Report to the Joint Standing Committee on
Environment and Natural Resources
128th Legislature, First Session

Surface Water Ambient Toxics Monitoring Program 2015/2016

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TABLE OF CONTENTS Page

Introduction

This 2015/2016 Surface Water Ambient Toxic (SWAT) monitoring program final report is organized into an Executive Summary, Introduction and 4 modules:
1. Marine and Estuarine
2. Lakes
3. Rivers and Streams
4. Special Studies (update from 2013)

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:

Academic:	Dr. Adria Elskus, USGS; Dr. Rebecca Van Beneden, School of Marine Sciences, UMO
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EXECUTIVE SUMMARY

Maine's Surface Water Ambient Toxics (SWAT) monitoring program was established in 1993 (38 MRSA §420-B) and 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 2009 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 2015 and 2016 annual work plans recommended by the SWAT TAG in meetings June 29, 2015 and May 25, 2016. The 2015 and 2016 work plans focused on monitoring of mercury in lobsters, shellfish and sediment from known or suspected contaminated marine areas, cyanotoxins in Harmful Algal Blooms, mercury in black crappie (a favorite panfish with anglers), perflourinated compounds (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 2015 and 2016 SWAT programs for each of the modules.

- **MARINE AND ESTUARINE**

General Approach:

- In 2015-16, blue mussel tissue taken from Scarborough River, Scarborough; Spring Point, S. Portland; East End Beach, Portland; Mare Brook, Brunswick; Crockett Point, Rockland; and Sears Island, Searsport was analyzed for contaminants including metals, mercury, polycyclic aromatic hydrocarbons (PAHs), and PCBs. Blue mussel tissue from Mare Brook was also analyzed for PFCs.

- In 2015, softshell clam tissue taken from Kilkenny Cove, Hancock was analyzed for metals. Clam tissue from six sites, Back Cove, Portland; Presumpscot River west and east banks, Portland/Falmouth; Mare Brook, Brunswick; Mill Cove, Boothbay Harbor; and St. George River, Thomaston were analyzed for metals. In both studies, clam tissues were separated into edible and whole portions and the results compared.

- In 2015, American lobsters from the Sheepscot River estuary were analyzed for total mercury, a follow up to previous SWAT sampling for blue mussels and a limited sampling of lobsters that showed elevated levels of mercury. In 2016, lobsters were sampled from each of the Dept. of Marine Resources lobster management zones across the coast and analyzed for metals, including mercury.

Encouraging Results:

- PAH concentrations in mussel tissue did not exceed the National Status and Trends (NS&T Musselwatch) nationwide 85th percentile at any of the five sites tested; therefore, no sites were elevated. PAH levels in Maine shellfish tend to be low when compared to the national average.

- PCB concentrations in blue mussels did not exceed the NS&T Musselwatch 85th percentile at any site. PCB concentrations in mussel from four of five sites tested were below the MCDC fish tissue action level (FTAL) for cancer, indicating shellfish from most sites remained safe for human consumption regarding PCBs.

- Testing for PFCs, emerging contaminants of concern, was new to the marine SWAT program in 2013, continued at two blue mussel sites in 2014, and occurred at one site, Mare Brook, Brunswick, in 2016. Concentrations of 12 of 13 individual PFCs were below detection limits at the blue mussel site tested in 2016.

- Lead in softshell clam tissue was confirmed to differ significantly from the whole tissue to the edible portion of clam tissue in results from Kilkenny Cove, Hancock, and from six areas sampled across the coast. Lead concentrations in edible tissue are lower than in whole clam tissue. Lead in edible clam tissue from the six areas examined was low enough to allow consumption of the resource. Examination of lead concentrations in SWAT-tested softshell clams has fostered a collaborative discussion between DEP, Maine Department of Marine Resources (DMR), MCDC, and industry about the appropriate tissue action level for lead in Maine softshell clams.

- Sheepscot lobster meat was below the mercury faction level at five of six areas tested. Tail meat total mercury was near the action level from one area, but should not be a concern considering it is typically mixed with claw meat when consumed and the total mercury measured is a higher (more conservative) estimate than the toxic methylmercury used to determine the FTAL. American lobster meat remains safe for consumption across the coastwide sampling stations based on the metals testing conducted.

Contaminants and Areas to Watch:

- Mercury in blue mussel tissue at five of six sites tested in 2015-16 exceeded the NS&T Musselwatch 85th percentile concentration, therefore these five sites were considered elevated. Mercury levels in all 2015-16 mussel and clam tissue samples tested were below the MCDC methylmercury developmental FTAL for finfish, indicating shellfish at all sites remained safe for human consumption regarding mercury.

- Cadmium in lobster hepatopancreas remains elevated in coastwide sampling. Hepatopancreas tissue is already covered by a fish consumption advisory based on organic contaminants.

- PCBs in blue mussel tissue at Crockett Point, Rockland, exceeded the MCDC fish tissue action level (FTAL) for cancer, but did not exceed the higher non-cancer MCDC FTAL.

- The PFC perfluorooctane sulfonamide (PFOSA) was detected in two of four spatial samples in mussel tissue from Mare Brook. The 12 other PFCs for which testing were performed were all below the detection limit for those compounds

- **LAKES**

- A 2015 pilot study of mercury levels in large black crappie found concentrations significantly lower than those from other sport fish (bass, pickerel) that were the basis for the statewide Fish Consumption Advisory (FCA) for recreational fisheries. Consequently, in 2016, a larger study, initiated to gather enough data for MCDC to determine if black crappie mercury levels were low enough to warrant a revised FCA allowing more black crappie to be consumed, found concentrations similarly low as those in 2015. The study will be completed in 2017 and data sent to MCDC for review of the FCA.

- **RIVERS AND STREAMS**
  - In 2015, forty-five stations were assessed for the condition of the benthic macroinvertebrate community. Twenty-five stations attained the aquatic life criteria of their assigned class. Five non-SWAT funded stations that were sampled in 2015 were included in this report because of their location in watersheds of interest. All five stations did not attain their assigned class.

  - In 2016, forty-one stations were assessed for the condition of the benthic macroinvertebrate community. Twenty-six stations attained the aquatic life criteria of their assigned class.

  - A 2015 study of perfluorinated compounds (PFCs) in fish from rivers below municipal sewage treatment plants in Sanford, Augusta, Farmington, Houlton, and Caribou, found mostly perfluorooctane sulfonate (PFOS) at measurable levels but near a level of concern for subsistence fishers only in white perch from the Mousam River at the confluence with Estes Lake in Sanford. In 2016 PFCs were measured in largemouth bass and white perch from Estes Lake, and in largemouth bass from Number One Pond in downtown Sanford and from Mousam Lake in Acton. Concentrations of PFOS in both species in Estes Lake were similar to those in 2015, but near a new level of concern for Maine recreational anglers. Concentrations in bass in Number One Pond and Mousam Lake were progressively lower, but levels in bass from Number One Pond were near a new level of concern for subsistence fishers.

  - Red Brook in Scarborough has a history of PCB contamination from a metal recycling facility, and possibly from a commercial landfill with industrial and municipal waste. Following some remediation of the recycling facility, in 2015 brook trout from Red Brook were found to contain PCB concentrations ~5x higher than concentrations measured before remediation. A repeat of the study in 2016 found levels were intermediate of those from 2015 and earlier years, but still above a level of concern.

- Goosefare Brook in Saco is listed by DEP as an urban impaired stream and has a long history of contamination due to industrial discharges and urban runoff. Benthic macroinvertebrate communities do not attain the Class C Water Quality Standards of Goosefare Brook. In 2015, concentrations of heavy metals measured in brook trout from Goosefare Brook did not exceed effects thresholds for fish derived from the literature except for a No Observed Effects Level (NOEL) for copper based on limited studies. Concentrations of PCBs exceeded the Maine Center for Disease Control and Prevention's Fish Tissue Action Level (FTAL) similar to levels in fish from many other waterbodies in watersheds with human activity.

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 increased 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 are ubiquitous and readily collected across the coast of Maine, as well as throughout the entire Gulf of Maine. Published information about contaminants in mussels provides some historical context and allows comparisons between geographic areas and over time. Since blue mussels are consumed as food by humans, they can be used to understand potential human exposure to contaminants. Mussels are sessile, allowing attribution of their contaminant burdens to the environment where they were collected. Mussels filter large volumes of water as they feed, allowing them to concentrate many chemicals from the water column or 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 2015-16 from six sites along the Maine coast. All mussel tissue samples were analyzed for heavy metals (including mercury), five of the six were analyzed for PCBs, and PAHs; and one of the sites was analyzed for PFCs. In order to provide comparability of results from the 2015-16 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 2015 from two different projects on the Maine coast. Softshell clam tissue was sampled from fifteen stations in Kilkenny Cove, Hancock in conjunction with a DEP Remediation sediment sampling project focused on impacts from a tannery which historically operated adjacent to the cove. In the second project, softshell clams were sampled at six locations in Casco Bay and the mid-coast. All samples were analyzed for metals.

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 metals. The six locations selected for sampling from Casco Bay and the mid-coast were chosen based on historic lead data to represent a variety of lead concentrations, allowing comparison of partitioning of lead between the skin and edible portions of the clams.

1.1.3 American Lobster

This report presents data from American lobster (*Homerus americanus*) tissues collected in 2015 from the Sheepscot River estuary and from the Department of Marine Resources' (DMR) lobster management zones statewide in 2016. For both projects, 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 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 last NCCA sampling efforts in 2010 (and prior). 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 this report, are part of a continuing effort to generate new and useful

lobster tissue contaminant data which has 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 at several locations, and on previous sampling of lobster by NCCA in 2005-06 and 2010 at many more locations along the Maine coast.

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 in an attempt 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 six sites: Three sites during September, 2015 and three sites in September 2016. All six mussel 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: 2015-2016

Site Name	Municipality	Station Code	West Longitude	North Latitude	Date Sampled	Site Type[1]
Scarborough R.	Scarborough	CBSRRR	-70.34339	43.5553	9/22/2015	T
Spring Point	S. Portland	CBSPSP	-70.22757	43.65055	9/21/2015	T
East End Beach	Portland	CBEEEE	-70.24072	43.66959	9/22/2015	T
Mare Brook	Brunswick	CBMBBH	-69.9381	43.85447	9/22/2016	F
Crockett Pt.	Rockland	PBRKCP	-69.1064	44.10656	9/23/2016	T
Sears Is.	Searsport	PBSIWS	-68.88961	44.45089	9/20/2016	T

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 whenever possible. Gauges were used to sort mussels by shell length in the field, and mussels within a size range of 50-60 mm were selected for analysis. For metals analysis, a minimum of 20 mussels 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^{o} 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.

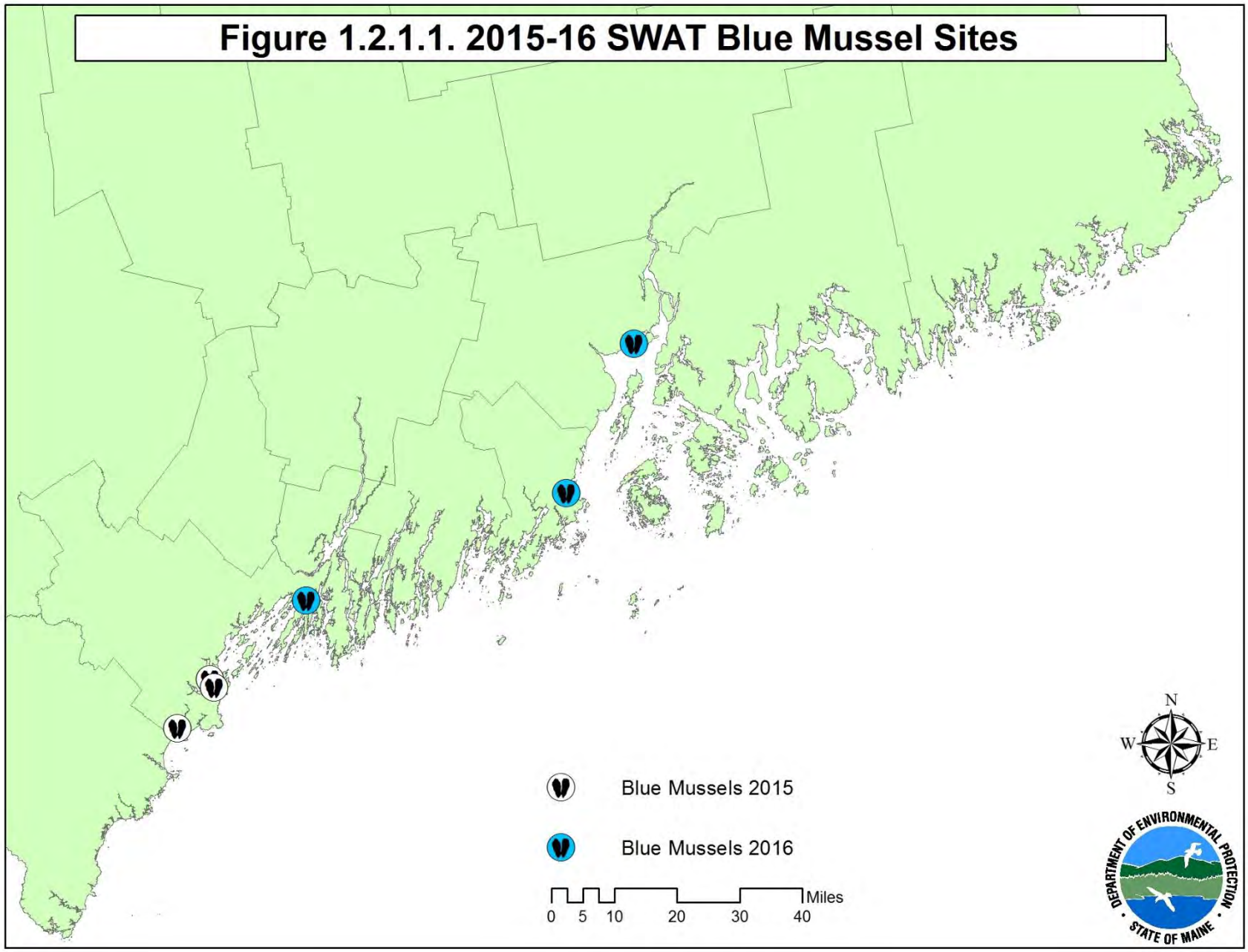
Figure 1.2.1.1. 2015-16 SWAT Blue Mussel Sites
Blue Mussels 2015
Blue Mussels 2016
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1.2.2 Softshell Clam

At Kilkenny Cove, Hancock, softshell clams were collected from fifteen individual locations which were co-located with sites sampled for sediments collected by the DEP Bureau of Remediation and Waste Management. A minimum of twenty clams were collected at each station, placed in plastic bags, and kept in coolers until they reached the laboratory. Clams were washed, measured, and ranked ordered by size within each location sampled. 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 partitioning of metals into the clam skin. Locations sampled at Kilkenny Cove are presented in Table 1.2.2.1

Table 1.2.2.1: Kilkenny Cove Softshell Clam Sites 2015

Municipality	Station Code	West Longitude	North Latitude	Date Sampled
Hancock	UK101	-68.3189	44.53414	4/15/2015
Hancock	UK102	-68.3198	44.53479	4/15/2015
Hancock	UK103	-68.3183	44.535	4/15/2015
Hancock	UK104	-68.3188	44.53551	4/15/2015
Hancock	P101	-68.3113	44.53353	4/15/2015
Hancock	P102	-68.3099	44.53252	4/15/2015
Hancock	P105	-68.3128	44.53213	4/15/2015
Hancock	P202	-68.3064	44.52927	4/15/2015
Hancock	P203	-68.3076	44.52929	4/15/2015
Hancock	P205			4/15/2015
Hancock	S101	-68.3183	44.53152	4/15/2015
Hancock	S102	-68.3186	44.53072	4/15/2015
Hancock	S104	-68.3168	44.53144	4/15/2015
Hancock	S202	-68.3158	44.53269	4/15/2015
Hancock	S204	-68.3159	44.53358	4/15/2015

At six sites from Casco Bay to St. George River, softshell clams were collected from sites sampled in previous years for softshell clams. Sites were chosen to represent a range of lead concentrations based on historical data. Clams were sampled, composited and dissected as described above in the Kilkenny Cove section. Edible and whole tissue composites were analyzed for metals, including lead, to determine partitioning of metals into the clam skin. The six locations sampled in autumn 2015 are presented in Table 1.2.2.2 and Figure 1.2.2.2.

TABLE 1.2.2.2: SWAT Softshell Clam Sites: 2015

Site Name	Municipality	Station Code	West Longitude	North Latitude	Date Sampled	Site Type[1]
Back Bay	Portland	CBBBBB	-70.27083	43.67956	10/2/2015	S
Presumpscot R.	Portland/Falmouth	CBPRWS	-70.25193	43.70231	10/5/2015	S
Presumpscot R.	Portland/Falmouth	CBPRES	-70.24484	43.69762	9/24/2015	S
Mare Brook	Brunswick	CBMBBH	-69.93341	43.86148	10/6/2015	S
Mill Cove	Boothbay	MCBBMC	-69.6343	43.85141	10/1/2015	S
St. George R.	Thomaston	MCSGHP	-69.17484	44.05694	9/23/2015	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 five distinct areas (replicates) along the shoreline at each site 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^{o} C for up to two months until analyses could be completed. Frozen tissue was shipped overnight to the laboratory for analysis. Softshell clam tissues tested for metals in 2015-16 were analyzed by Pacific Northwest National Laboratory operated by Battelle, Sequim, Washington.

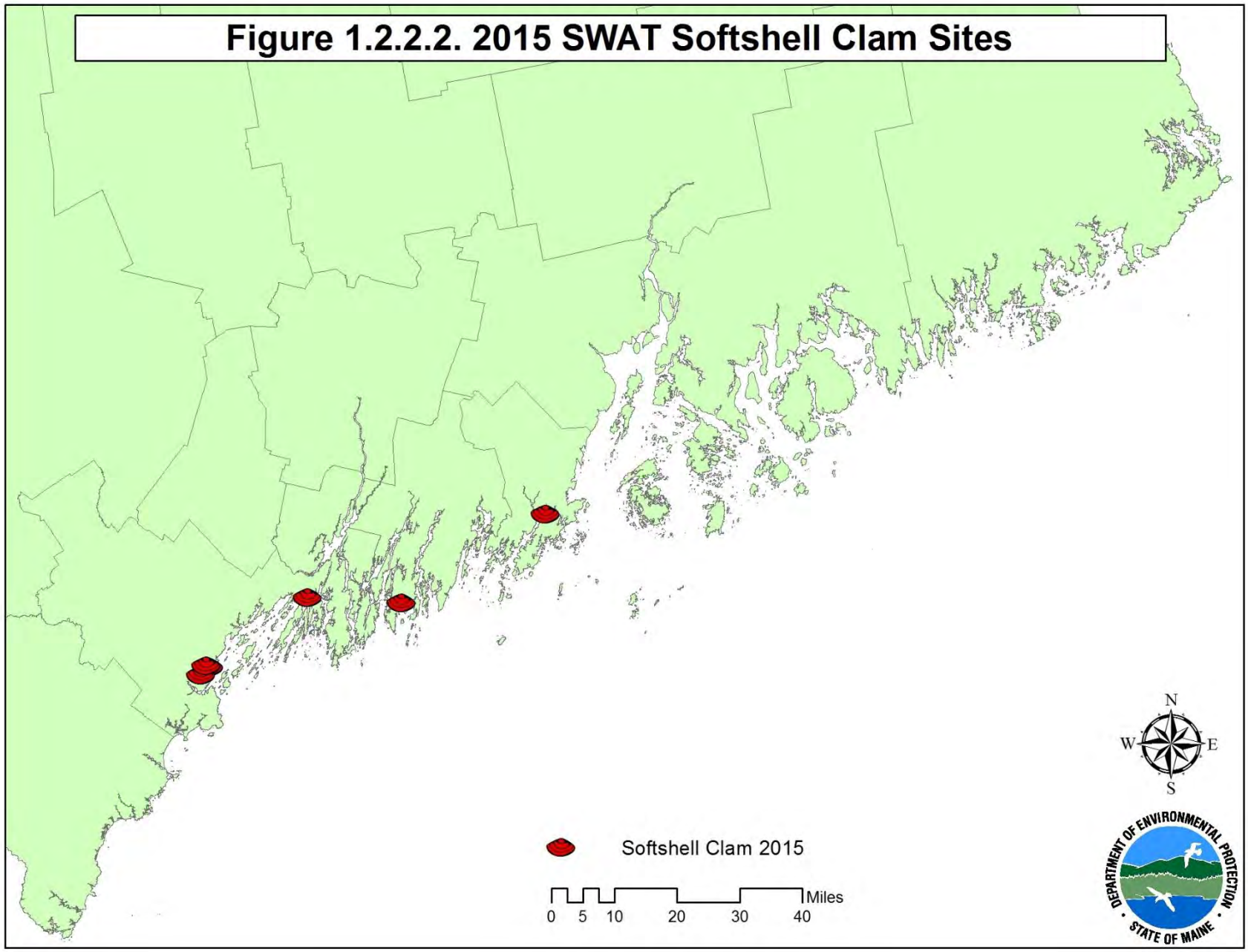
Figure 1.2.2.2. 2015 SWAT Softshell Clam Sites
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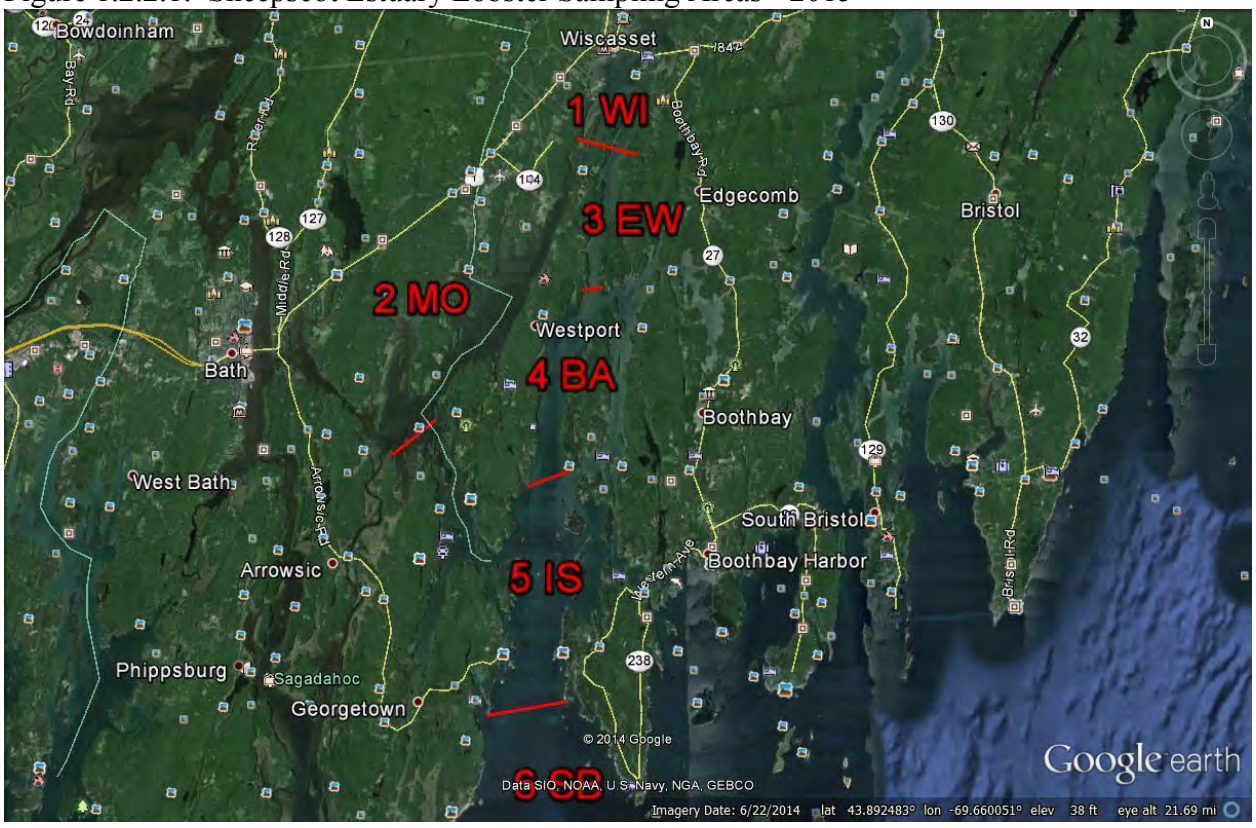
Softshell Clam 2015
Miles
0 5 10 20 30 40
DEPARTMENT OF ENVIRONMENTAL PROTECTION
STATE OF MAINE

1.2.3 American Lobster

Sheepscot River lobsters were sampled from six areas from Wiscasset down to Sheepscot Bay, with ten lobsters collected from each area (Figure 1.2.2.1). 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 for analysis of each tissue separately for total mercury. Claw tissue included all dissected muscle tissue from both claws and both knuckles, while tail meat included the entire tail with the gut tract removed. Lobsters were not composited but were analyzed as individuals with a separate claw and tail total mercury concentration derived for each to provide an understanding of variability among individual lobster muscle tissue concentrations. Tissue samples were placed in precleaned jars and frozen until delivery to the contracted laboratory.

Figure 1.2.2.1: Sheepscot Estuary Lobster Sampling Areas - 2015



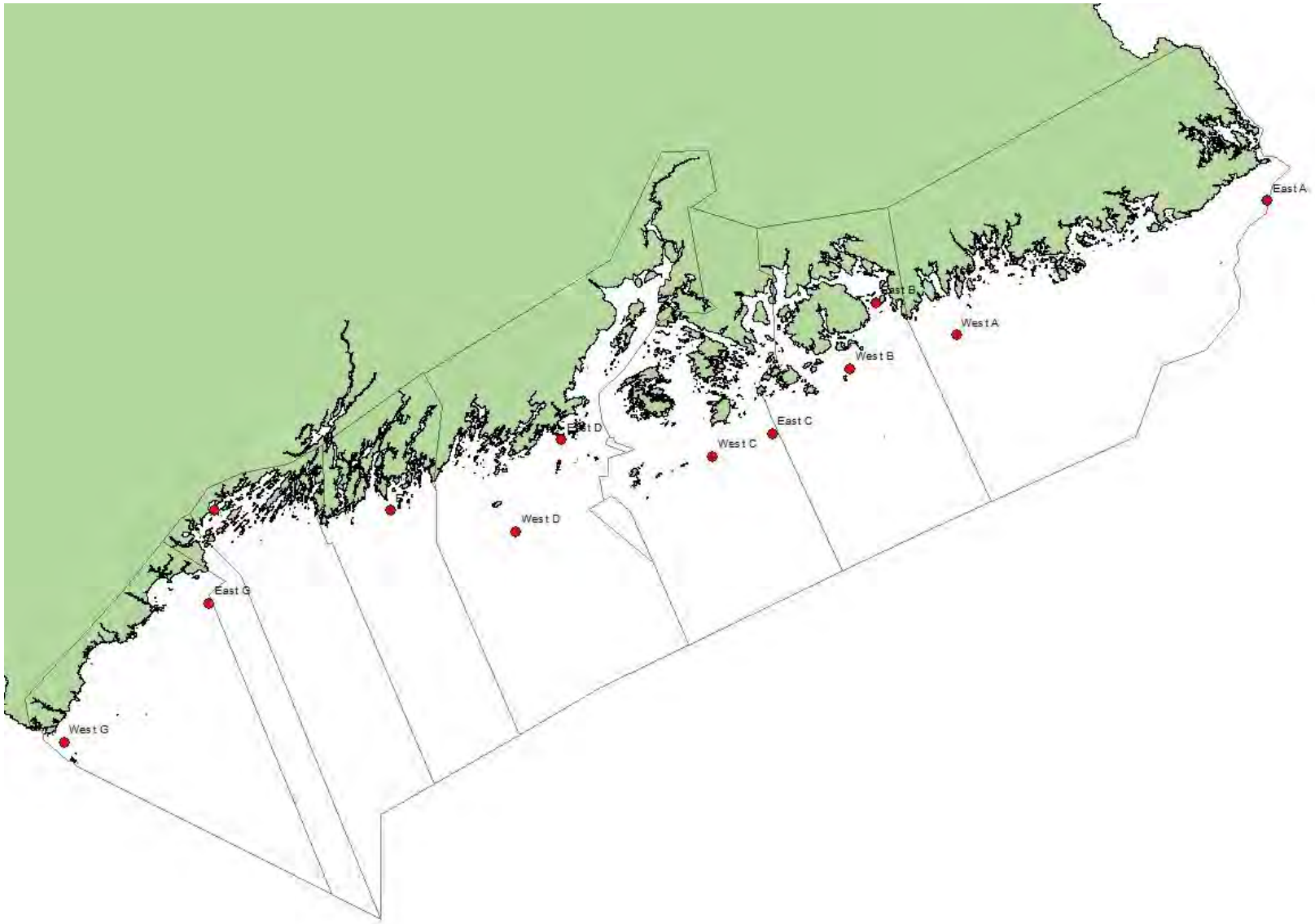
Statewide lobster sampling conducted in 2016 drew samples from the seven DMR lobster management zones, A through G, with the five largest zones sampled at both an east and west location. The smaller zones, E and F, were sampled at one location (Figure 1.2.2.2).

At each of the 12 areas sampled, ten lobsters were collected and composited into two five lobster composite samples. Both muscle and hepatopancreas tissues were analyzed for twelve metals by the contracted laboratory.

DEP SWAT personnel dissected lobsters, which had been trapped and frozen by DMR, separating the hepatopancreas tissue while partially frozen. Muscle tissue consisted of a sample of both claws and the tail meat, which were analyzed together as a "muscle tissue" sample. An Accu-Punch 12 mm diameter punch was used to cut a plug from each claw and two plugs from the lobster tail. All four muscle plugs were composited as one lobster's "muscle tissue" sample, as noted above. In addition, tissue from five lobsters was analyzed together as a composite sample, such that ten lobsters from each location yielded two hepatopancreas and two muscle tissue composite samples. Thus, two concentration values for each tissue type were produced for each area analyzed. For data analysis, the two concentrations for each tissue were averaged and mean values were discussed.

Tissue composites were immediately placed in pre-cleaned glass jars and capped. Jars were pre-labeled and filled jars were stored at -5^{o} C for up to six months until analyses could be completed. Frozen tissue was shipped overnight to the laboratory for analysis. Lobster tissues tested for metals in 2016 were analyzed by Pacific Northwest National Laboratory operated by Battelle, Sequim, Washington. Lobster sampled from the Sheepscot River in 2015 were analyzed by Alpha Analytical, Westborough, Massachusetts.

Figure 1.2.2.2: DMR Lobster Management Zones and Locations of SWAT Lobster Samples -2016.
(Note two samples in zones A – D and G.)



1.3 RESULTS AND DISCUSSION

1.3.1 Metals

1.3.1.1 Blue Mussels

Mussel tissue samples collected in 2015-16 were analyzed for 11 metals: Silver (Ag), aluminum (Al), arsenic (As), 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 of the six locations sampled in 2015-16 (Figure 1.3.1.1.1.1). Silver levels measured in mussels ranged from a low mean concentration of 0.027 µg/g dry wt. at Spring Point, S. Portland, to a high mean concentration of 0.080 µg/g dry wt. at East End Beach, Portland. Silver concentrations at Spring Point, S. Portland, Mare Brook, Brunswick, and Crockett Point, Rockland fell below the 2008 Gulfwatch median, while concentrations at Scarborough River and Sears Island, Searsport 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 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.

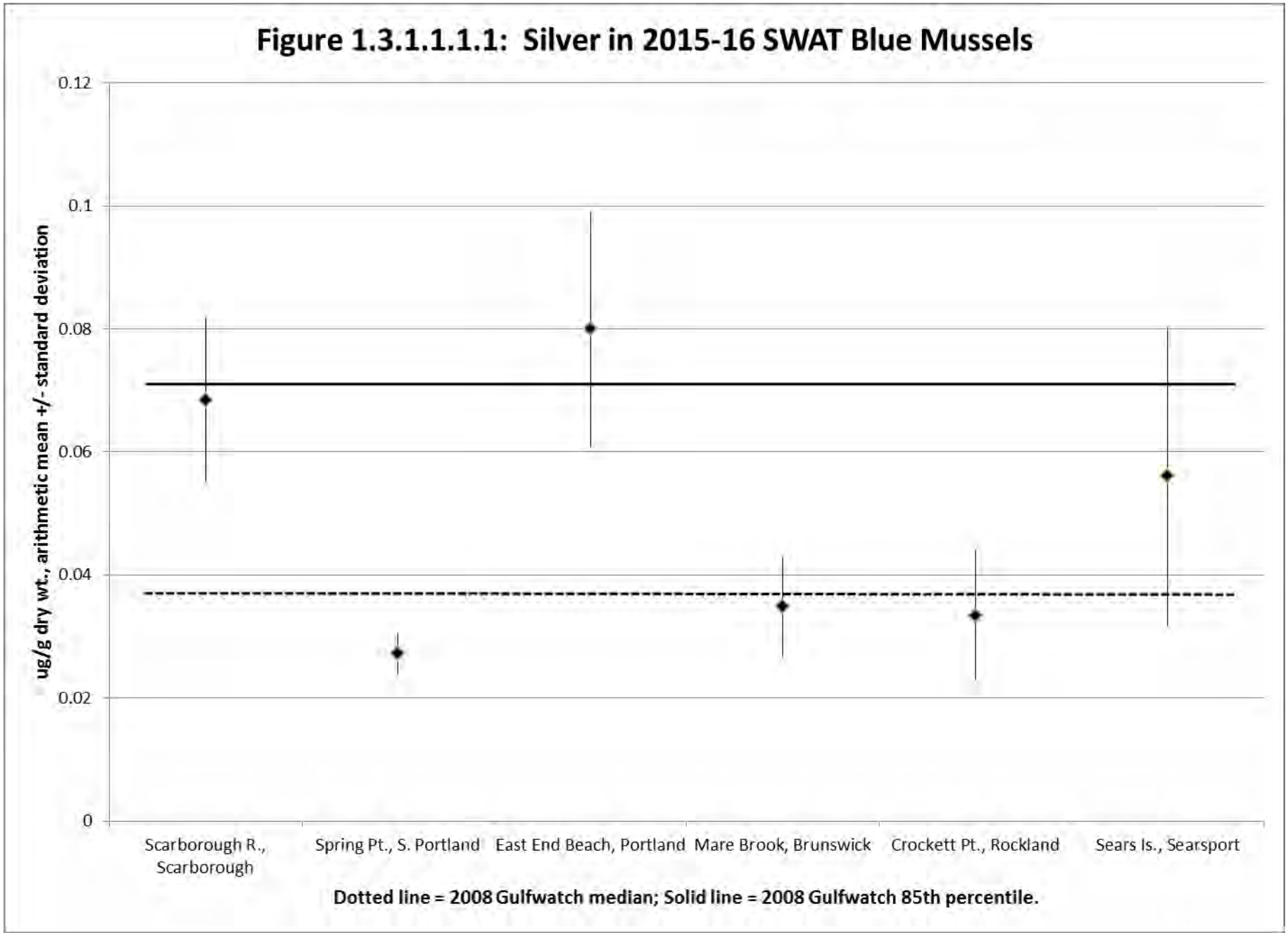


Figure 1.3.1.1.1.1: Silver in 2015-16 SWAT Blue Mussels
ug/g dry wt., arithmetic mean +/- standard deviation
0.12
0.1
0.08
0.06
0.04
0.02
0
Scarborough R., Scarborough
Spring Pt., S. Portland
East End Beach, Portland
Mare Brook, Brunswick
Crockett Pt., Rockland
Sears Is., Searsport
Dotted line = 2008 Gulfwatch median; Solid line = 2008 Gulfwatch 85th percentile.

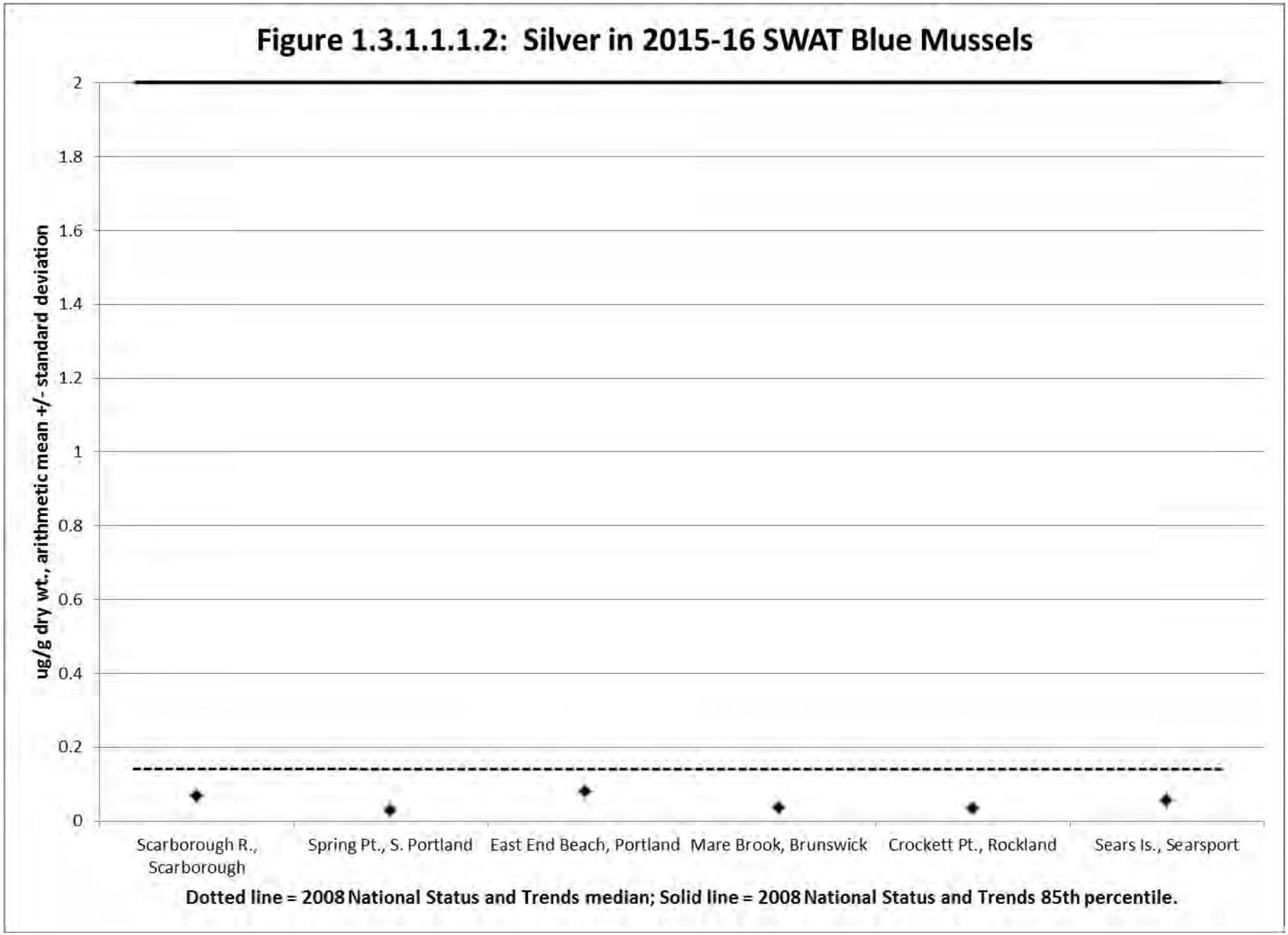


Figure 1.3.1.1.1.2: Silver in 2015-16 SWAT Blue Mussels
ug/g dry wt., arithmetic mean +/- standard deviation
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Scarborough R., Scarborough
Spring Pt., S. Portland
East End Beach, Portland
Mare Brook, Brunswick
Crockett Pt., Rockland
Sears Is., Searsport
Dotted line = 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 six locations sampled in 2015-16 (Figure 1.3.1.1.2.1). Arsenic levels measured in mussels ranged from a low mean concentration of 9.5 µg/g dry wt. at Mare Brook, Brunswick, to a high mean concentration of 16.9 µg/g dry wt. at Spring Point, S. Portland. While Gulfwatch does not monitor arsenic concentrations, they are tracked regionally and nationally by NS&T. In blue mussels, NS&T considers 12-22 parts per million dry wt. (directly comparable to SWAT µg/g data) to be in the mid-range of three ranges of arsenic concentration nationally (Kimbrough et al., 2008). Five of six blue mussel sites sampled in 2015-16 had arsenic concentrations which fell into the mid-range of the three NS&T ranges, while only Mare Brook, Brunswick, had a blue mussel tissue concentration that occurred within the lowest of three categories for the 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, 2015-16 SWAT blue mussel inorganic arsenic concentrations are estimated to range from 0.15 µg/g wet wt. to 0.25 µg/g wet wt. All six sites exceeded the MCDC cancer FTAL of 0.014 µg/g wet wt.

Comparing recent data from all 60+ mussel sites sampled from 2007-16, 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 2007-16 had calculated blue mussel tissue inorganic arsenic concentrations exceeding the MCDC cancer action level of 0.014 µg/g wet wt. None of the six sites sampled in 2015-16 were calculated to have exceeded

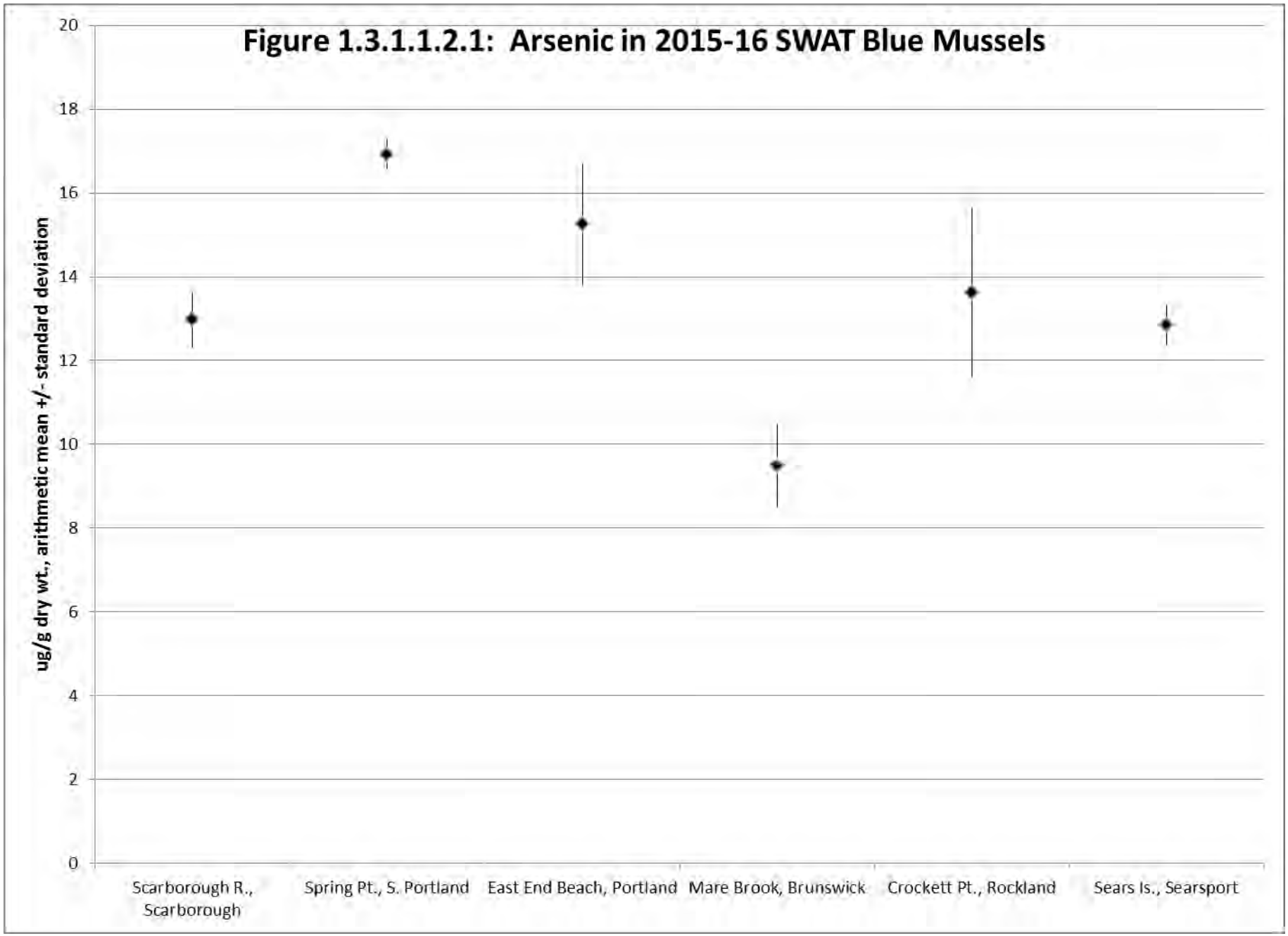


Figure 1.3.1.1.2.1: Arsenic in 2015-16 SWAT Blue Mussels
ug/g dry wt., arithmetic mean +/- standard deviation
20
18
16
14
12
10
8
6
4
2
0
Scarborough R., Scarborough
Spring Pt., S. Portland
East End Beach, Portland
Mare Brook, Brunswick
Crockett Pt., Rockland
Sears Is., Searsport

the MCDC non-cancer action level of 0.6 µg/g wet wt. for inorganic arsenic. Similarly, 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 six locations visited in 2015-16 (Figure 1.3.1.1.3.1). Cadmium levels measured in mussels ranged from a low mean concentration of 1.53 µg/g dry wt. at Mare Brook, Brunswick, to a high mean concentration of 1.96 µg/g dry wt. at Spring Point, S. Portland. The cadmium concentrations at Scarborough River, Mare Brook, Brunswick, Crockett Point, Rockland, and Sears Island, Searsport, fell below the 2008 Gulfwatch median, while the concentrations at Spring Point, S. Portland and East End Beach, Portland, 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 2015-16 SWAT site, Spring Point, S. Portland, had a mean cadmium concentration of 0.28 µg/g wet wt., which is below the MCDC and FDA action levels.

