	22.2	8.5	21	7.07	9/21/11	15.7	8.7	19	6.95
East Machias River	494	2056	7/25/11	24.5	8.4	19	6.96	8/24/11	22.0	8.7	18	
Eaton Brook	973	2032	7/12/11	25.3	5.9	86	6.26	8/11/11	20.4	6.0	88	7.07
French Stream	505	2039	7/14/11	23.8	7.3	171	7.35	8/16/11	19.9	7.4	196	7.03
Great Falls Branch	504	2060	7/26/11	20.2	6.8	37	6.23	8/25/11	19.8	3.1	70	4.32
Kenduskeag Stream	508	2042	7/14/11	20.7	8.2	110	7.47	8/16/11	18.4	8.1	108	7.58
Kenduskeag Stream	829	2027	7/8/11	22.8	8.5	138	7.88	8/9/11	25.2	9.9	192	
Millinocket Stream	287	2063	7/21/11	24.6	8.2	17	6.60	9/21/11	18.0	8.8	13	6.85
Mopang Stream	501	2055	7/25/11	24.7	8.1	14	6.25	8/24/11	22.4	8.5	12	6.20
Narraguagus River	81	2058	7/26/11	23.9	8.1	26	6.97	8/25/11	21.6	8.5	23	6.99
Narraguagus River	111	2057	7/26/11	20.6	7.4	21	6.44	8/24/11	22.9	8.3	24	7.12
Narraguagus River	112	2054	7/25/11	26.2	8.2	26	7.07	8/24/11	22.1	8.3	18	7.02
Penjajawoc Stream	314	2024	7/8/11	19.5	8.6	469	7.35	8/9/11	19.6	8.1	844	7.61
Penjajawoc Stream	315	2025	7/8/11	19.0	9.0	487	7.59	8/9/11	21.5	9.2	674	8.18
Penjajawoc Stream	511	2026	7/8/11	21.7	6.6	143	6.60	8/9/11	19.4	6.6	362	7.30

Temp = water temperature, DO = dissolved oxygen, SPC = specific conductance, pH.

Table 3.1.2. 2011 SWAT Field Data (continued)

Site	Station	Log	Sampler Deployment					Sampler Retrieval				
			Date	Temp	DO	SPC	pH	Date	Temp	DO	SPC	pH
				Dec C	mg/L	uS/cm	STU		Dec C	mg/L	uS/cm	STU
Penobscot River	62	2023	7/8/11	25.3	8.5	50	7.13	8/9/11	24.6	8.2	53	
Piscataquis River	83	2051	7/20/11	24.4	8.0	34	6.89	8/23/11	19.9	8.8	18	7.18
Piscataquis River	152	2050	7/20/11	24.4	9.0	66	7.97	8/22/11	24.1	8.4	45	
Seboeis River	737	2065	7/28/11	21.0	8.7	36	7.61	9/21/11	14.6	9.2	27	7.34
Seboeis Stream	665	2045	7/18/11	27.4	8.0	18	7.06	8/17/11	21.4	8.1	18	7.01
Sedgeunkedunk Stream	972	2031	7/12/11	25.8	7.8	28	6.10	8/11/11	20.6	8.2	37	7.26
Shaw Brook	480	2036	7/13/11	22.1	5.0	297	7.17	8/15/11	20.7	6.2	365	7.57
Sheepscot River	74	2020	7/7/11	23.9	7.4	62	7.20	8/8/11	23.0	7.6	59	
Silver Lake Outlet Stream	285	2046	7/19/11	24.9	5.7	82	6.64	8/18/11	20.4	5.8	74	6.64
Souadabscook Stream	291	2037	7/13/11	25.6	8.2	83	7.45	8/15/11	22.1	8.9	143	7.05
Sucker Brook	624	2034	7/13/11	23.1	8.8	430	7.90	8/15/11	21.3	12.1	633	8.63
Sucker Brook	971	2035	7/13/11	20.4	8.8	566	7.99	8/15/11	19.0	8.8	709	8.27
Tunk Stream	159	2030	7/11/11	24.8	8.6	11	5.30	8/10/11	21.8	8.0	16	6.21
West Branch Narraguagus River	502	2059	7/26/11	23.3	7.1	21	6.40	8/25/11	20.2	7.7	17	6.10
West Branch Sheepscot River	268	2022	7/7/11	22.4	8.1	53	6.86	8/8/11	23.2	8.1	60	
West Seboeis Stream	818	2053	7/21/11	22.7	8.4	30	6.66	8/23/11	18.6	8.7	15	6.42

Temp = water temperature, DO = dissolved oxygen, SPC = specific conductance, pH.

Table 3.1.3. 2011 SWAT Water Chemistry Data

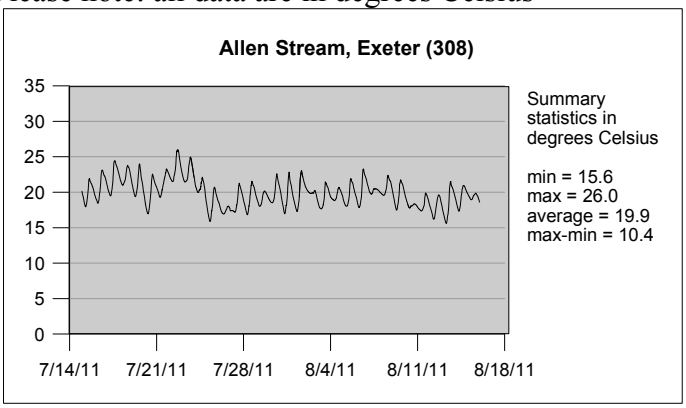
Samples were analyzed by the Health & Environmental Testing Laboratory, Augusta, ME. Highlighted values indicate high results.

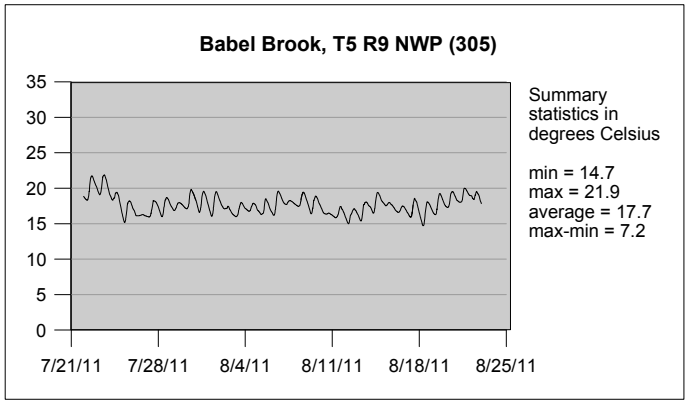
Waterbody	Station	Log	Sampling Date	DOC	NH_3-N	TKN	NO_2-NO_3-N	SRP	Total P	TSS	TDS
				mg/L	mg/L	mg/L	mg/L	ug/L	mg/L	mg/L	mg/L
Babel Brook	305	2052	8/23/11	5.6	<0.01	0.4	0.01	3	0.017	<2	36
Birch Stream	312	2033	8/11/11	2.4	0.03	0.3	0.32	5	0.026	<2	250
Card Brook	814	2028	8/10/11	8.9	0.01	0.7	0.01	4	0.024	<2	160
Card Brook	815	2029	8/10/11	7.8	0.01	0.7	0.06	4	0.026	2.0	190
French Stream	505	2039	8/16/11	5.5	0.01	0.5	0.13	3	0.033	2.3	130
Great Falls Branch	504	2060	8/25/11	98.0	<0.01	1.0	<0.01	480	0.670	6.0	200
Kenduskeag Stream	829	2027	8/9/11	3.8	0.01	0.4	0.02	1	0.013	<2	140
Kenduskeag Stream	508	2042	8/16/11	4.3	0.01	0.4	0.85	2	0.029	4.5	80
Narraguagus River	81	2058	8/25/11	6.7	<0.01	0.5	<0.01	2	0.016	<2	42
Penjajawoc Stream	314	2024	8/9/11	4.3	0.13	0.4	0.28	5	0.028	3.3	570
Penjajawoc Stream	315	2026	8/9/11	6.1	0.01	0.6	0.22	8	0.040	5.1	190
Penobscot River	62	2023	8/9/11	5.1	0.03	0.4	0.03	10	0.028	<2	50
Piscataquis River	152	2050	8/22/11	3.3	<0.01	0.4	0.01	11	0.023	<2	47
Sedgeunkedunk Stream	972	2031	8/11/11	3.4	0.01	0.4	0.02	2	0.016	<2	38
Sheepscot River	74	2020	8/8/11	4.0	0.01	0.3	0.02	2	0.017	<2	50
Souadabscook Stream	291	2037	8/15/11	4.9	0.01	0.4	0.04	4	0.017	<2	100
Sucker Brook	624	2034	8/15/11	3.5	0.01	0.3	0.04	3	0.017	<2	440
West Branch Sheepscot River	268	2022	8/8/11	4.0	0.01	0.4	0.03	1	0.012	<2	46

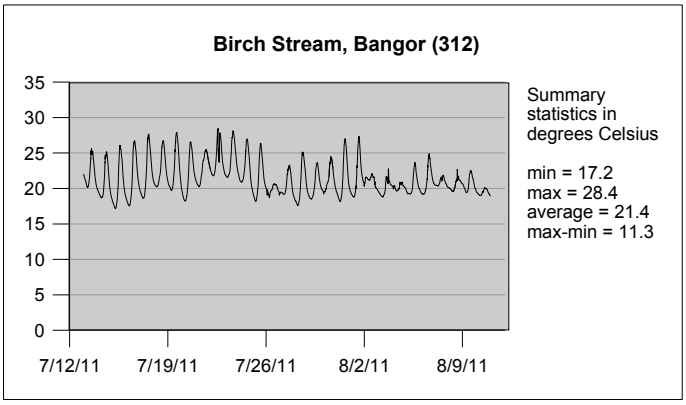
DOC = dissolved organic carbon, NH_3-N = ammonia-nitrogen, TKN = total Kjeldahl-nitrogen, NO_2-NO_3-N = nitrite-nitrate-nitrogen, SRP = soluble reactive phosphorus (ortho-phosphate), Total P = total phosphorus, TSS = total suspended solids, TDS = total dissolved solids, "<" = constituent not detected at the reporting limit.

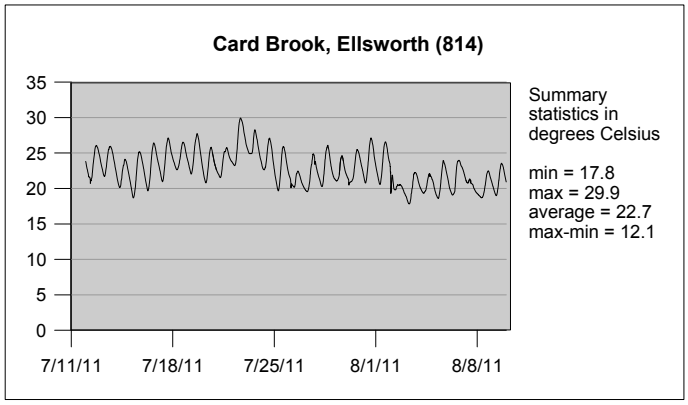
Figure 3.1.1. 2011 In-Stream Continuous Temperature Data

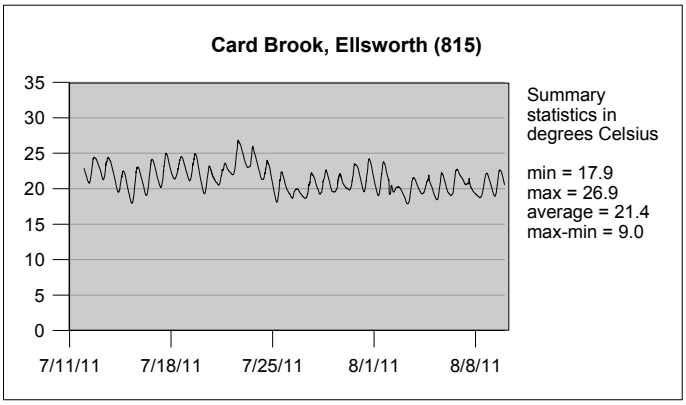
Please note: all data are in degrees Celsius

