Report to the Joint Standing Committee on Environment and Natural Resources
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Surface Water Ambient Toxics Monitoring Program 2017-2018

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Introduction

This 2017/2018 Surface Water Ambient Toxic (SWAT) monitoring program final report is organized into an Executive Summary, Introduction and 4 modules:
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4. Special Studies

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

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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:

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EXECUTIVE SUMMARY

Maine's Surface Water Ambient Toxics (SWAT) monitoring program was established in 1993 (38 MRSA §420-B) and is administered by the Department of Environmental Protection to determine the nature, scope and severity of toxic contamination in the surface waters and fisheries of the State. The authorizing statute states that the 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. The 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 five-year conceptual work plan in addition to annual work plans which are each reviewed by a Technical Advisory Group (TAG). The TAG is composed of 12 individuals, including two representatives with scientific backgrounds representing each of five various interests (business, municipal, conservation, public health and academic), and two legislators.

The SWAT program is divided into four modules: 1) Marine and Estuarine, 2) Lakes, 3) Rivers and Streams, and 4) Special Studies. This annual report follows the goals of the 2014 five-year conceptual plan, which are generally to continue to monitor previously identified and new toxic issues in the marine environment, lakes and ponds, and rivers and streams, including but not limited to providing baseline data for use by the Department of Marine Resources (DMR) in evaluating and assessing shellfish harvesting areas; providing fish and shellfish contaminants data to the Maine Center for Disease Control and Prevention (MCDC) for use in revising Maine's fish consumption advisories; and continuing biological assessment of rivers' and streams' attainment of Maine's Water Quality Standards.

This report more specifically presents the findings of the 2017 and 2018 annual work plans recommended by the SWAT TAG in meetings July 12, 2017 and June 4, 2018. The 2017 and 2018 work plans focused on monitoring of PCBs, dioxins and furans in lobsters, heavy metals, PCBs, PAHs, and perfluorinated compounds (PFCs) in marine shellfish in known or suspected contaminated marine areas, cyanotoxins in Harmful Algal Blooms, mercury in black crappie (a favorite panfish with anglers), PFCs in rivers below sewage treatment plants as requested by MCDC, contaminants in two urban streams, biomonitoring of aquatic life in waters in southern Maine, Penobscot River watershed, and Downeast areas that need to be monitored for evaluation of discharge permits, and a study of mercury resistance in fish from the Penobscot River. Following is a summary of key findings from the 2017 and 2018 SWAT programs for each of the modules.

- MARINE AND ESTUARINE

  - 2017 Blue Mussels
    - Blue mussels collected from East End Beach, Portland; Mill Creek, Falmouth; and Whiting Cove, Whiting; had mean mercury, nickel, zinc, silver, and cadmium concentrations below MCDC Fish Tissue Action Levels (FTALs). Blue mussel mean lead concentrations from East End and Whiting Cove were below the retired MCDC blood lead level FTAL (0.6 µg/g).

    - Blue mussels from East End Beach, Portland, had a lead mean concentration over the retired MCDC blood lead concentration model FTAL of 0.6 µg/g, with two of the four spatial subsamples exceeding the FTAL. These concentrations are comparable to previous data from this site.

    - Total arsenic mean concentrations from blue mussel tissue from all three sites were converted to inorganic arsenic (assumed to be 10% of total arsenic) and compared to the MCDC non-cancer and cancer FTALs. All three sites had calculated mean inorganic arsenic concentrations above the MCDC cancer FTAL (0.014 µg/g), while none of the three sites had a calculated mean inorganic arsenic concentration exceeding the non-cancer FTAL (0.6 µg/g).

    - Calculated coplanar PCB toxic equivalents (CTE) suggest that all blue mussel sites tested do not approach the 0.4 pg/g FTAL for sportfish. Blue mussel tissues from East End Beach and Mill Creek show somewhat higher levels of PCBs than tissue from Whiting Cove.

    - Total PAHs were highest in blue mussel tissue at East End Beach, somewhat lower at Mill Creek, and lowest at Whiting Cove.

  - 2017 Softshell Clams
    - Softshell clams collected from Broad Cove, Eastport, had mean mercury, nickel, zinc, silver, and cadmium concentrations below MCDC FTALs in both edible and whole tissue types.

- Softshell clams collected from Broad Cove had an edible tissue lead mean concentration of 0.5 µg/g when averaged across five spatial subsamples taken, just below the retired MCDC blood lead concentration model FTAL of 0.6 µg/g. The edible tissue lead mean across four spatial subsamples was 0.26 µg/g, with the outlying fifth spatial subsample (1.48 µg/g) left out. The fifth spatial subsample was collected further west at the foot of the former Eastport landfill.

- The softshell clam whole tissue mean lead concentration from Broad Cove exceeded the old 0.6 µg/g MCDC FTAL, with all five spatial subsamples also exceeding the FTAL. The fifth spatial sample, taken near the landfill, was by far the highest in lead at 9.4 µg/g wet wt.

- Calculated coplanar PCB toxic equivalents (CTE) suggest that tissue concentrations for Broad Cove, Eastport, do not approach the 0.4 pg/g FTAL for sportfish.

- Softshell clam edible and whole tissues from Mare Brook, Brunswick, and Broad Cove, Eastport, were analyzed for 12 PFCs. All compounds in edible and whole clam tissues from both sites were below detection levels in all spatial subsamples. Previous data from Mare Brook showed low levels in blue mussels for several PFCs, but close to detection/reporting limits.

- 2018 American lobster
  - Lobster collected in 2018 were dissected and muscle and hepatopancreas (known as tomalley) tissues were analyzed for PCBs, including coplanar PCBs, dioxins and furans to provide newer data to inform the existing hepatopancreas consumption advisory. Hepatopancreas remains problematic for human consumption, as it exceeds the MCDC fish tissue action level for summed toxic equivalents for these compounds. Lobster muscle tissue (meat of claw and tail) is well below the action level and remains safe for human consumption. These updated results correspond to values obtained in previous work completed on lobster in past years. Dioxins/furans and coplanar PCBs persist in the environment, but predominantly are sequestered into the lobster's hepatopancreas.

- LAKES

  - In 2017 cyanobacteria samples were collected from randomly chosen lakes greater than 150 acres in populated counties (Cumberland and York). Because the remaining counties have a low mean population, lakes greater than 150 acres were identified in populated towns/townships in Aroostook, Franklin, Hancock, Oxford, Penobscot, Somerset and Washington Counties. Half of the randomly drawn lakes were sampled in 2018. In addition, samples were obtained from chronic bloomers from late summer through mid-autumn both years. All samples have been analyzed for pigments (chlorophyll and phycocyanin) using a fluorometer. The sample having the highest phycocyanin concentration out of each set of replicate samples will be analyzed for microcystin within the next month by a DEP contractor at the HETL facility. The ELISA method was set up and tested by the contractor. Lab splits were run at a lab doing the same analysis in Dartmouth.

  - Responding to increased angling for black crappie, in 2015 the Maine Department of Inland Fisheries and Wildlife (DIFW) inquired of the MeCDC about the safety for human consumption of black crappie. To determine if the statewide fish consumption advisory due to mercury could be modified for black crappie, MCDC recommended a 5-lake pilot study of mercury levels in black crappie which was followed by additional sampling to complete a 20-lake sample in 2016 (7 lakes reported in the 2016 SWAT report) and 2017. In 2017, ten black crappies from each of 8 lakes were analyzed for mercury, completing the 20-lake sample. The mean concentration of mercury in the 2017 fish was similar to those from previous years. To gather data from additional lakes with significant fisheries in 2018, black crappie from an additional 14 lakes were sampled for mercury. The mean for all years (2015-2018) combined was 0.28 µg/g, significantly lower than the mean concentration from DEP's 1993-4 Fish Tissue Contamination in Maine Lakes study used as the basis for the statewide fish consumption advisory (0.48 µg/g). The data were sent to the Maine Center for Disease Control and Prevention for review of the Statewide Fish Consumption Advisory due to mercury.

  - Northern pike, illegally introduced to freshwaters all over Maine, have become an increasingly sought-after sport fish among anglers. Even though the Statewide Fish Consumption Advisory is listed in DIFW's Fishing Laws booklet and on MCDC's website, recently the question has arisen about the safety of human consumption of northern pike. Since DEP had very little data for mercury in

northern pike, in 2017 five northern pike from each of five lakes or ponds were collected and analyzed for mercury. The results showed a wide range (0.09-0.72 mg/l) in mercury levels among the lakes and ponds, most of which could be accounted for by known sources or other factors. The data were sent to the Maine Center for Disease Control and Prevention for review of the Statewide Fish Consumption Advisory due to mercury.

- RIVERS AND STREAMS

  - In 2017, 41 stations were assessed for the condition of the benthic macroinvertebrate community. Thirty stations attained the aquatic life criteria of their assigned class.

  - In 2018, 44 stations were assessed for the condition of the benthic macroinvertebrate community. Twenty-nine stations attained the aquatic life criteria of their assigned class.

  - As part of an effort to develop Site-Specific Criteria (an alternative to Maine's Ambient Water Quality Criteria) for metals below Woodland Pulp on the St. Croix River, sediments were collected above and below the mill discharge and were analyzed for heavy metals and biological community structure. The results showed no significant difference between the two sites.

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 in recent years, especially in the southwestern portion of the state's coastline. With development, increases in chemical contaminants discharged to the marine environment may occur. Some contaminants can also become concentrated as they move through the food chain, bioaccumulating at higher trophic levels and potentially impacting the viability of marine species and ecosystem health, and causing concern about potential consequences to human health. All these factors suggest that the monitoring of chemical contaminants is an important component of assessing the health of the marine environment in Maine.

1.1.1 Blue Mussels

Blue mussels (*Mytilus edulis*) have been relied upon extensively by the SWAT program (since 1986) and other monitoring programs as an indicator of exposure of marine environments to chemical pollutants. Mussels have been ubiquitous and readily collected across the coast of Maine, as well as throughout the entire Gulf of Maine, although their recent abundance has been more variable. 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 from sediments suspended in the water column. This allows detection in mussel tissue of contaminants that may be present below detection limits in particulate matter, sediment, or water. Use of mussels also provides insight into the biologically available portion of contaminants, which may not readily be discerned from background sediment or water concentrations.

This report presents and summarizes contaminant data from the collection and analysis of blue mussel tissue collected in 2017 from three sites along the Maine coast. All mussel tissue samples were analyzed for heavy metals (including mercury), PCBs, and PAHs. To provide comparability of results from the 2017 samples, blue mussel contaminant levels from the SWAT program are compared to blue mussel contaminant levels in other programs including the Gulfwatch program ("Gulfwatch": Gulf of Maine Council on the Marine Environment) and the National Status & Trends Mussel Watch Program ("NS&T": 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 from 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 to which humans are exposed when consuming clams. Site selection for clam testing is typically driven by human consumption and exposure, and clams are used less than blue mussels in SWAT (or Gulfwatch) as a general environmental monitor or sentinel.

This report presents and summarizes contaminant data from the analysis of softshell clam tissue samples collected in 2017 from two different projects on the Maine coast. Softshell clam tissue was sampled from five stations in Broad Cove, Eastport, to provide information about local toxic contamination in the clam resource adjacent to the former pearl essence manufacturing plant located in the upland and which discharged to Broad Cove. Tissues were analyzed for metals, including mercury, PCBs, PAHs, and PFCs. In the second project, softshell clams were sampled at four stations at Mare Brook in Harpswell Cove, Brunswick, and tissues were analyzed for PFCs to supplement prior work previously completed on other contaminants in clam tissue at this location.

Previous SWAT clam analysis indicated that metals apportioned differentially between the edible portion of the clam and the skin, which is removed both for fried clams and steamed clams. Half of each softshell clam sample was dissected to remove the skin, producing an edible portion. The remaining clams from each sample were analyzed as whole samples with no tissue removed. This approach allowed edible and whole samples to be compared for concentrations of various contaminants. Metals results were compared to results from six locations sampled in 2015 from Casco Bay and the mid-coast to place data in context.

1.1.3 American Lobster

This report presents data from American lobster (*Homarus americanus*) tissues collected in 2018 from the Department of Marine Resources' (DMR) lobster management zones statewide. Lobsters were collected by DMR via traps and furnished to DEP frozen whole for dissection. The DEP SWAT program has sampled and analyzed lobster previously as part of EPA's National Coastal Condition Assessment (NCCA), which also provides data on water column parameters, sediment chemistry, and benthic community structure. In most states participating in the NCCA, finfish are collected and used for fish tissue

contaminant analysis as part of the program. Some New England states have elected to collect lobster to fulfill the fish tissue portion of the NCCA, as Maine did in the 2010 and prior NCCA sampling efforts. EPA discontinued the use of lobster as a medium for fish tissue contaminant analysis for the 2015 NCCA sampling effort. Lobster analyses funded by SWAT, presented in the 2016 SWAT report, focused on metals in both meat and hepatopancreas tissues, part of a continuing effort to generate new and useful lobster tissue contaminant data. These data have been useful in confirming the cleanliness of lobster as seafood, particularly when foreign buyers in emerging markets develop questions about lobster contaminant concentrations.

Lobster were also analyzed to provide information concerning the quality of the benthic environment and because Maine has a fish consumption advisory on lobster hepatopancreas (tomalley) tissue. As predators and scavengers of benthic infauna and detritus on the sea bottom, lobsters ingest toxic contaminants and bioaccumulate those contaminants in their body tissues. Lobsters are ubiquitous along the Maine coast, allowing collections to take place along the entire coast and facilitating geographic comparisons. The lobster fishery is Maine's premier fishery, with the highest landed value of any commercial fishery in the state. In addition, Maine lobstermen strive to provide the highest quality product and determining and assuring the quality of this product is of importance to the future sustainability of the fishery. This project builds upon early work done by DEP in 1994-1996 on contaminants in lobster tissues, previous sampling of lobster by NCCA in 2005-06 and 2010 at additional locations, and 2016 SWAT metals analyses. Lobster tissues collected in 2018 were analyzed for PCBs, including coplanar PCBs, and dioxins/furans.

1.2 METHODS

Sites sampled in recent years within the context of this program can be divided into three types based on the goals outlined above that drive the need for information. These types are Spatial, Temporal, and Follow-Up sites. Sites that have never been sampled (or that have not been sampled for eight or more years), 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 gaps. Spatial sites enable a more complete picture of how contaminants vary along the Maine coastline, and provide screening data that can be used in assessing interest in 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 baseline with which to compare more heavily contaminated sites.

"Temporal" sites are locations where there is an interest in obtaining data to assess contaminant levels over 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 over time, which may permit trend analysis when

sufficient data are acquired. Relatively few temporal sites will be sampled to minimize costs associated with 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 to confirm earlier results, or sampling of additional nearby sites might be used to determine local contaminant distribution. Follow-up sites may include sites in the Temporal or Spatial categories as well based on their historical sampling and data needs.

Resampling in subsequent years at Temporal or Follow-up sites does not occur at the exact sub-site replicate coordinates sampled previously, but varies somewhat due to distribution and quantity of mussels available in the target size range from year to year. Samples from a site include mussels taken from four distinct, sub-site replicates or locations within the site. The slight spatial variation in sub-site replicates sampled provides additional information regarding patchiness of contaminants, and arithmetic means across all four sub-site replicates are used to compare between years.

1.2.1 Blue Mussels

Blue mussel samples have been analyzed from more than 90 distinct locations sampled over the past 30 years. Blue mussels were collected from three sites in 2017. Two of the three sites had been sampled previously as part of the SWAT program and are shown in Table 1.2.1.1. 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 have been provided in previous SWAT reports and in the Gulfwatch field manual (Sowles et al., 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 as possible any variability in factors that might cause a sample to be non-representative of the overall data being collected. Variations in mussel shell size, seasonal timing of collections relative to spawning, location within the intertidal zone, and sample location were all minimized to reduce conflicting signals in the contaminant data.

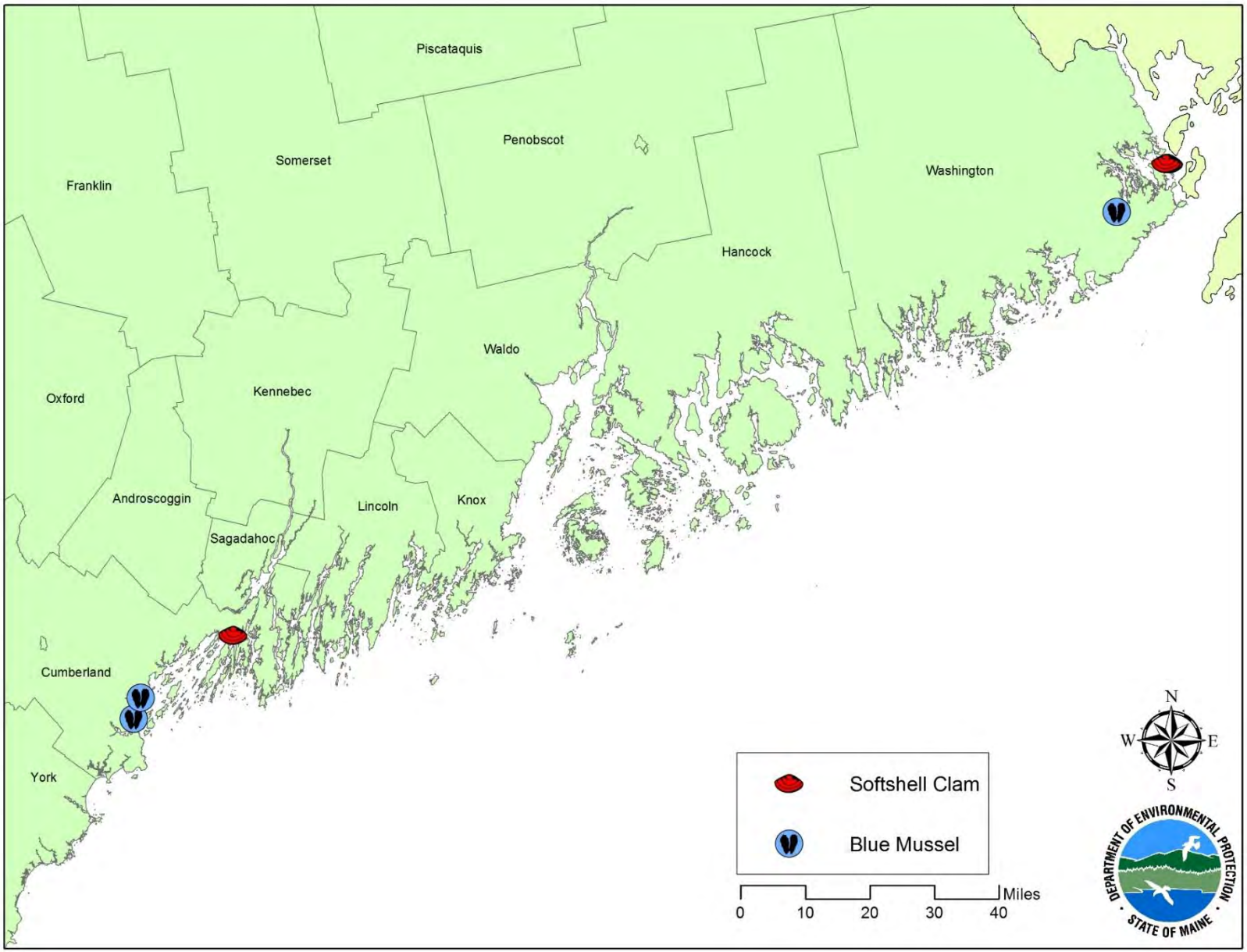
TABLE 1.2.1.1: SWAT Blue Mussel Sites: 2017

Site Name	Municipality	Station Code	West Longitude	North Latitude	Date Sampled	Site Type[1]
East End Beach	Portland	CBEEEE	-70.24145	43.67133	10/11/2017	T
Mill Creek	Falmouth	CBMCMC	-70.22113	43.71849	10/27/2017	T
Whiting Cove	Whiting	PMCKWC	-67.16984	44.79913	10/10/2017	S

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

In order to characterize the contaminants present in a general area at the sampling site, mussels were collected along the shoreline from four distinct intra-site locations

Figure 1.2.1.1: SWAT 2017 Blue Mussel and Softshell Clam Sites



whenever possible. One site, East End Beach, Portland, was only sampled over three intra-site locations in 2017 due to cost limitations in analyzing a fourth replicate. 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 within the target size range were selected from each of the four intra-site locations (replicates) and placed in separate containers. For organics analysis including PAHs, PCBs, and PFCs, a minimum of 30 mussels were collected at each intra-site location. Mussels 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 and width (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° C for up to two months until analysis.

Frozen mussel tissue was shipped overnight to the appropriate laboratory for analysis. Mussel tissues tested for PAHs, PCBs, and PFCs were analyzed by AXYS Analytical Services Ltd., Sidney, British Columbia. Mussel tissue tested for metals were analyzed by Battelle Marine Sciences Laboratory, Sequim, Washington.

1.2.2 Softshell Clam

Softshell clams were collected from four spatial locations within Mare Brook, Brunswick, in northern Harpswell Cove. A minimum of twenty clams were collected at each sublocation, placed in plastic buckets, and kept in coolers until they reached the laboratory where they were washed and measured. Two replicates were constructed by alternately selecting the largest clams, with the largest becoming a member of the composite sample for one replicate and the second largest becoming a member of the composite sample for the second replicate. This continued until the smallest clams were sorted into replicate one and two. Replicate one was then dissected to remove the skin covering the exterior of the clam, including the skin on the siphon, leaving an edible portion which was then shucked to remove the shell and composited to construct a sample of ten clams. Replicate two was shucked including the skin and all tissues and composited into a sample of ten clams termed a whole clam. Skin was removed from one replicate to allow comparison of replicates of edible and whole clam tissue at each location sampled to determine if contaminants partitioned differently in clam skin, which is known to show different concentrations of several heavy metals (Maine Department of Environmental Protection, 2017). Softshell clam tissues from Mare Brook were analyzed for PFCs to expand on previous work performed there for other contaminants in clam tissues. Previous work on PFCs in blue mussel tissue was conducted yielding several detects, but provided no information about concentrations in clam tissues.

Softshell clams were collected from five spatial locations within Broad Cove, Eastport. Broad Cove was sampled at the request of the Maine Department of Marine Resources to determine contaminant concentrations based on the historic discharge located within the cove. Clams were sampled, composited and dissected as described above in the Mare Brook section. Edible and whole tissue composites were analyzed for metals, PAHs, PCBs, and PFCs to determine partitioning of contaminants into the clam skin. The two locations sampled in autumn 2017 are presented in Table 1.2.2.1 and Figure 1.2.1.1 (both in previous section). To aid in interpreting data from Broad Cove, Figure 1.2.2.1 shows the locations of each of the five sublocations sampled in 2017.

TABLE 1.2.2.1: SWAT Softshell Clam Sites: 2017

Site Name	Municipality	Station Code	West Longitude	North Latitude	Date Sampled	Site Type[1]
Mare Brook	Brunswick	CBMBBH	-69.9371	43.8622	9/13/2017	F
Broad Cove	Eastport	PMCKBC	-67.00325	44.90526	9/14/2017	S

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

Methodologies of field collection, morphometric measurement, and laboratory preparation of mussel samples have been provided in previous SWAT reports and in the Gulfwatch field manual (Sowles et al., 1997), and any departures from that methodology in softshell clam sampling are noted in the following text. To characterize the contaminants present in a general area at the sampling station, softshell clams were collected from four or five distinct areas (replicates) along the shoreline at each site whenever possible. Whenever possible, clams at or above the commercial legal length of two inches (50.8 mm) were dug from each intra-site location. For metals analysis, a minimum of ten clams within the target size range were selected from each of the five intra-site locations and placed in separate containers. 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 and width (mm) and soft tissue wet weight (nearest 0.1 g) were also measured and recorded for ten clams in each replicate. All soft tissue was removed and combined with the soft tissue from the ten clams within the same replicate. Total soft tissue wet weights for each ten-clam replicate were recorded. Edible tissue was all soft tissue with the exception of the skin or membrane on the siphon and the perimeter of the clam adjacent to the shell opening and opposite the hinge.

Tissue composites were immediately placed in pre-cleaned glass jars and capped. Jars were pre-labeled and filled jars were stored at -5° C for up to two months until analyses could be

Figure 1.2.2.1: SWAT 2017 Softshell Clam Subsample Locations in Broad Cove, Eastport

completed. Frozen tissue was shipped overnight to the laboratory for analysis. Softshell clam tissues tested for metals in 2017 were analyzed by Pacific Northwest National Laboratory operated by Battelle, Sequim, Washington, while organic contaminants were analyzed by SGS AXYS Analytical Services Ltd., Sidney, British Columbia, Canada.

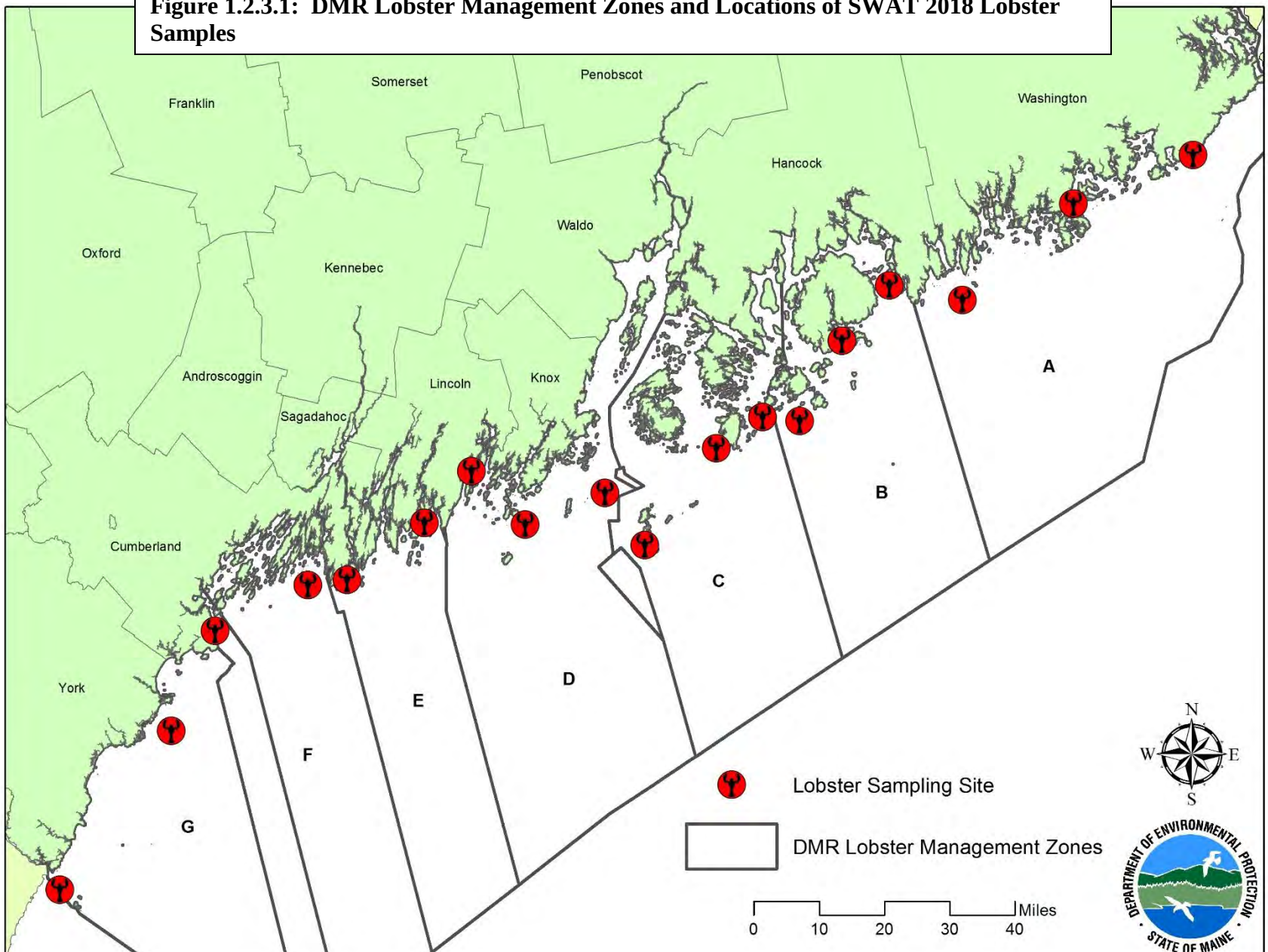
1.2.3 American Lobster

In 2018, lobsters were sampled from 18 areas across the coast of Maine, with samples distributed among the Department of Marine Resources lobster management zones (LMZs), which run east to west from A to G (Figure 1.2.3.1). Three areas from within the larger LMZs, A through D, were collected in an eastern, midzone, and western location. In the remaining three LMZs, samples from two areas (east and west) from within each LMZ were collected. Five lobsters were collected from each area sampled. Lobsters were trapped by DMR and frozen individually in plastic bags.

In the laboratory, DEP SWAT staff dissected each lobster, removing claw and tail meat to provide a muscle tissue sample, and hepatopancreas to provide a tomalley sample. Muscle tissue included pieces of similar mass from both claw and tail meat. Lobsters were composited into one sample for each of the two tissue types at a location. Tissue composites were immediately placed in pre-cleaned glass jars, and capped. Jars were pre-labeled and filled jars were stored at -5° C for up to six months until analyses could be completed. Frozen tissue was shipped overnight to the laboratory for analysis. Lobster tissues analyzed for PCBs, coplanar PCBs, and dioxins/furans by EPA Method 1613B and GC/HRMS and EPA Method 1668A and GC/HRMS (coplanar PCBs). Samples were analyzed by SGS AXYS Analytical Services Ltd. Sidney, British Columbia, Canada.

Previous statewide lobster sampling conducted in 2016 drew samples from the seven DMR lobster management zones, A through G, with 12 areas sampled in total and both muscle and hepatopancreas tissues analyzed for twelve metals. The 2018 SWAT lobster analyses were analyzed for PCBs, coplanar PCBs, and dioxins/furans to provide new data about these suites of contaminants in lobster tissues. MCDC already has a consumption advisory in place for hepatopancreas.

Figure 1.2.3.1: DMR Lobster Management Zones and Locations of SWAT 2018 Lobster Samples



1.3 RESULTS AND DISCUSSION

1.3.1 Metals

1.3.1.1 Blue Mussels

Mussel tissue samples collected in 2017 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 NS&T (Kimbrough et al., 2008) and Gulf of Maine (Gulfwatch) (LeBlanc et al., 2009) blue mussel monitoring program data (collected through 2008, the most recent available) 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 et al., 2009).

1.3.1.1.1 Silver (Ag)

Silver was detected at all three locations sampled in 2017 (Figure 1.3.1.1.1.1). Silver levels measured in mussels ranged from a low mean concentration of 0.033 µg/g dry wt. at Whiting Cove, Whiting, to a high mean concentration of 0.084 µg/g dry wt. at East End Beach, Portland. The silver concentration at Whiting Cove fell below the 2008 Gulfwatch median, while the concentration at Mill Creek, Falmouth, exceeded the Gulfwatch median but not the Gulfwatch 85th percentile. The silver concentration at East End Beach, Portland exceeded the 2008 Gulfwatch 85th percentile (Figure 1.3.1.1.1.1). Silver concentrations in blue mussel tissue at all sites fell below both the NS&T median and 85th percentile (Figure 1.3.1.1.1.2)(Kimbrough et al., 2008). Please note the different scale used in Figure 1.3.1.1.1.2, which allows comparison to the NS&T median and 85th percentile. Since tissue silver concentrations did not exceed the NS&T 85th percentile, no sites were considered elevated for silver.

Higher silver concentrations in water and sediments have been shown to coincide with municipal sewage discharge, and the SWAT mussel tissue silver data shows a higher silver concentration in tissue collected adjacent to the largest municipal sewage discharge in the state at East End Beach (Sanudo-Wilhelmy and Flegal, 1992; Buchholtz ten Brink et al., 1997). 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. Overall, silver concentrations in mussels from sampled locations appear to be relatively low. The highest Gulfwatch values, which came from sites in the Neponset River and Sandwich, Massachusetts exceeded the NS&T median but were below the NS&T 85th percentile.

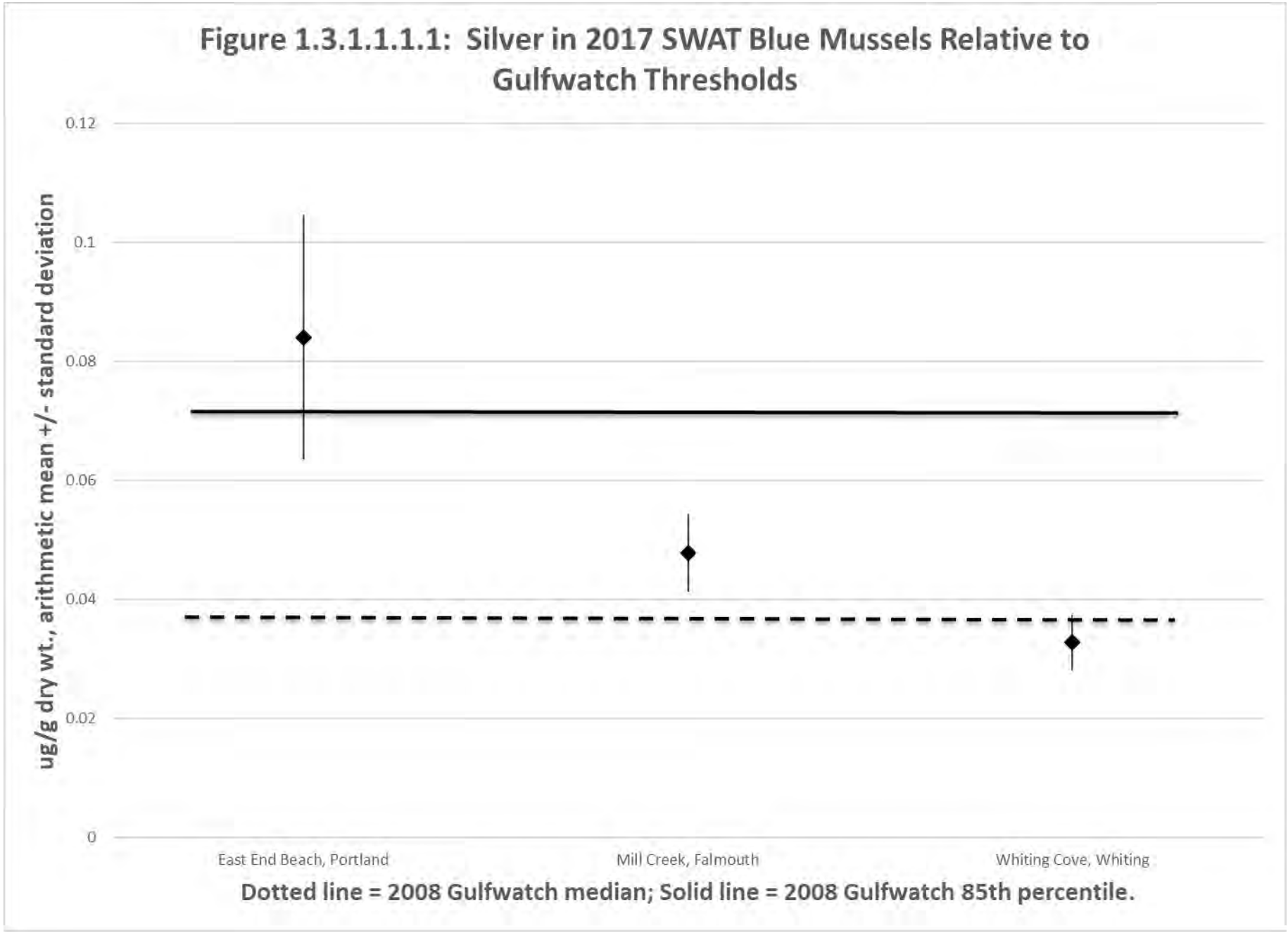


Figure 1.3.1.1.1.1: Silver in 2017 SWAT Blue Mussels Relative to Gulfwatch Thresholds
ug/g dry wt., arithmetic mean +/- standard deviation
0.12
0.1
0.08
0.06
0.04
0.02
0
East End Beach, Portland
Mill Creek, Falmouth
Whiting Cove, Whiting
Dotted line = 2008 Gulfwatch median; Solid line = 2008 Gulfwatch 85th percentile.

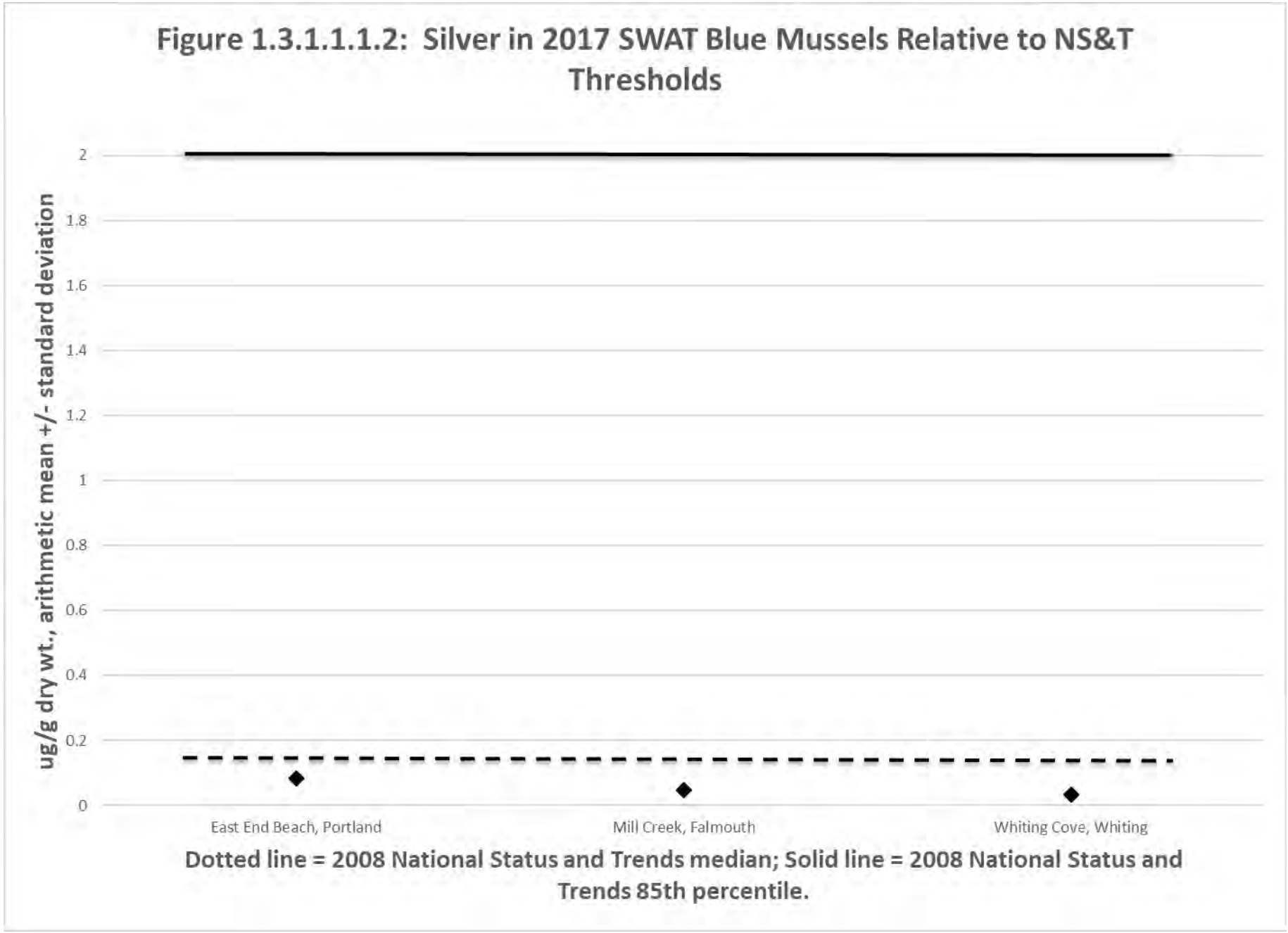


Figure 1.3.1.1.1.2: Silver in 2017 SWAT Blue Mussels Relative to NS&T Thresholds
ug/g dry wt., arithmetic mean +/- standard deviation
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
East End Beach, Portland
Mill Creek, Falmouth
Whiting Cove, Whiting
Dotted line = 2008 National Status and Trends median; Solid line = 2008 National Status and Trends 85th percentile.

The MCDC silver non-cancer FTAL is 11 µg/g wet wt. for non-commercially caught fish. In prior sampling, the highest SWAT blue mussel tissue mean silver concentration, when expressed on a wet weight basis, was approximately three orders of magnitude below the 11 µg/g wet wt. FTAL.

1.3.1.1.2 Arsenic (As)

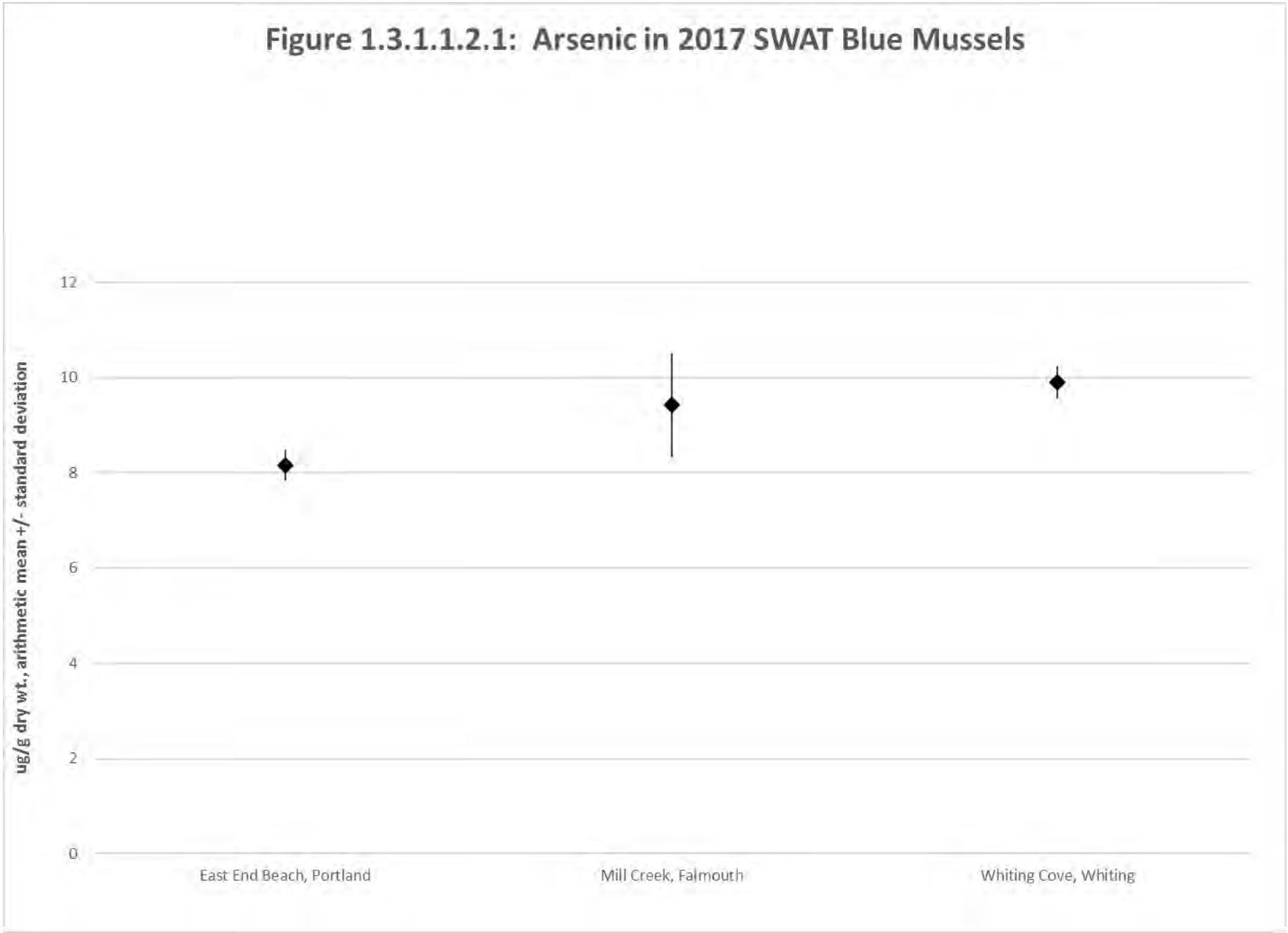
Arsenic was detected in mussel tissue at all three locations sampled in 2017 (Figure 1.3.1.1.2.1). Arsenic levels measured in mussels ranged from a low mean concentration of 8.4 µg/g dry wt. at East End Beach, Portland, to a high mean concentration of 9.9 µg/g dry wt. at Whiting Cove, Whiting. While Gulfwatch does not monitor arsenic concentrations, they are tracked regionally and nationally by NS&T. In blue mussels, NS&T considers less than 12 parts per million dry wt. (directly comparable to SWAT µg/g data) to be in the lowest of three ranges of arsenic concentration nationally (Kimbrough et al., 2008). All three blue mussel sites sampled in 2017 had arsenic concentrations which fell into the lowest range of the three NS&T ranges.

Nationally, the primary source for elevated levels of arsenic is crustal rock. In addition to 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 et al., 2008).

For non-commercially caught finfish, MCDC reports a cancer FTAL of 0.014 µg/g and a non-cancer FTAL of 0.6 µg/g, 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, approximate inorganic arsenic concentrations for SWAT blue mussels were calculated by dividing wet weight concentrations by a factor of 10. Therefore, 2017 SWAT blue mussel inorganic arsenic concentrations are estimated to range from 0.14 µg/g wet wt. to 0.18 µg/g wet wt. All three sites exceeded the MCDC cancer FTAL of 0.014 µg/g wet wt.

Comparing recent data from all 60+ mussel sites sampled from 2007-17, the calculated inorganic arsenic concentrations in SWAT blue mussel tissue ranged from a low of 0.11 µg/g wet wt. (Bar Harbor, 2007) to a high of 0.33 µg/g wet wt. (Turnip Island, Georgetown, 2012). All SWAT sites sampled from 2007-17 had calculated blue mussel tissue inorganic arsenic concentrations exceeding the MCDC cancer action level of 0.014 µg/g wet wt.

Figure 1.3.1.1.2.1: Arsenic in 2017 SWAT Blue Mussels



None of the 60 mussel stations sampled from 2007-16 were calculated to have exceeded the MCDC non-cancer action level of 0.6 µg/g wet wt. for inorganic arsenic. Similarly, none of the three sites sampled in 2017 were calculated to have 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 indicate that this 8 oz. meal size would translate to approximately 45-50 mussels per meal.

1.3.1.1.3 Cadmium (Cd)

Cadmium was detected in samples taken at all three locations sampled in 2017 (Figure 1.3.1.1.3.1). Cadmium levels measured in mussels ranged from a low mean concentration of 1.03 µg/g dry wt. at Mill Creek, Falmouth, to a high mean concentration of 2.01 µg/g dry wt. at Whiting Cove, Whiting. The cadmium concentrations at East End Beach, Portland, and Mill Cove, Falmouth, were below the Gulfwatch median. Cadmium in Whiting Cove blue mussel tissue exceeded the Gulfwatch median. None of the sites sampled had cadmium concentrations that exceeded the NS&T median (Figure 1.3.1.1.3.1)(Kimbrough et al., 2008). Since tissue cadmium concentrations did not exceed the NS&T 85th percentile, no sites were considered elevated for cadmium.

Cadmium originates from crustal elements as rocks weather and is transported seaward by rivers, which account for approximately half of all cadmium sources worldwide. Cadmium is also released 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 et al., 2008).

From a human health perspective, the MCDC non-cancer FTAL for cadmium in non-commercially caught finfish is 2.2 µg/g wet wt. The FDA action level for clams, oysters, and mussels is 4 µg/g wet wt. (Kimbrough et al., 2008). The highest scoring 2017 SWAT site, Whiting Cove, had a mean cadmium concentration of 0.34 µg/g wet wt., which is below the MCDC and FDA action levels.