1.3.1.1.4 Chromium (Cr)

Chromium was detected in samples taken at all six sites sampled in 2015-16. Chromium ranged from a low concentration of 0.95 µg/g dry wt. at Scarborough River to a high of 1.76 µg/g dry wt. at Spring Point, S. Portland. The chromium concentration at Spring Point, S. Portland, exceeded the 2008 Gulfwatch median, while the concentrations at the remaining five sites were all 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 Scarborough River was the only

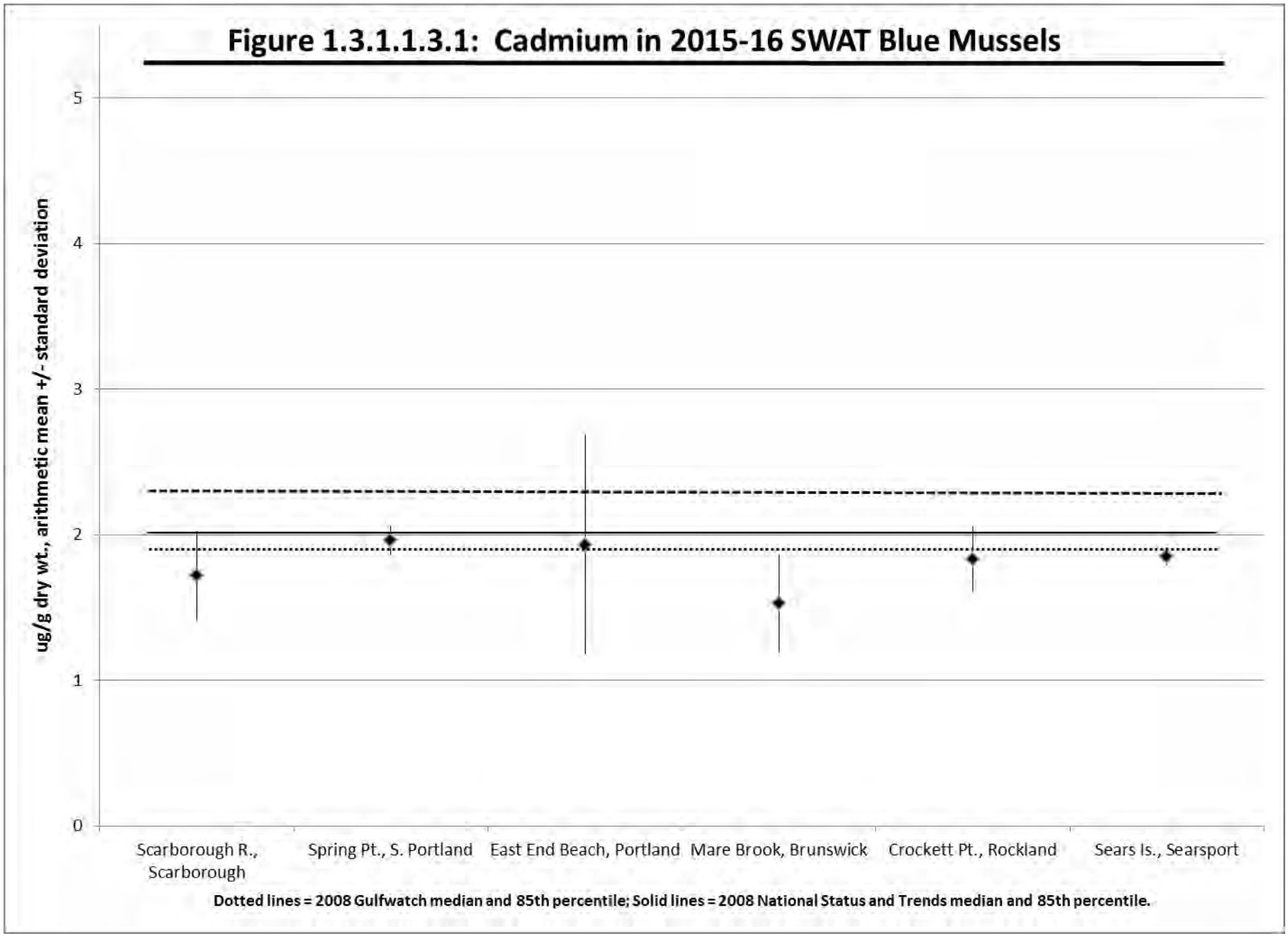


Figure 1.3.1.1.3.1: Cadmium in 2015-16 SWAT Blue Mussels
ug/g dry wt., arithmetic mean +/- standard deviation
5
4
3
2
1
0
Scarborough R., Scarborough
Spring Pt., S. Portland
East End Beach, Portland
Mare Brook, Brunswick
Crockett Pt., Rockland
Sears Is., Searsport
Dotted lines = 2008 Gulfwatch median and 85th percentile; Solid lines = 2008 National Status and Trends median and 85th percentile.

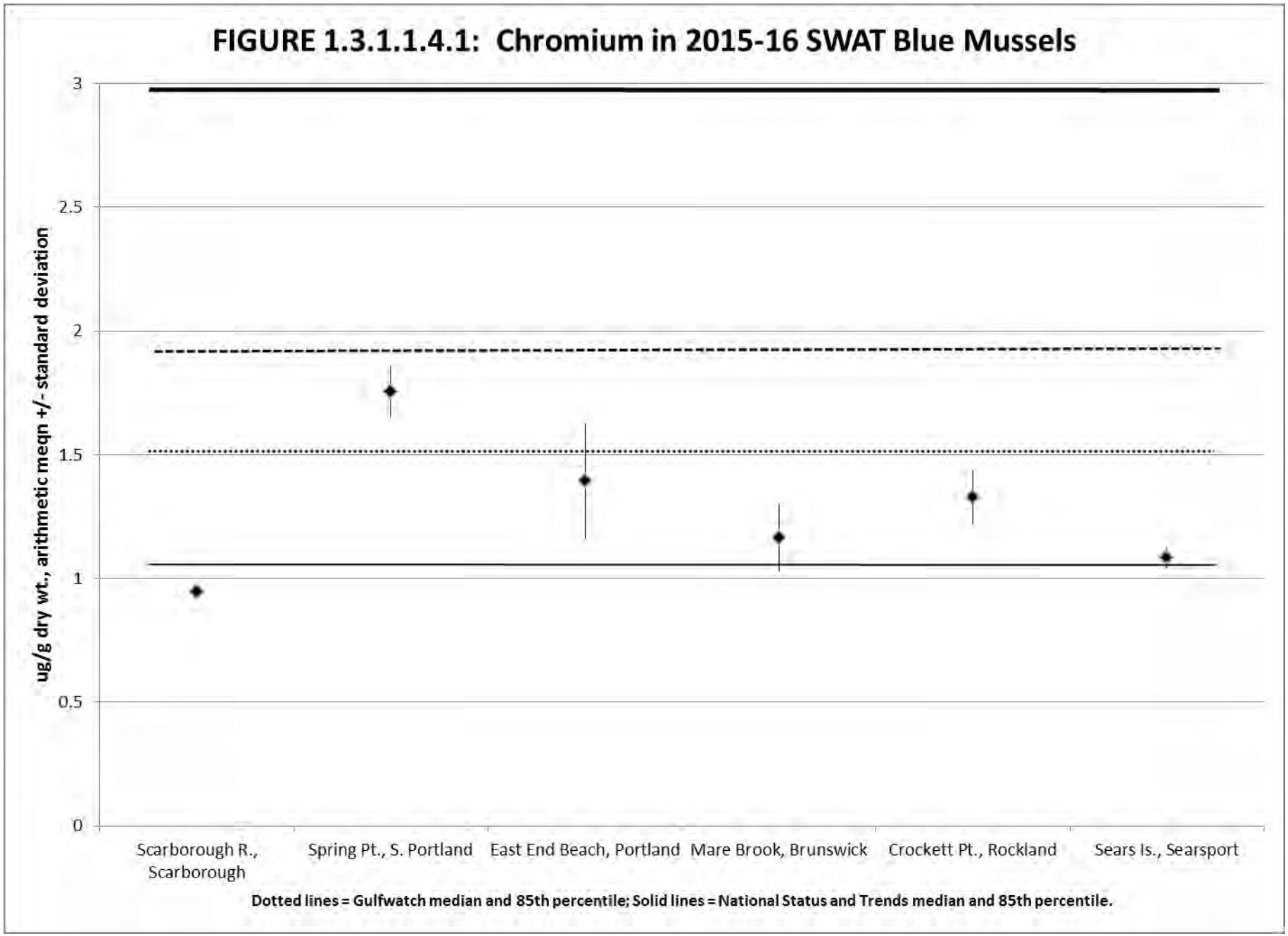


FIGURE 1.3.1.1.4.1: Chromium in 2015-16 SWAT Blue Mussels
ug/g dry wt., arithmetic meqn +/- standard deviation
3
2.5
2
1.5
1
0.5
0
Scarborough R., Scarborough
Spring Pt., S. Portland
East End Beach, Portland
Mare Brook, Brunswick
Crockett Pt., Rockland
Sears Is., Searsport
Dotted lines = Gulfwatch median and 85th percentile; Solid lines = National Status and Trends median and 85th percentile.

concentration that did not exceed the NS&T median, though 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 six SWAT mussel sites sampled in 2015-16 (Figure 1.3.1.1.5.1). Copper levels measured in mussels ranged from a low mean concentration of 4.97 µg/g dry wt. at Mare Brook, Brunswick, to a high mean concentration of 8.21 µg/g dry wt. at East End Beach, Portland. Copper concentrations at Spring Point,S. Portland, East End Beach, Portland, and Crockett Point, Rockland, exceeded the Gulfwatch median but only East End Beach exceeded the 85th percentile (LeBlanc et al., 2009). The remaining three sites had copper concentrations below the Gulfwatch median. SWAT copper concentrations at all six sites sampled in 2015-16 fell below the NS&T median and 85th percentile (Figure 1.3.1.1.5.2) (Kimbrough et al., 2008). None of the six sites sampled in 2015-16 was considered elevated for copper.

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).

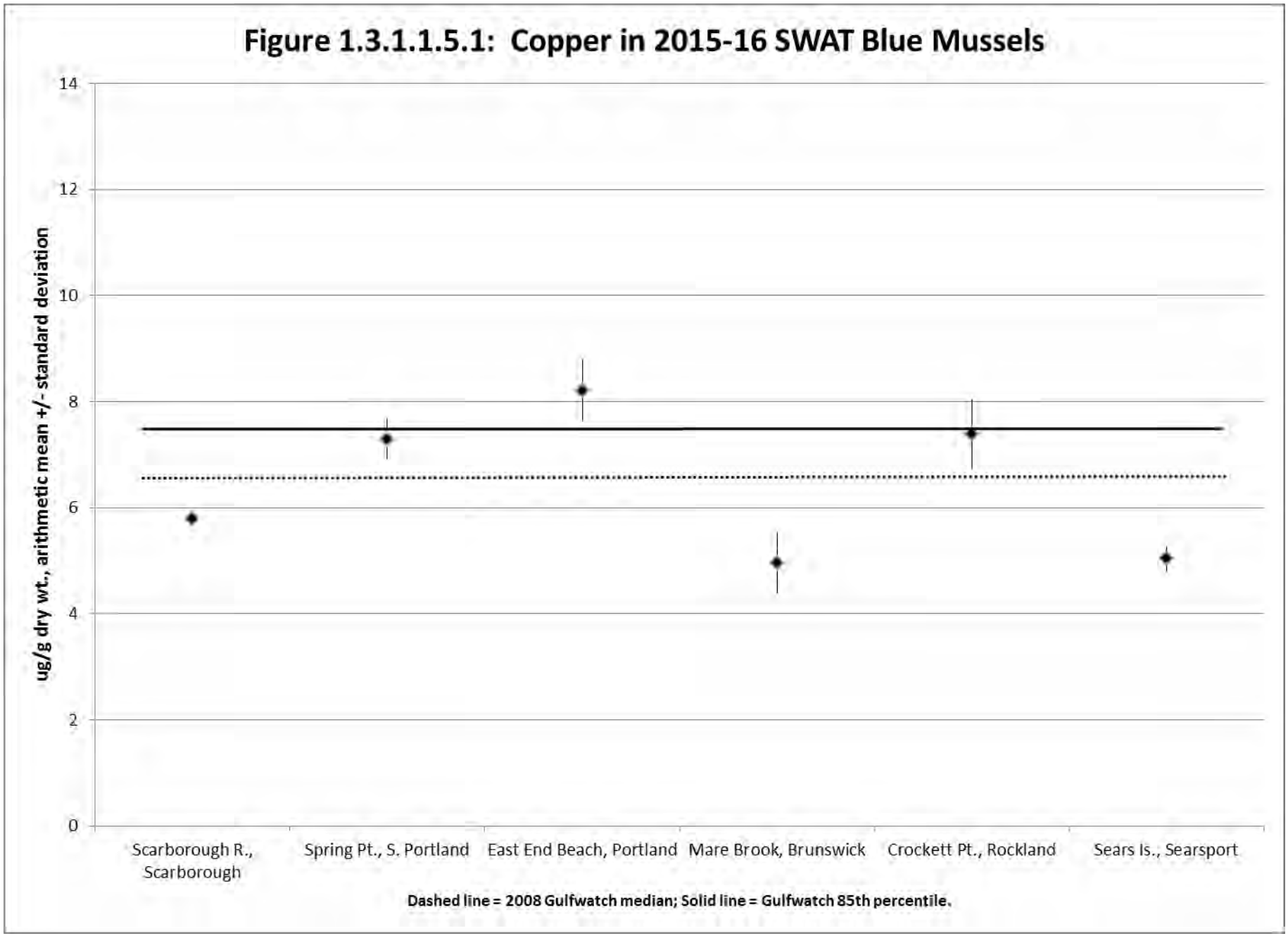


Figure 1.3.1.1.5.1: Copper in 2015-16 SWAT Blue Mussels
ug/g dry wt., arithmetic mean +/- standard deviation
14
12
10
8
6
4
2
0
Scarborough R., Scarborough
Spring Pt., S. Portland
East End Beach, Portland
Mare Brook, Brunswick
Crockett Pt., Rockland
Sears Is., Searsport
Dashed line = 2008 Gulfwatch median; Solid line = Gulfwatch 85th percentile.

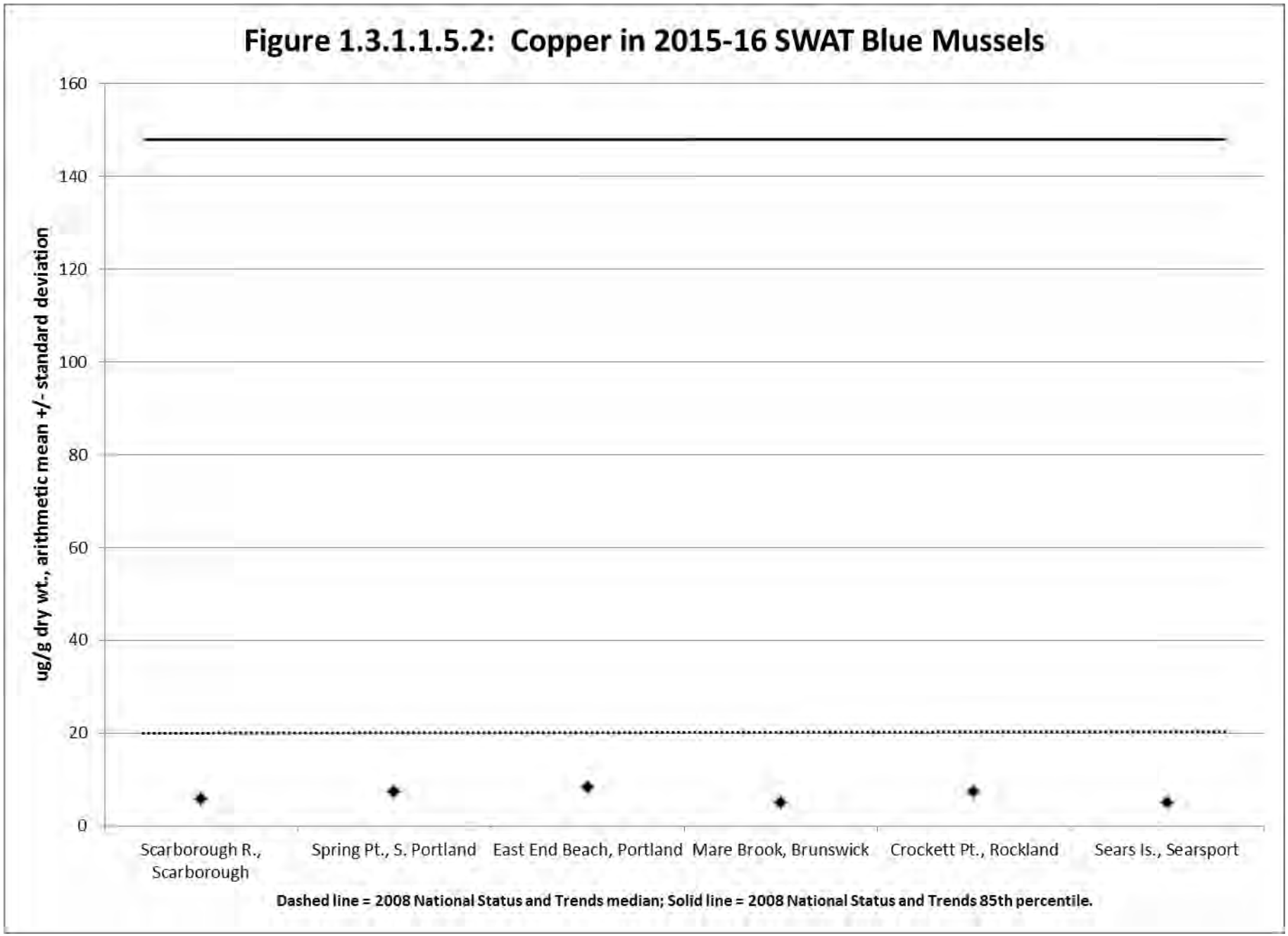


Figure 1.3.1.1.5.2: Copper in 2015-16 SWAT Blue Mussels
ug/g dry wt., arithmetic mean +/- standard deviation
160
140
120
100
80
60
40
20
0
Scarborough R., Scarborough
Spring Pt., S. Portland
East End Beach, Portland
Mare Brook, Brunswick
Crockett Pt., Rockland
Sears Is., Searsport
Dashed line = 2008 National Status and Trends median; Solid line = 2008 National Status and Trends 85th percentile.

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 six SWAT blue mussel sites sampled in 2015-16 (Figure 1.3.1.1.6.1). Iron concentrations measured in mussels ranged from a low mean concentration of 246 µg/g dry wt. at Scarborough River to a high mean concentration of 526 µg/g dry wt. at Mare Brook, Brunswick. The iron concentration in samples from Spring Point,S. Portland, and Mare Brook, Brunswick, exceeded the Gulfwatch and NS&T medians, though no concentration from any site exceeded the Gulfwatch or NS&T 85th percentiles for iron. 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 six SWAT mussel sites sampled in 2015-16 (Figure 1.3.1.1.6.2). Aluminum levels measured in mussels ranged from a low mean concentration of 112 µg/g dry wt. at Scarborough River to a high mean concentration of 265 µg/g dry wt. at Mare Brook, Brunswick. Aluminum concentrations at Spring Point, S. Portland, East End Beach, Portland, and Mare Brook, Brunswick, exceeded the NS&T median, but none of the sites had aluminum concentrations that exceeded the Gulfwatch median. None of the six sites had aluminum concentrations approaching the Gulfwatch or NS&T 85th percentiles (LeBlanc et al., 2009)(Kimbrough et al., 2008). None of the six sites sampled in 2015-16 was considered elevated for aluminum.

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 six SWAT blue mussel sites sampled in 2015-16 (Figure 1.3.1.1.7.1). Nickel levels measured in mussels ranged from a low mean

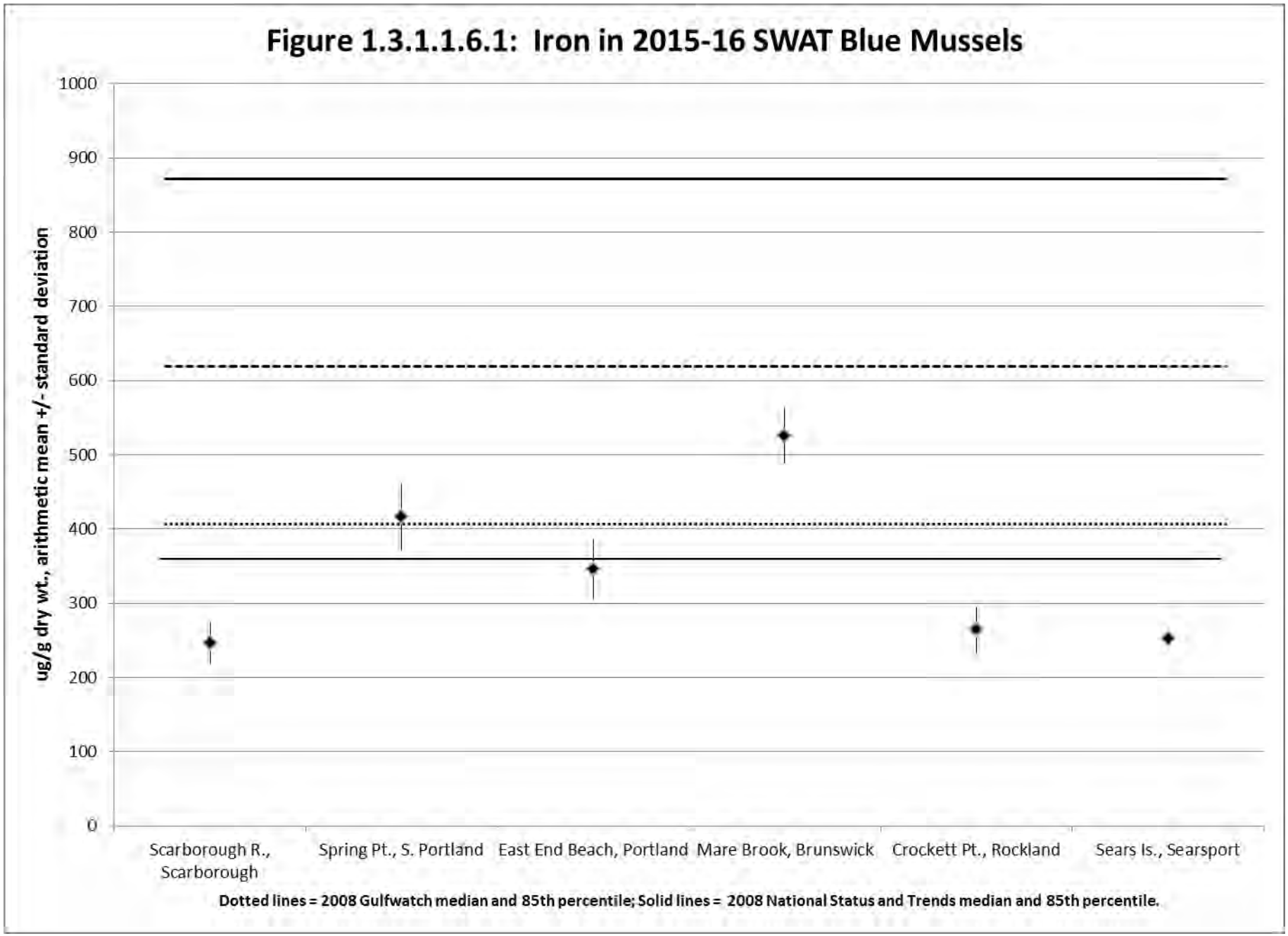
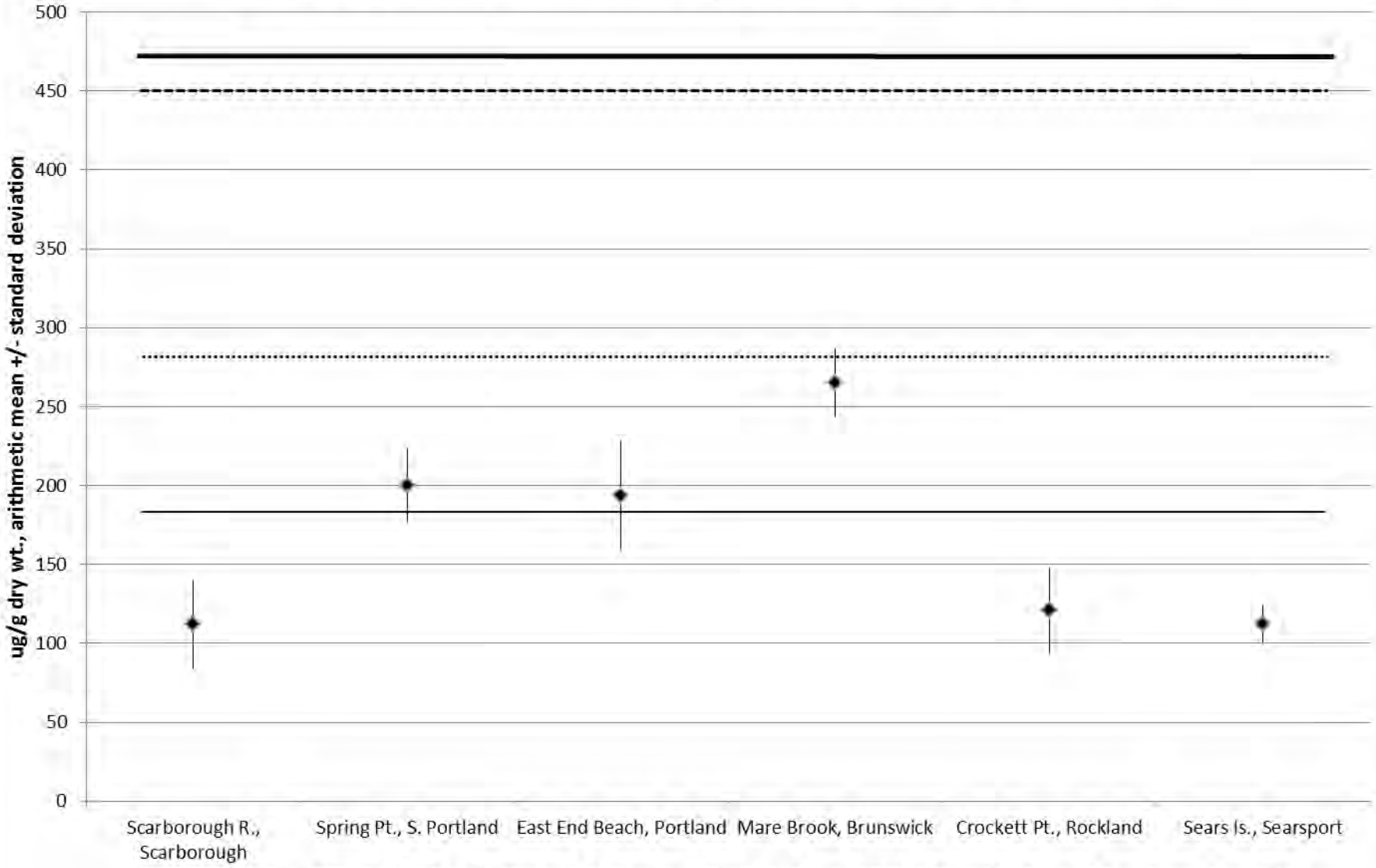


Figure 1.3.1.1.6.1: Iron in 2015-16 SWAT Blue Mussels
ug/g dry wt., arithmetic mean +/- standard deviation
1000
900
800
700
600
500
400
300
200
100
0
Scarborough R., Scarborough
Spring Pt., S. Portland
East End Beach, Portland
Mare Brook, Brunswick
Crockett Pt., Rockland
Sears Is., Searsport
Dotted lines = 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 2015-16 SWAT Blue Mussels



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

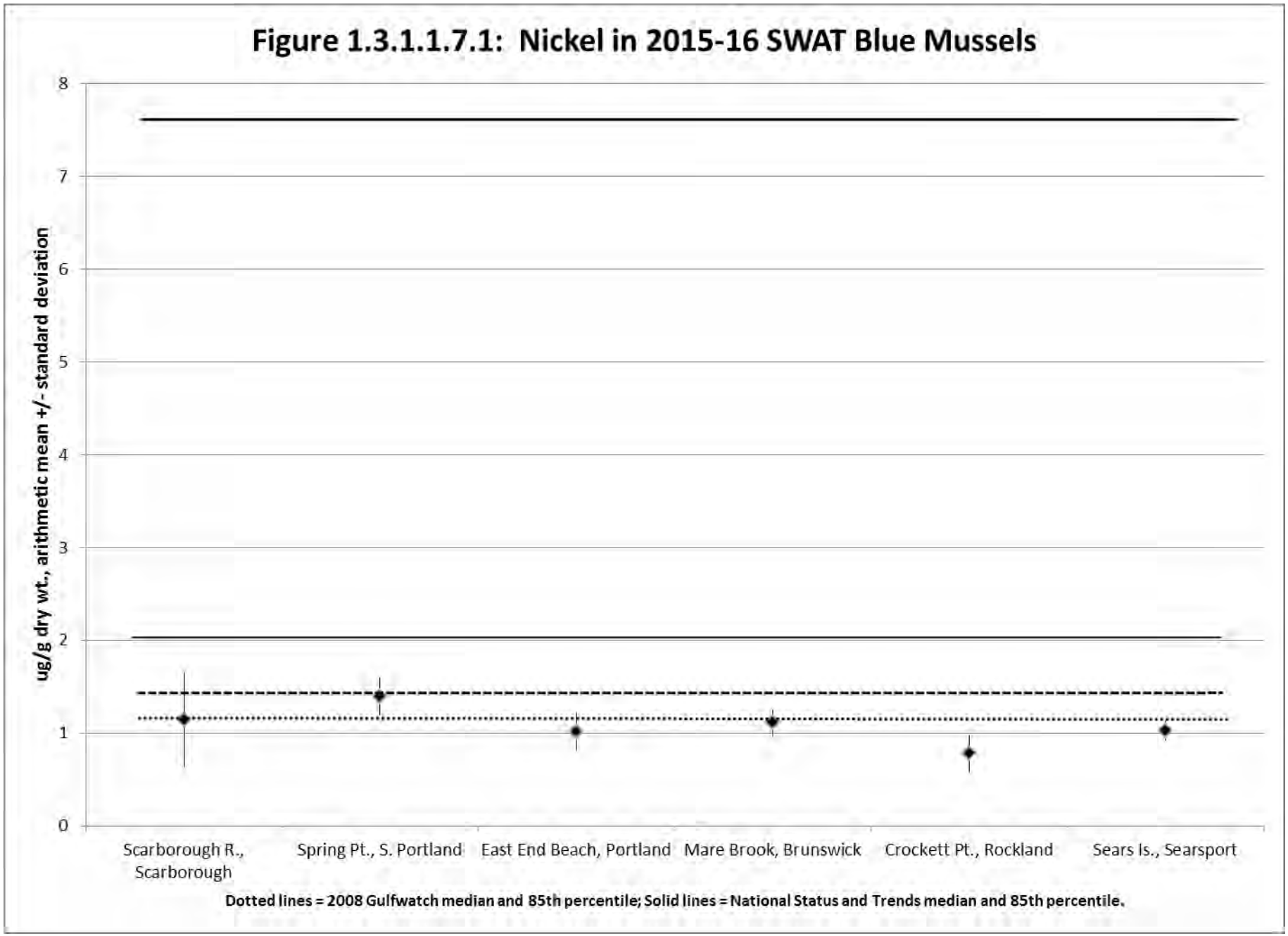


Figure 1.3.1.1.7.1: Nickel in 2015-16 SWAT Blue Mussels
ug/g dry wt., arithmetic mean +/- standard deviation
8
7
6
5
4
3
2
1
0
Scarborough R., Scarborough
Spring Pt., S. Portland
East End Beach, Portland
Mare Brook, Brunswick
Crockett Pt., Rockland
Sears Is., Searsport
Dotted lines = 2008 Gulfwatch median and 85th percentile; Solid lines = National Status and Trends median and 85th percentile.

concentration of 0.78 µg/g dry wt. at Crockett Point, Rockland, to a high mean concentration of 1.40 µg/g dry wt. at Spring Point, S. Portland. Only Spring Point, S. Portland, had a nickel concentration exceeding the Gulfwatch median. None of the sites had concentrations of nickel in tissue that exceeded the Gulfwatch 85th percentile, or the NS&T median or NS&T 85th percentile(LeBlanc et al., 2009)(Kimbrough et al., 2008). None of the SWAT sites were considered to be elevated for nickel. Higher nickel concentrations are probably associated with sediment ingestion, similar to iron and aluminum concentrations.

Nickel occurs naturally in the environment and is 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 2014 of 0.17 µg/g wet wt. at Spring Point, S. Portland is two orders of magnitude below the more conservative MCDC action level. MCDC does not report a cancer action level for nickel.

1.3.1.1.8 Lead (Pb)

Lead was detected in tissue from all six SWAT blue mussel sites sampled in 2015-16 (Figure 1.3.1.1.8.1). Lead levels measured in mussels ranged from a low mean concentration of 1.02 µg/g dry wt. at Scarborough River to a high mean concentration of 9.28 µg/g dry wt. at East End Beach, Portland. Three sites had lead concentrations less than the Gulfwatch median, but exceeding the NS&T median. Three sites had lead concentrations exceeding the NS&T 85th percentile and so were 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 five of the six sites were compared to the 2015-16 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 five 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

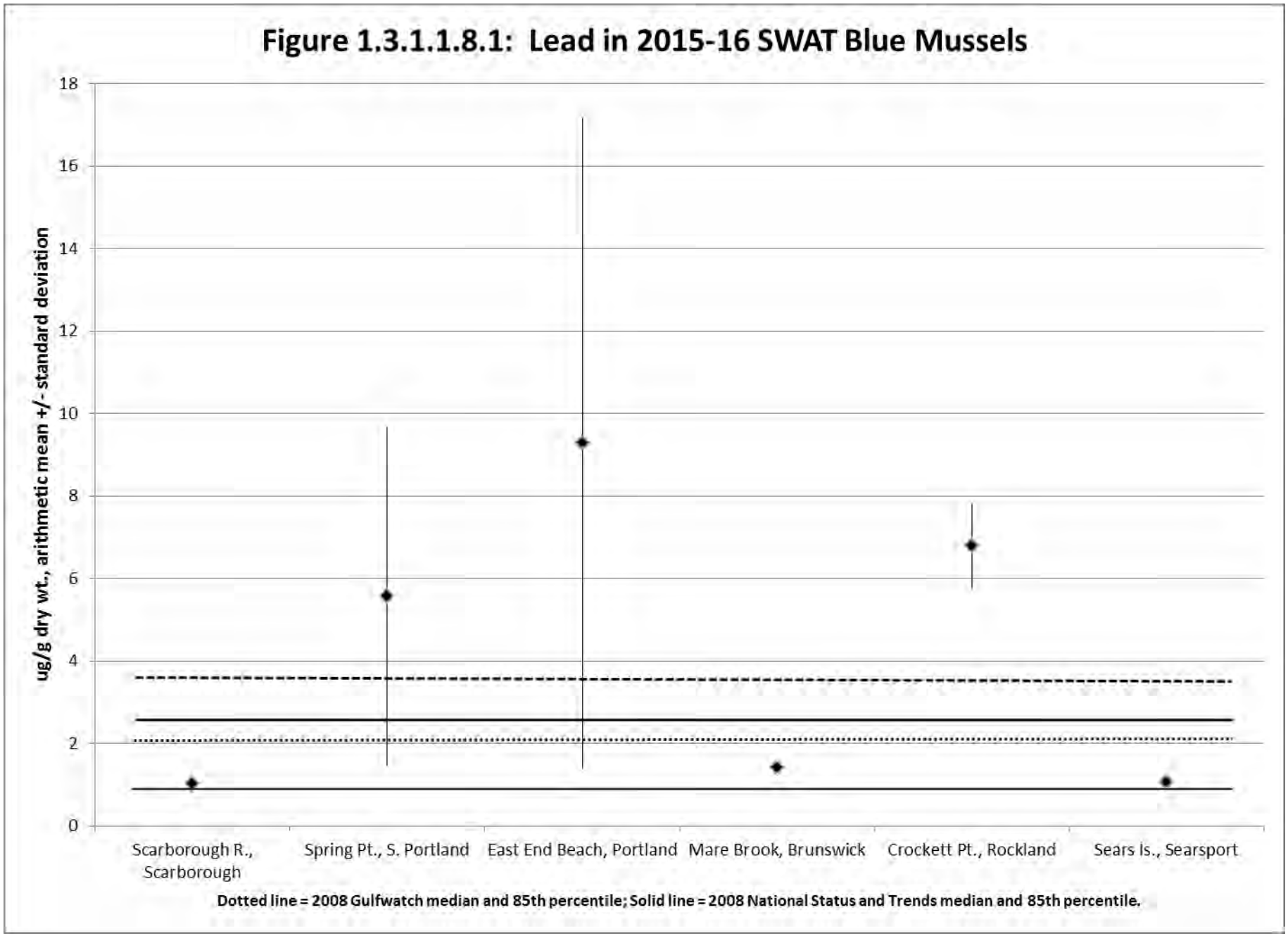


Figure 1.3.1.1.8.1: Lead in 2015-16 SWAT Blue Mussels
ug/g dry wt., arithmetic mean +/- standard deviation
18
16
14
12
10
8
6
4
2
0
Scarborough R., Scarborough
Spring Pt., S. Portland
East End Beach, Portland
Mare Brook, Brunswick
Crockett Pt., Rockland
Sears Is., Searsport
Dotted line = 2008 Gulfwatch median and 85th percentile; Solid line = 2008 National Status and Trends median and 85th percentile.

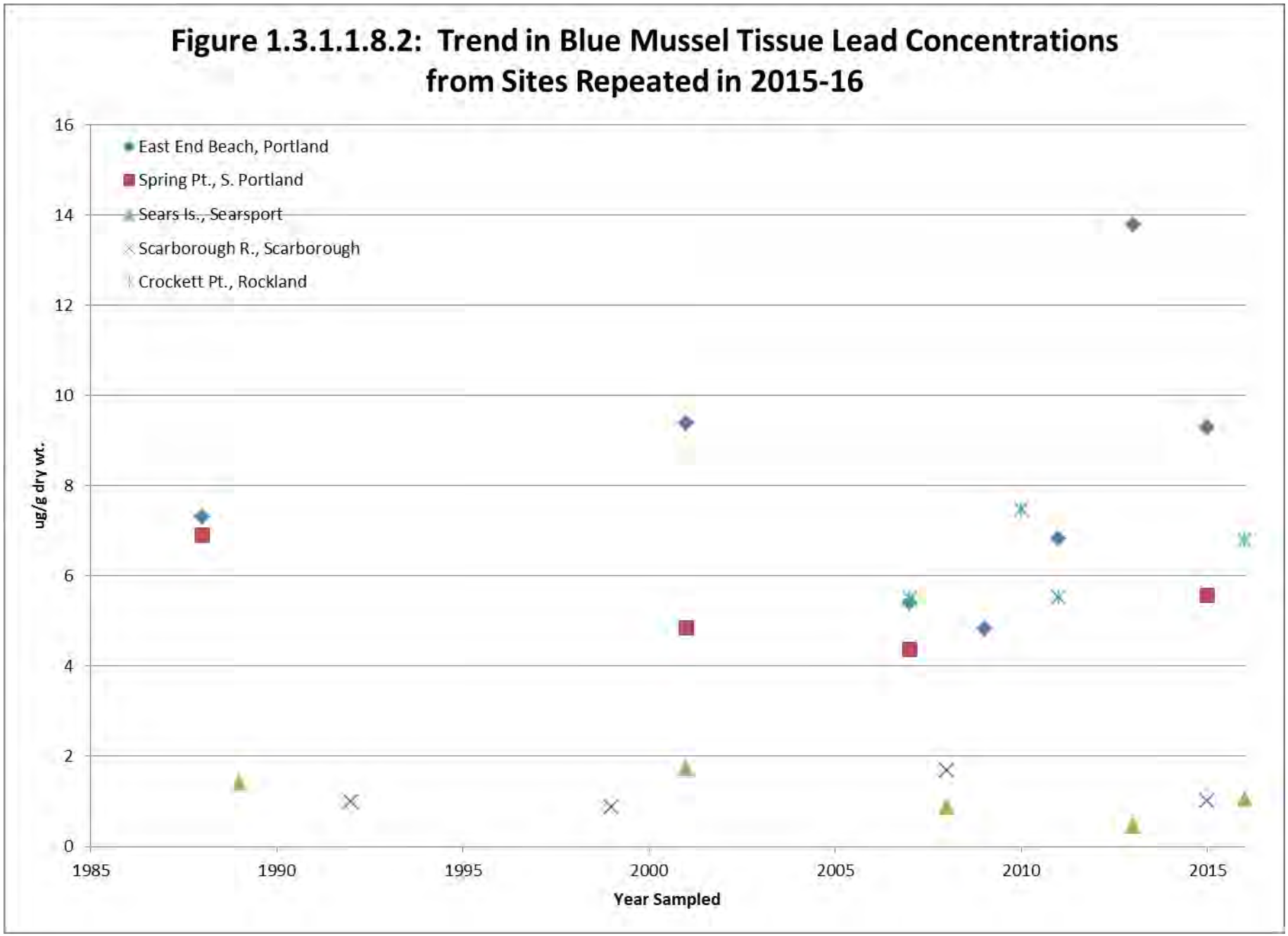


Figure 1.3.1.1.8.2: Trend in Blue Mussel Tissue Lead Concentrations from Sites Repeated in 2015-16
East End Beach, Portland
Spring Pt., S. Portland
Sears Is., Searsport
Scarborough R., Scarborough
Crockett Pt., Rockland
ug/g dry wt.
0
2
4
6
8
10
12
14
16
1985
1990
1995
2000
2005
2010
2015
Year Sampled

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 apparently was eliminated at the 2007 Interstate Shellfish Sanitation Conference. The more conservative MCDC lead FTAL in non-commercially caught sportfish is 0.6 µg/g wet wt., which is based on a blood lead concentration model. The highest mean concentration in the 2015-16 Maine SWAT mussel data, 1.41 µg/g wet wt. at East End Beach, Portland, exceeds MCDC lead FTAL. The mean lead concentrations in tissues from Crockett Point, Rockland, 1.12 ug/g wet wt., and Spring Point, S. Portland, 0.80 ug/g wet wt., also exceeded the MCDC lead FTAL. Three remaining three sites sampled in 2015-16 were lower and did not exceed the MCDC FTAL for lead.