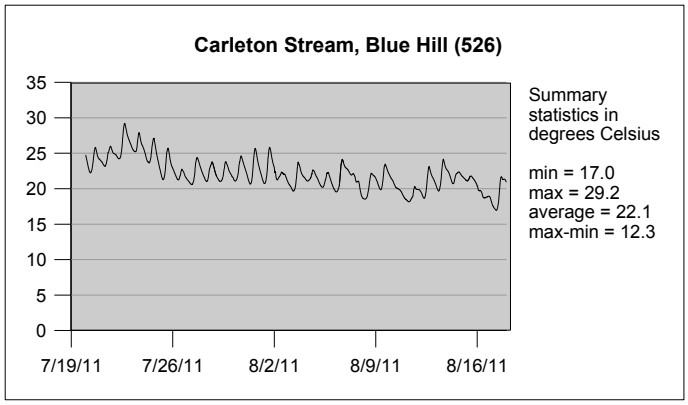


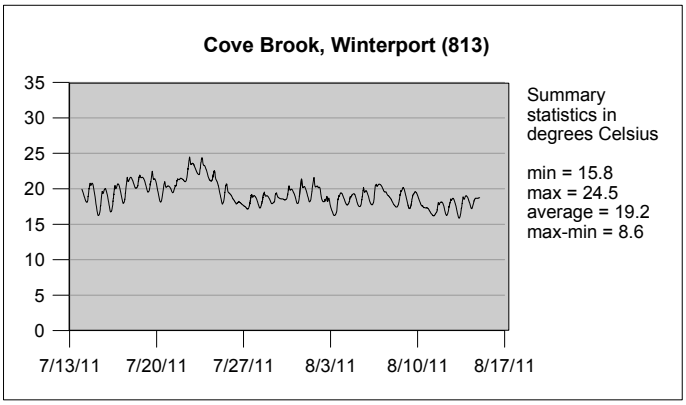












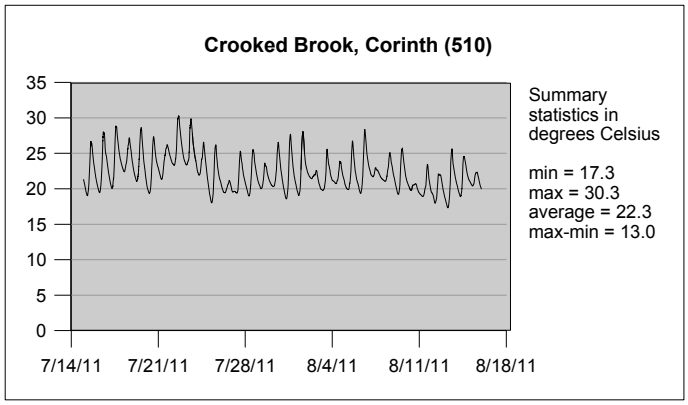
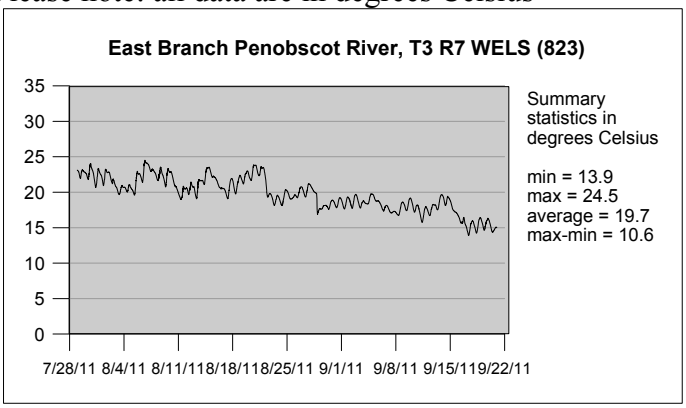
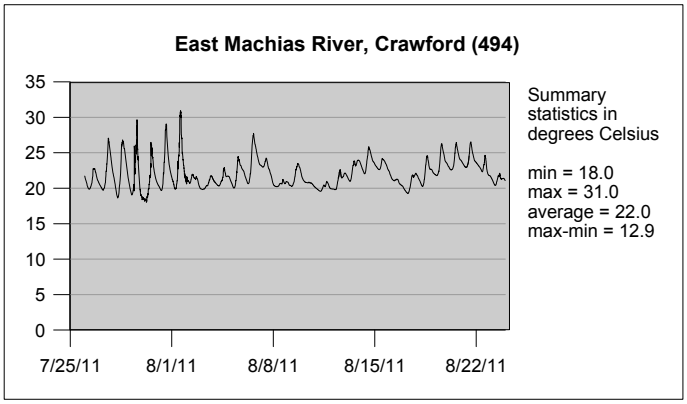
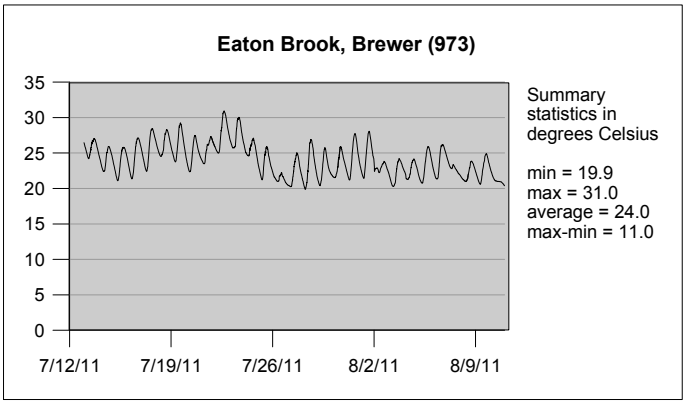
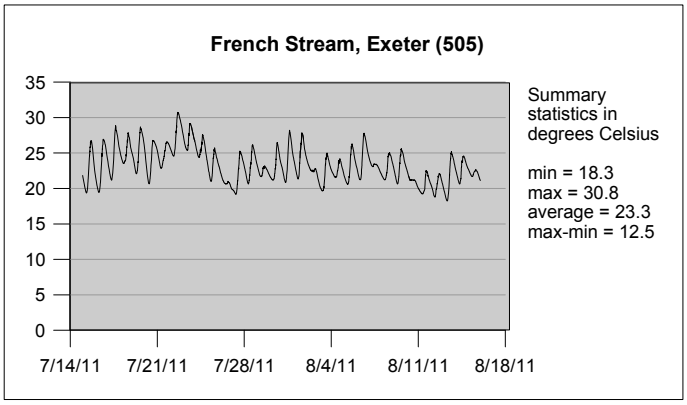


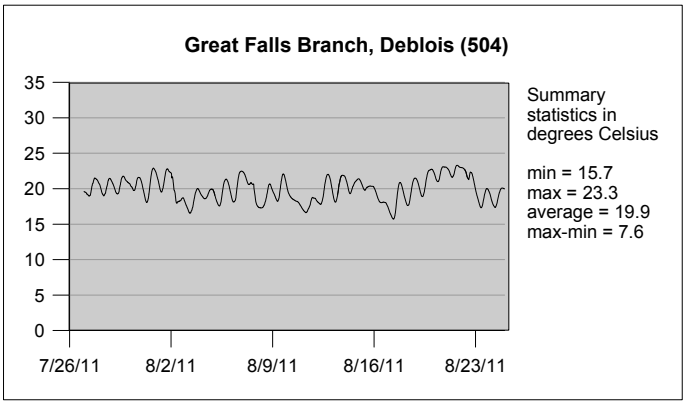
Figure 3.1.1. 2011 In-Stream Continuous Temperature Data (continued)
Please note: all data are in degrees Celsius

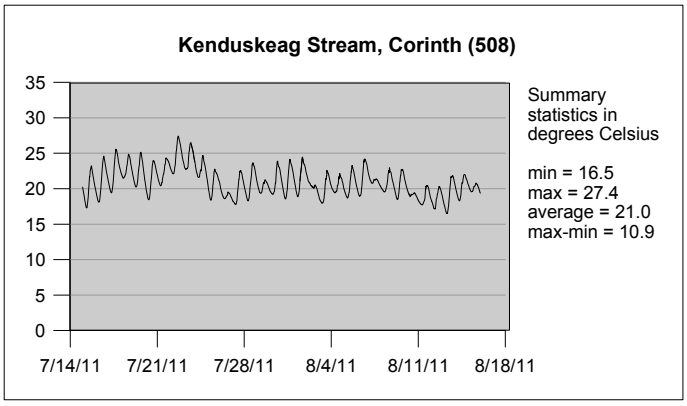


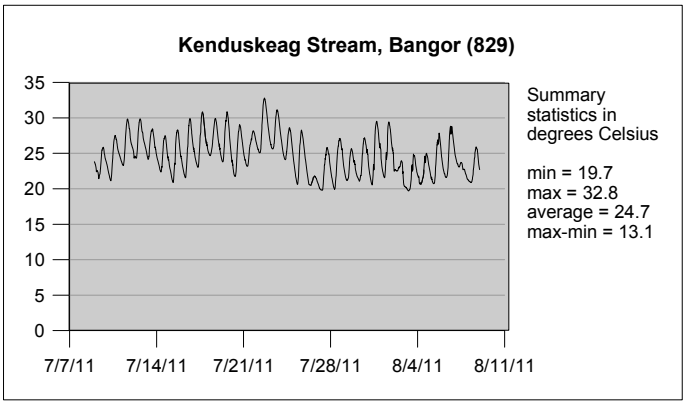












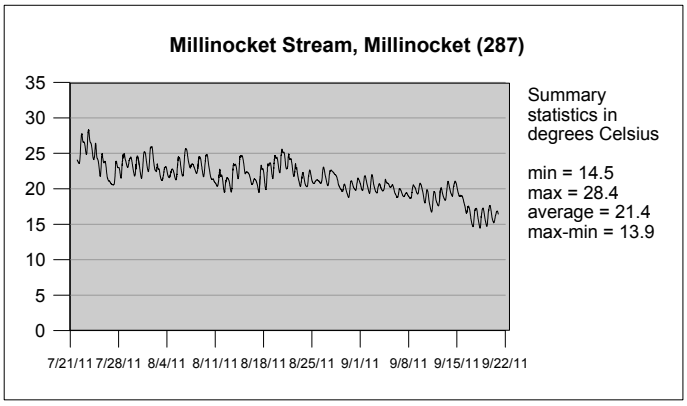
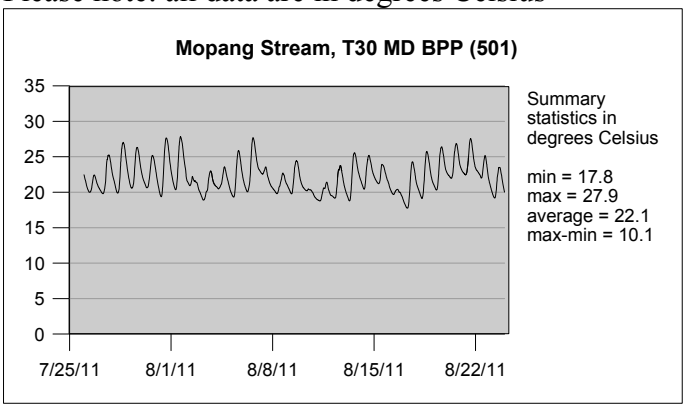
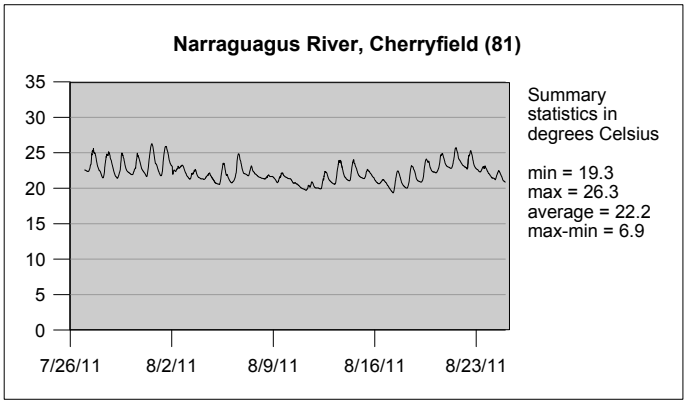
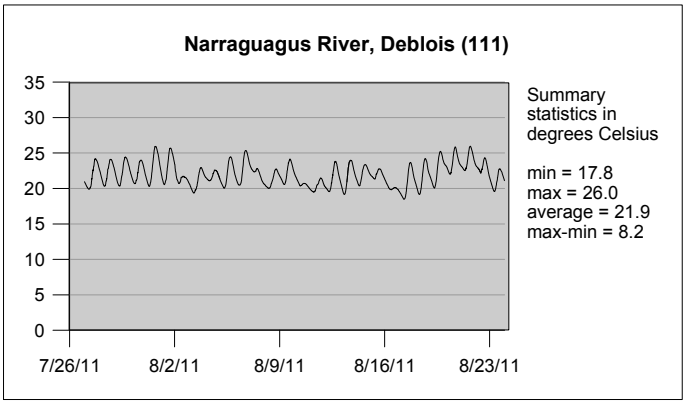
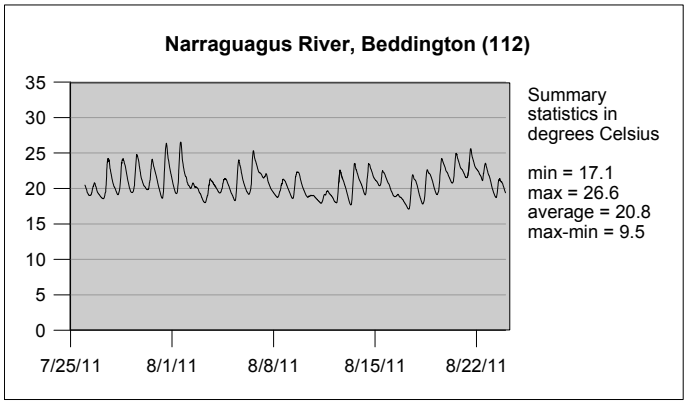


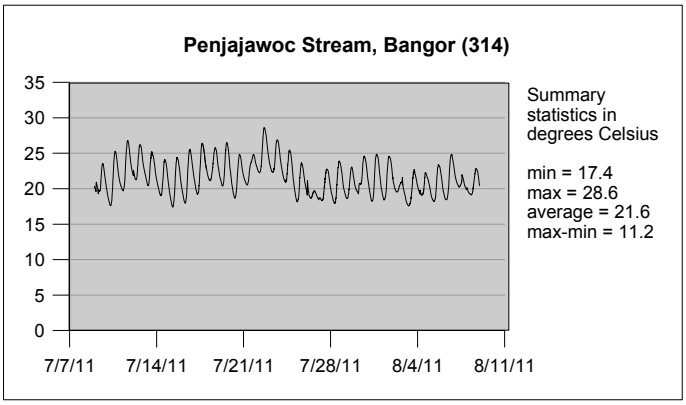
Figure 3.1.1. 2011 In-Stream Continuous Temperature Data (continued)
Please note: all data are in degrees Celsius