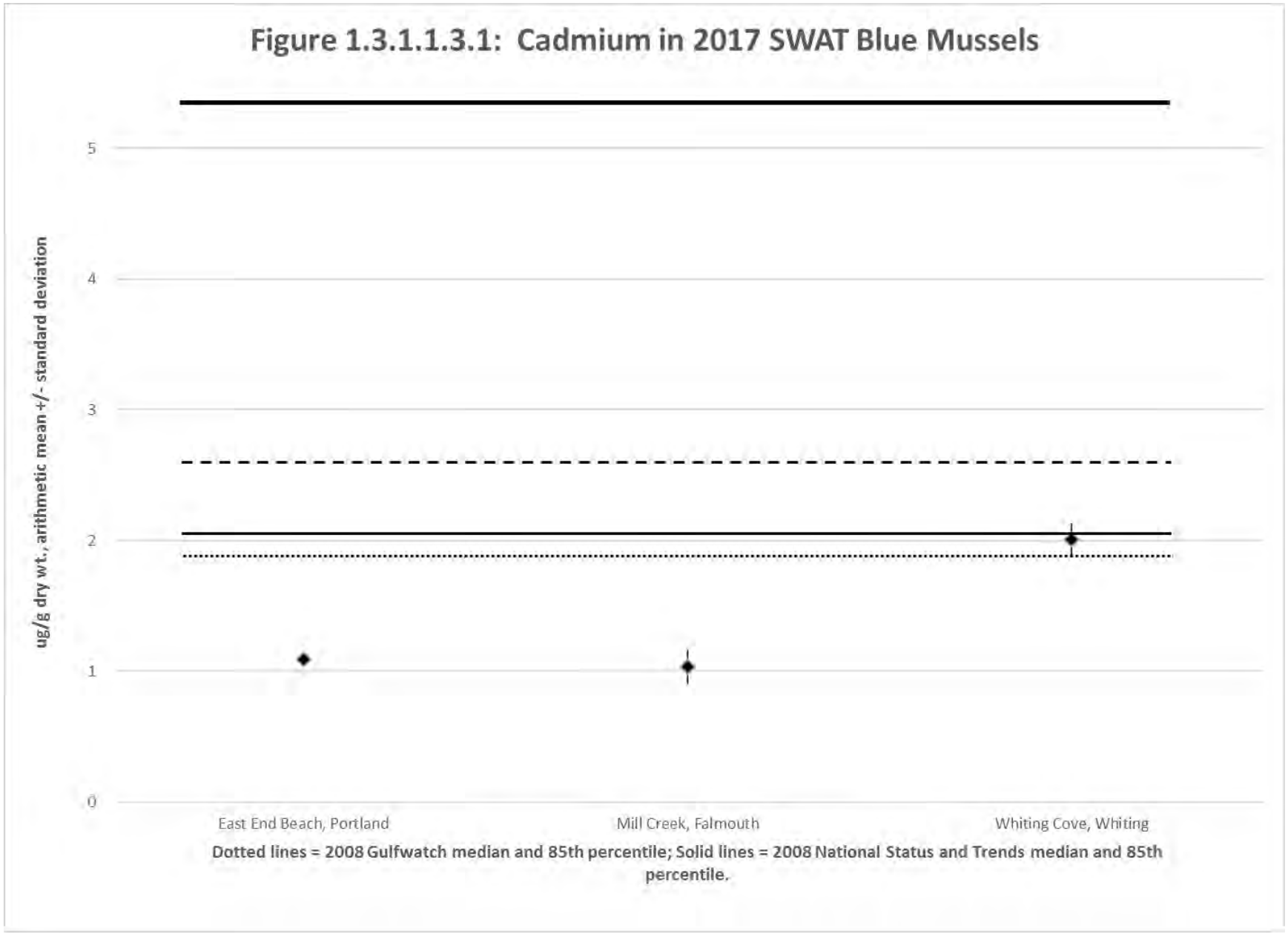


Figure 1.3.1.1.3.1: Cadmium in 2017 SWAT Blue Mussels
ug/g dry wt., arithmetic mean +/- standard deviation
5
4
3
2
1
0
East End Beach, Portland
Mill Creek, Falmouth
Whiting Cove, Whiting
Dotted lines = 2008 Gulfwatch median and 85th percentile; Solid lines = 2008 National Status and Trends median and 85th percentile.

1.3.1.1.4 Chromium (Cr)

Chromium was detected in samples taken at all three sites sampled in 2017. Chromium ranged from a low concentration of 0.76 µg/g dry wt. at Mill Creek, Falmouth, to a high of 1.65 µg/g dry wt. at Whiting Cove, Whiting. The chromium concentration at Whiting Cove exceeded the 2008 Gulfwatch median, while the concentrations at the remaining sites were both below the Gulfwatch median. None of the sites sampled had chromium concentrations that exceeded the Gulfwatch 85th percentile (Figure 1.3.1.1.4.1). The chromium concentration at Whiting Cove was the only concentration that exceeded the NS&T median, and none of the sites exhibited concentrations that exceeded the NS&T 85th percentile (Figure 1.3.1.1.4.1)(Kimbrough et al., 2008). Since tissue chromium concentrations did not exceed the NS&T 85th percentile, no sites were considered elevated for chromium.

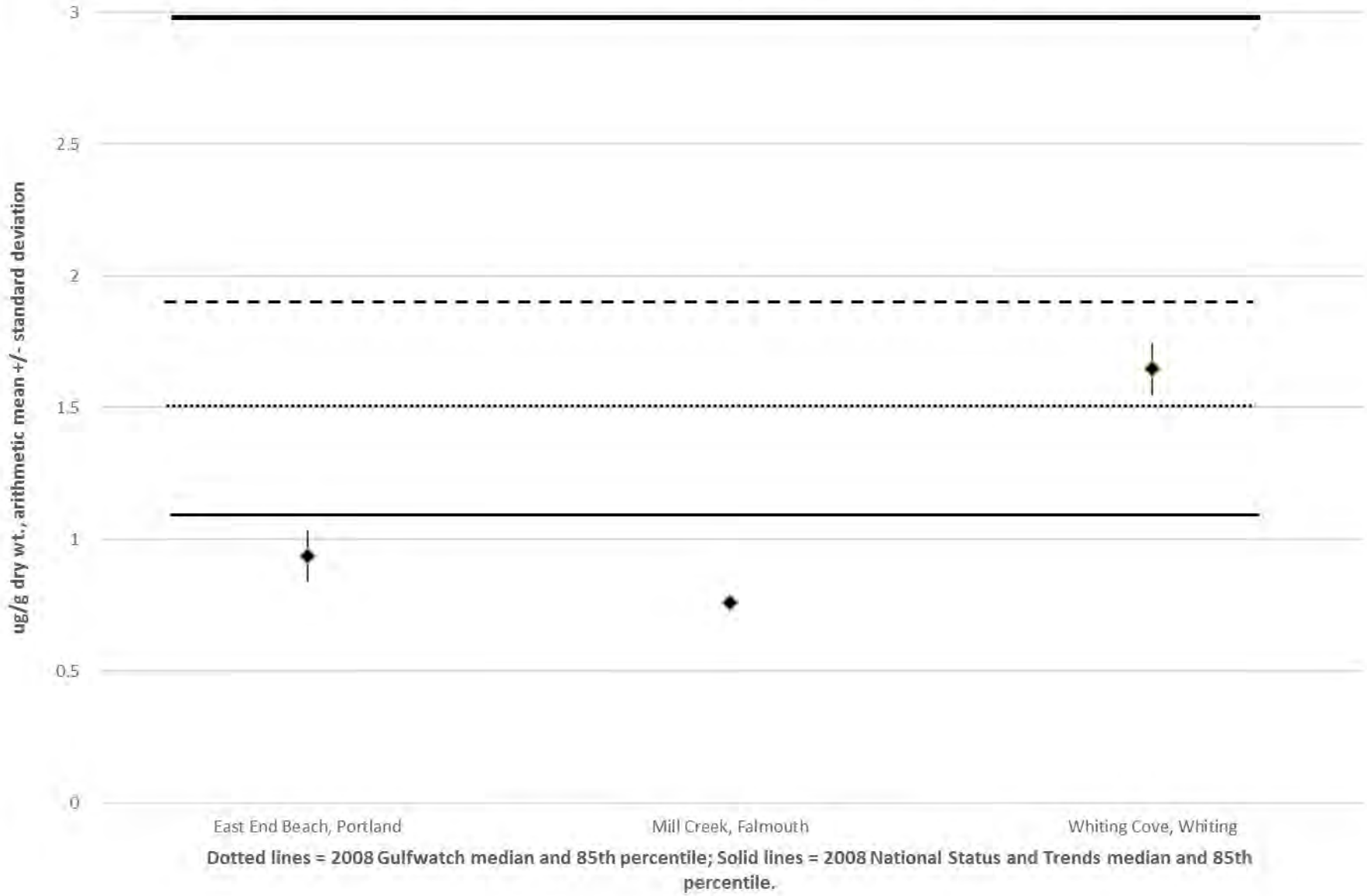
Natural sources of chromium include leaching from soil and rock into surface waters. Chromium is released from textile, electroplating, and leather tanning industries. Chromium is used extensively in tanning leather and was frequently discharged with untreated tannery effluent during the last two centuries. Chromium persists in the marine environment in sediments near anthropogenic sources (Kimbrough et al., 2008).

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

1.3.1.1.5 Copper (Cu)

Copper was detected in tissue taken at all three SWAT mussel sites sampled in 2017 (Figure 1.3.1.1.5.1). Copper levels measured in mussels ranged from a low mean concentration of 5.29 µg/g dry wt. at Whiting Cove, Whiting, to a high mean concentration of 7.54 µg/g dry wt. at East End Beach, Portland. Only the copper concentration at East End Beach, Portland, exceeded the Gulfwatch median and the 85th percentile (LeBlanc et al., 2009). The remaining two sites had copper concentrations below the Gulfwatch median. SWAT copper concentrations at all three sites sampled in 2017 fell below the NS&T median and 85th percentile (Figure 1.3.1.1.5.2) (Kimbrough et al., 2008). None of the three sites sampled in 2017 was considered elevated for copper.

Figure 1.3.1.1.4.1: Chromium in 2017 SWAT Blue Mussels



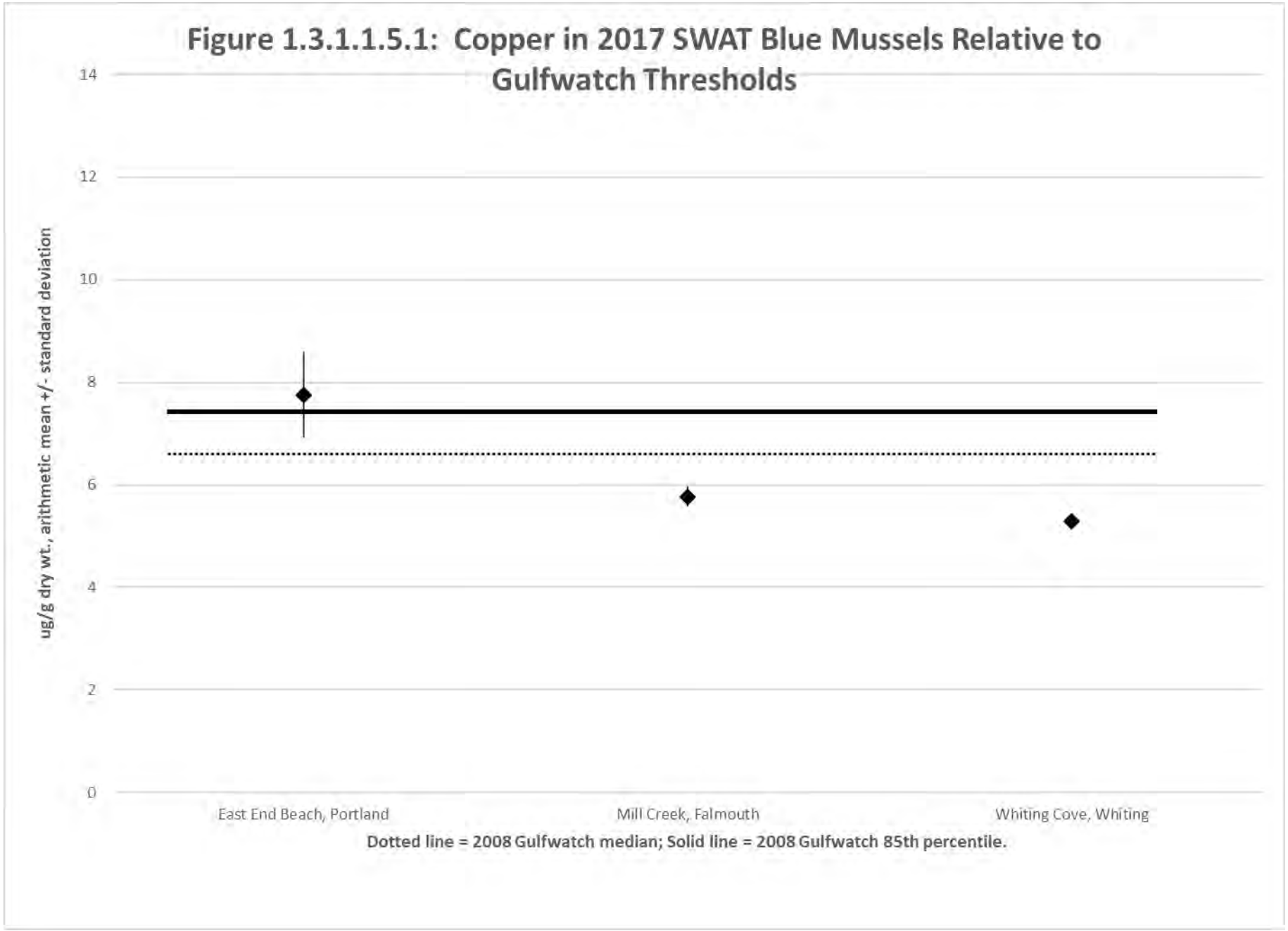


Figure 1.3.1.1.5.1: Copper in 2017 SWAT Blue Mussels Relative to Gulfwatch Thresholds
ug/g dry wt., arithmetic mean +/- standard deviation
14
12
10
8
6
4
2
0
East End Beach, Portland
Mill Creek, Falmouth
Whiting Cove, Whiting
Dotted line = 2008 Gulfwatch median; Solid line = 2008 Gulfwatch 85th percentile.

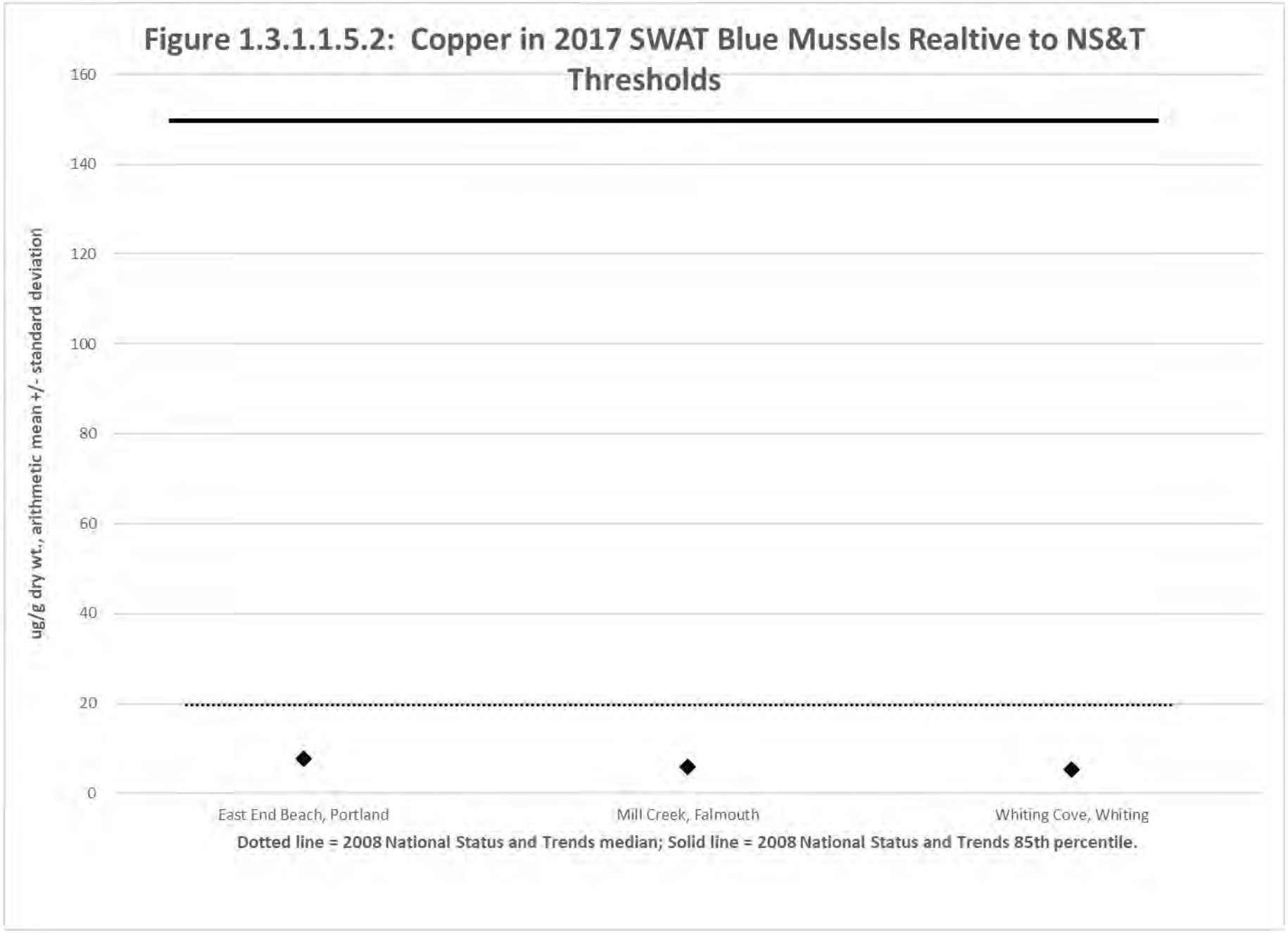


Figure 1.3.1.1.5.2: Copper in 2017 SWAT Blue Mussels Realtive to NS&T Thresholds
160
140
120
100
80
60
40
20
0
ug/g dry wt., arithmetic mean +/- standard deviation
East End Beach, Portland
Mill Creek, Falmouth
Whiting Cove, Whiting
Dotted line = 2008 National Status and Trends median; Solid line = 2008 National Status and Trends 85th percentile.

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. Elevated copper concentrations can occur due to contributions from 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 its 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 1980s, resulting in increased use of copper-based antifouling paints, and removal of asbestos from the manufacture of brake pads has been offset by increased usage of copper in their manufacture (Kimbrough et al., 2008).

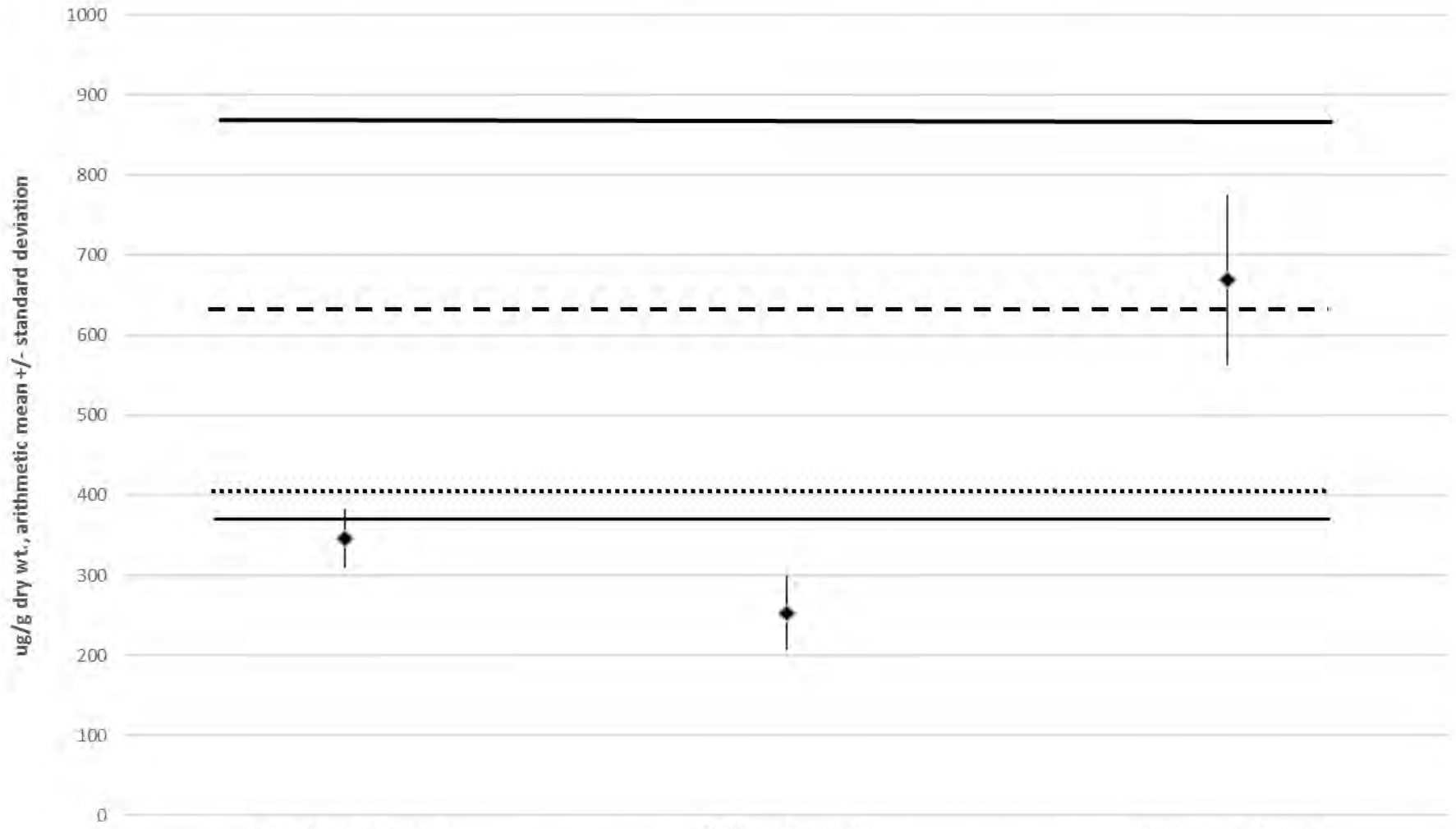
Copper is not highly toxic to humans, though exposure can lead to some chronic effects. There is no recommended FDA safety level for human consumption for copper in fish or shellfish (Kimbrough et al., 2008), and MCDC does not report a FTAL for copper in non-commercially caught sportfish.

1.3.1.1.6 Iron (Fe) and Aluminum (Al)

Iron was detected in tissue from all three SWAT blue mussel sites sampled in 2017 (Figure 1.3.1.1.6.1). Iron concentrations measured in mussels ranged from a low mean concentration of 253 µg/g dry wt. at Mill Creek, Falmouth, to a high mean concentration of 669 µg/g dry wt. at Whiting Cove, Whiting. The mean iron concentration in samples from Whiting Cove exceeded the Gulfwatch and NS&T medians, and the Gulfwatch 85th percentile. The two remaining sites did not exceed either the Gulfwatch or NS&T medians. Since none of the sites sampled had an iron concentration exceeding the NS&T 85th percentile, no site was considered elevated for iron (Figure 1.3.1.1.6.1).

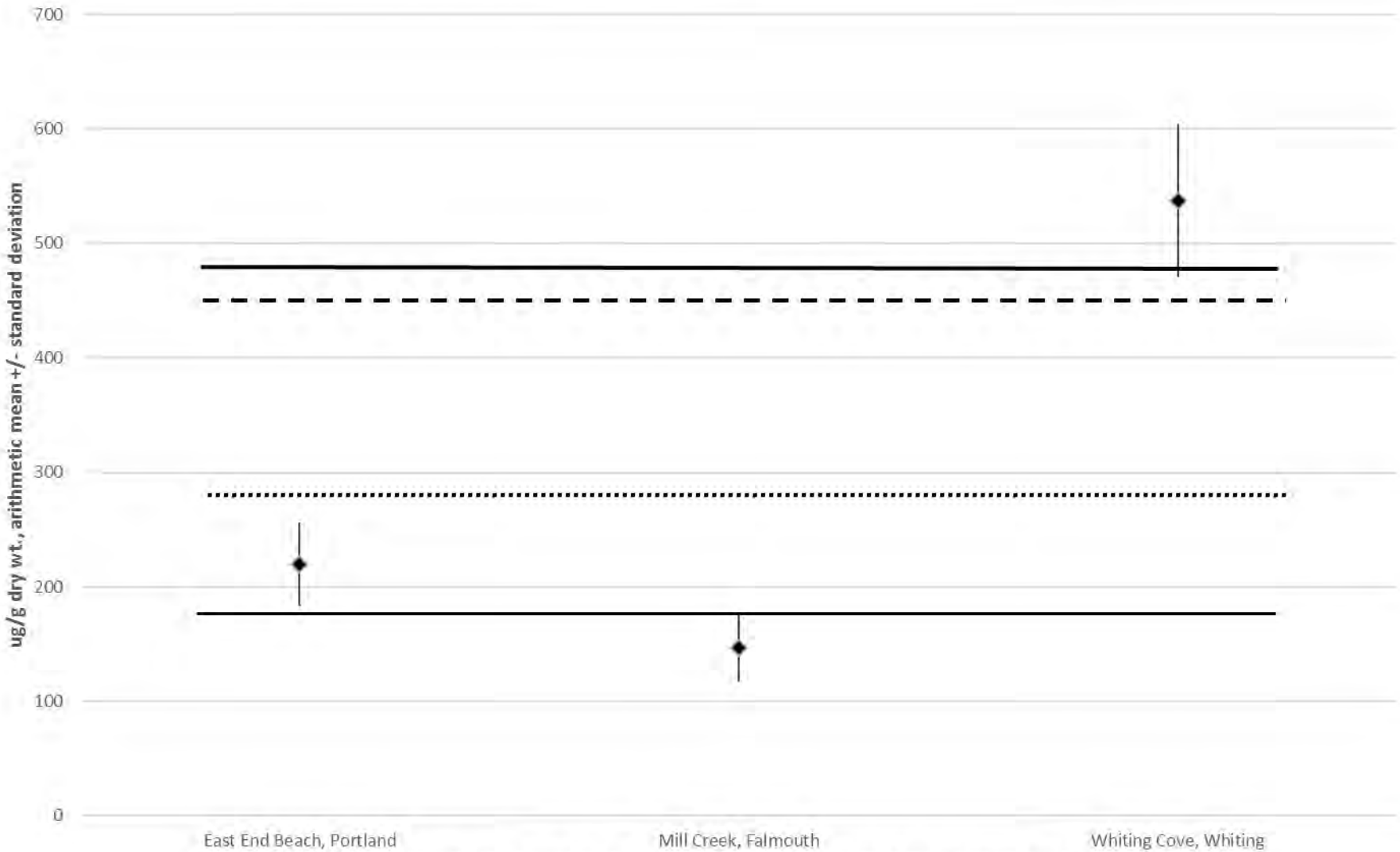
Aluminum was detected in tissue taken at all three SWAT mussel sites sampled in 2017 (Figure 1.3.1.1.6.2). Aluminum levels measured in mussels ranged from a low mean concentration of 147 µg/g dry wt. at Mill Creek, Falmouth, to a high mean concentration of 537 µg/g dry wt. at Whiting Cove, Whiting. Aluminum concentrations at Mill Creek, Falmouth, and East End Beach, Portland, were less than and exceeded the NS&T median, respectively, but only Whiting Cove had an aluminum concentration that exceeded the Gulfwatch median. Only Whiting Cove had an aluminum concentration that exceeded both the Gulfwatch and NS&T 85th percentiles (LeBlanc et al., 2009)(Kimbrough et al., 2008). Only blue mussel tissue from Whiting Cove was elevated for aluminum.

Figure 1.3.1.1.6.1: Iron in 2017 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 2017 SWAT Blue Mussels



Dotted lines = 2008 Gulfwatch median and 85th percentile; Solid lines = 2008 National Status and Trends median and 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 (Leblanc et al., 2009). 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.

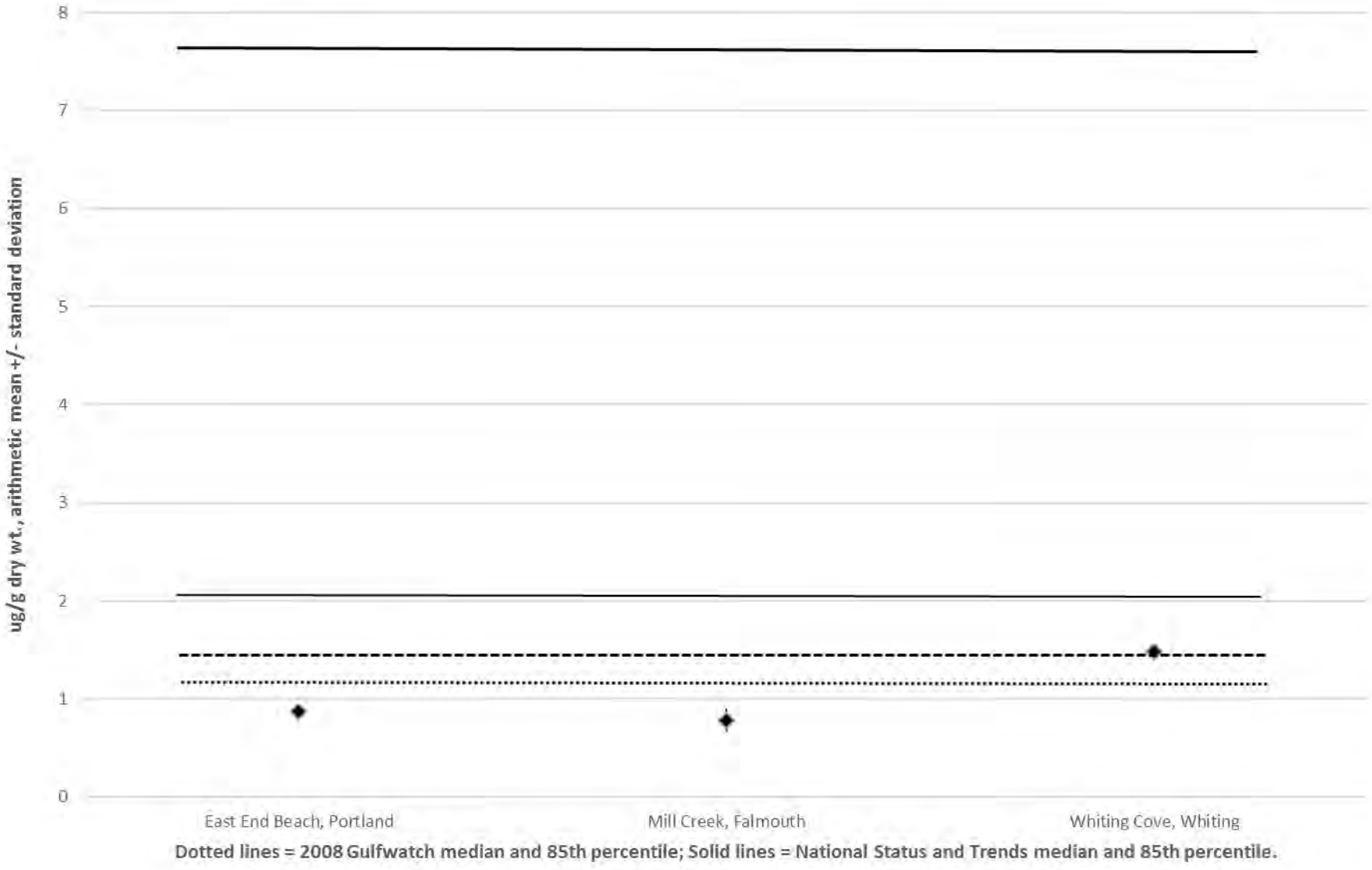
1.3.1.1.7 Nickel (Ni)

Nickel was detected in tissue from all three SWAT blue mussel sites sampled in 2017 (Figure 1.3.1.1.7.1). Nickel levels measured in mussels ranged from a low mean concentration of 0.79 µg/g dry wt. at Mill Creek, Falmouth, to a high mean concentration of 1.48 µg/g dry wt. at Whiting Cove, Whiting. Only Whiting Cove had a nickel concentration exceeding the Gulfwatch median and 85th percentile. None of the sites had concentrations of nickel in tissue that exceeded the NS&T median or NS&T 85th percentile (LeBlanc et al., 2009)(Kimbrough et al., 2008). None of the SWAT sites were 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 essential to biological processes as a trace element. 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. Elevated 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 et al., 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 et al., 2008). The MCDC reports a non-cancer FTAL for nickel in non-commercially caught finfish of 43 µg/g wet wt., which is more conservative than the FDA action level for shellfish of 80 µg/g wet weight. The maximum mean concentration detected by SWAT in 2017 of 0.25 µg/g wet wt. at Whiting Cove 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 2017 SWAT Blue Mussels



1.3.1.1.8 Lead (Pb)

Lead was detected in tissue from all three SWAT blue mussel sites sampled in 2017 (Figure 1.3.1.1.8.1). Lead levels measured in mussels ranged from a low mean concentration of 1.88 µg/g dry wt. at Whiting Cove to a high mean concentration of 3.65 µg/g dry wt. at East End Beach, Portland. Two sites had lead concentrations less than the Gulfwatch median, but exceeding the NS&T median. East End Beach had a lead concentration below the Gulfwatch 85th percentile, but exceeding the NS&T 85th percentile and so was considered elevated based on criteria in the SWAT and Gulfwatch programs (Figure 1.3.1.1.8.1).

Lead tissue concentrations from prior samples at two sites were compared to the 2017 concentrations (Figure 1.3.1.1.8.2). Lead concentrations fluctuate somewhat from year to year, which is probably due to patchiness of contamination within the sites. Across the two sites, lead concentrations do not appear to trend up or down, and lead concentrations in mussel tissue at other Maine sites sampled in recent years suggest that concentrations are not increasing but have been relatively stable statewide (and Gulf-wide in the Gulfwatch program, as supported by longer-term data sets).

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 et al., 2008).

From a human health perspective, the FDA action level for lead in clams, oysters, and mussels (molluscan shellfish) had been 1.7 µg/g wet wt. (Kimbrough et al., 2008). This limit was dropped at the 2007 Interstate Shellfish Sanitation Conference. The formerly used more conservative MCDC lead FTAL in non-commercially caught sportfish was 0.6 µg/g wet wt., which is based on a blood lead concentration model. This MCDC FTAL is no longer in use, but a new lead FTAL has not yet been developed. The highest mean concentration in the 2017 Maine SWAT mussel data, 0.61 µg/g wet wt. at East End Beach, Portland, exceeds the outdated MCDC lead FTAL. The two remaining sites sampled in 2017 were lower and did not exceed the outdated MCDC FTAL for lead.

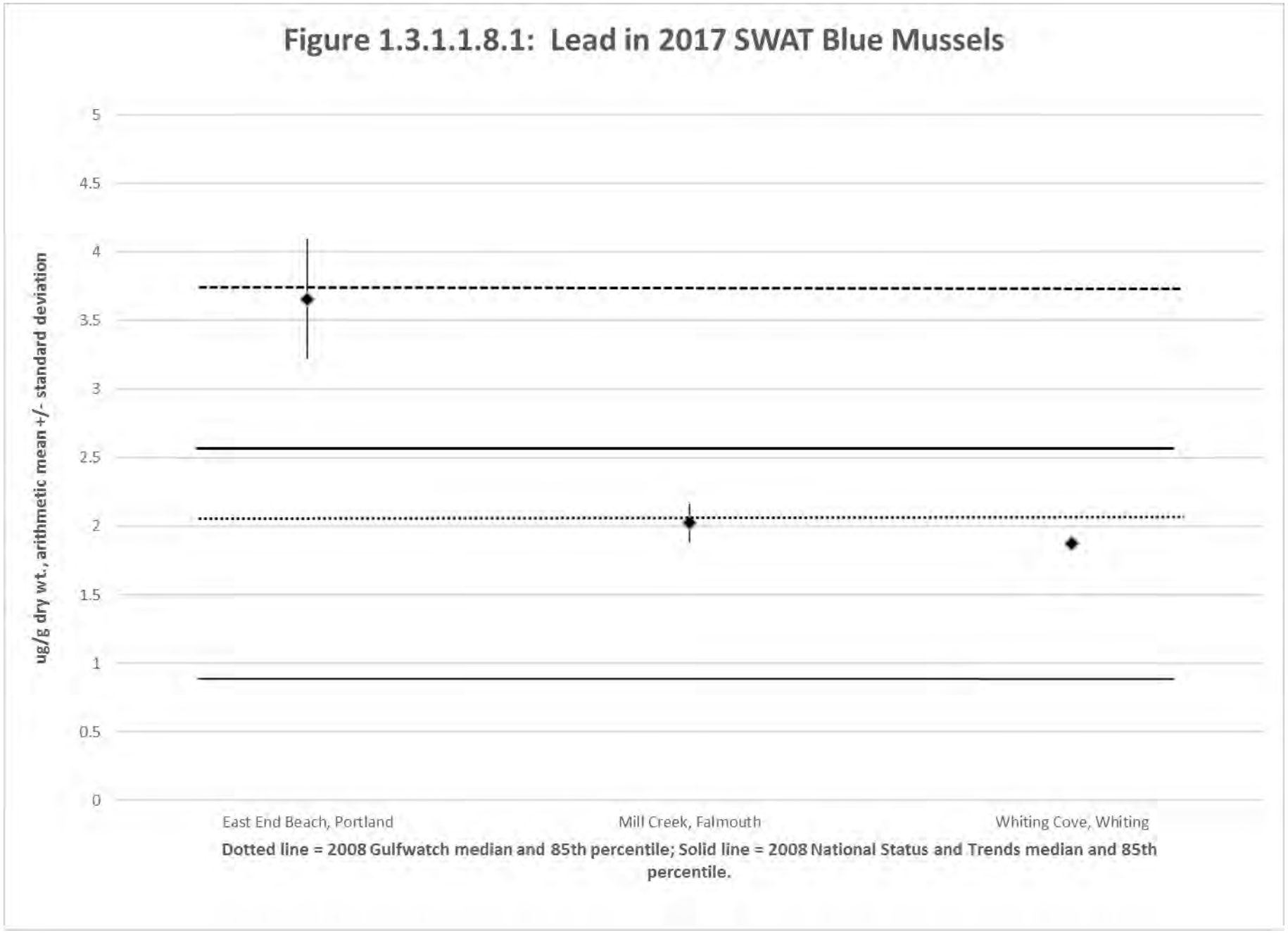
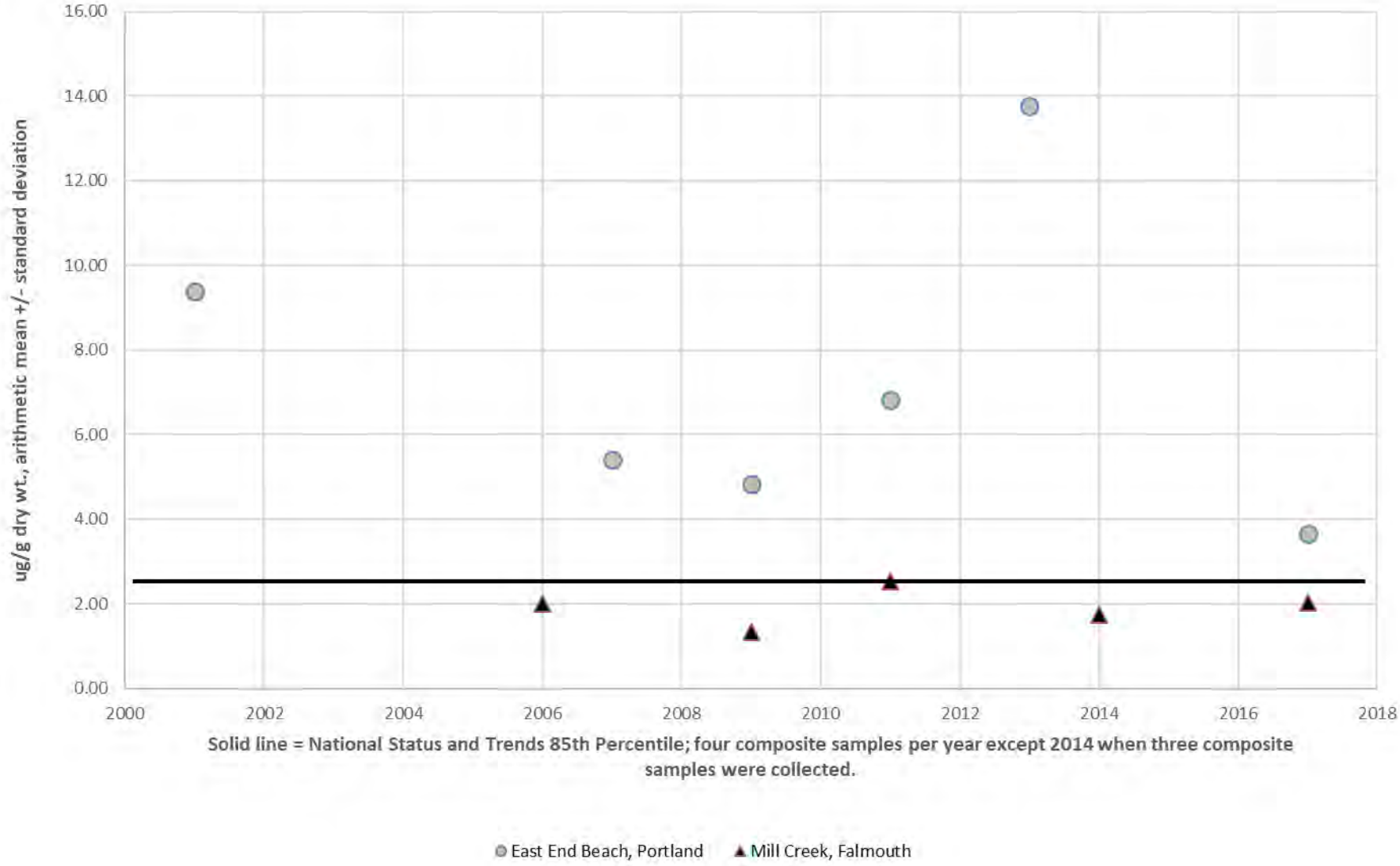


Figure 1.3.1.1.8.1: Lead in 2017 SWAT Blue Mussels
ug/g dry wt., arithmetic mean +/- standard deviation
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
East End Beach, Portland
Mill Creek, Falmouth
Whiting Cove, Whiting
Dotted line = 2008 Gulfwatch median and 85th percentile; Solid line = 2008 National Status and Trends median and 85th percentile.

Figure 1.3.1.1.8.2: Trend in Blue Mussel Tissue Lead Concentrations from East End Beach, Portland, and Mill Creek, Falmouth, 2001 - 2017



Review of the 2007-17 SWAT blue mussel sampling data from 62 sites indicates that mean lead concentrations at eight sites equaled or exceeded the MCDC lead FTAL. Sites sampled in those years equaling or exceeding the MCDC FTAL for lead are presented in Table 1.3.1.1.8.1:

Table 1.3.1.1.8.1: Lead Concentrations in Blue Mussel Tissue Exceeding 0.6 mg/g wet Wt.

Site	Municipality	Years Sampled	Concentration or Mean (Wet wt.)	Standard Deviation
Piscataqua River Back Channel	Kittery	2008	0.6*	
Spring Point	S. Portland	2007, 2010, 2012, 2015	0.7	0.096
Middle Fore River	Portland	2007	0.6*	
East End Beach	Portland	2007, 2009, 2011, 2013, 2015, 2017	1.1	0.559
Turnip Island	Georgetown	2012	1.4*	
Crockett Poiint	Rockland	2007, 2010, 2011, 2016	1.2	0.100
Ocean Pursuits Boat Yard	Rockland	2013	0.6*	
Town Landing	Rockland	2013	0.9*	
Camden Harbor	Camden	2007	0.7*	
Goose Falls	Brooksville	2007	1.1*	

* Site only sampled in one year

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

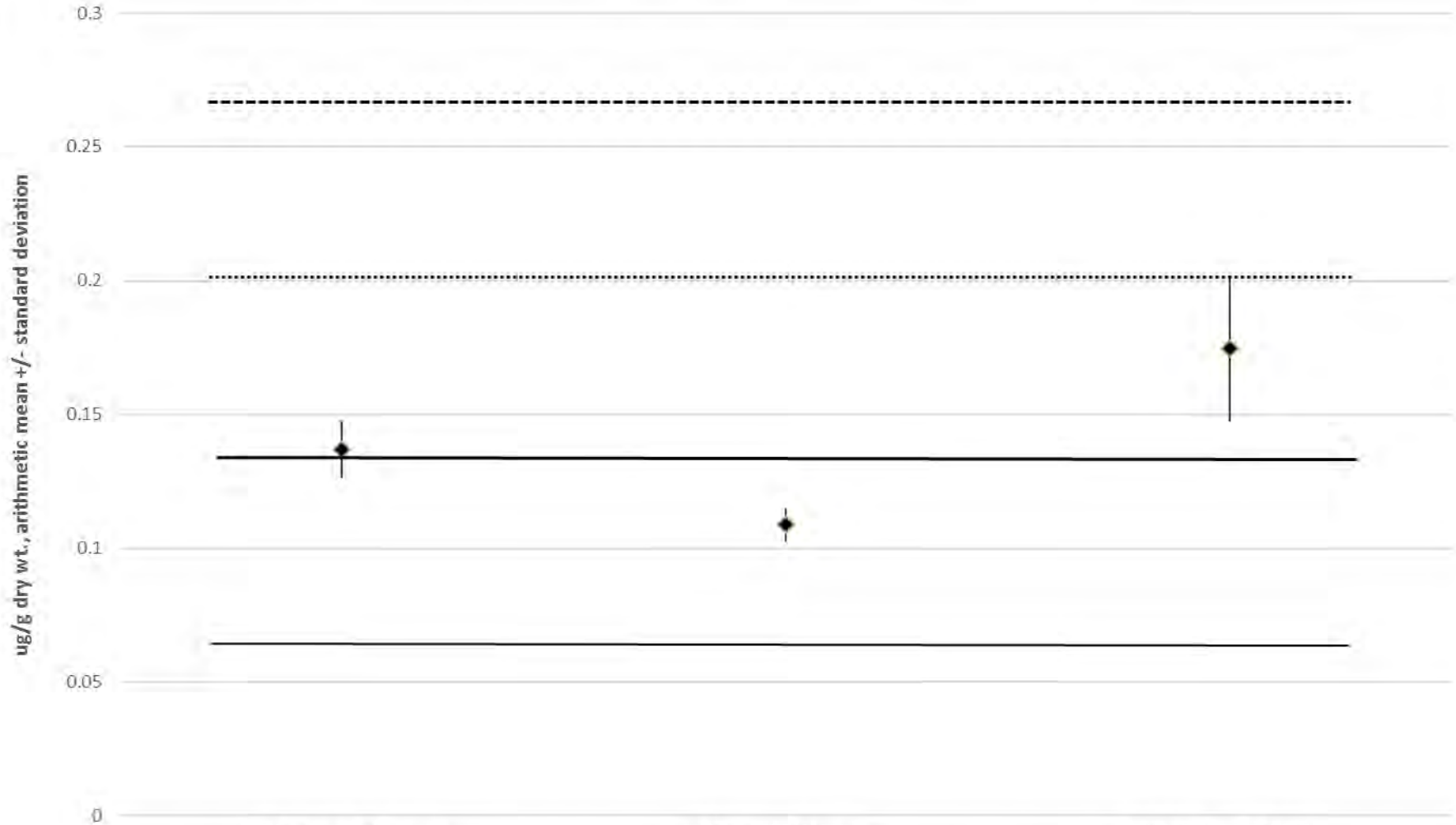
1.3.1.1.9 Mercury (Hg)

Mercury was detected in tissue from all three blue mussel sample locations tested in 2017 (Figure 1.3.1.1.9.1). Mercury levels measured in mussels ranged from a low mean concentration of 0.11 µg/g dry wt. at Mill Creek, Falmouth, to a high mean concentration of 0.17 µg/g dry wt. at Whiting Cove, Whiting. None of the three sites exceeded the 2008 Gulfwatch median or 85th percentile concentration. Figure 1.3.1.1.9.1 also compares 2017 SWAT blue mussel mercury concentrations to NS&T Mussel Watch median and 85th percentile values. 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 deposition of airborne mercury from a wide range of sources in the US Midwest. Based on the Gulfwatch and SWAT criteria of "elevated" contaminants being those above the NS&T 85th percentile, two SWAT sites (East End Beach and Whiting Cove) tested in 2017 would be considered elevated for mercury despite the more typical magnitude of their scores when compared to other northeast US samples from the Gulf of Maine. Mill Creek, Falmouth, had a mercury concentration in mussel tissue below the NS&T 85th percentile.

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 et al., 2008).

From a human health perspective, the developmental methylmercury FTAL (more protective) used by the MCDC is 0.2 µg/g 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. The highest mean blue mussel total tissue mercury concentration measured in Maine in 2017 was 0.029 µg/g wet wt. at Whiting Cove. This mean concentration, as well as those from the other two sites sampled, compares favorably with the MCDC methylmercury developmental FTAL of 0.2 µg/g, 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 mussels based on the mean mass per mussel collected by the SWAT program.