Review of the 2007-16 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:

Spring Point, S. Portland, 2007	0.6 ppm wet wt.
Spring Point, S. Portland, 2010	0.7 ppm wet wt.
Spring Point, S. Portland, 2012	0.6 ppm wet wt.
Spring Point, S. Portland, 2015	0.8 ppm wet wt.
Middle Fore R., Portland, 2007	0.6 ppm wet wt.
East End Beach, Portland, 2007	0.8 ppm wet wt.
East End Beach, Portland, 2009	0.8 ppm wet wt.
East End Beach, Portland, 2011	0.9 ppm wet wt.
East End Beach, Portland, 2013	2.1 ppm wet wt.
East End Beach, Portland, 2015	1.4 ppm wet wt.
Turnip Island, Georgetown, 2012	1.4 ppm wet wt.
Crockett Point, Rockland, 2007	1.1 ppm wet wt.
Crockett Point, Rockland, 2010	1.3 ppm wet wt.
Crockett Point, Rockland, 2011	1.1 ppm wet wt.
Crockett Point, Rockland, 2016	1.1 ppm wet wt.

Ocean Pursuits Boat Yard, Rockland, 2013	0.6 ppm wet wt.
Town Landing, Rockland, 2013	0.9 ppm wet wt.
Camden Harbor, Camden, 2007	0.7 ppm wet wt.
Goose Falls, Brooksville, 2007	1.1 ppm wet wt.
Piscataqua River Back Channel, Kittery, 2008	0.6 ppm wet wt.

The MCDC lead FTAL is based on the consumer eating an 8 oz. meal. Maine SWAT data 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 six blue mussel sample locations tested in 2015-16 (Figure 1.3.1.1.9.1). Mercury levels measured in mussels ranged from a low mean concentration of 0.12 µg/g dry wt. at Scarborough River to a high mean concentration of 0.29 µg/g dry wt. at Spring Point, S. Portland. Four of six sites exceeded the 2008 Gulfwatch median, while only Spring Point, S. Portland, exceeded the Gulfwatch 85th percentile concentration. Figure 1.3.1.1.9.1 also compares 2015-16 SWAT blue mussel mercury concentrations to NS&T Mussel Watch median and 85th percentile values. The reader should note that Gulfwatch median and 85th percentile values actually exceed NS&T Mussel Watch median and 85th percentile values, respectively, since the northeastern US has relatively high mercury levels due to 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, five SWAT sites tested in 2015-16 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. Scarborough River 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 2015-16 was 0.042 µg/g wet wt. at Spring Point, S. Portland. This mean concentration, as well as those from the other five sites sampled, compares favorably with the

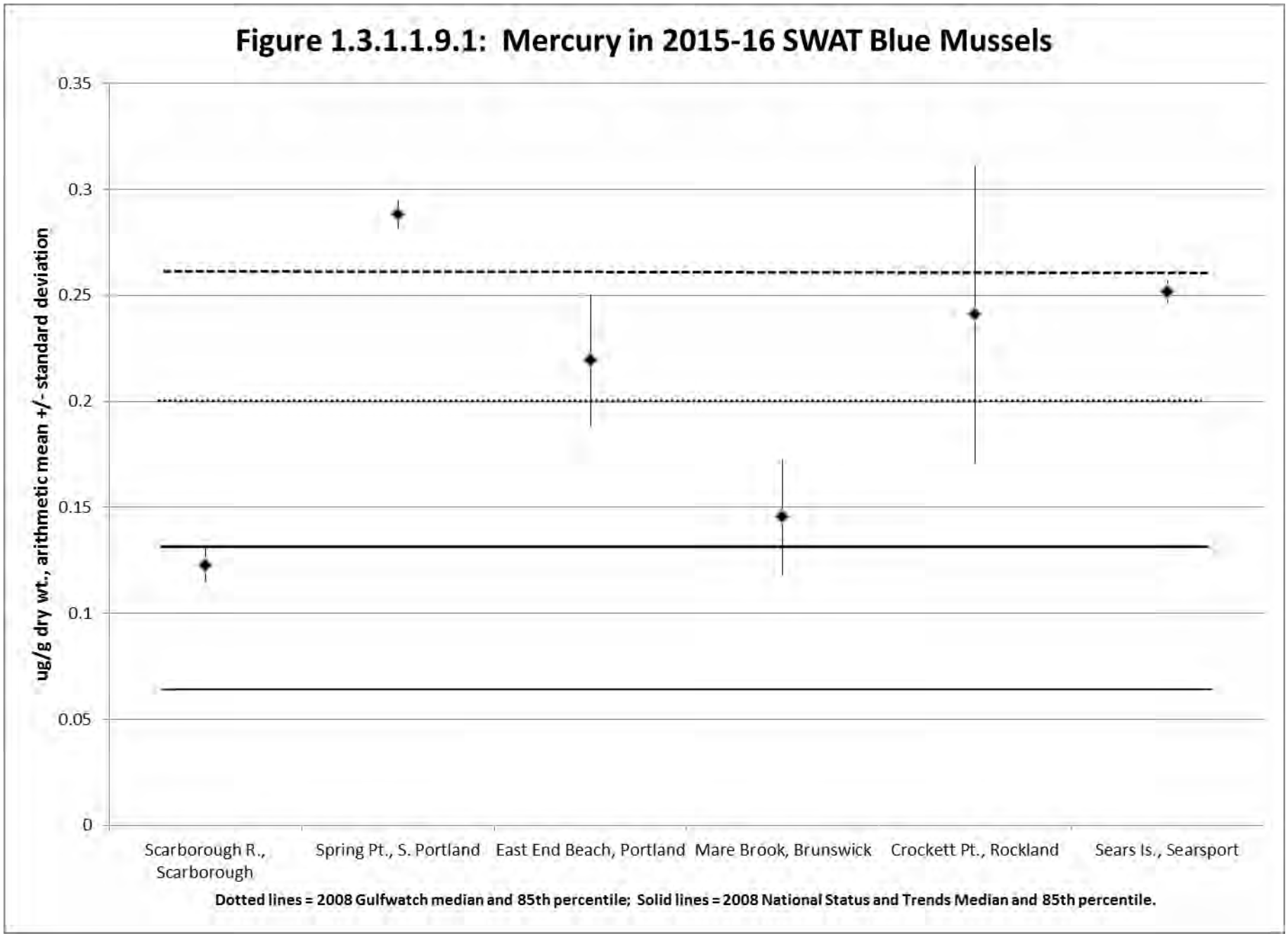


Figure 1.3.1.1.9.1: Mercury in 2015-16 SWAT Blue Mussels
ug/g dry wt., arithmetic mean +/- standard deviation
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Scarborough R., Scarborough
Spring Pt., S. Portland
East End Beach, Portland
Mare Brook, Brunswick
Crockett Pt., Rockland
Sears Is., Searsport
Dotted lines = 2008 Gulfwatch median and 85th percentile; Solid lines = 2008 National Status and Trends Median and 85th percentile.

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.

1.3.1.1.10 Zinc (Zn)

Zinc was detected in tissues taken from all six locations sampled in 2015-16 (Figure 1.3.1.1.10.1). Zinc levels measured in mussels ranged from a low mean concentration of 65.6 µg/g dry wt. at Mare Brook, Brunswick, to a high mean concentration of 135.0 µg/g dry wt. at East End Beach, Portland. Zinc concentrations in tissue from East End Beach, Portland, and Crockett Point, Rockland, exceeded the the 2008 Gulfwatch median and the 2008 Gulfwatch 85th percentile. Figure 1.3.1.1.10.2 shows 2015-16 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

Kilkenny Cove, Hancock

Softshell clam tissues, edible and whole as described above, 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 for the sites in Kilkenny were compared to Gulf of Maine (Gulfwatch, see LeBlanc et al. 2009) softshell clam data to place Maine SWAT data in a regional context.

1.3.1.2.1 Silver (Ag)

Silver was detected at all 15 sample locations (Figure 1.3.1.2.1.1). Silver concentrations in edible tissue ranged from a low concentration of 0.25 µg/g dry wt. to a high concentration of 01.04 µg/g dry wt. Silver concentrations in edible softshell clam tissue were compared to the Gulfwatch mean concentration for four sites sampled in 2008 (two in Maine and two in New Hampshire). Silver concentrations at Kilkenny Cove were below the Gulfwatch mean (1.32 µg/g dry wt.).

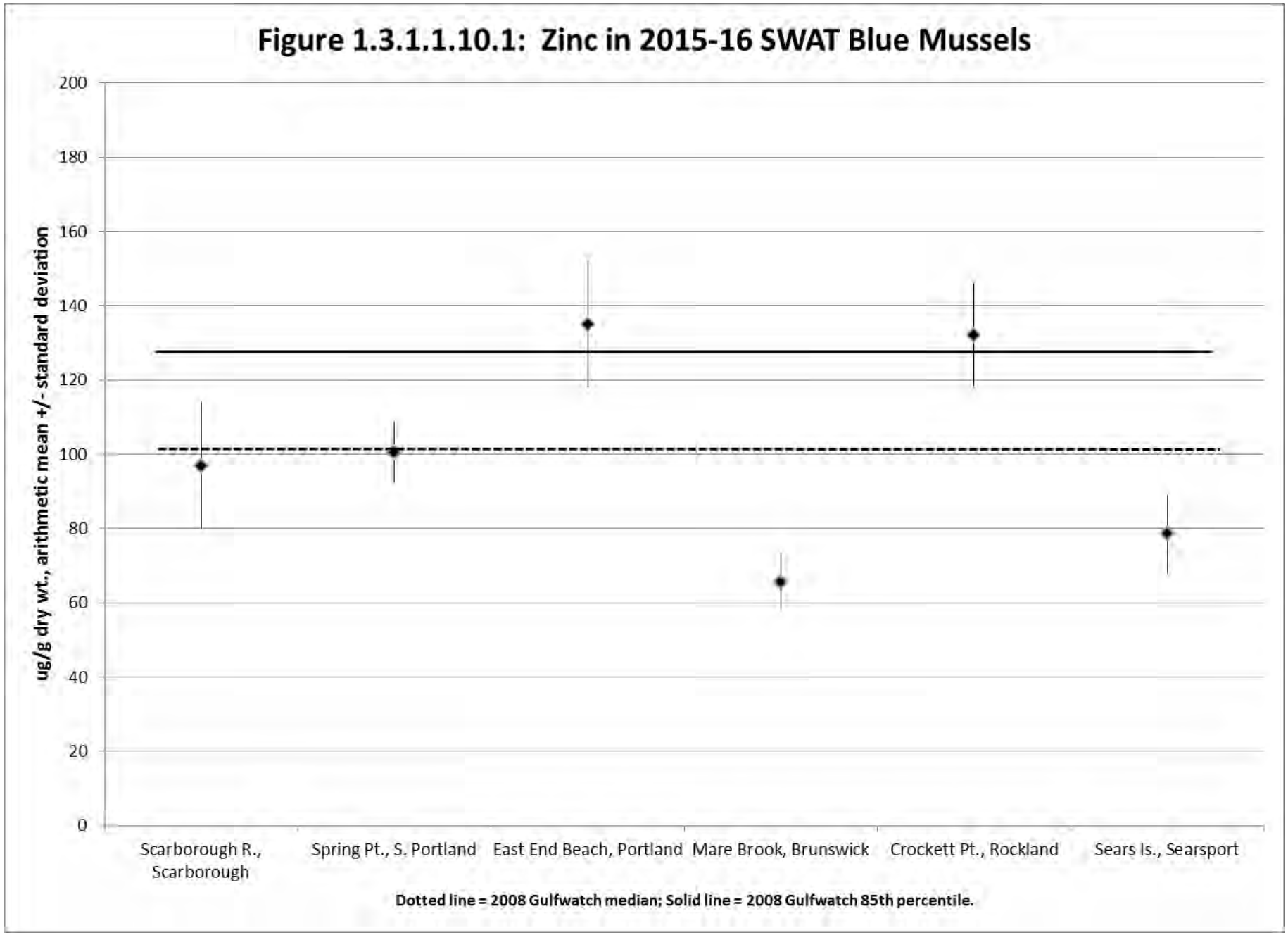


Figure 1.3.1.1.10.1: Zinc in 2015-16 SWAT Blue Mussels
ug/g dry wt., arithmetic mean +/- standard deviation
200
180
160
140
120
100
80
60
40
20
0
Scarborough R., Scarborough
Spring Pt., S. Portland
East End Beach, Portland
Mare Brook, Brunswick
Crockett Pt., Rockland
Sears Is., Searsport
Dotted line = 2008 Gulfwatch median; Solid line = 2008 Gulfwatch 85th percentile.

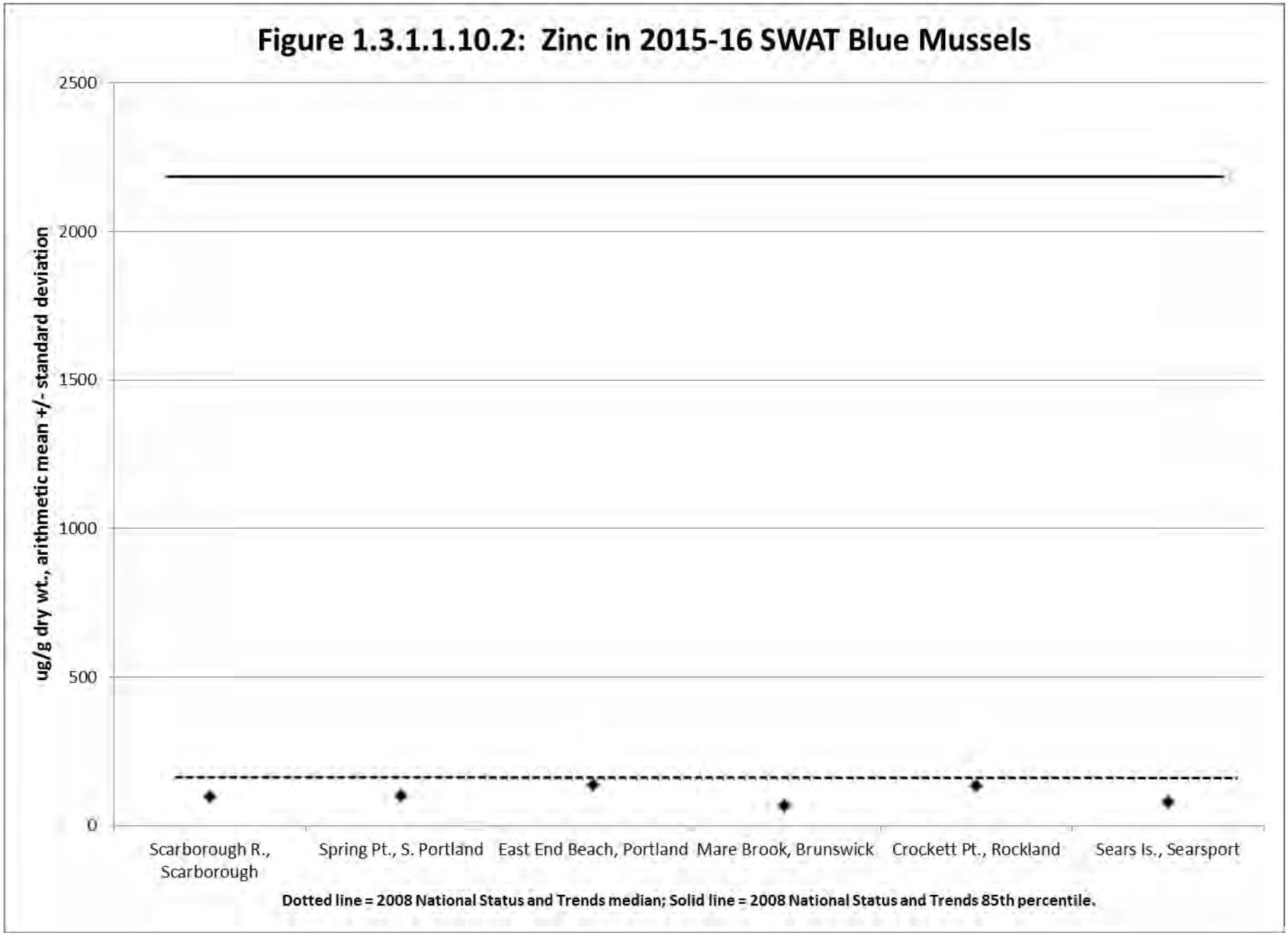


Figure 1.3.1.1.10.2: Zinc in 2015-16 SWAT Blue Mussels
ug/g dry wt., arithmetic mean +/- standard deviation
2500
2000
1500
1000
500
0
Scarborough R., Scarborough
Spring Pt., S. Portland
East End Beach, Portland
Mare Brook, Brunswick
Crockett Pt., Rockland
Sears Is., Searsport
Dotted line = 2008 National Status and Trends median; Solid line = 2008 National Status and Trends 85th percentile.

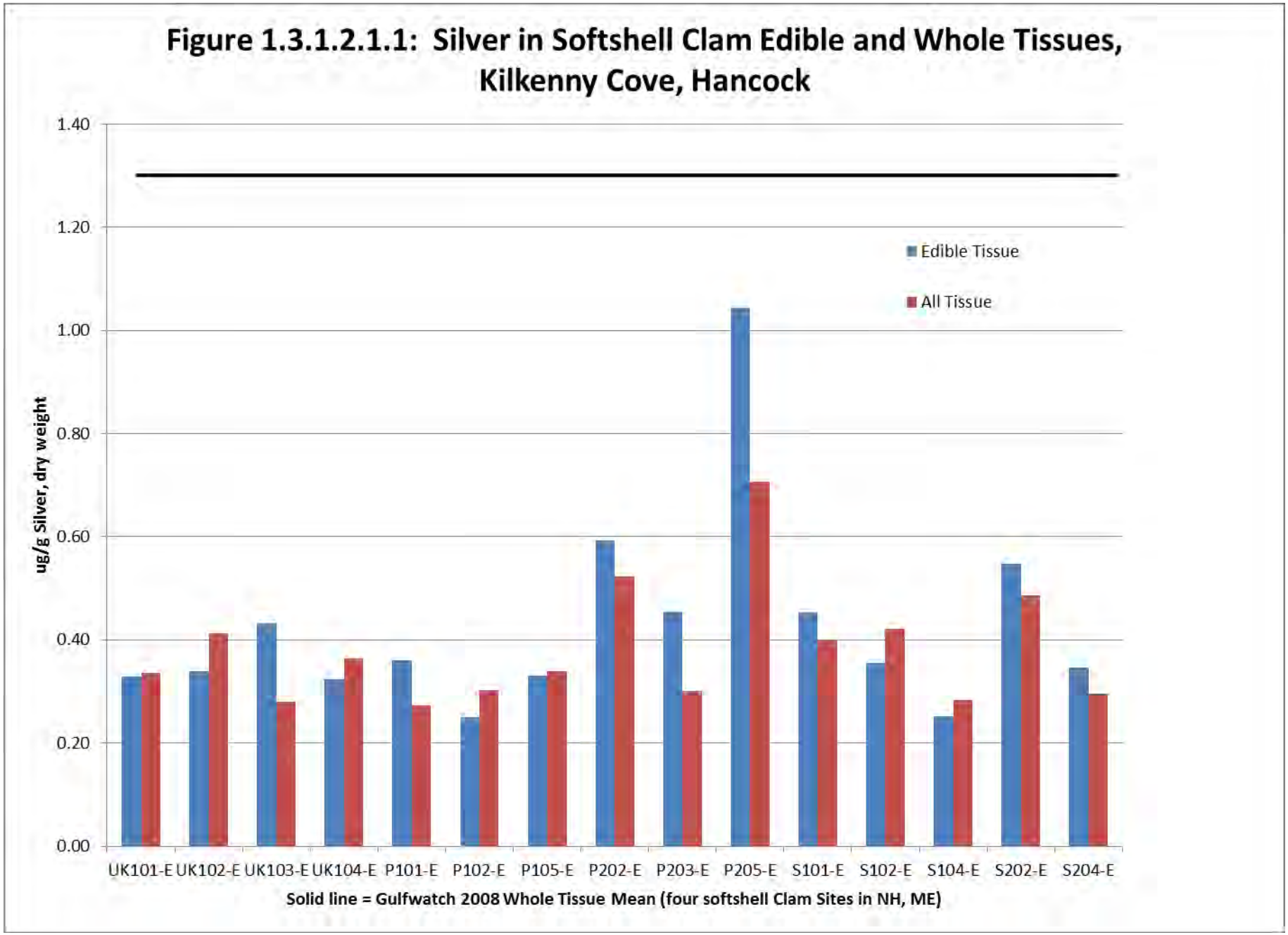


Figure 1.3.1.2.1.1: Silver in Softshell Clam Edible and Whole Tissues, Kilkenny Cove, Hancock
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
ug/g Silver, dry weight
Edible Tissue
All Tissue
UK101-E
UK102-E
UK103-E
UK104-E
P101-E
P102-E
P105-E
P202-E
P203-E
P205-E
S101-E
S102-E
S104-E
S202-E
S204-E
Solid line = Gulfwatch 2008 Whole Tissue Mean (four softshell Clam Sites in NH, ME)

Silver concentrations in whole tissue ranged from a low concentration of 0.27 µg/g dry wt. to a high concentration of 0.71 µg/g dry wt. Silver concentrations in edible softshell clam tissue were compared to the Gulfwatch mean concentration for four sites sampled in 2008 (two in Maine and two in New Hampshire). Silver concentrations in whole clam tissue at Kilkenny Cove were below the Gulfwatch mean (1.32 µg/g dry wt.).

Edible and whole clam tissue silver concentrations differed slightly. The whole to edible tissue ratio of silver concentrations varied from 0.6 to 1.2, with the mean ratio across all fifteen sites at 0.9.

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. Silver concentrations in Maine softshell clams appear to be relatively low. The highest Gulfwatch values, which came from the two NH sites, were just over 2 µg/g dry wt., which is very similar to the Mast Cove, Eliot, SWAT site tissue concentration.

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 highest Kilkenny Cove edible softshell clam tissue silver concentration, when expressed on a wet weight basis, is 0.21 µg/g wet weight. This concentration is over an order 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 15 sample locations (Figure 1.3.1.2.2.1). Arsenic concentrations in edible tissue ranged from a low concentration of 9.67 µg/g dry wt. to a high concentration of 12.13 µg/g dry wt. Arsenic concentrations in whole tissue ranged from a low concentration of 12.72 µg/g dry wt. to a high concentration of 33.37 µg/g dry wt.

While Gulfwatch does not monitor arsenic in blue mussels or softshell clams in the Gulf of Maine, arsenic in mussels and oysters is tracked regionally and nationally by NS&T. In blue mussels, NS&T considers 5-11 parts per million dry wt. (directly comparable to SWAT ug/g data) to be in the lowest of three ranges of arsenic concentration within the region (Kimbrough et al., 2008). The edible tissue arsenic concentration in softshell clams at eleven of fifteen sites in Kilkenny Cove fell into this range, while the arsenic concentrations at four of fifteen sites were just above the upper end of this range (Kimbrough et al., 2008). The arsenic concentrations in softshell clam whole tissue were in the NS&T regional mid-range except the four highest concentrations, which were in

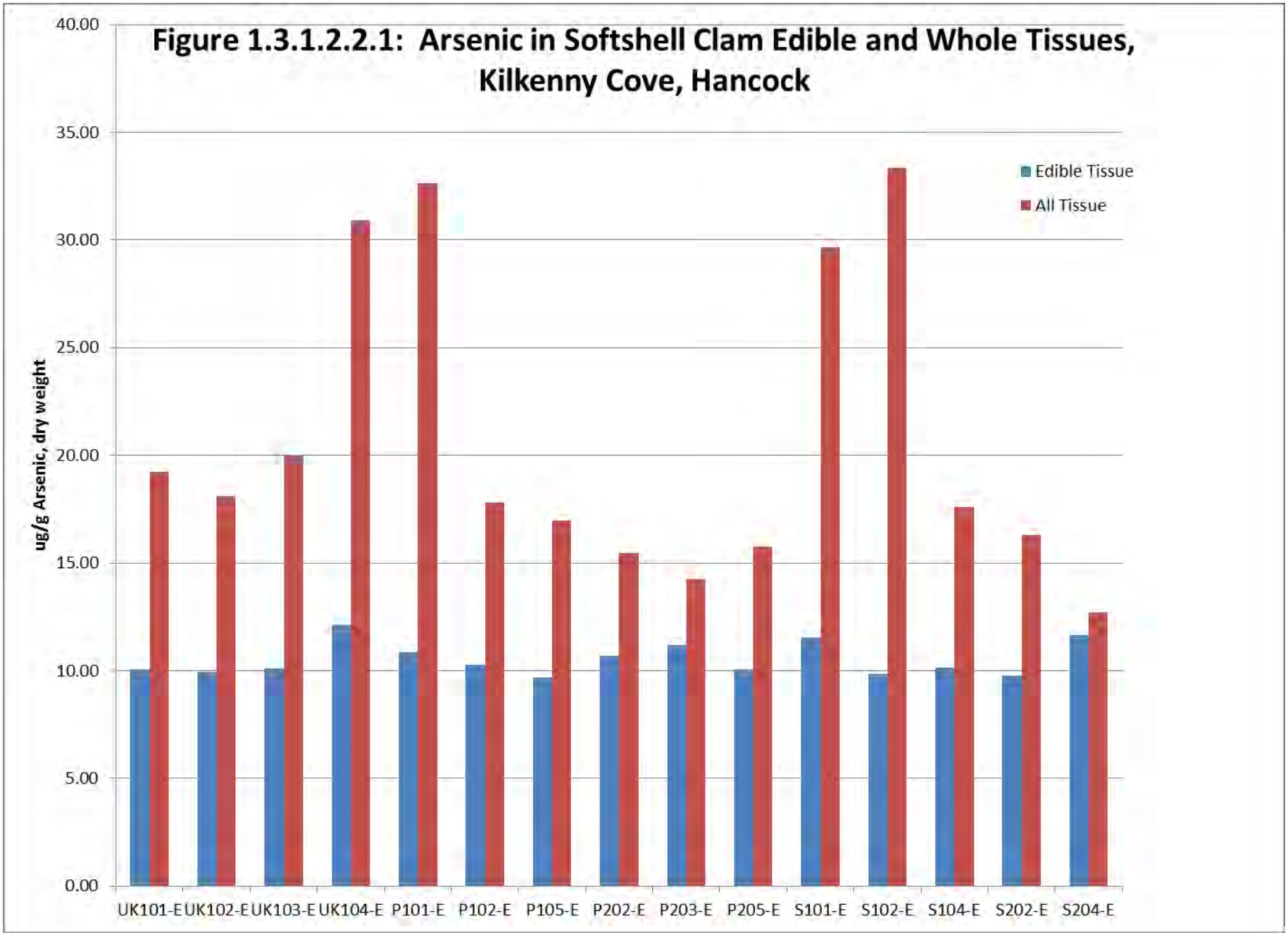


Figure 1.3.1.2.2.1: Arsenic in Softshell Clam Edible and Whole Tissues, Kilkenny Cove, Hancock
ug/g Arsenic, dry weight
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Edible Tissue
All Tissue
UK101-E
UK102-E
UK103-E
UK104-E
P101-E
P102-E
P105-E
P202-E
P203-E
P205-E
S101-E
S102-E
S104-E
S202-E
S204-E

the highest range used by NS&T. regionally (23-41) and nationally (23-57 ppm). The NS&T ranges are based on mussels or oysters as regionally available. However, it is of interest to give a point of comparison for Maine clam data. Edible and whole clam tissue arsenic concentrations differed markedly. The whole to edible tissue ratio of arsenic concentrations varied from 1.1 to 3.4, with the mean ratio across all fifteen sites at 2.0.

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, including the SWAT blue mussel tissue data, are analyzed for total arsenic, not inorganic arsenic. MCDC uses FDA's 1993 assumption that 10% of total arsenic in finfish is inorganic arsenic. Using this assumption, 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 arsenic wet weight concentrations. Using this methodology, the range of concentrations of inorganic arsenic in Kilkenny Cove edible clam tissue is estimated to be 0.16 to 0.23 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 ever since arsenic data have been recorded as part of the SWAT program all blue mussel sites sampled have also exceeded the MCDC cancer FTAL. 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 15 sample locations (Figure 1.3.1.2.3.1). Cadmium concentrations in edible tissue ranged from a low concentration of 0.37 µg/g dry wt. to a high concentration of 0.57 µg/g dry wt. Cadmium concentrations in whole tissue ranged from a low concentration of 0.37 µg/g dry wt. to a high concentration of 0.49 µg/g dry wt.

Cadmium concentrations in edible softshell clam tissue were compared to the Gulfwatch mean concentration for four sites sampled in 2008 (two in Maine and two in New Hampshire). Cadmium concentrations at Kilkenny Cove were below the Gulfwatch mean (0.90 µg/g dry wt.). Cadmium concentrations in whole tissue ranged from a low

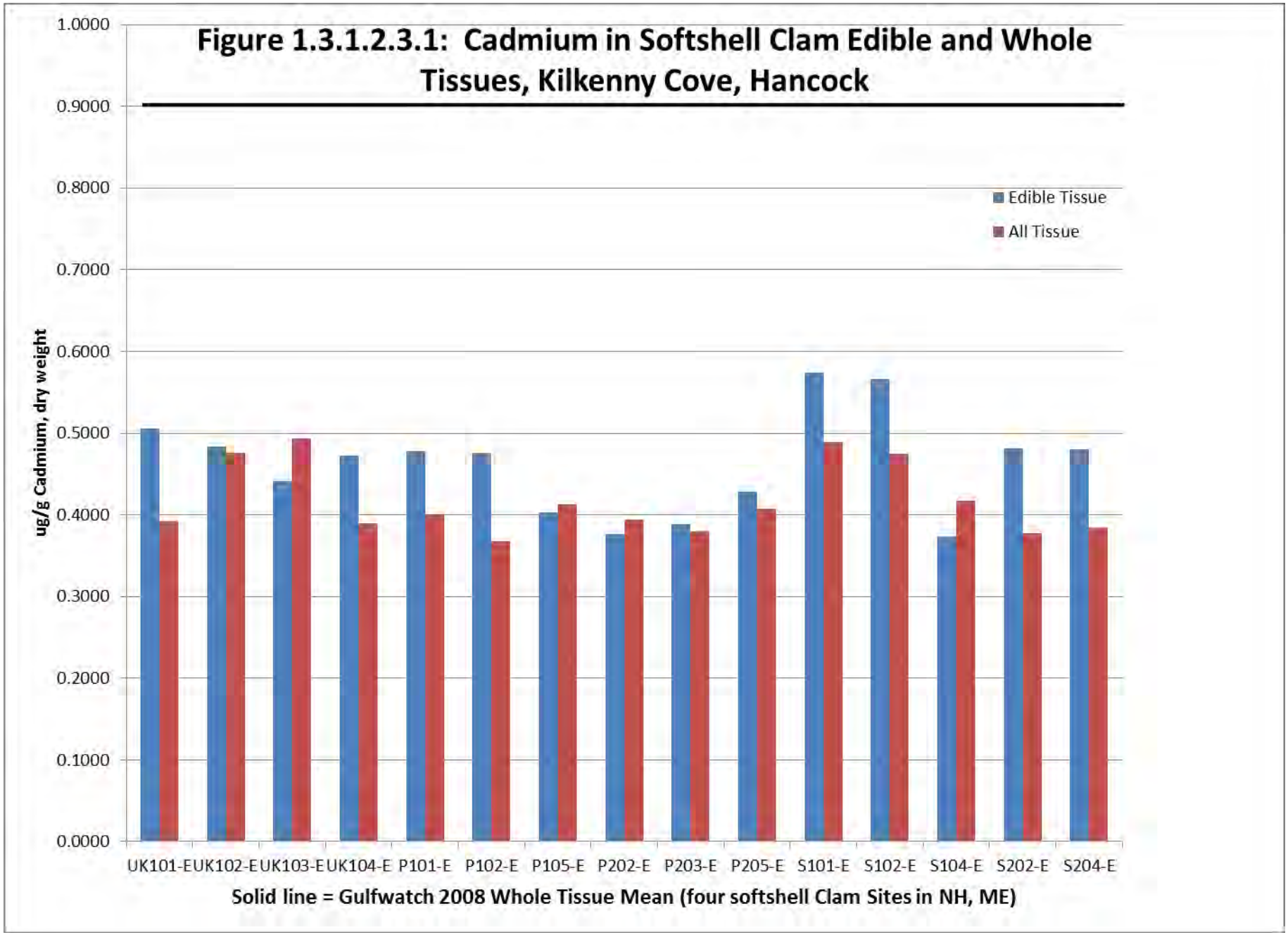


Figure 1.3.1.2.3.1: Cadmium in Softshell Clam Edible and Whole Tissues, Kilkenny Cove, Hancock
1.0000
0.9000
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
ug/g Cadmium, dry weight
Edible Tissue
All Tissue
UK101-E
UK102-E
UK103-E
UK104-E
P101-E
P102-E
P105-E
P202-E
P203-E
P205-E
S101-E
S102-E
S104-E
S202-E
S204-E
Solid line = Gulfwatch 2008 Whole Tissue Mean (four softshell Clam Sites in NH, ME)

concentration of 0.37 µg/g dry wt. to a high concentration of 0.49 µg/g dry wt. Cadmium concentrations in edible softshell clam tissue were compared to the Gulfwatch mean concentration for four sites sampled in 2008 (two in Maine and two in New Hampshire). Cadmium concentrations in whole clam tissue at Kilkenny Cove were below the Gulfwatch mean (0.90 µg/g dry wt.).

Edible and whole clam tissue cadmium concentrations differed slightly. The whole to edible tissue ratio of silver concentrations varied from 0.8 to 1.1, with the mean ratio across all fifteen sites at 0.8.

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 in Kilkenny Cove was 0.128 µg/g wet wt., which was well below the MCDC and FDA action levels (5% of the more conservative MCDC non-cancer FTAL).

1.3.1.2.4 Chromium (Cr)

Chromium was detected at all 15 sample locations (Figure 1.3.1.2.4.1). Chromium concentrations in edible tissue ranged from a low concentration of 1.94 µg/g dry wt. to a high concentration of 4.09 µg/g dry wt. Chromium concentrations in edible softshell clam tissue were compared to the Gulfwatch mean concentration for four sites sampled in 2008 (two in Maine and two in New Hampshire). Chromium concentrations in edible clam tissue at Kilkenny Cove were below the Gulfwatch mean (4.52 µg/g dry wt.). Chromium concentrations in whole tissue ranged from a low concentration of 5.51 µg/g dry wt. to a high concentration of 11.24 µg/g dry wt. and were above the Gulfwatch mean.

Edible and whole clam tissue chromium concentrations differed markedly. The whole to edible tissue ratio of chromium concentrations varied from 1.5 to 3.6, with the mean ratio across all fifteen sites at 2.6.

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

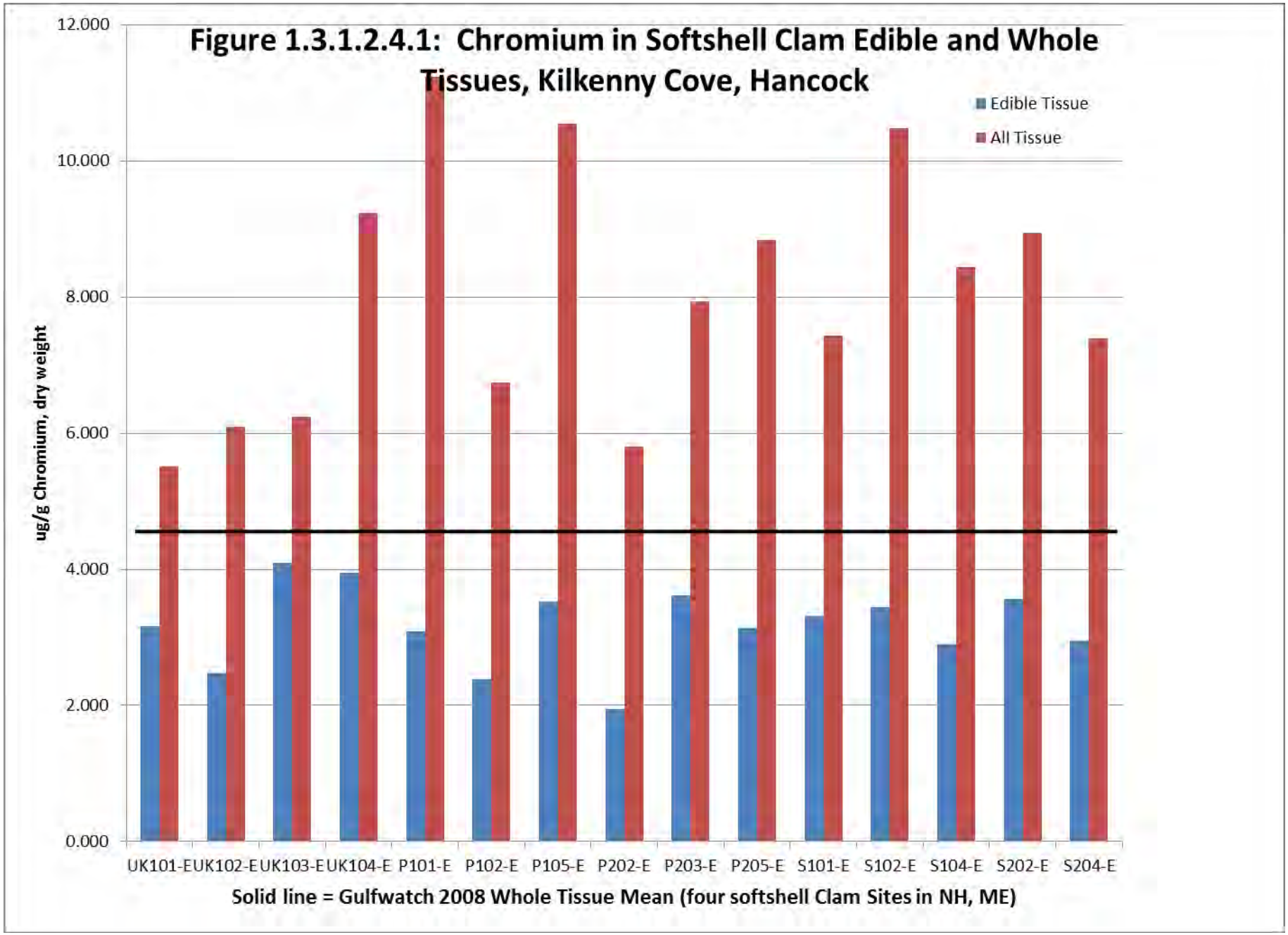


Figure 1.3.1.2.4.1: Chromium in Softshell Clam Edible and Whole Tissues, Kilkenny Cove, Hancock
Edible Tissue
All Tissue
ug/g Chromium, dry weight
12.000
10.000
8.000
6.000
4.000
2.000
0.000
UK101-E
UK102-E
UK103-E
UK104-E
P101-E
P102-E
P105-E
P202-E
P203-E
P205-E
S101-E
S102-E
S104-E
S202-E
S204-E
Solid line = Gulfwatch 2008 Whole Tissue Mean (four softshell Clam Sites in NH, ME)

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 for total chromium.

1.3.1.2.5 Copper (Cu)

Copper was detected at all 15 sample locations (Figure 1.3.1.2.5.1). Copper concentrations in edible tissue ranged from a low concentration of 8.06 µg/g dry wt. to a high concentration of 13.44 µg/g dry wt. Copper concentrations in edible softshell clam tissue were compared to the Gulfwatch mean concentration for four sites sampled in 2008 (two in Maine and two in New Hampshire). Copper concentrations in edible clam tissue at Kilkenny Cove were below the Gulfwatch mean (14.38 µg/g dry wt.). Copper concentrations in whole tissue ranged from a low concentration of 9.15 µg/g dry wt. to a high concentration of 14.07 µg/g dry wt. and were below the Gulfwatch mean.

Edible and whole clam tissue copper concentrations differed only slightly. The whole to edible tissue ratio of copper concentrations varied from 0.8 to 1.4, with the mean ratio across all fifteen sites at 1.1.

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 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.

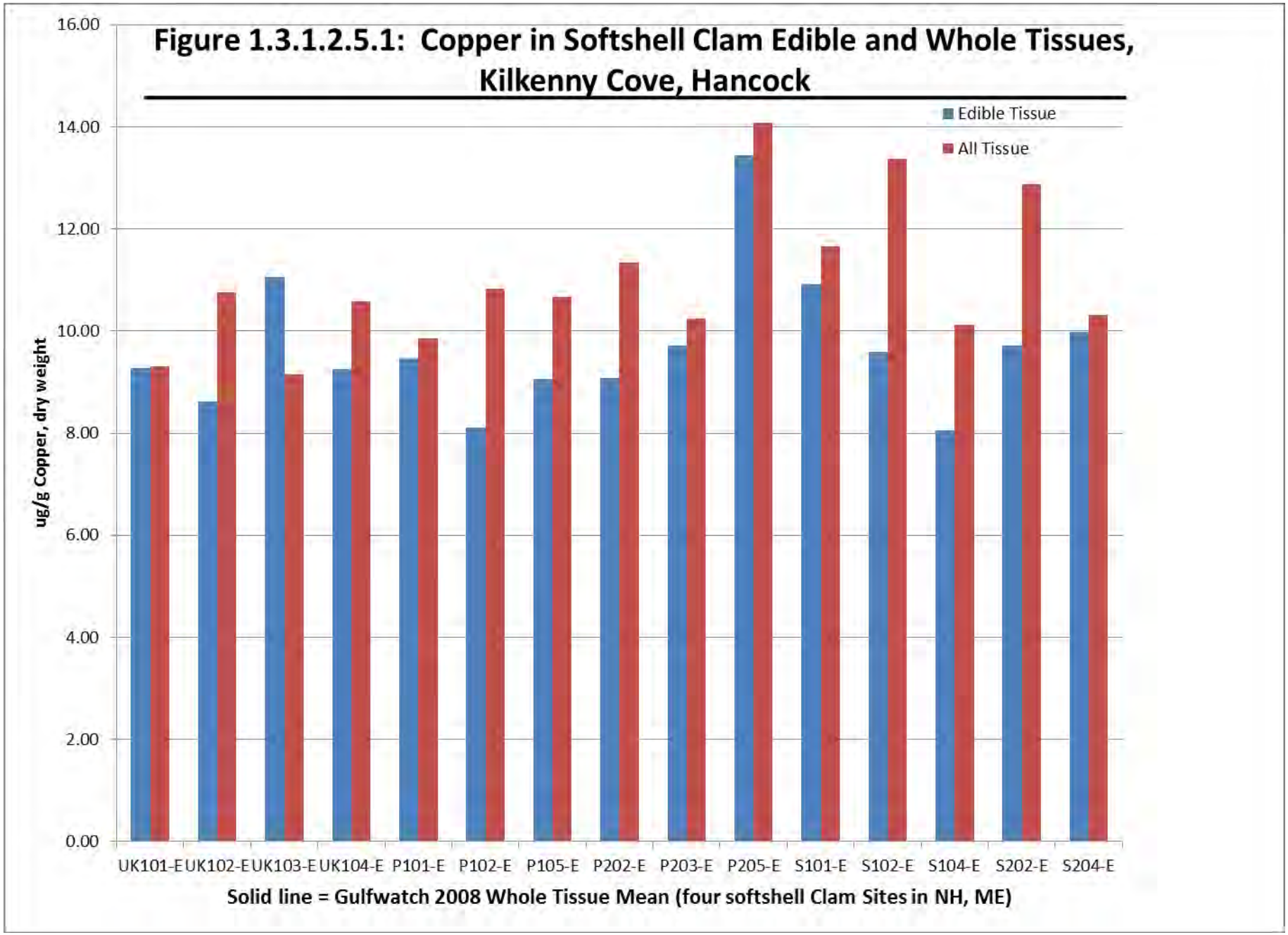


Figure 1.3.1.2.5.1: Copper in Softshell Clam Edible and Whole Tissues, Kilkenny Cove, Hancock
Edible Tissue
All Tissue
ug/g Copper, dry weight
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
UK101-E
UK102-E
UK103-E
UK104-E
P101-E
P102-E
P105-E
P202-E
P203-E
P205-E
S101-E
S102-E
S104-E
S202-E
S204-E
Solid line = Gulfwatch 2008 Whole Tissue Mean (four softshell Clam Sites in NH, ME)

1.3.1.2.6 Iron (Fe) and Aluminum (Al)

Iron was detected at all 15 sample locations (Figure 1.3.1.2.6.1). Iron concentrations in edible tissue ranged from a low concentration of 1,040 µg/g dry wt. to a high concentration of 2,960 µg/g dry wt. Iron concentrations in edible softshell clam tissue were compared to the Gulfwatch mean concentration for four sites sampled in 2008 (two in Maine and two in New Hampshire). Iron concentrations in edible clam tissue at Kilkenny Cove were below the Gulfwatch mean (8,716 µg/g dry wt.). Iron concentrations in whole tissue ranged from a low concentration of 3,290 µg/g dry wt. to a high concentration of 13,800 µg/g dry wt. and three of fifteen locations exceeded the Gulfwatch mean.