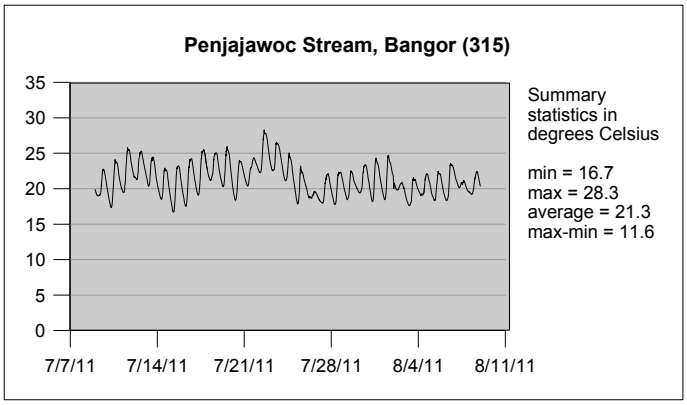


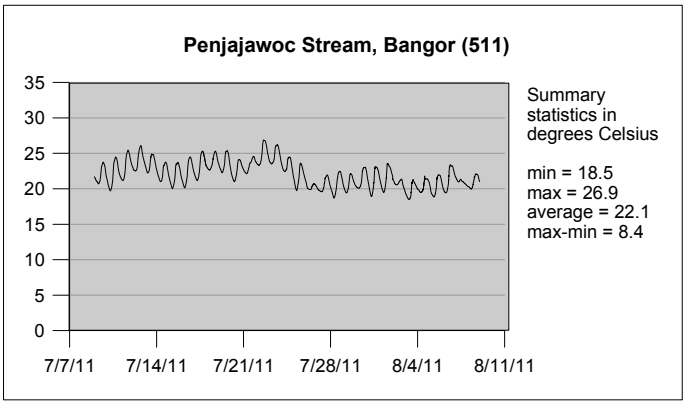












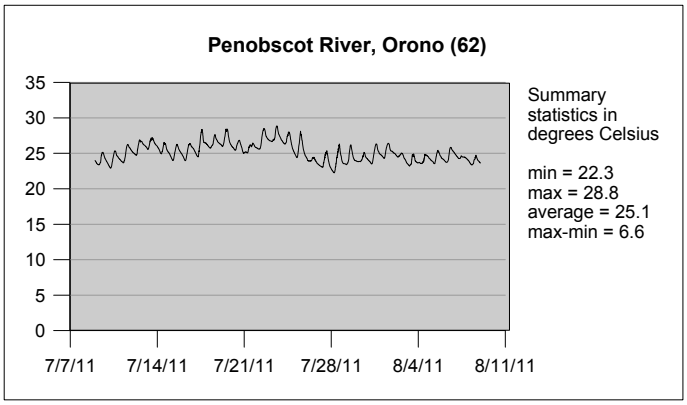
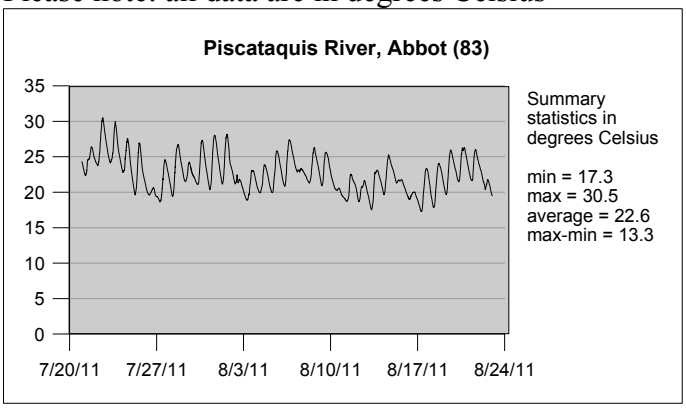
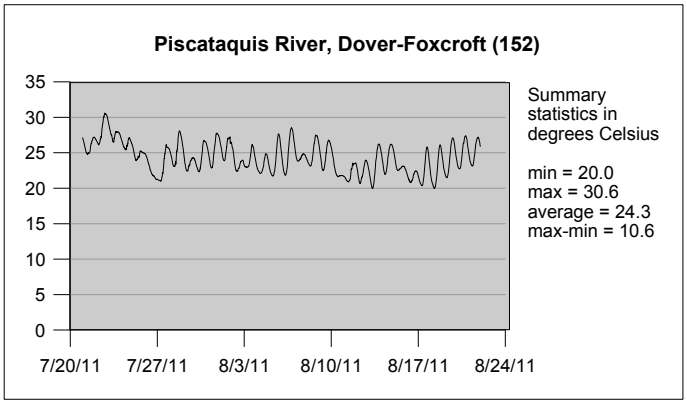
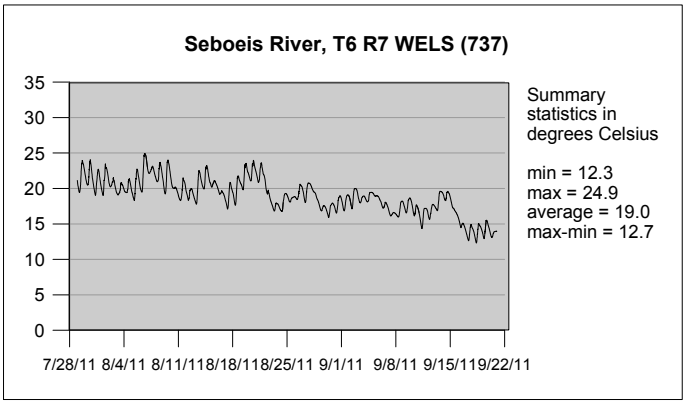
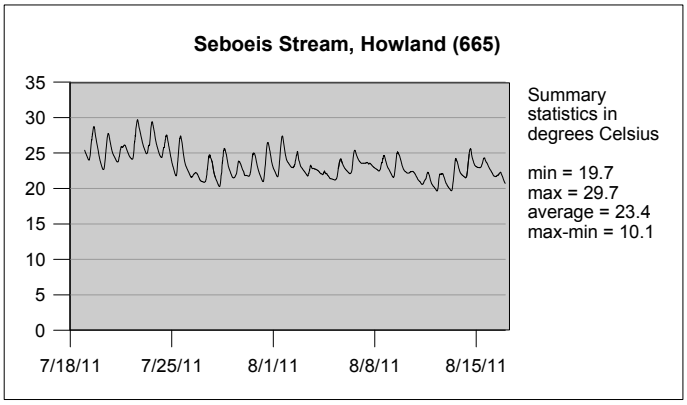


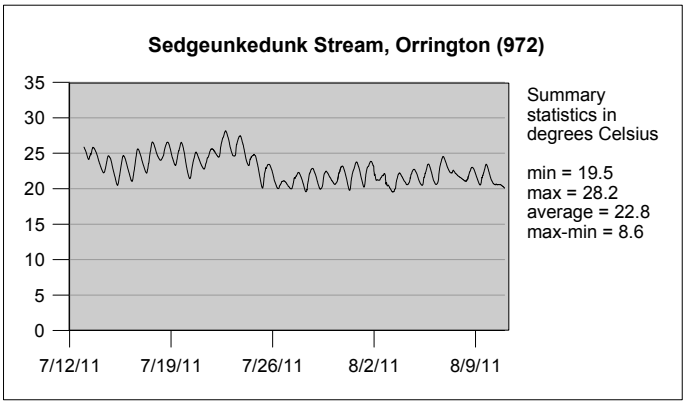
Figure 3.1.1. 2011 In-Stream Continuous Temperature Data (continued)
Please note: all data are in degrees Celsius

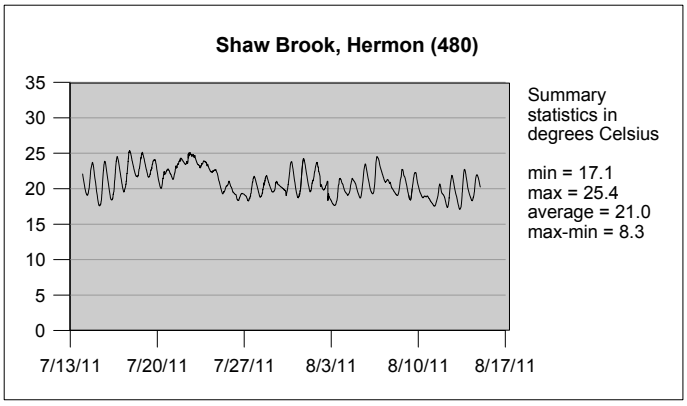


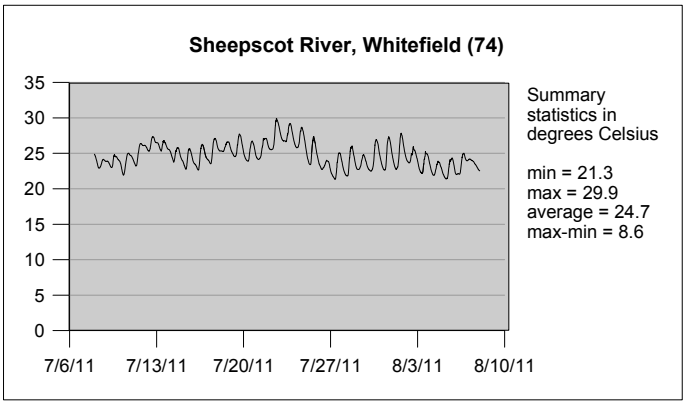












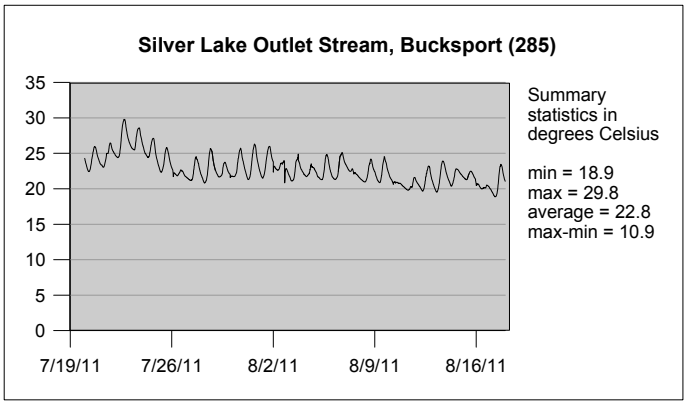
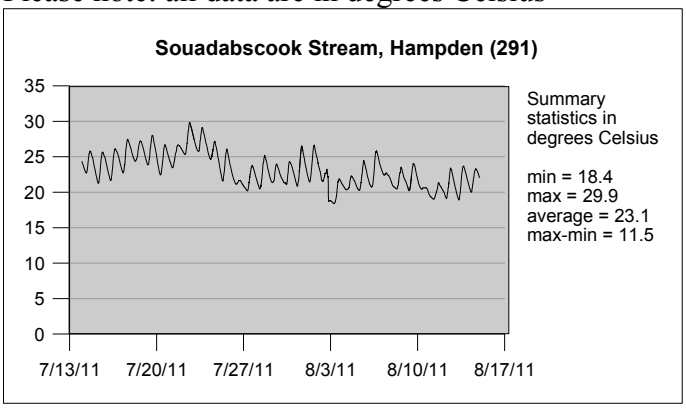
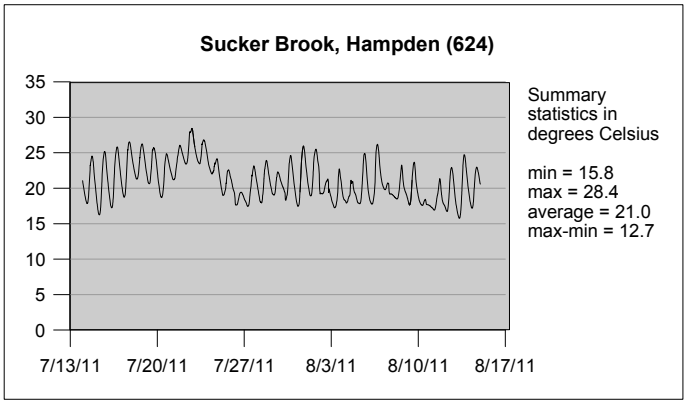
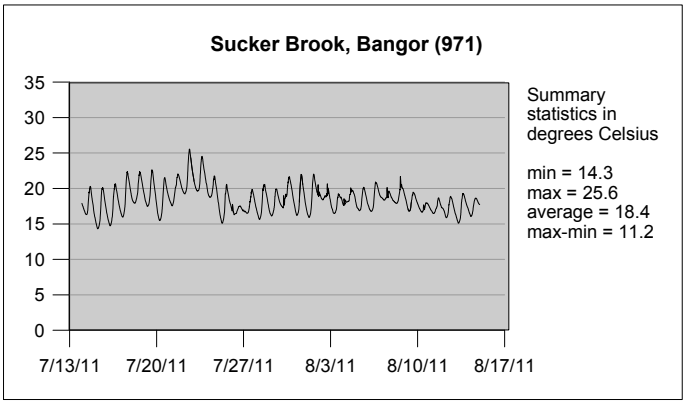
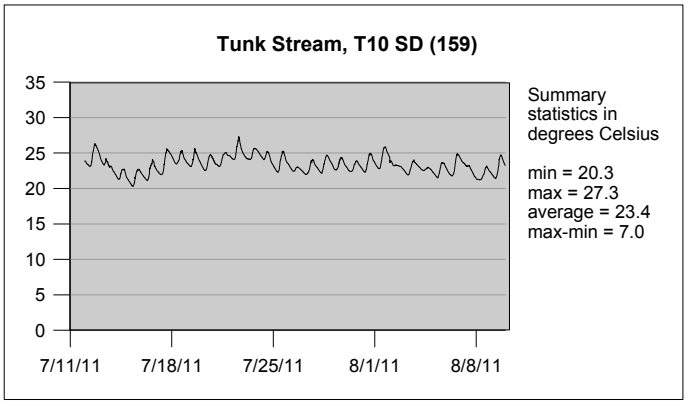


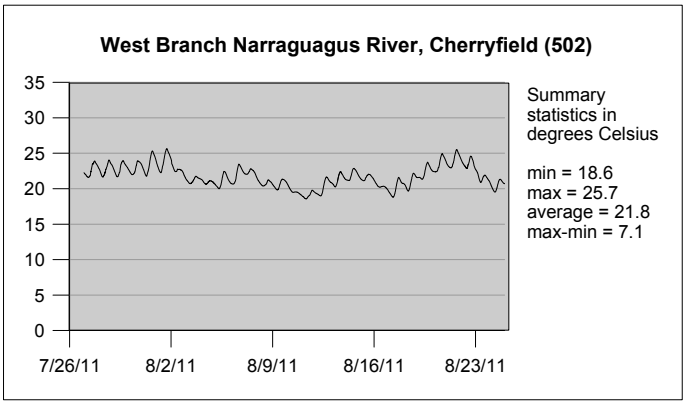
Figure 3.1.1. 2011 In-Stream Continuous Temperature Data (continued)
Please note: all data are in degrees Celsius

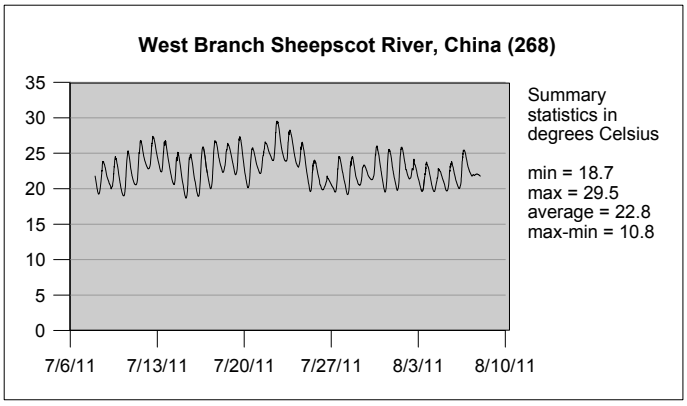


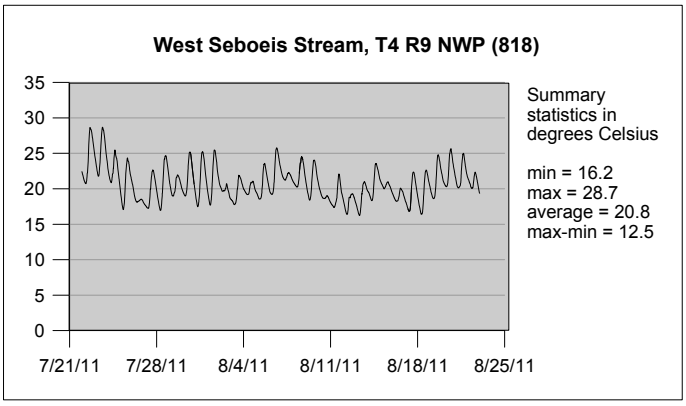












3.1.3 Attainment History of Sampling Stations prior to 2011

The table below provides the attainment history for sampling stations that have been sampled in the past.