Figure 1.3.1.1.9.1: Mercury in 2017 SWAT Blue Mussels



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

1.3.1.1.10 Zinc (Zn)

Zinc was detected in tissues taken from all three locations sampled in 2017 (Figure 1.3.1.1.10.1). Zinc levels measured in mussels ranged from a low mean concentration of 69.2 µg/g dry wt. at Whiting Cove, Whiting, to a high mean concentration of 98.2 µg/g dry wt. at East End Beach, Portland. Zinc concentrations in tissue from all three sites were below the 2008 Gulfwatch median and the 2008 Gulfwatch 85th percentile. Figure 1.3.1.1.10.2 shows 2017 Maine SWAT blue mussel zinc concentrations were all below the NS&T Mussel Watch median and 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 et al., 2008). Though an essential nutrient at low levels, higher levels in 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 µg/g wet wt., which is higher than any wet wt. concentrations observed in SWAT blue mussel tissue. There is no recommended FDA safety level for zinc in fish (Kimbrough et al., 2008).

1.3.1.2 Softshell Clams

1.3.1.2 Softshell Clam Tissues from Broad Cove, Eastport

Softshell clams collected from five locations within Broad Cove in 2017 were dissected into edible and whole tissues as described above, and analyzed for 11 metals: Silver (Ag), aluminum (Al), arsenic (Ar), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), nickel (Ni), selenium (Se), and zinc (Zn). Edible and whole portions were analyzed to demonstrate differences in the concentrations of some contaminants when the skin or membrane tissue is included (whole) and excluded (edible).

1.3.1.2.1 Silver (Ag)

Silver was detected at all five subsampled locations in Broad Cove (Figure 1.3.1.2.1.1). Silver concentrations in Broad Cove edible tissue ranged from a low concentration of 0.33 µg/g dry wt. to a high concentration of 0.68 µg/g dry wt. Silver concentrations in Broad Cove whole tissue ranged from a low concentration of 0.28 µg/g dry wt. to a high concentration of 0.48 µg/g dry wt. Edible and whole clam tissue silver concentrations differed slightly. The whole to edible tissue ratio of silver concentrations varied from 0.8 to 1.0, with the mean ratio across five subsamples at 0.9. Compared to six softshell clam sites sampled in 2015, Broad Cove was on the low end of silver concentrations in both tissue types (Figure 1.3.1.2.1.1).

Figure 1.3.1.1.10.1: Zinc in 2017 SWAT Blue Mussels Relative to Gulfwatch Thresholds

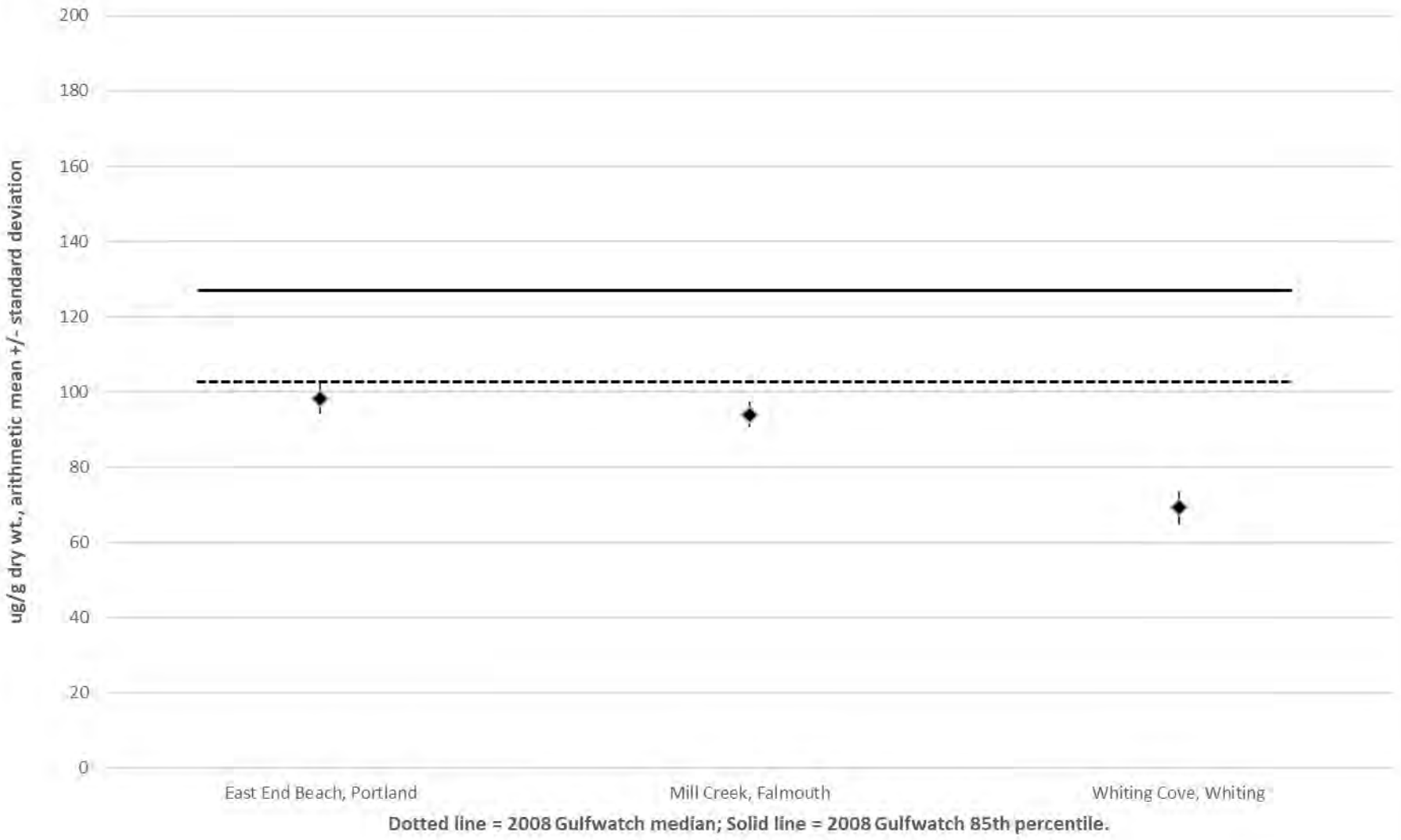
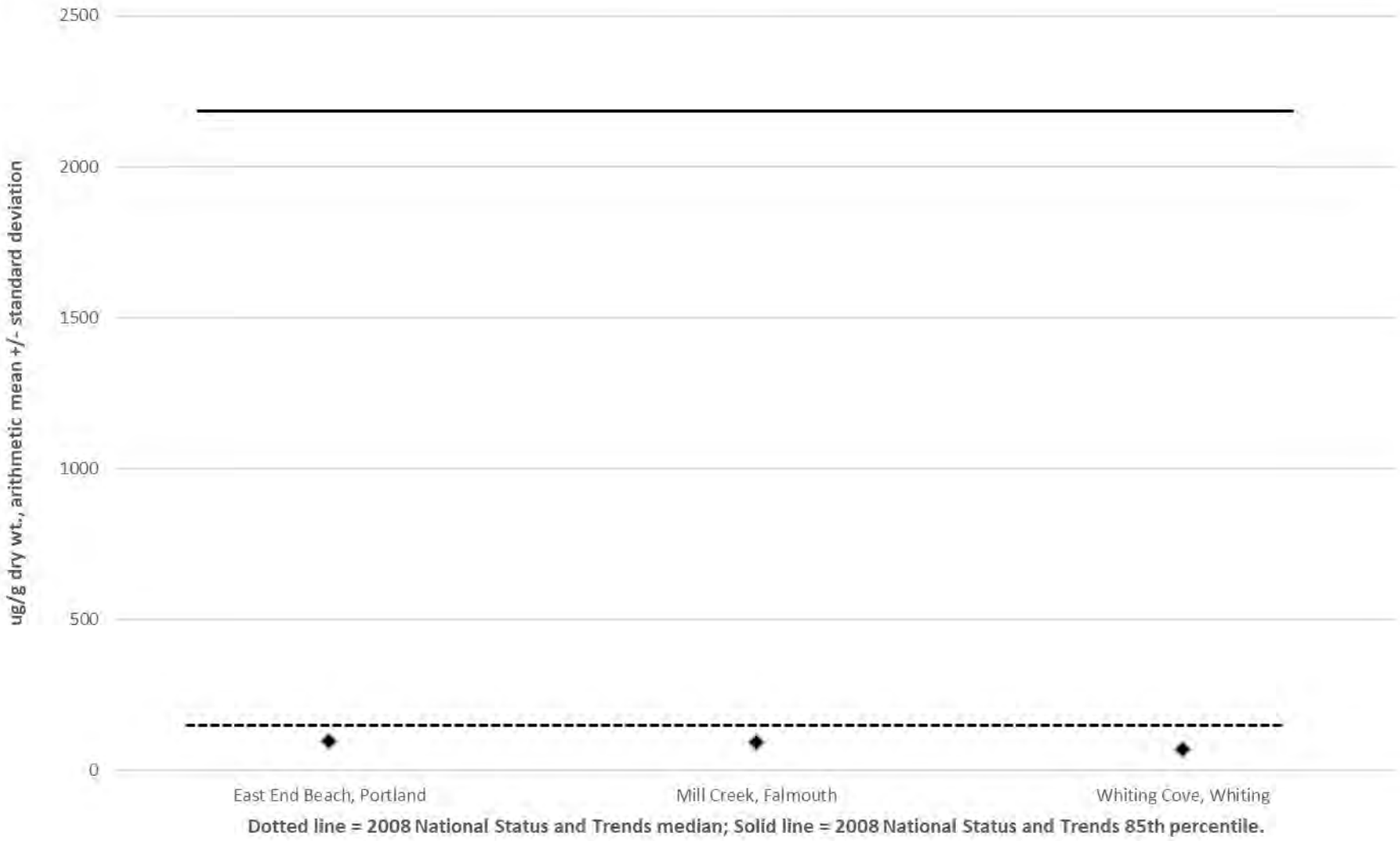


Figure 1.3.1.1.10.2: Zinc in 2017 SWAT Blue Mussels Relative to NS&T Thresholds



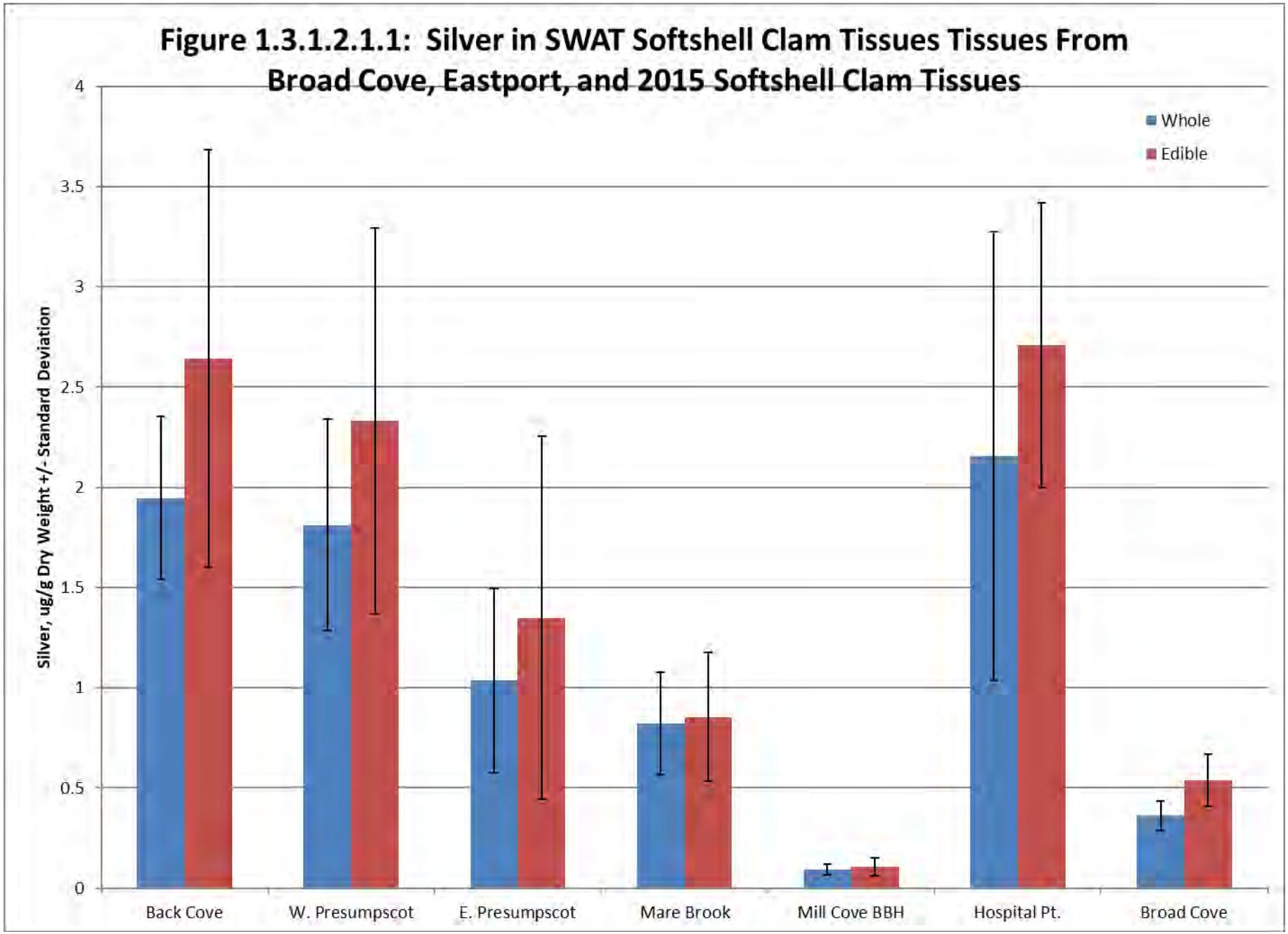


Figure 1.3.1.2.1.1: Silver in SWAT Softshell Clam Tissues Tissues From Broad Cove, Eastport, and 2015 Softshell Clam Tissues
Whole
Edible
Silver, ug/g Dry Weight +/- Standard Deviation
4
3.5
3
2.5
2
1.5
1
0.5
0
Back Cove
W. Presumpscot
E. Presumpscot
Mare Brook
Mill Cove BBH
Hospital Pt.
Broad Cove

Higher silver concentrations in water and sediments have been shown to coincide with municipal sewage discharge (Sanudo-Wilhelmy and Flegal, 1992; Buchholtz ten Brink et al., 1997). 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 FTAL is 11 µg/g wet wt. for non-commercially caught fish. The mean edible softshell clam tissue silver concentration in Broad Cove, when expressed on a wet weight basis, is 0.09 µg/g wet weight. This concentration is several orders of magnitude below the 11 µg/g wet wt. FTAL, assuming the same meal size is applied.

1.3.1.2.2 Arsenic (As)

Arsenic was detected at all five subsampled areas within Broad Cove (Figure 1.3.1.2.2.1). Arsenic concentrations in edible tissue ranged from a low concentration of 12.50 µg/g dry wt. to a high concentration of 15.4 µg/g dry wt. Arsenic concentrations in whole tissue ranged from a low concentration of 15.1 µg/g dry wt. to a high concentration of 24.7 µg/g dry wt.

Edible and whole clam tissue arsenic were similar or sometimes slightly higher in whole tissue. The whole to edible tissue ratio of arsenic concentrations varied from 1.0 to 1.6, with the mean ratio across all five samples at 1.3. Compared to six softshell clam sites sampled in 2015, tissue arsenic concentration from edible tissue from Broad Cove was comparable to edible tissue arsenic at other sites (Figure 1.3.1.2.2.2). The Broad Cove whole tissue arsenic concentration was comparable to four previously sampled sites, but lower than tissue concentrations from samples collected at West Presumpscot River and Hospital Point, St. George River (Figure 1.3.1.2.2.2).

Nationally, the primary source for elevated levels of arsenic is crustal rock. In addition to 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 et al., 2008).

For non-commercially caught finfish, MCDC reports a cancer FTAL of 0.014 µg/g and a non-cancer FTAL of 0.6 µg/g wet wt., both for inorganic arsenic (the most toxic form). Most fish tissue data, including the SWAT softshell clam 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, approximate inorganic arsenic concentrations for SWAT softshell clams were calculated by dividing total arsenic wet weight concentrations by a factor of 10 to convert to inorganic

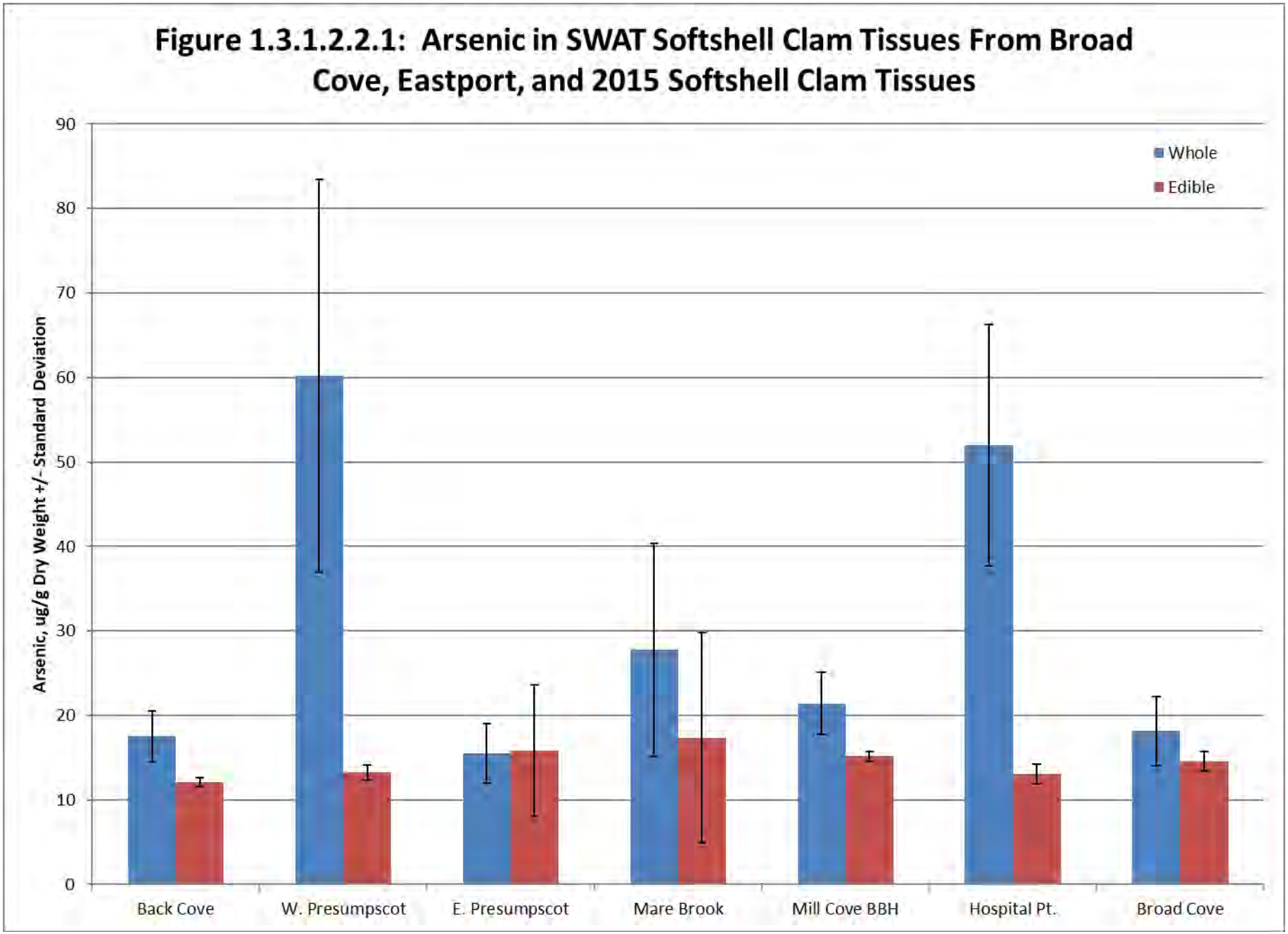


Figure 1.3.1.2.2.1: Arsenic in SWAT Softshell Clam Tissues From Broad Cove, Eastport, and 2015 Softshell Clam Tissues
Arsenic, ug/g Dry Weight +/- Standard Deviation
0
10
20
30
40
50
60
70
80
90
Whole
Edible
Back Cove
W. Presumpscot
E. Presumpscot
Mare Brook
Mill Cove BBH
Hospital Pt.
Broad Cove

arsenic wet weight concentrations. Using this methodology, the range of concentrations of inorganic arsenic in edible clam tissue from the five subsamples collected in Broad Cove is estimated to be 0.23 to 0.25 µg/g wet wt. Historically, all clam sites sampled for arsenic in prior years were calculated to have whole clam tissue concentrations exceeding the MCDC cancer FTAL of 0.014 µg/g wet wt. Note that since arsenic data have been recorded as part of the SWAT program, all blue mussel sites sampled (60+ sites) have also exceeded the MCDC cancer FTAL. None of the five subsamples from Broad Cove, and none of the six softshell clam sites sampled in 2015, had calculated inorganic arsenic edible tissue concentrations that approached the non-cancer FTAL of 0.6 µg/g wet wt. The 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)

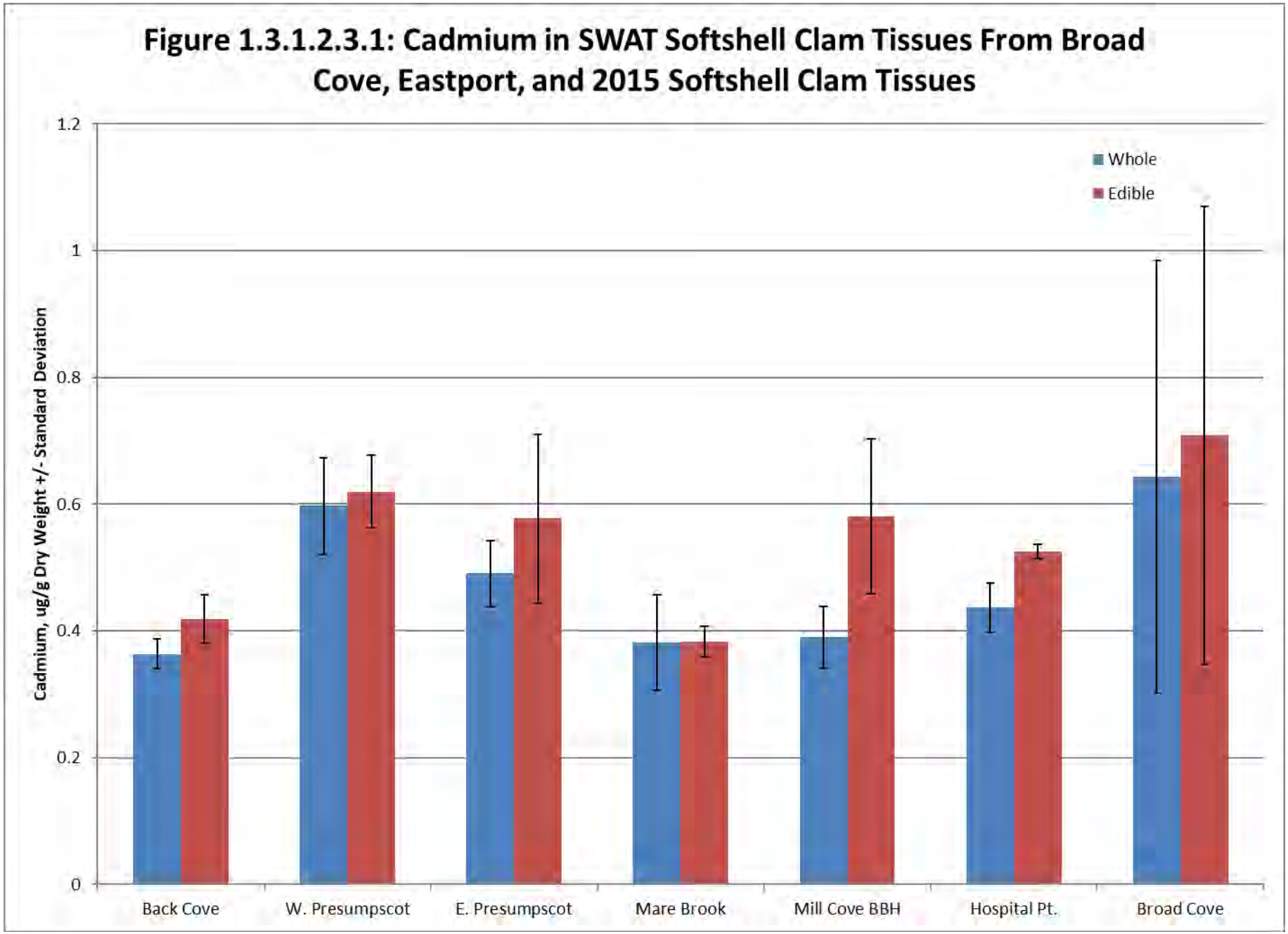
Cadmium was detected at all five locations within Broad Cove (Figure 1.3.1.2.3.1). Cadmium concentrations in edible tissue ranged from a low concentration of 0.42 µg/g dry wt. to a high concentration of 1.31 µg/g dry wt. Cadmium concentrations in whole tissue ranged from a low concentration of 0.42 µg/g dry wt. to a high concentration of 1.23 µg/g dry wt.

Edible and whole clam tissue cadmium concentrations differed very little. The whole to edible tissue ratio of cadmium concentrations varied from 0.8 to 1.0, with the mean ratio across all five samples at 0.9. Compared to six softshell clam sites sampled in 2015, cadmium concentration in edible tissue from Broad Cove was similar but on the high end of the range of tissue at other sites (Figure 1.3.1.2.3.1). The Broad Cove whole tissue cadmium concentration showed a similar relationship to concentrations at previously sampled sites. Broad Cove cadmium concentrations in both tissues exhibited more variability between subsamples compared to the six previously sampled 2015 clam sites (Figure 1.3.1.2.3.1).

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 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 et al., 2008).

From a human health perspective, the MCDC non-cancer FTAL for cadmium in non-commercially caught finfish is 2.2 µg/g wet wt. The FDA action level for clams, oysters, and mussels is 4 µg/g wet wt. (Kimbrough et al., 2008). The highest scoring edible clam tissue concentration from the five Broad Cove sites tested was 0.23 µg/g wet wt., which was well below the MCDC and FDA action levels (10% of the more conservative MCDC non-cancer FTAL). The mean edible tissue wet weight cadmium concentration (0.12 µg/g wet wt.) was half of the highest subsample, since the last location of five sampled had a much higher cadmium concentration than the other four. The highest concentration occurred in a section of Broad Cove immediately below a former landfill site.

Figure 1.3.1.2.3.1: Cadmium in SWAT Softshell Clam Tissues From Broad Cove, Eastport, and 2015 Softshell Clam Tissues



1.3.1.2.4 Chromium (Cr)

Chromium was detected at all five sample locations in Broad Cove (Figure 1.3.1.2.4.1). Chromium concentrations in edible tissue ranged from a low concentration of 1.38 µg/g dry wt. to a high concentration of 2.34 µg/g dry wt. Chromium concentrations in whole tissue ranged from a low concentration of 3.58 µg/g dry wt. to a high concentration of 5.67 µg/g dry wt.

Edible and whole clam tissue chromium concentrations differed markedly. The whole to edible tissue ratio of chromium concentrations varied from 1.5 to 2.9, with the mean ratio of 2.5. Compared to six softshell clam sites sampled in 2015, chromium concentration in edible tissue from Broad Cove was similar or at the lower end of the range of tissue concentrations at other sites (Figure 1.3.1.2.4.1). The Broad Cove whole tissue chromium concentration was similar to concentrations at previously sampled sites from 2015 (Figure 1.3.1.2.4.1).

Natural sources of chromium include leaching from soil and rock into surface waters. Chromium is released from textile, electroplating, and leather tanning industries. Chromium is used extensively in tanning leather and was frequently discharged with untreated tannery effluent during the last two centuries. Chromium persists in the marine environment in sediments near anthropogenic sources (Kimbrough et al., 2008).

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

1.3.1.2.5 Copper (Cu)

Copper was detected in all five subsamples from Broad Cove (Figure 1.3.1.2.5.1). Copper concentrations in edible tissue ranged from a low concentration of 10.7 µg/g dry wt. to a high concentration of 18.2 µg/g dry wt. Copper concentrations in whole tissue ranged from a low concentration of 9.4 µg/g dry wt. to a high concentration of 31.4 µg/g dry wt.

Edible and whole clam tissue copper concentrations differed only slightly. The whole to edible tissue ratio of copper concentrations varied from 0.8 to 1.7, with the mean ratio across five samples in Broad Cove at 1.1. Compared to six softshell clam sites sampled in 2015, copper concentration in edible and whole tissues from Broad Cove was at the lower end of the range of tissue concentrations at other sites (Figure 1.3.1.2.5.1).

Copper occurs naturally and is ubiquitous throughout the marine environment. Copper, in trace amounts, is an important nutrient for plant and animal growth. Elevated copper concentrations can occur due to contributions from 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 after being phased out by EPA, newer wood preservatives utilizing even higher levels of copper have come into use, including quaternary copper. Similarly,

Figure 1.3.1.2.4.1: Chromium in SWAT Softshell Clam Tissues From Broad Cove, Eastport, and 2015 Softshell Clam Tissues

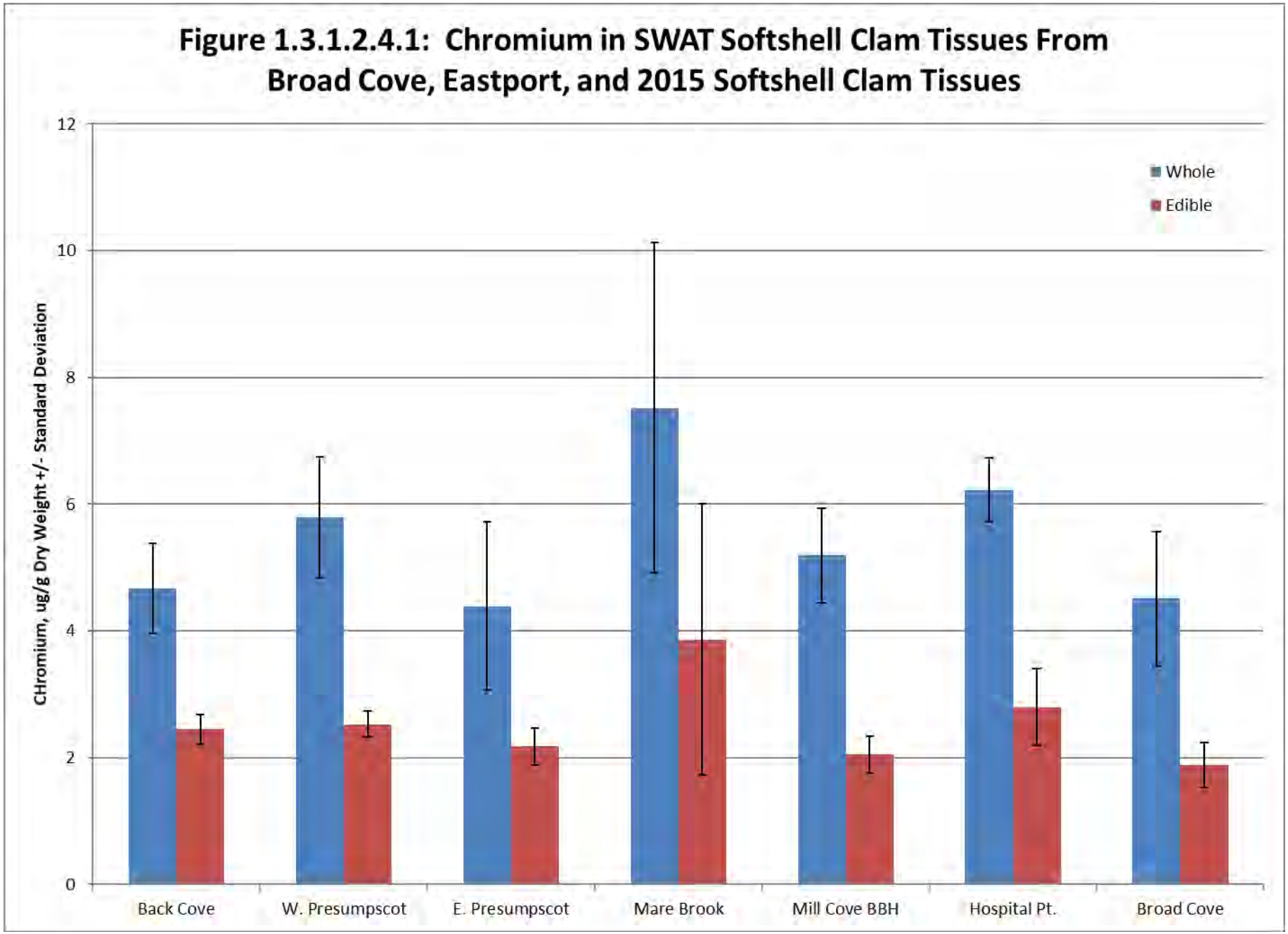
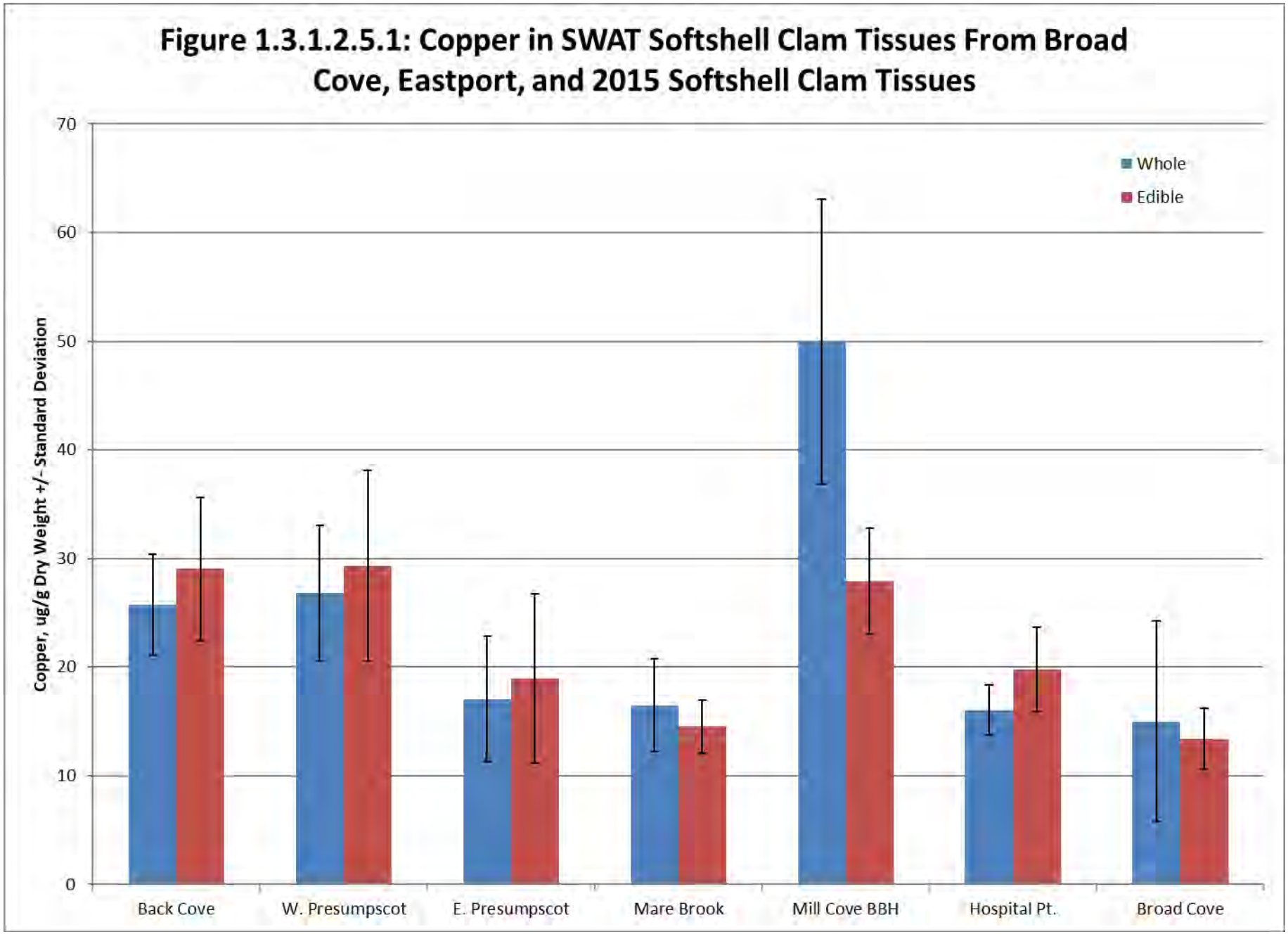


Figure 1.3.1.2.5.1: Copper in SWAT Softshell Clam Tissues From Broad Cove, Eastport, and 2015 Softshell Clam Tissues



tributyltin marine bottom paint use was reduced in the 1980s, resulting in increased use of copper-based antifouling paints, and removal of asbestos from the manufacture of brake pads has been offset by increased usage of copper in manufacturing brake pads (Kimbrough et al., 2008).

Copper is not highly toxic to humans, though exposure can lead to some chronic effects. There is no recommended FDA safety level for human consumption for copper in fish or shellfish (Kimbrough et al., 2008), and MCDC does not report a FTAL for copper in non-commercially caught sportfish.

1.3.1.2.6 Iron (Fe) and Aluminum (Al)

Iron was detected in all five sample locations. Iron concentrations in edible tissue ranged from a low concentration of 977 µg/g dry wt. to a high concentration of 2,020 µg/g dry wt. Iron concentrations in whole tissue ranged from a low concentration of 3,869 µg/g dry wt. to a high concentration of 8,231 µg/g dry wt. (Figure 1.3.1.2.6.1).

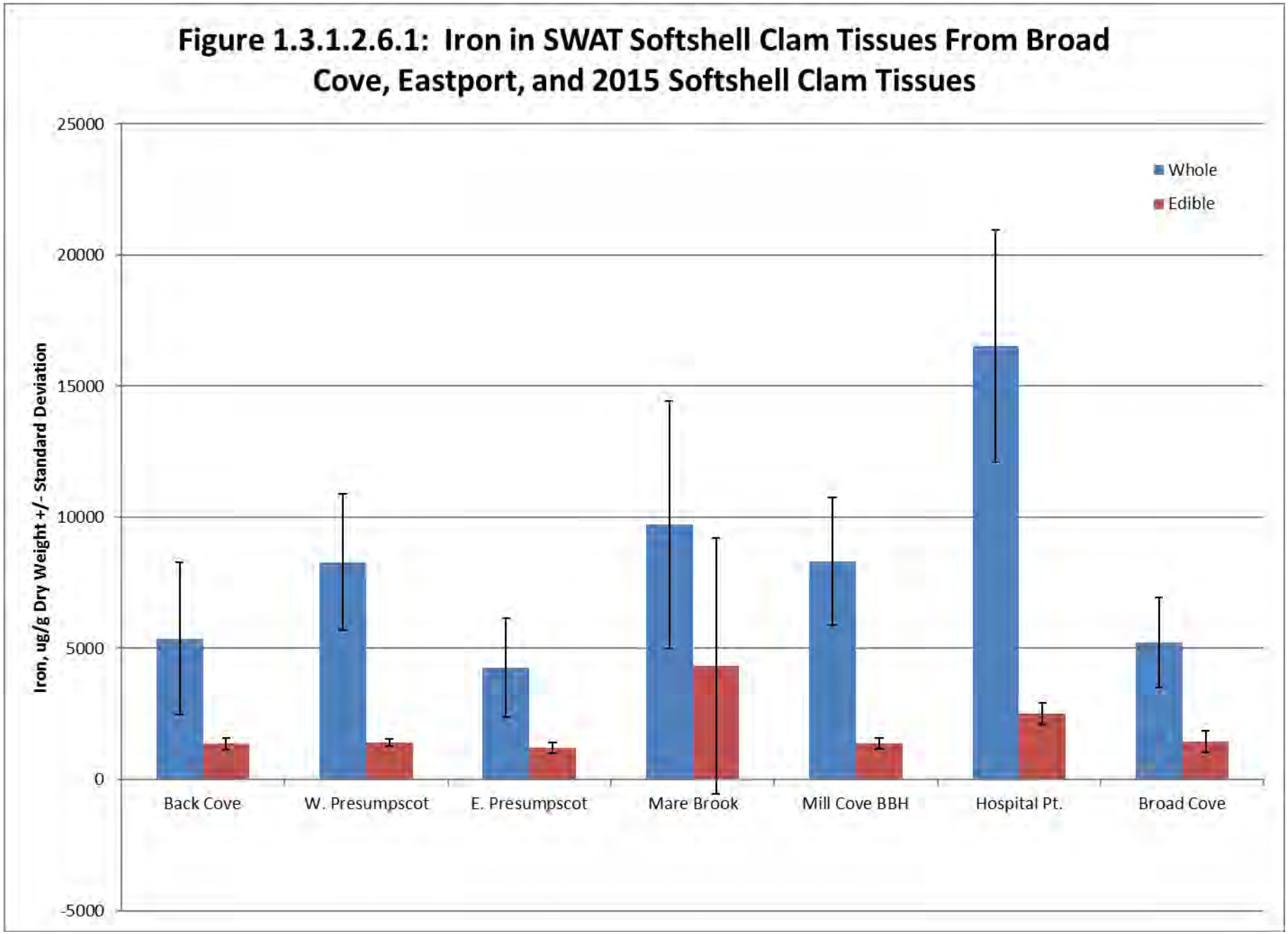
Edible and whole clam tissue iron concentrations differed markedly. The whole to edible tissue ratio of iron concentrations varied from 3.1 to 4.9, with the mean ratio across all fifteen sites at 3.7. Compared to six softshell clam sites sampled in 2015, iron concentrations in edible and whole tissues from Broad Cove were similar to tissue concentrations at other sites (Figure 1.3.1.2.6.1).

Aluminum was detected at all five sample locations in Broad Cove. Aluminum concentrations in edible tissue ranged from a low concentration of 710 µg/g dry wt. to a high concentration of 1,629 µg/g dry wt. Aluminum concentrations in whole tissue ranged from a low concentration of 2,343 µg/g dry wt. to a high concentration of 3,767 µg/g dry wt. (Figure 1.3.1.2.6.2).

Edible and whole clam tissue aluminum concentrations differed markedly (Figure 1.3.1.2.6.2). The whole to edible tissue ratio of aluminum concentrations varied from 1.7 to 3.8, with the mean ratio across all five subsamples at 3.1. Mean aluminum concentrations in edible and whole tissues from Broad Cove were comparable to concentrations in six clam sites sampled in 2015 (Figure 1.3.1.2.6.2).

High iron and aluminum concentrations are usually associated with the intake of high levels of suspended sediments by mussels and clams at sampled sites, since iron and aluminum are 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 detected in SWAT samples is associated with gut contents and not bioaccumulated loads (LeBlanc et al., 2009). Sediment loading in clam gut contents may be quite a bit higher than in mussel gut contents, thus affecting aluminum and iron levels disproportionately in clam tissue concentrations since no depuration occurs prior to tissue removal.

Figure 1.3.1.2.6.1: Iron in SWAT Softshell Clam Tissues From Broad Cove, Eastport, and 2015 Softshell Clam Tissues



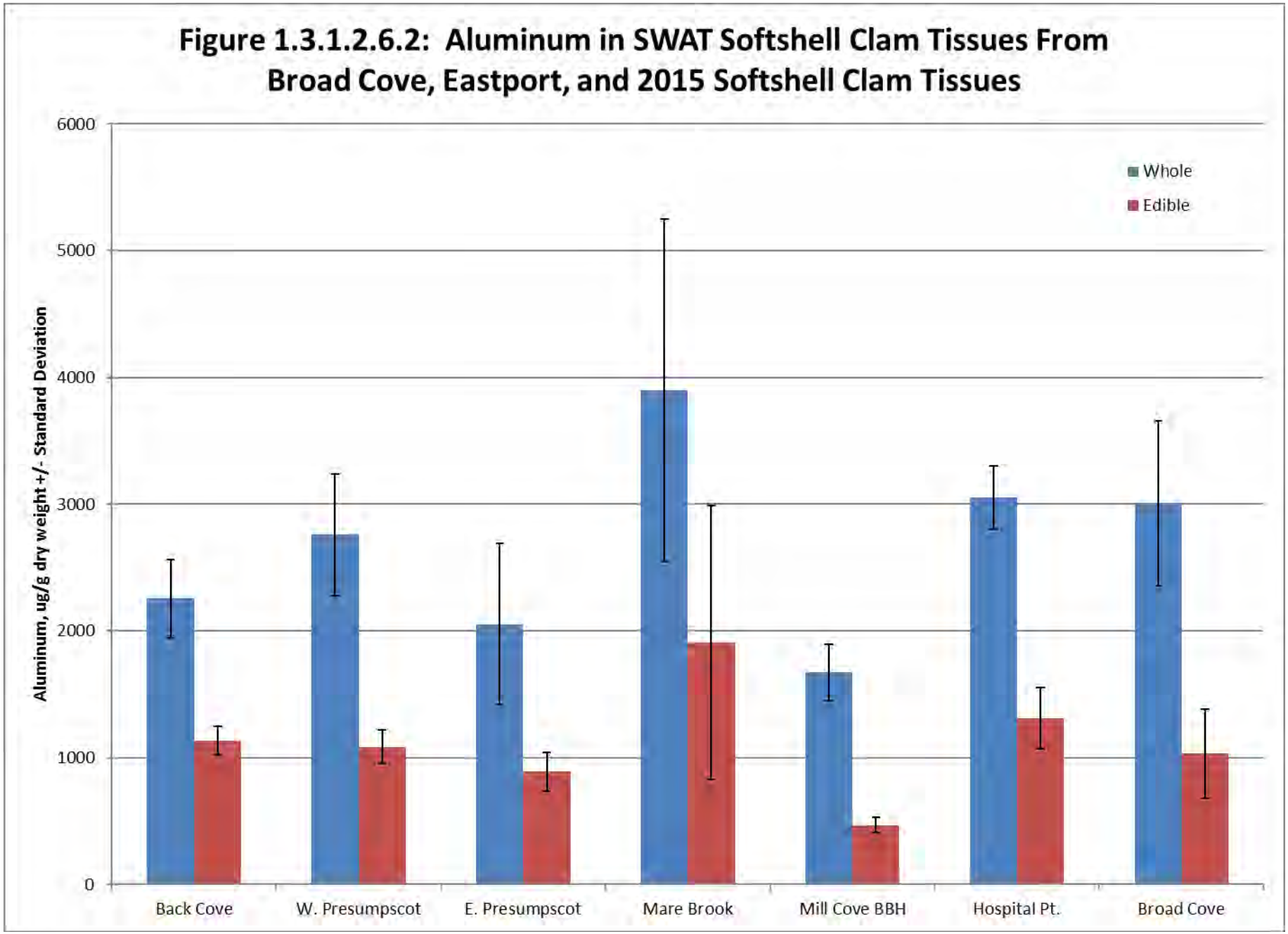


Figure 1.3.1.2.6.2: Aluminum in SWAT Softshell Clam Tissues From Broad Cove, Eastport, and 2015 Softshell Clam Tissues
Aluminum, ug/g dry weight +/- Standard Deviation
6000
5000
4000
3000
2000
1000
0
Whole
Edible
Back Cove
W. Presumpscot
E. Presumpscot
Mare Brook
Mill Cove BBH
Hospital Pt.
Broad Cove

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 samples. 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 within clam tissue.

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

1.3.1.2.7 Nickel (Ni)

Nickel was detected in clam tissue taken at all five sampling locations in Broad Cove. Nickel concentrations in edible tissue ranged from a low concentration of 1.43 µg/g dry wt. to a high concentration of 2.19 µg/g dry wt. Nickel concentrations in whole tissue ranged from a low concentration of 2.73 µg/g dry wt. to a high concentration of 4.02 µg/g dry wt.

Edible and whole clam tissue nickel concentrations differed markedly (Figure 1.3.1.2.7.1). The whole to edible tissue ratio of nickel concentrations varied from 1.6 to 2.5, with the mean ratio for the five samples at 1.9. Mean nickel concentrations in edible and whole tissues from Broad Cove were comparable to concentrations in six clam sites sampled in 2015 (Figure 1.3.1.2.7.1).

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. Elevated 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 et al., 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 et al., 2008). The MCDC reports a non-cancer FTAL for nickel in non-commercially caught finfish of 43 µg/g wet weight, which is more conservative than the FDA action level for shellfish of 80 µg/g wet weight. The highest scoring edible clam tissue concentration from the five Broad Cove sites tested was 0.38 µg/g wet wt., which was well below the MCDC and FDA action levels (orders of magnitude lower than the more conservative MCDC non-cancer FTAL). The highest whole tissue concentration within the subsamples from Broad Cove was 0.62 µg/g wet wt., still well below the MCDC non-cancer FTAL.