Edible and whole clam tissue iron concentrations differed markedly. The whole to edible tissue ratio of iron concentrations varied from 2.3 to 4.7, with the mean ratio across all fifteen sites at 3.9.

Aluminum was detected at all 15 sample locations (Figure 1.3.1.2.6.2). Aluminum concentrations in edible tissue ranged from a low concentration of 789 µg/g dry wt. to a high concentration of 1,670 µg/g dry wt. Aluminum concentrations in edible softshell clam tissue were compared to the Gulfwatch mean concentration for four sites sampled in 2008 (two in Maine and two in New Hampshire). Aluminum concentrations in edible clam tissue at Kilkenny Cove were below the Gulfwatch mean (1,757 µg/g dry wt.). Aluminum concentrations in whole tissue ranged from a low concentration of 2,510 µg/g dry wt. to a high concentration of 4,540 µg/g dry wt. and all fifteen locations exceeded the Gulfwatch mean.

Edible and whole clam tissue aluminum concentrations differed markedly. The whole to edible tissue ratio of aluminum concentrations varied from 1.8 to 3.2, with the mean ratio across all fifteen sites at 2.6. 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

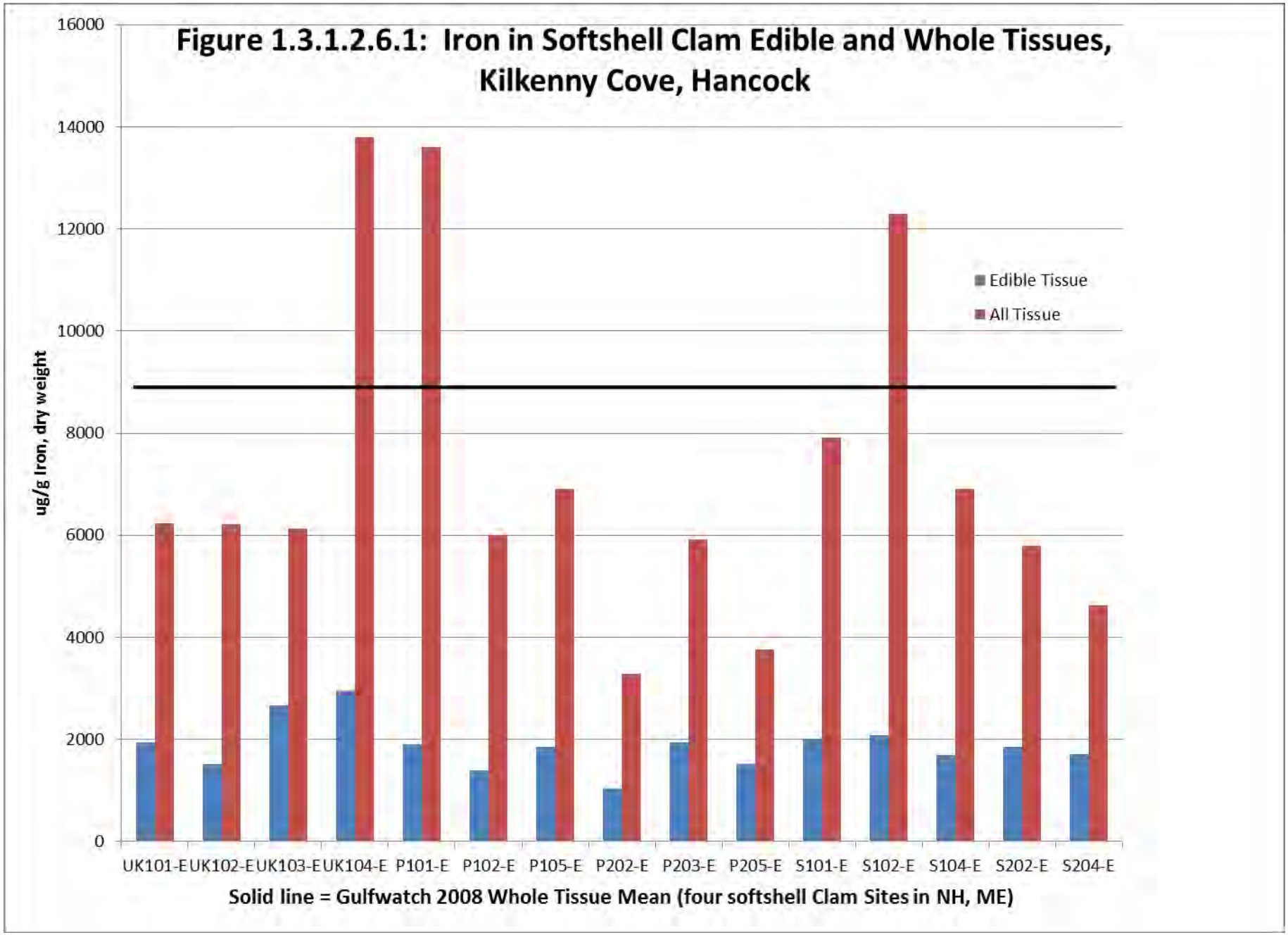


Figure 1.3.1.2.6.1: Iron in Softshell Clam Edible and Whole Tissues, Kilkenny Cove, Hancock
16000
14000
12000
10000
8000
6000
4000
2000
0
ug/g Iron, dry weight
Edible Tissue
All Tissue
UK101-E
UK102-E
UK103-E
UK104-E
P101-E
P102-E
P105-E
P202-E
P203-E
P205-E
S101-E
S102-E
S104-E
S202-E
S204-E
Solid line = Gulfwatch 2008 Whole Tissue Mean (four softshell Clam Sites in NH, ME)

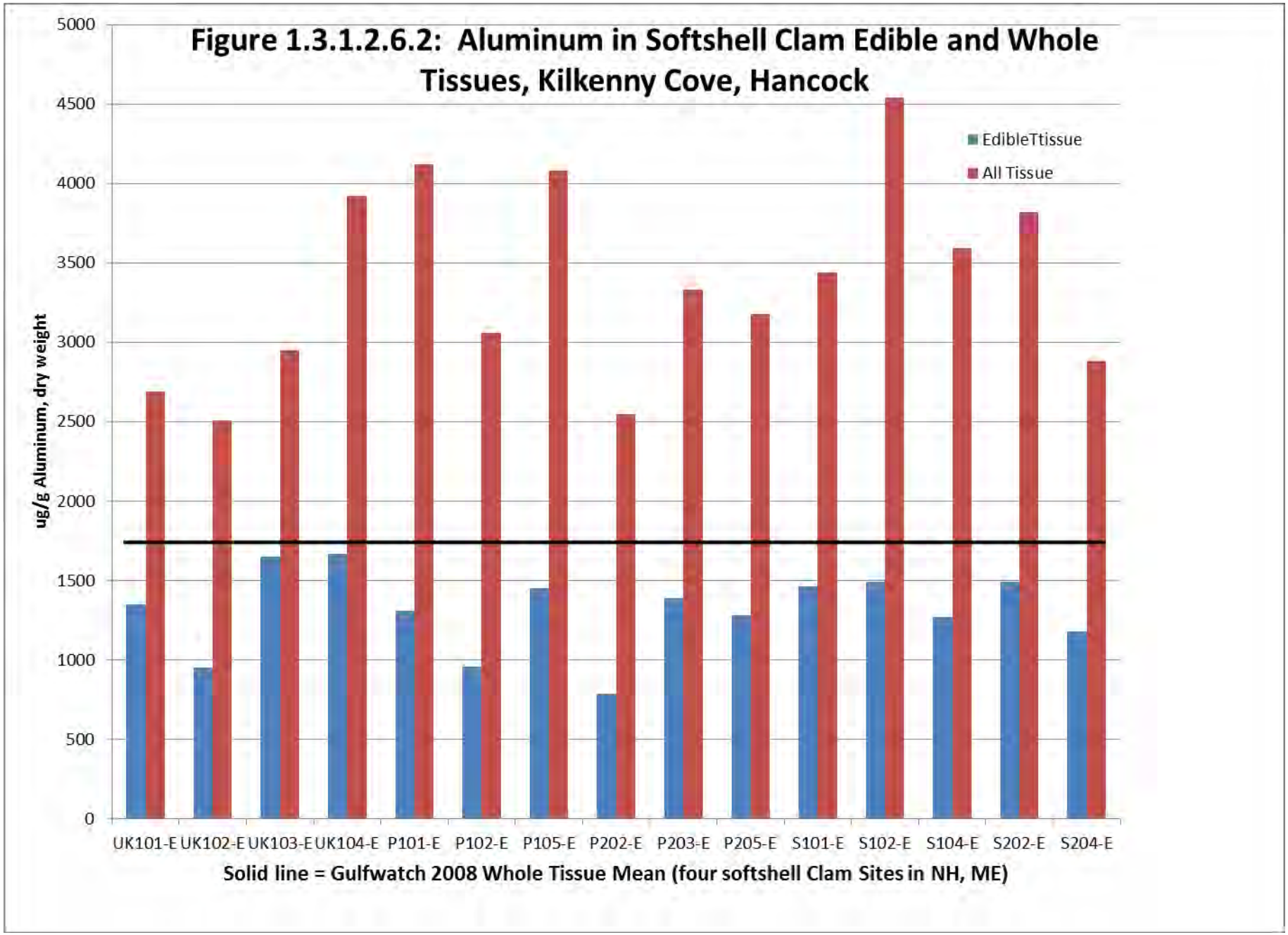


Figure 1.3.1.2.6.2: Aluminum in Softshell Clam Edible and Whole Tissues, Kilkenny Cove, Hancock
ug/g Aluminum, dry weight
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
EdibleTtissue
All Tissue
UK101-E
UK102-E
UK103-E
UK104-E
P101-E
P102-E
P105-E
P202-E
P203-E
P205-E
S101-E
S102-E
S104-E
S202-E
S204-E
Solid line = Gulfwatch 2008 Whole Tissue Mean (four softshell Clam Sites in NH, ME)

aluminum and iron levels disproportionately in clam tissue concentrations since no depuration occurs prior to tissue removal.

Monitoring for iron and aluminum provides an important reference to gauge sediment intake by clams, allowing iron and aluminum levels to be referenced if other more toxic metals or contaminants are detected in tissue 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 15 sampling locations (Figure 1.3.1.2.7.1). Nickel concentrations in edible tissue ranged from a low concentration of 1.4 µg/g dry wt. to a high concentration of 2.4 µg/g dry wt. Nickel concentrations in edible softshell clam tissue were compared to the Gulfwatch mean concentration for four sites sampled in 2008 (two in Maine and two in New Hampshire). Nickel concentrations in edible clam tissue at Kilkenny Cove were below the Gulfwatch mean (2.4 µg/g dry wt.) except for site UK103, which was slightly higher. Nickel concentrations in whole tissue ranged from a low concentration of 2.9 µg/g dry wt. to a high concentration of 4.7 µg/g dry wt. and all fifteen locations exceeded the Gulfwatch mean.

Edible and whole clam tissue nickel concentrations differed markedly. The whole to edible tissue ratio of nickel concentrations varied from 1.2 to 2.6, with the mean ratio across all fifteen sites at 2.0

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

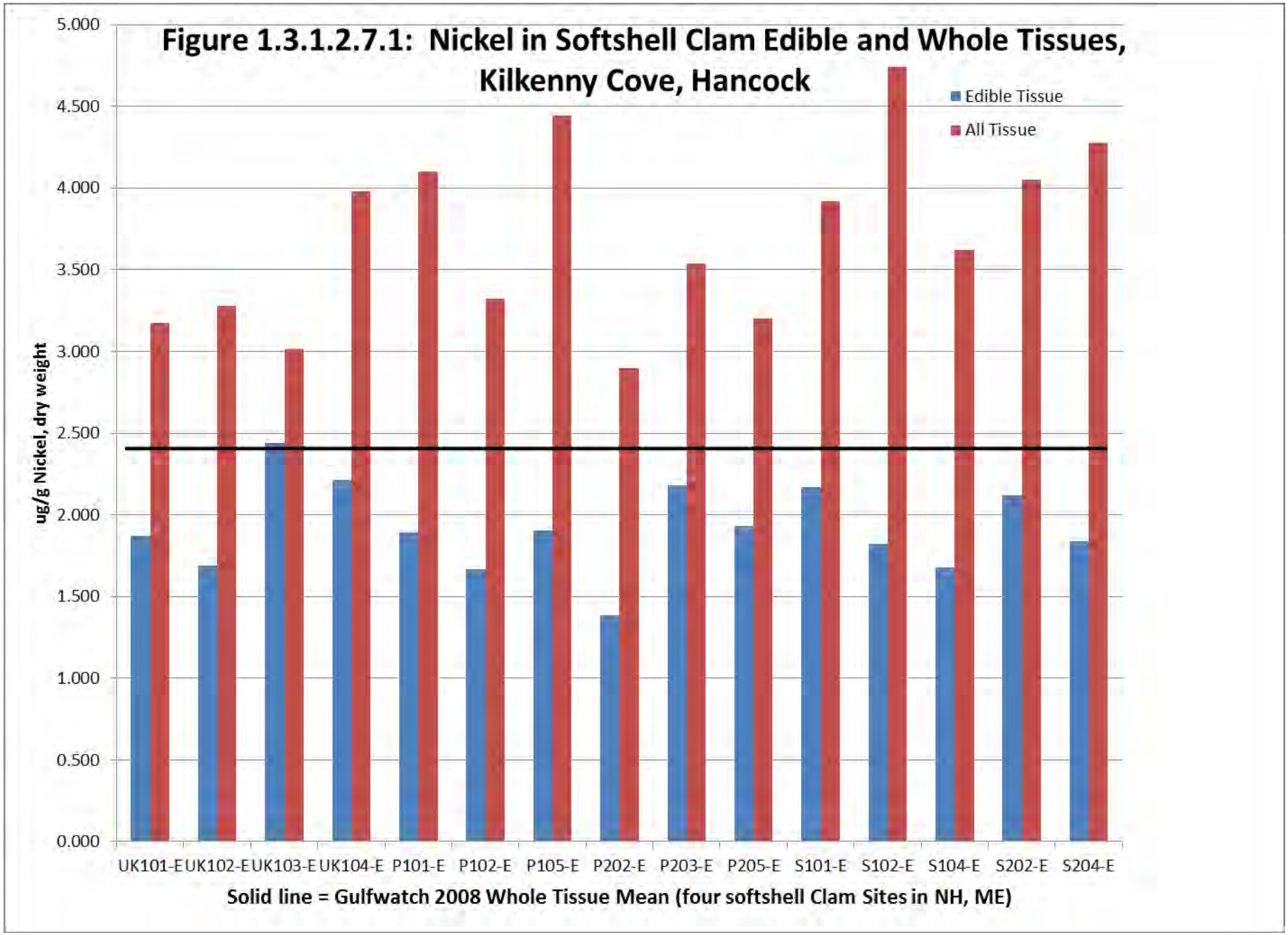


Figure 1.3.1.2.7.1: Nickel in Softshell Clam Edible and Whole Tissues, Kilkenny Cove, Hancock
Edible Tissue
All Tissue
ug/g Nickel, dry weight
5.000
4.500
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
UK101-E UK102-E UK103-E UK104-E P101-E P102-E P105-E P202-E P203-E P205-E S101-E S102-E S104-E S202-E S204-E
Solid line = Gulfwatch 2008 Whole Tissue Mean (four softshell Clam Sites in NH, ME)

maximum mean concentration detected by SWAT in edible clam tissue from Kilkenny Cove is 0.47 µg/g wet wt. at site UK103, which is several orders of magnitude lower than the more conservative MCDC action level. MCDC does not report a cancer action level for nickel. The highest whole tissue concentration was at site p105, which at 0.86 ug/g wet wt. is still well below the MCDC non-cancer FTAL.

1.3.1.2.8 Lead (Pb)

Lead was detected in clam tissue samples taken at all 15 sampling sites in Kilkenny Cove (Figure 1.3.1.2.8.1). Lead levels measured in clam edible tissue ranged from a low mean concentration of 0.87 µg/g dry wt. to a high mean concentration of 1.58 µg/g dry wt. at site UK104. Mean lead edible clam tissue concentrations at all 15 sites fell below the 2008 Gulfwatch mean (for whole tissue). Lead levels measured in whole clam tissue ranged from a low mean concentration of 2.67 µg/g dry wt. to a high mean concentration of 5.73 µg/g dry wt. at site S101. Mean lead whole clam tissue concentrations at all 15 sites fell below the 2008 Gulfwatch mean.

Edible and whole clam tissue lead concentrations differed markedly. The whole to edible tissue ratio of lead concentrations varied from 2 to 4.8, with the mean ratio across all fifteen sites at 3.5.

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 more conservative MCDC lead FTAL in non-commercially caught sportfish is 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. On this whole clam tissue basis, ten of the 15 locations tested in Kilkenny Cove exceeded the MCDC former FTAL of 0.6 ug/g wet wt. for recreationally caught sportfish. Testing of the clam edible tissues produced markedly different results, with the lead

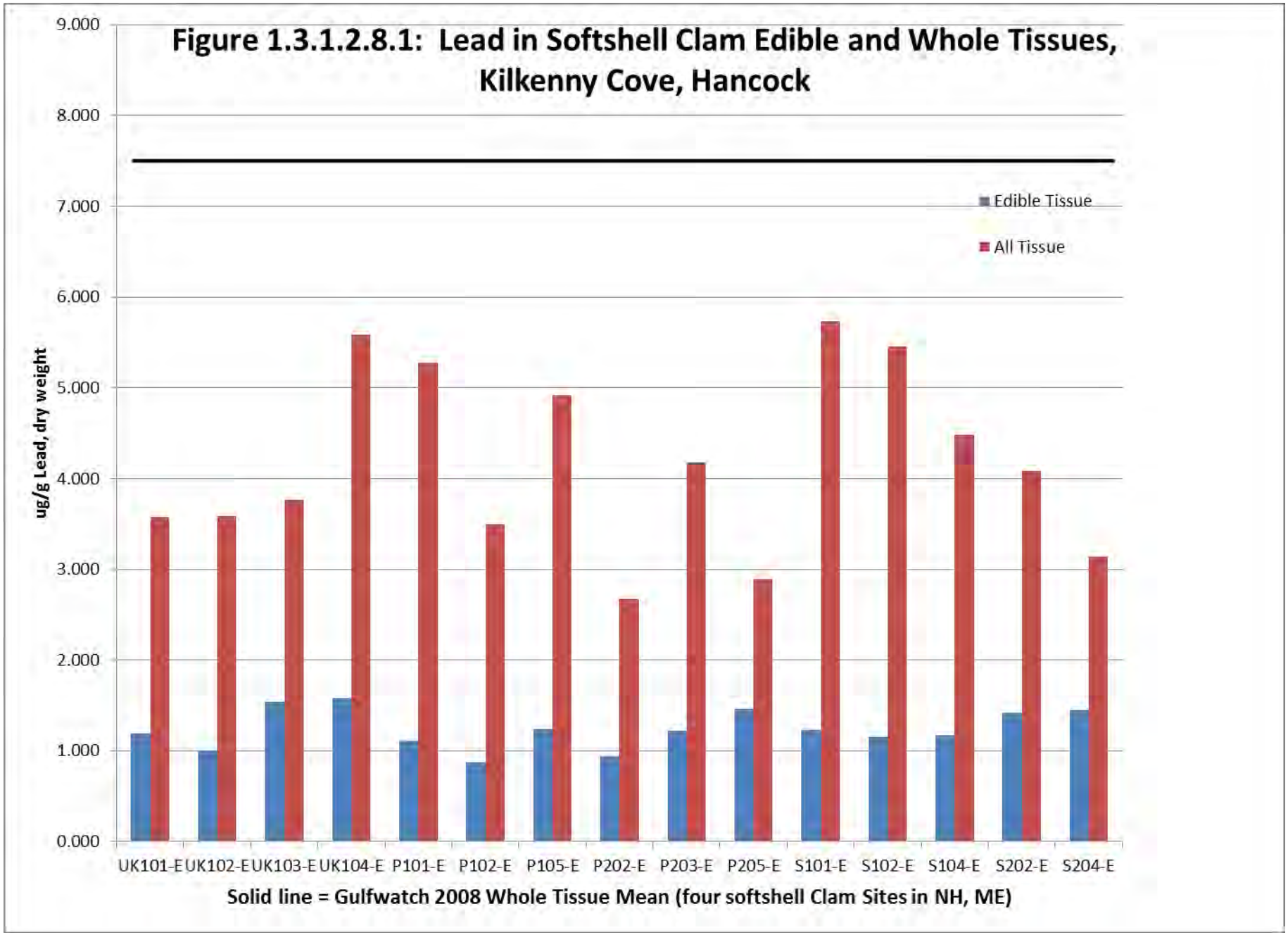


Figure 1.3.1.2.8.1: Lead in Softshell Clam Edible and Whole Tissues, Kilkenny Cove, Hancock
9.000
8.000
7.000
6.000
5.000
4.000
3.000
2.000
1.000
0.000
ug/g Lead, dry weight
Edible Tissue
All Tissue
UK101-E
UK102-E
UK103-E
UK104-E
P101-E
P102-E
P105-E
P202-E
P203-E
P205-E
S101-E
S102-E
S104-E
S202-E
S204-E
Solid line = Gulfwatch 2008 Whole Tissue Mean (four softshell Clam Sites in NH, ME)

concentrations in the edible tissues averaging 3.5 times less lead (when compared on a dry wt. basis). Edible tissue concentrations topped out at less than half the MCDC lead FTAL for recreationally caught finfish when considered on a wet wt. basis. Edible tissue lead concentrations ranged up to a maximum of 0.3 ug/g on a wet wt. basis.

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 is currently available from MCDC, but may include consumption, meal size, and risk groups that are not completely relevant to softshell clam consumption.

The MCDC 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 analysis was not performed on edible or whole clam tissue samples from Kilkenny Cove collected in 2015.

1.3.1.2.10 Zinc (Zn)

Zinc was detected in tissue taken at all 15 softshell clam sites in Kilkenny Cove(Figure 1.3.1.2.10.1). Zinc levels measured in clam edible tissue ranged from a low mean concentration of 68.7 µg/g dry wt. to a high mean concentration of 80.4 µg/g dry weight. Zinc concentrations in edible softshell clam tissue were compared to the Gulfwatch mean concentration for four sites sampled in 2008 (two in Maine and two in New Hampshire). Zinc concentrations in edible clam tissue at Kilkenny Cove were below the Gulfwatch mean (96.6 µg/g dry wt.) at all sites. Zinc concentrations in whole tissue ranged from a low concentration of 68.6 µg/g dry wt. to a high concentration of 81.1 µg/g dry wt. and all fifteen locations were below the Gulfwatch mean.

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 fifteen sites.

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 several orders of magnitude

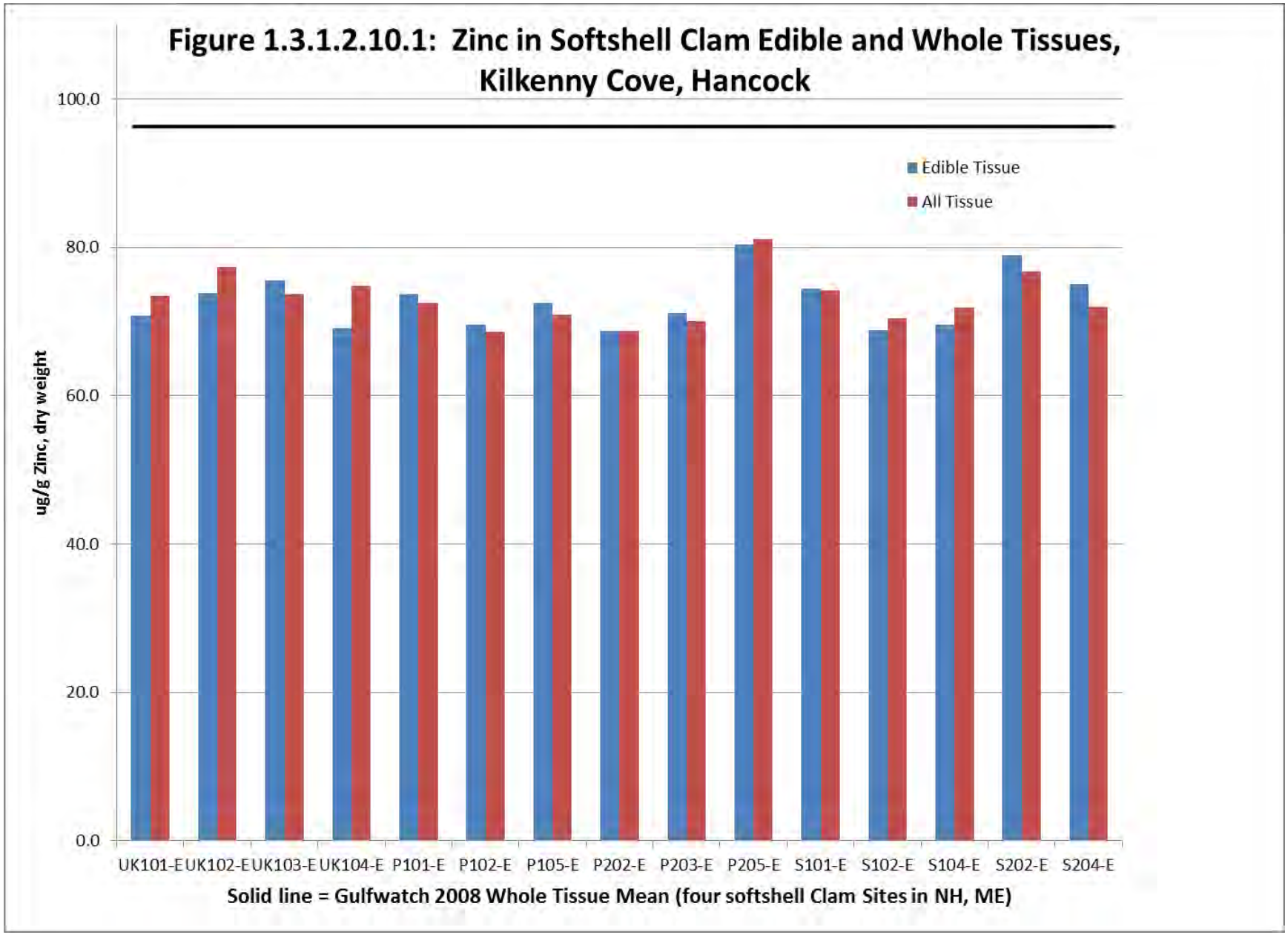


Figure 1.3.1.2.10.1: Zinc in Softshell Clam Edible and Whole Tissues, Kilkenny Cove, Hancock
100.0
80.0
60.0
40.0
20.0
0.0
ug/g Zinc, dry weight
Edible Tissue
All Tissue
UK101-E
UK102-E
UK103-E
UK104-E
P101-E
P102-E
P105-E
P202-E
P203-E
P205-E
S101-E
S102-E
S104-E
S202-E
S204-E
Solid line = Gulfwatch 2008 Whole Tissue Mean (four softshell Clam Sites in NH, ME)

higher than any wet wt. concentrations observed in SWAT clam tissue at Kilkenny Cove. There is no recommended FDA safety level for zinc in fish (Kimbrough et al., 2008).

Statewide Softshell Clam Tissues from Six Sites

Softshell clams collected from six stations in Casco Bay and the mid-coast were dissected into edible and whole tissues as described above, and analyzed for 11 metals: Silver (Ag), aluminum (Al), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), nickel (Ni), selenium (Se), and zinc (Zn). The primary interest was to see how the metals, particularly lead, were partitioned between the edible portion of the clam and the whole clam, which still included the skin or membrane tissue.

1.3.1.2.2.1 Silver (Ag)

Silver was detected at all six sample locations (Figure 1.3.1.2.2.1.1). Silver concentrations in edible tissue ranged from a low concentration of 0.11 µg/g dry wt. to a high concentration of 2.71 µg/g dry wt.

Silver concentrations in whole tissue ranged from a low concentration of 0.091 µg/g dry wt. to a high concentration of 2.16 µg/g dry wt.

Edible and whole clam tissue silver concentrations differed slightly. The whole to edible tissue ratio of silver concentrations varied from 0.7 to 1.0, with the mean ratio across all fifteen sites at 0.8.

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 highest mean edible softshell clam tissue silver concentration, when expressed on a wet weight basis, is 0.45 µg/g wet weight. This concentration is over an order of magnitude below the 11 µg/g wet wt. FTAL, assuming the same meal size is applied.

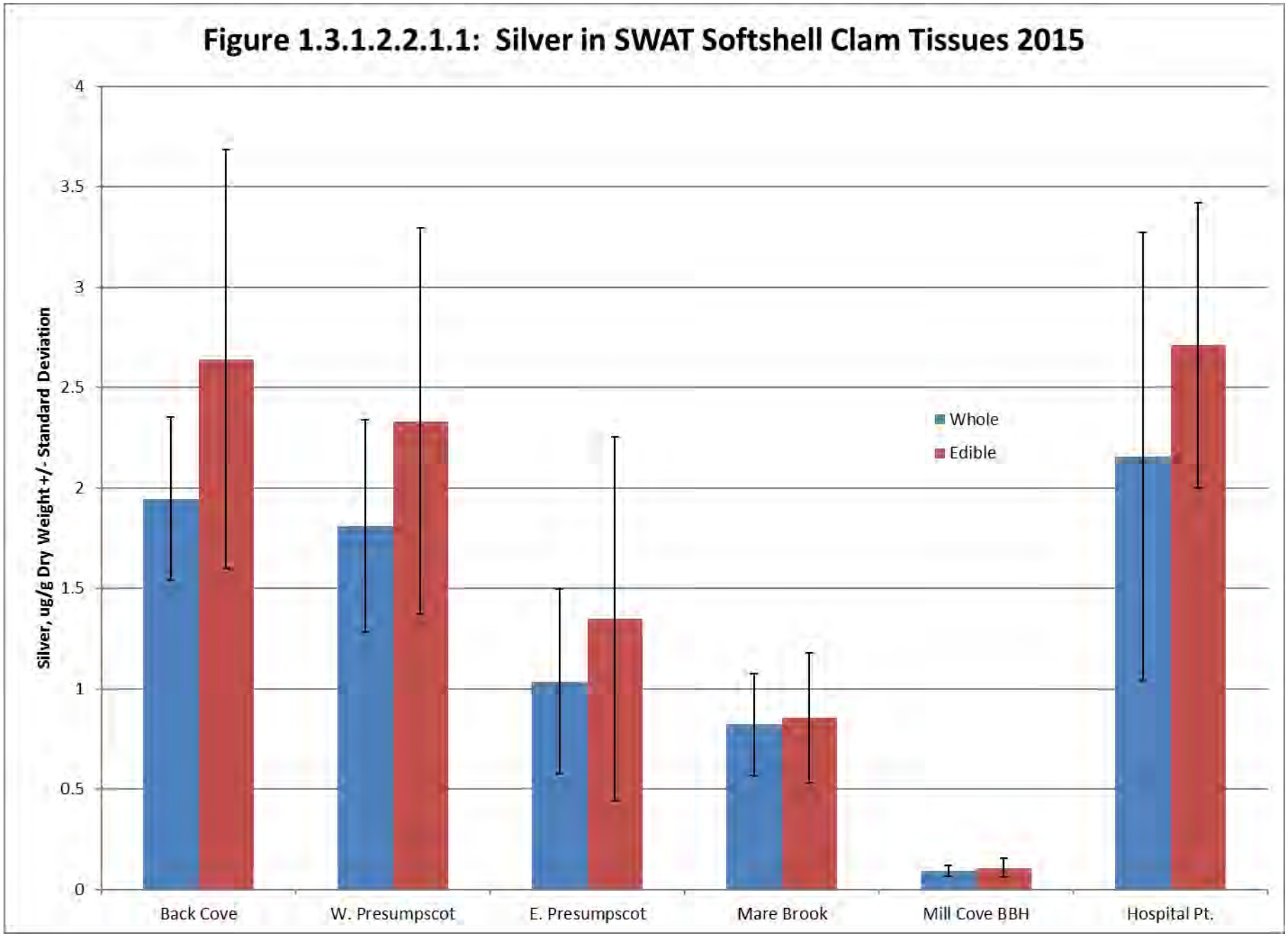


Figure 1.3.1.2.2.1.1: Silver in SWAT Softshell Clam Tissues 2015
Silver, ug/g Dry Weight +/- Standard Deviation
4
3.5
3
2.5
2
1.5
1
0.5
0
Whole
Edible
Back Cove
W. Presumpscot
E. Presumpscot
Mare Brook
Mill Cove BBH
Hospital Pt.

1.3.1.2.2.2 Arsenic (As)

Arsenic was detected at all six sample locations (Figure 1.3.1.2.2.2.1). Arsenic concentrations in edible tissue ranged from a low concentration of 15.50 µg/g dry wt. to a high concentration of 60.22 µg/g dry wt. Arsenic concentrations in whole tissue ranged from a low concentration of 12.12 µg/g dry wt. to a high concentration of 17.36 µg/g dry wt.

Edible and whole clam tissue arsenic were sometimes similar and sometimes very different at the various sites sampled in 2015. The whole to edible tissue ratio of arsenic concentrations varied from 1.0 to 4.5, with the mean ratio across all six sites at 2.3. West Presumpscot River and Hospital Point, St. George River, had the highest whole tissue arsenic concentrations and showed the widest variation in whole to edible tissue arsenic concentrations. Edible tissue arsenic concentrations showed less variability between sites.

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 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 softshell clams were calculated by dividing total arsenic wet weight concentrations by a factor of 10 to convert to inorganic arsenic wet weight concentrations. Using this methodology, the range of concentrations of inorganic arsenic in edible clam tissue from the six sites is estimated to be 0.20 to 0.24 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 ever since arsenic data have been recorded as part of the SWAT program all blue mussel sites sampled have also exceeded the MCDC cancer FTAL. None of the six softshell clam sites had calculated inorganic edible arsenic concentrations that approached the non-cancer FTAL of 0.6 ug/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.

1.3.1.2.2.3 Cadmium (Cd)

Cadmium was detected at all six sample locations (Figure 1.3.1.2.2.3.1). Cadmium concentrations in edible tissue ranged from a low concentration of 0.38 µg/g dry wt. to a high concentration of 0.62 µg/g dry wt. Cadmium concentrations in whole tissue ranged from a low concentration of 0.36 µg/g dry wt. to a high concentration of 0.60 µg/g dry wt.

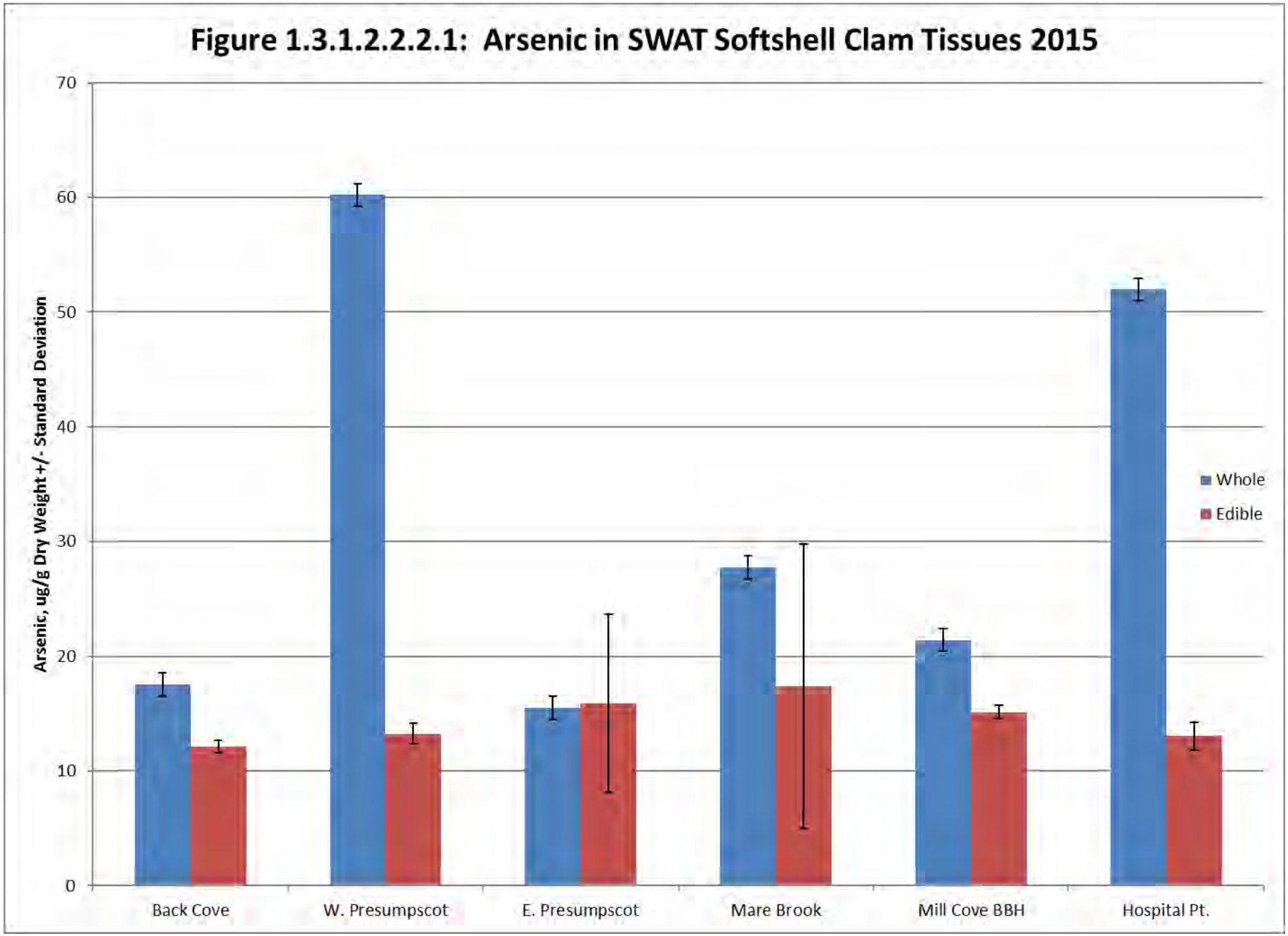


Figure 1.3.1.2.2.2.1: Arsenic in SWAT Softshell Clam Tissues 2015
Arsenic, ug/g Dry Weight +/- Standard Deviation
70
60
50
40
30
20
10
0
Back Cove
W. Presumpscot
E. Presumpscot
Mare Brook
Mill Cove BBH
Hospital Pt.
Whole
Edible

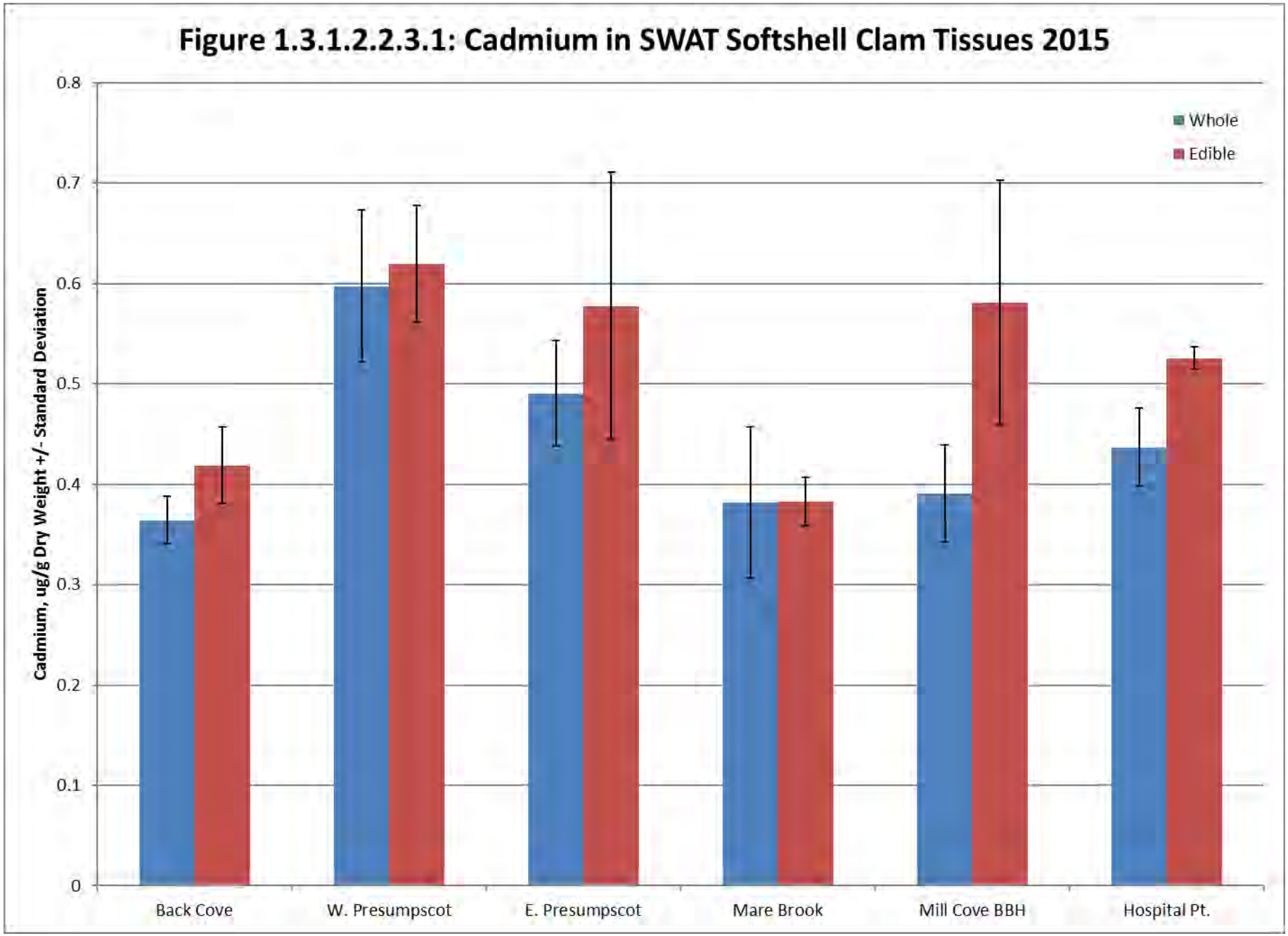


Figure 1.3.1.2.2.3.1: Cadmium in SWAT Softshell Clam Tissues 2015
Cadmium, ug/g Dry Weight +/- Standard Deviation
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Whole
Edible
Back Cove
W. Presumpscot
E. Presumpscot
Mare Brook
Mill Cove BBH
Hospital Pt.

Edible and whole clam tissue cadmium concentrations differed slightly. The whole to edible tissue ratio of cadmium concentrations varied from 0.7 to 1.0, with the mean ratio across all six sites at 0.9.

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 six sites tested was 0.098 µg/g wet wt., which was well below the MCDC and FDA action levels (<5% of the more conservative MCDC non-cancer FTAL).