Table 3.1.4. Past Attainment History

Waterbody	Station	Attained Class	Did not Attain Class	Indeterminate Result
Allen Stream	308	1997, 2001		
Babel Brook	305	1997, 2001		
Birch Stream	312		1997, 1999, 2001, 2003-2007, 2010	
Card Brook	814		2006	
Card Brook	815		2006	
Carleton Stream	526	2000	2009	
Cove Brook	813	2006		
Crooked Brook	510	2001, 2003		
East Branch Penobscot River	823	2006		
East Machias River	494	2001, 2006		
French Stream	505	2001		
Great Falls Branch	504		2001, 2006	
Kenduskeag Stream	508	1988, 2001		
Kenduskeag Stream	829	2006		
Millinocket Stream	287	1996, 2006		
Mopang Stream	501	2001, 2006		
Narraguagus River	81	2001, 2006	1984, 1993	
Narraguagus River	111	1987, 2001, 2006	1989, 1996	
Narraguagus River	112	1987, 2006		
Penjajawoc Stream	314		1997, 2001-2003, 2006, 2008	
Penjajawoc Stream	315	2001	1997, 2002, 2003, 2006, 2008	
Penjajawoc Stream	511		2001-2003, 2006, 2008, 2009	
Penobscot River	62	1984, 1993, 1994, 2006		
Piscataquis River	83	1984, 1985, 1989, 1996, 2006	1990	
Piscataquis River	152	1991, 1993, 1995, 2006		
Seboeis River	737	2006		
Seboeis Stream	665	2006		
Shaw Brook	480		2001, 2006	
Sheepscot River	74	1987-1990, 1992, 1995, 1996, 1998-2010	1984-1986, 1991, 1993, 1994, 1997	
Silver Lake Outlet Stream	285		1996	

Table 3.1.4. Past Attainment History

Waterbody	Station	Attained Class	Did not Attain Class	Indeterminate Result
Souadabscook Stream	291	2006	1996	
Sucker Brook	624		2002, 2004	
Tunk Stream	159	1991		
West Branch Narraguagus River	268	2001		
West Branch Sheepscot River	268	1996-1999, 2001, 2002, 2005, 2007, 2009, 2010	2000, 2003, 2004, 2006, 2008	1995 (low numbers)
West Seboeis Stream	818	2006		

3.2 FISH CONSUMPTION ADVISORIES

3.2.1 Dioxin and coplanar PCB in Fish Tissue

3.2.1.1 Introduction

Maine's Dioxin Monitoring Program (DMP), established in 1988, was merged with the Surface Water Ambient Toxics (SWAT) monitoring program in 2007 as 38 MRSA 420-B sub-§1-A for Dioxin monitoring. The goal of the monitoring is "to determine the nature of dioxin contamination in the waters and fisheries of the State" and to "determine the need for fish consumption advisories on affected waters". Charged with administration of the program, the Commissioner of the Department of Environmental Protection (DEP) is required to

1) Select a representative sample of wastewater treatment plant sludges from municipal wastewater treatment plants, bleached pulp mills or other sources. These facilities must be selected on the basis of known or likely dioxin contamination of their discharged effluent:
2) Sample and test the sludge of selected facilities of dioxin contamination at least once during each season of the year. The commissioner shall specify which congeners of dioxin will be analyzed;
3) At appropriate intervals, sample and test for dioxin contamination in selection of fish representative of those species present in the receiving waters of where there are consumption advisories for dioxin; Sufficient numbers of fish must be analyzed to provide a reasonable estimate of the level of contamination in the population of each waterbody affected; and
4) Assess the selected facilities of the costs of sample collection and analysis except that, if the selected facility is a publicly owned treatment works, the Commissioner may assess the primary industrial generator discharging effluent into the treatment facility if the generator is known or likely to be discharging dioxin into the treatment facility. Fees received under this subparagraph must be credited to the Maine Environmental Protection Fund. Payment of these fees is a condition of the discharge license issued pursuant to section 413 for continued operation of the selected facilities, except that if the selected facility is a publicly owned treatment works and the Commissioner assesses the fee on an industrial generator, payment of the fee is not a condition of the discharge license of the selected facility. The fees assessed under this subparagraph may not exceed a total of $250,0000 in any fiscal year. The fees assessed under this subparagraph to facilities subject to section 420, subsection 2, paragraph I may not exceed a total of $10,000 in any fiscal year.

The monitoring program is to be coordinated with other ongoing programs conducted by the Department, the Maine Center for Disease Control and Prevention (ME-CDC), US Environmental Protection Agency (EPA) and other federal agencies, or dischargers of wastewater. The proposed annual monitoring plan must be submitted to the Surface Water Ambient Toxics (SWAT) Technical Advisory Group (TAG), created under 38 MRSA section 420-B, for review and advice. The selected facilities must be notified of their inclusion in the proposed program at least 30 days prior to submittal to the TAG.

3.2.1.2 Program Design

Following attainment of the provisions of the 1997 Dioxin Law and elimination of the measurable discharge of dioxins (includes closely related furans) from the bleached kraft pulp and paper mills in 2003-2005, the Dioxin Monitoring Program is now focused on residual levels of dioxins from historic discharges and how they affect Maine's fish consumption advisories. This report contains the findings from the 2011 Dioxin Monitoring Program with respect to three objectives:

1. Human health assessment, Fish Consumption Advisories
2. Trend evaluation
3. 1997 Dioxin Law, Continued Compliance

This report also contains the (dioxin-like) coplanar polychlorinated biphenyl (PCB) data. Coplanar PCB data are included to show the total exposure to dioxin-like compounds from consumption of certain fish from several Maine rivers. The Environmental and Occupational Health Program (EOHP) of the Maine Center for Disease Control and Prevention (ME-CDC) uses both dioxins and coplanar PCB data, which are have similar toxicity characteristics to dioxins, in order to make a complete assessment of the fish consumption advisories. Sources of the coplanar PCBs are not known, but likely include historic use and discharge in Maine, and long range transport and atmospheric deposition.

In January 2008, the ME-CDC issued a report titled 'Evaluation of the Health Implications of levels of Polychlorinated Dibenzo-p-Dioxins (dioxins) and Polychlorinated Dibenzofurans (furans) in Fish from Maine Rivers – 2008 Update'. In the report, ME-CDC adopted a new provisional Fish Tissue Action Level (FTAL) of 0.4 pptr, based on the same toxicity data for non-cancer effects used since 1990, but adjusted downward to account for substantial background exposure from other dietary foods. ME-CDC reviewed the data collected since their last review in 2003, i.e. 2004-2007 with respect to the new FTAL.

For 2009, ME-CDC did not request any monitoring, but did request monitoring in 2010 and 2011.

2011 monitoring requested by Maine Center for Disease Control and Prevention

The following is our list of waters and fish species we believe additional data are needed for continued monitoring for fish consumption advisories. Based on decreasing concentrations of dioxins and PCBs over the last 10 to 15 years, fish consumption advice more restrictive than the current state-wide mercury advice may, overall, no longer be necessary. The current state-wide mercury advice recommends no recreational freshwater fish consumption for sensitive populations (pregnant and nursing women, women who may get pregnant and children under 8 years of age) and two meals per month for the general population. Less restrictive advice is offered for brook trout (defined by the Department of Inland Fisheries and Wildlife as brook trout, splake and Atlantic char) and landlocked salmon. We assume these two species are not significant fisheries on the major rivers of interest for these fish consumption advisories as we have never seen any data for them

Fish Tissue Action Levels (FTALs) have been developed by the Environmental and Occupational Health Program (EOHP) of the Maine Center for Disease Control and Prevention (ME-CDC) (provided at http://www.maine.gov/dhhs/eohp/fish/index.htm). FTALs are acceptable chemical concentrations in fish tissue, calculated assuming consumption of one 8-ounce fish meal per week and risk-based thresholds of a cancer risk of 1 in 100,000 or a noncancer hazard of 1. For dioxins and dioxin-like PCB congeners (summed and evaluated as total TEQ), the cancer-based FTAL is 1.5 parts per trillion (ppt) and the noncancer-based FTAL is 1.9 ppt. These FTALs are applicable to the general population. The lower of the two values is used for comparison to fish tissue concentration data as the lower value (1.5 ppt) is protective of both cancer and noncancer endpoints of toxicity. Therefore, the FTAL of 1.5 ppt is protective of members of the general population consuming recreationally caught freshwater fish at a rate of one fish meal per week. EOHP has also developed a provisional FTAL of 0.4 ppt for dioxins and dioxin-like PCB congeners that considers background dietary exposure, applicable to sensitive populations. Further discussion of the derivation of this FTAL for sensitive populations can be found at http://www.maine.gov/dhhs/eohp/fish/index.htm. However, due to the existence of "no consumption" advice based on mercury in freshwater recreational fish, the provisional FTAL of 0.4 ppt is not likely to be a driver of any advisories. Considering the state-wide mercury advice for consumption of freshwater fish species at a rate of two meals per month for the general population rather than one meal per week as assumed in FTAL development, total TEQ concentrations in fish of less than 3 ppt are protective of exposures to dioxins and dioxin-like PCB congeners.

There remain a few stations where total TEQ concentrations nearly equal or slightly exceed 3 ppt, the concentration thresholds corresponding to the current state-wide mercury advice for species other than brook trout and landlocked salmon (no consumption for sensitive populations; 2 meals per month for the general population). At each of these stations, the contribution of dioxins to the total TEQ exceeds 60%. Therefore, recommendations for sampling for the coming year are focused on further characterization of those stations with borderline total TEQ concentrations to support upcoming revisions to the fish advisories.

Future sampling for dioxins and dioxin-like PCB congeners will be recommended as part of a periodic monitoring program to confirm that total TEQ levels are either stable or continuing to trend downward. It should also be noted that if the state-wide mercury advice becomes less restrictive in the future, based on findings associated with recent data collection for mercury in fish tissue, additional total TEQ data may be required to determine whether the less restrictive mercury advice continues to be sufficiently protective of the presence of dioxins and PCBs in fish tissue.

Dioxin and Coplanar PCB Data for the Major Rivers

Requested dioxin and coplanar PCB sampling is based on the continued existence of stations with total TEQ concentrations nearly equal to or slightly above 3 ppt that may require fish consumption advice more restrictive than the state-wide mercury advice. Recommendations for further sampling for dioxins are provided below, by river. As in 2010, composite samples, with two samples being submitted for chemical analysis for any sampling location - fish species combination, are recommended. Analysis for total PCBs by the congener method or dioxin-like PCB congeners is requested. Quantification of total PCBs by the congener method will provide measurement of both

dioxin-like PCB congeners and total PCBs, both of which will be used to support revisions to the current fish advisories.

Androscoggin River: Stations and fish species with total TEQs at or above 3 ppt include: (1) small mouth bass at Rumford Point (2004 total TEQ of 2.98 ppt); and (2) white sucker at Livermore Falls and Riley (2007 total TEQs of 3.47 and 3.01 ppt, respectively). The contribution of dioxins to the total TEQ is 70% or more at each of these stations. The contribution of dioxin-like PCBs to the total TEQ is 30% or less at each of these stations. Data for dioxin and dioxin-like coplanar PCB congeners for the identified species at each of these stations is requested to confirm that total TEQ concentrations remain stable or have further decreased.

Kennebec River: White suckers have not been sampled for dioxins at Augusta or Sidney since 1995. Total TEQ concentrations were approximately 5 parts per trillion (ppt) at that time with the dioxin TEQ approaching 3 ppt. Sampling conducted in 2009 for coplanar PCBs indicates that the PCB TEQ in white sucker in the Augusta/Sidney reach of the river has decreased significantly and now is on the order of 0.5-0.6 ppt. Lacking companion dioxin data precludes a conclusion that total TEQ concentrations have now fallen below 3 ppt. The lack of recent dioxin TEQ data for white sucker is identified as a data gap and analysis for dioxins is requested for white sucker at either Augusta or Sidney to fill this data gap. It should be noted that these data were requested in 2010, but have been requested again as these data were not collected in 2010. Coplanar PCB data are also requested to complement the new TEQ data.

Sebasticook River: The total TEQ concentration for white sucker at Newport, based on data collected in 2010, slightly exceeds 3 ppt (3.08 ppt). Approximately 60% of the total TEQ is attributable to dioxins. Approximately 40% of the total TEQ is attributable to dioxin-like PCBs. Therefore, a second year of dioxin and dioxin-like PCB congener data for white sucker is requested from Newport.

3.2.1.3 Sampling Plan

In 2011 fish were collected by DEP by use of angling and gill nets. Fish were immediately killed, weighed and measured, rinsed in river water, wrapped in aluminum foil with the shiny side out, labeled, and placed in a cooler on ice for transport to DEP for secure storage in the freezer. Samples were transferred from DEP to the analytical laboratory for analysis using EPA method 1613b. All other procedures generally followed EPA's Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume I Fish Sampling and Analysis, 1993. Completed chain-of-custody field forms were kept in the freezer storage area for an inventory of samples at any time and an Excel spreadsheet documented final disposition of samples.

A total of 10 fish were targeted for collection and analysis at selected stations (Table 3.2.1). Skinless filets from all fish were analyzed for all 2378 substituted dioxins and furans and the 209 PCB congeners from which the TEQs (dioxin toxic equivalents (DTEhu) and coplanar PCB toxic equivalents CTEhu) were calculated. Sample costs were reduced from that of earlier years by

combining the 10 fish into analysis of two composites of five fish for each station. Facilities with known or likely dioxin contamination of their discharged effluent, identified as a DMP facility, were assessed fees for the cost of chemical analysis of samples below their discharge. Analysis of other samples, identified as SWAT samples, was funded by DEP.

An analytical issue is that of estimated maximum possible concentrations (EMPC). Some compounds, particularly hydroxydiphenyl ethers (DPEs), are coextracted with furans. Laboratory analysis has been modified to minimize these interferences, but some DPEs may remain. In the 2007 Dioxin Monitoring Program report, the Maine Center for Disease Control and Prevention calculated EMPCs as a detected value according to their policy for setting the fish consumption advisories. To be consistent for comparison with ME-CDC's FTAL, EMPCs were treated the same way in this report.