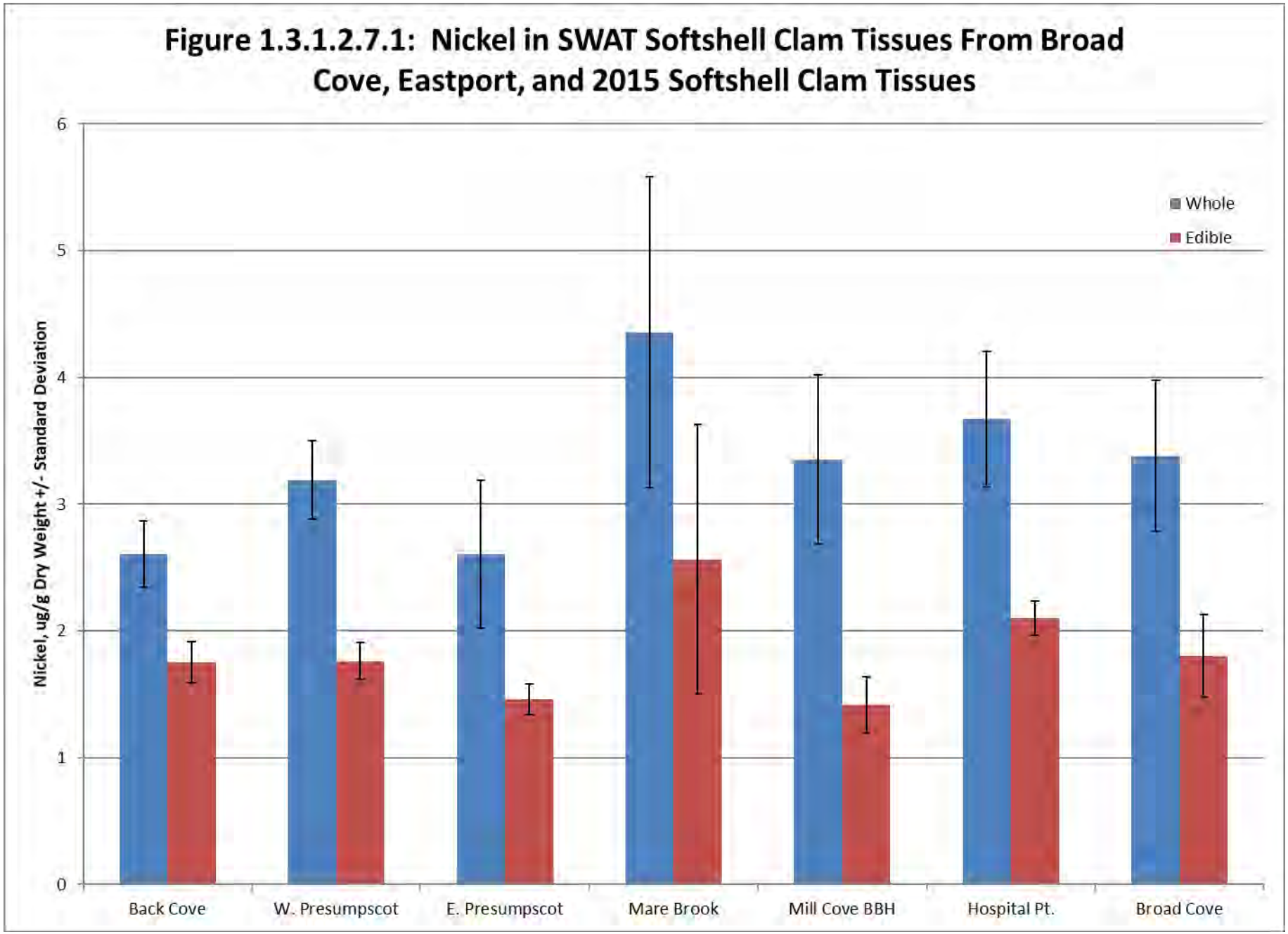


Figure 1.3.1.2.7.1: Nickel in SWAT Softshell Clam Tissues From Broad Cove, Eastport, and 2015 Softshell Clam Tissues
Nickel, ug/g Dry Weight +/- Standard Deviation
0
1
2
3
4
5
6
Whole
Edible
Back Cove
W. Presumpscot
E. Presumpscot
Mare Brook
Mill Cove BBH
Hospital Pt.
Broad Cove

1.3.1.2.8 Lead (Pb)

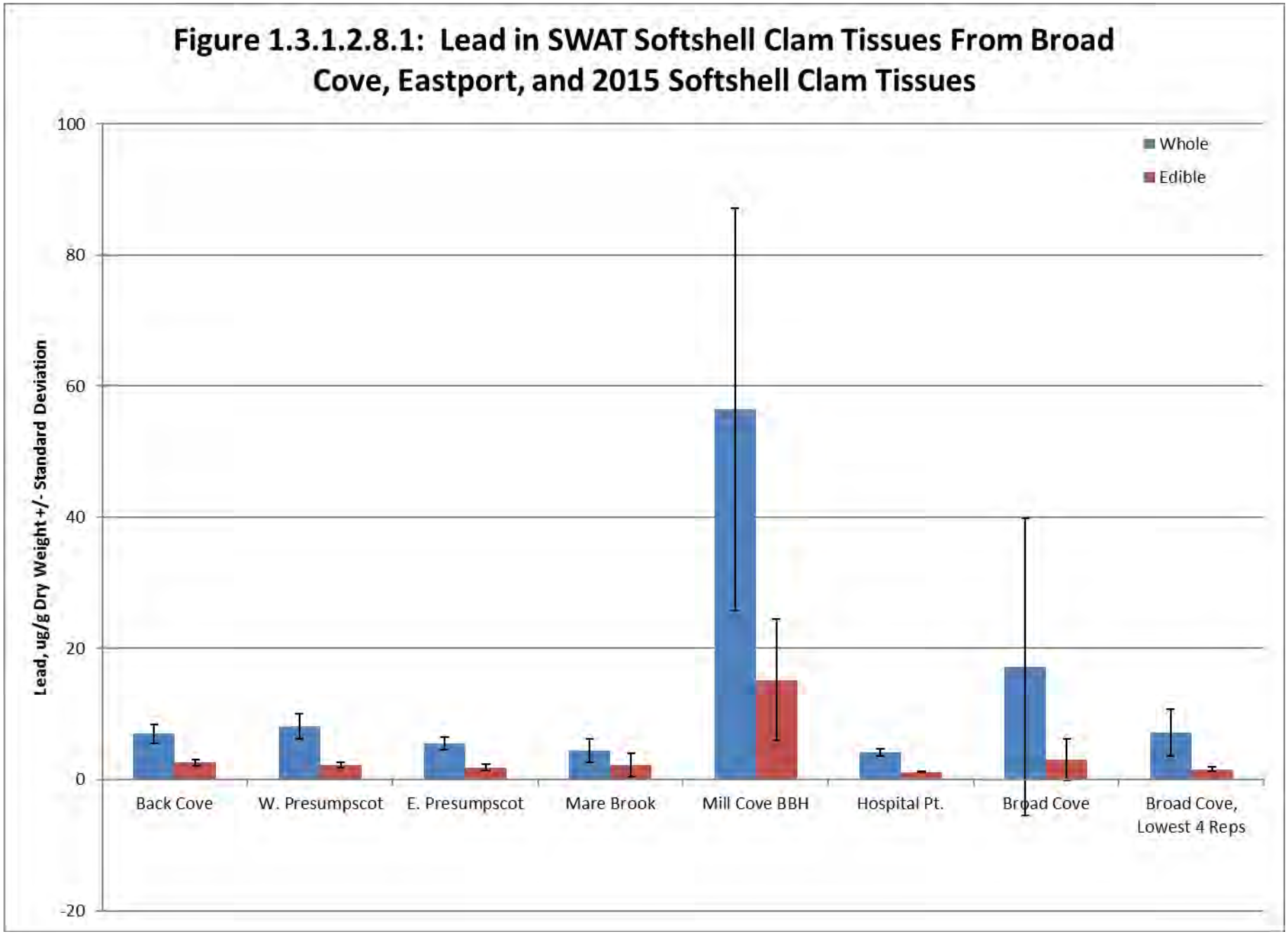
Lead was detected in clam tissue samples taken at all five subsamples in Broad Cove. Lead levels measured in clam edible tissue ranged from a low mean concentration of 1.12 µg/g dry wt. to a high mean concentration of 8.60 µg/g dry wt. Lead levels measured in whole clam tissue ranged from a low mean concentration of 5.54 µg/g dry wt. to a high mean concentration of 57.4 µg/g dry wt.

Edible and whole clam tissue lead concentrations differed markedly (Figure 1.3.1.2.8.1). The whole to edible tissue ratio of lead concentrations varied from 3.2 to 6.7, with the mean ratio across all five sites at 4.9. Mean lead concentration in whole tissue from Broad Cove were higher than five of six clam sites sampled in 2015. Mean edible tissue lead concentration was more comparable to the other six sites tested in 2015. Variability in lead concentration across the five Broad Cove subsamples was high, with the fifth subsample having a markedly higher lead concentration than the remaining four (8.60 µg/g dry wt. compared to 1.58, mean for four remaining subsamples). Since this last sample from the edge of the cove was away from the other four subsamples and adjacent to a historic landfill, data from Broad Cove is also presented with this fifth subsample excluded. This is shown in the figure as Broad Cove, Lowest 4 Replicates (Figure 1.3.1.2.8.1).

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

From a human health perspective, the FDA action level for lead in clams, oysters, and mussels (molluscan shellfish) had been 1.7 µg/g wet wt. (Kimbrough et al., 2008). This limit apparently was eliminated at the 2007 Interstate Shellfish Sanitation Conference (ISSC). The former (now discontinued), more conservative MCDC lead FTAL in non-commercially caught sportfish was 0.6 µg/g wet wt., which is based on a blood lead concentration model. As presented in past SWAT reports, the SWAT program previously tested whole softshell clam tissue only, such that all tissue is included in the sample for contaminant analysis except the shell. More recent work testing clam edible tissues produced markedly different results, with the lead concentrations in the edible tissues averaging 3.1 times less lead (when compared on a dry wt. basis). Edible tissue concentrations at five of six sites analyzed in 2015 topped out at less than half the discontinued MCDC lead FTAL for recreationally caught finfish when considered on a wet wt. basis. In 2017, the highest edible tissue lead concentration from subsamples taken in Broad Cove occurred in the fifth subsample, which exceeded the FTAL with a mean concentration of 1.48 µg/g wet wt. Lead concentrations at Broad Cove across the remaining four subsamples showed less variability when compared without the fifth

Figure 1.3.1.2.8.1: Lead in SWAT Softshell Clam Tissues From Broad Cove, Eastport, and 2015 Softshell Clam Tissues



subsample, with the first four subsamples having a mean edible tissue lead concentration of 0.26 µg/g wet wt. The fifth subsample, located at the foot of a historic landfill, appears to be an outlier compared to the remainder of Broad Cove.

Utilizing the newer edible portion lead concentrations, a reasonable approach might be the development of a softshell clam-specific FTAL, which would consider the frequency of consumption, meal size, and at-risk groups. The recreationally caught finfish FTAL applied above is that which was formerly available from MCDC, but may include consumption, meal size, and risk groups that are not completely relevant to softshell clam consumption. It has since been removed from use and a new lead FTAL may be developed.

The MCDC former FTAL for recreationally caught finfish is based on the consumer eating an 8 oz. meal weekly. Maine SWAT data indicate 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 five subsamples collected in Broad Cove in 2017. Total mercury concentrations measured in clam edible tissue ranged from a low concentration of 0.058 µg/g dry wt. to a high concentration of 0.113 µg/g dry wt. across the five subsamples. Total mercury levels measured in whole clam tissue ranged from a low mean concentration of 0.051 µg/g dry wt. to a high mean concentration of 0.113 µg/g dry wt. The mean concentration of total mercury in edible and whole clam tissue from Broad Cove is presented in Figure 1.3.1.2.9.1. Edible and whole clam tissue total mercury concentrations differed little (Figure 1.3.1.2.9.1). The whole to edible tissue ratio of lead concentrations varied from 0.84 to 1.0, with the mean ratio across all five sites at 0.9.

Total mercury analysis was not performed on edible or whole clam tissue samples from the six stations sampled in 2015, precluding comparison of Broad Cove total mercury concentrations to those other locations.

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 et al., 2008).

From a human health perspective, the developmental methylmercury FTAL (more protective) used by the MCDC is 0.2 µg/g 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. The highest edible tissue total mercury concentration measured in the five subsamples in Broad Cove in 2017 was 0.018 µg/g wet wt. in two of the subsamples. This concentration compares favorably with the MCDC methylmercury developmental FTAL of 0.2 µg/g, assuming a similar meal size and frequency. To consume approximately 8 oz. of softshell clam

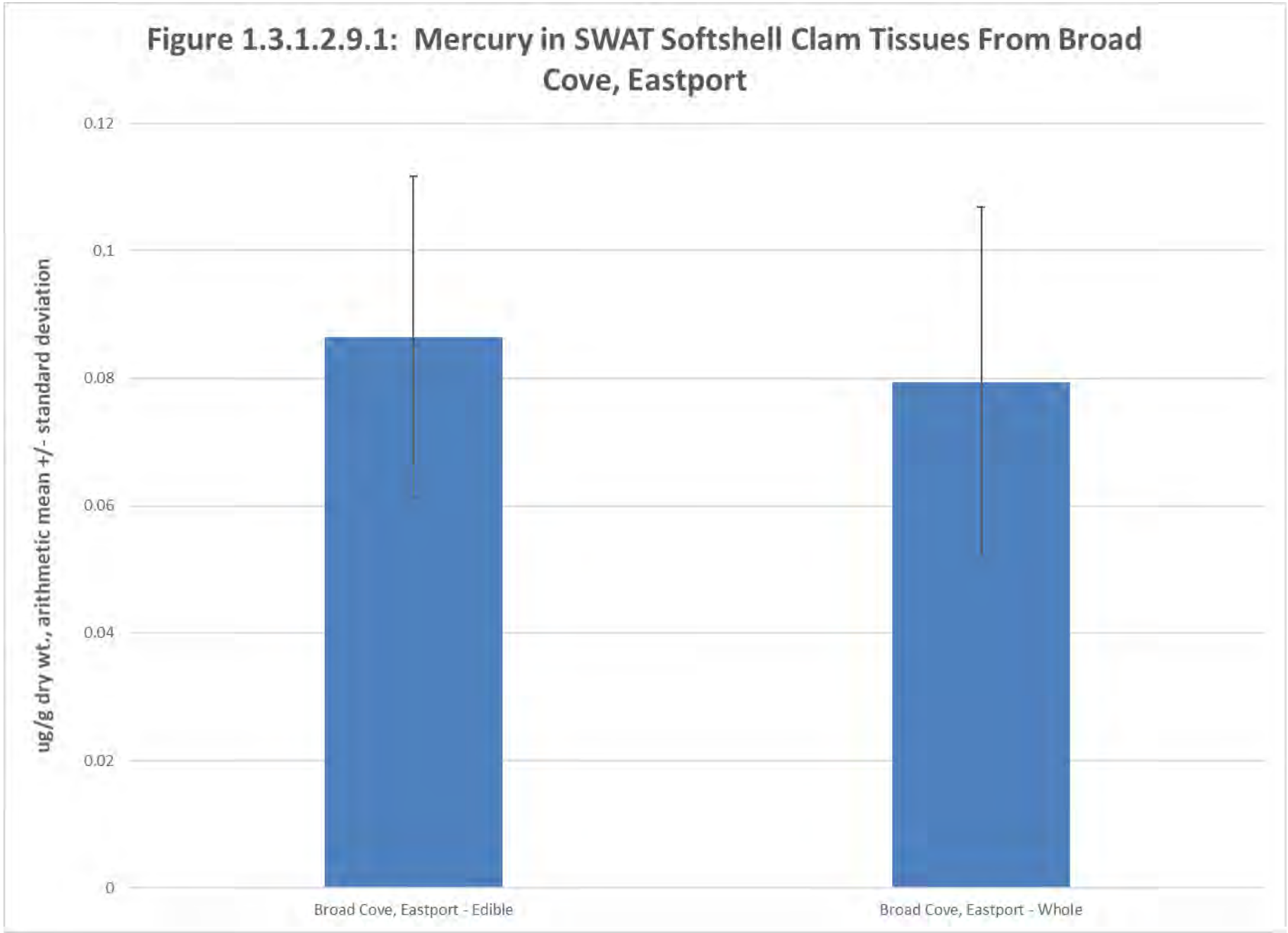


Figure 1.3.1.2.9.1: Mercury in SWAT Softshell Clam Tissues From Broad Cove, Eastport
ug/g dry wt., arithmetic mean +/- standard deviation
0.12
0,1
0.08
0.06
0.04
0.02
0
Broad Cove, Eastport - Edible
Broad Cove, Eastport - Whole

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

1.3.1.2.10 Selenium (Se)

Selenium was detected in all five subsample locations within Broad Cove. Selenium levels measured in clam edible tissue ranged from a low mean concentration of 3.04 µg/g dry wt. to a high mean concentration of 3.98 µg/g dry wt. Selenium levels measured in whole clam tissue ranged from a low mean concentration of 2.86 µg/g dry wt. to a high mean concentration of 3.15 µg/g dry wt.

The ratio of edible and whole clam tissue selenium concentrations varied only slightly among the locations sampled. The whole to edible tissue ratio of selenium concentrations varied from 0.7 to 1.0, with the mean ratio across all five samples at 0.8. Selenium concentrations in both tissue types were similar to concentrations found in tissues from six other softshell clam sites sampled in 2015 (Figure 1.3.1.2.10.1)

Selenium occurs naturally in the environment; however, elevated levels are associated with anthropogenic sources including coal and oil combustion, sewage effluent, agricultural runoff, and industrial wastewater. Natural sources include weathering of selenium from rocks and volcanic eruptions.

From a human health perspective, the selenium FTAL used by the MCDC is 11 µg/g wet wt. for non-commercially caught finfish (fish filet). This FTAL assumes an 8 oz. meal size is consumed weekly. The highest edible clam tissue selenium concentration measured across the five subsamples in Broad Cove in 2017 was 0.63 µg/g wet wt. and the highest whole clam tissue mean selenium concentration measured was 0.48 µg/g wet wt. The highest mean concentrations from both tissues compare favorably with the MCDC selenium FTAL, assuming a similar meal size and frequency.

1.3.1.2.11 Zinc (Zn)

Zinc was detected in tissue taken in all five subsamples from Broad Cove. Zinc levels measured in clam edible tissue ranged from a low concentration of 75.9 µg/g dry wt. to a high concentration of 88.1 µg/g dry weight. Zinc concentrations in whole tissue ranged from a low concentration of 83.5 µg/g dry wt. to a high concentration of 113.0 µg/g dry wt.

Edible and whole clam tissue zinc concentrations differed minimally. The whole to edible tissue ratio of zinc concentration was very close to 1 for all five subsamples (1.0 minimum to 1.3 maximum, mean of 1.1). Zinc concentrations in both edible and whole clam tissues were similar to zinc concentrations in clams from six sites sampled in 2015 (Figure 1.3.1.2.11.1).

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 et al., 2008). Though an

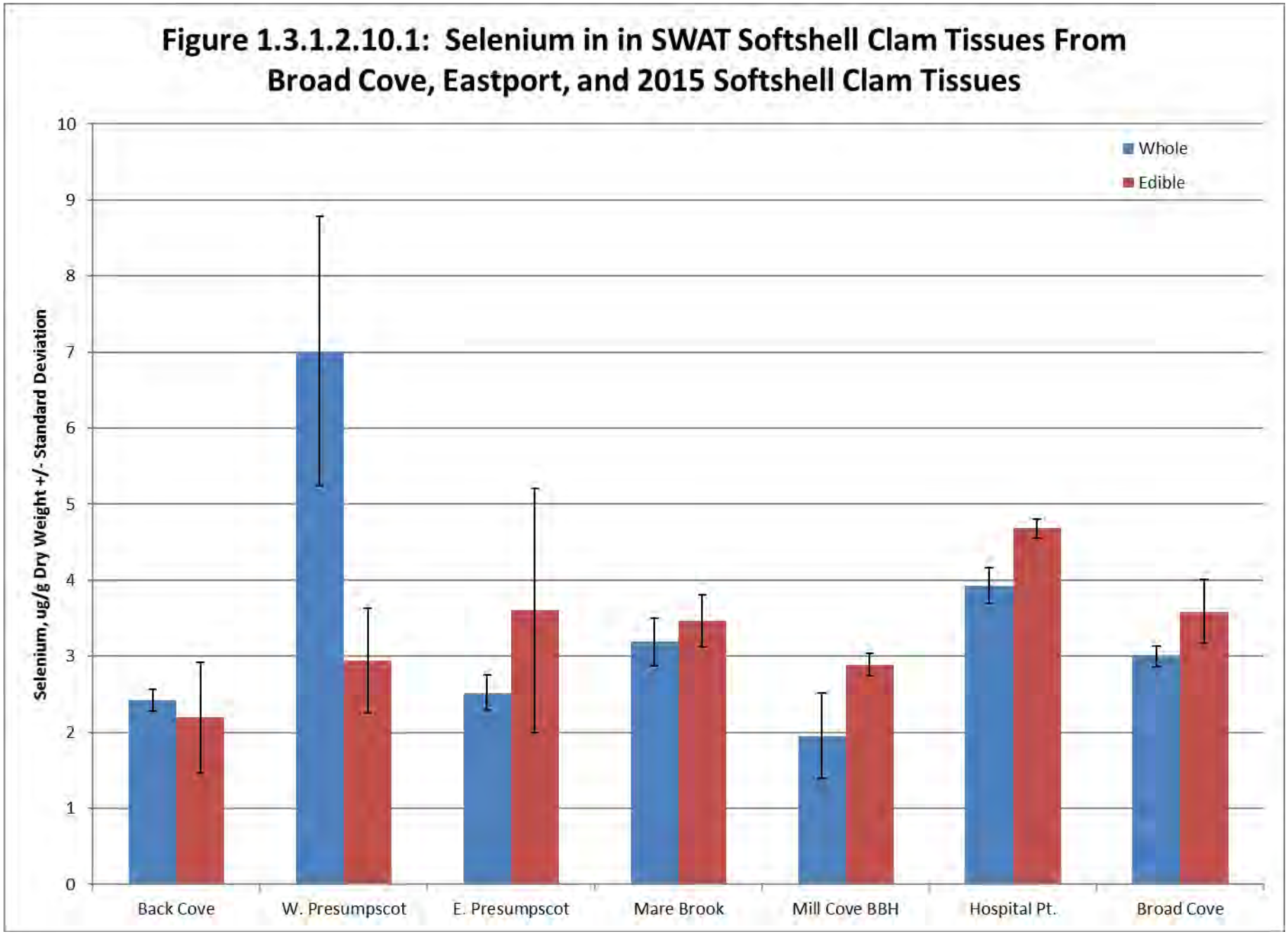


Figure 1.3.1.2.10.1: Selenium in in SWAT Softshell Clam Tissues From Broad Cove, Eastport, and 2015 Softshell Clam Tissues
Selenium, ug/g Dry Weight +/- Standard Deviation
0
1
2
3
4
5
6
7
8
9
10
Whole
Edible
Back Cove
W. Presumpscot
E. Presumpscot
Mare Brook
Mill Cove BBH
Hospital Pt.
Broad Cove

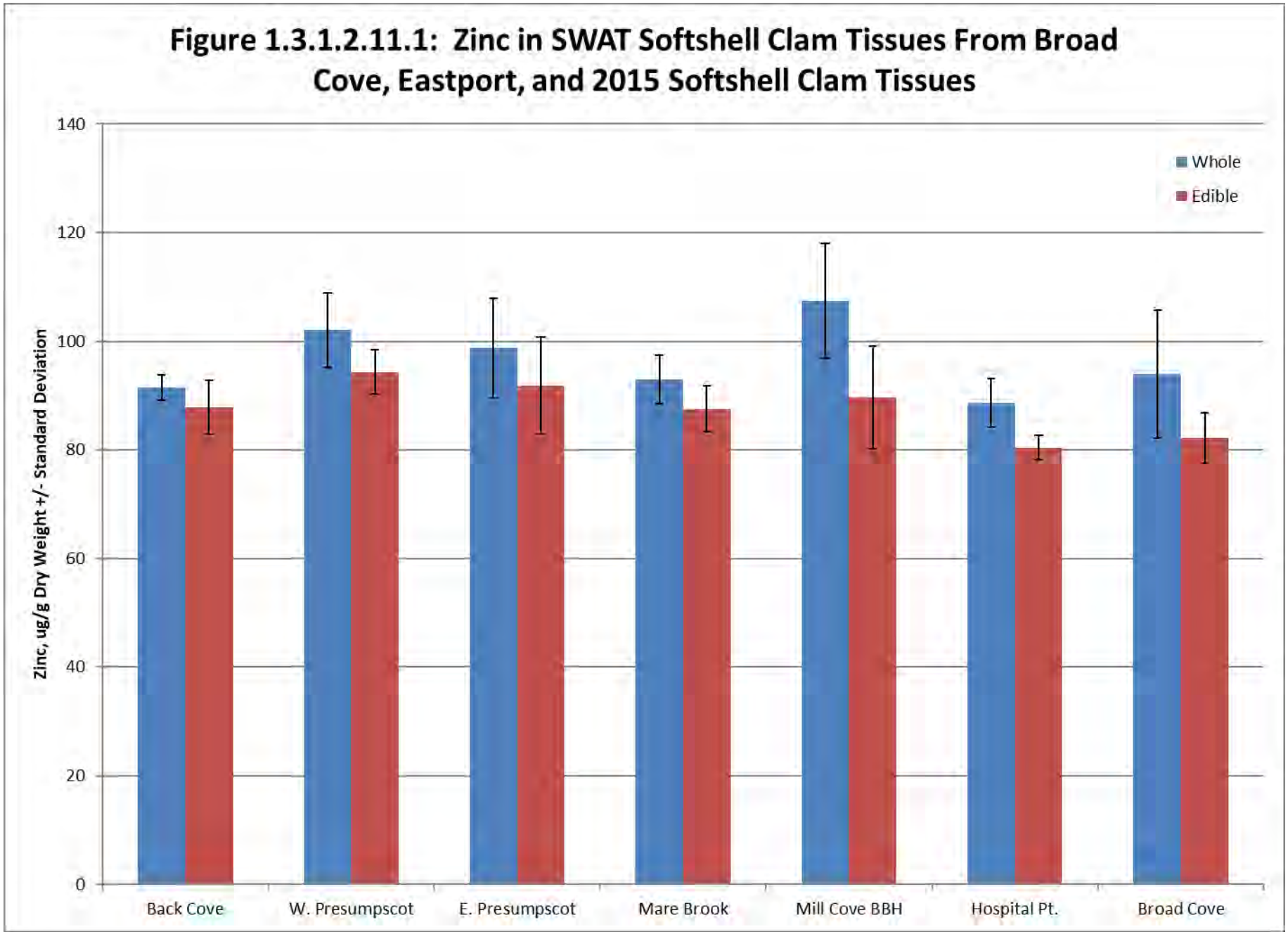


Figure 1.3.1.2.11.1: Zinc in SWAT Softshell Clam Tissues From Broad Cove, Eastport, and 2015 Softshell Clam Tissues
Zinc, ug/g Dry Weight +/- Standard Deviation
140
120
100
80
60
40
20
0
Whole
Edible
Back Cove
W. Presumpscot
E. Presumpscot
Mare Brook
Mill Cove BBH
Hospital Pt.
Broad Cove

essential nutrient at low levels, higher levels in 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 µg/g wet wt., which is more than an order of magnitude higher than any wet wt. concentrations observed in SWAT clam tissue from the Broad Cove in 2017 or the six sites sampled in 2015. There is no recommended FDA safety level for zinc in fish (Kimbrough et al., 2008).

1.3.2 Polycyclic Aromatic Compounds

Polycyclic Aromatic Hydrocarbon Compounds (PAHs) occur in elevated concentrations near petroleum manufacturing, creosote use, and burning wood (Kimbrough et al., 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 compounds are hydrocarbons composed of fused benzene rings, fusion of which may occur during combustion of other related compounds. However, they also occur in un-combusted coal and oil. PAHs in the environment are primarily from forest fires, coal-fired power plants, automobile exhaust, and spilled oil (Kimbrough et al., 2008).

1.3.2.1 Blue Mussels

Results were compared to national (NS&T) (Kimbrough et al., 2008) and Gulf of Maine (Gulfwatch) (LeBlanc et al., 2009) blue mussel monitoring program data (when available) to place Maine SWAT data in a national and regional context, respectively.

The NS&T and 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 75 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 19 non-alkylated PAHs from 2017 SWAT data. 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 Naphthalene, and C1-Phenanthrene). The 2017 SWAT PAH data can also be used to generate a summation for comparison with the Gulfwatch/NS&T summation of 40 PAHs, which includes even more alkylated PAHs. The corresponding SWAT data include 39 PAHs, the summation of which is the closest approximation possible. The difference between the Gulfwatch/NS&T summation and the SWAT summation is the absence of C4-Flourenes from the SWAT data set. 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 2017 PAH data include additional alkylated PAHs as well, with a total of 75 PAHs included. The summation of 75 PAHs 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 greater level of PAH analysis obtained for SWAT sites in recent years since 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.

Figure 1.3.2.1.1 shows the summation of the 19 non-alkylated PAHs, 24 PAHs, and 40 PAHs compared to the summation of all 75 ("total") PAHs (including many alkylated PAHs) at the three 2017 SWAT blue mussel sites analyzed for PAHs. Figure 1.3.2.1.1 also includes softshell clam data for two tissue types from Broad Cove, which will be discussed in the next section. The 19 summed non-alkylated PAHs and the total PAHs vary in a similar manner between sites, and 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 sum of 19 PAHs and the total PAHs illustrated in Figure 1.3.2.1.1.

Total mean PAH concentrations were 838 ng/g dry wt. at East End Beach, Portland, 344 ng/g dry wt. at Mill Creek, Falmouth, and 163 ng/g dry wt. at Whiting Cove, Whiting (Figure 1.3.2.1.1). The means of the sum of 19 non-alkylated PAHs were 330 ng/g dry wt. at East End Beach, Portland, 124 ng/g dry wt. at Mill Creek, Falmouth, and, and 44 ng/g dry wt. at Whiting Cove, Whiting (Figure 1.3.2.1.1). 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, the mean concentrations for the sum of 24 PAHs were 392 ng/g dry wt. at East End Beach, Portland, 159 ng/g dry wt. at Mill Creek, Falmouth, and 69 ng/g dry wt. at Whiting Cove, Whiting (Figure 1.3.2.1.1).

Figure 1.3.2.1.1 also shows the summation of 40 PAHs compared to the summation of all 75 PAHs (Total PAHs) at the 2017 SWAT blue mussel sites. Both the 40 summed PAHs and the total PAHs vary in a similar manner between sites, but the sum of the 40 PAHs makes up the bulk of the total PAHs found at each site. The mean concentrations for the sum of 40 PAHs were 669 ng/g dry wt. at East End Beach, Portland, 256 ng/g dry wt. at Mill Creek, Falmouth, and 103 ng/g dry wt. at Whiting Cove, Whiting (Figure 1.3.2.1.1).

TABLE 1.3.2.1.1: Analyzed PAHs and PAH Summation Calculations

	SWAT (single analytes)				SWAT, Gulfwatch, NS&T(summations)				
Parameter	2012-17	2010-11	2007-08	2004-05	ΣPAH19	ΣPAH24	ΣPAH40	Not Analyzed By Gulfwatch	Notes (See below list for more notes)
ACENAPHTHENE	x	x	x	x	x	x	x		
ACENAPHTHYLENE	x	x	x	x	x	x	x		
ANTHRACENE	x	x	x	x	x	x	x		
2-METHYLANTHRACENE	x	x						missing	
BENZ[A]ANTHRACENE	x	x	x	x	x	x	x		
DIBENZ(A,H)ANTHRACENE	x	x	x	x	x	x	x		
BIPHENYL	x	x	x	x	x	x	x		
BENZO[A]PYRENE	x	x	x	x	x	x	x		
BENZO(E)PYRENE	x	x	x	x	x	x	x		
7-METHYLBENZO[A]PYRENE	x	x						missing	
CHRYSENE	x	x	x	x	x	x	x		
1-METHYLCHRYSENE	x	x						missing	
5/6-METHYLCHRYSENE	x	x						missing	
5,9-DIMETHYLCHRYSENE	x	x						missing	
DIBENZOTHIOPHENE	x	x	1,2,3		x	x	x		
2,4-DIMETHYLDIBENZOTHIOPHENE	x	x						missing	
2/3-METHYLDIBENZOTHIOPHENES	x	x						missing	
FLUORANTHENE	x	x	x	x	x	x	x		
BENZO[B]FLUORANTHENES	x								SWAT split in 2012 from (B,J,K)
BENZO[J,K]FLUORANTHENES	x								SWAT split in 2012 from (B,J,K)
BENZO[B,J,K]FLUORANTHENES		x	x		x	x	x		in Gulfwatch list as BENZO[B]FLUORANTHENE and BENZO[K]FLUORANTHENE
3-METHYLFLUORANTHENE/BENZO[A]FLUORENE	x	x							
FLUORENE	x	x	x	x	x	x	x		
2-METHYLFLUORENE	x	x						missing	
1,7-DIMETHYLFLUORENE	x	x						missing	

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

	SWAT (single analytes)				SWAT, Gulfwatch, NS&T (summations)				
Parameter	2012-17	2010-11	2007-08	2004-05	ΣPAH19	ΣPAH24	ΣPAH40	Not Analyzed By Gulfwatch	Notes (See below list for more notes)
NAPHTHALENE	x	x	x	x	x	x	x		
1-METHYLNAPHTHALENE	x	x	x					missing	
2-METHYLNAPHTHALENE	x	x	x					missing	
1,2-DIMETHYLNAPHTHALENE	x	x						missing	
2,6-DIMETHYLNAPHTHALENE	x	x	x					missing	
2,3,5-TRIMETHYLNAPHTHALENE	x	x	x					missing	
2,3,6-TRIMETHYLNAPHTHALENE	x	x						missing	
1,4,6,7-TETRAMETHYLNAPHTHALENE	x	x						missing	
PERYLENE	x	x	x	x		x	x		
BENZO[GHI]PERYLENE	x	x	x	x	x	x	x		
PHENANTHRENE	x	x	x	x	x	x	x		
1-METHYLPHENANTHRENE	x	x	x					missing	
2-METHYLPHENANTHRENE	x	x						missing	
3-METHYLPHENANTHRENE	x	x						missing	
9/4-METHYLPHENANTHRENE	x	x						missing	
1,7-DIMETHYLPHENANTHRENE	x	x						missing	
1,8-DIMETHYLPHENANTHRENE	x	x						missing	
2,6-DIMETHYLPHENANTHRENE	x	x						missing	
3,6-DIMETHYLPHENANTHRENE	x	x						missing	
1,2,6-TRIMETHYLPHENANTHRENE	x	x						missing	
PYRENE	x	x	x	x	x	x	x		
INDENO[1,2,3-CD]PYRENE	x	x	x	x	x	x	x		

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

	SWAT (single analytes)				SWAT, Gulfwatch, NS&T (summations)				
Parameter	2012-17	2010-11	2007-08	2004-05	ΣPAH19	ΣPAH24	ΣPAH40	Not Analyzed By Gulfwatch	Notes (See below list for more notes)
RETENE	x	x						missing	
C1-ACENAPHTHENES	x	x						missing	
C1-BENZO[A]ANTHRACENES/CHRYSENES	x	x	3				x		in Gulfwatch list as C1-CHRYSENE
C2-BENZO[A]ANTHRACENES/CHRYSENES	x	x	3				x		in Gulfwatch list as C2-CHRYSENE
C3-BENZO[A]ANTHRACENES/CHRYSENES	x	x	3				x		in Gulfwatch list as C3-CHRYSENE
C4-BENZO[A]ANTHRACENES/CHRYSENES	x	x	3				x		in Gulfwatch list as C4-CHRYSENE
C1-BENZOFLUORANTHENES/BENZOPYRENES	x	x						missing	
C2-BENZOFLUORANTHENES/BENZOPYRENES	x	x						missing	
C1-BIPHENYLS	x	x						missing	
C2-BIPHENYLS	x	x						missing	
C1-DIBENZOTHIOPHENES	x	x	3				x		
C2-DIBENZOTHIOPHENES	x	x	3				x		
C3-DIBENZOTHIOPHENES	x	x	3				x		
C4-DIBENZOTHIOPHENES	x	x						missing	
C1-FLUORANTHENES/PYRENES	x	x	3				x		
C2-FLUORANTHENES/PYRENES	x	x	3				x		
C3-FLUORANTHENES/PYRENES	x	x						missing	
C4-FLUORANTHENES/PYRENES	x	x						missing	
C1-FLUORENES	x	x	3				x		
C2-FLUORENES	x	x	3				x		
C3-FLUORENES	x	x	3				x		
C1-NAPHTHALENES	x	x	2,3			x	x		
C2-NAPHTHALENES	x	x	2,3			x	x		
C3-NAPHTHALENES	x	x	2,3			x	x		
C4-NAPHTHALENES	x	x						missing	

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

	SWAT (single analytes)				SWAT, Gulfwatch, NS&T (summations)				
Parameter	2012-17	2010-11	2007-08	2004-05	ΣPAH19	ΣPAH24	ΣPAH40	Not Analyzed By Gulfwatch	Notes (See below list for more notes)
C1-PHENANTHRENES/ANTHRACENES	x	x	2,3			x	x		in Gulfwatch list as C1-PHENANTHRENE
C2-PHENANTHRENES/ANTHRACENES	x	x	3				x		in Gulfwatch list as C2-PHENANTHRENE
C3-PHENANTHRENES/ANTHRACENES	x	x	3				x		in Gulfwatch list as C3-PHENANTHRENE
C4-PHENANTHRENES/ANTHRACENES	x	x	3				x		in Gulfwatch list as C4-PHENANTHRENE
C4-FLUORENES			3				x		Not analyzed by SWAT

FOOTNOTES:

Prior to 2012: List of 'Sum PAH19' only has 18 compounds because BENZO[B]FLUORANTHENES and BENZO[K]FLUORANTHENES are listed as one compound, BENZO[B,J,K]FLUORANTHENES; same applies to 'Sum PAH24' which has only 23 compounds. For 2012-17: List of 'Sum PAH19' has 19 compounds because BENZO[B]FLUORANTHENES and BENZO[J,K]FLUORANTHENES are listed as two compounds: Same applies to 'Sum PAH24' which now has 24 compounds.

Prior to 2012: List of 'Sum PAH40' only has 38 compounds because BENZO[B]FLUORANTHENES and BENZO[K]FLUORANTHENES are listed as one compound, BENZO[B,J,K]FLUORANTHENES and SWAT/AXYS data do not exist for C-4 FLUORENES (at bottom of above list). For 2012-17: List of 'Sum PAH40' has 39 compounds because BENZO[B]FLUORANTHENES and BENZO[J,K]FLUORANTHENES are listed as two compounds, though SWAT/AXYS data do not exist 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 (prior to 2012), and the C1/2/3/4-BENZO[A]ANTHRACENES.

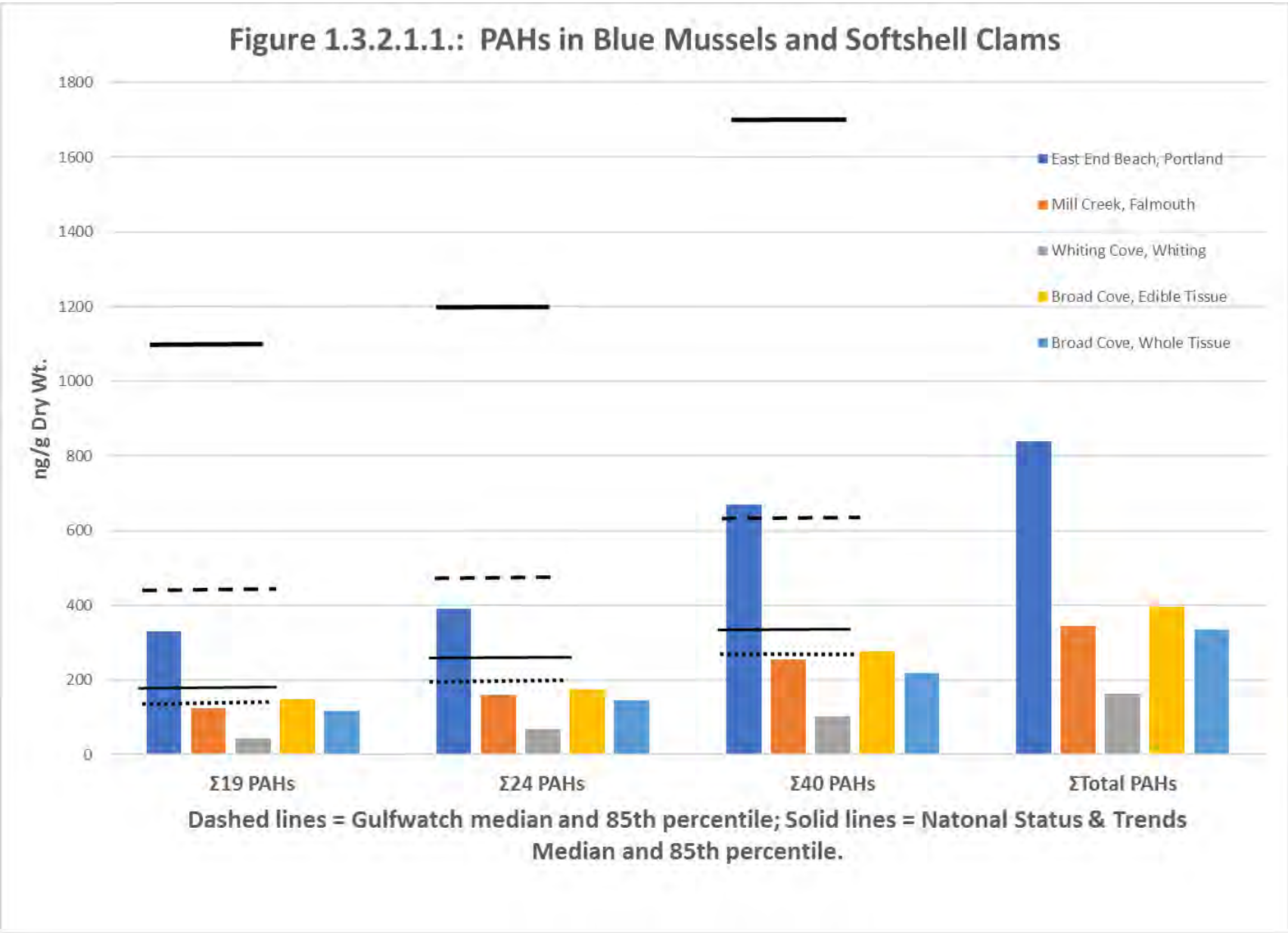


Figure 1.3.2.1.1.: PAHs in Blue Mussels and Softshell Clams
1800
1600
1400
1200
1000
800
600
400
200
0
ng/g Dry Wt.
East End Beach, Portland
Mill Creek, Falmouth
Whiting Cove, Whiting
Broad Cove, Edible Tissue
Broad Cove, Whole Tissue
Σ19 PAHs
Σ24 PAHs
Σ40 PAHs
ΣTotal PAHs
Dashed lines = Gulfwatch median and 85th percentile; Solid lines = Natonal Status & Trends Median and 85th percentile.

Figure 1.3.2.1.1 compares the sum of 19 PAHs at the SWAT blue mussel sites sampled in 2017 to the Gulfwatch 2008 median and 85th percentile results. The sum of 19 PAHs from mussel tissue at two sites was below the Gulfwatch median (154 ng/g dry wt.) and only one site, East End Beach, Portland, exceeded the Gulfwatch median. None of the three sites exceeded the Gulfwatch 85th percentile (429 ng/g dry wt.). The summation of non-alkylated PAHs is useful for putting Maine data into a regional, Gulf of Maine context. Figure 1.3.2.1.1 also compares the sum of 19 non-alkylated PAHs at the 2017 SWAT blue mussel sites to NS&T median and 85th percentile for 19 summed non-alkylated PAHs (2008 data, the most recent available). The sum of 19 PAHs in mussel tissue from two sites was below the 2008 NS&T median of 180 ng/g dry wt. for 19 summed non-alkylated PAHs, while only East End Beach, Portland, exceeded the NS&T 2008 median. None of the three SWAT mussel sites approached or exceeded the NS&T 85th percentile of 1,104 ng/g dry wt. for 19 summed PAHs.

Figure 1.3.2.1.1 compares the sum of 24 PAHs at the SWAT blue mussel sites sampled in 2017 to the Gulfwatch 2008 median and 85th percentile results. The sum of 24 PAHs from mussel tissue at two sites sampled in 2017 were below the Gulfwatch 2008 median of 198 ng/g dry wt. for 24 summed PAHs, while the remaining site at East End Beach, Portland, exceeded the Gulfwatch median. None of the sites exceeded the Gulfwatch 85th percentile. The summation of these PAHs is useful for putting Maine data into a regional, Gulf of Maine context. Figure 1.3.2.1.1 also compares the sum of 24 PAHs at the 2017 SWAT blue mussel sites to recent NS&T median and 85th percentile for 24 summed PAHs (2008 data, the most recent available). The sum of 24 PAHs from mussel tissue at East End Beach, Portland, was the only site which exceeded the NS&T 2008 median of 247 ng/g dry wt. for 24 summed PAHs, and none of the sites approached or exceeded the NS&T 85th percentile of 1,216 ng/g dry wt. for 24 summed PAHs.

Figure 1.3.2.1.1 compares the sum of 40 PAHs at the SWAT blue mussel sites sampled in 2017 to the Gulfwatch 2008 median and 85th percentile results. The sum of 40 PAHs from mussel tissue at East End Beach, Portland, exceeded the Gulfwatch 2008 median of 260 ng/g dry wt. for 40 summed PAHs. The sum of 40 PAHs at East End Beach also exceeded the Gulfwatch 85th percentile of 618 ng/g dry wt. 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 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 1.3.2.1.1.

Figure 1.3.2.1.1 also compares the sum of 40 PAHs at the 2017 SWAT mussel sites to the NS&T median and 85th percentile for 40 summed PAHs (2008 data, the most recent available). The concentration at East End Beach, Portland, exceeded the National Status and Trends median of 353 ng/g dry wt. for 40 summed PAHs but did not come close to the NS&T 85th percentile of 1,674 ng/g dry wt. for 40 summed PAHs.

For 2017 SWAT blue mussel sites (and softshell clam tissue from Broad Cove), Figure 1.3.2.1.2 presents a graphic representation of selected PAHs expressed as a ratio. The equation used to derive the ratio is:

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

This equation yields a numerical ratio, which is utilized to show relative concentrations of non-alkylated and alkylated PAHs. 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. All three SWAT blue mussel sites tested in 2017 have ratios above the 0.2 mark (all above 0.4), which indicates a pyrogenic source of PAHs.

Toxicities of PAHs vary, with hundreds of compounds making up the pool of PAHs. Toxic responses in aquatic organisms may include reproductive 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 et al., 2008).

1.3.2.2 Softshell Clams

As in the other clam analyses, softshell clam tissues were dissected to produce an edible tissue portion (all tissue except "skin" or membrane and shell) and a whole clam portion (all tissue except shell), which were analyzed individually. This report utilizes the Maine SWAT softshell clam tissue PAH data generated by AXYS Analytical, which includes 75 individual and summed alkylated PAHs. Summations of PAHs were calculated for 19, 24, and 40 PAHs as well as total PAHs, as described in the blue mussel section above. The lists of PAHs comprising the various summations are presented in Table 1.3.2.2.1.

The 19 summed non-alkylated PAHs and the total PAHs vary in a similar manner to the blue mussel data, with the non-alkylated PAHs making 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 sum of 19 PAHs and the total PAHs illustrated in Figure 1.3.2.1.1.

Total mean PAH concentrations were 285 ng/g dry wt. in edible softshell clam tissue, and 247 ng/g dry wt. in clam whole tissue in Broad Cove (Figure 1.3.2.1.1, right two columns in each grouping of PAHs summations). The means of the sum of 19 non-alkylated PAHs were 147 ng/g dry wt. in edible tissue and 118 ng/g dry wt. in whole tissue in clams from Broad Cove (Figure 1.3.2.1.1). 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, the mean concentrations for the sum of 24 PAHs were 175 ng/g dry wt. in edible tissue and 145 ng/g dry wt. in whole tissue in Broad Cove clams (Figure 1.3.2.1.1).