1.3.1.2.2.4 Chromium (Cr)

Chromium was detected at all six sample locations (Figure 1.3.1.2.2.4.1). Chromium concentrations in edible tissue ranged from a low concentration of 2.05 µg/g dry wt. to a high concentration of 3.86 µg/g dry wt. Chromium concentrations in whole tissue ranged from a low concentration of 4.39 µg/g dry wt. to a high concentration of 7.52 µg/g dry wt.

Edible and whole clam tissue chromium concentrations differed markedly. The whole to edible tissue ratio of chromium concentrations varied from 1.9 to 2.5, with the mean ratio across all fifteen sites at 2.2.

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 for total chromium.

1.3.1.2.2.5 Copper (Cu)

Copper was detected at all six sample locations (Figure 1.3.1.2.2.5.1). Copper concentrations in edible tissue ranged from a low concentration of 14.52 µg/g dry wt. to a high concentration of 29.32 µg/g dry wt. Copper concentrations in whole tissue ranged

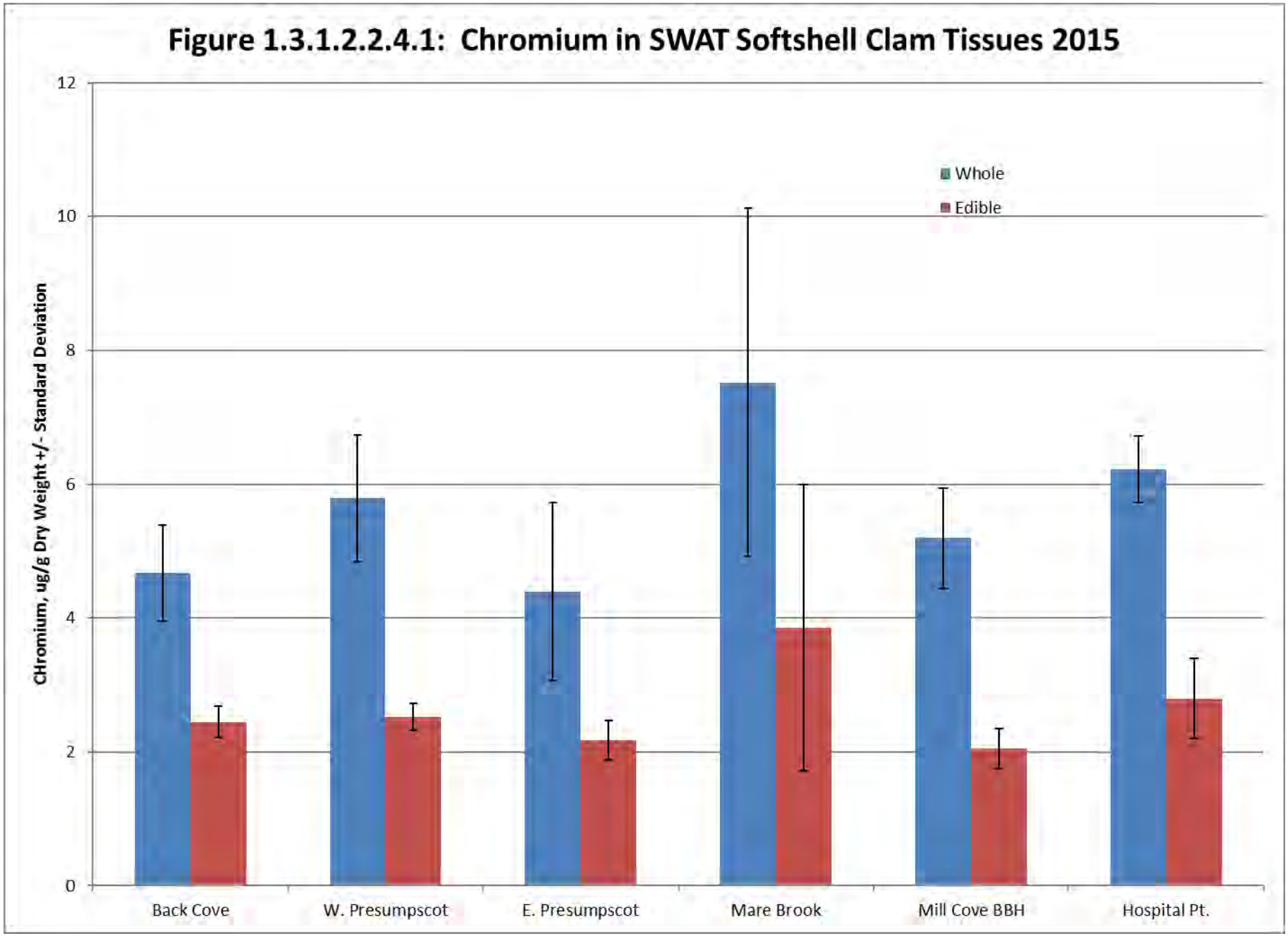


Figure 1.3.1.2.2.4.1: Chromium in SWAT Softshell Clam Tissues 2015
CHromium, ug/g Dry Weight +/- Standard Deviation
0
2
4
6
8
10
12
Whole
Edible
Back Cove
W. Presumpscot
E. Presumpscot
Mare Brook
Mill Cove BBH
Hospital Pt.

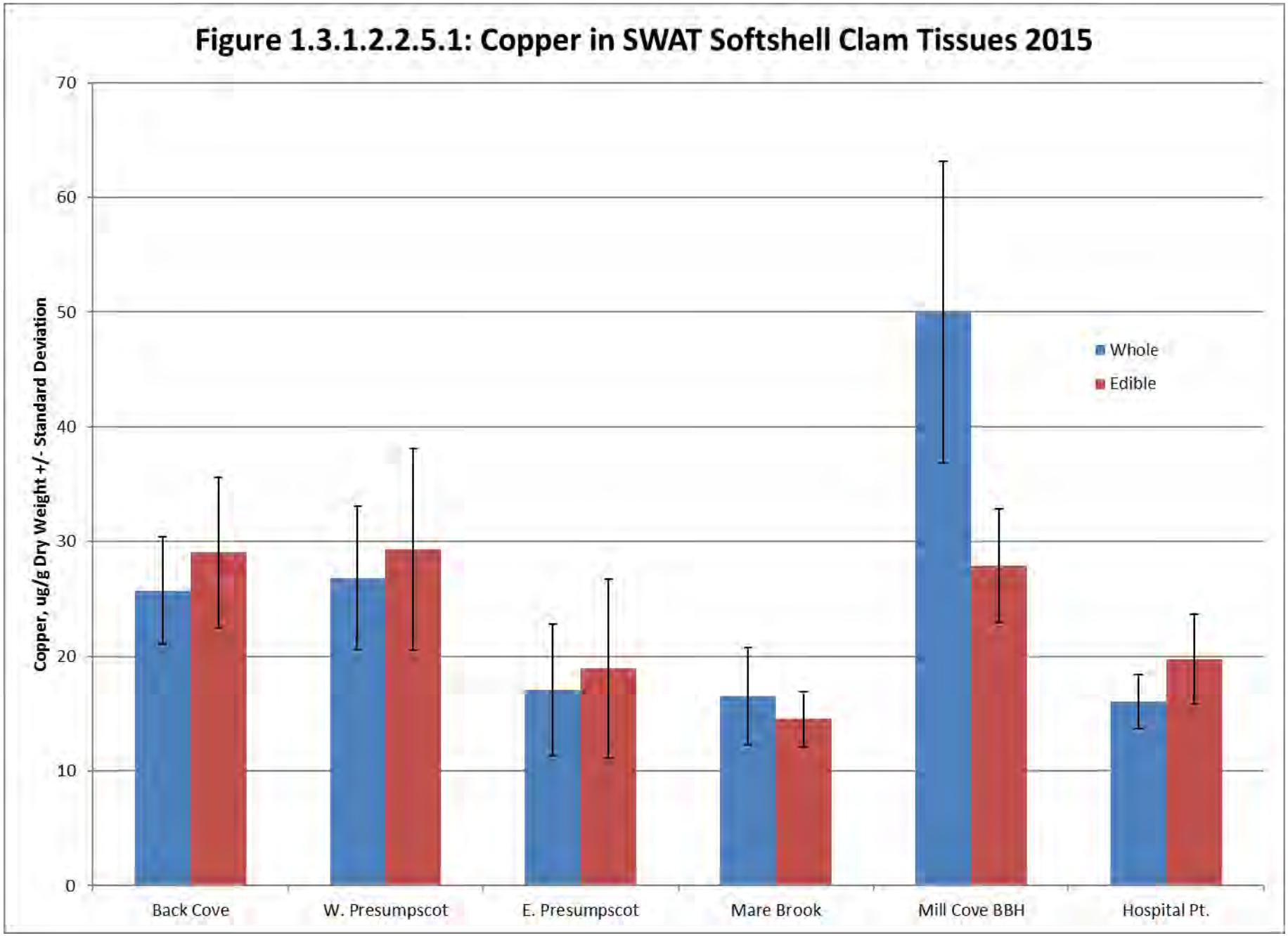


Figure 1.3.1.2.2.5.1: Copper in SWAT Softshell Clam Tissues 2015
Copper, ug/g Dry Weight +/- Standard Deviation
70
60
50
40
30
20
10
0
Whole
Edible
Back Cove
W. Presumpscot
E. Presumpscot
Mare Brook
Mill Cove BBH
Hospital Pt.

from a low concentration of 16.06 µg/g dry wt. to a high concentration of 49.98 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 1.8, with the mean ratio across all six sites at 1.1.

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, 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.

1.3.1.2.2.6 Iron (Fe) and Aluminum (Al)

Iron was detected at all six sample locations (Figure 1.3.1.2.2.6.1). Iron concentrations in edible tissue ranged from a low concentration of 1,204 µg/g dry wt. to a high concentration of 4,325 µg/g dry wt. Iron concentrations in whole tissue ranged from a low concentration of 4,256 µg/g dry wt. to a high concentration of 16,537 µg/g dry wt.

Edible and whole clam tissue iron concentrations differed markedly. The whole to edible tissue ratio of iron concentrations varied from 2.2 to 6.6, with the mean ratio across all fifteen sites at 4.7.

Aluminum was detected at all six sample locations (Figure 1.3.1.2.2.6.2). Aluminum concentrations in edible tissue ranged from a low concentration of 468 µg/g dry wt. to a high concentration of 1,909 µg/g dry wt. Aluminum concentrations in whole tissue ranged from a low concentration of 1,671 µg/g dry wt. to a high concentration of 3,899 µg/g dry wt. and all six locations exceeded the Gulfwatch mean.

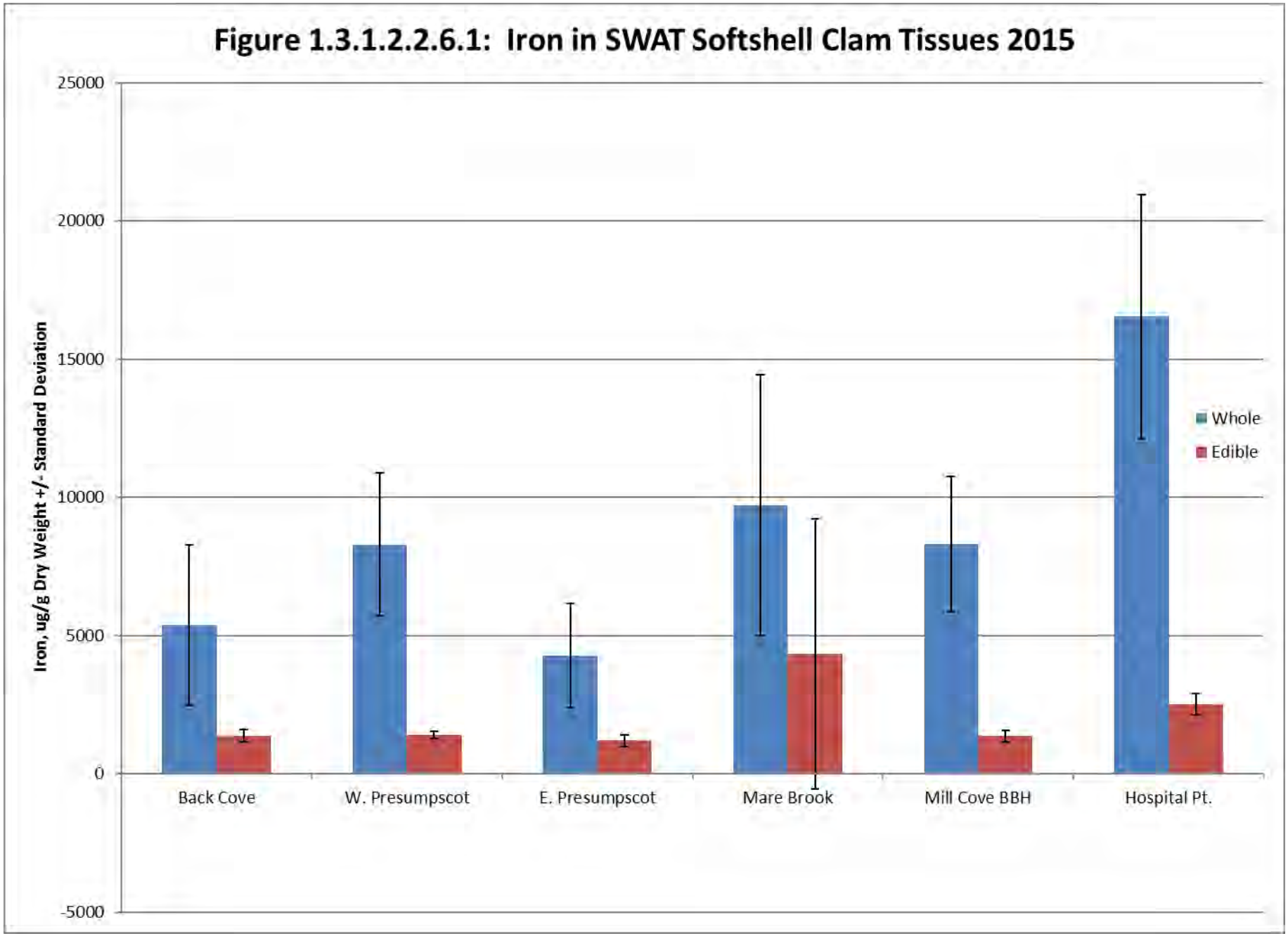


Figure 1.3.1.2.2.6.1: Iron in SWAT Softshell Clam Tissues 2015
Iron, ug/g Dry Weight +/- Standard Deviation
25000
20000
15000
10000
5000
0
-5000
Back Cove
W. Presumpscot
E. Presumpscot
Mare Brook
Mill Cove BBH
Hospital Pt.
Whole
Edible

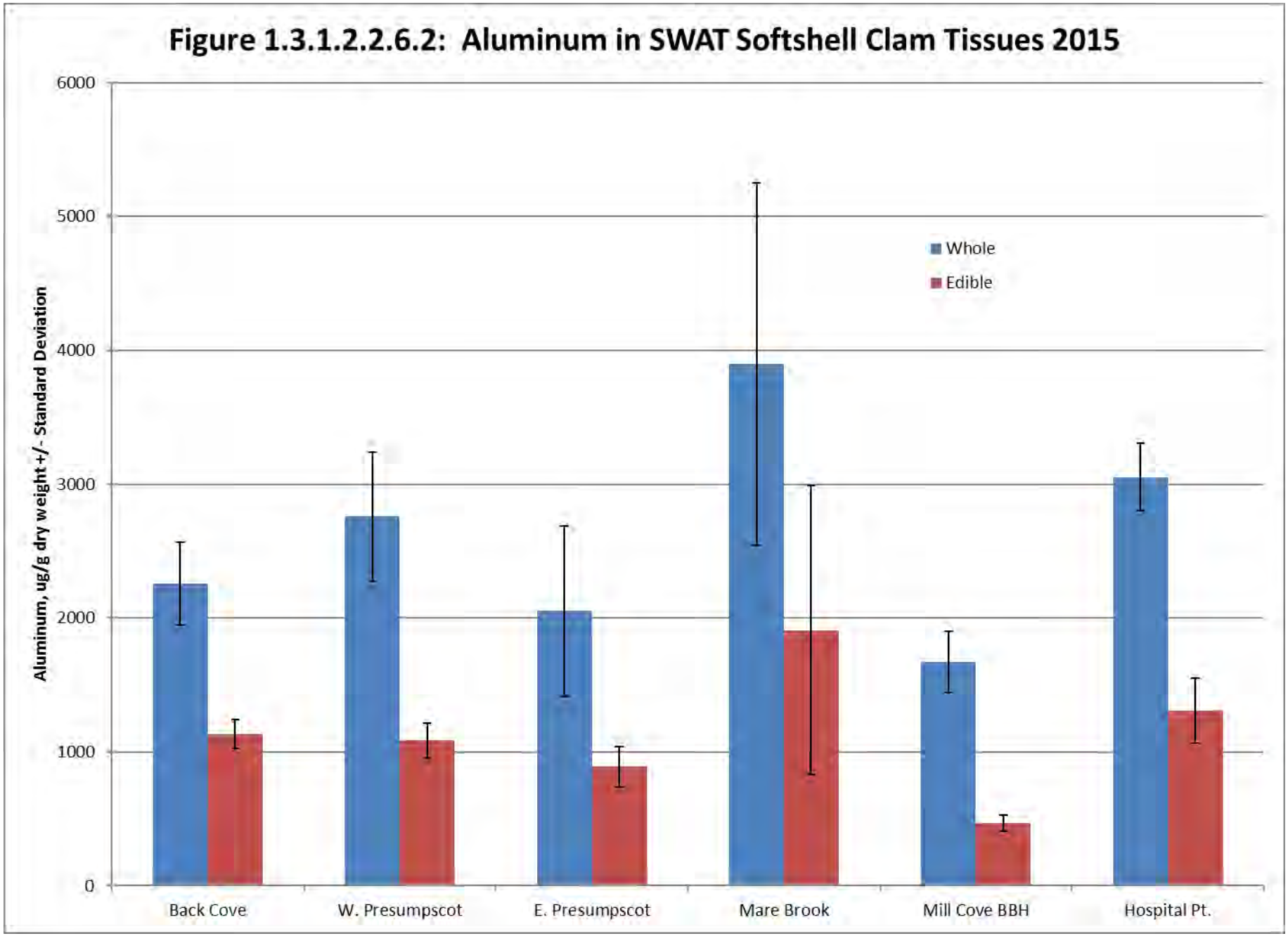


Figure 1.3.1.2.2.6.2: Aluminum in SWAT Softshell Clam Tissues 2015
Aluminum, ug/g dry weight +/- Standard Deviation
6000
5000
4000
3000
2000
1000
0
Whole
Edible
Back Cove
W. Presumpscot
E. Presumpscot
Mare Brook
Mill Cove BBH
Hospital Pt.

Edible and whole clam tissue aluminum concentrations differed markedly. The whole to edible tissue ratio of aluminum concentrations varied from 2.0 to 3.6, with the mean ratio across all six sites at 2.5. 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.

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.

1.3.1.2.2.7 Nickel (Ni)

Nickel was detected in clam tissue taken at all six sampling locations (Figure 1.3.1.2.2.7.1). Nickel concentrations in edible tissue ranged from a low concentration of 1.42 µg/g dry wt. to a high concentration of 2.56 µg/g dry wt. Nickel concentrations in whole tissue ranged from a low concentration of 2.60 µg/g dry wt. to a high concentration of 4.36 µg/g dry wt.

Edible and whole clam tissue nickel concentrations differed markedly. The whole to edible tissue ratio of nickel concentrations varied from 1.5 to 2.4, with the mean ratio across all fifteen sites at 1.8.

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

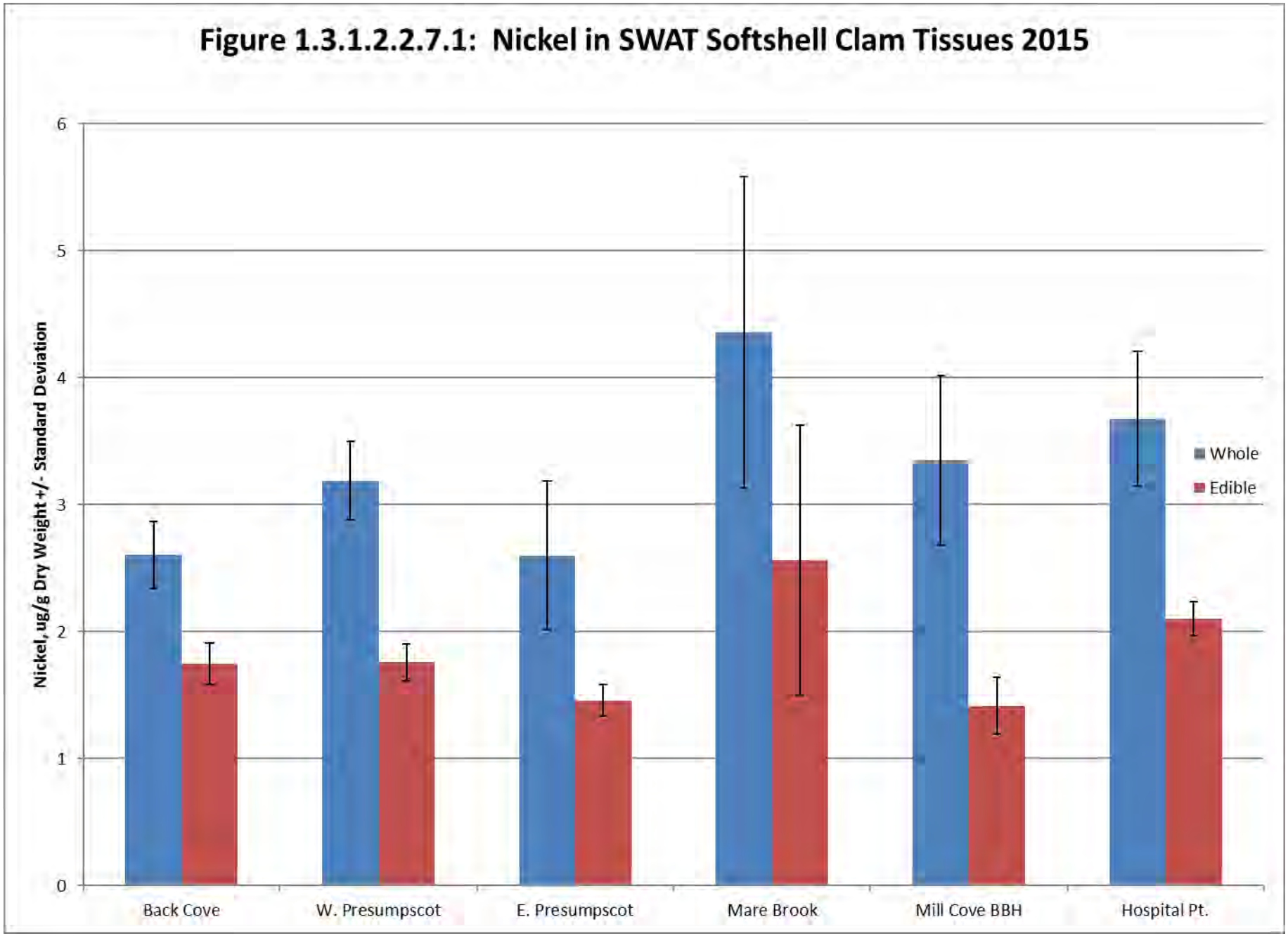


Figure 1.3.1.2.2.7.1: Nickel in SWAT Softshell Clam Tissues 2015
Nickel, ug/g Dry Weight +/- Standard Deviation
0
1
2
3
4
5
6
Back Cove
W. Presumpscot
E. Presumpscot
Mare Brook
Mill Cove BBH
Hospital Pt.
Whole
Edible

conservative than the FDA action level for shellfish of 80 µg/g wet weight. The maximum mean concentration detected by SWAT in edible clam tissue from the six sites is 0.36 µg/g wet wt., which is several orders of magnitude lower than the more conservative MCDC action level. MCDC does not report a cancer action level for nickel. The highest whole tissue concentration was 0.56 ug/g wet wt., still well below the MCDC non-cancer FTAL.

1.3.1.2.2.8 Lead (Pb)

Lead was detected in clam tissue samples taken at all six sites (Figure 1.3.1.2.2.8.1). Lead levels measured in clam edible tissue ranged from a low mean concentration of 1.16 µg/g dry wt. to a high mean concentration of 15.16 µg/g dry wt. Lead levels measured in whole clam tissue ranged from a low mean concentration of 4.16 µg/g dry wt. to a high mean concentration of 56.46 µg/g dry wt.

Edible and whole clam tissue lead concentrations differed markedly. The whole to edible tissue ratio of lead concentrations varied from 2 to 3.7, with the mean ratio across all six sites at 3.1.

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, 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. On this whole clam tissue basis, five of the six locations tested statewide exceeded the MCDC FTAL of 0.6 ug/g wet wt. for recreationally caught sportfish. Testing of the 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 topped out at less than half the MCDC former lead FTAL for recreationally caught finfish when

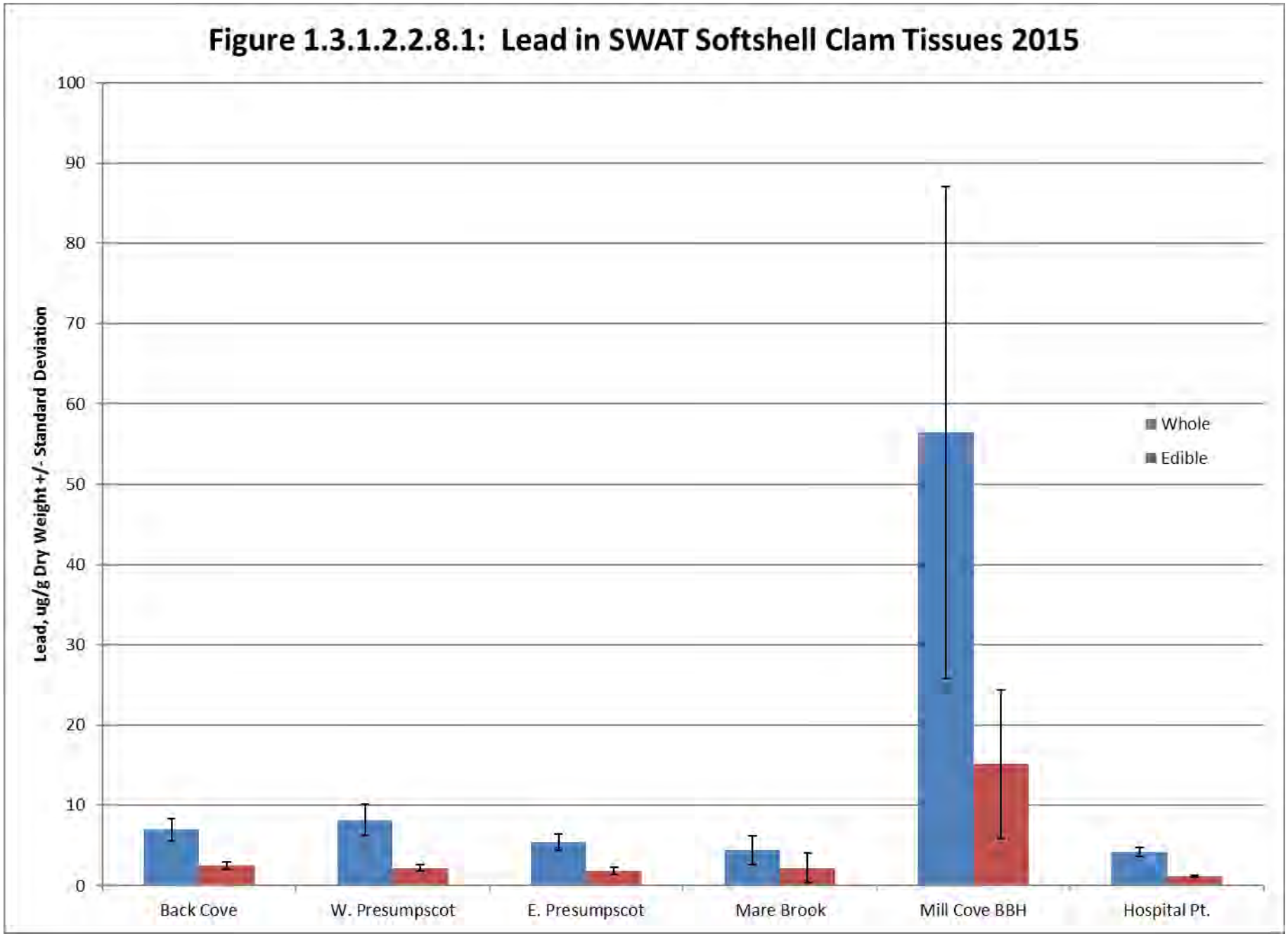


Figure 1.3.1.2.2.8.1: Lead in SWAT Softshell Clam Tissues 2015
Lead, ug/g Dry Weight +/- Standard Deviation
100
90
80
70
60
50
40
30
20
10
0
Whole
Edible
Back Cove
W. Presumpscot
E. Presumpscot
Mare Brook
Mill Cove BBH
Hospital Pt.

considered on a wet wt. basis. The highest edible tissue mean lead concentration from Mill Cove, Boothbay Harbor, exceeded the FTAL with a mean concentration of 2.2 ug/g wet wt. Lead concentrations at Mill Cove appeared to have high variability.

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.

1.3.1.2.2.9 Mercury (Hg)

Mercury analysis was not performed on edible or whole clam tissue samples from the six stations sampled in 2015.

1.3.1.2.2.10 Selenium (Se)

Selenium was detected at all six sample locations (Figure 1.3.1.2.2.10.1). Selenium levels measured in clam edible tissue ranged from a low mean concentration of 2.19 µg/g dry wt. to a high mean concentration of 4.68 µg/g dry wt. Selenium levels measured in whole clam tissue ranged from a low mean concentration of 1.95 µg/g dry wt. to a high mean concentration of 7.01 µg/g dry wt.

The ratio of edible and whole clam tissue selenium concentrations differed among the locations sampled. The whole to edible tissue ratio of selenium concentrations varied from 0.7 to 2.4, with the mean ratio across all six sites at 1.1.

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 mean selenium concentration measured in 2015 was 0.77 µg/g wet wt. and the highest whole clam tissue mean selenium concentration measured was 1.03 ug/g wet wt. The highest mean concentrations from both tissues compare favorably with the MCDC selenium FTAL, assuming a similar meal size and frequency.

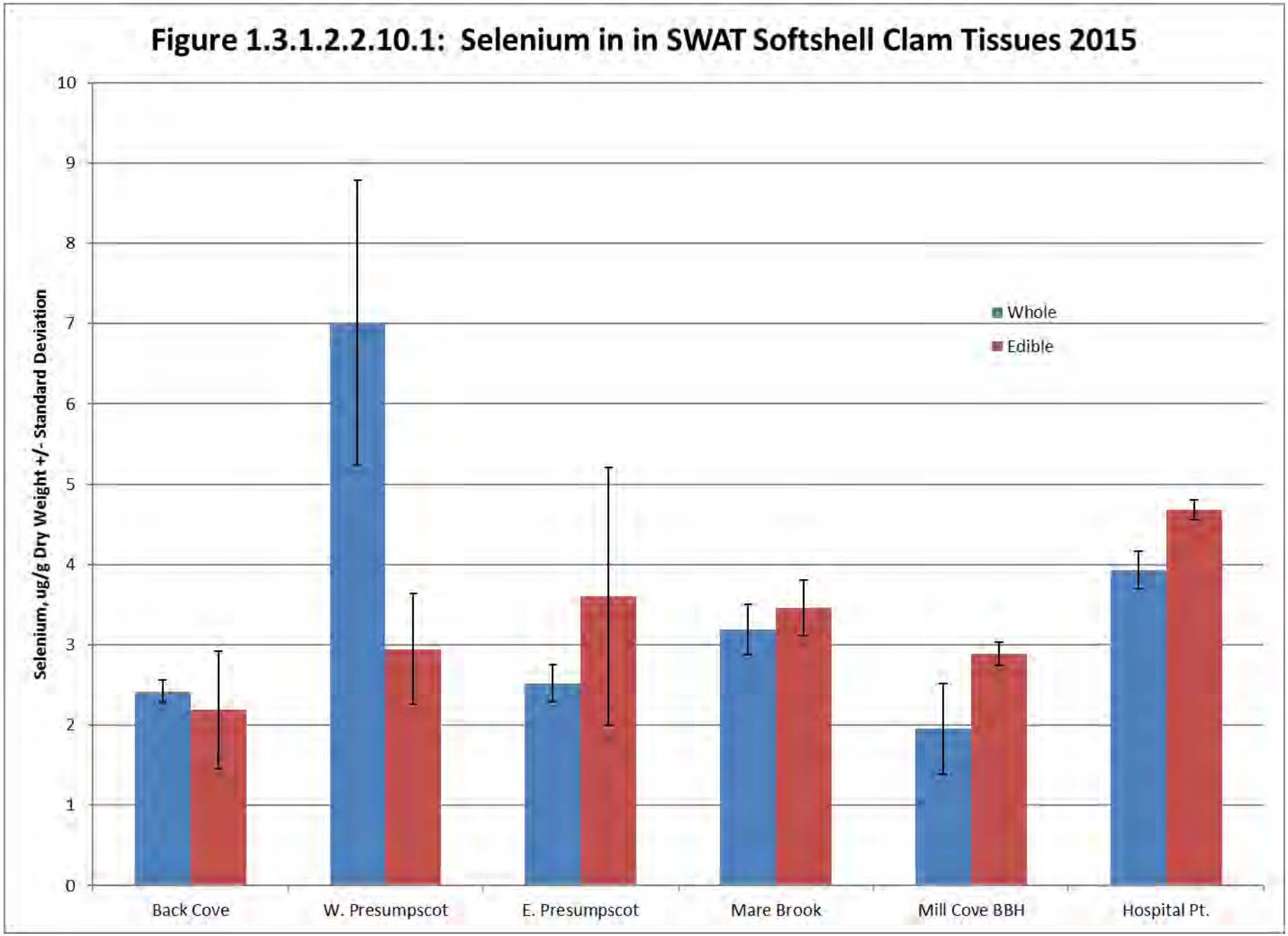


Figure 1.3.1.2.2.10.1: Selenium in in SWAT Softshell Clam Tissues 2015
Selenium, ug/g Dry Weight +/- Standard Deviation
0
1
2
3
4
5
6
7
8
9
10
Whole
Edible
Back Cove
W. Presumpscot
E. Presumpscot
Mare Brook
Mill Cove BBH
Hospital Pt.

1.3.1.2.2.11 Zinc (Zn)

Zinc was detected in tissue taken at all six softshell clam sites (Figure 1.3.1.2.2.11.1). Zinc levels measured in clam edible tissue ranged from a low mean concentration of 80.4 µg/g dry wt. to a high mean concentration of 94.3 µg/g dry weight. Zinc concentrations in whole tissue ranged from a low concentration of 88.7 µg/g dry wt. to a high concentration of 107.5 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 six sites.

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 more than an order of magnitude higher than any wet wt. concentrations observed in SWAT clam tissue from the six sites sampled in 2015. There is no recommended FDA safety level for zinc in fish (Kimbrough et al., 2008).

1.3.1.3 American Lobster

1.3.1.3.1 Sheepscot River Estuary Mercury Study

Lobster muscle, both tail and claw tissues, were analyzed separately for total mercury (Hg). Lobsters in this study were not composited but an individual total mercury concentration was produced for each lobster and for each of the two types of muscle tissues. For this study, hepatopancreas was not analyzed.

Results are presented in wet weight of total mercury, which will facilitate comparison to the MCDC FTAL, which is calculated based on wet weight tissue. Total mercury was detected in all muscle tissues analyzed.

Figure 1.3.1.3.1.1 shows the total mercury concentration in claw muscle tissue for each of the six areas of the estuary where samples were collected. Values are the mean total mercury concentration of ten lobsters per area. Areas sampled are shown roughly upriver to downriver, from left to right across the chart. Upriver areas, particularly 2MO, appear to have higher total mercury concentrations than areas further downriver. Variability in the 2MO area is also high. Concentrations generally compare favorably to the developmental methylmercury FTAL used by the MCDC, which is 0.2 ug/g (ppm) wet wt. for non-commercially caught finfish (fish filet).

Figure 1.3.1.3.1.2 shows the concentrations of total mercury in claw muscle tissue for individual lobsters from each of the six areas of the estuary. In area 2MO, one individual lobster had a concentration much higher than the other nine, which is the source of much of the variability and placed this one individual claw concentration above the level of the MCDC developmental

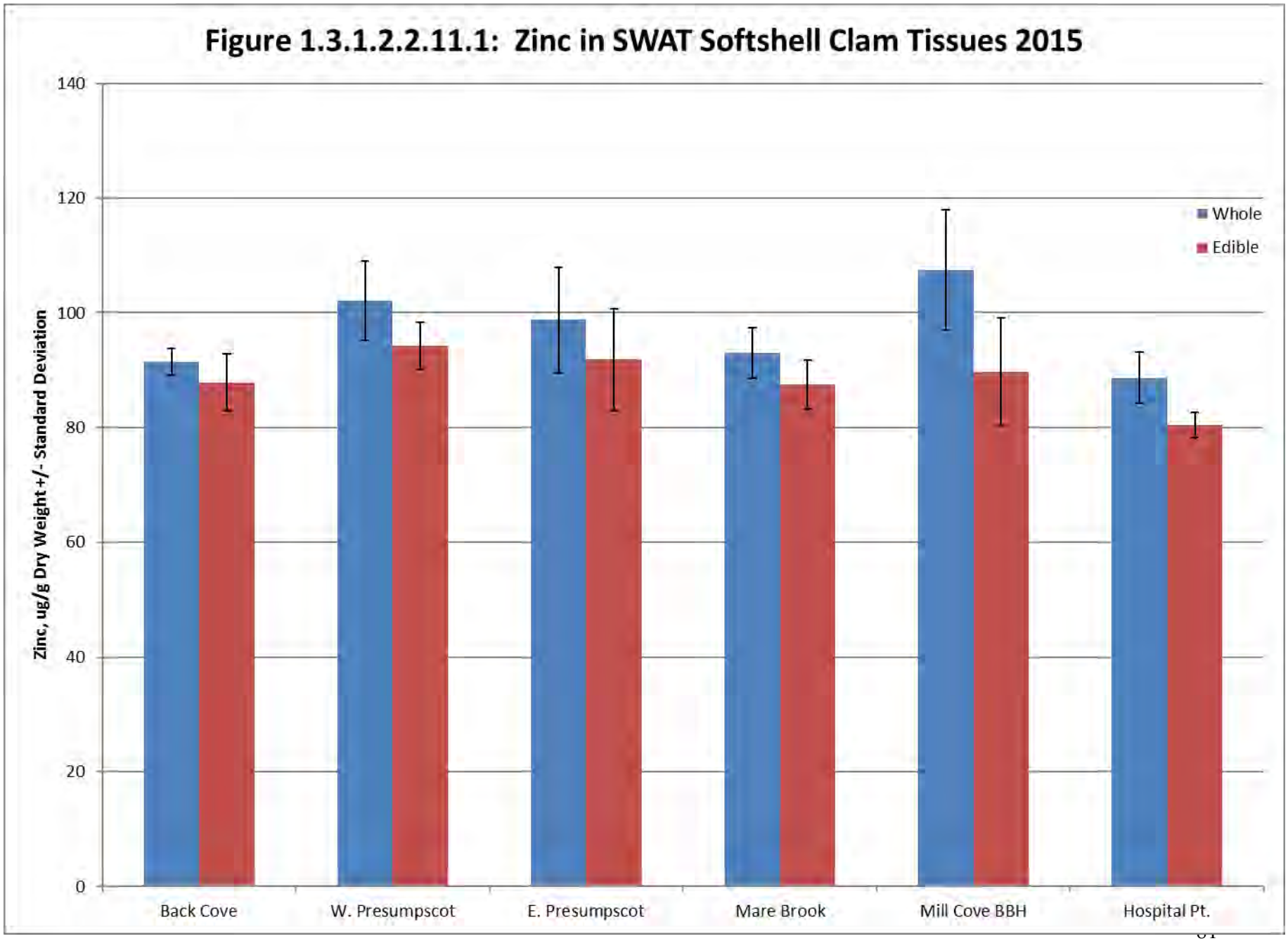


Figure 1.3.1.2.2.11.1: Zinc in SWAT Softshell Clam Tissues 2015
Zinc, ug/g Dry Weight +/- Standard Deviation
140
120
100
80
60
40
20
0
Whole
Edible
Back Cove
W. Presumpscot
E. Presumpscot
Mare Brook
Mill Cove BBH
Hospital Pt.

FTAL. The remaining nine lobsters from 2MO and the other five areas sampled all had claw total mercury concentrations below the FTAL.

Figure 1.3.1.3.1.3 shows the total mercury concentration in tail muscle tissue for each of the six areas of the estuary where samples were collected. Values are the mean total mercury concentration of ten lobsters per area. Upriver areas, particularly 2MO but also 1WI and 3EW, appear to have higher total mercury concentrations than areas further downriver. Variability in the 2MO area is also high. In five of the six areas, concentrations generally compare favorably to the developmental methylmercury FTAL used by the MCDC, which is 0.2 ug/g (ppm) wet wt. for non-commercially caught finfish (fish filet). Area 2MO has a mean total mercury concentration in tail muscle tissue that approximates the MCDC developmental methylmercury FTAL of 0.2 ug/g (ppm) wet wt.

Figure 1.3.1.3.1.4 shows the concentrations of total mercury in tail muscle tissue for individual lobsters from each of the six areas of the estuary. In 2MO, five of ten lobsters had a tail muscle total mercury concentration exceeding the MCDC developmental methylmercury FTAL. In 1WI, two of ten lobsters had a tail muscle total mercury concentration exceeding the MCDC developmental methylmercury FTAL, while the remaining eight did not. The other four areas sampled all had tail total mercury concentrations below the FTAL.

From a human health perspective, the developmental methylmercury FTAL (more protective) used by the MCDC is 0.2 ug/g (ppm) wet wt. for non-commercially caught finfish (fish filet). This FTAL assumes an 8 oz. meal size is consumed weekly. Maine SWAT data uses a total mercury value, which is a more complete measure of mercury than the methylmercury concentration, but includes this more toxic, methylmercury form. Thus, SWAT total mercury data does not exactly compare to methylmercury concentrations utilized to develop the FTAL. SWAT data would reflect a higher value, as it includes other forms of mercury besides the most toxic methylmercury form.

When lobsters are consumed, they may often be eaten as a combination of tail and claw meat, which would further reduce the concentrations of total mercury since the claw concentrations would dilute the higher levels of mercury found in the tail meat. In other words, the tail would not be the only tissue contributing to the 8 oz. meal size, so the mercury intake would likely be lower when all muscle tissue (including claw) is considered as part of the meal size.