Table 3.2.1 2011 Dioxin and Coplanar PCB Sample Workplan

RIVER	STATION	DMP PCDD/F	DMP facility	SWAT PCDD/F	SWAT CPCB
ANDROSCOGGIN	GILEAD			2C5 BKT	2C5 BKT
	RUMFORD POINT			2C5 SMB	2C5 SMB
	RILEY	2C5 WHS	RUMFORD PAPER CO		2C5 WHS
	LIVERMORE	2C5 WHS	VERSO PAPER CO		2C5 WHS
KENNEBEC	SIDNEY	2C5 WHS	SD WARREN SOMERSET		2C5 WHS
SEBASTICOOK					
EAST BRANCH	NEWPORT	2C5 WHS		2C5 WHS	2C5 WHS

2C5 = 2 composites of 5 fish each

BKT = brook trout, SMB= smallmouth bass, WHS= white sucker

DMP = Dioxin Monitoring Program funds, SWAT = SWAT program funds

PCDD/F= dioxins and furans, CPCB = coplanar PCBs

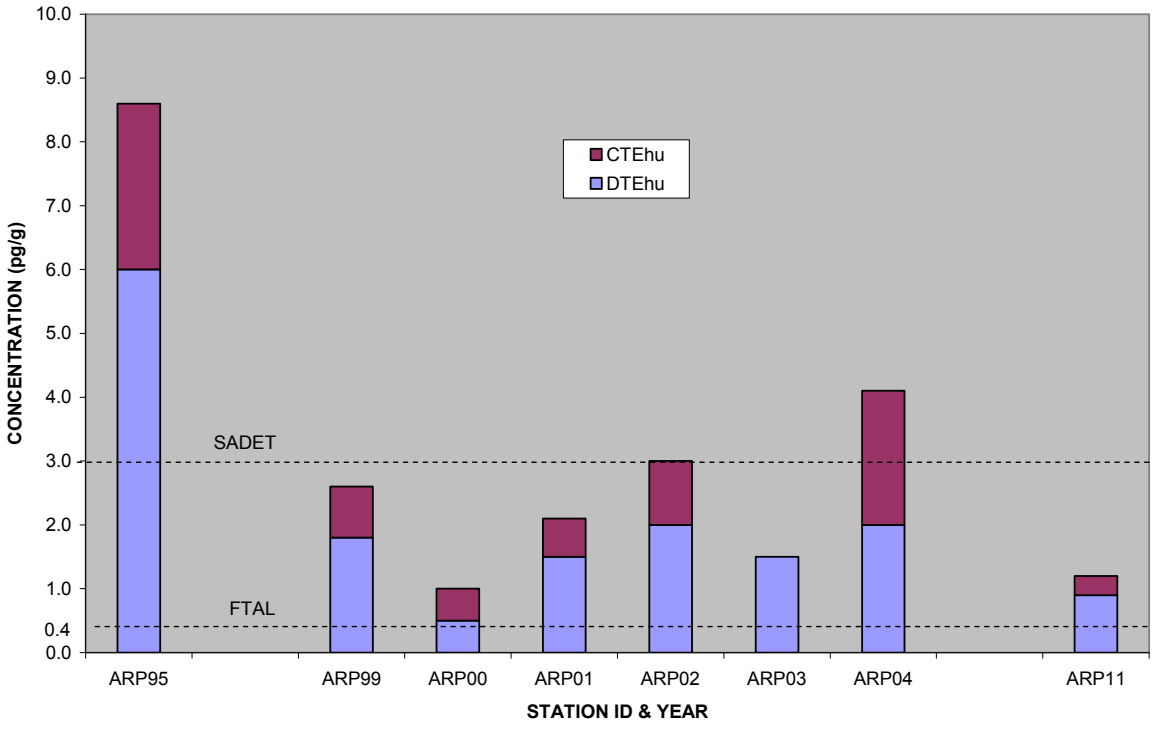
3.2.1.4 Results and Discussion

Contrary to ME-CDC's belief, there are significant brook trout fisheries in Maine rivers including the Androscoggin River at Gilead. Although attempts were made to collect brook trout from Gilead in 2011 for dioxin analysis, it was too late in the season to catch them. Attempts will be made earlier in 2012.

Androscoggin River

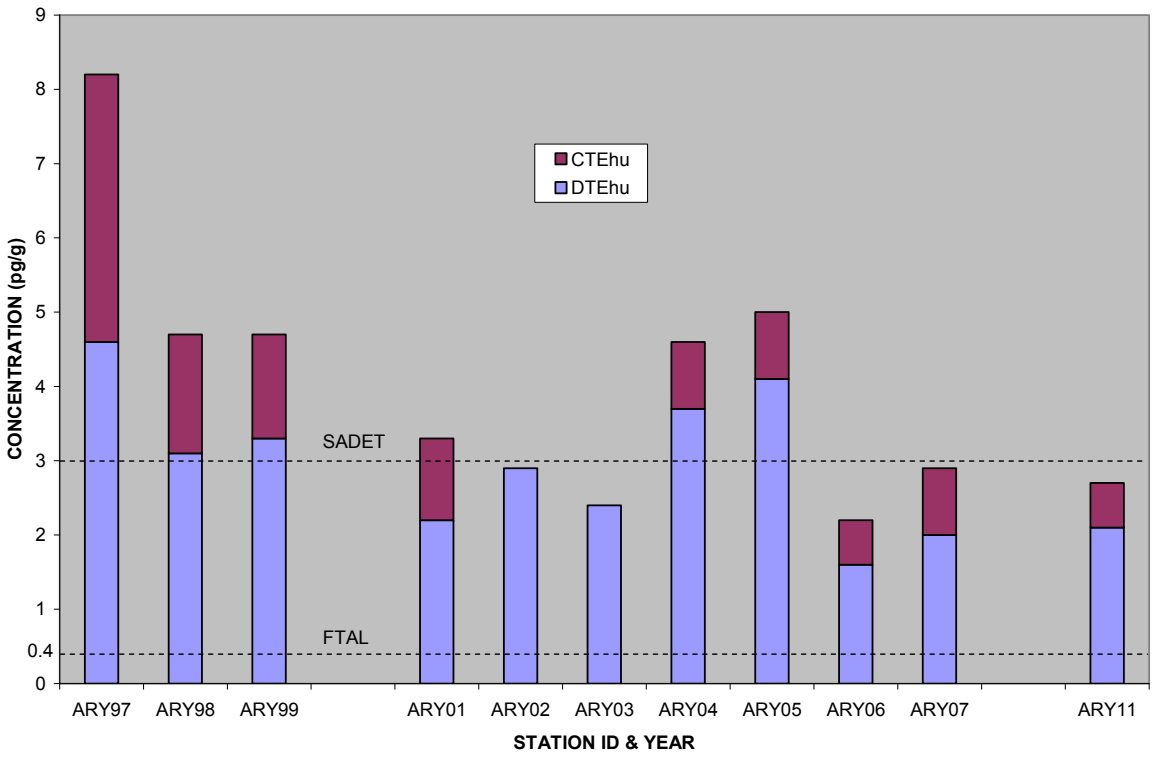
A total of ten smallmouth bass (SMB) were successfully collected from the Androscoggin River at Rumford Point (ARP). The dioxin toxic equivalent (DTEhu, calculated with non-detects at half of the detection limit as the upper 95th confidence level) concentration exceeded the ME-CDC FTAL for dioxin like compounds, but was below a mercury statewide advisory dioxin equivalent threshold (SADET= 3 pg/g) (Figure 3.2.1). Concentrations of coplanar PCB toxic equivalents (CTEhu, calculated at the 95th upper confidence level with non-detects at ½ of the detection limit) did not exceed the FTAL alone but the combination of the two groups of contaminants increased the exceedance of the FTAL. Concentrations of both DTEhu and CTEhu are well below those from 1995 and slightly lower than those of most recent years.

Figure 3.2.1. Dioxin (DTEhu) and coplanar PCB (CTEhu) toxic equivalents (95th upper confidence limit) in smallmouth bass from the Androscoggin River at Rumford Point (ARP).



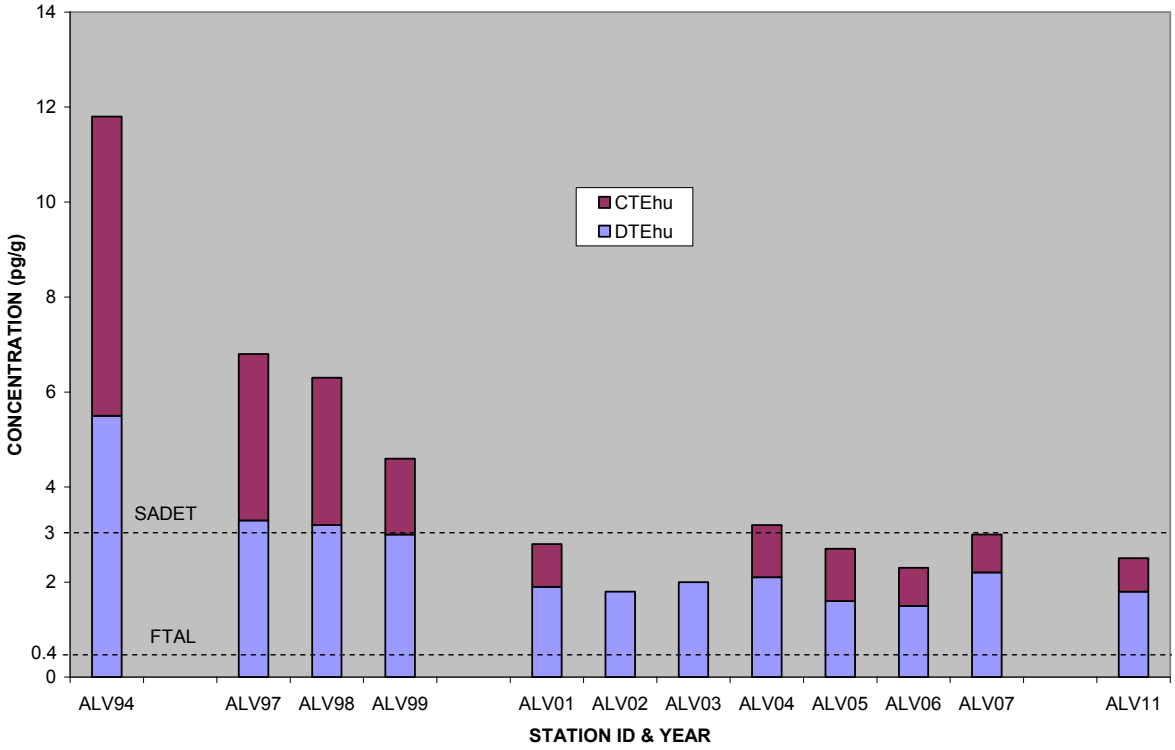
A total of ten white sucker (WHS) were collected from the Androscoggin River at Riley (ARY). The DTEhu concentration exceeded the FTAL for dioxin like compounds, but was below the SADET (Figure 3.2.2). The CTEhu concentration did not exceed the FTAL alone but the combination of the two groups of contaminants increased the exceedance of the FTAL. Concentrations of both DTEhu and CTEhu are well below those from 1997 and similar to those of most recent years.

Figure 3.2.2 . Dioxin (DTEhu) and coplanar PCB (CTEhu) toxic equivalents (95th upper confidence limit) in white sucker from the Androscoggin River at Riley (ARY).



A total of ten white sucker (WHS) were collected from the Androscoggin River at Livermore (ALV). The DTEhu concentration exceeded the FTAL for dioxin like compounds, but was below the SADET (Figure 3.2.3). The CTEhu concentration did not exceed the FTAL alone but the combination of the two groups of contaminants increased the exceedance of the FTAL. Concentrations of both DTEhu and CTEhu are well below those from 1999 and earlier and similar to those of most recent years. The DTEhu concentration at this station below the Verso Paper mill in Jay was no higher than the DTEhu concentration at ARY above the mill.

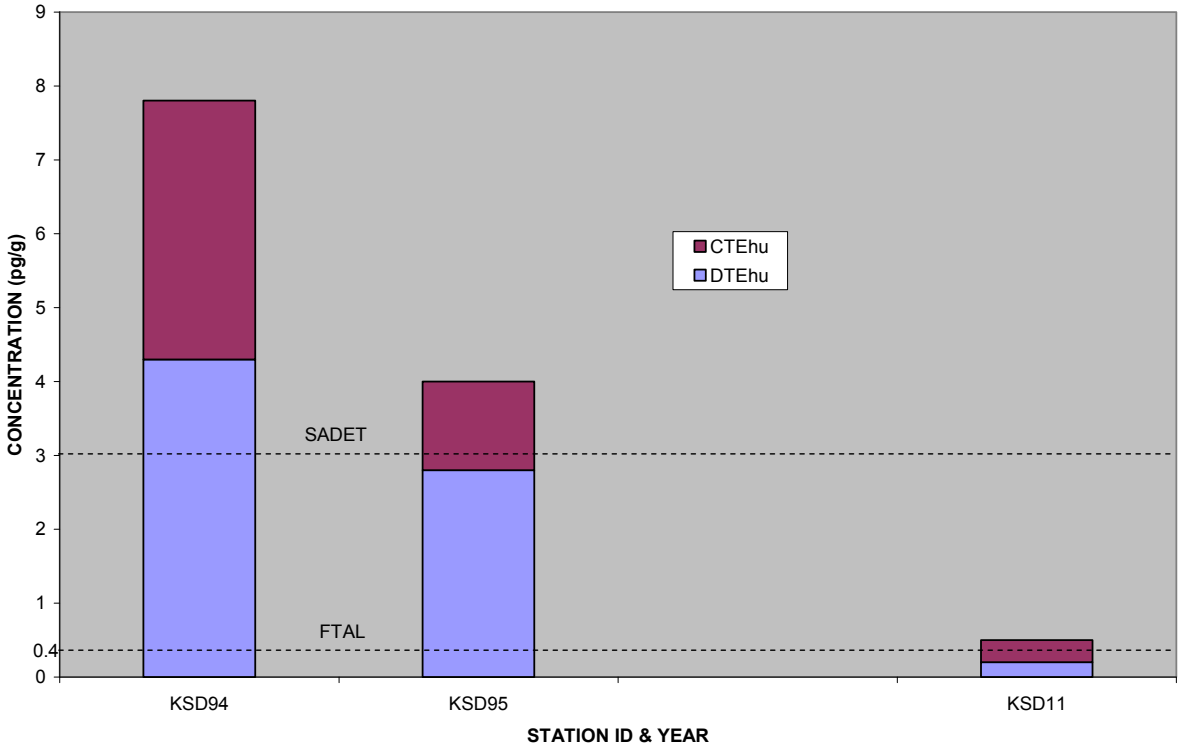
Figure 3.2.3 . Dioxin (DTEhu) and coplanar PCB (CTEhu) toxic equivalents (95th upper confidence limit) in white sucker from the Androscoggin River at Livermore (ALV).



Kennebec River

A total of ten white sucker (WHS) were collected from the Kennebec River at Sidney (KSD). The DTEhu concentration was below the FTAL for dioxin like compounds (Figure 3.2.4). The CTEhu concentration did not exceed the FTAL alone but the combination of the two groups of contaminants resulted in a slight exceedance of the FTAL although remained well below the SADET. Concentrations of both DTEhu and CTEhu are well below those from the only two earlier years with data.