Figure 1.3.2.1.1 also shows the summation of 40 PAHs compared to the summation of all 75 PAHs (Total PAHs) in 2017 Broad Cove clams tissues, with the sum of the 40 PAHs making up the bulk of the total PAHs found in each tissue. The mean concentrations for the sum of 40 PAHs were 276 ng/g dry wt. in edible tissue and 219 ng/g dry wt. in whole clam tissue in Broad Cove, Eastport (Figure 1.3.2.1.1).

Softshell clam tissue PAH summation means were similar to blue mussel PAH summation means in magnitude, falling about midway in the range of the three blue mussel sites. Edible clam tissue appeared to contain a smaller concentration of PAHs in each summation than the corresponding whole clam tissue, although differences were relatively small.

For 2017 SWAT softshell clam tissue from Broad Cove, Figure 1.3.2.1.2 presents a graphic representation of selected PAHs expressed as a ratio. The equation used to derive the ratio is:

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

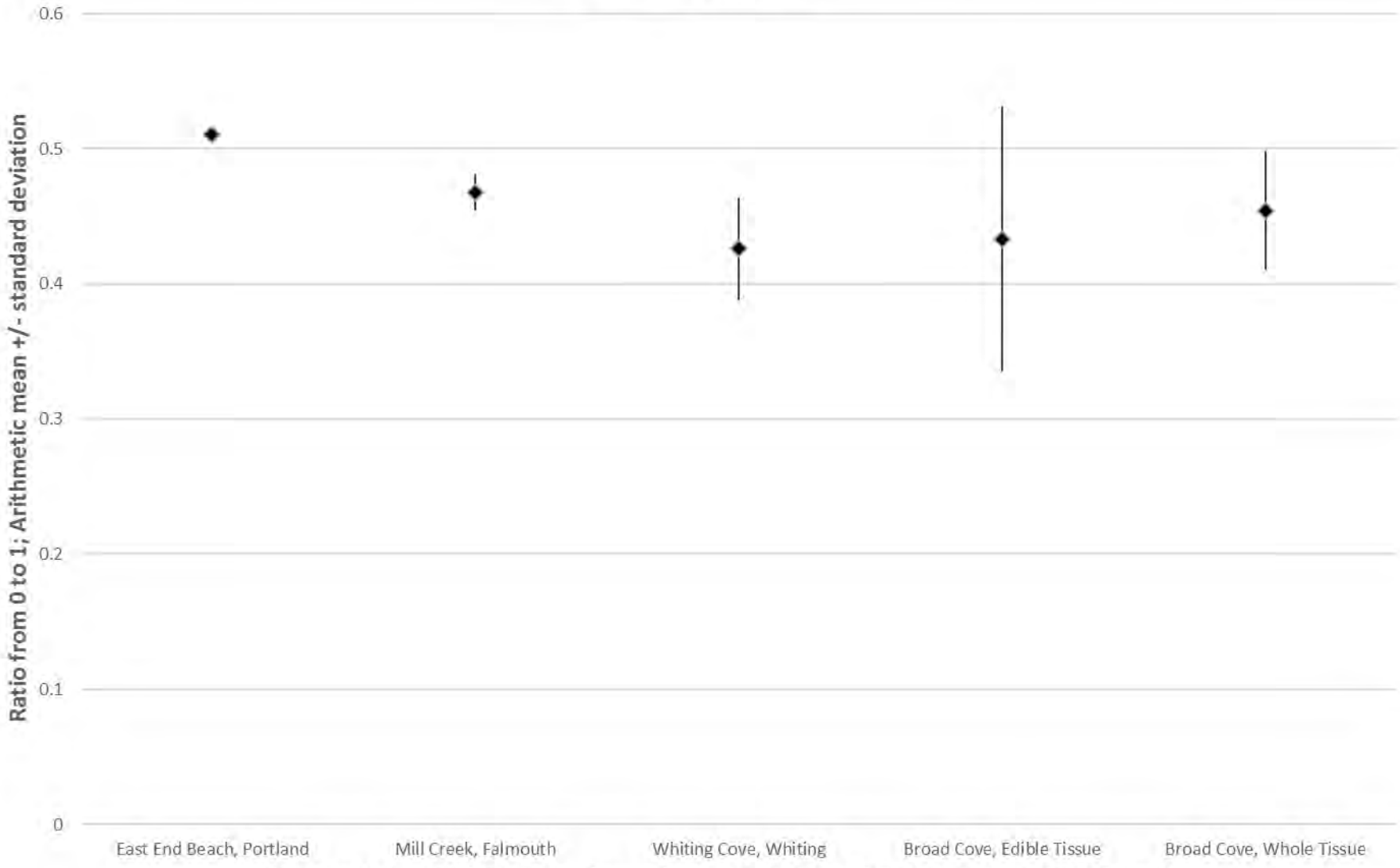
This equation yields a numerical ratio, which is utilized to show relative concentrations of non-alkylated and alkylated PAHs. Values <0.1 are interpreted as a petrogenic (unburned fuel or petroleum) source, while values >0.2 are interpreted as a pyrogenic (combusted fuel) source of PAHs. Both clam tissue types from Broad Cove tested in 2017 have ratios above the 0.2 mark (all above 0.4), which indicates a pyrogenic source of PAHs rather than a petrogenic source.

Toxicities of PAHs vary, with hundreds of compounds making up the pool of PAHs. Toxic responses in aquatic organisms may include reproductive 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 et al., 2008).

1.3.3 Polychlorinated Biphenyls

Polychlorinated Biphenyls (PCBs) 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

Figure 1.3.2.1.2: Flu+Pyr/Σ(FP C2-C4-P) in Blue Mussel and Softshell Clam Tissues



uses are in electrical equipment and transformers (Kimbrough et al., 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 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, 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 some congeners co-eluting differently or being summed differently at the various laboratories. 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. 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 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.

To illustrate 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 Gulfwatch and NS&T data sets. Comparing the three mussel sites sampled for PCBs in 2017, the SWAT PCBs were 38% at East End Beach, Portland, 40% at Mill Creek, Falmouth, and 41% at Whiting Cove, Whiting, of the total summed PCBs. Total PCB concentrations were 65 ng/g dry wt., 42 ng/g dry wt., and 11 ng/g dry wt., at East End Beach, Mill Creek, and Whiting Cove, respectively (Figure 1.3.3.1.1).

Figure 1.3.3.1.1 compares the SWAT PCBs (Σ35 PCBs) at the 2017 SWAT mussel sites to Gulfwatch median and 85th percentile for 2008 PCB data, the most recent available. Of the three SWAT mussel sites, only East End Beach, Portland, exceeded the Gulfwatch 2008 median of 24.1 ng/g dry wt., and none of the sites tested exceeded the Gulfwatch 85th percentile of 35.4 ng/g dry wt. for Gulfwatch PCBs.

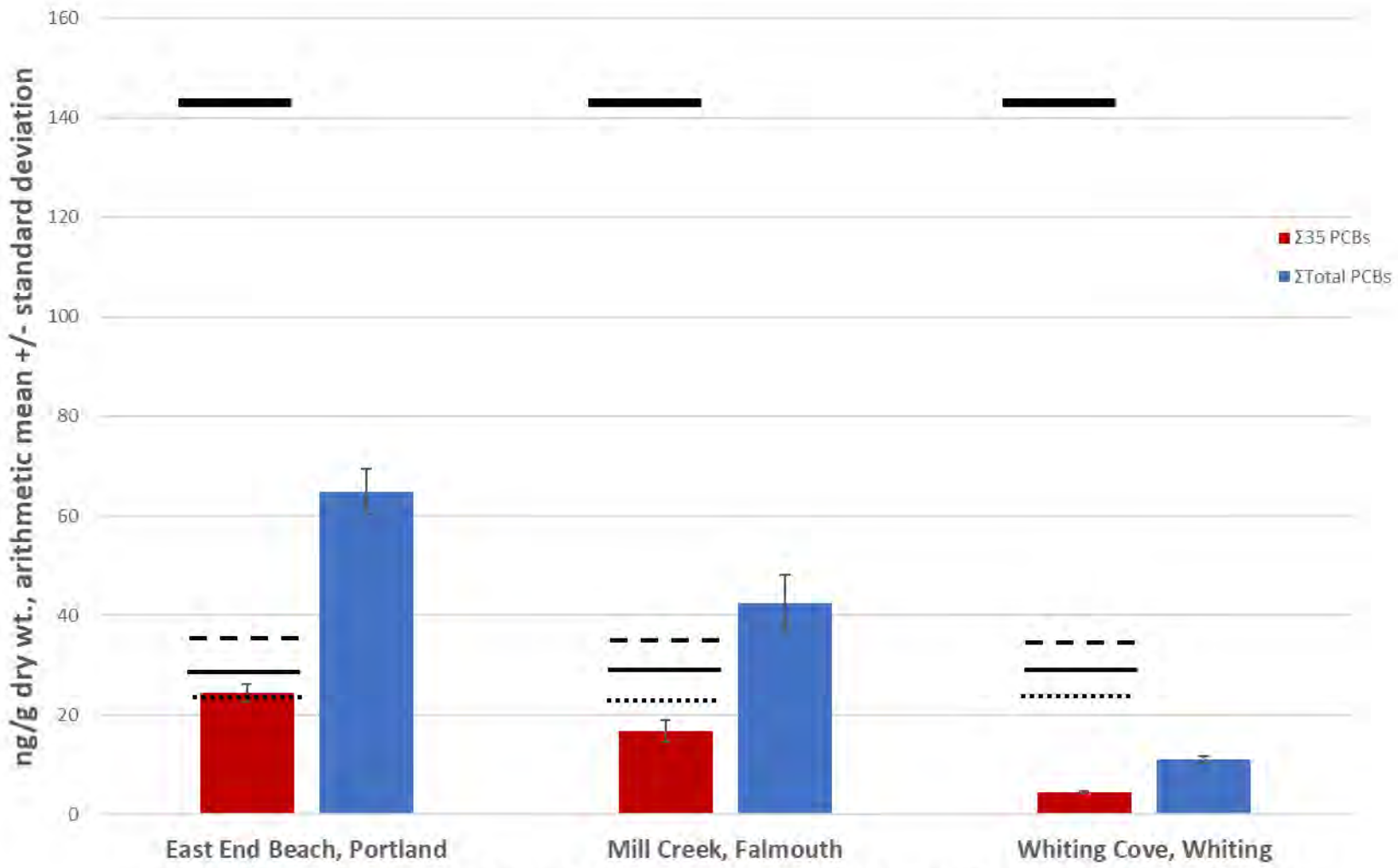
Figure 1.3.3.1.1 also compares the SWAT PCBs at the 2017 SWAT blue mussel sites to NS&T (NS&T) median and 85th percentile 2008 PCB data, the most recent available.

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-15	PCB-18/15
PCB 18/30	
PCB 26/29	PCB-29
PCB 20/28	PCB-28
PCB 50/53	PCB-50
PCB-52	PCB-52
PCB-66	PCB-66/95
PCB-77	PCB-77
PCB-90/101/113	PCB-101/90
PCB-118	PCB-118
PCB-126	PCB-126
PCB-132	PCB-153/132
PCB-153/168	
PCB-169	PCB-169
PCB-187	PCB-187
PCB-170	PCB-170/190
PCB-190	
PCB-128/166	PCB-128
PCB-195	PCB-195/208
PCB-208	
PCB-180/193	PCB-180
PCB-206	PCB-206
PCB-209	PCB-209
PCB-105	PCB-105
	PCB-44
	PCB-87
	PCB-138

Unique to SWAT Σ35 List	Unique to GW and NS&T Σ31 List
PCB-30	PCB-44
PCB-26	PCB-95
PCB-53	PCB-87
PCB-20	PCB-138
PCB-166	
PCB-193	

Figure 1.3.3.1.1: SWAT PCBs (Σ35 PCBs) and Total PCBs in 2017 SWAT Blue Mussels



Dashed lines = Gulfwatch Median and 85th Percentile (Gulfwatch PCBs, Σ31 PCBs); Solid lines = 2008 National Status and Trends Median and 85th Percentile (Σ31 PCBs).

None of the three SWAT sites exceeded the NS&T 2008 median, 29.2 ng/g dry wt., and so none of the three exceeded the NS&T national 85th percentile, 14. ng/g dry wt.

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 et al., 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). The highest mean of the sum of total PCBs occurred at East End Beach, Portland, and was 10.49 ng/g wet wt., which was slightly below 11 ng/g wet wt. MCDC cancer FTAL for total PCBs, the lower, more conservative of the two FTALs. The next highest mean total PCBs concentration, 7.5 ng/g wet wt., occurred at Mill Creek, Falmouth, and was below the MCDC cancer FTAL for total PCBs.

1.3.3.2 Softshell Clams

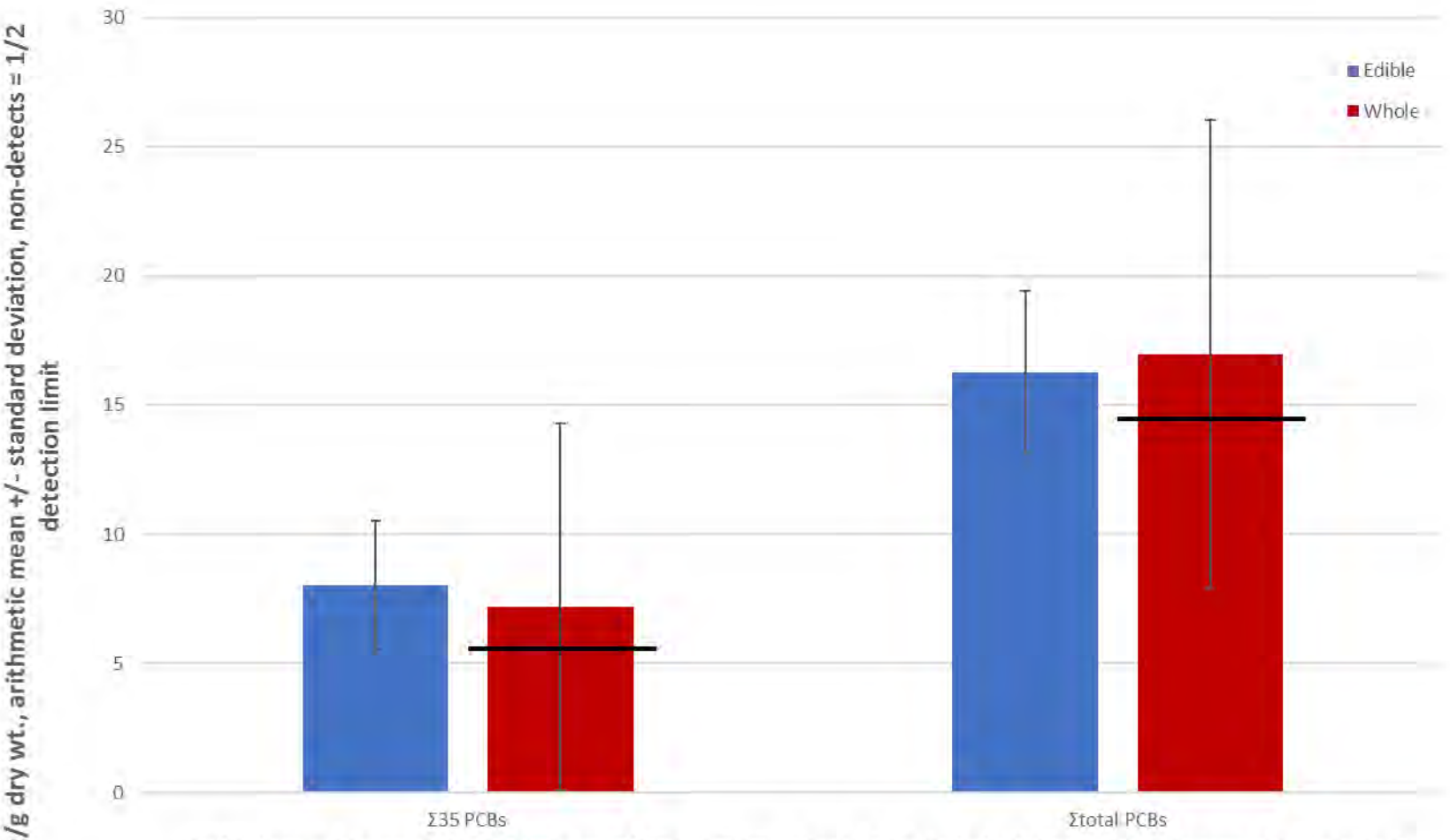
PCB summations for softshell clam tissues collected from Broad Cove were conducted as described at the beginning of section 1.3.3.1.

To illustrate what proportion of the total PCBs (209 congeners) the SWAT PCBs represent, Figure 1.3.3.2.1 shows the total PCBs next to the SWAT PCBs list used for comparison to Gulfwatch and NS&T data sets. The SWAT PCBs were 35% in edible clam tissue and 36% in whole clam tissue of the total summed PCBs. Total PCB concentrations were 16 ng/g dry wt. and 17 ng/g dry wt., in edible and whole tissues, respectively (Figure 1.3.3.2.1).

Figure 1.3.3.2.1 compares the SWAT PCBs (Σ35 PCBs) from the Broad Cove softshell clam edible and whole tissues to the mean of SWAT PCBs from nine softshell clam sites across Maine sampled by SWAT from 2005 to 2013. Data for these previous samples is only available on a whole clam tissue basis, so the comparison is made to whole tissue from Broad Cove. Whole tissue from Broad Cove had a mean Σ35 PCBs and a mean ΣTotal PCBs that just exceeded the mean concentration from nine softshell clam sites (Figure 1.3.3.2.1).

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). The ΣTotal PCBs (assuming non-detects equal half the detection limit) in edible clam tissue in Broad Cove ranged from 1.31 ng/g wet wt. to 3.87 ng/g wet wt., with a mean ΣTotal PCBs of 2.60 ng/g wet wt., which was below the 11 ng/g wet wt. MCDC cancer FTAL for total PCBs, the lower, more conservative of the two FTALs. The ΣTotal PCBs (assuming non-detects equal half the detection limit) in whole clam tissue in Broad Cove ranged from 1.08 ng/g wet wt. to 4.61 ng/g wet wt., with a mean ΣTotal PCBs of 2.37 ng/g wet wt., which was below the 11 ng/g wet wt. MCDC cancer FTAL for total PCBs, the lower, more conservative of the two FTALs.

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



Solid lines = Means of Σ35 PCBs and ΣTotal PCBs from Nine Softshell Clam Sites Statewide Sampled from 2005-2013.

1.3.3.3 American Lobster

Table 1.3.3.3.1 presents the dioxins, furans, and coplanar PCBs for which analysis was completed.

Table 1.3.3.3.1: SWAT Dioxins, Furans and Coplanar PCBs

Furans and Dioxins	Coplanar PCBs
2,3,7,8-TCDF	PCB-77
1,2,3,7,8-PECDF	PCB-81
2,3,4,7,8-PECDF	PCB-126
1,2,3,4,7,8-HXCDF	PCB-105
1,2,3,6,7,8-HXCDF	PCB-114
2,3,4,6,7,8-HXCDF	PCB-118
1,2,3,7,8,9-HXCDF	PCB-123
1,2,3,4,6,7,8-HPCDF	PCB-156/157
1,2,3,4,7,8,9-HPCDF	PCB-167
OCDF	PCB-169
2,3,7,8-TCDD	PCB-189
1,2,3,7,8-PECDD	
1,2,3,4,7,8-HXCDD	
1,2,3,6,7,8-HXCDD	
1,2,3,7,8,9-HXCDD	
1,2,3,4,6,7,8-HPCDD	
OCDD	

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). The ΣTotal PCBs (assuming non-detects equal half the detection limit, wet wt.) in hepatopancreas at all 18 sites exceeded the MCDC cancer FTAL of 11 ng/g wet wt. The ΣTotal PCBs (assuming non-detects equal half the detection limit, wet wt.) in hepatopancreas at 17 of 18 sites exceeded the higher MCDC non-cancer FTAL of 43 ng/g wet wt. (Figure 1.3.3.3.1).

The ΣTotal PCBs (assuming non-detects equal half the detection limit, wet wt.) in muscle tissue at all 18 sites were well below the MCDC cancer FTAL of 11 ng/g wet wt., with the highest summation only around 1/3 of that FTAL value. Thus, all 18 sites were below the higher MCDC non-cancer FTAL (Figure 1.3.3.3.2).

Concentrations in tissues of the individual compounds determined in the laboratory were multiplied by their toxic equivalency factors (TEFs) and summed to construct CTE and DTE, coplanar and dioxin toxic equivalencies. Compounds with non-detects were assigned a concentration value at half the detection limit, which were then used to calculate the CTE and DTE. CTE and DTE were calculated on a wet weight basis for the lobster tissues, as they are principally used from a human health perspective to assess risk associated with human dietary intake of these compounds in food. Since the food, lobster meat, is eaten in a wet weight form, the CTE and DTE were calculated in the wet weight format to provide the best prediction of CTE and DTE intake.

Figure 1.3.3.3.3 shows CTE and DTE calculated for lobster hepatopancreas tissue at the 18 lobster stations sampled in 2018. The stations run from left to right in east to west order along the Maine coast (from DMR LMZs A – G, with G near the New Hampshire border). Summed (coplanar PCBs) CTE comprise the base of each bar (shown in blue), with the top of each bar comprised of the summed (dioxins/furans) DTE (shown in orange). Since the toxicities of the coplanar PCBs and dioxins and furans are additive, the CTE and DTE are shown in one bar that adds their toxicity for comparison to the fish tissue action level.

Summed CTE/DTE in hepatopancreas ranged from 2.9 to 15.7 pg/g at zone C East , and zone F East, respectively. The Maine CDC has produced a fish tissue action level (FTAL) for dioxins, furans and coplanar PCBs (DTE/CTE) for recreationally caught finfish fillet. Maine CDC has recommended that this 0.4 pg/g (or parts per trillion) FTAL be utilized to compare lobster tissues to determine acceptability for human consumption. Consistent with prior hepatopancreas data, the 2018 data confirms that consumption of hepatopancreas should be avoided as all stations sampled had DTE/CTE well above the 0.4 pg/g FTAL. This FTAL assumes a meal size of 8 ounces (227 g), which may be quite high for hepatopancreas (requiring consumption of hepatopancreas from many lobsters in one meal). However, DTE/CTE in hepatopancreas are so high that recalculating the risk assessment with a smaller meal size will not change the recommendation that hepatopancreas consumption should be avoided.

Figure 1.3.3.3.4 shows CTE and DTE calculated for lobster muscle tissue at the 18 lobster stations sampled in 2018. The stations run from left to right in east to west order along the Maine coast (from DMR LMZs A – G, with G near the New Hampshire border). Summed (coplanar PCBs) CTE comprise the base of each bar (shown in blue), with the top of each bar comprised of the summed (dioxin/furan) DTE (shown in orange). Since the toxicities of the dioxins and furans and the coplanar PCBs are additive, the DTE and CTE are shown in one bar that adds their toxicity for comparison to the fish tissue action level.

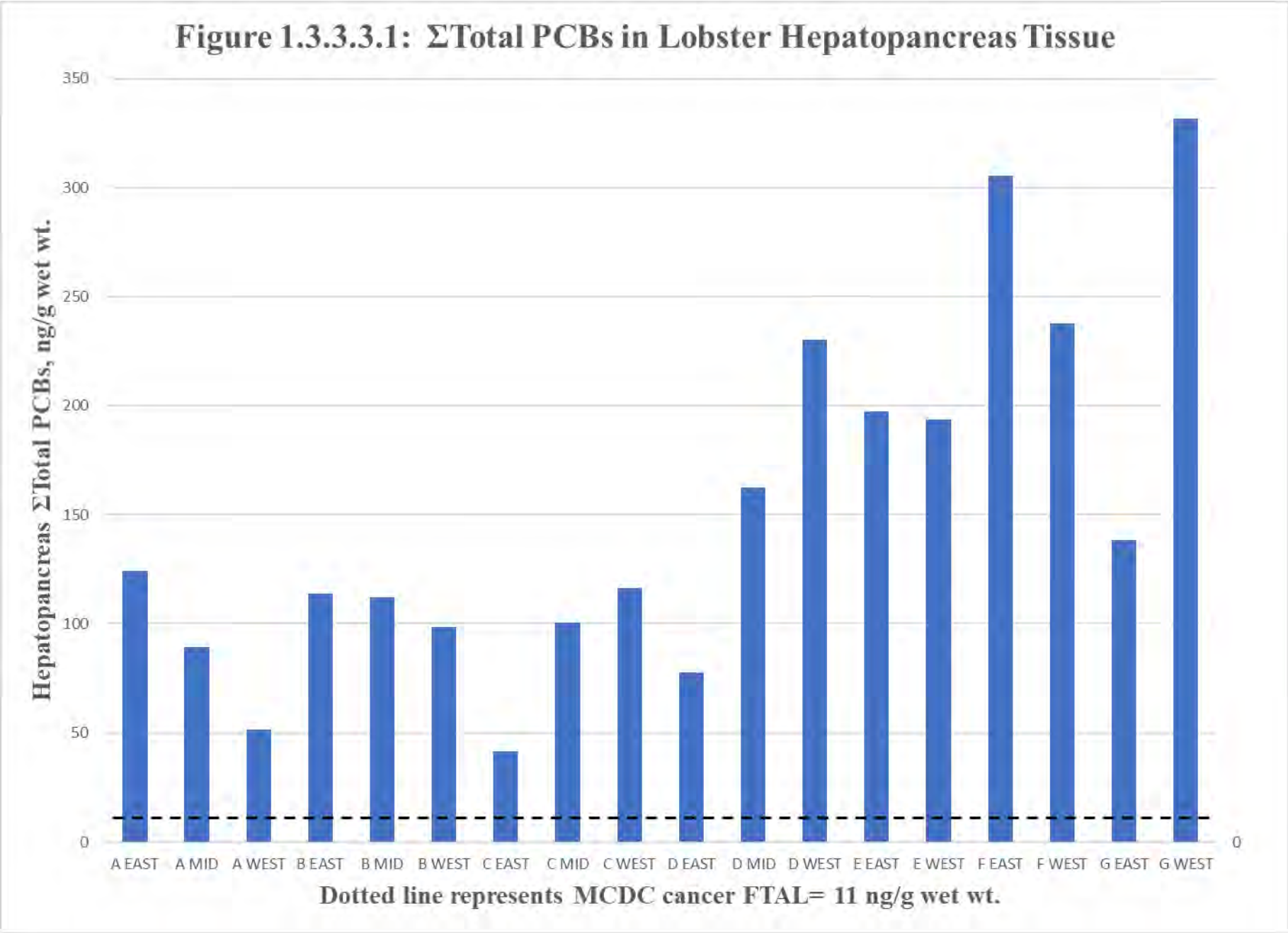


Figure 1.3.3.3.1: ΣTotal PCBs in Lobster Hepatopancreas Tissue
Hepatopancreas ΣTotal PCBs, ng/g wet wt.
350
300
250
200
150
100
50
0
A EAST
A MID
A WEST
B EAST
B MID
B WEST
C EAST
C MID
C WEST
D EAST
D MID
D WEST
E EAST
E WEST
F EAST
F WEST
G EAST
G WEST
Dotted line represents MCDC cancer FTAL= 11 ng/g wet wt.

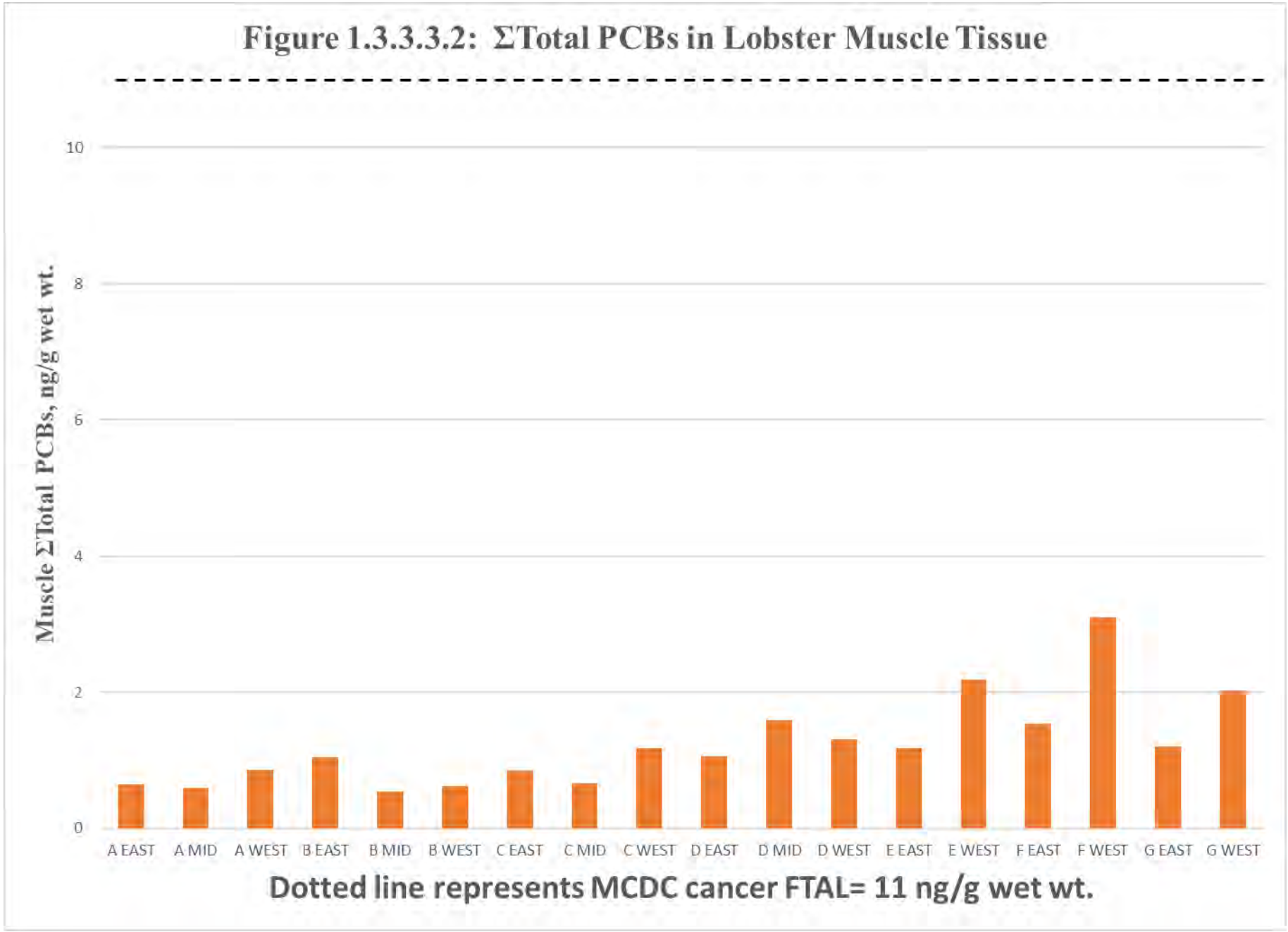


Figure 1.3.3.3.2: ΣTotal PCBs in Lobster Muscle Tissue
Muscle ΣTotal PCBs, ng/g wet wt.
10
8
6
4
2
0
A EAST
A MID
A WEST
B EAST
B MID
B WEST
C EAST
C MID
C WEST
D EAST
D MID
D WEST
E EAST
E WEST
F EAST
F WEST
G EAST
G WEST
Dotted line represents MCDC cancer FTAL= 11 ng/g wet wt.

Figure 1.3.3.3.3: Coplanar PCB and Dioxin/Furan Toxic Equivalents in SWAT 2018 Lobster Hepatopancreas Tissue

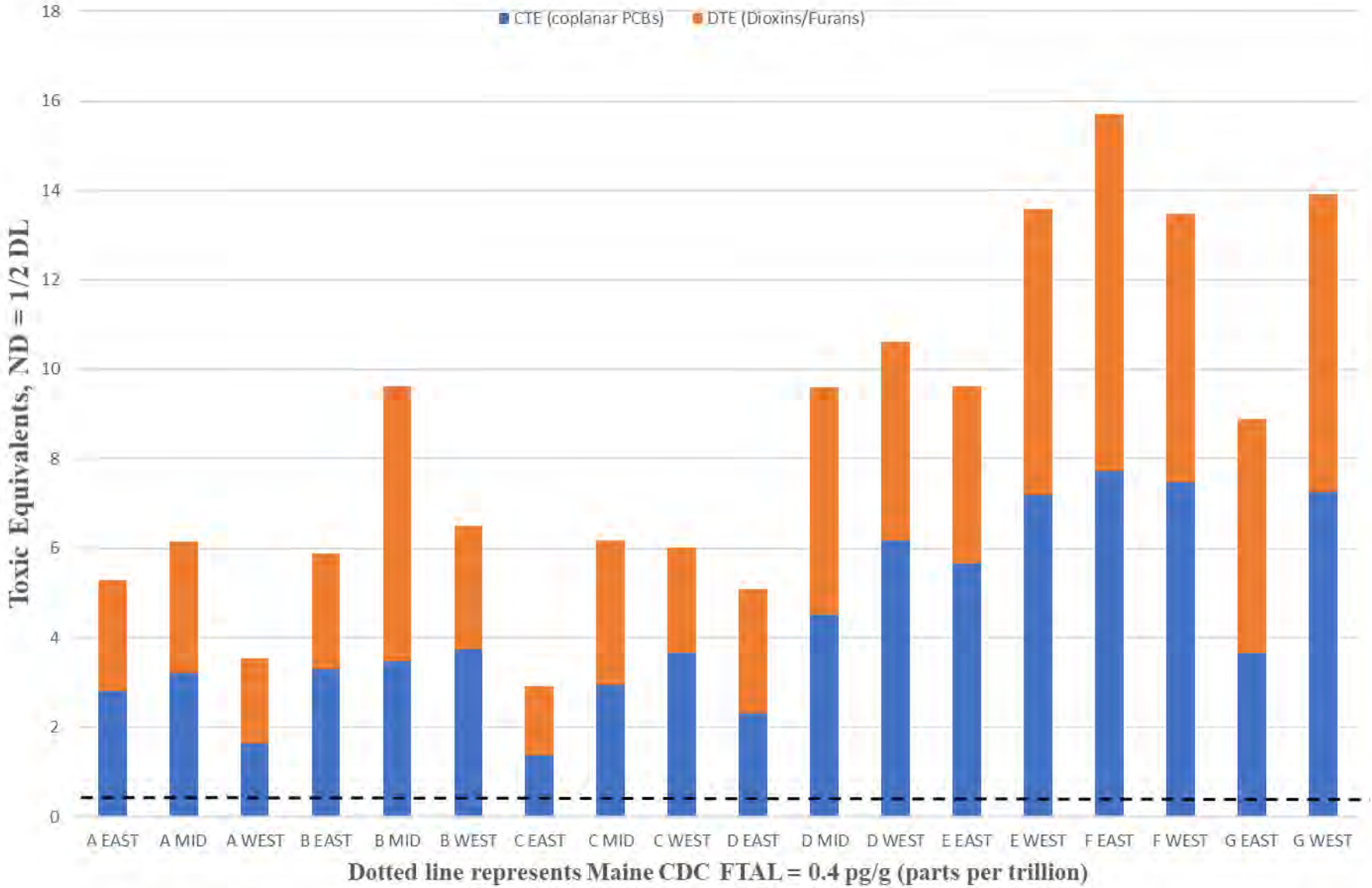
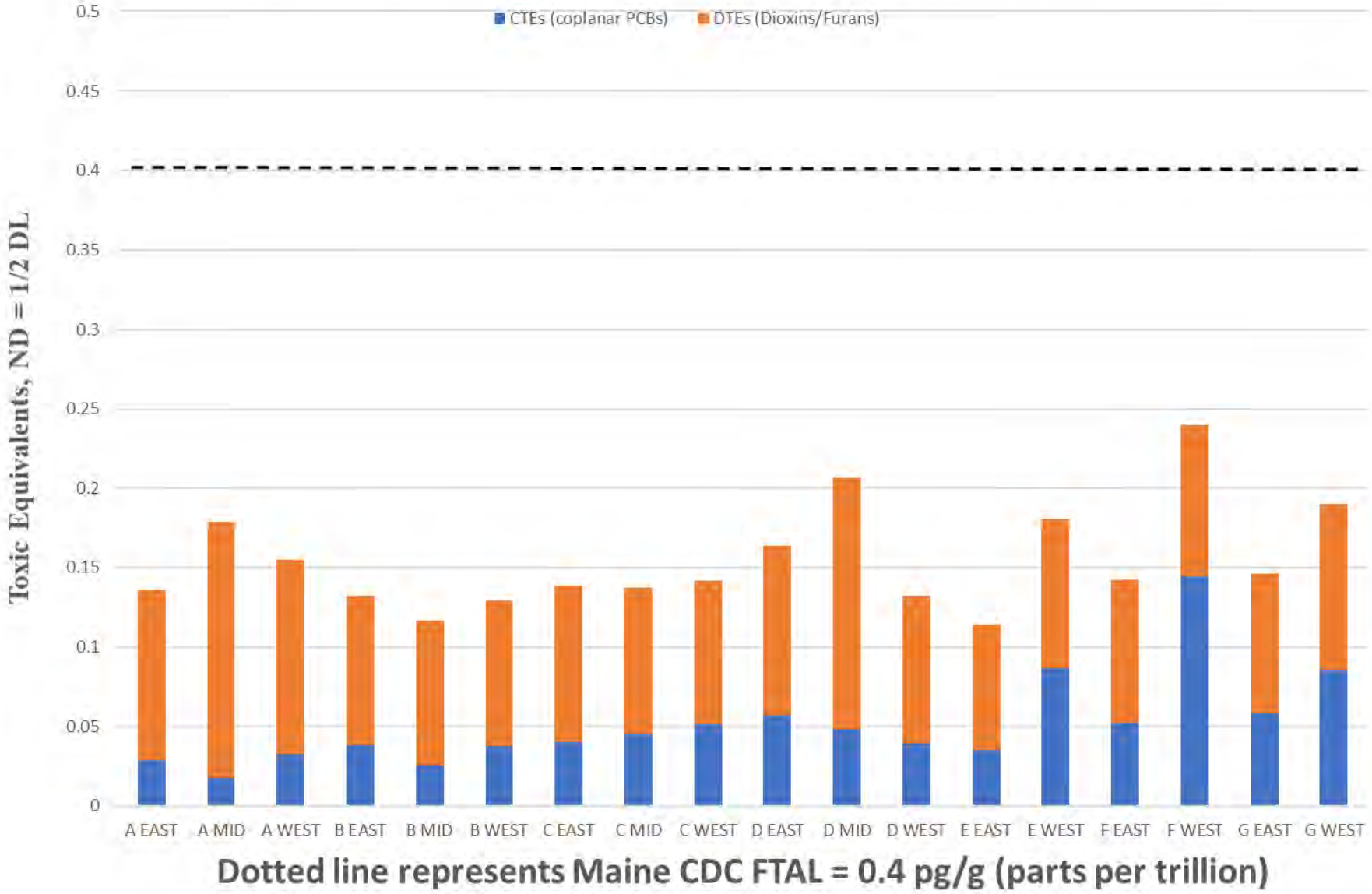


Figure 1.3.3.3.4: Coplanar PCB and Dioxin/Furan Toxic Equivalents in SWAT 2018 Lobster Muscle Tissue



Summed DTE/CTE in muscle ranged from 0.11 to 0.24 pg/g in zone E East and zone F West, respectively. Even the highest of these levels is well below the 0.4 pg/g FTAL, indicating that calculated DTE/CTE in lobster muscle tissue are much lower than those from hepatopancreas and that lobster muscle tissue is safe to eat. Of the 18 stations sampled in 2018, 16 had muscle tissue DTE/CTE of less than half the MCDC FTAL or even lower.

Hepatopancreas tissue appears to have a higher percentage of its overall toxicity contributed by CTE (from coplanar PCBs) than does the muscle tissue. This is most readily observed at the lower concentration sites, which have higher relative DTE to CTE in muscle tissue. Higher scoring sites appear to have a more even composition of CTE and DTE. This may be due to sequestration of the coplanar PCBs in the hepatopancreas. Both DTE and CTE in hepatopancreas appeared to be higher in four stations than in other areas of the coast. The highest four total TEQ values were zone E West, zone F East, zone F West, and zone G West, which correspond to sites just west of the Kennebec River, eastern and western Casco Bay, and near the Piscataqua River. In muscle tissue, there was less variability across the coast, but zone D Mid, zone F West and zone G West had slightly higher toxicities than the remainder of the stations, which correspond to Port Clyde, southern Casco Bay, and Piscataqua River.

1.3.4 Perfluorinated Compounds

Perfluorinated compounds or chemicals (PFCs) are organofluorine compounds that have fluorine substituted for all hydrogens where C-H bonds otherwise would occur in organic compounds. PFCs also have a functional group derived from the parent organic compound such that PFCs have properties of both fluorocarbons and the parent compound. The dual properties of PFCs make them useful in water, grease, and stain repellants (paper, fabric, and carpet treatments, notably Scotchgard by 3M), in the semiconductor industry, in firefighting foams, and as paint and other coating additives where flow is critical. Production of perfluorooctonatesulfonyl fluoride related compounds, notably PFOSA (a sulfonamide), was terminated by 3M by 2003 but production overseas has continued or increased. While PFOSA was synthesized for use by industry, it is also created as a degradation byproduct of alkylated-perfluorooctanesulfonamides (which were used to treat paper, carpet, and fabric) through conversion into acetates and eventually to PFOSA.

Analysis for PFCs in blue mussel tissue was initiated in 2013 and continued in 2014 and 2016 as recommended by the SWAT TAG. This report includes PFC data for two softshell clam sites tested in 2017. Mare Brook, Brunswick, was analyzed previously for PFCs in blue mussels, and was sampled in 2017 to generate PFC concentrations in softshell clam tissues. Broad Cove, Eastport, was sampled for PFCs in softshell clam tissue in 2017. At both sites, softshell clam samples were dissected to produce edible (all tissues except skin or membrane and shell) and whole tissue samples for analysis for PFCs. This report utilizes the Maine SWAT softshell clam tissue PFC data generated by AXYS Analytical, which includes 13 compounds as presented in Table 1.3.4.1.1. Table 1.3.4.1.1 also shows the low and high values for the sample-specific detection limits for the PFCs for which analyses were performed.

1.3.4.1 Softshell Clams

Softshell clams were tested for PFCs in 2017 from Mare Brook, Brunswick, in the northern portion of Harpswell Cove. This site has a history of military activity as Mare Brook drains a portion of the former Brunswick Naval Air Station.

None of the 12 perfluoronated compounds were present above the detection limits in either edible or whole softshell clam tissues in any of the four spatial subsamples examined from Mare Brook. In 2016 in a previous SWAT study, PFOSA was detected in two of four spatial replicates of blue mussel tissue collected at Mare Brook, while the remaining PFCs were all below detection limits at all four spatial replicates. Softshell clam tissues were examined in 2017 to examine if perfluoronated compounds, perhaps PFOSA as in the blue mussel tissue, might also be detected in clam tissue from Mare Brook. With the amount of PFOSA detected in mussels being so close to the detection limits and no detects in clams, it is difficult to say whether there is any difference between mussel and clam tissues regarding perfluoronated compound concentrations.

Softshell clams were tested for PFCs in 2017 from Broad Cove, Eastport, the second softshell clam site sampled that year. This site has a history of industrial activity including a former pearl essence manufacturing plant and one of the most toxic historic discharges in the state. None of the 12 perfluoronated compounds were present above the detection limits in either edible or whole softshell clam tissues in any of the five spatial subsamples examined from Broad Cove, Eastport in 2017. Sample-specific detection limits were approximately 3 to 8 parts per billion (ng/g) in softshell clam tissues on a dry weight basis.

Table 1.3.4.1.1: LIST OF PERFLUORONATED COMPOUNDS AND THE RANGE OF SAMPLE SPECIFIC DETECTION LIMITS FOR 2017 SWAT SOFTSHELL CLAMS

		Non-Detects (Dry Wt.) Softshell Clams	
		Low	High
PERFLUOROBUTANE SULFONATE	NG/G	5.607	7.645
PERFLUOROBUTANOATE	NG/G	2.804	3.823
PERFLUORODECANOATE	NG/G	2.804	3.823
PERFLUORODODECANOATE	NG/G	2.804	3.823
PERFLUOROHEPTANOATE	NG/G	2.804	3.823
PERFLUOROOCTANOATE	NG/G	2.804	3.823
PERFLUOROHEXANE SULFONATE	NG/G	5.607	7.645
PERFLUOROHEXANOATE	NG/G	2.804	3.823
PERFLUORONONANOATE	NG/G	2.804	3.823
PERFLUOROOCTANE SULFONATE	NG/G	5.607	7.645
PERFLUOROOCTANE SULFONAMIDE	NG/G	2.804	3.823
PERFLUOROPENTANOATE	NG/G	2.804	3.823

PFCs bioaccumulate and biomagnify through the food web. Testing of California *Mytilus spp*. tissue indicated >25% detection frequency for PFCs in samples and increasing concentrations with urbanization and proximity to stormwater discharge (Dodder et al., 2012). Total concentrations of PFCs ranged up to about 10 ppb, with some outliers above that range. Areas with mixed development topped out at total PFC concentrations of approximately 2 ng/g dry wt., while urban sites had higher total PFC concentrations approaching 9-10 ng/g dry wt. Two individual PFCs detected in the California study, PFDoDA and PFUnDA, had mean concentrations of 1.8 and 0.23 ng/g dry wt. respectively, which is roughly the same order of magnitude of the PFCs detected in recent SWAT blue mussel sampling in Maine (PFOSA – East End Beach (2013), Navy Pier and Mare Brook (2014), Mare Brook (2016) and PFHpA – Navy Pier (2014) (Dodder et al., 2012)). EPA has not released a fish tissue action level for PFCs.

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2.0 LAKES MODULE

2.0 LAKES

2.1. HARMFUL ALGAE BLOOMS (HABs)

Of continuing concern in the United States is that of Harmful Algae Blooms (HABs). HABs can produce hepatotoxic, neurotoxic and acutely dermatotoxic cyanobacterial (blue-green algae) toxins such as microcystins, cylindrospermopsins, anatoxins, and saxitoxins. Although Maine has several lakes and ponds that have experienced algal blooms for decades and there has been only two known toxic events (death of cattle in the 1960s according to Matt Scott, personal communication), there is a growing concern in Maine about the potential for HABs.

In 1998, the World Health Organization (WHO) established the following advisory levels for cyanotoxins: drinking water = 1 µg/L, low risk recreation = 10 µg/L. In early May of 2015, EPA released 10-day drinking water advisory levels for two populations: bottle-fed infants and pre-school children: > 0.3 µg/L, and, school-age children and adults: > 1.6 µg/L. EPA released draft recreation advisory levels in December of 2016. Because children spend more time in the water and ingest more water per body weight while recreating, criteria were derived based on children's recreational exposures. For swimming, the microcystin concentration of 4 µg/L is not to be exceeded on any day; for recreation, 4 µg/L is not to be exceeded more than 10% of days per recreation season up to one calendar year.

Complementary to related water quality measurements, samples for selected cyanotoxin analysis were collected from Maine lakes using a probability based approach and a targeted approach. Approximately 22 lakes were randomly selected each year; lakes greater than 150 acres in populated areas of the state were targeted for the probability selection and other lakes were targeted for time-series monitoring due to their history of algal blooms. Microcystin results from 2014 indicated that concentrations were elevated in many of the Kennebec county probability-draw lakes and in all of the targeted lakes; most lakes that are designated as impaired due to algal blooms are located in Kennebec County. Results from 2015 indicated that only a few probability-draw lakes (9%) from central coastal counties had slightly elevated microcystin, and again, all the targeted lakes had elevated concentrations. Most lakes that produced algal scums had scum concentrations that greatly exceeded WHO and EPA levels.

In 2016, DEP staff decided to develop the capacity to perform the microcystin analysis in-house to reduce long-term costs. Availability of funds designated for capital expenditure postponed purchases until early 2017. Facility and health issues also delayed setting up the method. Competing space needs in the DEP lab ultimately led to a decision to move the process to the Health and Environmental Lab (HETL); this will allow the Drinking Water Program as well as concerned citizens the ability to have samples processed in a timely manner because HETL staff will have use of the equipment. In January of 2019, a contract worker was hiered to get the equipment running, the method tested, SOPs written and frozen samples analyzed. As of the end of March 2019, all expendables, standards, and analytical plates needed to process samples were received. The fluorometric phycocyanin data (photosynthetic pigment in cyanobacteria

determined from the frozen samples) is being entered into electronic format to determine which of the triplicate samples will be analyzed. Analysis of the 2016-2018 samples will commence before the end of April 2019. Arrangements have been made with a researcher in Dartmouth performing the same analysis to run split samples to verify our results. The lab that ran our 2014 and 2015 samples has gone out of business so splitting samples with them is no longer a possibility. Although the microcystin plates have standards provided, standards will be purchased elsewhere as another means of validating the results.