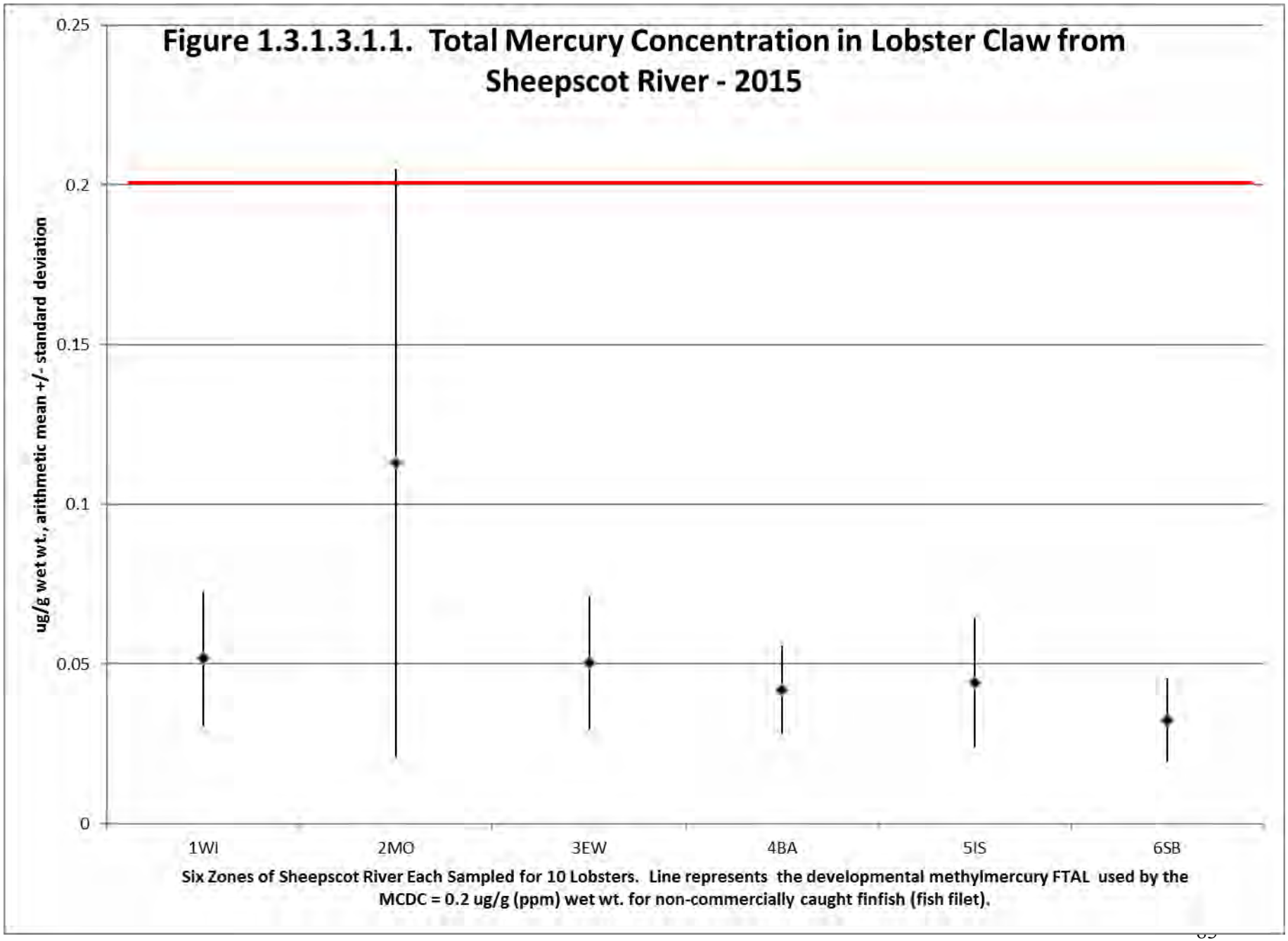


Figure 1.3.1.3.1.1. Total Mercury Concentration in Lobster Claw from Sheepscot River - 2015
ug/g wet wt., arithmetic mean +/- standard deviation
0.25
0.2
0.15
0.1
0.05
0
1WI
2MO
3EW
4BA
5IS
6SB
Six Zones of Sheepscot River Each Sampled for 10 Lobsters. Line represents the developmental methylmercury FTAL used by the MCDC = 0.2 ug/g (ppm) wet wt. for non-commercially caught finfish (fish filet).

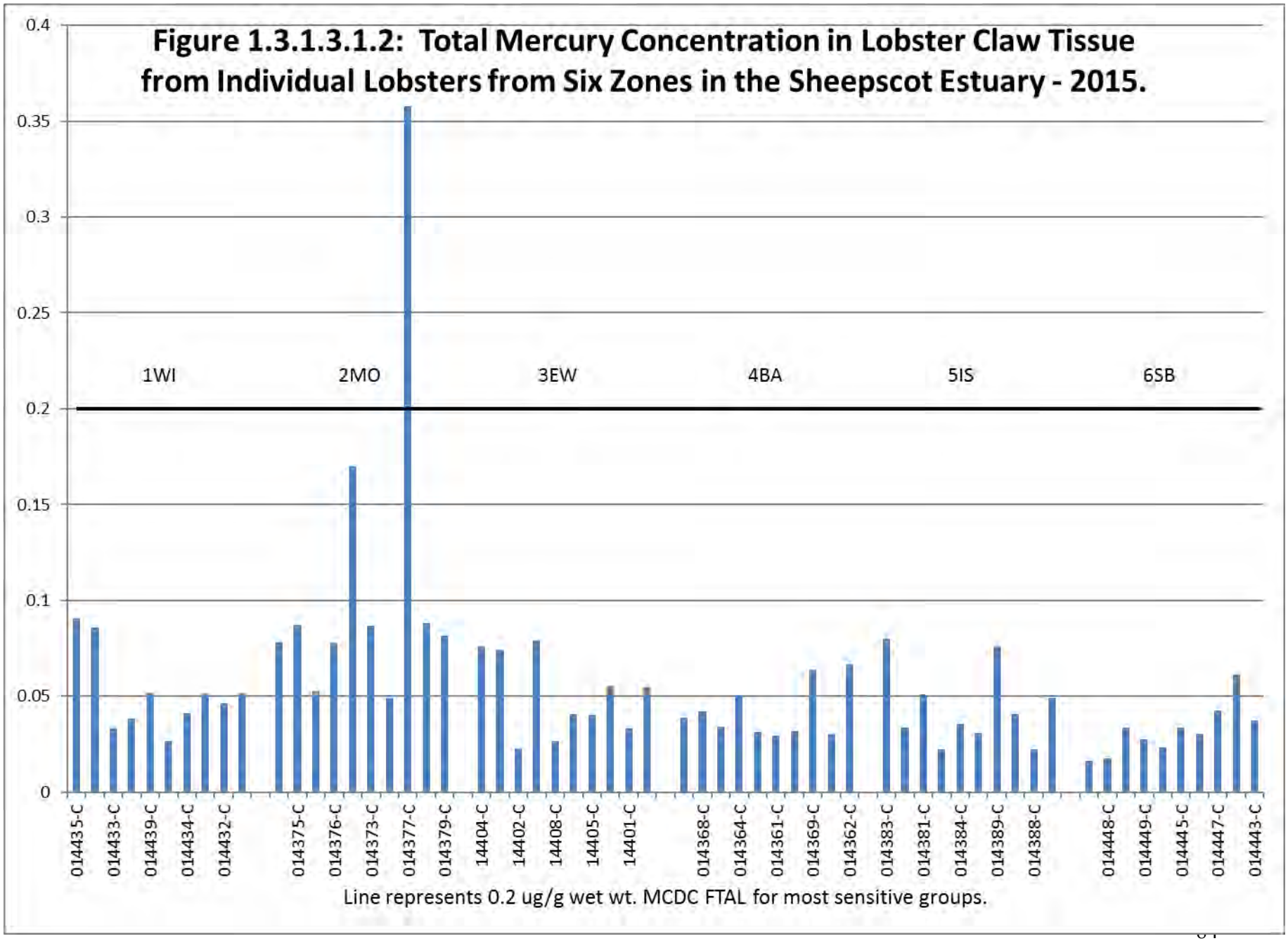


Figure 1.3.1.3.1.2: Total Mercury Concentration in Lobster Claw Tissue from Individual Lobsters from Six Zones in the Sheepscot Estuary - 2015.
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1WI
2MO
3EW
4BA
5IS
6SB
014435-C
014433-C
014439-C
014434-C
014432-C
014375-C
014376-C
014373-C
014377-C
014379-C
14404-C
14402-C
14408-C
14405-C
14401-C
014368-C
014364-C
014361-C
014369-C
014362-C
014383-C
014381-C
014384-C
014389-C
014388-C
014448-C
014449-C
014445-C
014447-C
014443-C
Line represents 0.2 ug/g wet wt. MCDC FTAL for most sensitive groups.

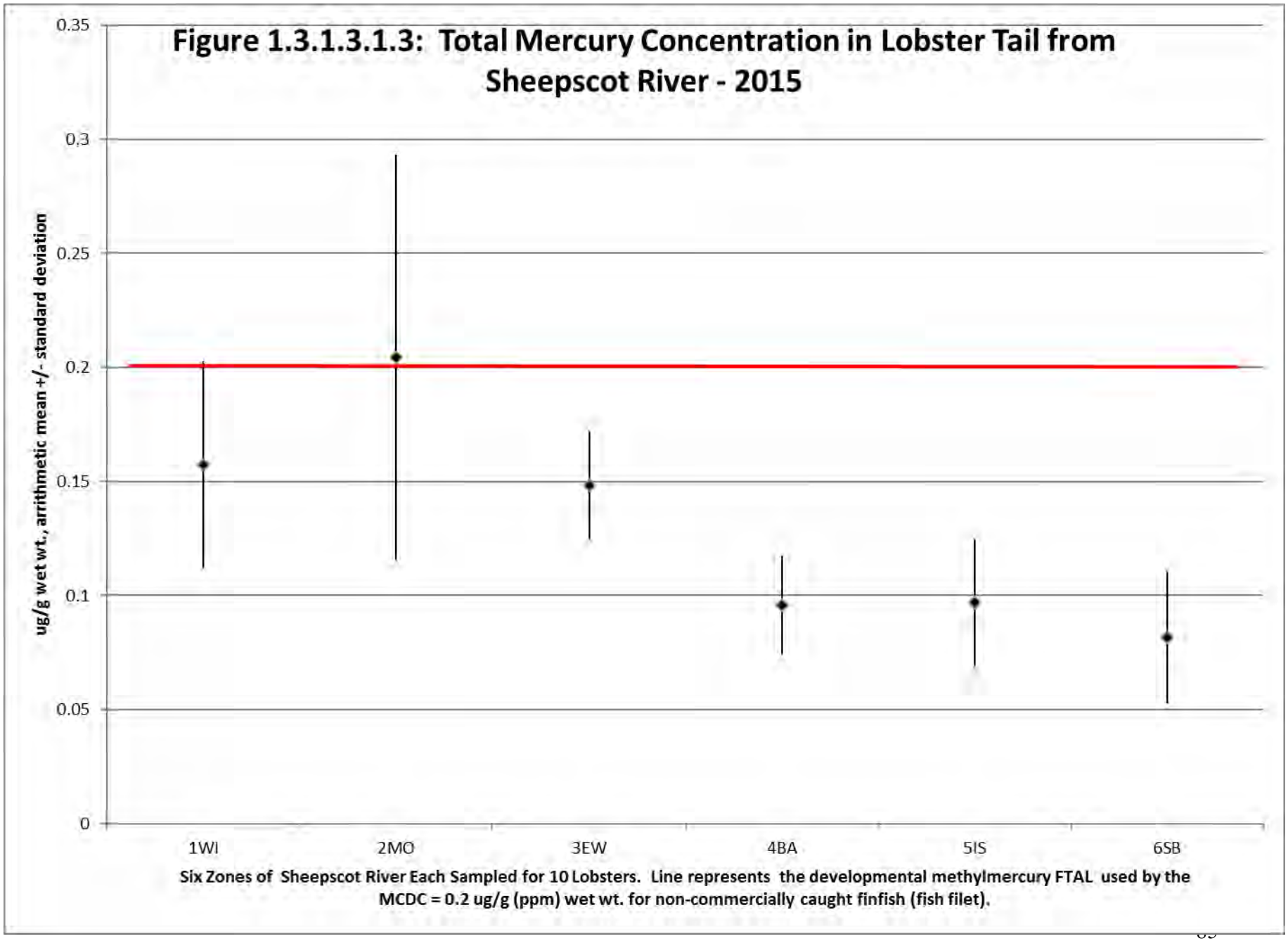


Figure 1.3.1.3.1.3: Total Mercury Concentration in Lobster Tail from Sheepscot River - 2015
ug/g wet wt., arrithmetic mean +/- standard deviation
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1WI
2MO
3EW
4BA
5IS
6SB
Six Zones of Sheepscot River Each Sampled for 10 Lobsters. Line represents the developmental methylmercury FTAL used by the MCDC = 0.2 ug/g (ppm) wet wt. for non-commercially caught finfish (fish filet).

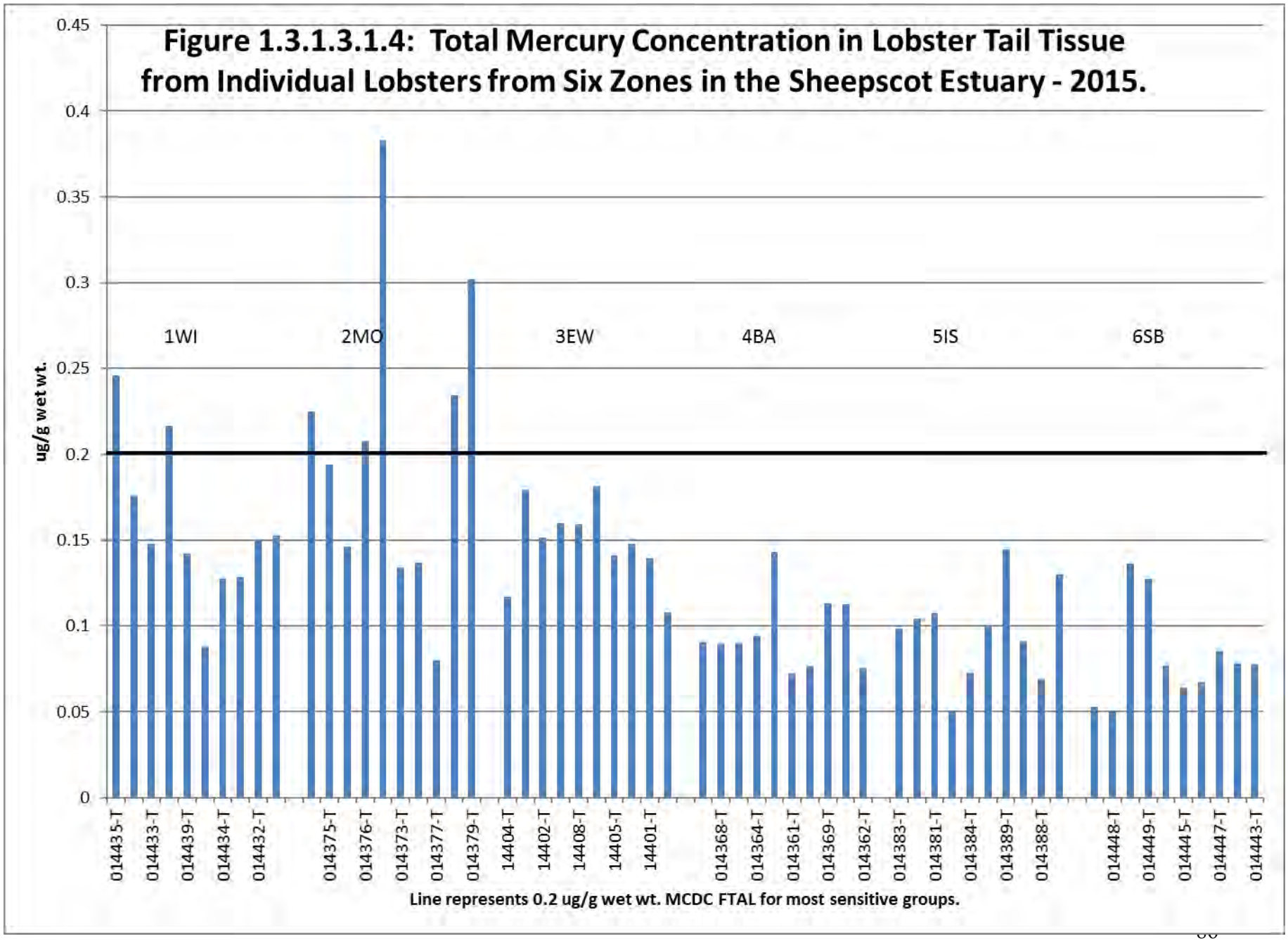


Figure 1.3.1.3.1.4: Total Mercury Concentration in Lobster Tail Tissue from Individual Lobsters from Six Zones in the Sheepscot Estuary - 2015.
ug/g wet wt.
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1WI
2MO
3EW
4BA
5IS
6SB
014435-T
014433-T
014439-T
014434-T
014432-T
014375-T
014376-T
014373-T
014377-T
014379-T
14404-T
14402-T
14408-T
14405-T
14401-T
014368-T
014364-T
014361-T
014369-T
014362-T
014383-T
014381-T
014384-T
014389-T
014388-T
014448-T
014449-T
014445-T
014447-T
014443-T
Line represents 0.2 ug/g wet wt. MCDC FTAL for most sensitive groups.

1.3.1.3.2 Lobster Management Zones

Lobster hepatopancreas and muscle tissues were analyzed for 12 metals: Silver (Ag), aluminum (Al), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), mercury (Hg), nickel (Ni), selenium (Se), and zinc (Zn).

1.3.1.3.2.1 Silver (Ag)

Silver was detected at all 12 sample locations (Figure 1.3.1.3.2.1). Silver concentrations in muscle tissue ranged from a low concentration of 0.83 µg/g dry wt. to a high concentration of 1.80 µg/g dry wt. Silver concentrations in hepatopancreas tissue ranged from a low concentration of 1.37 µg/g dry wt. to a high concentration of 10.50 µg/g dry wt.

Muscle and hepatopancreas tissue silver concentrations differed markedly. The hepatopancreas to muscle tissue ratio of silver concentrations varied from 1.6 to 9.4, with the mean ratio across all twelve sites at 3.4.

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 highest lobster muscle tissue silver concentration, when expressed on a wet weight basis, is 0.27 µg/g wet weight. This concentration is over an order of magnitude below the 11 µg/g wet wt. FTAL, assuming the same meal size is applied. The highest lobster hepatopancreas tissue silver concentration, when expressed on a wet weight basis, is 3.14 µg/g wet weight. This concentration is well below the 11 µg/g wet wt. FTAL, assuming the same meal size is applied.

1.3.1.3.2.2 Arsenic (As)

Arsenic was detected at all 12 sample locations (Figure 1.3.1.3.2.2). Arsenic concentrations in muscle tissue ranged from a low concentration of 12.14 µg/g dry wt. to a high concentration of 86.95 µg/g dry wt. Arsenic concentrations in hepatopancreas tissue ranged from a low concentration of 15.69 µg/g dry wt. to a high concentration of 54.30 µg/g dry wt.

Muscle and hepatopancreas tissue arsenic concentrations differed minimally. The hepatopancreas to muscle tissue ratio of arsenic concentrations varied from 0.6 to 1.3, with the mean ratio across all twelve sites at 0.8.

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).

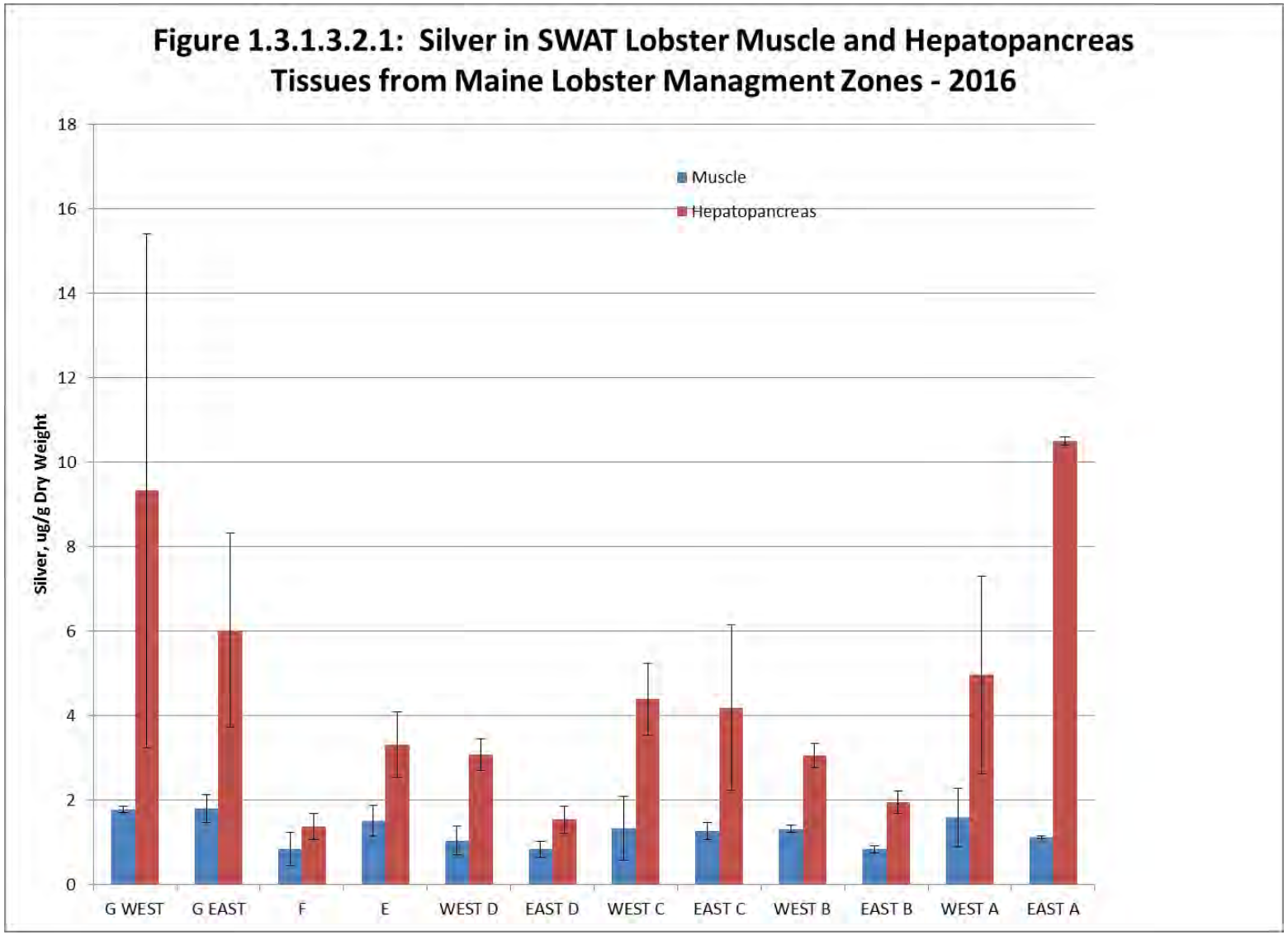


Figure 1.3.1.3.2.1: Silver in SWAT Lobster Muscle and Hepatopancreas Tissues from Maine Lobster Managment Zones - 2016
Silver, ug/g Dry Weight
0
2
4
6
8
10
12
14
16
18
Muscle
Hepatopancreas
G WEST
G EAST
F
E
WEST D
EAST D
WEST C
EAST C
WEST B
EAST B
WEST A
EAST A

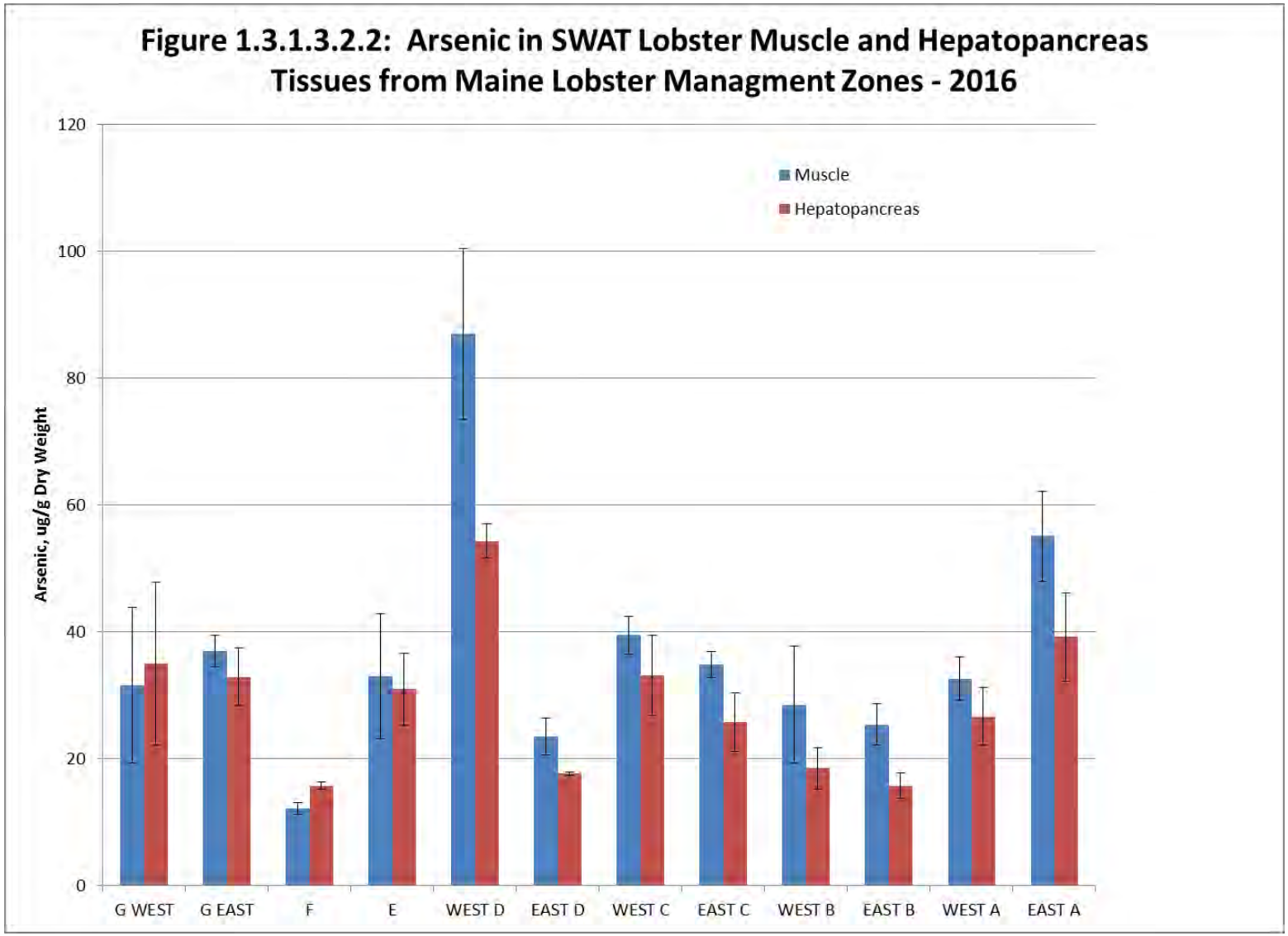


Figure 1.3.1.3.2.2: Arsenic in SWAT Lobster Muscle and Hepatopancreas Tissues from Maine Lobster Managment Zones - 2016
Arsenic, ug/g Dry Weight
120
100
80
60
40
20
0
Muscle
Hepatopancreas
G WEST
G EAST
F
E
WEST D
EAST D
WEST C
EAST C
WEST B
EAST B
WEST A
EAST A

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, including the SWAT lobster 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 lobster tissues were calculated by dividing total arsenic wet weight concentrations by a factor of 10 to convert to inorganic arsenic wet weight concentrations. Using this methodology, the range of concentrations of inorganic arsenic in lobster muscle tissue is estimated to be 0.18 to 1.52 µg/g wet wt. The range of concentrations of inorganic arsenic in lobster hepatopancreas tissue is estimated to be 0.47 to 1.69 µg/g wet wt. All locations sampled had muscle and hepatopancreas calculated inorganic arsenic concentrations exceeding the MCDC cancer FTAL of 0.014 ug/g. Muscle tissue calculated inorganic mean arsenic concentrations exceeded the MCDC non-cancer FTAL of 0.6 ug/g wet weight at three of the twelve areas tested, West C, West D, and East A. Hepatopancreas tissue calculated inorganic mean arsenic concentrations exceeded the MCDC non-cancer FTAL of 0.6 ug/g wet weight at nine of the twelve areas tested, but not in F, and East B. The East D hepatopancreas tissue calculated inorganic mean arsenic concentration was very close to the MCDC non-cancer FTAL.

Historically, and in comparison, 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 ever since arsenic data have been recorded as part of the SWAT program all blue mussel sites sampled have also exceeded the MCDC cancer FTAL. The MCDC non-commercially caught finfish FTALs applied here assume an 8 oz. meal eaten by the consumer on a weekly basis.

1.3.1.3.2.3 Cadmium (Cd)

Cadmium was detected at all 12 sample locations (Figure 1.3.1.3.2.3). Cadmium concentrations in muscle tissue ranged from a low concentration of 0.0099 µg/g dry wt. to a high concentration of 0.083 µg/g dry wt. Cadmium concentrations in hepatopancreas tissue ranged from a low concentration of 3.50 µg/g dry wt. to a high concentration of 56.26 µg/g dry wt.

Muscle and hepatopancreas tissue cadmium concentrations differed markedly. The hepatopancreas to muscle tissue ratio of arsenic concentrations varied from 259 to 891, with the mean ratio across all twelve sites at 614.

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).

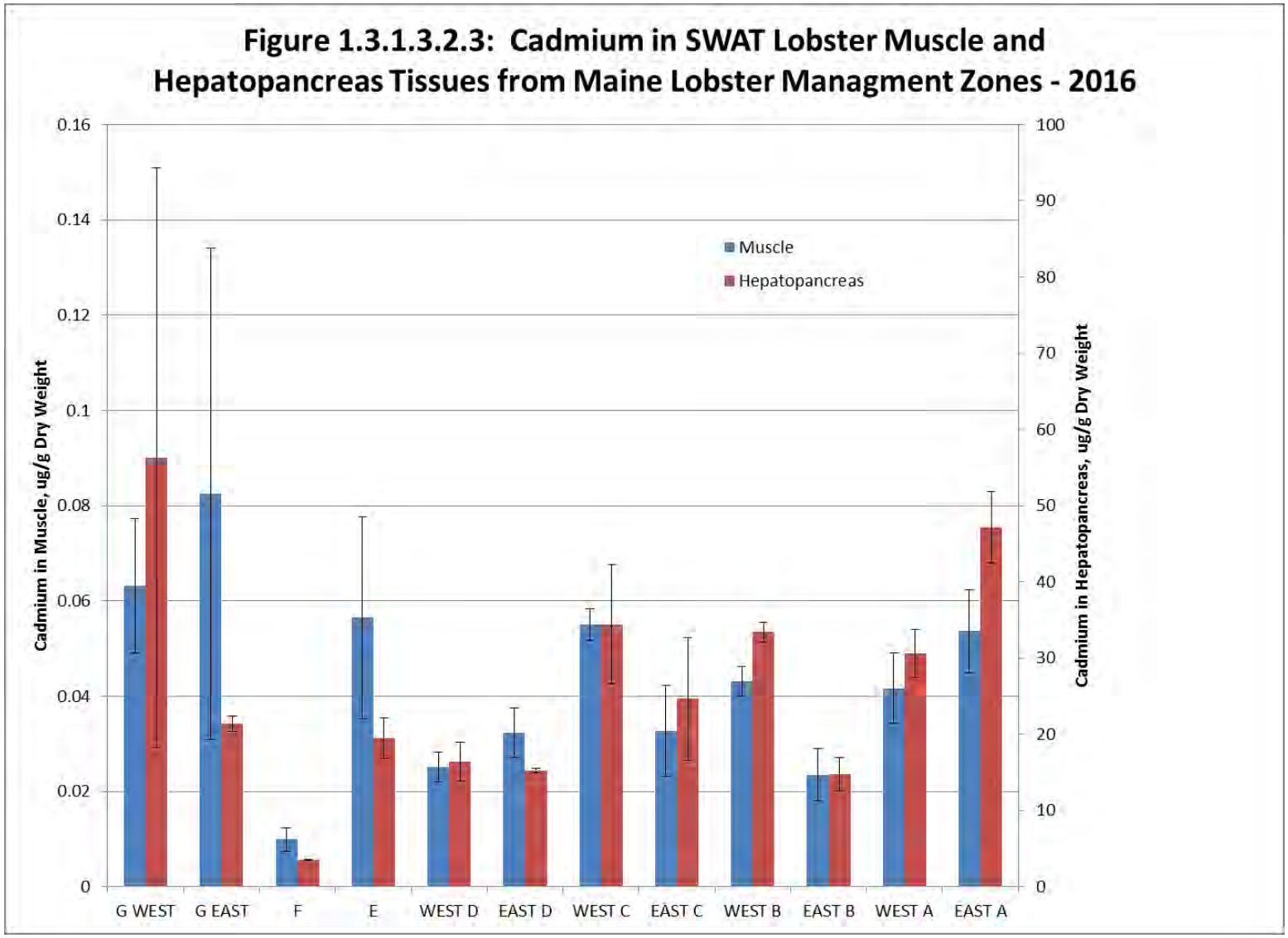


Figure 1.3.1.3.2.3: Cadmium in SWAT Lobster Muscle and Hepatopancreas Tissues from Maine Lobster Managment Zones - 2016
Cadmium in Muscle, ug/g Dry Weight
Cadmium in Hepatopancreas, ug/g Dry Weight
Muscle
Hepatopancreas
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
100
90
80
70
60
50
40
30
20
10
0
G WEST
G EAST
F
E
WEST D
EAST D
WEST C
EAST C
WEST B
EAST B
WEST A
EAST A

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). Muscle tissue mean cadmium concentrations ranged from 0.0014 to 0.013 ug/g wet weight, two orders of magnitude below the MCDC FTAL. Hepatopancreas tissue mean cadmium concentrations ranged from 1.047 to 14.57 ug/g wet weight, and eleven of twelve areas tested exceeded the MCDC FTAL. Only Zone F had a hepatopancreas mean cadmium wet weight concentration below the MCDC FTAL.

1.3.1.3.2.4 Chromium (Cr)

Chromium was detected at all 12 sample locations (Figure 1.3.1.3.2.4). Chromium concentrations in muscle tissue ranged from a low concentration of 0.47 µg/g dry wt. to a high concentration of 0.58 µg/g dry wt. Chromium concentrations in hepatopancreas tissue ranged from a low concentration of 0.19 µg/g dry wt. to a high concentration of 0.45 µg/g dry wt.

Muscle and hepatopancreas tissue cadmium concentrations differed. The hepatopancreas to muscle tissue ratio of chromium concentrations varied from 0.4 to 0.8, with the mean ratio across all twelve sites at 0.6. On average, chromium concentrations in hepatopancreas were nearly half of concentrations in muscle.

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 for total chromium.

1.3.1.3.2.5 Copper (Cu)

Copper was detected at all 12 sample locations (Figure 1.3.1.3.2.5). Copper concentrations in muscle tissue ranged from a low concentration of 33.20 µg/g dry wt. to a high concentration of 62.06 µg/g dry wt. Copper concentrations in hepatopancreas tissue ranged from a low concentration of 102.03 µg/g dry wt. to a high concentration of 786.33 µg/g dry wt.

Muscle and hepatopancreas tissue copper concentrations differed markedly. The hepatopancreas to muscle tissue ratio of copper concentrations varied from 2.3 to 17.2, with the mean ratio across all twelve sites at 6.7.

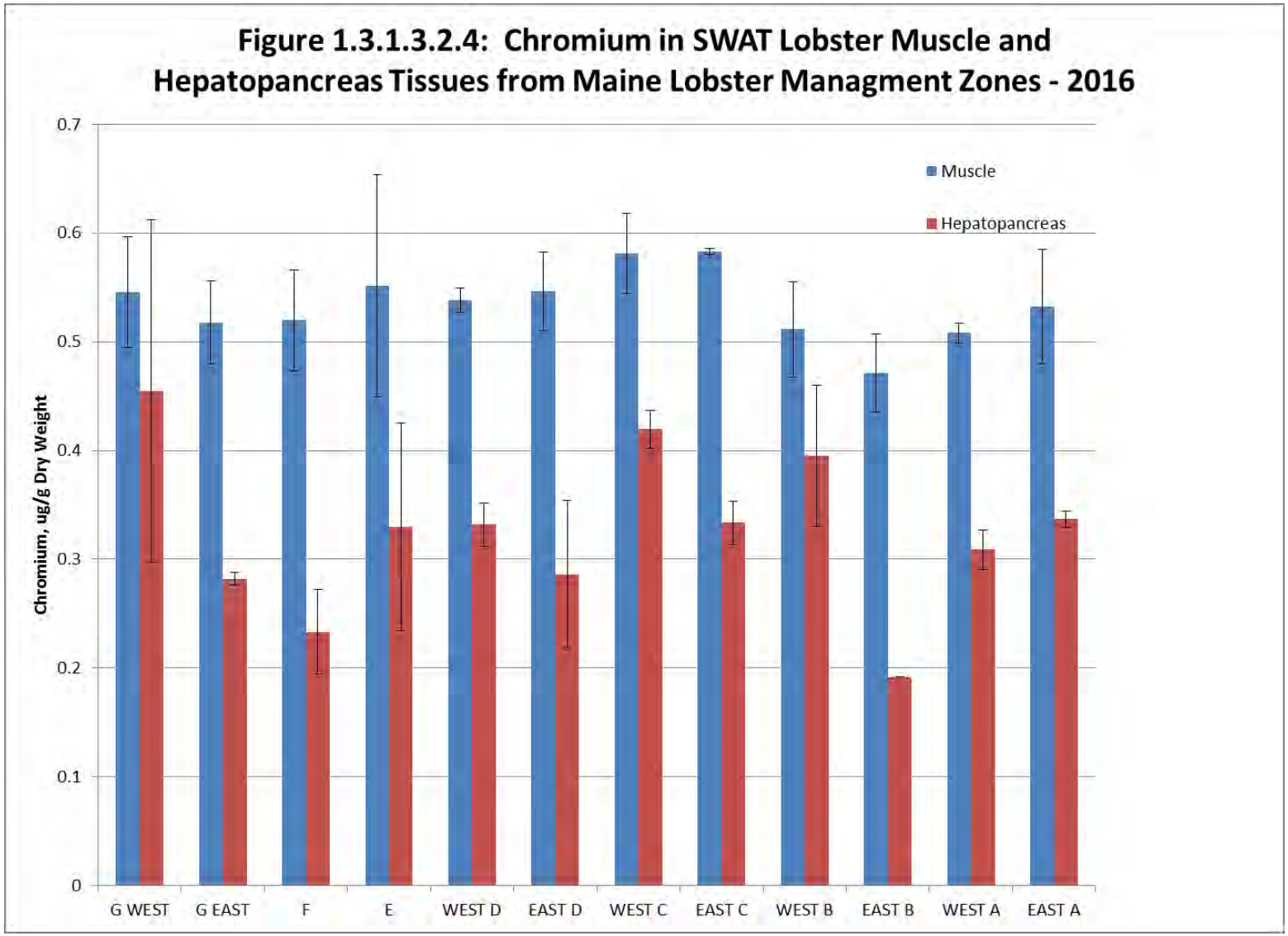


Figure 1.3.1.3.2.4: Chromium in SWAT Lobster Muscle and Hepatopancreas Tissues from Maine Lobster Managment Zones - 2016
Chromium, ug/g Dry Weight
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Muscle
Hepatopancreas
G WEST
G EAST
F
E
WEST D
EAST D
WEST C
EAST C
WEST B
EAST B
WEST A
EAST A

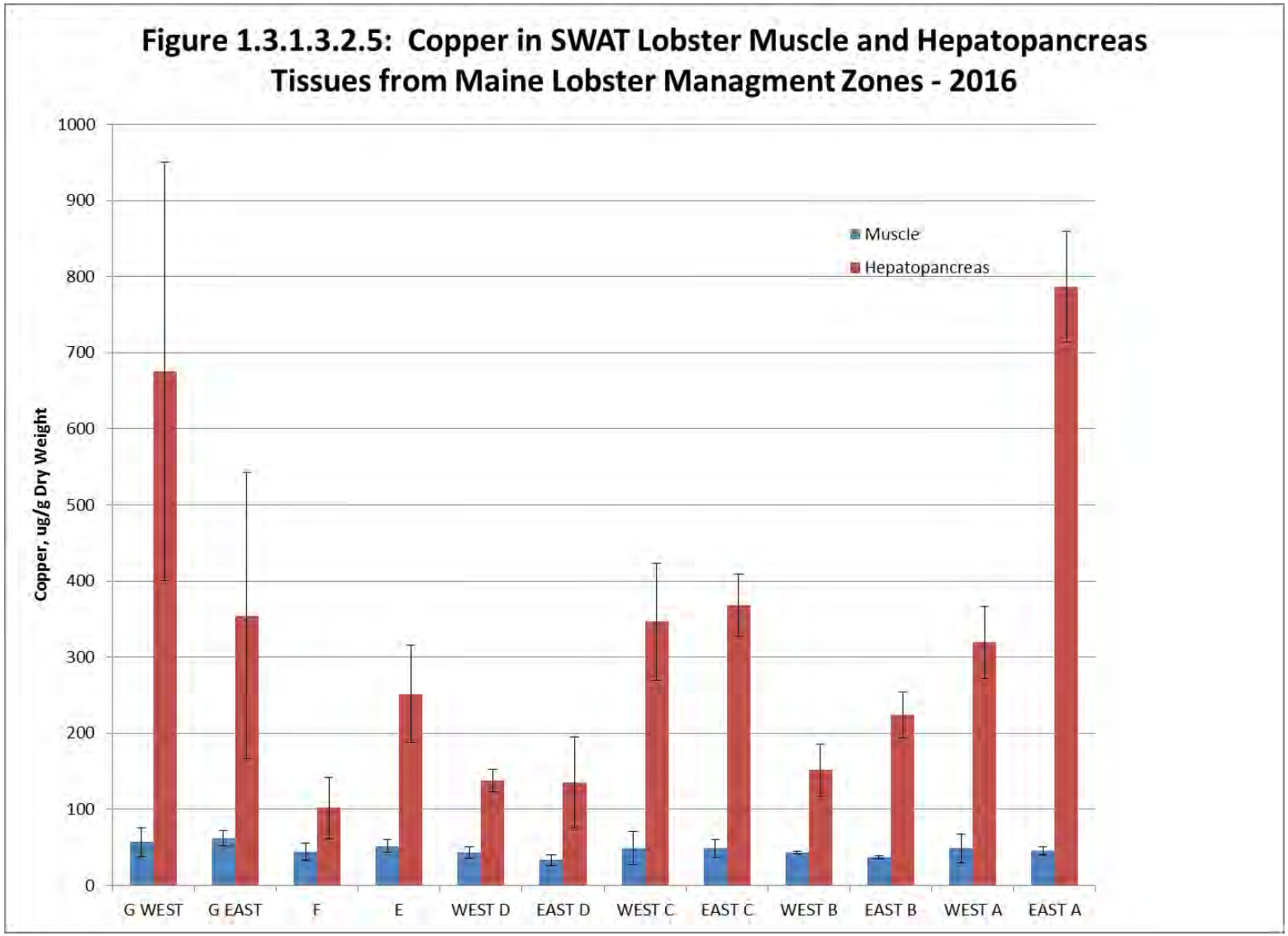


Figure 1.3.1.3.2.5: Copper in SWAT Lobster Muscle and Hepatopancreas Tissues from Maine Lobster Managment Zones - 2016
Copper, ug/g Dry Weight
1000
900
800
700
600
500
400
300
200
100
0
Muscle
Hepatopancreas
G WEST
G EAST
F
E
WEST D
EAST D
WEST C
EAST C
WEST B
EAST B
WEST A
EAST A

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 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 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.

1.3.1.3.2.6 Iron (Fe) and Aluminum (Al)

Iron was detected at all 12 sample locations (Figure 1.3.1.3.2.6.1). Iron concentrations in muscle tissue ranged from a low concentration of 4.32 µg/g dry wt. to a high concentration of 10.94 µg/g dry wt. Iron concentrations in hepatopancreas tissue ranged from a low concentration of 68.62 µg/g dry wt. to a high concentration of 121.89 µg/g dry wt.

Muscle and hepatopancreas tissue iron concentrations differed markedly. The hepatopancreas to muscle tissue ratio of iron concentrations varied from 6.5 to 20.6, with the mean ratio across all twelve sites at 13.9.

Aluminum was detected at all 12 sample locations (Figure 1.3.1.3.2.6.2). Aluminum concentrations in muscle tissue ranged from a low concentration of 1.18 µg/g dry wt. to a high concentration of 6.47 µg/g dry wt. Aluminum concentrations in hepatopancreas tissue ranged from a low concentration of 2.64 µg/g dry wt. to a high concentration of 27.48 µg/g dry wt.

Muscle and hepatopancreas tissue aluminum concentrations differed markedly in some samples and were similar in other samples. The hepatopancreas to muscle tissue ratio of aluminum concentrations varied from 0.9 to 9.5, with the mean ratio across all fifteen sites at 3.2.