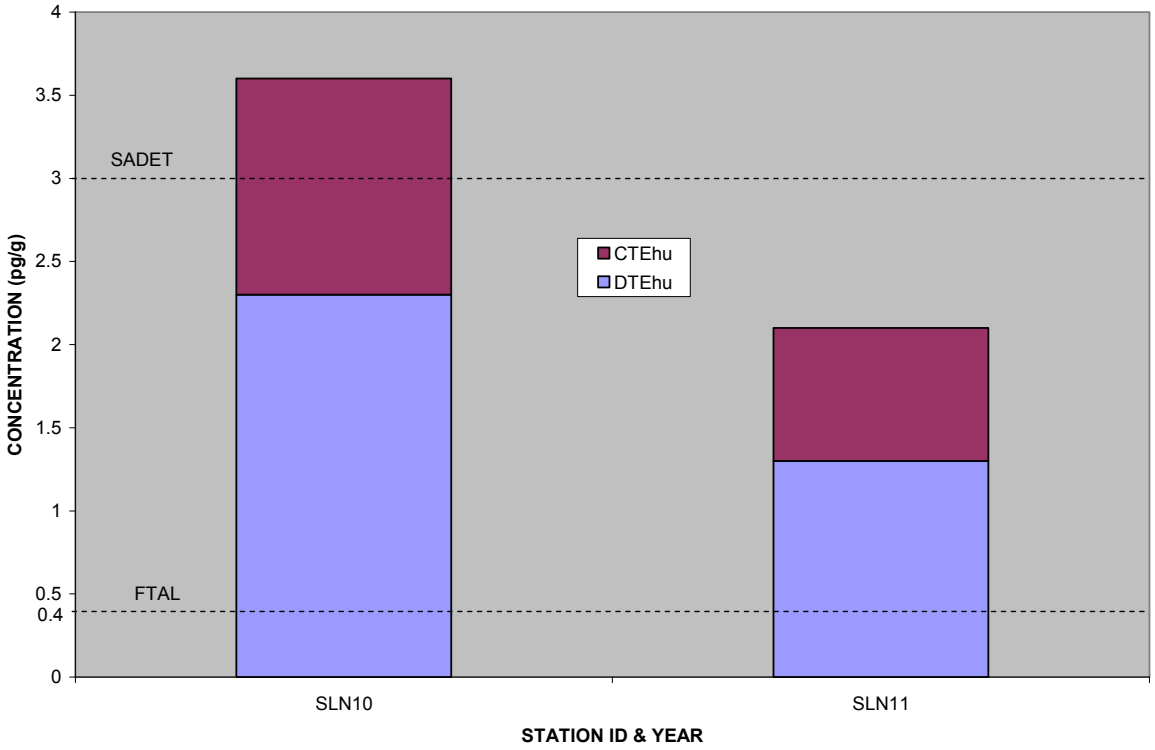
Figure 3.2.4 . Dioxin (DTEhu) and coplanar PCB (CTEhu) toxic equivalents (95th upper confidence limit) in white sucker from the Kennebec River at Sidney (KSD).



Sebasticook River

A total of ten white sucker (WHS) were collected from Sebasticook Lake at Newport (SLN). The lake is approximately 3 miles downstream of a former textile mill and Superfund site on the East Branch of the Sebasticook River in Corinna and a half mile below an historical dioxin sample station (SEN) and popular fishing spot at the County Road bridge. The DTEhu concentration exceeded the FTAL for dioxin like compounds, but was below the SADET (Figure 3.2.5). The CTEhu concentration did not exceed the FTAL alone but the combination of the two groups of contaminants increased the exceedance of the FTAL. Concentrations of both DTEhu and CTEhu are below those from 2010, the only other year white sucker were collected from either station.

Figure 3.2.5 . Dioxin (DTEhu) and coplanar PCB (CTEhu) toxic equivalents (95th upper confidence limit) in white sucker from Sebasticook Lake at Newport (SLN). .



3.2.2 Total PCBs in Fish Tissue

3.2.2.1 Introduction

Total PCBs for the Major Rivers

The request from ME-CDC was for dioxin-like coplanar PCB data from some rivers and total PCB data from some rivers. The method used for both is congener specific analysis from which both may be calculated. Consequently, DEP requested calculation of both from the lab for all samples discussed above for dioxins and coplanar PCBs. There is a river-specific fish consumption advisory for the Kennebec River due to total PCBs.

A total of 10 fish were captured at each station and analyzed as two composites of skinless filets from each of five fish for all 209 or coeluting PCB congeners via EPA method 1668. Total PCBs were then calculated as the sum of congeners and coeluting groups.

3.2.2.2 Results and Discussion

Contrary to ME-CDC's belief, there are significant brook trout fisheries in Maine rivers including the Androscoggin River at Gilead. Although attempts were made to collect brook trout from Gilead in 2011 for PCB analysis, it was too late in the season to catch them. Attempts will be made earlier in 2012.

Androscoggin River

Mean total PCB (TPCB) concentration in smallmouth bass (SMB) at Rumford Point (ARP), below Berlin, NH, exceeded ME-CDC's FTAL of 11 ng/g in 2011 (Table 3.2.1). Both mean and maximum concentrations in 2011 were higher than all previous years except for 2002. Mean and maximum concentrations of TPCB in white sucker (WHS) from Riley (ARY), below Rumford, also exceeded the FTAL. Concentrations were similar to those in 2010, both of which were higher than previous years. Mean and maximum concentrations of TPCB in white sucker (WHS) from Livermore (ALV), below Jay, also exceeded the FTAL and was higher than in previous years and similar to that upstream at Riley. Concentrations at both ARY and ALV were among the highest for all stations on the river, except for concentrations at Jay in 1994. The variation in concentrations within species among all years may reflect differences among the four different labs that were used, although all data meet quality assurance and control objectives, or simply the natural variation in individuals and condition among years.

Table 3.2.1. Total PCBs in fish from the Androscoggin River, ng/g. mean and (max value where n=2 or 95th upper confidence level wher

Year	Species	Gilead AGL	Rumford Pt ARP	Rumford ARF	Riley ARY	Jay ARJ	Livermore 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)						21 (24)	
2010	SMB				47 (58)					
2011	SMB		66 (71)							
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)	
2010	WHS				86 (110)					
2011	WHS				96 (104)		97 (110)			

Kennebec River

Mean total PCB (TPCB) concentration in white sucker (WHS) at Sidney (KSD) below Fairfield, exceeded ME-CDC's FTAL of 11 ng/g in 2011 (Table 3.2.2). Concentrations were lower than when last measured in 2009, but similar to those of other years. Concentrations are generally lower at this station below Waterville than at Fairfield (KFF) which is below the pulp and paper mill on the Skowhegan Fairfield town line. The variation in concentrations within species among all years may reflect differences among the four different labs that were used, although all data meet quality assurance and control objectives, or simply the natural variation in individuals and condition among years.

Sebasticook Lake

Mean and maximum total PCB (TPCB) concentrations in white sucker (WHS) from Sebasticook Lake (SLN) at Newport exceeded ME-CDC's FTAL of 11 ng/g in 2011 (Table 3.2.3). Both mean and maximum concentrations in 2011 were similar or slightly higher than those of 2010, the only other year for which there are data. This station is below a former textile mill on the on the East Branch of the Sebasticook River at Corinna which became a Superfund site that has been remediated for other contaminants. Concentrations from other years are higher downstream below the confluence with the West Branch.

Table 3.2.2. Total PCBs in fish from the Kennebec River, ng/g. mean and (max if n=2 or 95th upper confidence level if n>2)

Year		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)					
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)			
2002	EEL								377
2005	SLT								46 (64)
2007	SLT						60 (83)		
2009	SLT							18 (20)	
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)			
2011	WHS				26 (32)				

Table 3.2.3. Total PCBs in fish from the Sebasticook River, ng/g
mean and (max value where n=2 or 95th upper confidence level where n>2)

Year	Species	E Br Newport SEN	Sebasticook L SLN	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	
2010	LMB	38 (40)			54 (63) SMB	
1997	WHP	4				
1997	WHS			6	7	14
2009	WHS			7 (8)	70 (77)	
2010	WHS		60 (67)		113 (133)	
2011	WHS		49 (49)			

3.3 MERCURY BODY BURDENS IN NON-MIGRATORY RESIDENT FISH ALONG THE PENOBSCOT RIVER

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SWAT FINAL REPORT – MARCH 2012

Title: Mercury body burdens in non-migratory, resident fish along the Penobscot River

Principal Investigator:
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Abstract: Fish populations that are chronically exposed to mercury can develop resistance to the toxic effects of this metal, including mummichogs (*Fundulus heteroclitus*). Such resistance allows them to potentially accumulate very high levels of this contaminant and act as 'toxic prey packages' which can be consumed by higher trophic level predators, including fish and piscivorous birds that may not be resistant. Mercury is a neurotoxin that affects behavior, including swimming and the ability to capture prey in fish and behavior, reproduction and immune function in birds. Ingestion of mercury contaminated prey could have significant, and severe, effects on migratory fish and piscivorous birds, including loons. Mercury contamination of the lower Penobscot River has been well-characterized, and mummichog populations have been found in fish surveys along this river at several sites. In this study, mummichogs were collected by NOAA Fisheries by seine from 8 sites in the Penobscot River: Soudabascook, Snub Point – Bartlett Cove, Bald Hill Cove, Parker Point, Drachm Point, South West Verona Island, and Old Pier as part of their ongoing river survey census of resident and migratory fish species. Fish were frozen (-20 C), and skinless muscle fillets analyzed for total mercury using a Direct Mercury Analyzer. As a non-migratory species, *Fundulus heteroclitus* is often used as a sentinel of persistent pollutants in its immediate environment. Mercury concentrations in Penobscot River *F. heteroclitus* populations ranged from 136 – 241 ppb (total Hg wet wt fillet) in juvenile fish from Soudabascook to Old Pier; levels which are 9 – 16 fold higher than those of mummichog collected from Little River, a reference site in the Wells National Estuarine Research Reserve. Mercury levels in Penobscot River mummichog are below those shown to have adverse effects in juvenile/adult fish (> 500 ppb). No concentration gradient was evident in mummichog Hg levels. These results will be used to design future laboratory studies to evaluate the relative resistance of the Penobscot mummichog populations to mercury toxicity.

Introduction

The ability of fish to develop resistance to toxic chemicals is well established. Chemical tolerance is most often observed in populations of non-migratory species generationally exposed to chemicals in their habitats. The first reported case was of DDT-resistant mosquito fish living in agricultural streams (Vinson et al. 1963). Since then, there have been numerous reports of fish acquiring

tolerance to a variety of toxins, including dioxin, polychlorinated biphenyls, polynuclear aromatic hydrocarbons and mercury (Elskus et al. 1999; Nacci et al. 1999; Weis 2002).

As a neurotoxin, mercury adversely affects a wide range of systems, including growth, physiological processes, and behavior. In fish, it provokes severe cranial-facial and spinal abnormalities, alters swimming, prey capture and feeding, and affects immune response, among other endpoints (Samson et al. 2001; Zhou et al. 2001; Weis 2002; Wang et al. 2011). An analysis of published fish mercury data in 2005 concluded that mercury body burdens below 0.2 ppm (whole body) for juvenile and adult fish, and below 0.02 ppm for early life stage fish are unlikely to cause adverse effects (Beckvar et al. 2005), with further work providing a body residue-response curve for mercury in fish (Dillon et al. 2010). More recent studies have modified these thresholds (0.3 ppm whole adult fish; 0.5 ppm fillet) (Sandheinrich et al. 2011).

Although many fish species are capable of developing tolerance, mummichogs have been the most intensively studied. Embryos of mercury resistant populations remain unaffected by exposure to methylmercury concentrations that cause skeletal deformities in non-resistant reference populations (Weis 2002). Interestingly, these fish become more methylmercury sensitive as larvae and adults (Weis 2002). One consequence of resistance is the survival of tolerant populations with potentially very high body burdens of mercury that could be toxic to non-resistant predators. In effect, they become 'toxic prey packages'. Ingestion of mercury contaminated prey could have significant, and severe, effects on migratory fish and piscivorous birds, including loons (Evers et al. 2008; Hawley et al. 2009).

Mummichogs (*Fundulus* sp), also known as killifish, are widespread, occurring along salinity gradients from fresh to coastal waters along the east coast of the US to the St. Lawrence river in Canada (Scott et al. 1998), including the Penobscot River in Maine (C. Lipsky, NOAA pers comm.). They are non-migratory, deposit benthic eggs and exhibit high site fidelity (Lotrich 1975; Teo et al. 2003; Meyer et al. 2009), all of which serve to make them ideal sentinels of their local habitat and contribute to the development of discrete populations.

Due to inputs of mercury from a recently closed (2000) chlor-alkali facility located at Perc Point in Orrington, Maine, sediments in the lower Penobscot River are contaminated with mercury (Merritt et al. 2007; Bodaly et al. 2009). Mummichog populations have been found in fish surveys along this river at several sites (Justin Stevens, NOAA; C. Yoder, pers comm.).

We measured total mercury body burdens in discrete populations of resident killifish along the Penobscot River from just above Perc Point, the site of the now closed chlor-alkai facility, south to Old Pier.

Approach

Fish Collection

As part of a routine survey being conducted in the Penobscot River (July – October 2011), researchers from NOAA's Northeast Fisheries Office (Orono, ME) collected killifish (*Fundulus heteroclitus*) from sites up and downstream of Orrington, the site of a former chlor-alkali plant and

point source of significant amounts of mercury to the river (Merritt et al. 2007). These sites include (North to South): Souadabscook, Snub Point, Bald Hill Cove, Oak Point, Parker Point, Drachm Point, Southwest Verona Island and Old Pier (Figure 1, Table 1). Fish were collected by seine, placed in plastic zip lock bags or wrapped individually in aluminum foil, immediately placed on ice, and frozen (- 20 C) within 8 - 10 hours of collection. Reference mummichog were collected by Michelle Dionne from Little River, Site 2 in Wells National Estuarine Research Reserve (Figure 2, Table 1), a site whose mummichog population is known to have low mercury body burdens (Chen et al. 2009).