2.2 BLACK CRAPPIE MERCURY STUDY

Within the US Environmental Protection Agency's (EPA) Regional Environmental Monitoring and Assessment Program (REMAP), DEP conducted the 'Fish Tissue Contamination in Maine Lakes' study of 125 Maine lakes and ponds in 1993. Upon finding widespread elevated concentrations of mercury in fish from all over Maine, including lakes with little or no human influence other than atmospheric deposition, the Maine Bureau of Health (now Maine Center for Disease Control and Prevention-MCDC) issued a fish consumption advisory (FCA) for lakes and ponds in 1994. Following a finding of similar elevated levels in fish from Maine rivers and streams in 1994, MCDC revised the FCA to include all freshwaters in the state. The advisory can be seen at http://www.maine.gov/dhhs/MCDC/environmental-health/eohp/fish/2kfca.htm , and, with the data showing higher levels of mercury in warmwater fish than in trout and salmon, recommends the following:

Pregnant and nursing women, women who may get pregnant, and children under age 8 *SHOULD NOT EAT any freshwater fish from Maine's inland waters. Except, for brook trout and landlocked salmon, 1 meal per month is safe.*

All other adults and children older than 8 *CAN EAT 2 freshwater fish meals per month. For brook trout and landlocked salmon, the limit is 1 meal per week.*

In the REMAP study, the concentration of mercury was lower (0.18 µg/g ww) in black crappie from Ben Annis Pond, the only pond where they were caught, than in other warmwater game fish (0.48 µg/g ww) from other lakes and ponds that was the basis for the FCA. In 2010, black crappie from Ben Annis Pond and Hermon Pond, immediately downstream, were sampled for mercury which again showed somewhat lower levels (0.19 µg/g ww and 0.37 µg/g ww, respectively) than other warmwater gamefish.

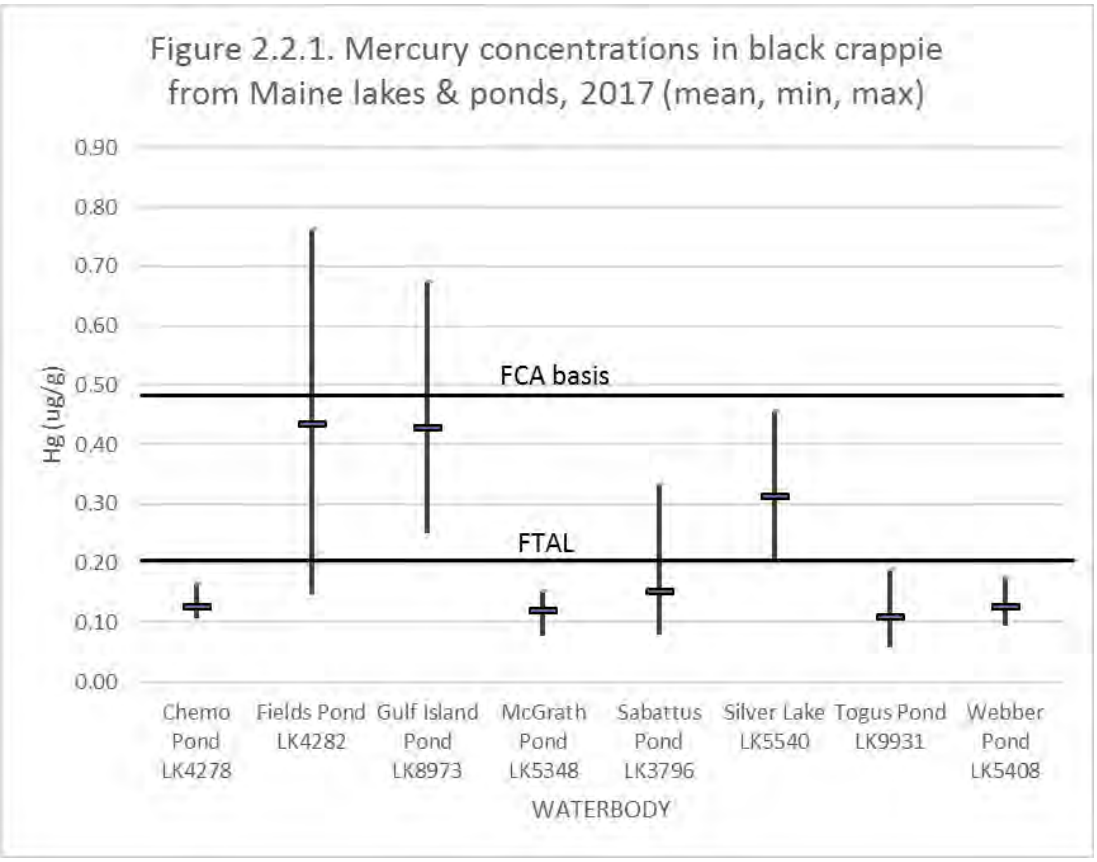
Recently the Department of Inland Fisheries and Wildlife (DIFW) reported increasing angling for black crappie in many lakes and ponds and inquired about human consumption of the species. MCDC feels that the current FCA is protective of consumption of black crappie, and to make a specific FCA for the species, with more liberal consumption, would require data from at least 20 lakes and ponds. DIFW believes there are approximately 20 lakes and ponds with significant fisheries for black crappie.

As a screening level survey, in 2015 DEP collected 10 large size black crappie from each of 5 lakes and ponds to analyze for mercury, with the idea that if concentrations were low enough in large crappie to suggest a possible modification of the FCA, the concentrations would be even lower in smaller crappie more commonly caught and this would be a reason to complete the study of 20 lakes and ponds. The results showed mean lake mercury concentrations ranged from 0.20 – 0.38 µg/g with an overall mean of 0.26 µg/g for all 5 lakes and ponds, well below the FCA basis.

Subsequently, discussion with MCDC has indicated that even with the lower concentrations measured in 2015, some sort of an advisory would still be needed. MCDC left it up to DIFW and DEP to decide if the desire to change the FCA any amount was worth the cost. After consultation, DIFW has noted an increased popularity of anglers catching and wanting to eat black crappie and was supportive of the larger study. Therefore, ten black crappie were to be captured from 15 additional lakes and ponds identified by DIFW as having significant fisheries for this species. Due to the limited budget, black crappie were collected from only 7 lakes and ponds in 2016. Mean lake mercury concentrations ranged from 0.20-0.42 µg/g with an overall mean of 0.31 µg/g for all 7 lakes and ponds, again well below the FCA basis.

2017

In 2017, to complete the requested sample size of 20 lakes and ponds, black crappie were collected from the remaining 8 lakes and ponds (including Gulf Island Pond in the Androscoggin River-AGI) and analyzed individually for mercury. The results showed that mean mercury concentrations ranged from 0.11-0.43 µg/g with an overall mean of 0.23 µg/g for all 8 lakes and ponds, all below the FCA basis and 5 below the Maine Center for Disease Control and Prevention's (MCDC) Fish Tissue Action Level (FTAL) (Figure 2.2.1).



There was no clear relationship between mercury concentrations and size among lakes, as the smallest fish, from Gulf Island Pond on the Androscoggin River, had the second highest mercury levels, and the largest fish, from Sabattus Pond, had concentrations among the lowest of all lakes and ponds (Table 2.2.1). Fish from Fields Pond, which had the highest concentrations, were the second largest fish, although not much more than those from McGrath, Togus, and Webber ponds, which were among the lowest in fish mercury.

Table 2.2.1. Lengths, weights, and mercury levels in Black Crappie from Maine Lakes and Ponds, 2017 (mean ± std)

LAKE SAMPLE	LENGTH mm	WEIGHT g	Hg µg/g ww
Chemo Pond LK4278	260 ± 12	238 ± 30	0.12 ± 0.02
Fields Pond LK4282	281 ± 20	306 ± 80	0.44 ± 0.23
Gulf Island Pond LK8973	256 ± 11	237 ± 31	0.43 ± 0.11
McGrath Pond LK5348	264 ± 21	279 ± 61	0.13 ± 0.03
Sabattus Pond LK3796	321 ± 19	500 ± 125	0.15 ± 0.08
Silver Lake LK5540	257 ± 13	256 ± 40	0.31 ± 0.07
Togus Pond LK9931	274 ± 24	306 ± 73	0.11 ± 0.05
Webber Pond LK5408	264 ± 19	249 ± 71	0.12 ± 0.03

The results from the 2017 lakes were similar to and combined with those from previous years to complete the 20 lake sample. For all 3 years, 2015-2017, mean concentrations of fish from all 20 lakes and ponds ranged from 0.11-0.44 µg/g and were all below MCDC's FCA basis.

2018

Of the 20 lakes sampled from 2015-2017, only 3 were from lakes considered by DIFW to be directed or targeted fisheries. There are at least 18 other lakes and ponds of known directed fisheries for black crappie. MCDC suggested also sampling these lakes for mercury analysis. Therefore, in 2018, DEP attempted to sample ten black crappie from these waters or substitute others with known fisheries if staff was unable to collect fish from some of the 18 lakes and ponds. Due to limitations of budget and staff, only 14 lakes and ponds were sampled.

The results showed that the mean concentrations ranged from 0.17-0.48 µg/g, at or below the FCA basis (Figure 2.2.2). The mean for all 14 lakes was 0.30 µg/g, within the range of those of previous years. Although the pond with the longest fish, Parker Pond, had the highest mercury concentration, the pond with the second largest mean length of crappie had the lowest crappie mercury concentration, Puffers Pond (Table 2.2.2). A plot of mean mercury concentration versus mean length showed no clear relationship (not shown).

The mean for all 34 lakes and ponds for all years combined (2015/2018) was 0.28 µg/g exceeding the FTAL but well below the FCA basis (Table 2.2.3). There was no clear relationship between size (length) and mercury concentrations. The data were sent to the MCDC for review of the statewide fish consumption advisory due to mercury.

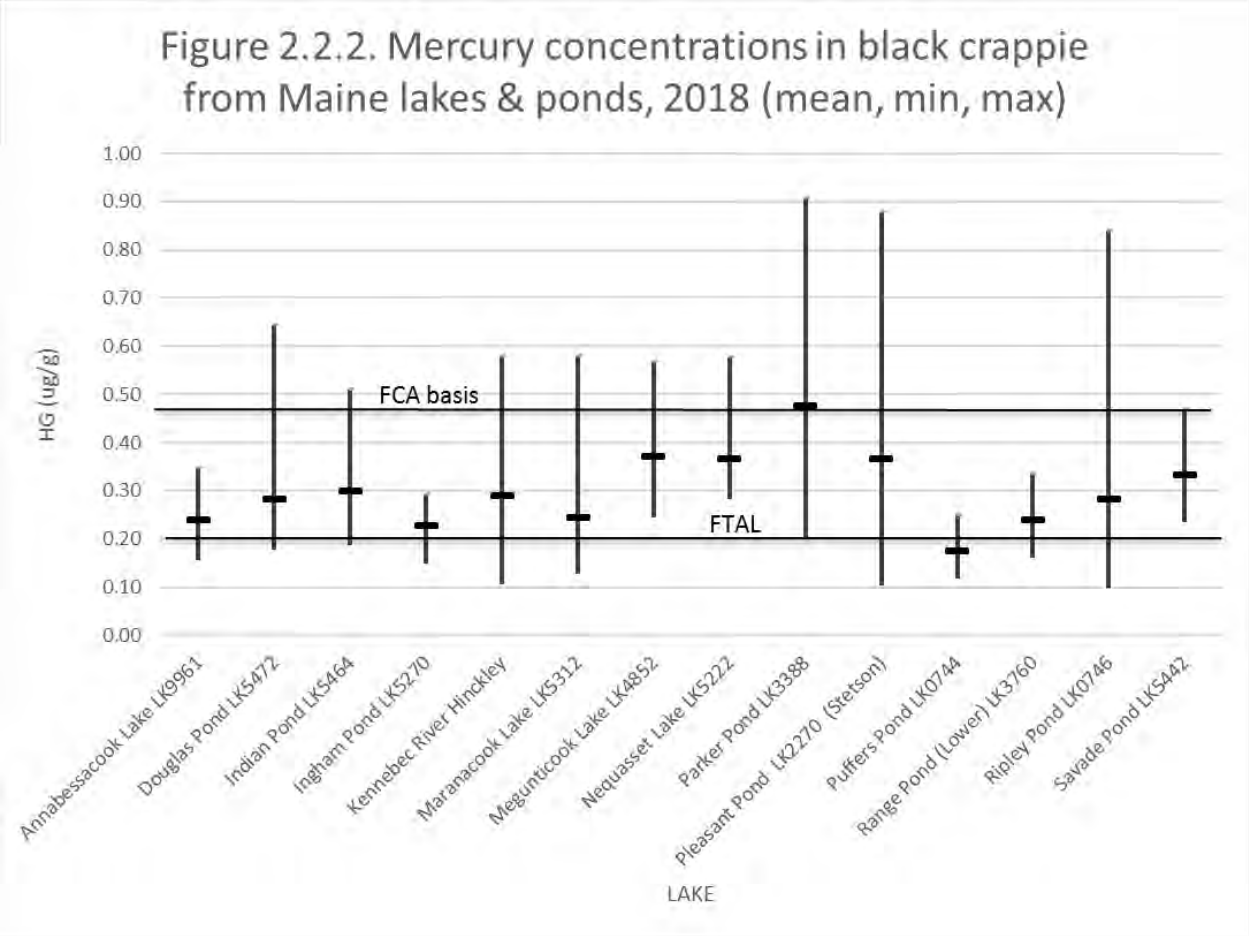


Table 2.2.2. Lengths, weights, and mercury levels in Black Crappie from Maine Lakes and Ponds, 2018 (mean ± std)

LAKE SAMPLE	LENGTH mm	WEIGHT g	Hg µg/g ww
Annabessacook Lake LK9961	298 ± 42	389 ± 169	0.24 ± 0.08
Douglas Pond LK5472	235 ± 30	201 ± 87	0.28 ± 0.14
Indian Pond LK5464	264 ± 10	232 ± 33	0.30 ± 0.10
Ingham Pond LK5270	315 ± 24	500 ± 115	0.23 ± 0.04
Kennebec River Hinckley	254 ± 19	231 ± 48	0.29 ± 0.17
Maranacook Lake LK5312	288 ± 23	325 ±107	0.18 ± 0.07
Megunticook Lake LK4852	276 ± 33	356 ± 107	0.37 ± 0.12
Nequasset Lake LK5222	292 ± 16	342 ± 58	0.36 ± 0.09
Parker Pond LK3388	336 ± 12	574 ± 68	0.48 ± 0.26
Pleasant Pond LK2270 (Stetson)	309 ± 32		0.37 ± 0.23
Puffers Pond LK0744	334 ± 16		0.17 ± 0.04
Range Pond (Lower) LK3760	308 ± 15	452 ± 65	0.24 ± 0.07
Ripley Pond LK0746	303 ± 48	492 ± 183	0.28 ± 0.22
Savade Pond LK5442	269 ± 23	283 ± 81	0.33 ± 0.08

Table 2.2.3. Lengths, weights, and mercury levels in black crappie from Maine lakes and ponds , 2015-2018 (mean ± std)

LAKES AND PONDS	L mm	W g	Hg ug/g
Togus Pond LK9931	274 ± 24	306 ± 73	0.11 ± 0.05
Chemo Pond LK4278	260 ± 12	238 ± 30	0.12 ± 0.02
Webber Pond LK5408	264 ± 19	249 ± 71	0.12 ± 0.03
McGrath Pond LK5348	264 ± 21	279 ± 61	0.13 ± 0.03
Sabattus Pond LK3796	321 ± 19	500 ± 125	0.15 ± 0.08
Puffers Pond LK0744	334 ± 16		0.17 ± 0.04
Maranacook Lake LK5312	288 ± 23	325 ± 107	0.18 ± 0.07
Cobbosseecontee Lake LK5236	306 ± 31	376 ± 129	0.20 ± 0.05
East Pond LK5349	311 ± 23	509 ± 103	0.20 ± 0.05
Threemile Pond LK5416	297 ± 22	370 ± 72	0.20 ± 0.08
Sebasticook Lake LK2264	289 ± 21	351 ± 52	0.20 ± 0.11
Ingham Pond LK5270	315 ± 24	500 ± 115	0.23 ± 0.04
Little Cobbosseecontee LK8065	316 ± 33	447 ± 125	0.24 ± 0.07
Range Pond (Lower) LK3760	308 ± 15	452 ± 65	0.24 ± 0.07
Annabessacook Lake LK9961	298 ± 42	389 ± 169	0.24 ± 0.08
Sand Pond LK5238	260 ± 32	267 ± 86	0.27 ± 0.10
Douglas Pond LK5472	235 ± 30	201 ± 87	0.28 ± 0.14
Ripley Pond LK0746	303 ± 48	492 ± 183	0.28 ± 0.22
Kennebec River Hinckley	254 ± 19	231 ± 48	0.29 ± 0.17
Hermon Pond LK 2286	238 ± 9	176 ± 20	0.29 ± 0.20
Indian Pond LK5464	264 ± 10	232 ± 33	0.30 ± 0.10
Silver Lake LK5540	257 ± 13	256 ± 40	0.31 ± 0.07
Woodbury Pond LK5240	283 ± 23	330 ± 96	0.31 ± 0.08
Savade Pond LK5442	269 ± 23	283 ± 81	0.33 ± 0.08
Unity Pond LK 5172	268 ± 23	288 ± 84	0.33 ± 0.13
Nequasset Lake LK5222	292 ± 16	342 ± 58	0.36 ± 0.09
Megunticook Lake LK4852	276 ± 33	356 ± 129	0.37 ± 0.12
Pleasant Pond LK2270 (Stetson P)	309 ± 32		0.37 ± 0.23
North Pond LK5344	318 ± 52	559 ± 225	0.38 ± 0.28
Pleasant Pond LK5254	264 ± 20	224 ± 46	0.41 ± 0.15
Sibley Pond LK2612	268 ± 18	247 ± 37	0.42 ± 0.23
Gulf Island Pond LK8973 (Androscoggin River-AGI)	256 ± 11	237 ± 31	0.43 ± 0.11
Fields Pond LK4282	281 ± 20	306 ± 80	0.44 ± 0.23
Parker Pond LK3388	336 ± 12	574 ± 68	0.48 ± 0.26
GRAND MEAN			**0.28 ± 0.11**
FTAL			**0.020**
FCA basis			**0.48**

2.3 NORTHERN PIKE MERCURY STUDY

A recent contact reported meeting an angler who has been catching, eating and feeding large northern pike to his pregnant daughter-in-law. The Statewide Mercury Fish Consumption Advisory (FCA) recommends

Pregnant and nursing women, women who may get pregnant, and children under age 8 *SHOULD NOT EAT any freshwater fish from Maine's inland waters. Except, for brook trout and landlocked salmon, 1 meal per month is safe.*

All other adults and children older than 8 *CAN EAT 2 freshwater fish meals per month. For brook trout and landlocked salmon, the limit is 1 meal per week.*

There has been a fair amount of publicity about the advisory. It is listed in DIFW's Fishing Laws. MCDC developed a brochure which is given to new mothers by OBGYN's, and an MCDC survey shows ~80% awareness, but the recent contact confirms that not everyone knows or adheres to the advisory.

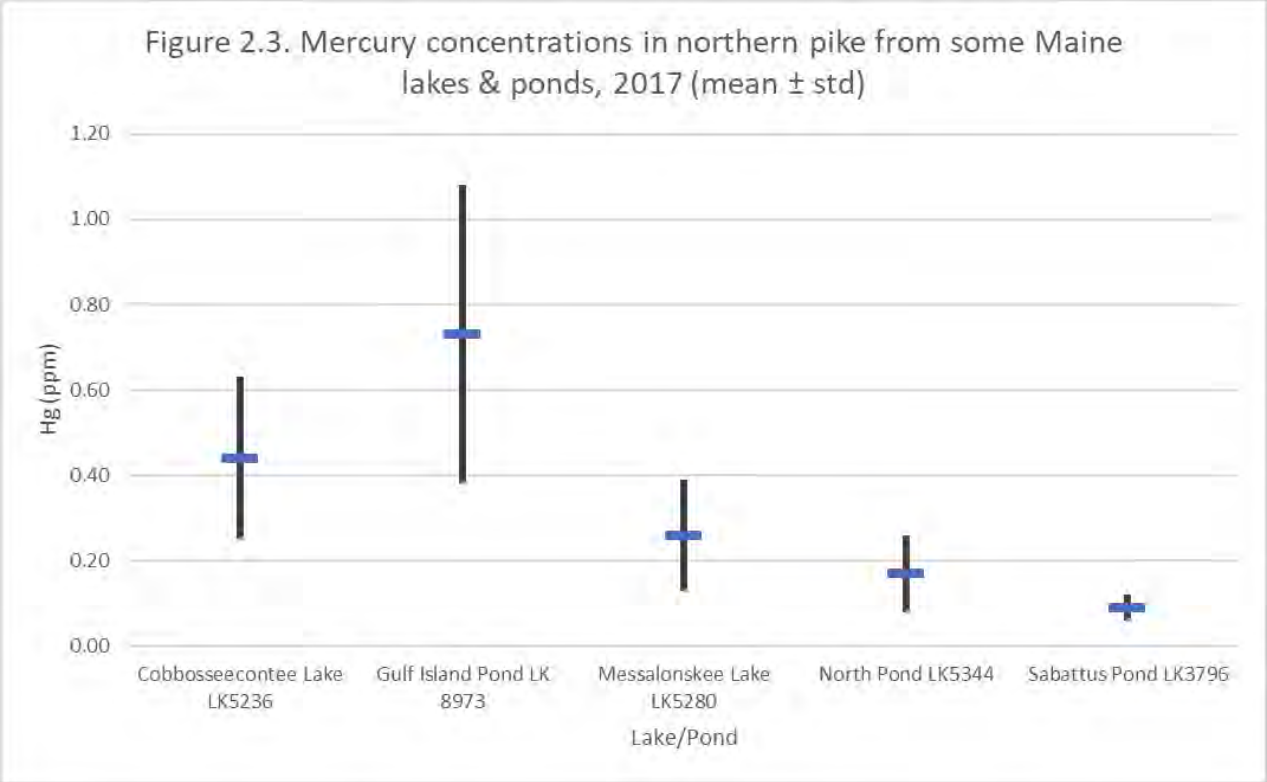
There was also a question about the availability of data for mercury in pike. DEP has data for mercury in pike only from Sabattus Pond in 2000 and 2001. Mercury levels were very low (<0.2 µg/g) in pike 18-23 inches (457-584 mm) long, much lower than the mean concentration (0.72 µg/g) in slightly smaller (12-23 inches, - 305-584 mm long) chain pickerel sampled from seven lakes in the early 1990s. Given that both species are from the same genus and piscivorous, that the mercury concentration in pike of the same relative size or a little larger is not more similar to that in pickerel, may be a function of small sample size.

Since data for pike were limited, more were needed. In 2017 five northern pike in a range of sizes from each of five waterbodies, where the Maine Department of Inland Fisheries and Wildlife identifies significant fisheries, were collected and analyzed individually as skinless filets for mercury.

Results show that concentrations varied with size (Table 2.3) and among waterbodies (Figure 2.2).

Table 2.3. Lengths, weights, and mercury levels in northern pike from Maine Lakes and Ponds, 2017 (mean ± std)

LAKE SAMPLE	LENGTH mm	WEIGHT g	Hg µg/g ww
Cobbosseecontee Lake LK5236	715 ± 74	2508 ± 391	0.44 ± 0.19
Gulf Island Pond LK 8973 (Androscoggin River-AGI)	576 ± 113	1048 ± 628	0.73 ± 0.35
Messalonskee Lake LK5280	620 ± 73	1497 ± 646	0.26 ± 0.13
North Pond LK5344	619 ± 112	1572 ± 779	0.17 ± 0.09
Sabattus Pond LK3796	588 ± 97	1162 ± 546	0.09 ± 0.03



The highest mean concentration from Gulf Island Pond was due to high concentrations (0.99 ppm, 1.22 ppm) in 2 large (740 mm, 680 mm) pike of the 5 fish composite, although mercury concentrations in the remaining 3 fish were lower, they were still higher (0.46-0.52 ppm) than pike from the other lakes and ponds. The mean length of all 5 pike was the lowest of the pike from all the lakes and ponds. These results are similar to those for black crappie which were the smallest yet had the second highest concentrations, both of which suggest that this site, an impoundment in the Androscoggin River, is more heavily contaminated than natural lakes and ponds. This is similar to conclusions from previous fish mercury data collected years ago in the SWAT program. Three large pulp and paper mills upstream have a history of use of mercury and have been subject to hazardous waste cleanup projects for mercury.

The lowest concentration of mercury was in pike from Sabattus Pond, similar to low levels found in 2000 and 2001 despite the fact that the 2017 pike were much larger. The low concentrations also found in black crappie suggests that there is some factor about Sabattus Pond different from other lakes and ponds. Dr. Celia Chen at Dartmouth College has published a paper reporting that algal bloom dilution reduces uptake of mercury into fish (Chen and Holt, 2005). Algal bloom dilution occurs when there is an bloom of blue-green algae wherein the algae, which are not favored food items for primary consumers, sequester mercury making it unavailable for trophic transfer up the food chain.

These data have been shared with MCDC to inform any revisions of the FCA.

Reference

Chen, C.Y. and C.L. Folt, 2005. High Plankton Densities Reduce Mercury Biomagnification. Environ. Sci. Technol.39, 115-121.

3.0 RIVERS AND STREAMS MODULE

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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 2017, we evaluated the condition of 41 sample locations, primarily in the Kennebec basin. In 2018, we evaluated the condition of 44 sample locations, primarily in the Androscoggin 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.

Tables 3.1.1a and 3.1.1b summarize the results of biological monitoring activities, sorted by waterbody name, for the 2017 and 2018 SWAT Programs respectively. Column headings of Tables 3.1.1a and 3.1.1b 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.

2017 field and water chemistry data for each sampling event (where available) are given in Table 3.1.2a and 3.1.3a, respectively. 2018 field and water chemistry data for each sampling event (where available) are given in Table 3.1.2b and 3.1.3b, respectively. 2017 and 2018 continuous water temperature data are given in Figures 3.1.1a and 3.1.1b., respectively. The data from Tables 3.1.1a and b to 3.1.3a and b 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. The attainment history of sampling stations prior to 2017 and 2018, where available, is given in Tables 3.1.4a and 3.1.4b.

For more information about the Biological Monitoring Unit, please e-mail us at biome@maine.gov or visit our web site: www.maine.gov/dep/water/monitoring/biomonitoring/. The Data and Maps page of this website provides access to station information and available data via Google Earth.

2017 Results

3.1.2a 2017 Results Summary

The Biological Monitoring Unit concentrated its sampling in 2017 in the Kennebec basin. Forty-one stations were sampled under the SWAT Program (Table 3.1.1a).

Thirty of these stations met the aquatic life criteria for their statutory class. No licensing / relicensing issues have been found in waterbodies sampled below municipalities or industries. There were two waterbodies that had indeterminate results, see Table 3.1.1 for probable cause.

Bond Brook- Unnamed Tributary – Augusta Station 489

The Unnamed Tributary to Bond Brook is a first order stream with a water quality goal of Class B. It originates on the western side of the Kennebec River in a highly-developed area. The stream is crossed by I-95 before it enters Bond Brook. The benthic macroinvertebrate community is comprised mainly of tolerant midges. There are very few sensitive organisms present in the community. EPT Generic Richness (mayflies, stoneflies, caddisflies) is comprised of only 9 taxa. The stream does not meet the minimum Class C criteria for aquatic life. The Specific Conductance (Table 3.1.2) is very high indicating non-point source runoff or possible ground water contamination. The stream has been listed on the 303(d) list and is part of a percent impervious cover TMDL.

Cobbosseecontee Stream – Gardiner Station 253

Cobbosseecontee Stream in Gardiner is a fourth order system with a water quality goal of Class B. The stream does not meet the Class B aquatic life criteria but does meet the Class C criteria for aquatic life. Pleasant Pond flows into the stream approximately 5 miles above the sampling location. The pond is enriched and this is reflected in the water quality of Cobbosseecontee Stream. Total Abundance is over 1100 organisms per sampler. However, there are no stoneflies in the samplers and the relative abundance of mayflies is only 1% of the community. The

dominant organism in the community is the snail *Amnicola* which makes up 46% of the community. *Amnicola* is a scraper who is feeding on the abundant algae in the system.

Cold Brook – Skowhegan Station 255

Cold Brook in Skowhegan is a second order stream that has a water quality goal of Class B. The stream flows from West to East and is ponded due to a small dam just above Route 201. The sampling station is located below the dam and Route 201. The stream does not meet the minimum Class C aquatic life criteria. Total Mean Abundance and Generic Richness (number of different taxa) are low. The abundance of mayflies in the sample is very low. Two of the mayfly taxa are the tolerant genera *Stenacron* and *Caenis* which have protective gill plates. The five dominant taxa in the sample are all tolerant organisms. These are the amphipod, *Hyallella*, snail, *Ferrisia*, and the tolerant midges *Paratanytarsus*, *Tanytarsus,* and *Microtendipes*. Specific conductance (Table 3.1.2) at sampler pick-up was very high, indicating possible urban runoff.

Cove Brook – Winterport Station 813

Cove Brook is a second order system that has a water quality goal of Class AA. The stream flows west to east and enters the Penobscot River just below Rt. 1A in Winterport. Station 813 is located approximately 370 meters above Rt. 1A. The stream has a distinct population segment of Atlantic salmon. Cove Brook did meet the Class A aquatic life criteria in 2017 but did not in 2016. In 2016, benthic macroinvertebrates colonized the samplers at a mean of 489 organisms per sampler. However, Generic Richness (number of different taxa) was low at 20 different taxa collected. Forty-four percent of the aquatic community was made up by the filter feeding caddisfly *Hydropsyche*. It was noted that the stream was very silty at both sampler placement and retrieval (30 day interval). In addition, the flow in the stream was very low during the sampling period. The combination of silt on the substrate and low flows could have reduced the number of different taxa found in the system. In 2017, Cove Brook was resampled. The macroinvertebrate community rebounded significantly. Generic Richness increased by 30 taxa in 2017, and EPT taxa (mayflies, stoneflies, caddisflies) increased from 12 to 24 taxa. Flows were higher in 2017 although drought conditions persisted. Cove Brook is an important aquatic resource and sampling will continue in the future.

Ducktrap River – Lincolnville Station 626

The Ducktrap River is a third order system that has a water quality goal of Class AA. The river flows west to east and enters Ducktrap Harbor just below Route 1 in Lincolnville. Station 626 is located approximately 4000 meters upstream of Ducktrap Harbor. The Ducktrap River did not meet the Class A aquatic life criteria but did meet the Class B criteria in 2017. In 2007 and 2012, Class A aquatic life criteria were met (Table 3.1.4). In 2016, Total Mean Abundance (mean of 3 samplers) was good and Generic Richness (number of different taxa) was very good consisting of 60 different taxa collected. However, the dominant taxa were made up of tolerant genera with the chironomid *Tanytarsus* totaling 29% of the aquatic macroinvertebrate community. Flow was visible at the time of retrieval but did not register on the flow meter. The low summer flows probably reduced the number of sensitive taxa present in the community. We followed up sampling in 2017, which was also a very low flow year. The Generic Richness was good with 49 taxa present. However, as in 2016, the dominant taxa in the community are made up of tolerant genera. *Dubiraphia,* a tolerant beetle, and *Tanytarsus* made up 25% of the

macroinvertebrate community. *Dubiraphia* is found in both lentic and lotic waters and is a clinger found on macrophytes. *Tanytarsus* is a tolerant midge that is a climber and clinger as well. This habit may aid in survival during fluctuating flows and siltation events. The Ducktrap River is a Class A mid-coast river and we recommend that macroinvertebrate sampling be repeated next year.

Halfmoon Stream – Thorndike Station 697

Halfmoon Stream is a third order stream which flows east to west to the town of Unity entering Sandy Stream and eventually Unity Pond. Above the Route 220 bridge crossing in Thorndike, where the station is located, the water quality goal is Class A. The station has been sampled every year since 2012 (Table 3.1.3). The history of sampling results and a discussion of the biological community changes and possible stressors to the system for the previous years sampled can be found in SWAT 2015. In 2016, the Total Mean Abundance (2306 organisms/sampler) and Generic Richness (59 taxa) closely resembled the 2015 data (SWAT 2015). Water chemistry data indicated agricultural runoff was a primary stressor. The Dominant Taxa consisted of the caddisflies *Helicopsyche* (33% of the community), which is a scraper that feeds on algal, detritus, and animal material, and the filter feeding caddisflies *Hydropsyche* and *Cheumatopsyche* (33% of the community) which were found in high numbers in 2015 as well. Halfmoon Stream was Indeterminate for Class A (.46) as it was in 2015. The Final Determination was not raised to Class A based on the Total Abundance and Dominant Taxa found in the aquatic community. In 2017, the Total Mean Abundance (3258 organisms/sampler) is higher than it was in 2016. Generic Richness (47 taxa) is lower than in 2016 (59 taxa). The dominant taxon in 2017 is the filter feeding caddisfly *Cheumatopsyche* which makes up 46% of the community. The aquatic community does not meet the Class A aquatic life criteria in 2017. Halfmoon Stream is a long-term monitoring site and is an example of a Class A system that has become enriched due to agricultural inputs.

Kennedy Brook – Augusta Station 620

Kennedy Brook is a first order stream that has a water quality goal of Class B. The stream flows West to East through Augusta and enters the Kennebec River near the municipal treatment plant. The sampling station is located below Rt 11/27 and just upstream of the treatment plant. The stream met the Class C aquatic life criteria in 2017. Kennedy Brook is a cold-water system that has no stoneflies and very few mayflies. Generic Richness was good with 48 different taxa collected but only 7 taxa representing the sensitive EPT (mayflies, stoneflies, caddisflies) taxa. The specific conductance is very high (Table 3.1.2) pointing to possible groundwater contamination and the stream banks are washed out in areas indicating possible high storm water runoff.

Stone Brook- Augusta Station 944

Stone Brook is a second order stream that flows north to south and enters Bond Brook above I-95. The stream has a water quality goal of Class B. In 2012, the stream met the Class B aquatic life criteria (Table 3.1.4) but in 2017 Stone Brook only meets the Class C aquatic life criteria. There are very few sensitive organisms present in the macroinvertebrate community. The dominant organism making up 21% of the community is the tolerant midge *Microtendipes*. Conductivity is high at this station (Table 3.1.2) at both times of sampler placement and retrieval.

In addition, the water level was very low and the water had a somewhat milky appearance. Stone Brook should be monitored in the near future given the decline of the macroinvertebrate community.

Table 3.1.1a 2017 SWAT Benthic Macroinvertebrate Biomonitoring Results

Waterbody	Town	Station	Log	Potential sources of pollution[1]	Statutory Class/ Final Determination	Attains Class?	Probable Cause
Bond Brook	Augusta	30	2572	Urban NPS	B/B	Y	
Bond Brook	Augusta	597	2573	Urban NPS	B/B	Y	
Bond Brook - Unnamed Trib	Augusta	489	2570	Urban NPS	B/C	N	NPS Toxics / Salt
Burnham Brook	Big Moose TWP	869	2586	Reference	A/A	Y	
Carrabassett River	Kingfield	16	2563	Municipal	A/A	Y	
Cove Brook	Winterport	813	2558	NPS	AA/A	Y	
Carrying Place Stream	Carrying Place TWP	768	2557	Forestry	A/A	Y	
Cobbosseecontee Stream	Gardiner	253	2567	Urban NPS/lake outlet, hydro	B/C	N	Enriched, altered hydrology
Cold Brook	Skowhegan	255	2574	NPS	B/NA	N	NPS Toxics
Creamer Brook	T19 ED BPP	1115	2589	Salmon Study	A/A	Y	
Ducktrap River	Lincolnville	626	2560	Reference	AA/B	N	Low Flow
East Branch Wesserunsett Stream	Athens	486	2561	Long Term Monitoring	B/A	Y	
East Branch Sebasticook River	Corinna	194	2582	In-Place Contamination	C/C	Y	
Fifteenmile Stream	Benton	602	2569	Agric NPS	B/B	Y	
Halfmoon Stream	Thorndike	697	2551	Agricultural NPS/Long Term Monitoring	A/B	N	Class A (.46); enriched.
Hardy Brook	Madrid TWP	769	2578	Forestry	A/I		One sampler recovered
Jamie's Stream	Manchester	791	2577	Reference	B/I		Low numbers /Low Flow
Kennebec River	Bingham	636	2556	Municipal	A/A	Y	
Kennebec River	Madison	405	2581	Municipal/ Industrial	B/A	Y	
Kennedy Brook	Augusta	620	2576	Urban NPS	B/C	N	NPS Toxics / Salt
Lily Bay Brook	Lily Bay TWP	844	2585	Reference	A/A	Y	
Little River	Belfast	850	2559	NPS	B/C	N	Habitat/ Low Flow/ Resample

[1] NPS, non-point source pollution.

Table 3.1.1a 2017 SWAT Benthic Macroinvertebrate Biomonitoring Results (continued)

Waterbody	Town	Station	Log	Potential sources of pollution[1]	Statutory Class/ Final Determination	Attains Class?	Probable Cause
Martin Stream	Dixmont	755	2553	Agricultural NPS	A/A	Y	Very low flow.
Martin Stream	Dixmont	756	2552	Agricultural NPS	A/B	N	Class A (.29); very low flow.
Moose Brook	Big Moose TWP	1111	2587	Reference	A/A	Y	
North Brook	Lily Bay TWP	841	2584	Reference	A/A	Y	
Orbeton Stream	Madrid TWP	840	2579	Reference	A/A	Y	
Richardson Brook	T19 ED BPP	1114	2590	Salmon Study	A/A	Y	
Richardson Brook	T19 ED BPP	1115	2591	Salmon Study	A/A	Y	
Sandy River	Farmington	572	2575	Municipal/ Agric NPS	B/A	Y	
Sandy River	Phillips	17	2580	Reference	AA/A	Y	
Sheepscot River	Whitefield	74	2547	Long Term Monitoring	AA/A	Y	
South Branch Carrabassett River	Carrabassett Valley	836	2564	NPS/Ski area	AA/A	Y	
Stone Brook	Augusta	944	2571	Urban NPS	B/C	N	NPS Toxics
Stoney Brook	Wyman TWP	1113	2565	Reference	A/A	Y	
Stratton Brook	Wyman TWP	1114	2566	Reference	A/A	Y	
Togus Stream	Pittston	612	2568	Municipal/NPS	B/A	Y	
Wesserunsett Stream	Cornville	488	2562	Agricultural NPS	B/A	Y	
West Branch Sebasticook River	Pittsfield	27	2583	Municipal/ Industrial	C/A	Y	
West Branch Sheepscot	Whitefield	550	2548	Long Term Monitoring	AA/A	Y	
West Branch Sheepscot River	China	268	2549	Long Term Monitoring/ Agricultural NPS	AA/A	Y	

[1] NPS, non-point source pollution.

Table 3.1.2a 2017 SWAT Field Data

Measurements were obtained using handheld electronic meters. Highlighted values are of concern or do not attain criteria.

Site	Station	Log	Sample Deployment					Sample Retrieval				
			Date	Temperature Deg C	Dissolved Oxygen MG/L	Specific Conductance US/CM	pH STU	Date	Temperature Deg C	Dissolved Oxygen MG/L	Specific Conductance US/CM	pH STU
Bond Brook	30	2572	7/18/2017	20.9	9.08	**254.7**	7.92	8/15/2017	19.8	11.03	**213.5**	7.9
Bond Brook	597	2573	7/18/2017	19.6	10.4	**346.7**	8.22	8/15/2017	20.6	12.25	**315**	8.46
Bond Brook	489	2570	7/18/2017	17.6	9.92	**1724**	7.94	8/15/2017	16.5	9.89	**1706**	7.87
Burnham Brook	869	2586	7/26/2017	18.6	10.13	81	7.85	8/23/2017	22.3	9.57	81.6	7.6
Carrabassett River	16	2563	7/13/2017	17.1	10.81	50	7.61	8/10/2017	18.2	10.94	57.9	7.75
Carrying Place Stream	768	2557	7/10/2017	16.7	10.73	30.1	7.41	8/7/2017	16.3	11.07	35.7	7.69
Cobbosseecontee Stream	253	2567	7/17/2017	25.6	9.57	115.7	7.94	8/14/2017	24.3	9.81	116.1	7.66
Cold Brook	255	2574	7/19/2017	22	8.48	**279.6**	7.46	8/16/2017	21	8.48	**668**	7.49
Cove Brook	813	2558	7/11/2017	18.8	10.53	**216.7**	8.19	8/8/2017	17.5	10.67	**240.1**	8.33
Creamer Brook	1115	2589	7/27/2017	15.2	10.68	30	6.64	8/28/2017	13.2	6.23	40.3	**5.7**
Ducktrap River	626	2560	7/11/2017	22.2	9.19	55.6	7.15	8/8/2017	17.6	8.28	57.6	7.25
East Branch Sebasticook River	194	2582	7/25/2017	23.9	10.07	159.6	7.77	8/22/2017	23	9.18	160.5	7.3
East Branch Wesserunsett Stream	486	2561	7/12/2017	20.8	10.25	56	7.89	8/9/2017	17.9	11.38	101.3	8.26
Fifteenmile Stream	602	2569	7/17/2017	24	8.22	120.9	7.36	8/14/2017	25	8.8	130.6	7.65
Halfmoon Stream	697	2551	7/6/2017	19.2	10.67	125.3	7.65	8/2/2017	21.4	10.02	150.6	7.74
Hardy Brook	769	2578	7/24/2017	15.6	10.87	31.7	7.96	8/21/2017	17.8	10.58	32.2	6.63
Jamie's Stream	791	2577	7/20/2017	19.9	9.29	46.5	7.41	8/17/2017	14.9	10.66	79	6.97
Kennebec River	405	2581	7/25/2017	20.9	10.02	33.3	7.52	8/22/2017	22	9.93	36.9	6.84
Kennebec River	636	2556	7/10/2017	18.7	9.81	33.9	7.1	8/7/2017	21.3	10.4	34.3	7.59
Kennedy Brook	620	2576	7/20/2017	19.5	10.46	**824**	8.35	8/17/2017	15	11.44	**730**	8.15
Lily Bay Brook	844	2585	7/26/2017	16.3	10.59	26.4	7.36	8/23/2017	16.7	10.01	30.5	6.23

Table 3.1.2a 2017 SWAT Field Data (continued)

Site	Station	Log	Sample Deployment					Sample Retrieval				
			Date	Temperature Deg C	Dissolved Oxygen MG/L	Specific Conductance US/CM	pH STU	Date	Temperature Deg C	Dissolved Oxygen MG/L	Specific Conductance US/CM	pH STU
Little River	850	2559	7/11/2017	20.3	10.55	**191.3**	7.54	8/8/2017	16.3	10.29	150.6	7.65
Martin Stream (Dixmont)	755	2467	7/6/2017	22.9	10.68	123.8	7.96	8/2/2017	24.7	10.76	148.6	7.73
Martin Stream (Dixmont)	756	2466	7/6/2017	22.5	10.71	130.2	7.84	8/2/2017	22.8	10.3	150.2	7.66
Moose Brook	1111	2587	7/26/2017	15.8	10.89	35.7	7.75	8/23/2017	18.7	10.19	39.1	6.79
North Brook	841	2584	7/26/2017	15.1	10.99	46.4	7.57	8/23/2017	17.1	10.16	41.6	6.88
Orbeton Stream	840	2579	7/24/2017	16.3	10.99	28.7	7.78	8/21/2017	18.7	10.62	30.3	6.7
Richardson Brook	1116	2575	7/27/2017	17.6	10.64	10.6	6.59	8/28/2017	17.9	10.75	23.4	6.21
Richardson Brook	1117	2580	7/27/2017	17.7	10.23	20.2	6.44	8/28/2017	15.1	11.11	20.6	5.37
Sandy River	17	2341	7/24/2017	17.9	10.84	36.6	7.71	8/21/2017	22.8	10.17	37	7.14
Sandy River	572	2564	7/19/2017	24.4	9.58	48.2	6.47	8/16/2017	22.1	9.58	50.1	6.48
Sheepscot River	74	2571	7/5/2017	22.4	9.14	75	7.4	8/1/2017	21.3	8.37	101.5	7.43
South Branch Carrabassett River	836	2565	7/13/2017	14.8	10.94	26.1	7.25	8/10/2017	16.7	10.66	28.7	7.33
Stone Brook	944	2566	7/18/2017	21.8	9.25	**744**	7.97	8/15/2017	19.7	9.89	**843**	8.13
Stoney Brook	1113	2568	7/13/2017	14.3	11.23	31.1	7.5	8/10/2017	16.4	11.05	37.2	7.7
Stratton Brook	1114	2588	7/13/2017	18.15	8.73	48.7	7.08	8/10/2017	20.8	9.45	53.5	7.36
Togus Stream	612	2562	7/17/2017	24.4	10.91	109.8	7.74	8/14/2017	19.7	11.22	129.6	7.22
Wesserunsett Stream	488	2583	7/12/2017	23.5	10.23	72.9	8.42	8/9/2017	23.6	10.42	107	8.54
West Branch Sebasticook River	27	2548	7/25/2017	25.3	9.77	72.7	7.87	8/22/2017	26	10.18	87	8.02
West Branch Sheepscot River	268	2464	7/5/2017	20.5	10.41	88.5	7.69	8/1/2017	19.5	10.15	101.3	7.66
West Branch Sheepscot River	550	2584	7/5/2017	23.8	9.82	136.7	7.84	8/1/2017	22.7	10.29	163.8	8.18

Table 3.1.3a 2017 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**	**TKN** *(MG/L)*	**NO2-NO3-N** *(MG/L)*	**Total P** *(µg/L)*	**SRP** *(µg/L)*	**TSS** *(MG/L)*	**TDS** *(MG/L)*
Bond Brook	30	2572	08/15/2017	0.3	0.01	13	1	<2	130
Bond Brook	597	2573	08/15/2017	0.2	0.04	N/A	1	<2	200
Bond Brook – Unnamed Trib	489	2570	08/15/2017	0.2	0.44	N/A	2	<2	**1000**
East Branch Sebasticook River	194	2582	08/22/2017	0.5	0.01	22	1	<2	91
East Branch Wesserunsett Stream	486	2561	08/09/2017	0.2	0.03	6	1	<2	57
Fifteenmile Stream	602	2569	08/14/2017	0.6	0.01	**54**	2	4.4	87
Halfmoon Stream	697	2551	08/02/2017	0.2	0.64	13	1	2.1	93
Kennebec River	405	2581	08/22/2017	0.4	0.08	7	1	<2	24
Kennedy Brook	620	2576	08/17/2017	0.2	0.60	9	5	3.6	**520**
Martin Stream (Dixmont)	756	2552	08/02/2017	0.3	0.04	18	1	5.5	98
Orbeton Stream	840	2579	08/21/2017	0.3	0.06	4	2	<2	34
Sandy River	17	2580	08/21/2017	0.1	0.05	5	2	<2	29
Sheepscot River	74	2547	08/01/2017	0.3	0.010	10	<1	<2	59
Stone Brook	944	2571	08/15/2017	0.1	0.02	N/A	1	7.8	**490**
Togus Stream	612	2568	08/14/2017	0.4	0.02	22	3	<2	89
Wesserunsett Stream	488	2562	08/09/2017	0.2	0.03	9	1	<2	61
West Branch Sheepscot River	268	2464	08/01/2017	0.3	0.1	11	1	<2	61

TKN = Total Kjeldahl-Nitrogen, NO_2-NO_3-N = Nitrite-Nitrate-Nitrogen, Total P = Total Phosphorus, SRP = Soluble Reactive Phosphorus (ortho-phosphate), TSS = Total Suspended Solids, TDS = Total Dissolved Solids, "<" = constituent not detected at the reporting limit.