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

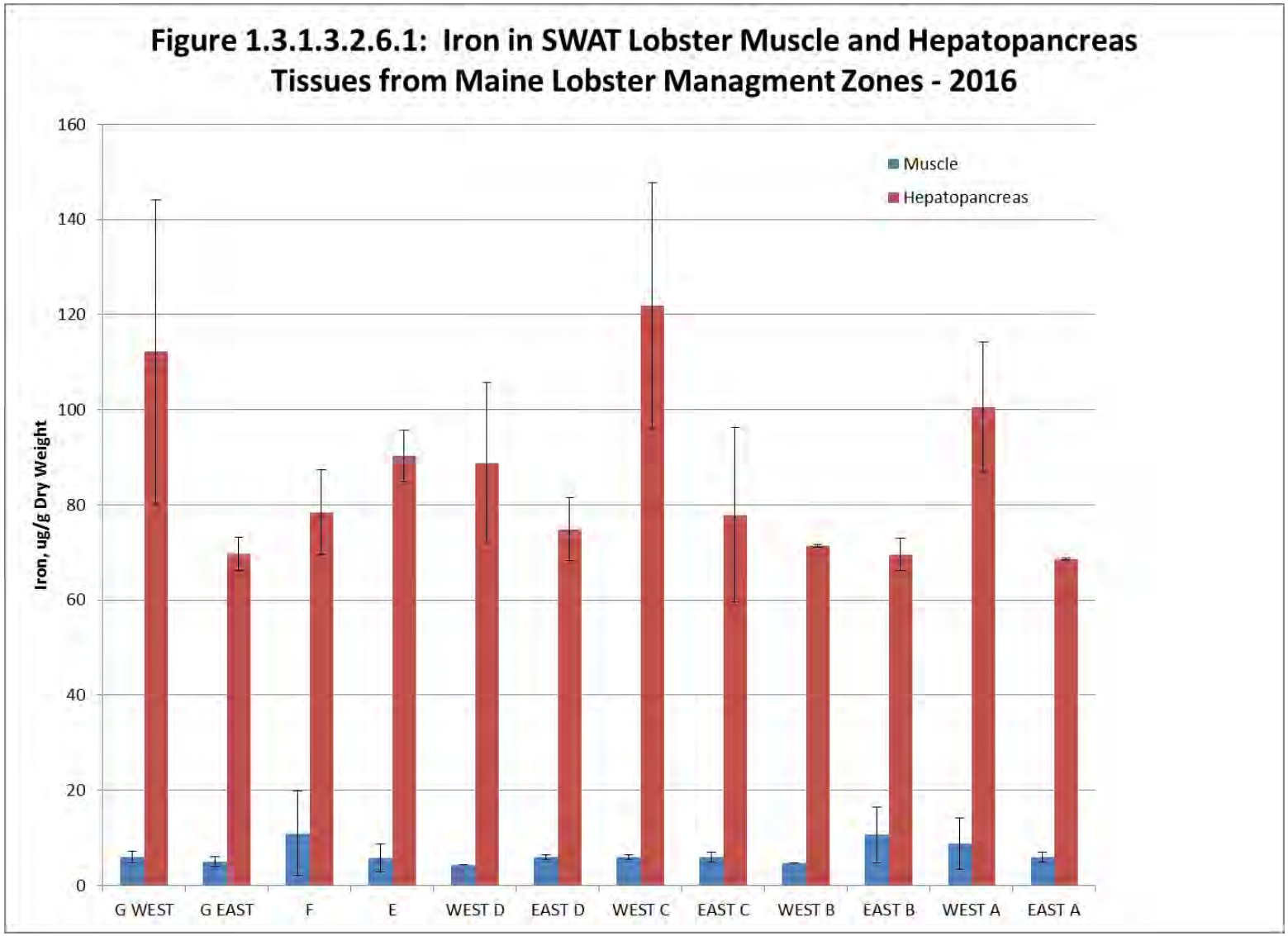


Figure 1.3.1.3.2.6.1: Iron in SWAT Lobster Muscle and Hepatopancreas Tissues from Maine Lobster Managment Zones - 2016
Iron, ug/g Dry Weight
160
140
120
100
80
60
40
20
0
Muscle
Hepatopancreas
G WEST
G EAST
F
E
WEST D
EAST D
WEST C
EAST C
WEST B
EAST B
WEST A
EAST A

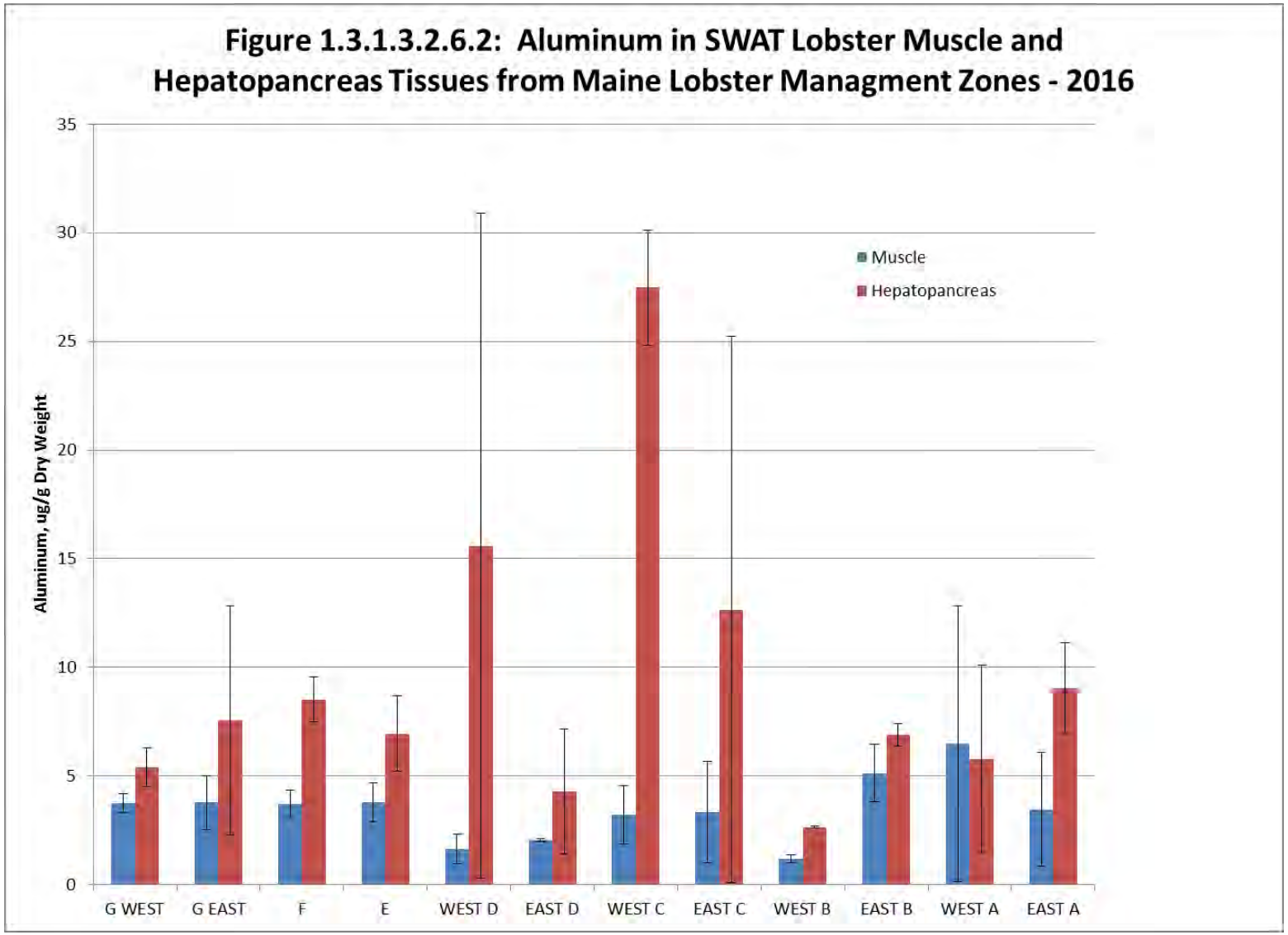


Figure 1.3.1.3.2.6.2: Aluminum in SWAT Lobster Muscle and Hepatopancreas Tissues from Maine Lobster Managment Zones - 2016
Aluminum, ug/g Dry Weight
35
30
25
20
15
10
5
0
Muscle
Hepatopancreas
G WEST
G EAST
F
E
WEST D
EAST D
WEST C
EAST C
WEST B
EAST B
WEST A
EAST A

1.3.1.3.2.7 Nickel (Ni)

Nickel was detected at all 12 sample locations (Figure 1.3.1.3.2.7). Nickel concentrations in muscle tissue ranged from a low concentration of 0.12 µg/g dry wt. to a high concentration of 0.50 µg/g dry wt. Nickel concentrations in hepatopancreas tissue ranged from a low concentration of 0.28 µg/g dry wt. to a high concentration of 1.96 µg/g dry wt.

Muscle and hepatopancreas tissue nickel concentrations differed markedly. The hepatopancreas to muscle tissue ratio of nickel concentrations varied from 1.2 to 6.7, with the mean ratio across all twelve sites at 3.4.

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 maximum mean concentration detected by SWAT in lobster muscle tissue is 0.079 µg/g wet wt., which is several orders of magnitude lower than the more conservative MCDC action level. MCDC does not report a cancer action level for nickel. The maximum mean hepatopancreas tissue nickel concentration of 0.52 ug/g wet wt. is still well below the MCDC non-cancer FTAL.

1.3.1.3.2.8 Lead (Pb)

Lead was detected at all 12 sample locations (Figure 1.3.1.3.2.8). Lead concentrations in muscle tissue ranged from a low concentration of 0.012 µg/g dry wt. to a high concentration of 0.10 µg/g dry wt. Lead concentrations in hepatopancreas tissue ranged from a low concentration of 0.061µg/g dry wt. to a high concentration of 0.34 µg/g dry wt.

Muscle and hepatopancreas tissue lead concentrations differed markedly. The hepatopancreas to muscle tissue ratio of lead concentrations varied from 1.4 to 7.7, with the mean ratio across all twelve sites at 4.5.

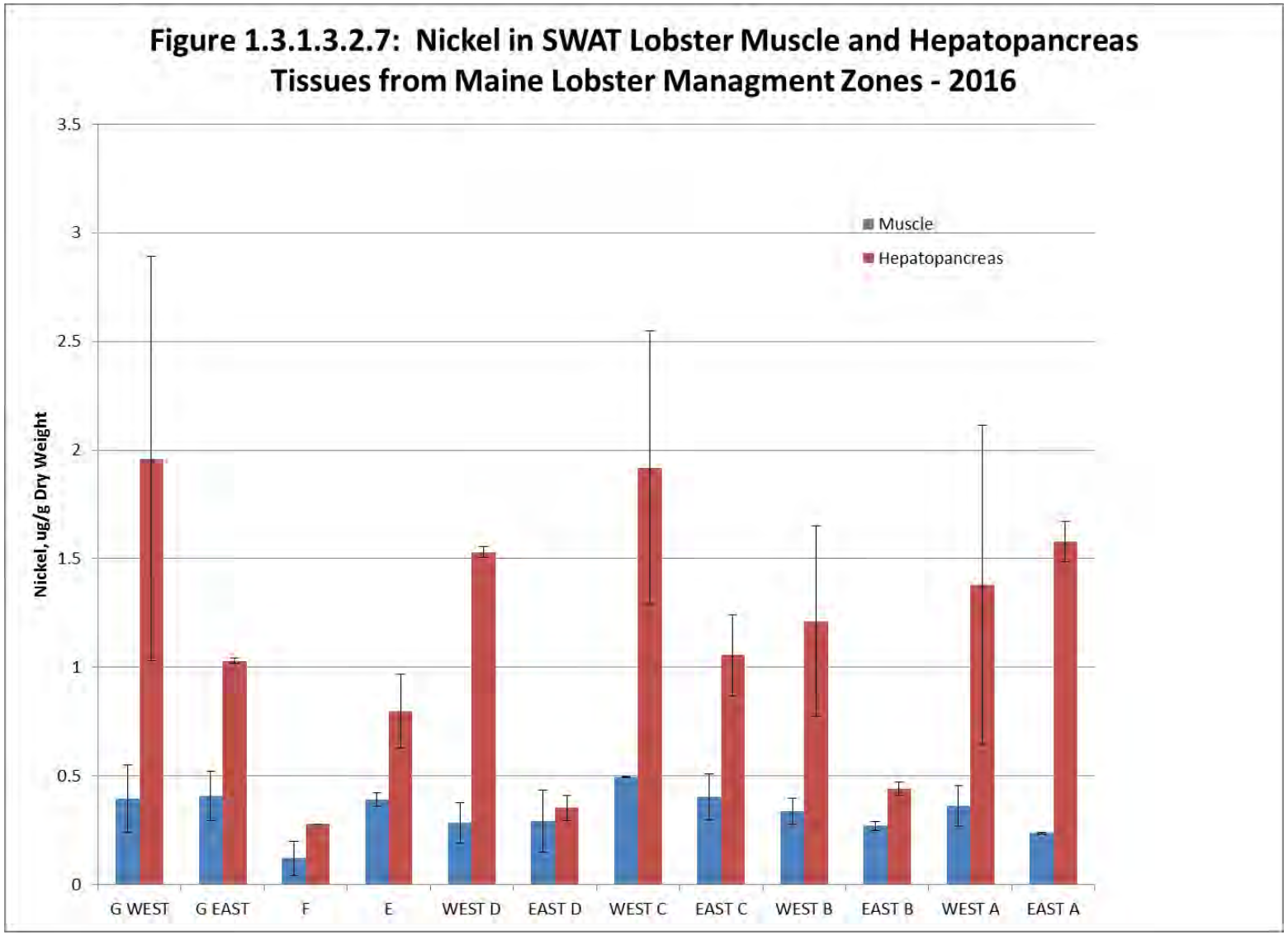


Figure 1.3.1.3.2.7: Nickel in SWAT Lobster Muscle and Hepatopancreas Tissues from Maine Lobster Managment Zones - 2016
Nickel, ug/g Dry Weight
3.5
3
2.5
2
1.5
1
0.5
0
Muscle
Hepatopancreas
G WEST
G EAST
F
E
WEST D
EAST D
WEST C
EAST C
WEST B
EAST B
WEST A
EAST A

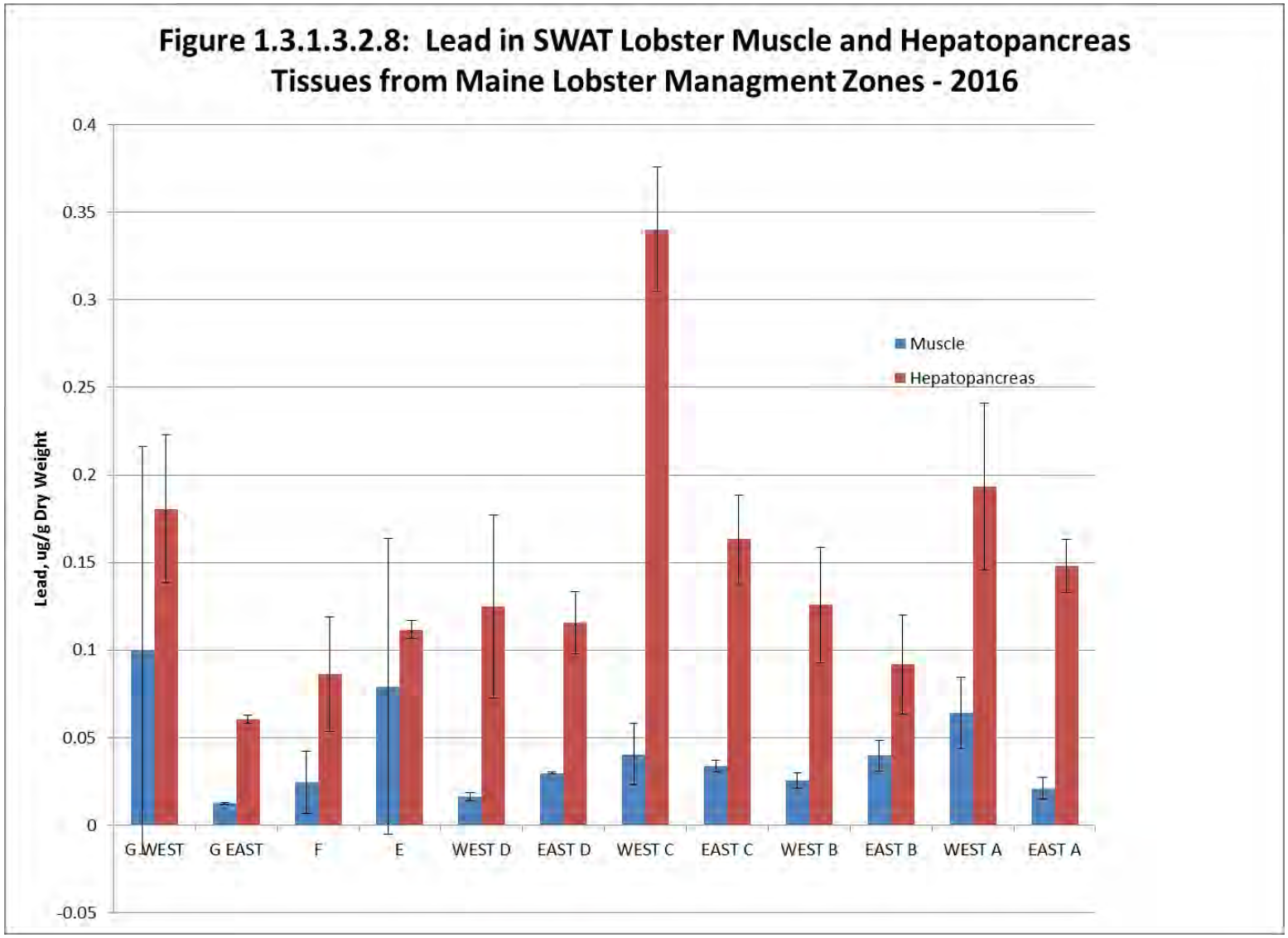


Figure 1.3.1.3.2.8: Lead in SWAT Lobster Muscle and Hepatopancreas Tissues from Maine Lobster Managment Zones - 2016
Lead, ug/g Dry Weight
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
Muscle
Hepatopancreas
G WEST
G EAST
F
E
WEST D
EAST D
WEST C
EAST C
WEST B
EAST B
WEST A
EAST A

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).

The MCDC former lead FTAL in non-commercially caught sportfish is 0.6 µg/g wet wt., which is based on a blood lead concentration model. The highest lobster muscle mean lead concentration was 0.013 ug/g wet wt., which is several orders of magnitude below the MCDC former FTAL of 0.6 ug/g wet wt. for recreationally caught sportfish. The highest lobster hepatopancreas mean lead concentration was 0.077 ug/g wet wt., which is nearly several orders of magnitude below the MCDC former FTAL of 0.6 ug/g wet wt. for recreationally caught sportfish. A new lead FTAL may be developed in the future.

1.3.1.3.2.9 Mercury (Hg)

Mercury was detected at all 12 sample locations (Figure 1.3.1.3.2.9). Mercury concentrations in muscle tissue ranged from a low concentration of 0.28 µg/g dry wt. to a high concentration of 0.58 µg/g dry wt. Mercury concentrations in hepatopancreas tissue ranged from a low concentration of 0.12 µg/g dry wt. to a high concentration of 0.36 µg/g dry wt.

Muscle and hepatopancreas tissue mercury concentrations differed markedly. The hepatopancreas to muscle tissue ratio of mercury concentrations varied from 0.3 to 0.6, with the mean ratio across all twelve sites at 0.5, reflecting the fact that the total mercury concentration in muscle tissue was about twice that in hepatopancreas.

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 lobster muscle tissue mean total mercury concentration measured in 2016 was 0.083 µg/g wet wt. and the highest hepatopancreas mean total mercury concentration measured was 0.096 ug/g wet wt. These two mean concentrations from both tissues compare favorably with the MCDC methylmercury developmental FTAL of 0.2 µg/g, assuming a similar meal size and frequency.

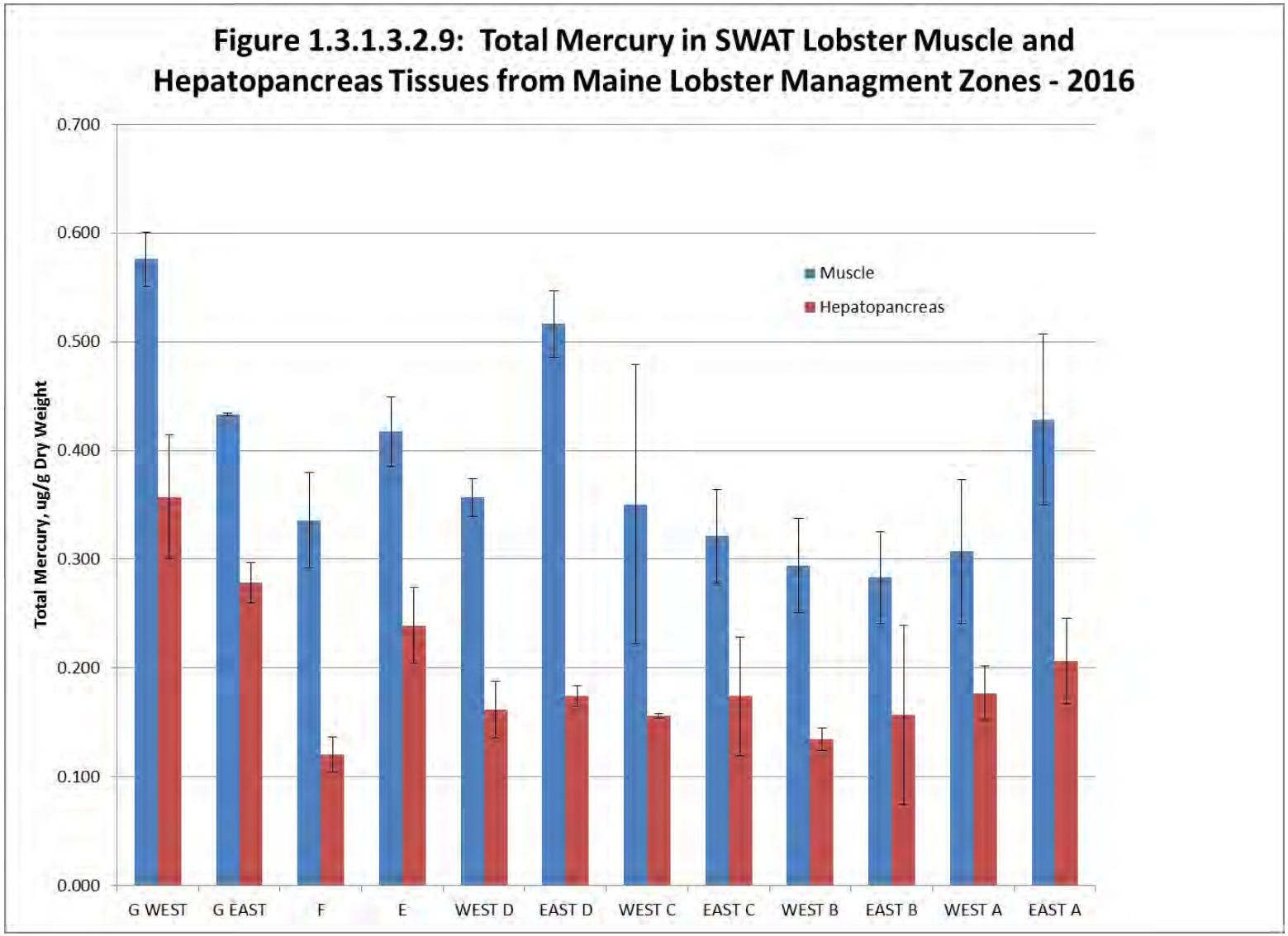


Figure 1.3.1.3.2.9: Total Mercury in SWAT Lobster Muscle and Hepatopancreas Tissues from Maine Lobster Managment Zones - 2016
Total Mercury, ug/g Dry Weight
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
Muscle
Hepatopancreas
G WEST
G EAST
F
E
WEST D
EAST D
WEST C
EAST C
WEST B
EAST B
WEST A
EAST A

1.3.1.3.2.10 Selenium (Se)

Selenium was detected at all 12 sample locations (Figure 1.3.1.3.2.10). Selenium concentrations in muscle tissue ranged from a low concentration of 2.50 µg/g dry wt. to a high concentration of 6.53 µg/g dry wt. Selenium concentrations in hepatopancreas tissue ranged from a low concentration of 2.12 µg/g dry wt. to a high concentration of 6.31 µg/g dry wt.

Muscle and hepatopancreas tissue selenium concentrations were similar. The hepatopancreas to muscle tissue ratio of selenium concentrations varied from 0.7 to 1.7, with the mean ratio across all twelve sites at 1.1, reflecting the fact that the selenium concentrations in both tissues were similar overall.

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 lobster muscle tissue mean selenium concentration measured in 2016 was 1.14 µg/g wet wt. and the highest hepatopancreas mean selenium concentration measured was 1.95 ug/g wet wt. These two mean concentrations from both tissues compare favorably with the MCDC selenium FTAL, assuming a similar meal size and frequency.

1.3.1.3.2.11 Zinc (Zn)

Zinc was detected in tissue taken at all 12 management zones sampled in 2016 (Figure 1.3.1.3.2.11). Zinc levels measured in lobster muscle tissue ranged from a low mean concentration of 94.3 µg/g dry wt. to a high mean concentration of 130.8 µg/g dry weight. Zinc concentrations in hepatopancreas tissue ranged from a low concentration of 34.0 µg/g dry wt. to a high concentration of 97.1 µg/g dry wt.

Muscle and hepatopancreas tissue zinc concentrations differed minimally. The hepatopancreas to muscle ratio of zinc concentration ranged from 0.3 to 0.8 and averaged 0.6 for all twelve sites.

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. The maximum mean concentrations of zinc in lobster muscle and

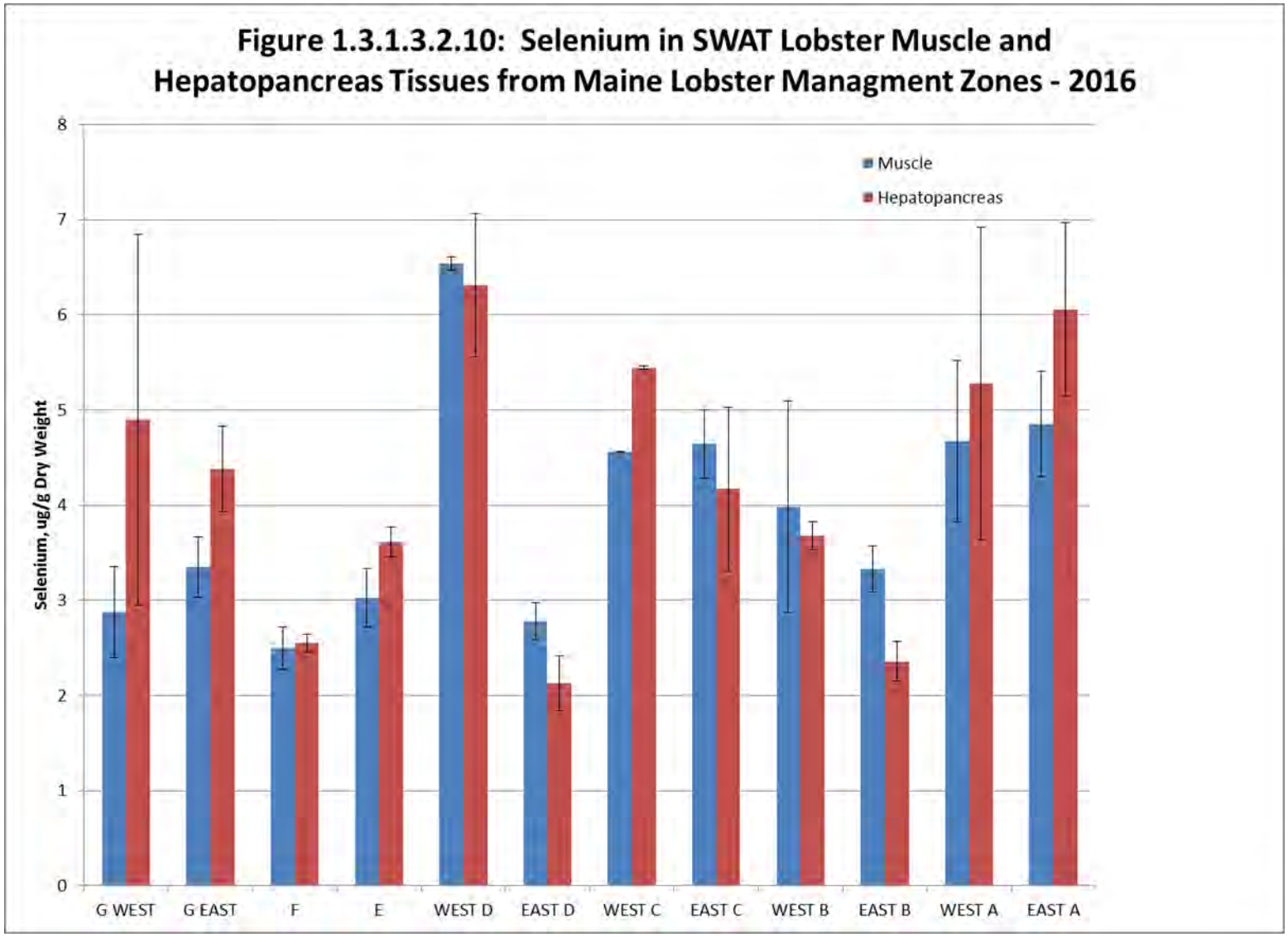


Figure 1.3.1.3.2.10: Selenium in SWAT Lobster Muscle and Hepatopancreas Tissues from Maine Lobster Managment Zones - 2016
Selenium, ug/g Dry Weight
0
1
2
3
4
5
6
7
8
Muscle
Hepatopancreas
G WEST
G EAST
F
E
WEST D
EAST D
WEST C
EAST C
WEST B
EAST B
WEST A
EAST A

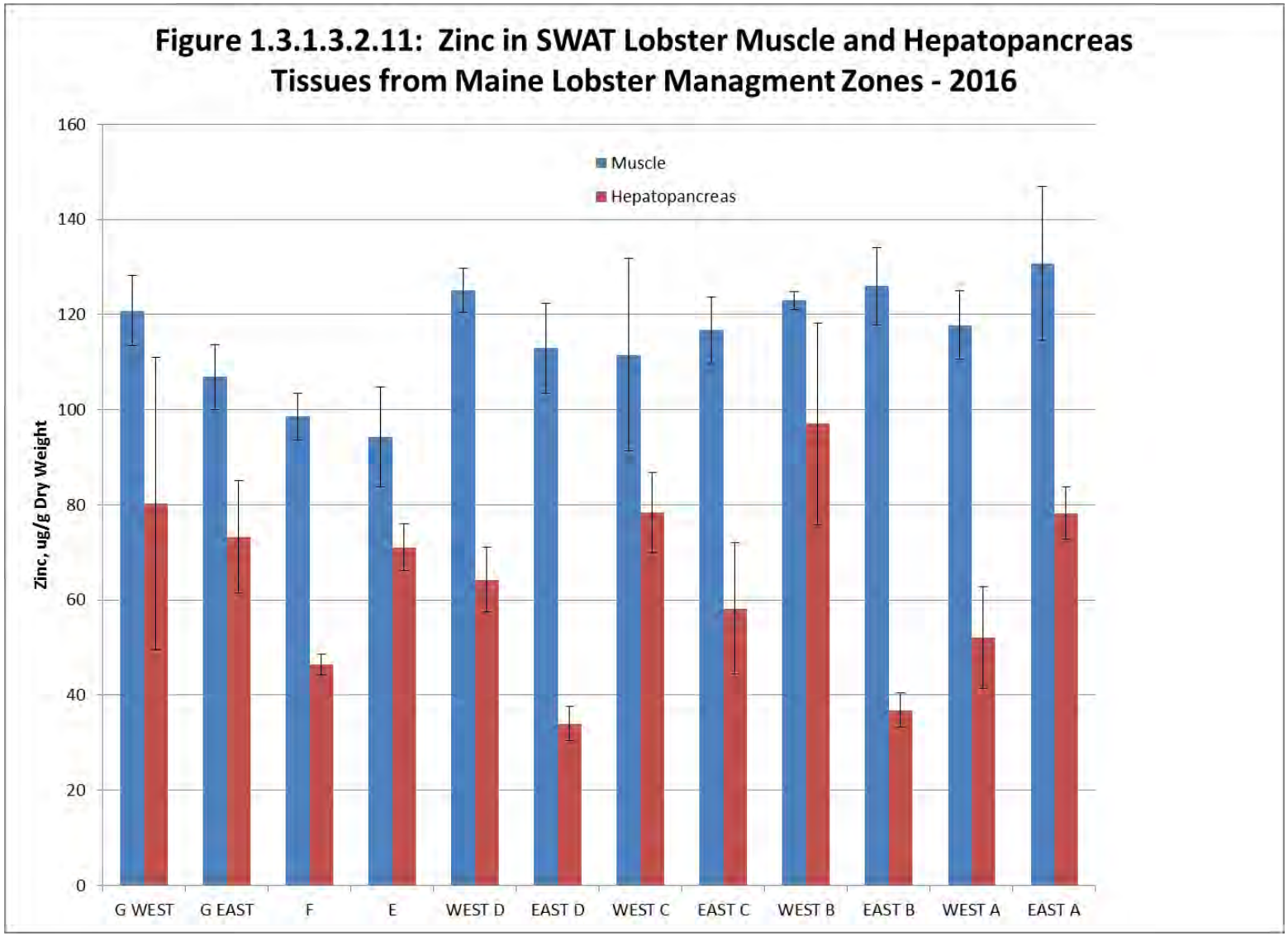


Figure 1.3.1.3.2.11: Zinc in SWAT Lobster Muscle and Hepatopancreas Tissues from Maine Lobster Managment Zones - 2016
Zinc, ug/g Dry Weight
Muscle
Hepatopancreas
0
20
40
60
80
100
120
140
160
G WEST
G EAST
F
E
WEST D
EAST D
WEST C
EAST C
WEST B
EAST B
WEST A
EAST A

hepatopancreas tissues were 22.3 ug/g wet wt. and 35.6 ug/g wet wt., respectively, which were both an order of magnitude lower than the MCDC FTAL. There is no recommended FDA safety level for zinc in fish (Kimbrough et al., 2008).

1.3.2 Polycyclic Aromatic Compounds

Polycyclic Aromatic 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 2014 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 2015-16 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.

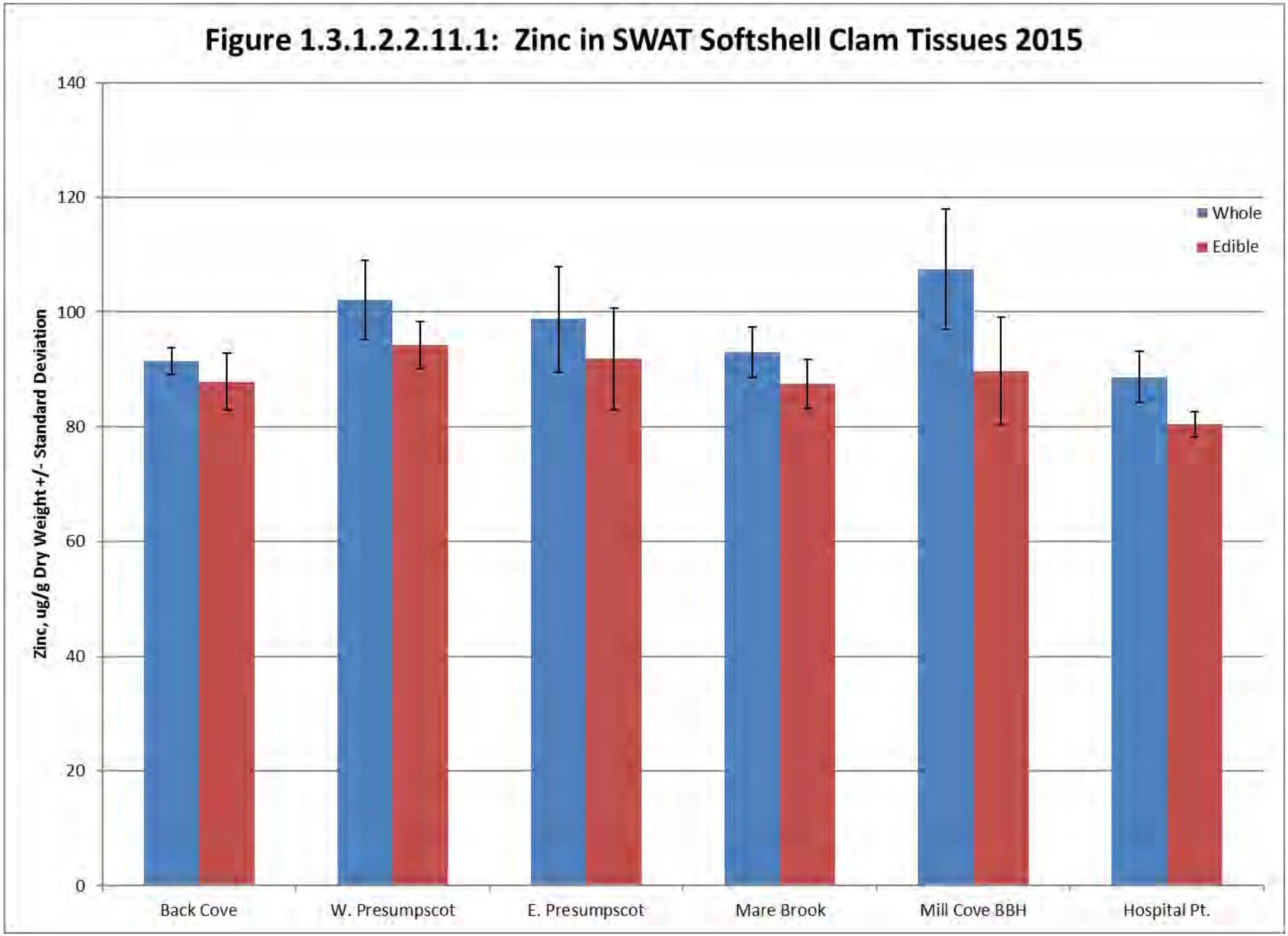


Figure 1.3.1.2.2.11.1: Zinc in SWAT Softshell Clam Tissues 2015
Zinc, ug/g Dry Weight +/- Standard Deviation
140
120
100
80
60
40
20
0
Whole
Edible
Back Cove
W. Presumpscot
E. Presumpscot
Mare Brook
Mill Cove BBH
Hospital Pt.

SWAT 2015-16 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 five 2015-16 SWAT blue mussel sites analyzed for PAHs. 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 281 ng/g dry wt. at Scarborough River, Scarborough, 912 ng/g dry wt. at Spring Point, S. Portland, 852 ng/g dry wt. at East End Beach, Portland, 1,682 ng/g dry wt. at Crockett Point, Rockland, and 360 ng/g dry wt. at Sears Island, Searsport (Figure 1.3.2.1.1). The means of the sum of 19 non-alkylated PAHs were 101 ng/g dry wt. at Scarborough River, Scarborough, 316 ng/g dry wt. at Spring Point, S. Portland, 304 ng/g dry wt. at East End Beach, Portland, 691 ng/g dry wt. at Crockett Point, Rockland, and 110 ng/g dry wt. at Sears Island, Searsport (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 135 ng/g dry wt. at Scarborough River, Scarborough, 367 ng/g dry wt. at Spring Point, S. Portland, 363 ng/g dry wt. at East End Beach, Portland, 829 ng/g dry wt. at Crockett Point, Rockland, and 148 ng/g dry wt. at Sears Island, Searsport (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 2015-16 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 231 ng/g dry wt. at Scarborough River, Scarborough, 757 ng/g dry wt. at Spring Point, S. Portland, 706 ng/g dry wt. at East End Beach, Portland, 1,363 ng/g dry wt. at Crockett Point, Rockland, and 279 ng/g dry wt. at Sears Island, Searsport (Figure 1.3.2.1.1).

TABLE 1.3.2.1.1: Analyzed PAHs and PAH Summation Calculations

	SWAT				Gulfwatch, Summations	NS&T,	SWAT		
Parameter	2012-16	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				Gulfwatch, NS&T, SWAT Summations				
Parameter	2012-16	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				Gulfwatch, NS&T, SWAT Summations				
Parameter	2012-16	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				Gulfwatch, NS&T, SWAT Summations				
Parameter	2012-16	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:

1. Prior to 2012: List of 'Sum PAH19' only has 18 compounds in it because we have BENZO[B]FLUORANTHENES and BENZO[K]FLUORANTHENES listed as one compound, BENZO[B,J,K]FLUORANTHENES; same applies to 'Sum PAH24' which has only 23 compounds. For 2012-14: List of 'Sum PAH19' has 19 compounds in it because we have BENZO[B]FLUORANTHENES and BENZO[J,K]FLUORANTHENES listed as two compounds: Same applies to 'Sum PAH24' which now has 24 compounds.