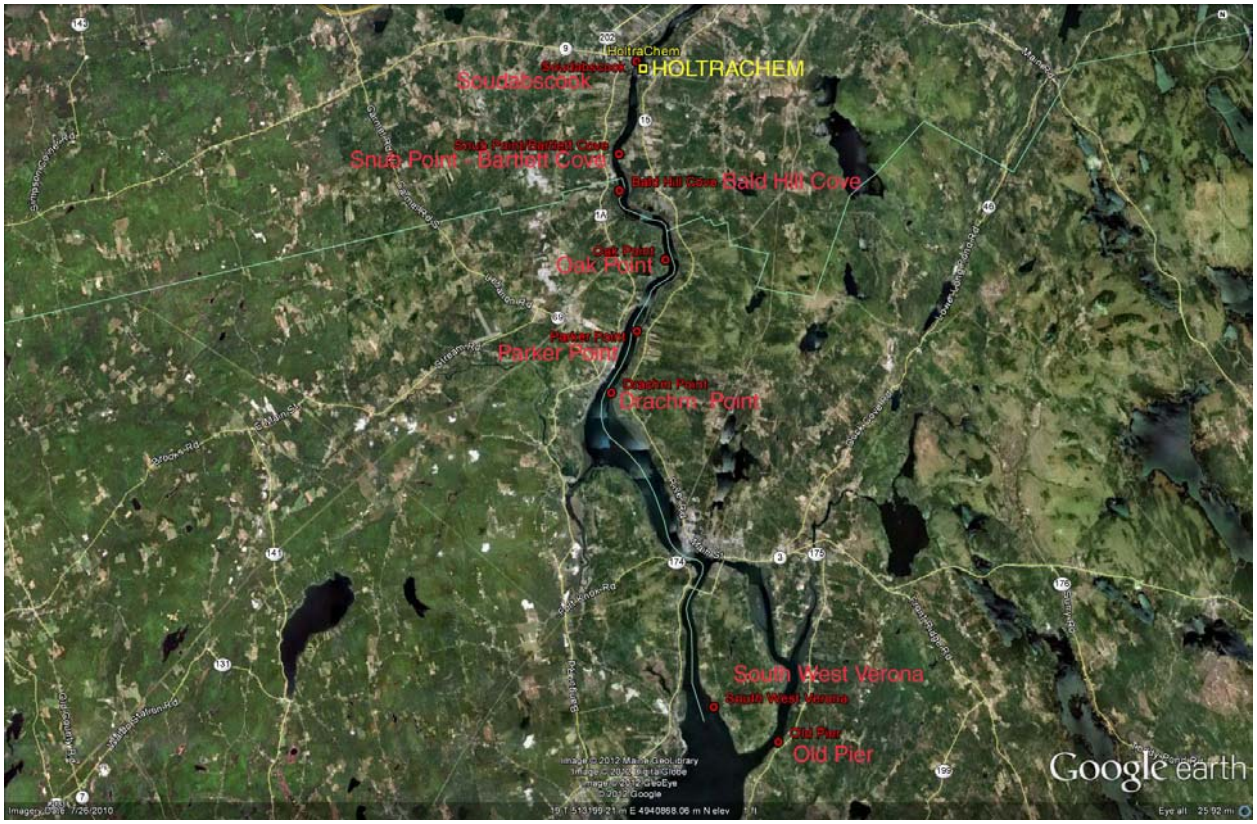

Figure 1. *F. heteroclitus* collection sites in the Penobscot River: Souadabscook, Snub Point, Bald Hill Cove, Oak Point, Parker Point, Drachm Point, Southwest Verona Island and Old Pier.

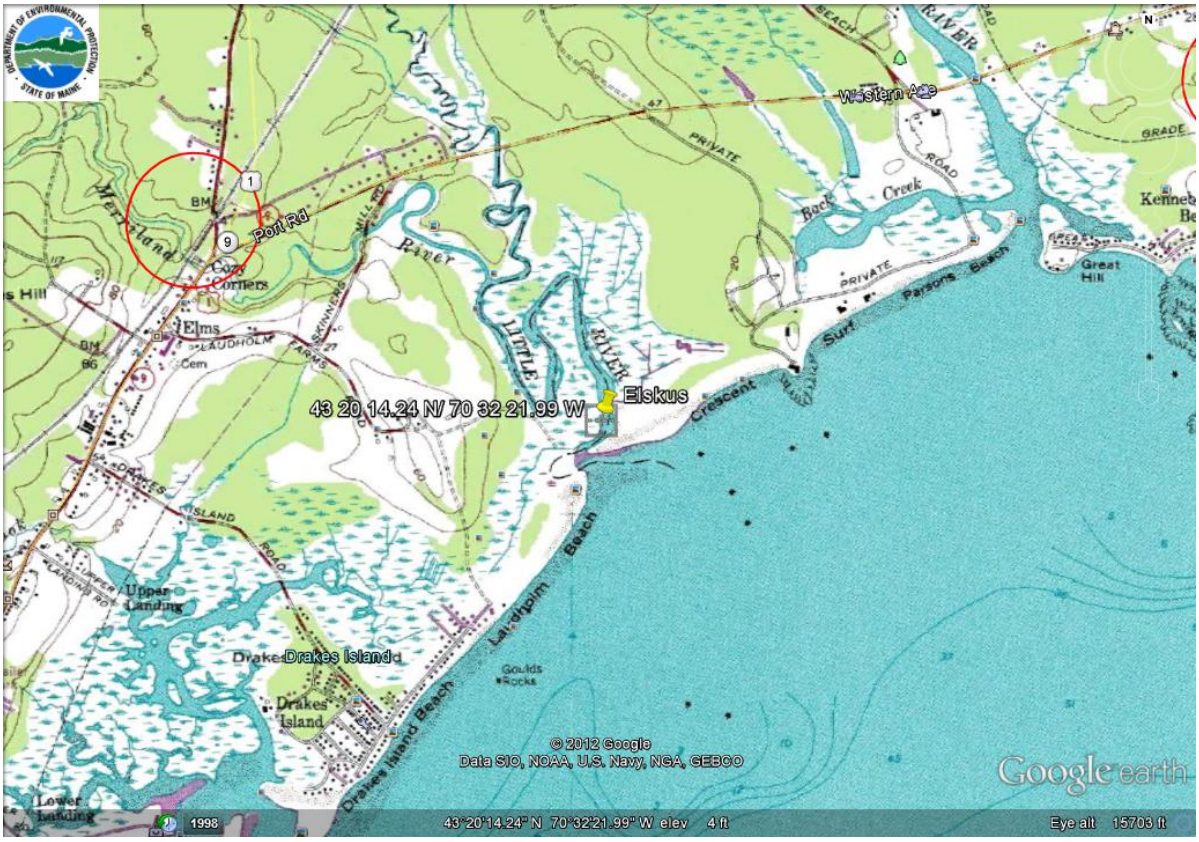

Figure 2. *F. heteroclitus* sampling site in the Wells National Estuarine Research Reserve: Little River, Site 2. Site marked by yellow thumbtack-Elskus.

Table 1. Collection dates, number of fish collected, site names and geographic locations of *F. heteroclitus* collections.

Date collected	# FISH	Site	town	Universal Transverse Mercator (UTM)	Lat/Long
Penobscot River					
10/4/2011	10	Souadabscook	Hampden	513458 4954385 [19]	44 44 33.806 / 68 49 48.019
8/3/2011	10	Snub Point/Bartlett Cove	Orrington	512791 4950816 [19]	44 42 38.185 / 68 50 18.672
8/3/2011	10	Bald Hill Cove	Winterport	512816 4949411 [19]	44 41 52.649 / 68 50 17.662
10/3/2011	6	Oak Point	Winterport	514593 4946762 [19]	44 40 26.677 / 68 48 57.191
7/22/2011	11	Parker Point	Winterport/Bucksport	513499 4944015 [19]	44 38 57.727 / 68 49 47.140
8/19/2011	11	Drachm Point	Frankfort/Bucksport	512520 4941642 [19]	44 37 40.885 / 68 50 34.796
9/1/2011	10	South West Verona	Verona	516498 4929577 [19]	43 20 14.242/70 32 22.002
10/6/2011	10	Old Pier	South Orland	518979 4928263 [19]	44 30 26.774/68 45 40.440
Wells National Estuarine Research Reserve					
9/30/2011	22	Little River, Site 2	Wells	375210 4799422 [19]	43 20 14.24 N/ 70 32 21.99 W

Tissue Sampling

Fillets were collected from individual fish using a Maine Department of Environmental Protection Agency protocol (Linda Bacon & Barry Mower, MDEP pers comm.). Working quickly to avoid tissue thaw and dewatering, frozen fish were held in place with a toothed forcep, the thin skin

removed using a scalpel, and muscle fillets successively sliced and collected until the spine was reached. Fillets were placed into 2 mL cryovials labeled with site and specimen number and immediately placed back at – 20 C until transferred to the Sawyer Environmental Chemistry Research Laboratory (SECRL) at the University of Maine, Orono, within 1 week. Muscle fillets were taken, rather than whole body homogenates, as fillets are representative of whole body mercury levels in fish (MDEP 2011), and require less sample manipulation.

Mercury Analysis

Muscle fillets were analyzed by SECRL using atomic absorption spectrometry on a Milestone DMA-80 Direct Mercury Analyzer. All analyses were accompanied by appropriate QA/QC samples, including analyzing 10% of the samples in duplicate, 10% of the samples for matrix spikes, procedural blanks, standards, and mercury reference materials. Sample reference material recovery ranged from 95.9-104.3%. Reported values are not corrected for recovery.

Statistics
Site differences were evaluated using 2-way ANOVA at a significance level of $p<0.05$.

Results

Fish metrics

F. heteroclitus were similar in size overall (Table 2), and ranged from 40 mm, 0.6 g body weight to 100 mm, 13.6 g body weight. Fish length and weight are linearly related (Figure 3).

Table 2. *F. heteroclitus* length and weight measurements.

Collection Site	**N**	**Length ±SD (mm)**	**Weight ± SD (g wet whole body)**
Souadabscook	10	55.6 ±5 .3	1.43 ± 0.30
Snub Point/Bartlett Cove	10	79.2 ± 5.8	6.49 ± 1.15
Bald Hill Cove	10	71.7 ± 10.4	5.59 ± 1.42
Oak Point	6	70.0 ± 17.0	5.09 ± 4.62
Parker Point	11	59.1 ± 5.3	2.66 ± 0.61
Drachm Point	11	77.5 ± 9.1	5.80 ± 2.18
South West Verona	10	79.6 ± 10.4	6.15 ± 2.65
Old Pier	10	61.0 ± 18.7	3.52 ± 2.92
Little River Site 2	20	51.0 ± 8.0	1.56 ± 0.91

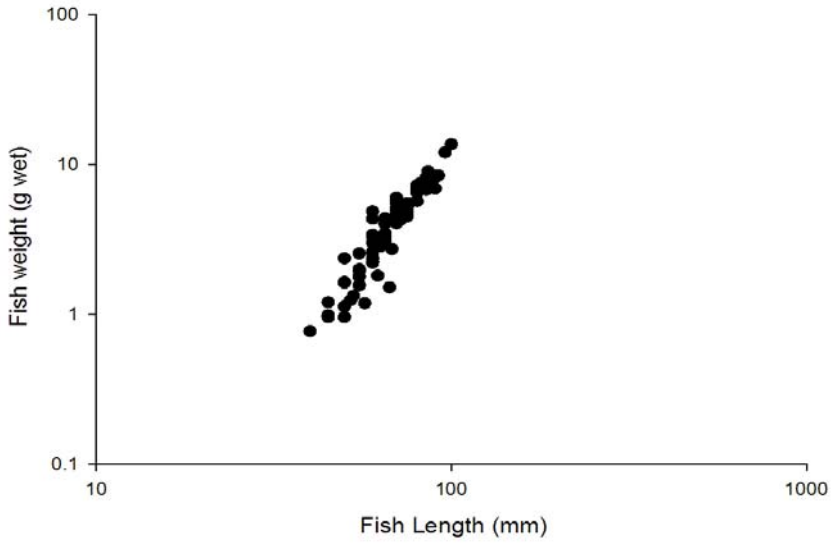

Figure 3. *F. heteroclitus* length-weight relationship on a log 10 scale.

Fish Mercury

There were no site differences in total mercury concentrations in muscle fillets among populations of *F. heteroclitus* from the Penobscot River. Mean mercury concentration in Penobscot fish ranged from 0.136 – 0.241 ppm (total Hg in □g/g wet wt fillet) (Figure 4). In contrast, mercury concentrations in *F. heteroclitus* from Little River in the Wells National Estuarine Research Reserve (WNERR), a site with known low mercury levels (Chen et al. 2009; M. Dionne, pers. comm.) ranged from below detection limits to 0.0052 - 0.037 ppm, concentrations 9 – 16 times lower than those of the Penobscot River fish (Figure 4). There was little relationship between fish size (length) and mercury body burden in Penobscot River populations (Figure 5).

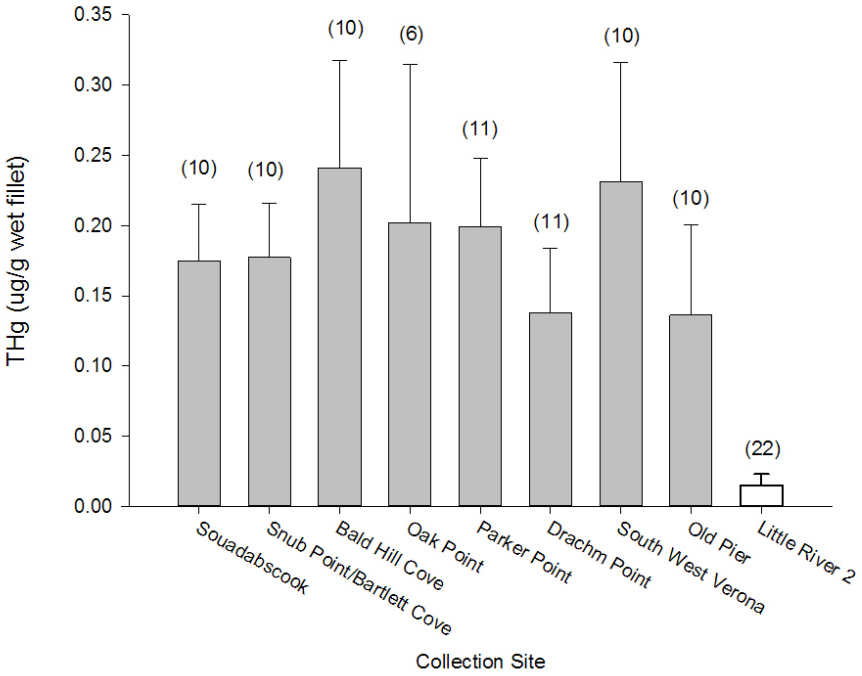

Figure 4. Mercury concentrations in F. heteroclitus from sites in the Penobscot River (gray bars) and a reference site in the Wells National Estuarine Research Reserve (open bar). Means +/- SD for (n) individuals.