Figure 3.1.1a 2017 In-Stream Continuous Temperature Data

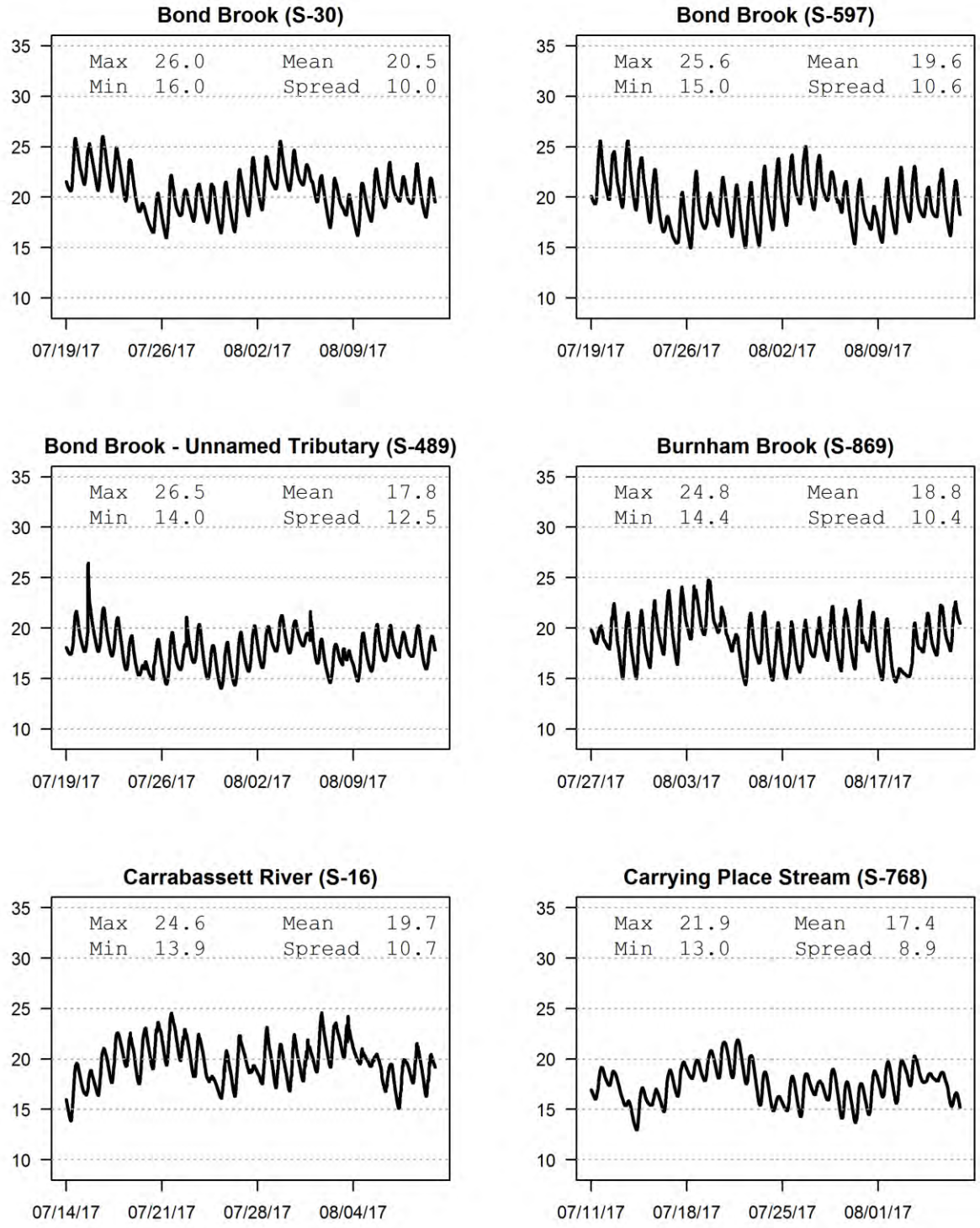


Figure 3.1.1a 2017 In-Stream Continuous Temperature Data (continued)

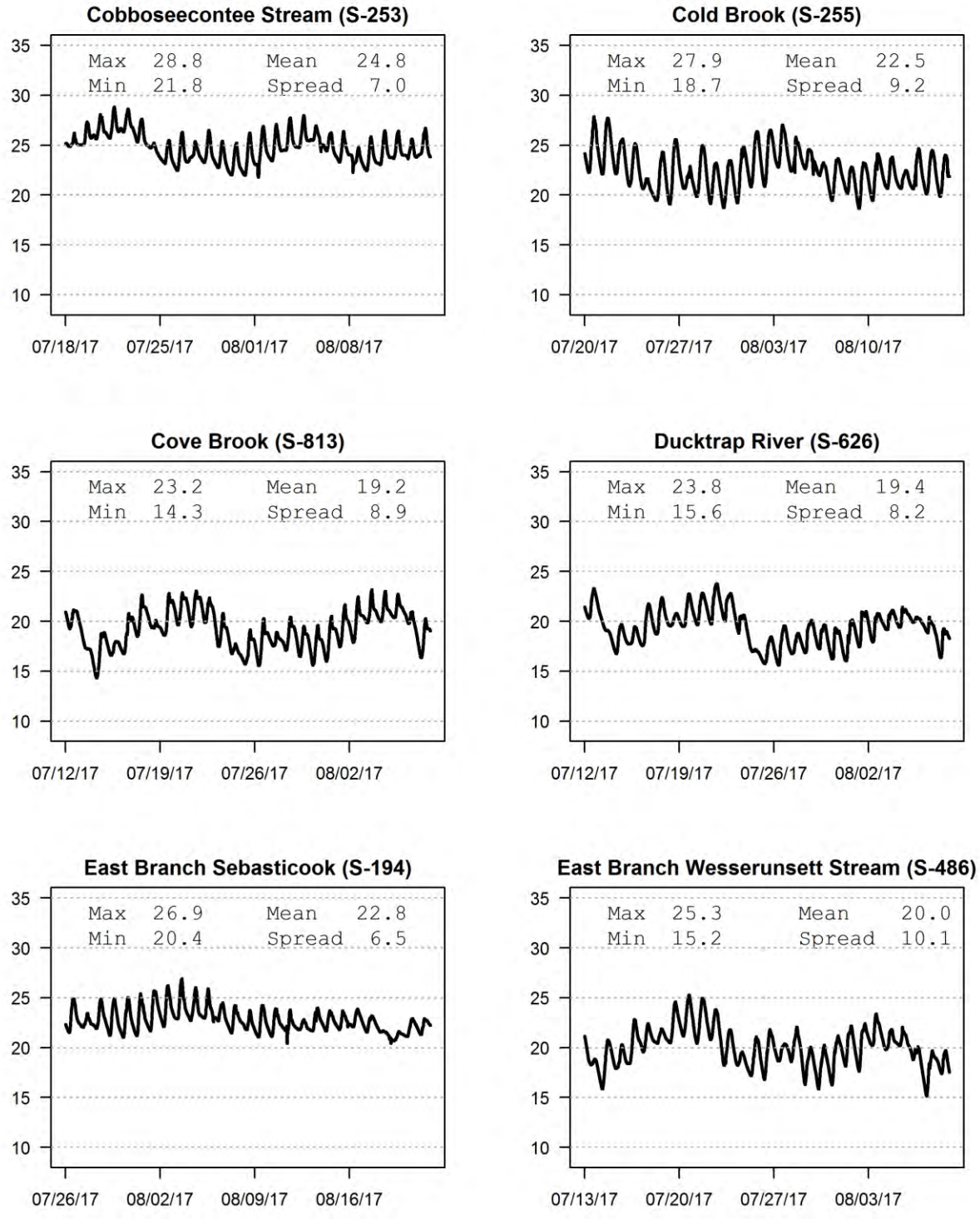


Figure 3.1.1a 2017 In-Stream Continuous Temperature Data (continued)

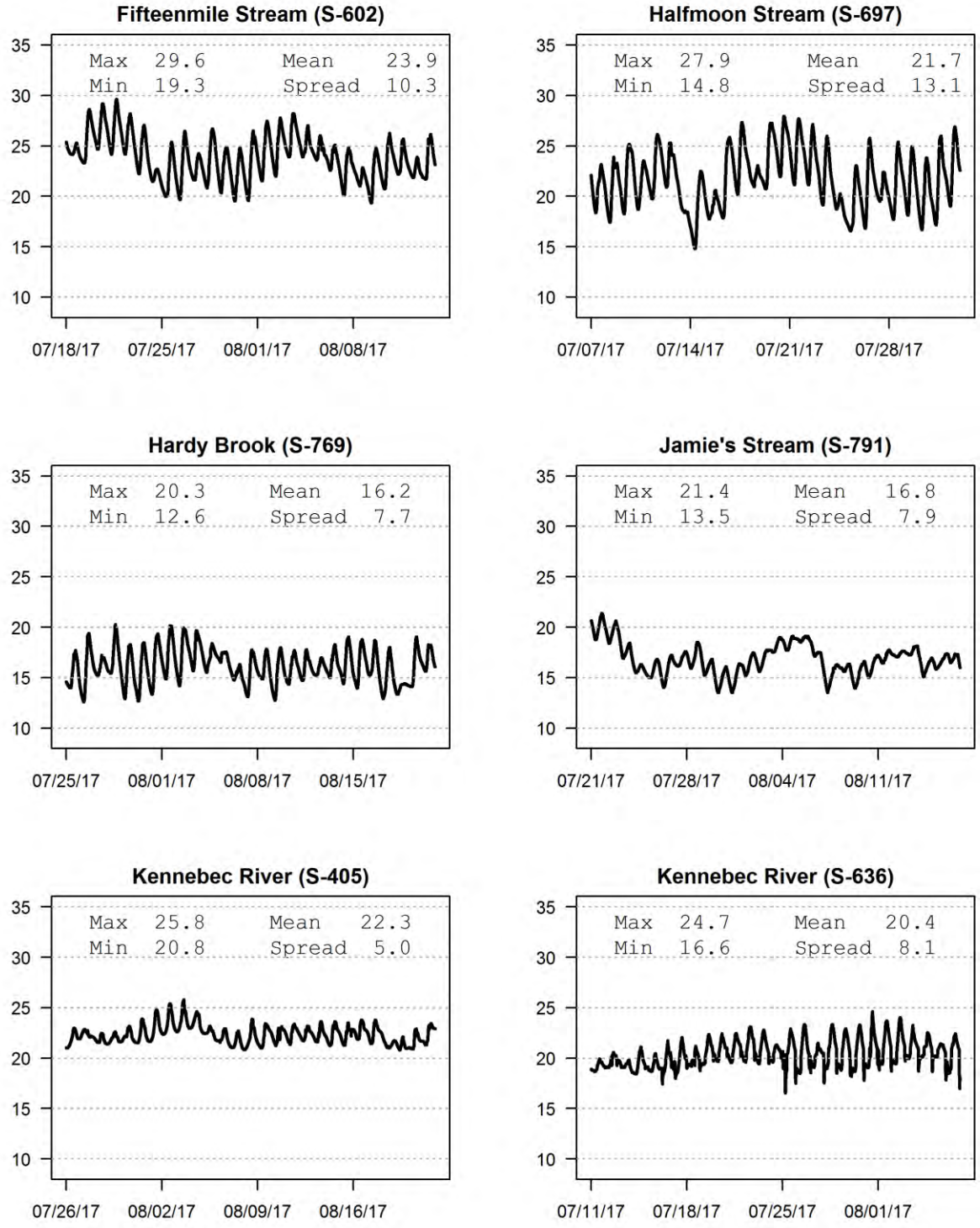


Figure 3.1.1a 2017 In-Stream Continuous Temperature Data (continued)

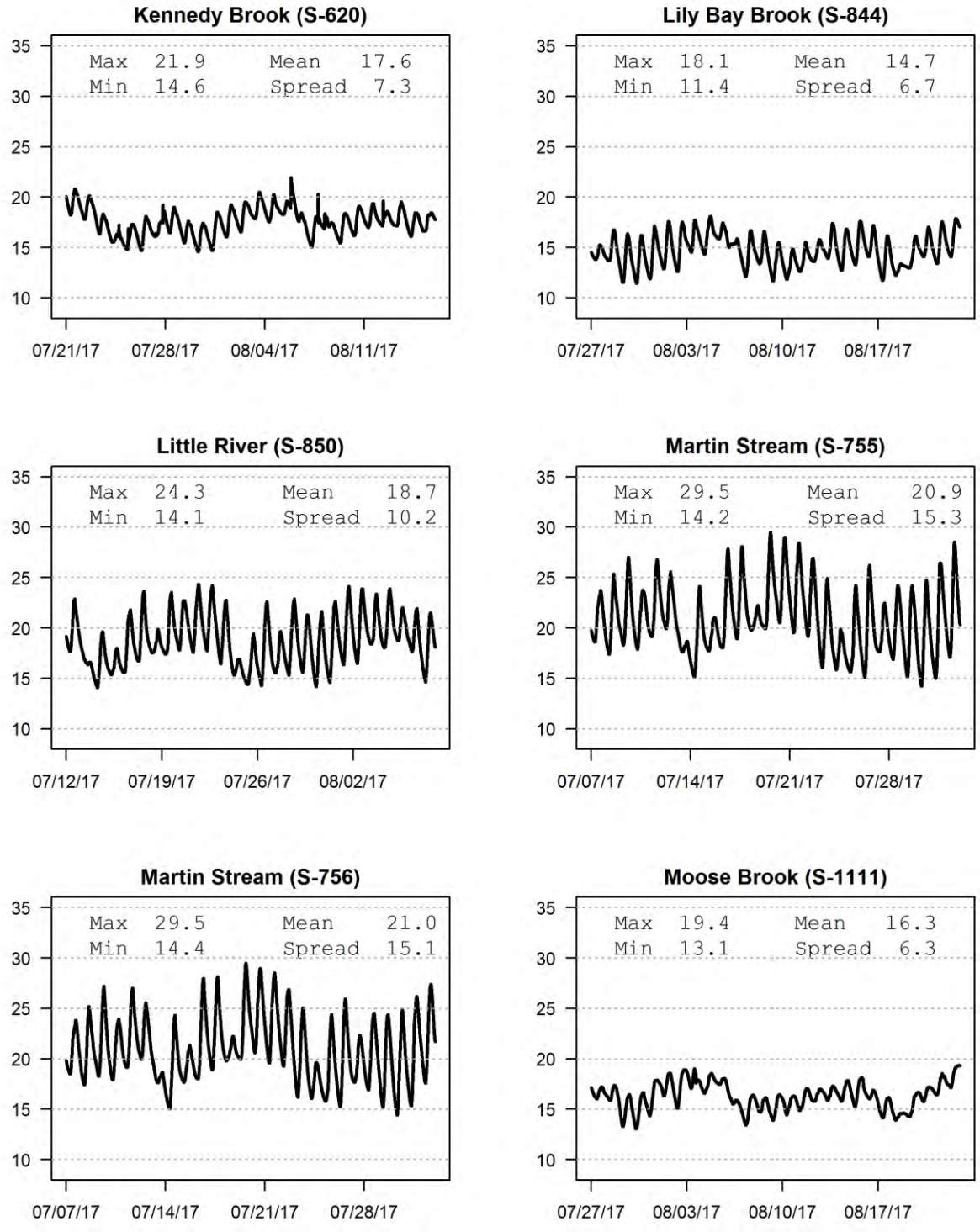


Figure 3.1.1a 2017 In-Stream Continuous Temperature Data (continued)

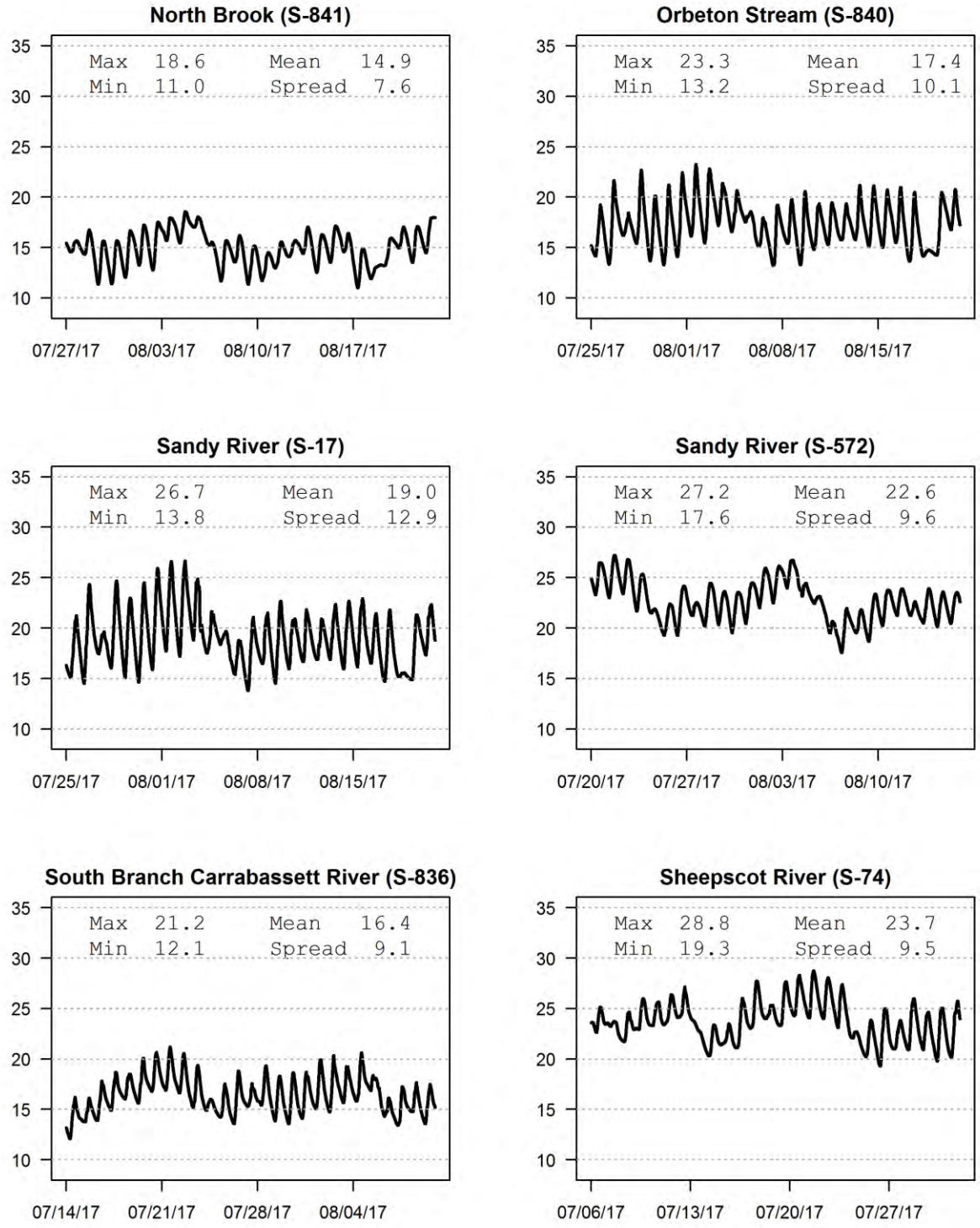


Figure 3.1.1a 2017 In-Stream Continuous Temperature Data (continued)

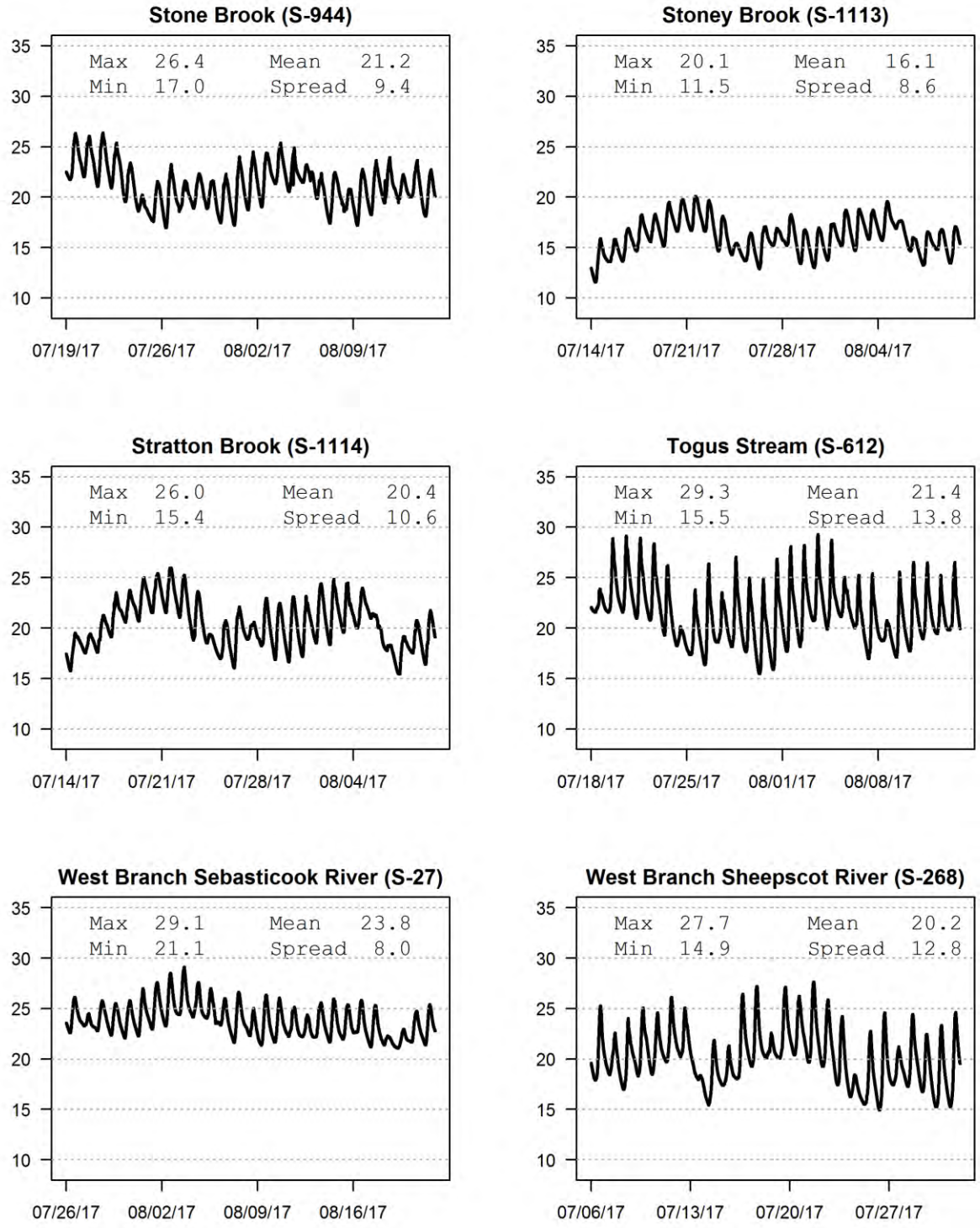


Figure 3.1.1a 2017 In-Stream Continuous Temperature Data (continued)

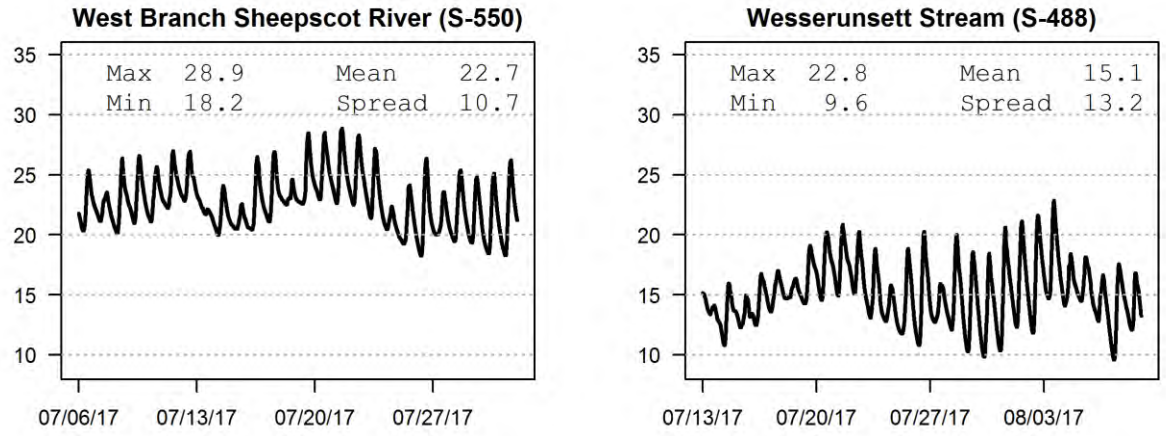


Table 3.1.4a Past Attainment History

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

Waterbody	Station	Attained Class	Did not Attain Class	Indeterminate Result
Bond Brook	30	1991, 1992, 1997, 2002, 2007, 2012		
Bond Brook	597	2002, 2007, 2012		
Bond Brook - Unnamed Trib	489		2001, 2001, 2007, 2012	
Burnham Brook	869	2012	2008	
Carrabassett River	16	1997, 2007, 2012		
Cove Brook	813	2006, 2011	2016	
Carrying Place Stream	768	2004, 2007, 2012		
Cobbosseecontee Stream	253		1997, 2007	
Cold Brook	255	1997		
Ducktrap River	626	2007, 2012	2002, 2016	
East Branch Wesserunsett Stream	486	2001, 2007, 2012-2016		
East Branch Sebasticook River	194	1993, 1997, 2003, 2007, 2012		
Fifteenmile Stream	602		2007	
Halfmoon Stream	697	2003, 2007	2012-2016	
Hardy Brook	769	2004, 2007, 2012		
Jamie's Stream	791	2009		2005
Kennebec River	636	2002, 2007, 2012		
Kennebec River	405	1999		
Kennedy Brook	620	2002	2004, 2007, 2012	

Table 3.1.4a Past Attainment History (continued)

Waterbody	Station	Attained Class	Did not Attain Class	Indeterminate Result
Lily Bay Brook	844	2007, 2012		
Little River	850	2007		
Martin Stream	755	2006	2004, 2005, 2016	2007
Martin Stream	756	2012	2005, 2006, 2007, 2016	2004
North Brook	841	2012		
Orbeton Stream	840	2007, 2012		
Sandy River	572	2007, 2012	2000	
Sandy River	17	2000, 2007, 2012		
Sheepscot River	74	1987-1990, 1992, 1995, 1996, 1998, 1999-2016	1984-1986, 1991, 1993, 1994, 1997	
South Branch Carrabassett River	836	2007, 2012		
Stone Brook	944	2012		
Togus Stream	612	2002, 2007, 2012		
Wesserunsett Stream	488	2001, 2007		
West Branch Sebasticook River	27	2002, 2007, 2012		
West Branch Sheepscot	550	2015		
West Branch Sheepscot River	268	1996-1999, 2001, 2002, 2005, 2007, 2009-2016	2000, 2003, 2004, 2006, 2008	1995

2018 Results

3.1.2b 2018 Results Summary

The Biological Monitoring Unit concentrated its sampling in 2018 in the Androscoggin basin. Forty-four stations were sampled under the SWAT Program (Table 3.1.1b).

Twenty-nine of these stations met the aquatic life criteria for their statutory class. No licensing / relicensing issues have been found in waterbodies sampled below municipalities or industries. There were two waterbodies that had indeterminate results, see Table 3.1.1b for probable cause. The streams that did not attain their statutory class were small rural or urban streams. Summaries on these streams are found below.

Bird Brook - Norway Station 340

Bird Brook in Norway is a second order stream with a water quality goal of Class B. Station 340 is located above the Rt. 117 crossing. The stream flows from the north, through Bird Pond, and

then south where it eventually enters the Little Androscoggin River below Rt. 26. Bird Brook does not attain the Class B aquatic life criteria. Total Mean Abundance and Generic Richness are low although the mayflies *Maccaffertium* and *Paraleptophlebia* are the dominant organisms in the sample. The mayflies *Maccaffertium* and *Paraleptophlebia* prefer lentic or low flow conditions. In addition, there are very few filter feeders in the sample which require higher flows to collect suspended solids in their nets. At the time of retrieval, the flow was very low but visible. Dissolved oxygen was also very low (2.62 mg/l) at retrieval (Table 3.1.2b). This may be a result of the stream being an outlet from Bird Pond and the dry conditions.

In 2008, Bird Brook attained Class B aquatic life criteria (Table 3.1.4b). The numbers of collector-filterers were much higher as it was a high water summer. Dissolved oxygen was still low in 2008 (5.1 mg/l) but not low enough to change the aquatic community. In 2018, the primary stressors affecting the aquatic community were low dissolved oxygen and low flow.

Gully Brook – Auburn Station 695

Gully Brook is a cold first order stream with a water quality goal of Class B. The sampling station is located at Pettengill Park in Auburn. Gully Brook does not attain the Class B aquatic life criteria. The Total Mean Abundance is high but Generic Richness and the number of sensitive taxa are very low. The dominant organism in the community is the tolerant midge *Stictochironomus* which makes up 60% of the community. *Stictochironomus* is prevalent in soft sediments of streams and slowly flowing rivers. Specific Conductance is elevated (Table 3.1.2b) and nutrient levels are very high (Table 3.1.3b). Gully Brook did attain Class B aquatic life criteria in 2003 and 2008 (Table 3.1.4b). Follow up sampling should be conducted to confirm the results of the 2018 sampling.

Halfmoon Stream – Thorndike Station 697

Halfmoon Stream is a third order stream flowing east to west to the town of Unity entering Sandy Stream and eventually Unity Pond. The water quality goal is Class A above the Route 220 bridge in Thorndike where Station 697 is located. Station 697 is a long-term monitoring site and has been sampled every year since 2012 (Table 3.1.4b), failing to attain Class A aquatic life criteria in each of those years. The history of sampling results and a discussion of the biological community changes and possible stressors to the aquatic community can be found in **SWAT 2015 and 2016**. In 2018, the aquatic community failed to attain Class A aquatic life criteria. The Total Mean Abundance dropped from 3258 organisms in 2017 to 1766 in 2018. However, Generic Richness increased from 45 taxa to 65 taxa. This is a significant increase in the different taxa within the macroinvertebrate community but there were no sensitive *Plecoptera* (stoneflies) found in the sample. Stoneflies prefer cold highly oxygenated water but during retrieval the water level was very low due to drought conditions. The water temperature was 28 degrees centigrade. These conditions may have affected the cold water taxa in the aquatic community.
In addition to the agricultural inputs that have enriched the system, drought conditions the past two years have influenced the community by reducing flow and increasing temperature.

Hall Brook- Thorndike Station 1147

Hall Brook is a second order stream which flows east to west entering Halfmoon Stream below the Rt. 220 bridge in Thorndike. Adjacent to the stream just above Rt. 220 is the Town of Thorndike's sand and salt pile which is not stored in a building but is covered with a tarp. The

water quality goal of Hall Brook is Class A. The station was sampled to evaluate the benthic macroinvertebrate community in 2018. In addition, conductivity loggers were deployed in the stream above and below the sand and salt pile in the fall of 2017 and again 2018. The macroinvertebrate community only attained the Class C aquatic life criteria. The macroinvertebrate community has low total abundance, no sensitive stoneflies, and no collector filterers. The dominant taxa consist of the mayflies *Paraleptophlebia* and *Eurylophella*. These two mayfly taxa prefer lentic or low flow conditions. At the time of sampler retrieval, there was no visible flow.

The overall conductivity pattern has been the same the past two years. The station above the salt pile is relatively constant at around 100 us/cm while the below station fluctuates depending on dilution from rain events. Before the rains occurred in 2018 the conductivity at the below station was measured at 284us/cm which was similar to last year's data. These data appear to confirm the salt intrusion into the surface and groundwater. Recently, DEP sent the town of Thorndike a notice of violation and the town has responded by addressing the issue at their annual town meeting.

Sabattus River – Lisbon Station 170

The Sabattus River in Lisbon is a third order system with a water quality goal of Class B. The Sabattus River begins at the outlet of Sabattus Pond in the town of Sabattus and flows south entering the Androscoggin River in the town of Lisbon. The Sabattus River does not attain the Class B aquatic life criteria in Lisbon. The number of sensitive organisms is low with no stoneflies present in the sample. The caddisfly *Cheumatopsyche* makes up 39% of the aquatic community. *Cheumatopsyche* genera tend to be more dominant in warmer systems and are more successful in streams too polluted for most other caddisflies. Sabattus Pond influences the system with high nutrients and warmer temperatures found in the river system. The temperature of the water at retrieval was 27 degrees (Table 3.1.2b) and Total Phosphorus was measured at 49 µg/l (Table 3.1.3b). In years of low rain fall, the stress on the aquatic community in the river system tends to be greater from the Pond. Sabattus River sampling should continue in the future as it is an important resource in the Sabattus and Lisbon area.

Unnamed Stream- Lewiston Station 857

Unnamed Stream in Lewiston is a first order stream with a water quality goal of Class B. The stream flows from north to south through a highly developed area and passes adjacent to Lewiston's Municipal Landfill before entering the Androscoggin River. The stream does not attain the minimum Class C criteria for aquatic life. The Total Mean Abundance and Generic Richness are low. The dominant taxon is the tolerant non-insect Caecidotea (Isopods) making up 62% of the aquatic community. The Nitrate + Nitrite as N level is very high at 1.20 mg/l (Table 3.1.3b) and Specific Conductance is high at 1046 uS/cm measured on July 10, 2018 (Table 3.1.2b). The stream habitat is in poor condition. Unnamed Stream in Lewiston did not attain class in 2008 and 2013 (Table 3.1.4b). Generic Richness dropped dramatically in 2018. In 2013, 61 different Genera were present in the aquatic community while in 2018 only 15 different Genera were present in the community. This loss of taxa may be attributed to the poor habitat and drought conditions the past few years.

Unnamed Stream (4) - Brunswick Station 643

Unnamed Stream (4) in Brunswick is a first order stream with a water quality goal of Class B. The stream flows west to east in Brunswick and enters the Androscoggin River below Jordan Avenue. The stream does not attain the minimum Class C criteria for aquatic life. There are very few sensitive organisms in the community with the mayfly *Baetis* the only EP (Ephemeroptera, Plecoptera) taxon present. The amphipod *Gammarus* makes up 45% of the community while *Frenesia,* a caddisfly, makes up another 14% of the community and the Isopod *Caecidotea* consists of 10% of the community. The sensitive EPT taxa (mayflies, stoneflies, caddisflies) only made up 25% of the community. Temperature in the stream is cold (Table 3.1.2b) and specific conductance is elevated measuring 351.1 uS/cm at retrieval of the samplers (Table 3.1.2b). The stream substrate is 75% sand and there are storm water surges in the stream disrupting the macroinvertebrate habitat. This favors fast colonizers like *Gammarus* and *Caecidotea*. The stream did not attain aquatic life criteria in 2002 and 2008 (Table 3.1.4b).

Unnamed Stream (4) – Topsham Station 634

Unnamed Stream (4) in Topsham is a second order system with a water quality goal of Class B. The stream runs north to south through the Topsham Fair Mall development before entering the Androscoggin River in Topsham. The stream does not attain the minimum Class C criteria for aquatic life. Total Mean Abundance and Generic Richness are adequate but there are very few sensitive organisms present even though the temperature of the water is cold (Table 3.1.2b). There are no mayflies present and only one stonefly taxon (*Leuctra)* which is found in cold sandy streams. The dominant organisms are the chironomid *Prodiamesa,* caddisfly *Diplectrona*, and amphipod *Synurella*. These organisms are found in cool streams. Specific conductance is very high (Table 3.1.2b) and measured 1081 uS/cm at retrieval of the samplers. This conductance value most likely indicates salt contamination in this small ground water fed waterbody. In addition, the stream substrate is comprised of 80% sand and the remainder detritus which is very unstable during storm surges. These two stressors probably play a large role in the fluctuating aquatic community. The stream did not attain aquatic life criteria in 2008 and 2014 (Table 3.1.4b).

Table 3.1.1b 2018 SWAT Benthic Macroinvertebrate Biomonitoring Results

Waterbody	Town	Station	Log	Potential sources of pollution[1]	Statutory Class/ Final Determination	Attains Class?	Probable Cause
Androscoggin River	Bethel	355	2655	Municipal	B/A	Yes	
Androscoggin River	Brunswick	954	2660	Municipal / Industrial	C/A	Yes	
Androscoggin River	Mexico	41	2668	Municipal / Industrial	C/A	Yes	
Aunt Hannah Brook	Dixfield	343	2673	Reference	B/A	Yes	
Bear River	Newry	866	2681	Reference	AA/B	No	
Bird Brook	Norway	340	2664	Urban NPS	B/C	No	Low Flow; Low DO; Habitat

[1] NPS, non-point source pollution.

Table 3.1.1b 2017 SWAT Benthic Macroinvertebrate Biomonitoring Results (continued)

Waterbody	Town	Station	Log	Potential sources of pollution[1]	Statutory Class/ Final Determination	Attains Class?	Probable Cause
Bobbin Mill Brook	Auburn	357	2675	Urban NPS	B/I		Samplers Disturbed
Bowley Brook	Weld	1003	2674	Reference	B/A	Yes	
Cupsuptic River	Upper Cupsuptic TWP	999	2686	Reference	AA/A	Yes	
Ducktrap River	Lincolnville	1146	2652	Agriculture NPS/Ref	AA/A	Yes	
Ducktrap River	Lincolnville	626	2653	Reference	AA/B	No	Low Flow; Habitat
E. Br. Wesserunsett	Athens	486	2648	Long-term Monitoring	B/A	Yes	
East Brook	Weld	1002	2672	Reference	B/A	Yes	
Frye Brook	Andover West Surplus	1000	2678	Reference	A/I		Low Numbers, Resample.
Gully Brook	Auburn	695	2677	Urban NPS	B/NA	No	NPS Toxics; Habitat
Halfmoon Stream	Thorndike	697	2649	Agricultural NPS	A/C	No	Nutrients; Low Flow
Hall Brook	Thorndike	1147	2650	Sand/Salt Pile	A/C	No	Low Flow; NPS Toxics.
Kennebago River	Rangeley	868	2685	Reference	AA/A	Yes	
Little Androscoggin R.	Greenwood	1009	2680	NPS	A/A	Yes	
Little Androscoggin R.	Paris	43	2662	Municipal	C/A	Yes	
Little Androscoggin R.	Paris	79	2663	Municipal	C/A	Yes	
Little Androscoggin R.	Welchville/ Oxford	1001	2667	Municipal	C/A	Yes	
Little River	Belfast	850	2651	NPS	B/A	Yes	
Nezinscot River	Turner	860	2665	NPS	B/C	No	Low Numbers
Rangeley River	Rangeley	136	2683	Control	A/B	No	Lake Outlet
Rangeley River	Rangeley	137	2684	Hatchery	A/A	Yes	Lake Outlet
Sabattus River	Sabattus	629	2647	Municipal/Agric NPS	C/C	Yes	
Sabattus River	Sabattus	359	2646	Municipal/Agric NPS	C/C	Yes	
Sabattus River	Lisbon	170	2645	Urban NPS	B/C	No	Habitat; Nutrients
Stetson Brook	Lewiston	356	2676	NPS	B/A	Yes	
Sunday River	Newry	444	2682	Reference	A/A	Yes	
Sunday River	Bethel	354	2654	NPS	A/A	Yes	

[1] NPS, non-point source pollution.

Table 3.1.1b 2017 SWAT Benthic Macroinvertebrate Biomonitoring Results (continued)

Waterbody	Town	Station	Log	Potential sources of pollution[1]	Statutory Class/ Final Determination	Attains Class?[2]	Probable Cause
Swift River	Roxbury	346	2669	Reference	A/A	Yes	
Swift River	Rumford	345	2670	Urban NPS	B/B	Yes	
Tumbledown Brook	Weld	1142	2671	Reference	B/A	Yes	
Twitchell Brook	Greenwood	1141	2657	NPS	B/A	Yes	
Unnamed Stream	Lewiston	857	2644	Municipal Landfill	B/NA	No	NPS Toxics; In-Place Contamina-tion; Habitat
Unnamed Stream #4	Topsham	634	2658	Urban NPS	B/NA	No	NPS Toxics; Habitat
Unnamed Stream #4	Brunswick	643	2659	Urban NPS	B/NA	No	NPS Toxics; Habitat
W. Br. Ellis River	Andover	872	2679	Reference	A/A	Yes	
W. Br. Nezinscot R.	Sumner	664	2661	NPS	A/A	Yes	
W. Br. Sheepscot R	Whitefield	550	2643	NPS	AA/A	Yes	
W. Br. Sheepscot R.	China	268	2642	Long Term Monitoring	AA/B	No	Low Flow
Wild River	Gilead	103	2656	Reference	AA/A	Yes	

Table 3.1.2b 2018 SWAT Field Data

Measurements were obtained using handheld electronic meters. Highlighted values are of concern or do not attain criteria.

Site	Station	Log	Sample Deployment					Sample Retrieval				
			Date	Temperature Deg C	Dissolved Oxygen MG/L	Specific Conductance US/CM	pH STU	Date	Temperature Deg C	Dissolved Oxygen MG/L	Specific Conductance US/CM	pH STU
Androscoggin River	355	2655	7/16/2018	24	8.75	35.8	6.91	8/13/2018	22.4	9.26	35.4	6.63
Androscoggin River	954	2660	7/17/2018	25.2	8.85	100.9	7.23	8/14/2018	24.5	9.91	74.4	7.11
Androscoggin River	41	2668	7/23/2018	23.2	9.28	79.4	7.26	8/20/2018	22.8	9.95	70.3	7.29
Aunt Hannah Brook	343	2673	7/24/2018	19	9.92	49.3	6.97	8/22/2018	16.3	9.72	52.9	6.72
Bear River	866	2681	7/31/2018	17.9	10.62	35.7	6.74	8/28/2018	19.4	10.73	39.4	6.81
Bird Brook	340	2664	7/18/2018	21.6	**4.7**	77.6	6.61	8/15/2018	23	**2.62**	**104.5**	6.64
Bobbin Mill Brook	357	2675	7/26/2018	21.7	9.51	**332.8**	7.97	8/23/2018	17.9	10.59	**407.6**	8.21
Bowley Brook	1003	2674	7/24/2018	21.5	9.79	46.4	7.5	8/22/2018	17.4	10.36	45.9	7.34
Cupsuptic River	999	2686	7/30/2018	17.4	10.26	22.2	6.89	8/29/2018	20.4	9.78	27	6.94
Ducktrap River	1146	2652	7/12/2018	19.5	9.09	66	6.85	8/9/2018	22.8	8.17	70.9	6.82
Ducktrap River	626	2653	7/12/2018	19.9	7.37	59.5	6.68	8/9/2018	23.4	**5.95**	61.9	6.57
E. Br. Wesserunsett	486	2648	7/11/2018	20.2	9.91	78.6	8.06	8/8/2018	23.3	9.54	49.1	7.42
East Brook	1002	2672	7/24/2018	19.4	9.93	47.2	7.05	8/22/2018	16.9	10.23	45.9	7.05
Frye Brook	1000	2678	8/1/2018	17.3	10.33	19.5	6.85	8/27/2018	17.8	10.43	22.9	6.88
Gully Brook	695	2677	7/26/2018	19	8.16	**618**	7.55	8/23/2018	15.5	9.5	**537**	7.72
Halfmoon Stream	697	2649	7/11/2018	23.9	11	138.3	8.29	8/8/2018	**28.8**	11.29	159.5	8.52
Hall Brook	1147	2650	7/11/2018	19.5	9.68	131.6	7.69	8/8/2018	21.5	7.42	**284.4**	6.99
Kennebago River	868	2685	7/30/2018	21.8	9.55	27.2	7.72	8/29/2018	22.3	9.58	33.7	6.95
Little Androscoggin R.	1009	2680	7/31/2018	21.3	10.02	65.1	6.99	8/28/2018	23.2	9.8	69.5	6.85
Little Androscoggin R.	43	2662	7/18/2018	22.7	8.99	134.5	6.96	8/15/2018	23.1	9.44	105.8	6.86
Little Androscoggin R.	79	2663	7/18/2018	21.9	9.03	148.4	6.99	8/15/2018	23	9.75	113.7	6.94
Little Androscoggin R.	1001	2667	7/19/2018	21.9	8.71	128.2	7.09	8/16/2018	24.8	8.94	113.1	6.98
Little River	850	2651	7/12/2018	17.5	10.3	105.1	7.33	8/9/2018	21.3	8.93	133.3	7.25

Table 3.1.2b 2018 SWAT Field Data (continued)

Site	Station	Log	Sample Deployment					Sample Retrieval				
			Date	Temperature Deg C	Dissolved Oxygen MG/L	Specific Conductance US/CM	pH STU	Date	Temperature Deg C	Dissolved Oxygen MG/L	Specific Conductance US/CM	pH STU
Nezinscot River	860	2665	7/19/2018	23.5	8.34	102.7	7.08	8/16/2018	23.4	8.56	86.7	6.9
Rangeley River	136	2683	7/30/2018	21.9	9.36	42.5	7.25	8/29//2018	21.5	9.61	42.5	6.84
Rangeley River	137	2684	7/30/2018	22.7	9.57	43.5	7.09	8/29/2018	21.8	9.86	43.6	6.94
Sabattus River	629	2647	7/10/2018	24.9	8.18	105.4	7.19	8/7/2018	**27.8**	9.57	112.9	7.3
Sabattus River	359	2646	7/10/2018	24.6	8.36	**198.4**	7.37	8/7/2018	25.4	8.53	**260**	7.08
Sabattus River	170	2645	7/10/2018	25.9	9.62	**219.1**	8.04	8/7/2018	27	9.45	**255.5**	7.5
Stetson Brook	356	2676	7/26/2018	21.8	8.99	**190.4**	7.5	8/23/2018	17.6	10.1	**157.5**	7.44
Sunday River	444	2682	7/31/2018	18.5	9.81	22.7	6.27	8/28/2018	19.6	10.1	25.7	6.41
Sunday River	354	2654	7/16/2018	20.3	8.57	35.9	6.31	8/13/2018	18.5	9.52	35.1	6.27
Swift River	346	2669	7/23/2018	19.8	9.77	43	6.38	8/20/2018	18.5	10.81	32.2	6.89
Swift River	345	2670	7/23/2018	21.5	10.25	63.8	6.94	8/20/2018	19.8	10.7	40.6	6.7
Tumbledown Brook	1142	2671	7/24/2018	17.9	10.18	30	7.08	8/22/2018	16.3	10.85	28.3	6.7
Twitchell Brook	1141	2657	7/16/2018	25.1	9.65	53	7.4	8/13/2018	20.6	10.84	46.2	7.51
Unnamed Stream	857	2644	7/10/2018	18.1	7.09	**1046**	7.57	8/7/2018	20.4	7.9	**956**	7.65
Unnamed Stream #4	634	2658	7/17/2018	15.2	9.61	**941**	6.73	8/13/2018	16.1	9.81	**1082**	6.82
Unnamed Stream #4	643	2659	7/17/2018	15.7	10	**350.2**	7.09	8/14/2018	16	10.33	**351.1**	7.03
W. Br. Ellis River	872	2679	8/1/2018	18	10	40	6.5	8/27/2018	17.9	10.06	45	7.1
W. Br. Nezinscot R.	664	2661	7/18/2018	20.2	8.57	39.1	6.81	8/15/2018	21.8	8.92	38.3	6.57
W. Br. Sheepscot R.	550	1643	7/9/2018	23.6	8.77	135.1	7.67	8/6/2018	24	9.42	174.1	7.76
W. Br. Sheepscot R.	268	2643	7/9/2018	19	8.61	104.3	7.4	8/6/2018	20.4	8.84	145.8	7.47
Wild River	103	2656	7/16/2018	19.9	9.79	19.5	6.67	8/13/2018	20	10.19	16.3	6.45

Table 3.1.3b 2018 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	TKN *(MG/L)*	NO2-NO3-N *(MG/L)*	Total P *(µg/L)*	SRP *(µg/L)*
Androscoggin River	954	2660	7/17/2018	0.3	0.15	19	2
Androscoggin River	41	2668	6/19/2018	0.2	0.08	21	1
Aunt Hannah Brook	343	343	6/19/2018	0.3	0.06	22	2
Cupsuptic River	999	2686	7/02/2018	0.2	0.06	14	1
Frye Brook	1000	2678	7/25/2018	0.3	0.02	6	2
Gully Brook	695	2677	7/18/2018	**1.0**	**1.1**	**44**	5
Little Androscoggin River	43	2662	7/09/2018	0.2	0.13	15	1
Little Androscoggin River	79	2663	7/09/2018	0.4	0.15	23	3
Little Androscoggin River	1001	2667	7/23/2018	0.2	0.09	13	1
Little Androscoggin River	1009	2680	6/26/2048	0.2	0.04	17	1
Sabattus River	170	2645	6/20/2018	0.6	0.12	**49**	1
Sabattus River	629	2647	6/20/2018	0.6	0.08	**53**	**11**
Stetson Brook	356	2676	06/25/2018	0.4	0.18	**46**	**6**
Sunday River	354	2654	07/24/2018	0.2	0.04	6	1
Swift River	345	2670	06/27/2018	0.1	0.03	8	1
Swift River	346	2669	6/27/2018	0.2	0.03	4	1
Twitchell Brook	1141	2657	6/26/2018	0.2	0.02	11	1
Unnamed Stream	857	2644	6/25/2018	0.9	**1.20**	17	3
West Branch Sheepscot River	268	2642	6/18/2018	0.4	0.26	16	3
West Branch Nezinscot River	664	2661	7/11/2018	0.3	0.02	26	1

TKN = Total Kjeldahl-Nitrogen, NO_2-NO_3-N = Nitrite-Nitrate-Nitrogen, Total P = Total Phosphorus, SRP = Soluble Reactive Phosphorus (ortho-phosphate), "<" = constituent not detected at the reporting limit.