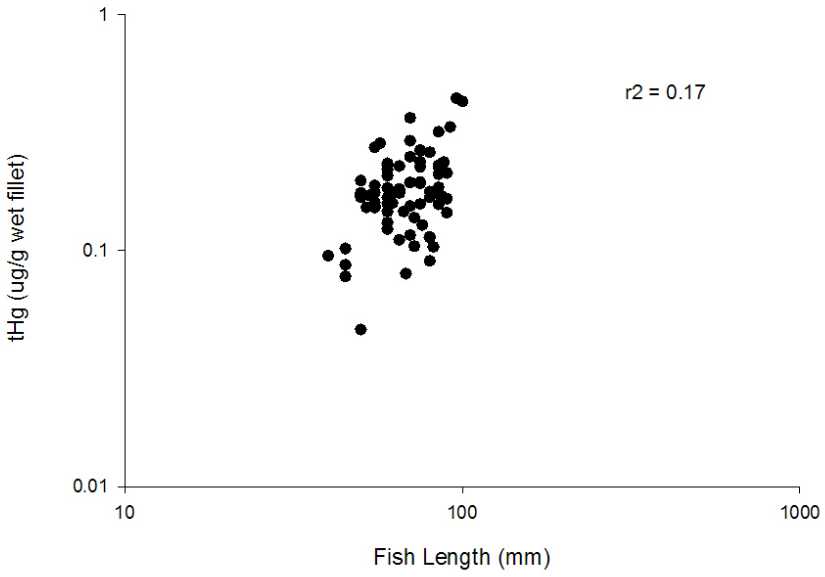

Figure 5. Mercury concentrations in fillets versus fish length in Penobscot River *F. heteroclitus* populations.

Summary and Significance

The results of this study indicate that populations of *Fundulus heteroclitus*, a resident, non-migratory fish living in close-association with mercury-contaminated sediments in the Penobscot River, are accumulating significant levels of mercury in their bodies. There were no site differences in mercury body burdens of populations from just above the Holtrachem facility to Old Pier, a distance of approximately 15 river miles, reflecting the relatively consistent mercury levels of the sediments along this reach (Bodaly et al. 2009). The total Hg levels in *F. heteroclitus* fillets at 0.136 – 0.241 ppm wet are similar to those reported in 2009 for whole body Hg of a related species along this reach, *Fundulus diaphanous,* at 0.138 – 0.421 ppm wet (Bodaly et al. 2009).

Mercury levels in Penobscot *F. heteroclitus* populations are elevated 9-16 times over concentrations in fish from a reference site in the Wells National Estuarine Research Reserve in Wells, Maine whose body burdens ranged from 0.0052 - 0.037 ppm wet fillet. Penobscot mummichog mercury concentrations are nonetheless below those considered to adversely affect fish health (0.5 ppm wet fillet) (Sandheinrich et al. 2011). Whether mercury exposure of Penobscot River *F. heteroclitus* has produced mercury resistant populations, and whether the mercury body burdens of Penobscot mummichogs are indicative of resistance, are unknown and deserve further study.

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4.0 SPECIAL STUDIES

4.1 CAN FUNGICIDE MODE OF ACTION BE USED TO PREDICT EFFECTS IN FISH? Azoxystrobin effects on respiratory burst in zebrafish.

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Abstract
Relatively few data are available on the effects of fungicides on non-target organisms in the aquatic environment, despite decades of agricultural and urban use. Fungicides exert their toxic effects by disrupting basic biochemical reactions in fungal cells and there is evidence that modes of toxic action in fungi may be predictive of modes of toxic action in vertebrates and invertebrates. The fungicide azoxystrobin blocks fungal growth by inhibiting mitochrondrial respiration and there is recent evidence that it also disrupts mitochondrial respiration in fish. Mitochondrial respiration generates energy needed for cell growth, but also produces significant amounts of reactive oxygen species (ROS) as toxic by-products through oxidative phosphorylation. ROS production is a key component of innate immunity in fish. We hypothesized that the fungicide azoxystrobin may affect the innate immune response of fish by blocking ROS production. To test this theory, we exposed zebrafish (*Danio rerio*) to environmentally relevant concentrations of azoxystrobin (10 – 5,000 ng/L) from fertilization through 4 days post-fertilization and measured innate immunity using the respiratory burst assay. We also conducted preliminary studies using high, non-environmentally relevant concentrations of azoxystrobin (47,000 – 235,000 ng/L). Our results indicate that exposure to azoxystrobin at environmentally relevant concentrations during embryonic development does not affect production of ROS by early life stage fish, and thus is not likely to affect the innate immune system of this life stage. Fish exposed to these concentrations also developed and hatched normally. In contrast, high, non-environmentally relevant concentrations of azoxystrobin decreased survival, induced deformities and suppressed respiratory burst activity, providing preliminary information on possible modes of action in fish. We conclude that as a solitary chemical at concentrations reported in surface waters of the US, azoxystrobin is not likely to pose a threat to the development, survival or innate immunity of fish.

Introduction
Fungicides are used in many agricultural settings in Maine, and have recently been detected in surface waters near potato agricultural areas in Aroostook County (K. Kuivila, USGS pers comm.). Relatively few data are available on the effects of fungicides on non-target organisms in the aquatic environment, despite decades of agricultural and urban use. Given the basic modes of action through which fungicides exert their toxic effects (mitosis and cell division, nucleic acids synthesis, respiration, amino acids and protein synthesis, signal transduction, lipids and membrane synthesis, sterol biosynthesis in membranes, glucan synthesis, melanin synthesis in cell wall, host plant defense induction, multi-site contact activity, with some whose mode of action is still unknown), one might expect these chemicals to be potent toxicants for all biological life. Indeed, an increasing number of studies report dramatic, and in some cases severe, effects of fungicides on fish and invertebrates at environmentally relevant concentrations.

Recent work through ToxCast, a U.S. Environmental Protection Agency program, has demonstrated that conazoles and triazole fungicides, along with pyrethroids, had effects on a broad spectrum of pathways, showing activity for at least 10 of the 33 biochemical pathways tested using mammalian based assays (Judson et al. 2010). It is likely, then, that biochemical modes of fungicide action in fungi could be used to predict analogous modes of action, target site(s), and/or toxic effects for non-fungal species. In this regard, there are some tantalizing parallels. Chlorothalonil exerts its toxic effects on fungi by complexing with sulphydryl-containing proteins which leads to depletion of glutathione reserves (Arvanites et al. 2001), one mechanism of toxicity. Some of these same thiol-reactive processes are affected in fish (Davies 1985; Gallagher et al. 1992; Davies et al. 1994) and invertebrates (Davies et al. 1994; Baier-Anderson et al. 1998; Baier-Anderson et al. 2000).

Azoxystrobin affects respiration in fungi by inhibiting electron transport in mitochrondria, leading to cellular oxidative stress and disruption of fungal metabolism and growth (Bartlett et al. 2002; Kim et al. 2007; Gisi et al. 2008). There is evidence that azoxystrobin may also disrupt mitochrondrial respiration in fish, although the biochemical mechanism is not known. Significant alterations have been reported in liver, muscle and blood parameters associated with mitochrondrial respiration, oxidative stress, and cell growth and proliferation in smolts of Atlantic salmon (*Salmo salar*) exposed to azoxystrobin (61 – 352 □g/L) for 4 days (Olsvik et al. 2010), a duration representative of their exposure during downstream migration through agricultural runoff.

ROS production is the first line of defense against pathogens and a key indicator of the strength of the innate immune system in vertebrates, including fish (Hermann et al. 2004). There are many sources of ROS, including mitochondrial respiration (Bulua et al. 2011) and NADPH oxidases found in phagocytes and numerous other cell types (Babior 2000; Desouki et al. 2005; Aguirre et al. 2010).

This study tested the hypothesis that the fungicide azoxystrobin may affect the innate immune response of fish by blocking ROS production as measured using the respiratory burst assay.

Approach

Zebrafish (Danio rerio)

Zebrafish embryos (AB strain) were obtained from the Zebrafish Core located at the University of Maine, Orono. Embryos attaining the 8-cell stage post-fertilization (2-3 hr old) were used for all experiments.

Fungicide

Azoxystrobin (CAS No. 131860-33-8, Sigma Aldrich, purity > 98%) was acquired from Kelly Smalling at the U.S. Geological Survey laboratory in Sacramento, CA as a stock solution in acetone (250 mg/L, November 2011) and was used to create the dosing solutions.

Exposure Solutions

Azoxystrobin concentrations were based on concentrations observed in surface waters (Smalling et al. 2011). For dosing purposes, azoxystrobin was dissolved in acetone to prepare the stock solution (250 mg/L) and stored in an amber bottle at -20 C. Environmentally relevant concentrations of azoxystrobin 10, 150 and 5,000 ng/L were prepared by serial dilution in egg water (0.6 percent Instant Ocean prepared in nanopure water). Concentrations of acetone in the treatments were maintained at 20 □/L, as recommended (Hutchinson et al. 2006), and acetone was used as a vehicle control at 20 □/L. Because azoxystrobin is sensitive to light (Smalling, Elskus and Smith, unpublished data), treatment solutions were prepared fresh daily.

Experimental Design

Zebrafish embryos were exposed to azoxystrobin, acetone carrier (20 □/L) or egg water (0.6-percent Instant Ocean prepared in nanopure water) for 4 days (96 h) in 100 x 15 mm plastic petri dishes (20-23 embryos/dish) at 28 °C on a 14-h/10-h light/dark cycle from 2 to 3 h post-fertilization (Day 0) to 96 h post-fertilization (Day 4), an age when they display immunologic competence (Hermann et al. 2004). Treatment water in the petri dishes was renewed daily to remove any waste material generated by the zebrafish embryos and larvae (e.g. ammonia, chorions remaining after hatch, etc) and replaced with freshly prepared solutions. Five (5) independent, replicate experiments were conducted, with one replicate experiment run per week using embryos from an assortment of approximately 14 females and 12 males.

Innate Immune Function- Respiratory Burst Assay

We evaluated respiratory burst, a simple innate immune system assay, as described (Hermann et al. 2004). Briefly, on Day 4 (96 h post fertilization) zebrafish larvae were transferred from exposure dishes (egg water alone, 20 □/L acetone, 10 ng/L AZ, 150 ng/L AZ, 5000 ng/L AZ) to black 96 well plates, one larva per well, and exposed to either substrate alone (H2DCFDA in 6 wells) or substrate plus phorbol 12-myristate 13-acetate (PMA in 6 wells). PMA provokes the production of superoxide. In turn, superoxide oxidizes the substrate H2DCFDA (a non-fluorescent dye) to dichlorofluorescein (DCF, a fluorescent product). In fish with a healthy immune system, PMA exposure in the presence of H2DCFDA provokes substantial production of DCF. PMA thus serves both as the stimulant and as a positive control to confirm the assay is working properly. Evolution of DCF was monitored for 4.0 h in a BioTek Synergy4 fluorescence plate reader at an excitation/emission of 485 ± 20 nm/528 ± 20 nm.

Mortality, Time to Hatch, Developmental Abnormalities

Zebrafish embryos were monitored daily for mortality, hatch success, and evidence of developmental abnormalities. Based on previous studies with this fungicide (Elskus and Smith, unpublished data), we expected all concentrations to be non-lethal and have no deleterious effects on hatch or development.

Statistics

Treatment differences were evaluated using 2-way ANOVA at a significance level of $p<0.05$.

Results and Discussion

Exposure to environmentally relevant concentrations of azoxystrobin (10-5,000 ng/L) during the first 96 hours following fertilization did not significantly affect development, hatch success, or survival of early life stage zebrafish (Table 1). Azoxystrobin exposure also did not affect respiratory burst activity in these larvae, with no significant difference between control and treated fish at any dose ($p < 0.74$)(Table 1). It is interesting to note that the variance for the respiratory burst response is twice as high in the azoxystrobin treated groups as in the controls, which may indicate some effect on the fungicide on this parameter in these fish, but one that is not significant at these doses.

Table 1. The effects of exposure to azoxystrobin (fertilization to 4 days post-fertilization) on development, hatch success, survival and relative respiratory burst activity in zebra fish early life stages. Values are mean ± SD for N = 5 independent experiments of 20-23 embryos per treatment per experiment.

Treatment, ng azoxystrobin/L	Developmental deformities (%)	Hatch success (%)	Survival (%)	Respiratory Burst (% of controls)
Egg water alone	**0**	**97.7 ± 2.6**	**97.7 ± 2.6**	
Vehicle control	**0**	**98.5 ± 2.9**	**98.5 ± 2.9**	**96.4 ± 8.1**
10	**0**	**96.0 ± 8.9**	**96.0 ± 8.9**	**92.7 ± 17.1**
150	**0**	**95.2 ± 3.5**	**96.1 ± 4.2**	**97.0 ± 13.7**
5,000	**0**	**93.3 ± 5.5**	**94.3 ± 5.5**	**103.6 ± 15.8**

Preliminary experiments (a single experiment of 23 embryos per treatment group exposed from fertilization to 4 days post-fertilization) at non-environmental doses demonstrated azoxystrobin can be toxic to early life stage zebrafish at very high concentrations. Embryos exposed to 235,000 ng/L azoxystrobin experienced 100% mortality within 24 hours. This dose represents half of the acute toxic dose for fish (96 hr LC50 = 0.47 mg/L for azoxystrobin for rainbow trout early life stages (PPDB 2011), indicating that zebrafish embryos may be more sensitive to this fungicide than US EPA model test organisms. Lesser, but still environmentally unrealistic doses also reduced survival and provoked some developmental abnormalities (65.2% survival and 8.7% deformities at 94,000 ng/L). Respiratory burst activity was also suppressed relative to vehicle controls in embryos treated with high azoxystrobin concentrations: respiratory burst activity was74.4% of controls at 47,000 ng/L and 62.6% of controls at 94,000 ng/L. The respiratory burst assay measures the production of ROS by NADPH oxidases (Hermann et al. 2004). Suppression of respiratory burst in zebrafish by high doses of azoxystrobin indicates that NADPH oxidase may be a target site for this fungicide in fish.

Members of the NADPH oxidase (Nox) family of enzymes are found in several cell types in addition to phagocytes (Babior 2000; Desouki et al. 2005; Aguirre et al. 2010)and regulate a broad

diversity of biological functions, including cell-to-cell signaling and morphogenesis (Aguirre et al. 2010). Disruption of Nox enzymes by azoxystrobin could affect numerous biological systems. Whether the gross developmental deformities and the lethal effects observed at high doses of azoxystrobin in the present study are mediated through disruption of Nox enzymes is unknown.

In fungi, azoxystrobin blocks mitochrondrial respiration by binding to the Qo site of cytochrome b, blocking the transfer of electrons from cytochrome b to cytochrome c1, thereby stopping production of energy (ATP) and preventing fungal growth (Bartlett et al. 2002). Whether azoxystrobin also acts via the Qo site of cytochrome b to block mitochrondrial production of ATP in fish is unknown.

The results of this study will be used as preliminary data on which to base proposals to examine the predictive potential of fungal modes of action for biochemical and physiological effects in fish. Such predictive capability would greatly accelerate our ability to evaluate potential environmental effects of fungicides on non-target species, including fish and aquatic invertebrates. Such information will also help in selection of which fungicides to use based on their mode of action, before they are used in areas containing threatened and endangered amphibian, fish and invertebrate species.

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