Figure 3.1.1b 2018 In-Stream Continuous Temperature Data

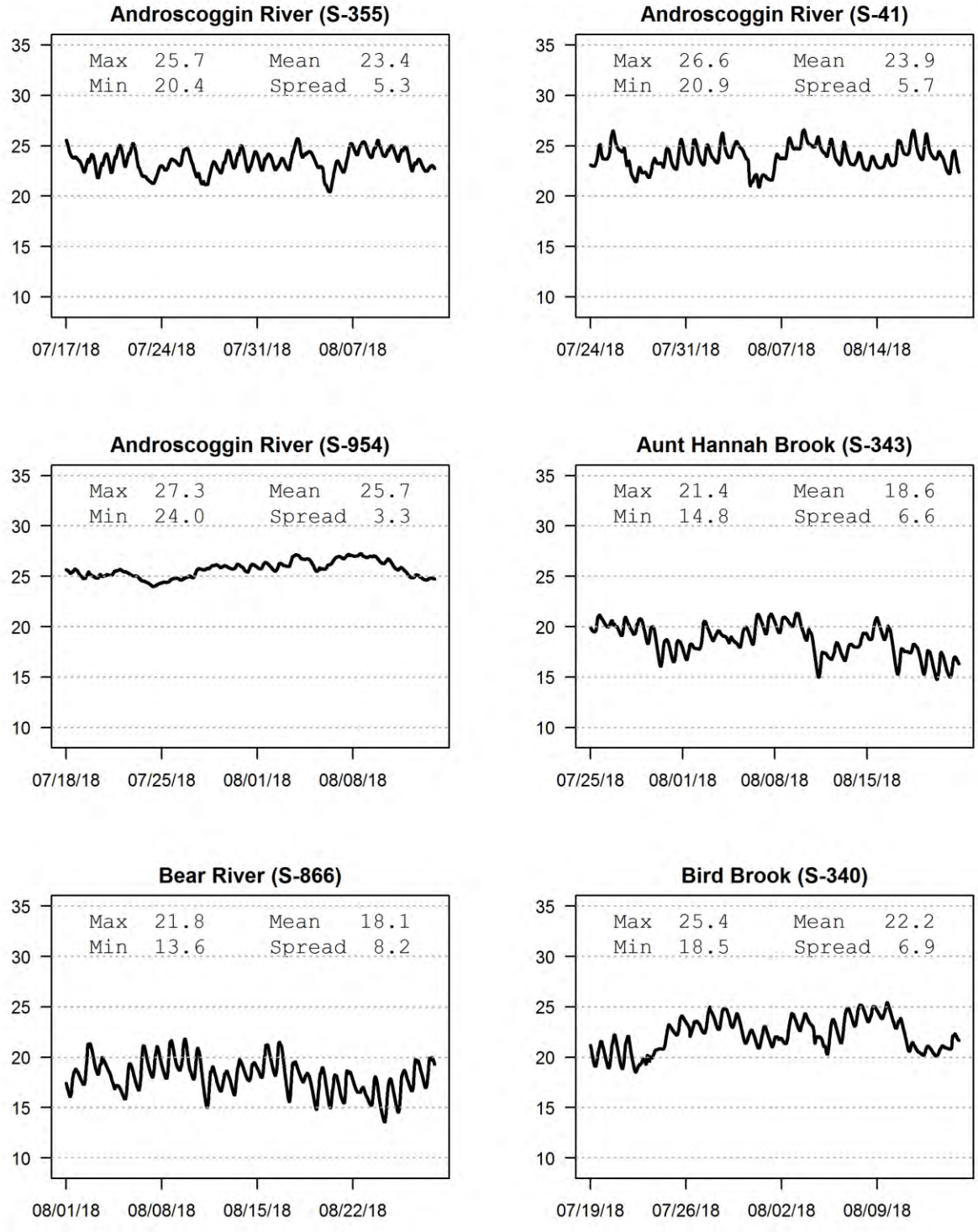


Figure 3.1.1b 2018 In-Stream Continuous Temperature Data (continued)

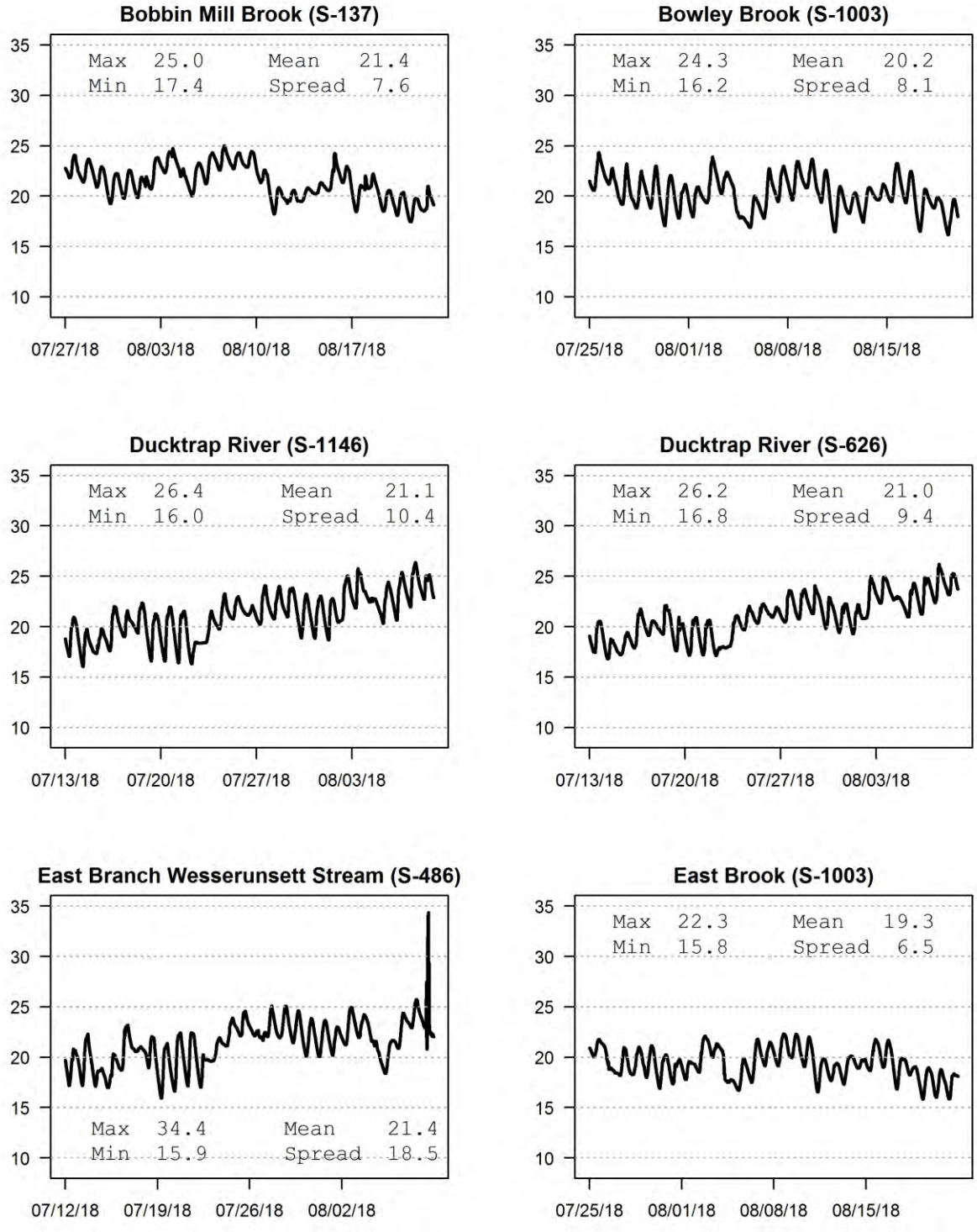


Figure 3.1.1b 2018 In-Stream Continuous Temperature Data (continued)

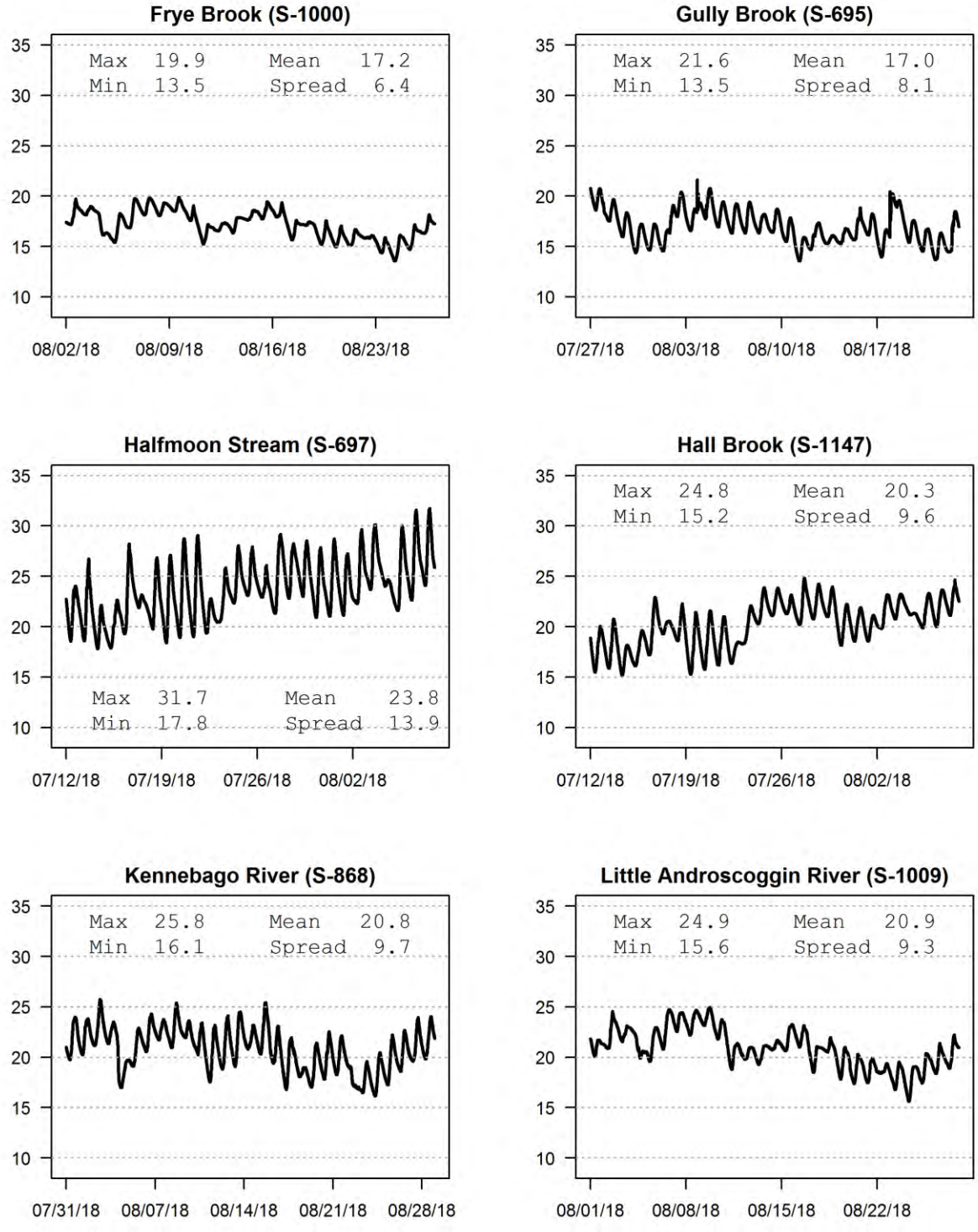


Figure 3.1.1b 2018 In-Stream Continuous Temperature Data (continued)

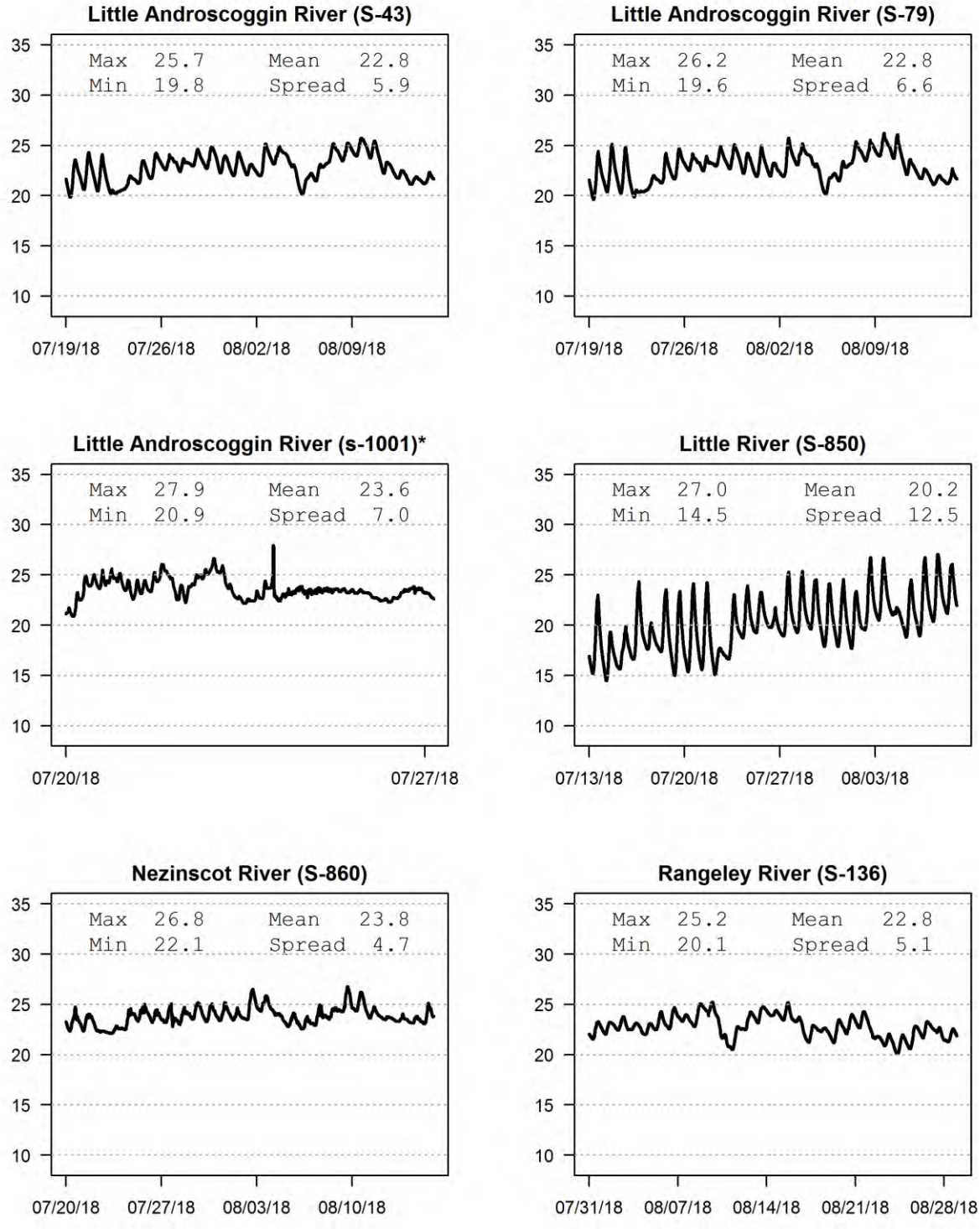
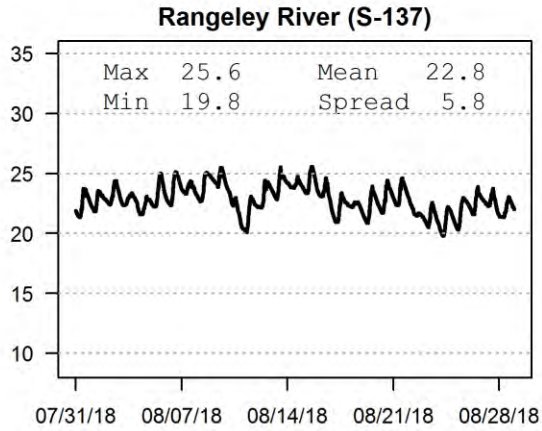
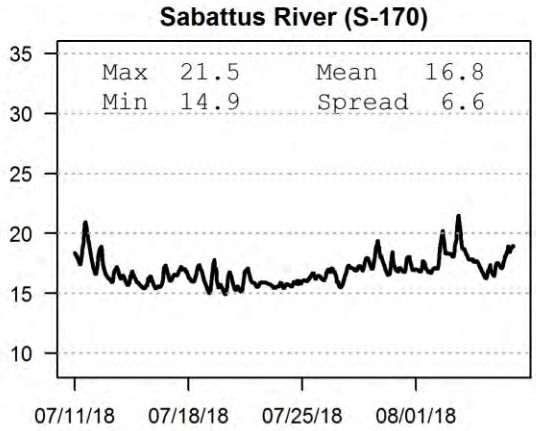
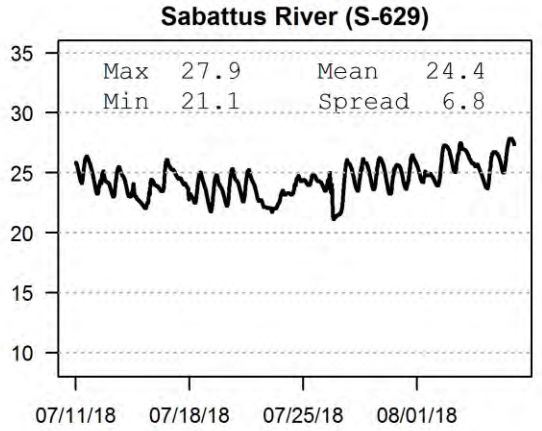
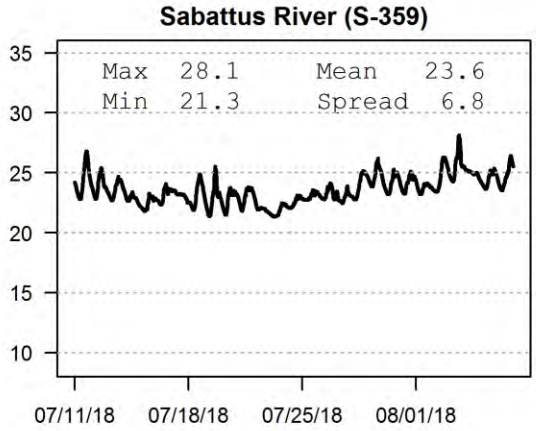


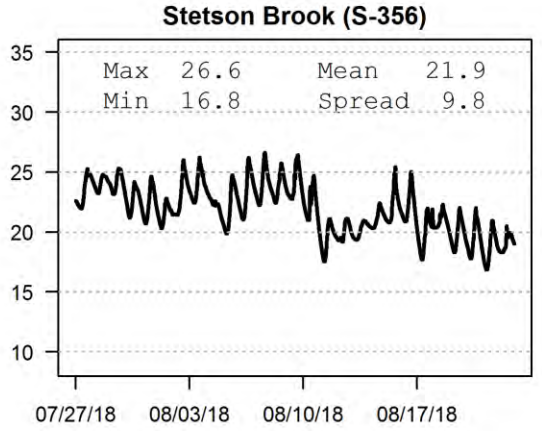
Figure 3.1.1b 2018 In-Stream Continuous Temperature Data (continued)











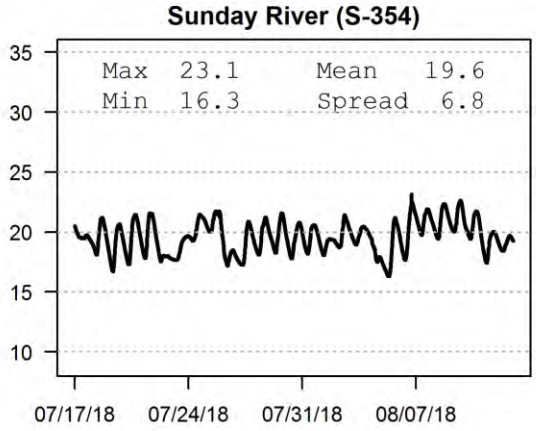


Figure 3.1.1b 2018 In-Stream Continuous Temperature Data (continued)

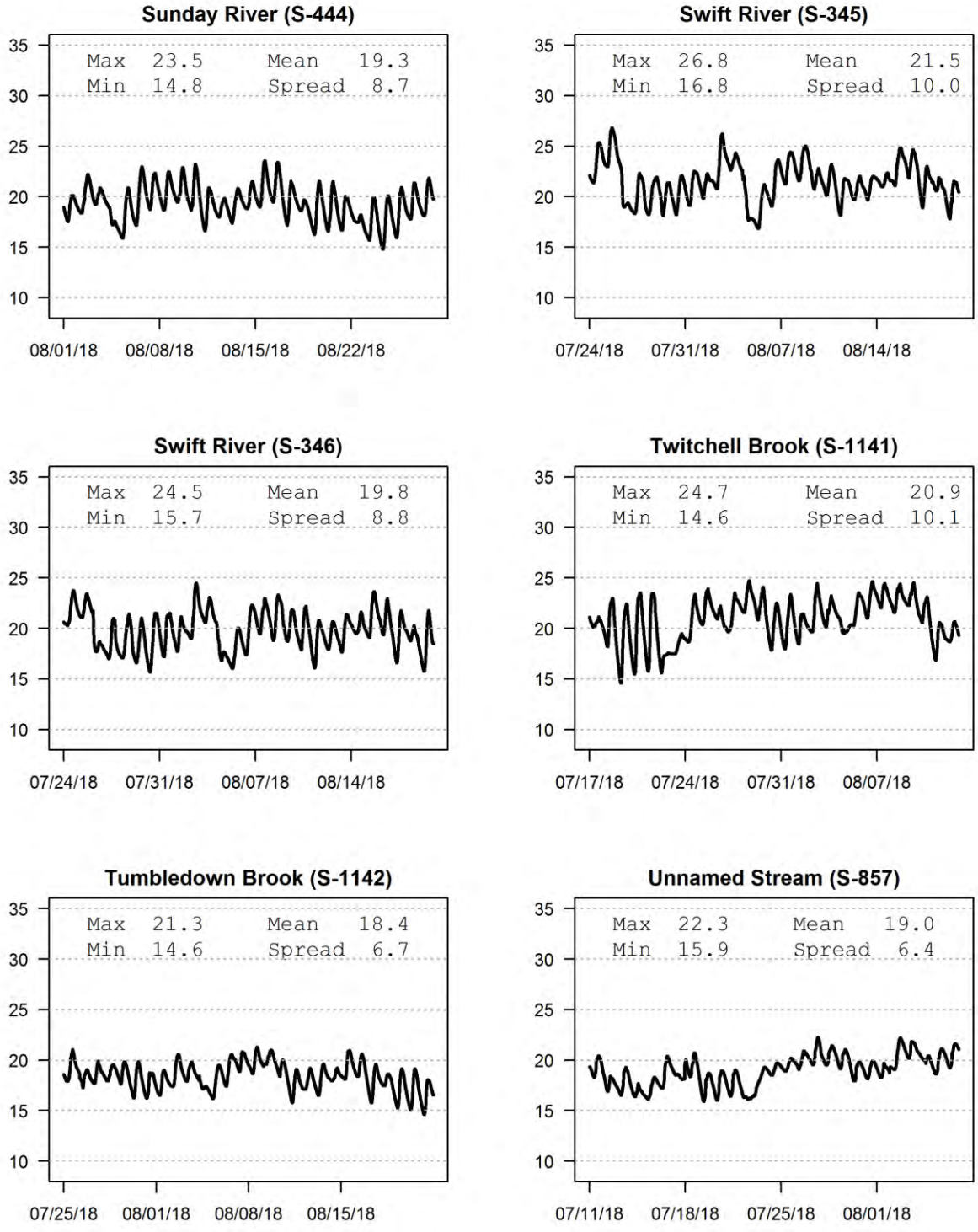


Figure 3.1.1b 2018 In-Stream Continuous Temperature Data (continued)

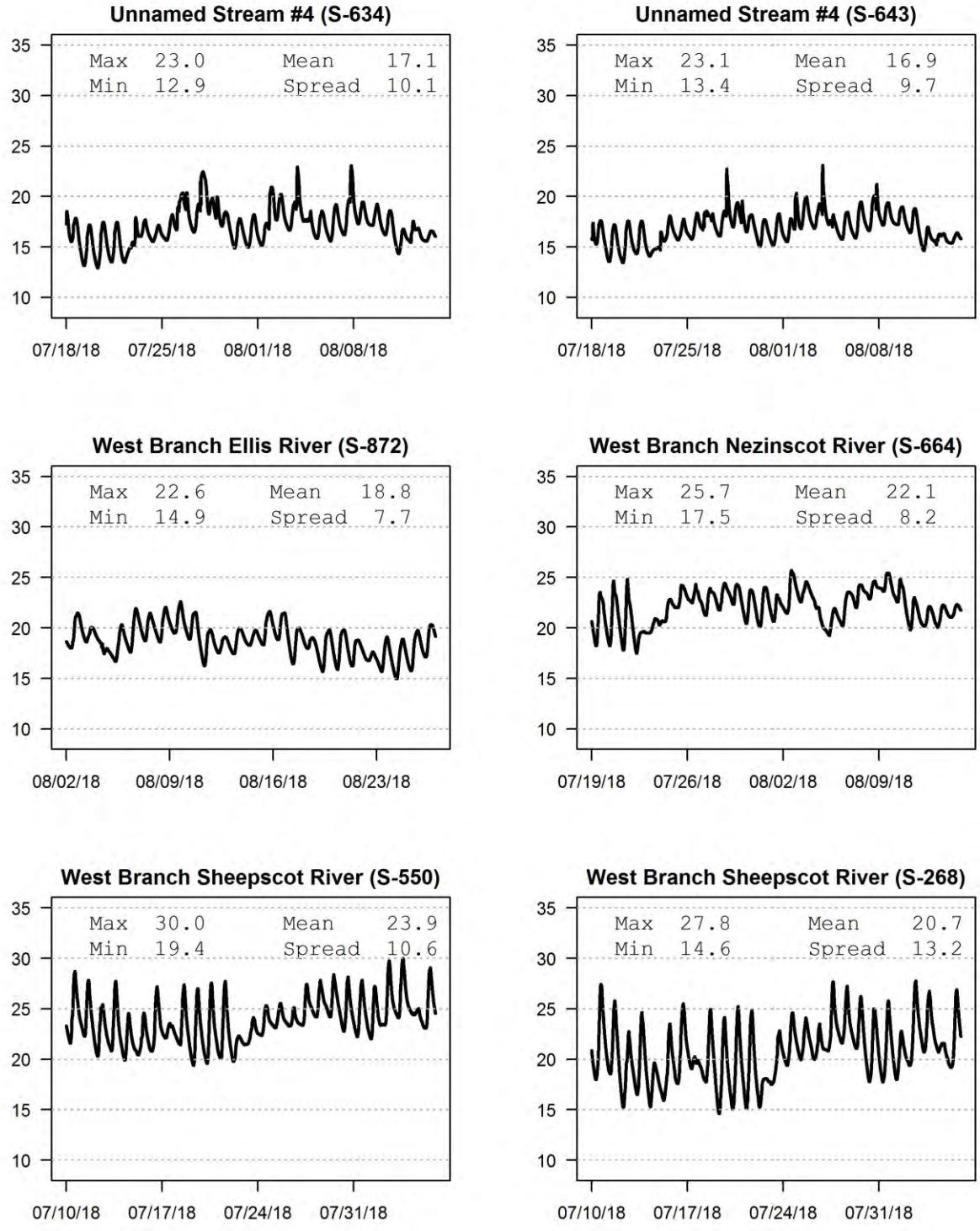


Figure 3.1.1b 2018 In-Stream Continuous Temperature Data (continued)

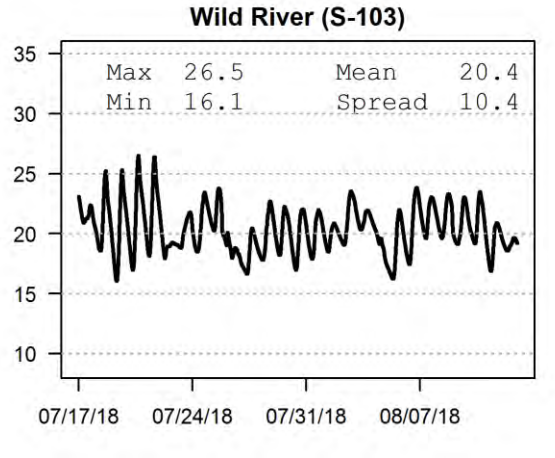


Table 3.1.4b Past Attainment History

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

Waterbody	Station	Attained Class	Did not Attain Class	Indeterminate Result
Androscoggin River	355	1998, 2003, 2008, 2013		
Androscoggin River	954	2010		
Androscoggin River	41	1983, 1994, 1998, 2003		
Aunt Hannah Brook	343	1998, 2003, 2008, 2013		
Bear River	866	2008, 2013		
Bird Brook	340	2008	1998, 2003	
Bobbin Mill Brook	357	2003, 2008, 2013	1998	
Bowley Brook	1003	2013		
Cupsuptic River	999	2013		
Ducktrap River	626	2007, 2012	2002, 2016, 2017	
East Branch Wesserunsett	486	2001, 2007, 2012-2017		
East Brook	1002	2013		
Frye Brook	1000	2013		
Gully Brook	695	2003, 2008		
Halfmoon Stream	697	2003, 2007	2012-2017	
Kennebago River	868	2008, 2013		

Table 3.1.4b Past Attainment History (continued)

Waterbody	Station	Attained Class	Did not Attain Class	Indeterminate Result
Little Androscoggin R.	43	1998, 2003, 2008, 2013		
Little Androscoggin R.	79	1998, 2003, 2008, 2013		
Little Androscoggin R.	1001	2013		
Little River	850	2007	2017	
Martin Stream	693	2003, 2008, 2013		
Nezinscot River	860	2008, 2013		
Sabattus River	629	2002, 2003, 2008, 2013		
Sabattus River	359	1998, 2008, 2013		
Sabattus River	170	2010	1998, 2003, 2008	2013
Sheepscot River	74	1987 - 1990, 1992, 1995, 1996, 1998 - 2017	1984-1986, 1991, 1993, 1994, 1997	
Stetson Brook	356	1998, 2008, 2013		
Sunday River	444	2008, 2013	2000, 2003	
Sunday River	354	2000, 2003, 2008, 2013	1998	
Swift River	346	1998, 2003	2013	2008
Swift River	345	1998, 2003, 2013		
Unnamed Stream	857		2008, 2013	
Unnamed Stream #4	634	2002, 2006	2008, 2014	2013
Unnamed Stream #4	643		2002, 2008	
W. Br. Ellis River	872	2008, 2013		
W. Br. Nezinscot R.	664	2003, 2008, 2013		
W. Br. Sheepscot R.	268	1996-1999, 2001, 2002, 2005, 2007, 2009, 2010-2017	2000, 2003, 2004, 2006, 2008	1995
W.Br. Sheepscot R.	550	2015, 2017		
Wild River	103	1987, 2008, 2013		

3.2 ST CROIX RIVER SEDIMENTS

3.2.1 Introduction

As required by EPA, Maine has adopted ambient water quality criteria (AWQC) for toxic pollutants by rule at CMA 06-096 Chapter 584 to be used in calculation of effluent limits for dischargers (see http://www.maine.gov/sos/cec/rules/06/chaps06.htm). AWQC for heavy metals are expressed as total metal, even though the most bioavailable and toxic specie are ionic forms. Use of total metal provides some margin of safety for various uncertainty factors. The AWQC are developed according to EPA guidelines to include toxicity data, usually from laboratory studies, from 8 families of aquatic organisms. Chapter 584 also allows development of site specific criteria (SSC) generally following EPA guidance with additional requirements specified in the rule. The development of SSC is usually initiated by a discharger with the recognition that for heavy metals, some is bound to particles and therefore not bioavailable or toxic; their goal is to determine the amount of total metal that can be safely discharged to the receiving stream, so their discharge permits can be modified accordingly. One concern is that an increase in total metal discharged to a waterbody may result in an increased in sediment concentrations and have negative effects on aquatic organisms in the sediment that is not evaluated by AWQC, which addresses only water column toxicity. According to EPA (2005)

Toxic contaminants in bottom sediments of the nation's lakes, rivers, wetlands, and coastal waters create the potential for continued environmental degradation even where water column contaminant levels meet applicable water quality standards. In addition, contaminated sediments can lead to water quality impacts, even when direct discharges to the receiving water have ceased.

The AWQC for many metals are functions of hardness. Most Maine rivers that receive discharges have relatively soft water. Consequently, DEP uses a default value for total hardness of 20 mg/l CaCO3 for calculation of AWQC for those metals. One method for development of SSC for metals is to use a site-specific total hardness value. To address potential seasonal variability, DEP requires total hardness to be measured at least monthly over a period of a year. Although increased hardness reduces the amount of dissolved metal responsible for toxicity in the water column, total loading of metals to the receiving water system would not be reduced, but in fact be increased. Much of the increased metal could precipitate or sorb to particles and settle out to the sediments downstream, where it could be toxic to benthic organisms. To account for this uncertainty and provide a margin of safety, DEP has required measurement of site-specific hardness upstream of discharges. Dischargers have requested that hardness be measured downstream of their discharges to better represent actual conditions. EPA recommended the downstream sample location, but agreed that states could make their own determination.

Another method for developing SSC for copper is Use of EPA's BLM (Biotic Ligand Model). The BLM uses measurements of 10 water quality variables (temperature, alkalinity, calcium, magnesium, sodium, sulfate, potassium, chloride, dissolved organic carbon, and pH) to calculate the bioavailable fraction of copper to be used as the basis for the permit limit. There are draft BLMs for other metals as well. The BLM also raises concern for the potential effects of increased loading of total copper to the sediments.

Recently, DEP developed DETOX, a mass balance based waste load allocation model for toxic pollutants, which allocates waste loads of specific pollutants among all the dischargers to a waterbody to ensure that the AWQC are not exceeded anywhere in the waterbody. Application of DETOX to the St. Croix River identified the discharge of several heavy metals from multiple dischargers that would result in exceedance of the AWQC in at least one reach of the river. One of the dischargers, Woodland Pulp, initiated development of SSC for these metals using downstream site-specific total hardness and or the BLM.

To address sediment contamination and the effects on aquatic biota, there are several methods that have been used. Bulk sediments may be analyzed for total metal and results compared to SQC or guidelines (MacDonald et al. 2000). Total metals are not always biologically available, however, and have not always been predictive of sediment toxicity. It is the dissolved metal (and to a much lesser extent some other metal compounds such as metal hydroxides) that account for toxicity. To better address bioavailability and toxicity, EPA suggests use of the Equilibrium Partitioning (EqP) approach, and development of Equilibrium partitioning Sediment Benchmarks (ESBs) (EPA, 2005). Two approaches are proposed for establishment of ESBs.

One is measurement of sediment pore water and comparison to AWQC. In this approach, sediments containing these should not cause direct toxicity to benthic organisms if the sum of the dissolved interstitial water concentrations for each of the metals ($\sum M_{i,d}$) divided by their respective Water Quality Criteria (WQC) Final Chronic Value (FCV) is ≤ 1.0. Sampling sediment interstitial water for metals is not a routine procedure. The least invasive technique employs a diffusion sampler that has cavities covered with a filter membrane. The sampler is inserted into the sediment and the concentrations on either side of the membrane equilibrate. Because the sampler is removed after equilibration, the concentrations of metals inside the sampler should be equal to the concentrations of freely-dissolved metals in the interstitial water. The time required for equilibration, typically several days, depends on the size of the filter membrane and the geometry of the cavity. An alternative technique for separating interstitial water is to obtain an undisturbed sediment sample as a whole sediment or core that can be sliced for vertical resolution, filter or centrifuge the sample, and then filter the resultant interstitial water twice. For anaerobic sediments, this must be done in a nitrogen atmosphere to prevent precipitation of iron hydroxide, which would scavenge the metals and yield artificially low dissolved concentrations of metals (EPA, 2005).

Another method is use of the ratio of simultaneously extracted metals and acid volatile sulfides (SEM-AVS), which has been used to predict the combined sediment toxicity of copper (Cu), cadmium (Cd), nickel (Ni), lead (Pb), silver (Ag), and zinc (Zn) (Ankley et al. 1996; Berry et al. 1996). Research indicates that the amount of AVS present in sediment limits the metal bioavailability and subsequent toxicity in sediments. Sulfide is an important binding component in modeling metal sorption in sediments (Morse et al. 1987). In the presence of excess sulfide, most of the reactive metal will form insoluble metal sulfides. The AVS becomes an indicator of the ratio of available sulfide to the SEM metals and allows the partitioning of free aqueous phase metal and solid phase metal in sediments. Silver (Ag) and the five divalent metals (Cd, Ni, Cu, Pb and Zn) form metal sulfide complexes. If the molar ratios of the SEMs are greater than that of the AVS, the excess fraction of the metals may be considered to have a high potential for

bioavailability. For divalent metals, one mole of SEM will react with one mole of AVS, whereas for silver one mole of SEM will bind two moles of Ag. These metals should not cause direct toxicity to benthic organisms if the ∑SEM-AVS is ≤0. Uncertainty bounds on ∑SEM-AVS f_{OC} can be used to identify sediments where toxicity, because of these metals, is unlikely, uncertain, or likely. If the ∑SEM-AVS is >0 or $\sum M_{i,d}$ divided by their respective FCVs is >1, effects may occur with increasing severity as the degree of exceedance increases. Toxicity may be estimated from the excess SEM normalized to the fraction of organic carbon (fOC). Toxicity is likely when ∑SEM-AVS)/fOC>3000 umol/g OC, uncertain between 130 and 3000 umol/g OC, and unlikely <130 umol/g OC (EPA, 2005). In addition to varying with depth, AVS can vary seasonally. For example, in systems where overlying water contains appreciable oxygen during cold-weather months, AVS tends to decrease, presumably because of a constant rate of oxidation of the AVS linked to a decrease in its generation by sulfate-reducing bacteria. Because of potential temporal and spatial variability of AVS, it appears that the way to avoid possible underestimation of metal bioavailability is to sample the biologically "active" zone of sediments at times when AVS might be expected to be present at low concentrations. It is recommended that, at a minimum, AVS and SEM measurements be made using samples of the surficial (0 to 2.0 cm) sediments during the period from November to early May. (EPA, 2005)

Assessment of attainment of Maine's Water Quality Standards is the goal of this study, particularly effects of contaminated sediments on 'habitat for fish and other aquatic life'.

3.2.2 Methods

Due to delays in contracting, sampling was not attempted originally until early December 2016, by which time the preferred sample stations had unsafe ice cover. Secondary stations were sampled but did not provide acceptable samples. Sampling was rescheduled for March 2017 on ice, but an early thaw again provided unsafe ice cover and prevented sampling. Sampling finally occurred during low river flow on October 12, 2017. Duplicate sediment samples were collected upstream of the Woodland Pulp Inc pulp and paper mill (station SCA), from the southwest cove of the Woodland Impoundment approximately 100 m below the boat ramp. Duplicate samples were also collected below the mill (station SCB) from a small cove on the western shore approximately 40 m upstream of the train trestle in Baring.

Sediments were collected with a pre-cleaned Eckman dredge and the top 2 cm were collected from the center of the dredge to avoid contact with it. Each sediment sample was divided into two sealed airtight clean glass jars, one for analysis for grain size and total organic carbon, and one for analysis of SEM-AVS and total metals. Enough sediment was collected to fill each jar. Samples were kept on ice and transported to the lab where they were kept at 4° C until shipped on ice to the US Department of Energy's Pacific Northwest National Laboratory operated by Battelle to be analyzed for total metals, SEM-AVS, percent moisture, grain size, and total organic carbon.

Sediment samples were also collected with the dredge for macroinvertebrate community assessment. One dredge sample was placed into a wash bucket to remove fine grain sediments. The remaining material was transferred into a 1 quart Mason canning jar and preserved with 95%

alcohol. Later the samples were sorted to separate the debris from aquatic organisms which were then examined for identification and enumeration.

3.2.3 Results and Discussion

The potential toxicity of the sediments was evaluated by comparisons between both stations by three methods, 1) comparison of the concentrations of metals in the bulk sample to sediment quality guidelines (MacDonald et al 2000) and (2) AVS-SEM, and 3) evaluation of the macroinvertebrate community structure. A suitable site upstream of the mill at SCA was easily accessible and two replicates were collected, one each from the port and starboard side of the anchored boat. Access downstream of the mill was limited and it was difficult to find a suitable depositional site as most of the river below the mill is fast flowing and eroding. The best depositional site accessible was adjacent to the west shore in a small cove and was sampled by wading. Several dredge samples were needed to get enough of what appeared to be fine grained sediment, as often sticks, leaves, and gravel were predominant in the dredge sample.

Grain Size Analysis

Since contaminants such as heavy metals sorb to fine grained sediments, to aid interpretation of the reulsts, sediments from each sample was analyzed for grain size.

Grain size distribution was not homogenous between replicates or sites. Correspondence between replicates was poorer at SCA than at SCB, but mean % Total Fines was significantly higher upstream of the mill at SCA than below the mill at SCB where there was a greater percentage of gravel and sand (Table 3.2.1). These differences were considered in interpretation of potential sediment toxicity from the metals as discussed below.

Table 3.2.1. Grain size in St Croix River sediments, 2017

STATION Variable	SCA-1 rep 1	SCA-2 rep 2	SCA ave		SCB-1 rep 1	SCB-2 rep 2	SCB ave
Cobbles	**ND**	**ND**	**ND**		**ND**	**ND**	**ND**
% Coarse Gravel	ND	ND	ND		ND	ND	ND
% Fine Gravel	2.5	4.1	3.3		10.2	10	10.1
% Total Gravel	**2.5**	**4.1**	**3.3**		**10.2**	**10**	**10.1**
% Coarse Sand	11.2	26.8	19.0		13.1	4.2	8.7
% Medium Sand	21.4	53.2	37.3		31.3	20.2	25.8
% Fine Sand	15.7	12.7	14.2		33.2	47.3	40.3
% Total Sand	**48.3**	**92.7**	**70.5**		**77.6**	**71.7**	**74.7**
% Silt Fine	20.3	1.1	10.7		4.2	9.1	6.7
% Clay Fine	28.9	2.1	15.5		8	9.2	8.6
% Total Fines	**49.2**	**3.2**	**26.2**		**12.2**	**18.3**	**15.3**

Bulk Sample Chemistry

Concentrations of five metals (Cd, Cu, Ni, Pb, and Zn) were compared to threshold effects concentrations (TEC) and probable effects concentrations (PEC) determined by consensus of leading researchers in the field (MacDonald et al. 2000). TECs are concentrations of metals in bulk sediments below which there were negative effects in less than 25% of sediments in studies from the literature and are unlikely to cause adverse effects on aquatic biota. PECs are concentrations in bulk sediments above which there were effects in more than 75% of the sediments studied and above which adverse effects are probable.

The results showed reasonably good correspondence between replicates at both stations (Table 3.2.2). There were higher levels of cadmium and zinc downstream of the mill despite fewer fines. But no metals had concentations exceeding the PEC. Nickel concentrations slightly exceeded the TEC at both SCA and SCB and zinc concentrations slightly exceeded the TEC at SCB. None of these results suggest likely toxicity of these metals at either station.

Table 3.2.2. Total metals in St Croix River sediments, 2017

	Cd	Cu	Ni	Pb	Zn
[1]TEC ug/g dw	0.99	31.6	22.7	35.8	121
PEC ug/g dw	4.98	149	48.6	128	459
	ug/g dw	ug/g dw	ug/g dw	ug/g dw	ug/g dw
SCA-1	0.325	15.4	32.4	23.2	90.1
SCA-2	0.330	15.3	32.5	22.6	89.7
SCA-2	0.352	15.8	32.6	23.7	90.4
ave SCA2	0.341	15.6	32.5	23.1	90.1
MEAN	**0.333**	**15.5**	**32.5**	**23.1**	**90.1**
SCB-1	0.593	14.8	22.8	20.4	123
SCB-2	0.638	18.2	26.4	26.7	145
MEAN	**0.615**	**16.5**	**24.6**	**23.5**	**134**

[1] TEC= threshold effect concentration, PEC = probable effect concentration.
From MacDonald et al. 2000
exceeds TEC

SEM-AVS

The sum of simultaneously extracted metals minus acid volatile sulfides (∑SEM-AVS) was negative for all samples) demonstrating that all metal would be bound to AVS and not bioavailable to exert toxicity (Table 3.4.3. Mean ∑SEM-AVS normalized to organic carbon (∑SEM-AVS)/fOC were also negative and therefore well below the threshold where toxicity is unlikely (<130 umol/$g_{oc)}$. These results corroborate and are a necessary result of the total metals finding of low probability of toxicity of these metals at these two stations.

Table 3.2.3. Simultaneously extracted metals - acid volatile sulfides (SEM-AVS) in sediments from St Croix River 2017

SAMPLE ID	∑ SEM (µmole/g DW)	AVS (µmole/g DW)	∑ SEM-AVS (µmole/g DW)	[1]fOC	(SEM-AVS)/fOC (µmole/g_{oc})
SCA					
SCA1	1.12	3.41	-2.295	0.064	-36.0
SCA2	0.86	2.86	-1.999	0.068	-29.6
MEAN	**0.99**	**3.13**	**-2.15**	**0.066**	**-32.8**
SCB					
SCB1	2.06	3.48	-1.420	0.133	-10.7
SCB2	1.61	6.20	-4.588		
SCB2	1.29	5.35	-4.061		
ave SCB2	1.45	5.77	-4.324	0.051	-85.1
MEAN	**1.75**	**4.63**	**-2.87**	**0.092**	**-47.9**
[1]fOC = fraction of organic carbon					

Although the % fines were lower at SCB than SCA, which may have resulted in lower metals concentrations than would occur if the % fines were higher, the concentrations are far below toxic thresholds for both total metals and SEM-AVS. Furthermore, there does not appear to be a significant depositional area below the mill until perhaps downstream in the Calais impoundment. Although the Calais impoundment was not sampled, it represents a small portion of the river below the mill; consequently, it is unlikely that there is significant toxicity in the sediments of the river.

The macroinvertebrate community was not significantly different above (SCA) than below (SCB) the mill (Figure 3.2). Total Abundance, Total Richness (number of taxa), and Total EPT (number of sensitive mayfly, stonefly, and caddisfly taxa) were quite similar between these two stations. These data corroborate the results of the metals analyses.

Figure 3.2. Macroinvertebrates from the St Croix River above (SCA) and below (SCB) Woodland Pulp, 2017.			
SC-A		**SC-B**	
Taxa	**Count**	**Taxa**	**Count**
Amphipoda	88	Amphipoda	128
Annelida:Oligochaeta	-	Annelida:Oligochaeta	2
Ceratopogonidae	-	Ceratopogonidae	34
Chaoboridae	-	Chaoboridae	1
Coleoptera:Elmidae	7	Coleoptera:Elmidae	-
Coleoptera:Elmidae:Dubiraphia	3	Coleoptera:Elmidae:Dubiraphia	-
Diptera:Chironomidae	272	Diptera:Chironomidae	212
Hirudinae	2	Hirudinae	1
Hydracarina	-	Hydracarina	2
Malacostrace: Isopoda	-	Malacostrace: Isopoda	1
Ephemeroptera:Caenidae	6	Ephemeroptera:Caenidae	10
Ephemeroptera:Ephemeridae:*Hexagenia sp.*	-	Ephemeroptera:Ephemeridae:*Hexagenia sp.*	1
Mollusca:Gastropoda:Ancylidae	1	Mollusca:Gastropoda:Ancylidae	-
Mollusca:Gastropoda:planorbidae	2	Mollusca:Gastropoda:planorbidae	-
Mollusca:Gastropoda:Snails(dextral)	5	Mollusca:Gastropoda:Snails(dextral)	6
Mollusca:Pelecypoda:Fingernail clams	12	Mollusca:Pelecypoda: fingernail clams	9
Nematomorpha	-	Nematomorpha	3
Neuroptera:Sialidae:Sialis Latreille	9	Neuroptera:Sialidae:Sialis Latreille	-
Neuroptera:Sisyridae	-	Neuroptera:Sisyridae	1
Odonata:Anisoptera:Aeshnidae	1	Odonata:Anisoptera:Aeshnidae	-
Odonata:Anisoptera:Gomphidae	1	Odonata:Anisoptera:Gomphidae	-
Odonata:Anisoptera:Libellulidae	1	Odonata:Anisoptera:Libellulidae	-
Odonata:Zygoptera:Coenagrionidae	2	Odonata:Zygoptera:Coenagrionidae	1
Trichoptera:Hydroptilidae	-	Trichoptera:Hydroptilidae	2
Trichoptera:Hydroptilidae: *Oxyethira sp.*	-	Trichoptera:Hydroptilidae: *Oxyethira sp.*	1
Trichoptera:Leptoceridea	-	Trichoptera:Leptoceridea	5
Trichoptera:Molannidae(cf.)	1	Trichoptera:Molannidae(cf.)	-
Trichoptera:Odontoceridae	3	Trichoptera:Odontoceridae	-
Trichoptera:Polycentropodidae	7	Trichoptera:Polycentropodidae	2
Total Abundance:	**423**	**Total Abundance:**	**422**
Total Richness:	**18**	**Total Richness:**	**19**
Total EPT:	**4**	**Total EPT:**	**6**

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