2. Prior to 2012: List of 'Sum PAH40' only has 38 compounds in it because we have BENZO[B]FLUORANTHENES and BENZO[K]FLUORANTHENES listed as one compound, BENZO[B,J,K]FLUORANTHENES and we do not have SWAT/AXYS data for C-4 FLUORENES (at bottom of above list). For 2012-14: List of 'Sum PAH40' has 39 compounds in it because we have BENZO[B]FLUORANTHENES and BENZO[J,K]FLUORANTHENES listed as two compounds, though we still do not have SWAT/AXYS data for C-4 FLUORENES (at bottom of above list)

3. 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

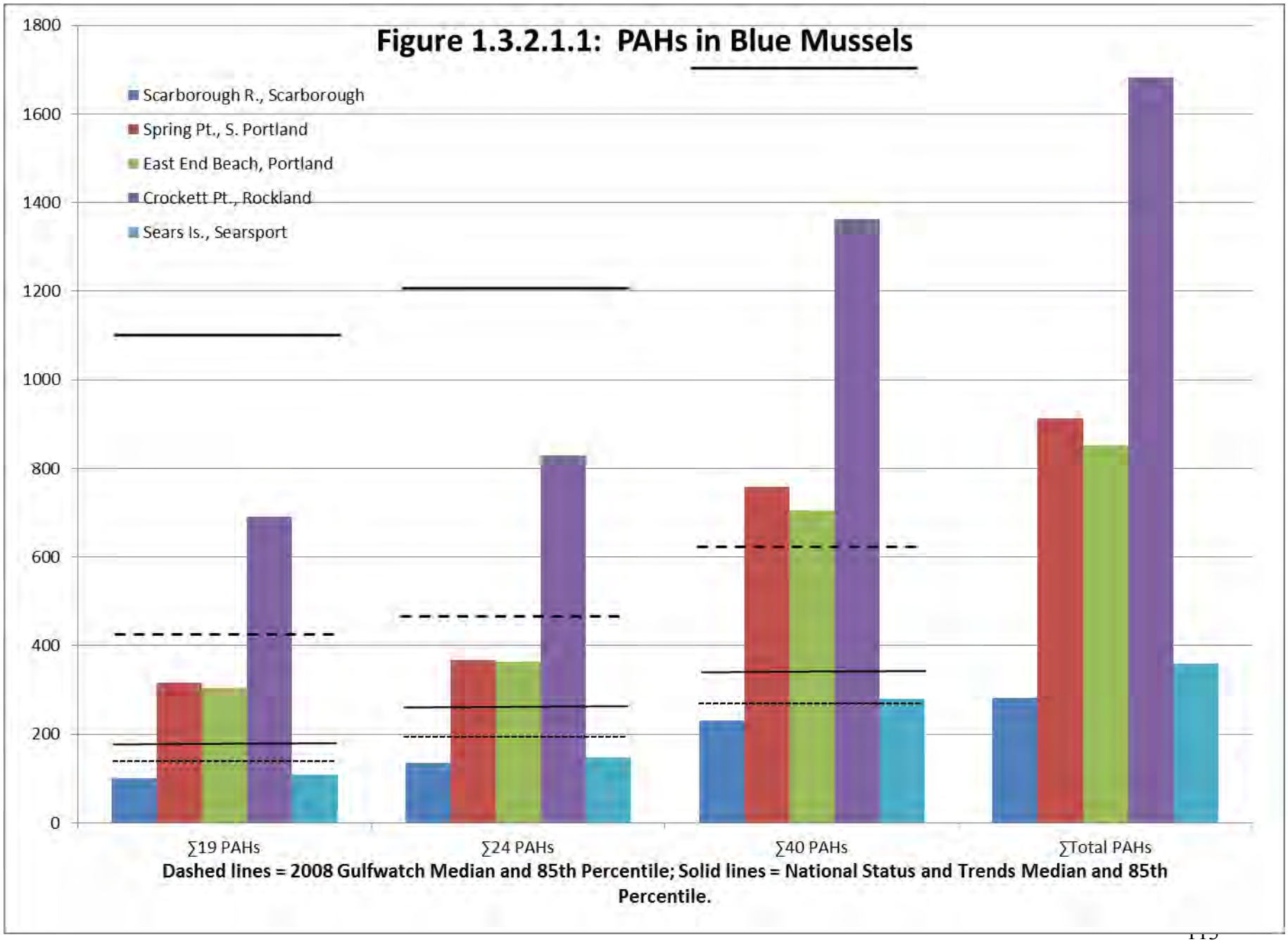


Figure 1.3.2.1.1: PAHs in Blue Mussels
Scarborough R., Scarborough
Spring Pt., S. Portland
East End Beach, Portland
Crockett Pt., Rockland
Sears Is., Searsport
1800
1600
1400
1200
1000
800
600
400
200
0
∑19 PAHs
∑24 PAHs
∑40 PAHs
∑Total PAHs
Dashed lines = 2008 Gulfwatch Median and 85th Percentile; Solid lines = National Status and 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 2015-16 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, Crockett Point, 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 2015-16 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 the three remaining sites 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 2015-16 to the Gulfwatch 2008 median and 85th percentile results. The sum of 24 PAHs from mussel tissue at two sites sampled in 2015-16 were below the Gulfwatch 2008 median of 198 ng/g dry wt. for 24 summed PAHs, while the remaining three sites exceeded the Gulfwatch median. Only one site, Crockett Point, 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 2015-16 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 three sites sampled in 2015-16 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 2015-16 to the Gulfwatch 2008 median and 85th percentile results. The sum of 40 PAHs from mussel tissue at four sites sampled exceeded the Gulfwatch 2008 median of 260 ng/g dry wt. for 40 summed PAHs, although the sum of 40 PAHs from Sears Island, Searsport, was only marginally above the Gulfwatch mean. The sum of 40 PAHs at three sites sampled in 2015-16 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 2015-16 SWAT mussel sties to the NS&T median and 85th percentile for 40 summed PAHs (2008 data, the most recent available). The sum of 40 PAHs from mussel tissue at three sites sampled in 2015-16 exceeded the NS&T 2008 median of 353 ng/g dry wt. for 40 summed PAHs, and none of the sites exceeded the NS&T 85th percentile of 1,674 ng/g dry wt. for 40 summed PAHs.

For 2015-16 SWAT blue mussel sites, 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 five SWAT blue mussel sites tested in 2015-16 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).

1.3.3 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 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

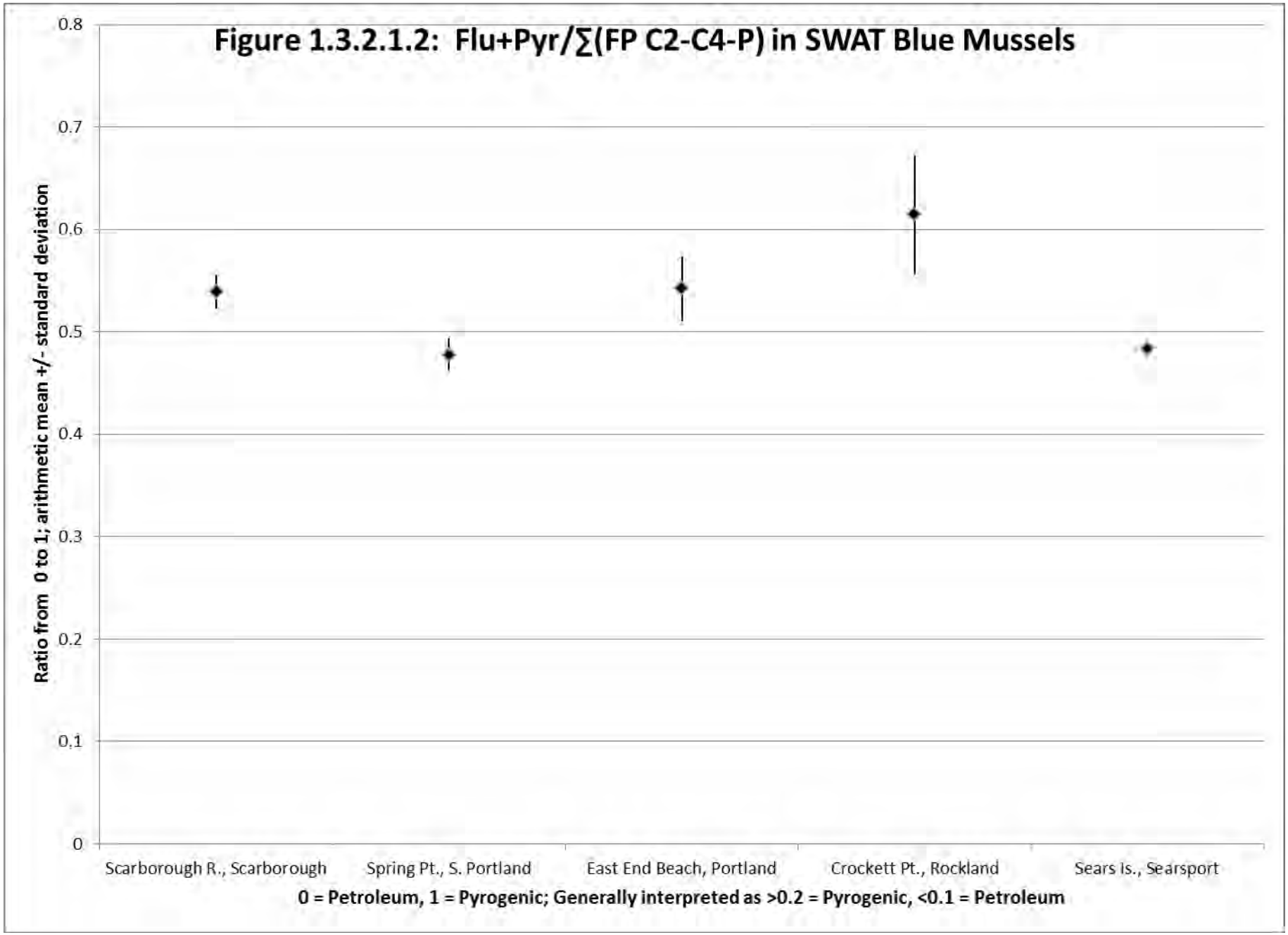


Figure 1.3.2.1.2: Flu+Pyr/∑(FP C2-C4-P) in SWAT Blue Mussels
Ratio from 0 to 1; arithmetic mean +/- standard deviation
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0,1
0
Scarborough R., Scarborough
Spring Pt., S. Portland
East End Beach, Portland
Crockett Pt., Rockland
Sears Is., Searsport
0 = Petroleum, 1 = Pyrogenic; Generally interpreted as >0.2 = Pyrogenic, <0.1 = Petroleum

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 five mussel sites sampled for PCBs in 2015-16, the SWAT PCBs were 39% at Scarborough River, Scarborough, 38% at Spring Point, S. Portland, 37% at East End Beach, Portland, 34% at Crockett Point, Rockland, and 37% at Sears Island, Searsport of the total PCBs, . Total PCB concentrations were 13 ng/g dry wt., 60 ng/g dry wt., 62 ng/g dry wt., 83 ng/g dry wt., and 17 ng/g dry wt., at the five sites in the same respective order as state previously (Figure 1.3.3.1.1).

Figure 1.3.3.1.1 compares the SWAT PCBs at the 2015-16 SWAT mussel sites to Gulfwatch median and 85th percentile for 2008 PCB data, the most recent available. Of the five SWAT mussel sites, only Crockett Point, Rockland, 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 2015-16 SWAT sites to NS&T (NS&T) median and 85th percentile 2008 PCB data, the most recent available. None of the five SWAT sites exceeded the NS&T 2008 median, 29.2 ng/g dry wt., and none of the five exceeded the NS&T national 85th percentile, 14.1 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).

TABLE 1.3.3.1.1: Comparison of 35 PCBs Summed for SWAT to 31 PCBs Summed for National Status & Trends and Gulfwatch.

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

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

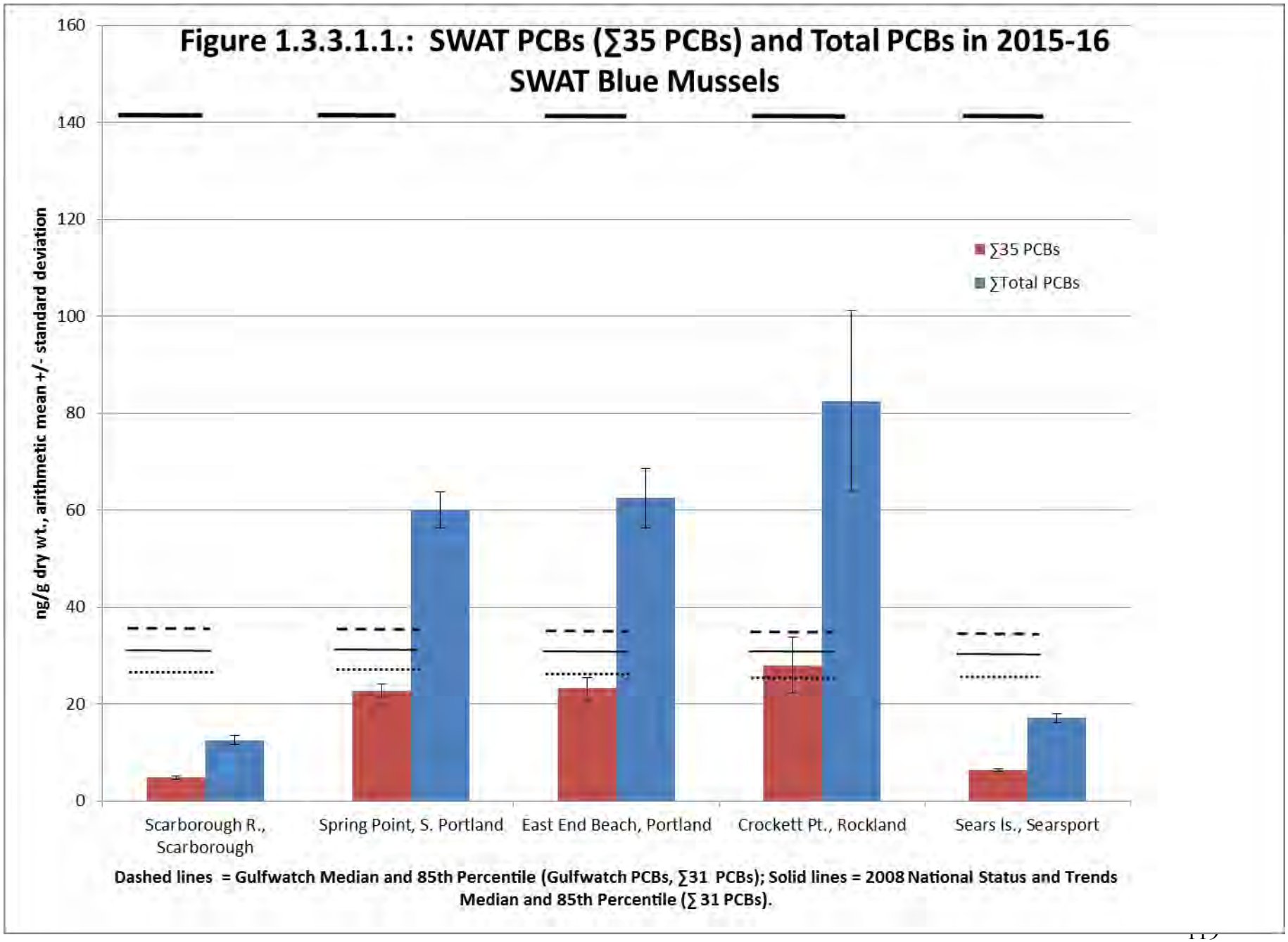


Figure 1.3.3.1.1.: SWAT PCBs (∑35 PCBs) and Total PCBs in 2015-16 SWAT Blue Mussels
ng/g dry wt., arithmetic mean +/- standard deviation
160
140
120
100
80
60
40
20
0
∑35 PCBs
∑Total PCBs
Scarborough R., Scarborough
Spring Point, S. Portland
East End Beach, Portland
Crockett Pt., Rockland
Sears Is., Searsport
Dashed lines = Gulfwatch Median and 85th Percentile (Gulfwatch PCBs, ∑31 PCBs); Solid lines = 2008 National Status and Trends Median and 85th Percentile (∑ 31 PCBs).

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 sum of total PCBs occurred at Crockett Point, Rockland, which was 12.9 ng/g wet wt., which slightly exceeded the 11 ng/g wet wt. MCDC cancer FTAL for total PCBs, the lower, more conservative of the two FTALs. The next highest total PCBs concentration occurred at East End Beach, Portland, and was below the MCDC cancer FTAL for total PCBs.

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 was initiated in 2013 and continued in 2014 as recommended by the SWAT TAG. This report includes data for one additional blue mussel site tested in 2016. Mare Brook, Brunswick, was tested again in 2016 to follow up on results obtained in 2014, which were taken from a site much further south and seaward from the mouth of Mare Brook. Sampling in 2016 was closer to the head of the estuary and the mouth of Mare Brook. This report utilizes the Maine SWAT blue mussel tissue and softshell clam tissue PFC data generated by AXYS Analytical, which includes 13 compounds as presented in Table 1.3.4.1.1.

1.3.4.1 Blue Mussels

Blue mussels were tested for PFCs in 2016 from Mare Brook, Brunswick. This site has a history of military activity as Mare Brook drains a portion of the former Brunswick Naval Air Station.

PFOSA was detected in two of four spatial replicates of mussel tissue collected at Mare Brook. The remaining PFCs were all below detection limits at all four spatial replicates within Mare Brook.

Table 1.3.4.1.1: LIST OF PERFLUORONATED COMPOUNDS AND THE RANGE OF SAMPLE SPECIFIC DETECTION LIMITS FOR 2016 SWAT BLUE MUSSELS

		Non-Detects Mussels	
		Low	High
PERFLUOROBUTANE SULFONATE	NG/G	5.468	62.7
PERFLUOROBUTANOATE	NG/G	2.734	3.135
PERFLUORODECANOATE	NG/G	2.734	3.135
PERFLUORODODECANOATE	NG/G	2.734	3.135
PERFLUOROHEPTANOATE	NG/G	2.734	3.135
PERFLUOROOCTANOATE	NG/G	2.734	3.135
PERFLUOROHEXANE SULFONATE	NG/G	5.468	6.27
PERFLUOROHEXANOATE	NG/G	2.734	3.135
PERFLUORONONANOATE	NG/G	2.734	3.135
PERFLUOROOCTANE SULFONATE	NG/G	5.468	6.27
PERFLUOROOCTANE SULFONAMIDE*	NG/G	2.734	3.108
PERFLUOROPENTANOATE	NG/G	2.734	3.135
PERFLUOROUNDECANOATE	NG/G	2.734	3.135

* Non-detect values for mussels are from two spatial replicates (two detects occurred out of four spatial replicates).

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. In general, sample-specific detection limits were approximately 3 to 7 parts per billion (ng/g) in mussel tissue on a dry weight basis. PFOSA levels detected in tissue from Mare Brook ranged from 3.052 to 4.05 ng/g dry wt. across the two spatial replicates where it was detected.

PFOSA has eight carbon atoms and breaks down into PFOS. It was an ingredient in the 3M Scotchgard formulation prior to its being discontinued and was used as a grease and water repellent in food packaging and other applications.

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 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

2.1. 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 cyanobacteria (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 have been only two known toxic events (death of cattle in the 1960s, 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 microcystin LR 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 analyses for selected cyanotoxins were collected in Maine in 2014 (Kennebec County), 2015 (Sagadahoc, Knox, Lincoln, and Androscoggin Counties) and 2016 (Waldo and Western Hancock Counties) using a probability based approach and a targeted approach. Approximately 20 lakes were randomly selected each year; lakes were greater than 150 acres were targeted for the probability selection and other lakes were tested because of their history of algal blooms. Of the probability draws, 2014 data showed that 45% had microcystin concentrations >0.3 µg/L and 35% had microcystin concentrations > 1.6 µg/L, and, the 2015 showed that 9% had microcystin concentrations >0.3 µg/L and none had microcystin concentrations > 1.6 µg/L. Samples collected in 2016 have yet to be analyzed due to flooding in the DEP lab in late 2016 through spring of 2017.

In 2014, 100% of the targeted lakes had microcystin concentrations >0.3 µg/L and 75% had microcystin concentrations > 1.6 µg/L; In 2015, 100% of the targeted lakes had microcystin concentrations >0.3 µg/L and none had microcystin concentrations > 1.6 µg/L. Again, samples collected in 2016 have yet to be analyzed. Most lakes that produced algal scums had microcystin levels greatly exceeding all WHO and EPA levels.

2.2. MERCURY IN BLACK CRAPPIE

Within the US Environmental Protection Agency's (EPA) Regional Environmental Monitoring and Assessment Program (REMAP), the Maine Department of Environmental Protection (MeDEP) 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-MeCDC) 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 1997 MeCDC revised the FCA to include all freshwaters in the state. The advisory can be seen at http://www.maine.gov/dhhs/mecdc/environmental-health/eohp/fish/2kfca.htm , which, with 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.*

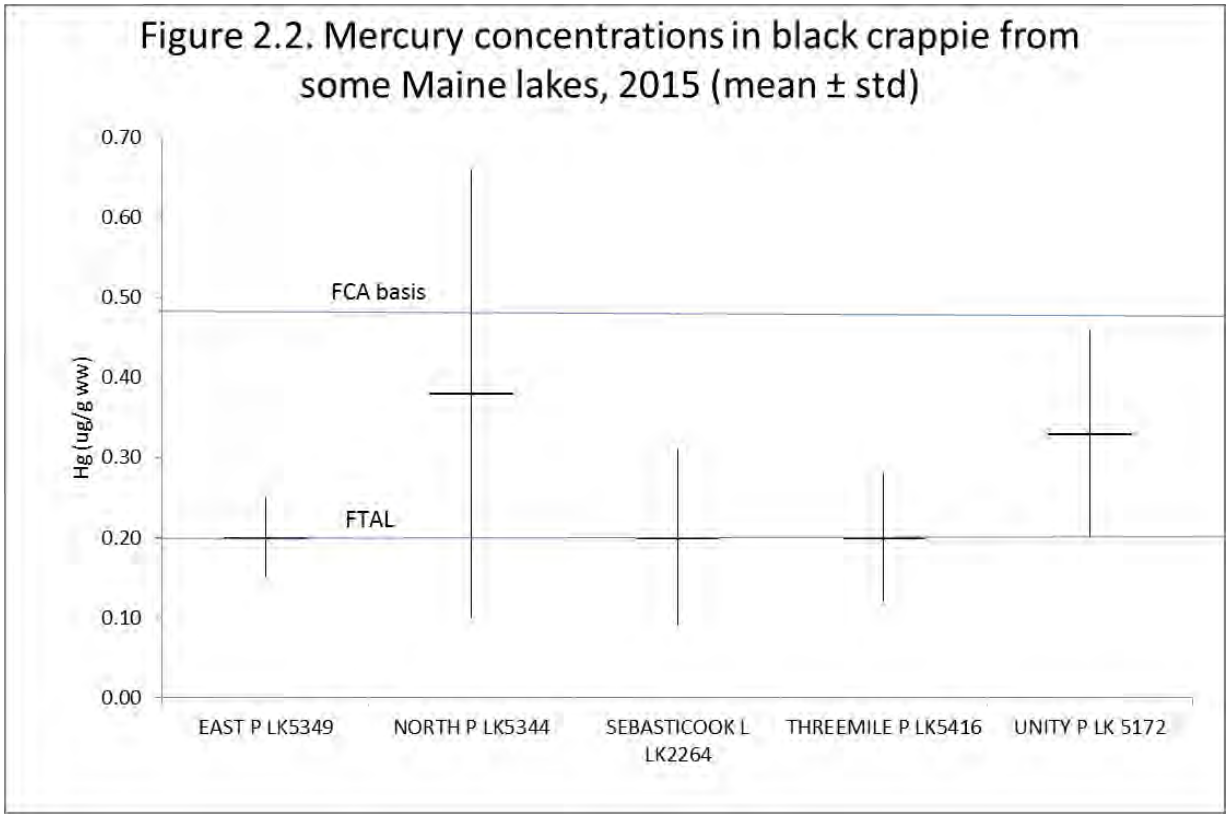
All other adults and children older than 8 *CAN EAT 2 freshwater fish meals per month. For brook trout and landlocked salmon, the limit is 1 meal per week.*

In the REMAP study, the concentration of mercury was lower (0.18 ug/g ww) in black crappie from Ben Annis Pond, the only pond where they were caught, than in other warmwater game fish (0.48 ug/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, and again levels were lower (0.19 ug/g ww and 0.37 ug/g ww, respectively) than other warmwater gamefish from the REMAP study.

Recently the Department of Inland Fisheries and Wildlife (DIFW) reported increasing angling for black crappie in a number of lakes and ponds and inquired about human consumption of the species. MeCDC 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 or ponds. DIFW feels that there are about 20 lakes and ponds with significant fisheries for black crappie.

As a screening level survey, in 2015 DEP was to collect 10 large size black crappie from each of 5 lakes or ponds to analyze for mercury. If the results showed low concentrations relative to other gamefish, then in 2016 DEP would survey the other lakes and ponds with significant black crappie fisheries to gather more data for MeCDC to use in potentially making a specific FCA for this species. If the results showed concentrations similar to those of other gamefish, then the current FCA will suffice and no further data would be needed. All fish were collected, stored on ice until transferred to the DEP lab where they were frozen until shipped to Battelle Marine Sciences Laboratory in Sequim, Washington. At Battelle the fish were skinned, fileted, homogenized and analyzed for total mercury by CVAA – EPA Method 245.6m (modified).

The results showed that the mean concentration for black crappie from all five lakes (0.26 ug/g) was much lower than the mean for all warmwater game fish (0.48 ug/g in whole body) from the REMAP study. Mean concentrations in three of five lakes sampled were at MCDC's Fish Tissue Action Level (FTAL = 0.20 ug/g) for recreational anglers (Figure 2.2). Size was not strongly correlated with mercury levels. While mean size of black crappie from North Pond was the largest, mean size from East Pond were next largest and mean size from Unity Pond the smallest (Appendix 2.1).



Since the 2015 results showed mean mercury concentrations significantly lower than those in warmwater fish used as the basis for the FCA, the decision was to gather additional data to complete the sample size of 20 lakes. Due to budget limitations, in 2016, black crappie were captured from only 7 additional lakes and ponds and analyzed for mercury. The results showed that the mean concentration for all seven lakes (0.31 ug/g) was similar to those from 2015 and well below the concentration that was the basis for the Statewide Fish Consumption Advisory (FCA). Mean concentrations in five of the seven lakes were closer to MCDC's FTAL than the FCA basis (Figure 2.3). The largest fish were from Little Cobbossee Lake and Cobbossee Lake respectively, while the smallest fish were from Hermon Pond (Appendix 2.2). In Sibley Pond two fish had 0.96 ug/g and 0.62 ug/g mercury, while in Pleasant Pond there were three fish with mercury levels greater than 0.5 ug/g. In 2017, 8 more lakes will be sampled to complete the study.

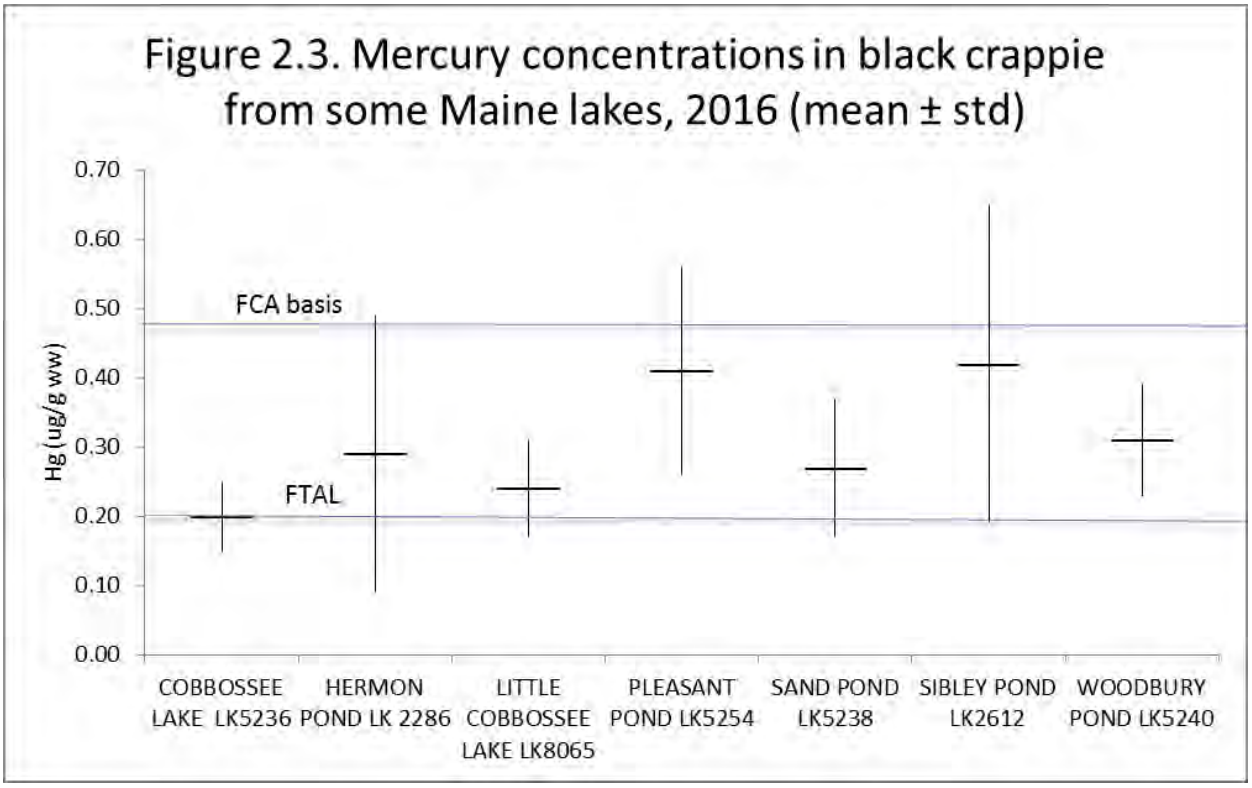


Figure 2.3. Mercury concentrations in black crappie from some Maine lakes, 2016 (mean ± std)
Hg (ug/g ww)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
FCA basis
FTAL
COBBOSSEE LAKE LK5236
HERMON POND LK 2286
LITTLE COBBOSSEE LAKE LK8065
PLEASANT POND LK5254
SAND POND LK5238
SIBLEY POND LK2612
WOODBURY POND LK5240

3.0 RIVERS AND STREAMS MODULE

3.1 AMBIENT BIOLOGICAL MONITORING

3.1.1 Background

As part of the SWAT program, DEP's Biological Monitoring Unit evaluates benthic macroinvertebrate communities of Maine streams and rivers to determine if they are potentially impaired by toxic contamination. For reasons of comparability, a small number of unimpaired reference sites are also evaluated. Benthic macroinvertebrates are animals without backbones that can be seen with the naked eye and live on the stream bottom, such as mayflies, stoneflies, caddisflies, crayfish, snails, and leeches. In 2015, we evaluated the condition of 45 sample locations, primarily in the Southern Maine basin. In 2016, we evaluated the condition of 41 sample locations, primarily in the Penobscot and Downeast Basins.

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 2015 and 2016 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.

2015 field and water chemistry data for each sampling event (where available) are given in Table 3.1.2a and 3.1.3a, respectively. 2016 field and water chemistry data for each sampling event (where available) are given in Table 3.1.2b and 3.1.3b, respectively. 2015 and 2016 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 2015 and 2016, 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: http://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.

2015 Results

3.1.2a 2015 Results Summary

The Biological Monitoring Unit concentrated its sampling in 2015 in the Southern Maine basin. Forty-five stations were sampled under the SWAT Program (Table 3.1.1a).

Forty-five stations have been analyzed for aquatic life attainment with twenty-five of these stations in attainment of their statutory class. No licensing / relicensing issues were found in waterbodies sampled below municipalities or industries. The streams that did not attain their statutory class were small rural or urban systems; summaries on these streams are found below.
In addition, five stations that were not funded by the SWAT Program were included in the report because of their location and possible influence on nearby SWAT stations. These stations are indicated by an asterisk (*).

Bear Brook – Saco Station 1041*
Bear Brook is a small second order stream with a water quality goal of Class B. The brook flows southeast through a residential area and enters Goosefare Brook just above the Old Orchard Road in Saco. Station 1041 is located approximately 10 to 15 meters above the Old Orchard Road crossing. Bear Brook did not attain the minimum Class C aquatic life criteria. Generic Richness (the number of different taxa) was high with 62 different taxa present. However, there were no taxa present from the sensitive orders of mayflies and stoneflies. Dominant taxa were comprised of the tolerant organisms *Dubiraphia* (beetle), *Tanytarsus* (midge), and *Gammarus* (amphipod). Specific Conductance was high and Dissolved Oxygen only measured 6.39 mg/l at retrieval (Table 3.1.2a). Bear Brook did not meet the minimum Class C aquatic life criteria in 2014 (Table 3.1.4a).

Capisic Brook – Portland Station 257
Capisic Brook is a second order stream with a water quality goal of Class C. The sampling station is located 50 meters below the Lucas Street bridge crossing in Capisic Park. The stream flows southeast through a heavily developed area before reaching the Fore River. The stream did not meet the minimum Class C aquatic life criteria. Ninety-five percent of the community was comprised of the tolerant non-insect *Gammarus* (amphipod), which have been found to be

amazingly abundant in small habitats without fish. The most common food of *Gammarus* is detritus, either as fine or coarse particles. The invertebrate community was poorly represented with only 16 different genera present and no sensitive organisms. Total Phosphorus was very high at retrieval with a value of 100 ppb and Total Dissolved Solids were elevated at 560 mg/l (Table 3.1.3a). The water appeared cloudy with silt covering the bottom of the stream. Capisic Brook was sampled in 1996, 1999, 2003, and 2009 and has never attained the Class C aquatic life criteria (Table 3.1.4a).

Goodall Brook – Sanford Station 747

Goodall Brook is a cold first order stream with a water quality goal of Class B. Goodall Brook was sampled upstream of Roberts Street in a highly developed area. The mean temperature of the stream during the time the samplers were in place was 12.8 degrees (Figure 3.1.1a). Cold water temperature during the summer months benefits the aquatic community. However, the habitat was highly degraded and the Specific Conductance during the summer was very high with the reading at deployment at 652 uS/cm (Table 3.1.2a). The aquatic macroinvertebrate community did not meet the minimum Class C aquatic life criteria. Generic Richness, or the number of different organisms found in the community, was low and EPT Generic Richness (the number of mayflies, stoneflies, caddisflies) was only represented by two taxa, the cold-water caddisflies *Rhyacophila* and *Frenesia.* The dominant organism in the community was the tolerant midge *Micropsectra,* which made up 48% of the community. The station was last sampled in 2004 and did not meet the minimum Class C aquatic life criteria (Table 3.1.4a).

Goosefare Brook – Saco Stations 48, 49*, 271, 272, 338*, 1065* (ordered from upstream to downstream)

Goosefare Brook is a first order stream above Saco and becomes a second order system below Main Street in Saco. It flows west to east and empties into Saco Bay. Goosefare Brook has a water quality goal of Class B. It is listed by DEP as an urban impaired stream and has a long history of contamination.

Goosefare Brook – Station 48

Station 48 is a well-established station which has been periodically sampled since 1984 (Table 3.1.4a). The station is located below the Jenkins Road crossing in Saco on the upper part of the watershed and is used as a reference station. The upper part of the watershed is unique as it consists of a large raised bog called the Great Heath. The Great Heath is the southernmost raised bog in North America. The upper part of the watershed can become highly acidic when the sphagnum moss dies off in the fall. In addition, the stream was highly colored with tannic water. The Specific Conductance was not unusually high at 185.9 uS/cm at sampler retrieval (Table 3.1.2a). The benthic macroinvertebrate community met the goal of Class B aquatic life criteria. The macroinvertebrate community consisted of a number of different types of organisms (Generic Richness) and one-third of those were EPT taxa (mayflies, stoneflies, caddisflies) which were the most sensitive group in the community. The mayflies in the family *Leptophlebiidae* were one of the most dominant taxa in the community. This mayfly family is tolerant of acidic conditions which the aquatic organisms are frequently subjected to from the Great Heath. Station 48 did not attain Class B aquatic life criteria in 2005 and 2010 (Table 3.1.4a).

Goosefare Brook – Station 271
Station 271 is located above the Industrial Park Road crossing and below the former Saco Steel site. This site is listed as an uncontrolled hazardous waste site. The DEP continues implementation of clean-up projects at the former recycling facility. Station 271 has been sampled five times since 1995 and attained class once (Table 3.1.4a). The stream has a sandy bottom with pockets of woody debris at this location. It is slow moving and has dark water. The Specific Conductance was very high at this station at 883 uS/cm at retrieval (Table 3.1.2a), which is not surprising given its location below the former Saco Steel site. The macroinvertebrate community did not meet the goal of Class B or the minimum Class C aquatic life criteria. Total Abundance was low and 80% of the community was made up of tolerant non-insect taxa. The amphipod *Gammarus* makes up almost 50% of the community. There were no mayfly or stonefly genera (EP) in the sample. The community was exhibiting a toxic response to the stressors in this area.

Goosefare Brook – Station 49*
Station 49 is located below I-195 in Saco. As with Station 271, the substrate in this area of the stream is largely sand and detritus. There is medium-size woody debris present. Specific Conductance was very high at this station; at sampler retrieval, it was 1066 uS/cm (Table 3.1.2a). The macroinvertebrate community did not meet the goal of Class B or the minimum Class C aquatic life criteria. There was some improvement in the community as compared to Station 271, which is located upstream of this station. Generic Richness, or the number of different organisms found in the community, increased by 19 different organisms and the Total Mean Abundance increased by 80 organisms per sampler. The tolerant amphipod *Gammarus* was the dominant organism making up 34% of the community. The tolerant midge *Tanytarsus* made up an additional 15% of the community. There were seven different caddisfly taxa present, but they were found in very low numbers.

Goosefare Brook – Station 338*
Station 338 is located below General Dynamics and near Sweetser School. Samplers were placed upstream of the Gorge. The habitat is dominated by bedrock and boulder at this location. Storm surges of water appear to have depleted the macroinvertebrate community as the Total Mean Abundance of the samplers was very low at 51. There are very few interstitial spaces or woody debris for organisms to seek refuge. In addition, one of the three samplers deployed was vandalized. Specific Conductance was very high at deployment measuring 902 uS/cm (Table 3.1.2a). The benthic community did not meet the minimum Class C criteria for aquatic life. Total Mean Abundance, Generic Richness, and Generic Diversity were very low at this location with the collector-filterer midge *Rheotanytarsus* making up 27% of the community. Their behavior of clinging to substrate by building tubes and nets probably helped them withstand the intermittent storm surges.

Goosefare Brook – Station 1065*
Station 1065 is a new station located below Ross Road in Saco. The habitat is 40% clay and 35% sand. The brook in this area has an extensive riparian forest. The Specific Conductance was high at retrieval of the samplers measuring 861 uS/cm (Table 3.1.2a). This indicates that urban runoff is still a problem here. The aquatic macroinvertebrate community met the minimum Class C aquatic life criteria but did not meet the Class B goal. The community appeared to be recovering in the lower part of the watershed. The Total Mean Abundance increased to 723 organisms per

sampler and Generic Richness increased from 27 taxa at Station 338 to 43 taxa at this station. However, the number of sensitive organisms was still very low. The dominant organism was the midge *Stichtochironomus,* which is found in soft sediments and is tolerant of organic pollution.

Goosefare Brook – Station 272

Station 272 is located below the Old Orchard Road in Saco and is the lowest station in the watershed. Specific Conductance at this station dropped to 493 uS/cm at retrieval (Table 3.1.2a). The aquatic community attained the Class C aquatic life criteria but did not meet the Class B goal. There was measurable improvement at this station compared to stations upstream. The macroinvertebrate community increased to over 1000 organisms per sampler and filter feeders were more prevalent. Mayflies from the families *Baetidae* and *Leptophlebiidae* were present in low numbers and the community is more balanced than at the above stations.

Halfmoon Stream – Thorndike Station 697

Halfmoon Stream is a third order stream which flows west to the town of Unity entering Sandy Stream and eventually Unity Pond. Above the Rt. 220 bridge crossing in Thorndike, where this station is located, its water quality goal is Class A. The stream flows through a concentrated agricultural area consisting of large dairy farms. The station was sampled in 2003 and 2007 and met the Class A aquatic life criteria. In 2012, the macroinvertebrate community showed signs of enrichment with the Total Mean Abundance of the sample totaling over 1300 individuals. Although the Generic Richness was high, the total number of sensitive organisms was low compared to the total mean abundance and the most dominant taxa in the sample consisted of tolerant collector-filterers and scrapers (see SWAT 2012). The stream did not meet the Class A aquatic life criteria. The stream was sampled again during the 2013 field season. The Total Mean Abundance of the sample totaled over 1700 individuals. The Generic Richness dropped to 29 taxa as compared to 70 taxa in 2012. Possible explanations for this significant drop in Generic Richness were the combination of a 3-foot change in water level due to a storm event in 2013 and the lack of algae attached to the rock bags during sample pick up. In 2012, dense mats of algae were present on the samplers. Members of the family Chironomidae and some mayfly taxa use the algae as a food source and as attachment sites. In addition, the Nitrate + Nitrite as N level was high at 0.62 mg/l (Table 3.1.3a) indicating possible runoff from the agricultural fields. The stream did not meet the Class A aquatic life criteria. In 2014, Halfmoon Stream was indeterminate for Class A (0.55) aquatic life criteria but the final determination was not raised to Class A based on abundance and dominant taxa found. The Total Mean Abundance of the 2014 sample was very high (3886 organisms/sampler) indicating very high enrichment. Although the Generic Richness increased from 29 taxa in 2013 to 90 taxa in 2014 the makeup of the dominant taxa in the community consisted of organisms that are moderately to very tolerant to increased organic loading. *Polypedilum,* a tolerant midge, made up 26% of the sample or over 1000 organisms per sampler. In 2015, Halfmoon Stream was again indeterminate for Class A (0.40) but the final determination was not raised to Class A based on the abundance and dominant taxa found. The Total Mean Abundance of the 2015 sample dropped from 3886 organisms/sampler in 2014 to 2600 organisms/sampler, but the abundance of organisms was still much greater than one would expect to find in a Class A community. The drop in abundance was mainly due to a significant drop in the tolerant midge *Polypedilum,* which was the dominant organism in 2014. The dominant taxa switched to the filtering caddisflies *Hydropsyche* and *Cheumatopsyche* which are found in good numbers in a Class B community. The Generic Richness remained high (67 taxa). The Nitrate +

Nitrite as N level remained high at 0.75 mg/l at retrieval (Table 3.1.3a), indicating runoff from the adjacent agricultural fields. This high quality resource has shown a trend of increasing enrichment since 2003. Halfmoon Stream is now a long-term monitoring station for the Biological Monitoring Unit. Hopefully this will allow us to understand community shifts due to agricultural inputs over time.

Kennebunk River – Kennebunk Station 270

The Kennebunk River is a third order river with a water quality goal of Class B. The river flows southeast from Lyman and enters the bay in Kennebunkport. Station 270 is located 15 meters above the Route 1 bridge in Kennebunk. The river showed continued signs of enrichment with a Total Mean Abundance of almost 2000 organisms per sampler. The dominant taxa in the community were the filter feeders *Hydropsyche* and *Rheotanytarsus*. The proportion of sensitive organisms in the sample was lower than expected for a Class B waterbody. The Class B aquatic life criteria were not met, but the minimum of Class C aquatic life criteria were met. The river was running brown at sampler deployment indicating runoff in the system. Total Phosphorus was measured at 30 ug/L in August (Table 3.1.3a). Past attainment history indicates the river met its goal in 2010 but not in 2005 (Table 3.1.4a).

Long Creek – South Portland Station 752

Station 752 is located 30 meters upstream of Foden Road. Long Creek is a second order system at this location with a water quality goal of Class C, and the habitat is primarily sand and clay. There was also a heavy layer of silt present. The Specific Conductance was very high at retrieval, measuring 1287 uS/cm (Table 3.1.2a). The macroinvertebrate community did not meet the minimum Class C aquatic life criteria. Total Mean Abundance was good and Generic Richness (number of different taxa) was adequate, but 65% of the community was made up of the tolerant amphipod *Gammarus*. The number and kinds of sensitive taxa were very low. Urban NPS, altered hydrology, and altered habitat are the primary stressors in the system.

Long Creek – South Portland Station 414

Station 414 is located in the lower part of the watershed on the right branch facing upstream. The stream at this location has a water quality goal of Class C. The Specific Conductance at retrieval was very high, measuring 709 uS/cm (Table 3.1.2a). The aquatic community did not meet the goal of Class C aquatic life criteria. The tolerant amphipod *Gammarus* and the tolerant midge *Stictochironomus* made up 65% of the community. There were no sensitive taxa present in the community. Stressors include urban NPS pollution, altered hydrology, and altered habitat.

Long Creek – Westbrook Station 411*

Station 411 is located in Westbrook in the upper part of the watershed and has a water quality goal of Class B. The Specific Conductance at sampler placement was very high at 1131 uS/cm and Dissolved Oxygen was under 5 mg/l (Table 3.1.2a). The macroinvertebrate community did not meet the goal of Class B aquatic life criteria but did meet the minimum Class C criteria for aquatic life. Dominant organisms in the sample included the tolerant beetle *Dubiraphia*, which has a plastron to aid in taking oxygen from the water surface, and the mayfly *Caenis,* which has a protective gill plate. Class C aquatic life was met as the community included organisms that represent all the functional feeding groups in the stream. Urban runoff is a primary stressor to the system.

South Branch Long Creek – South Portland Station 408

Station 408 is located near Hoyts Theater and has a water quality goal of Class C. The Specific Conductance at this station was very high at sampler retrieval, measuring 1474 uS/cm (Table 3.1.2a). The habitat is 90% sand and one sampler was fully buried due to urban runoff. The aquatic community did not meet the goal of Class C aquatic life criteria. Generic Richness was low and the dominant organism making up 65% of the community was the midge *Polypedilum,* which is a climber and clinger. This behavior aids them in remaining in place during storm surges and sand movement. There were no sensitive taxa present. Urban runoff is the primary stressor to the system. The station attained Class C aquatic life criteria in 1999 (Table 3.1.4a).

Lord's Brook – Lyman Stations 875, 863

Lord's Brook is a small first order stream with a water quality goal of Class B. Station 875 is located off of Davis Road and below a composting facility. In 2008, compost was flowing directly into the stream and consequently the stream did not meet the minimum Class C aquatic life criteria. The composting facility was served a notice of violation in 2008 and there was a dramatic improvement in the stream in 2015. The stream met the Class A aquatic life criteria at this station with Generic Richness (number of different taxa) increasing from 24 to 43. In addition, sensitive EPT taxa (mayflies, stoneflies, caddisflies) increased from 2 to 15. Dominant taxa included the mayfly *Leptophlebiidae* (24%) and the cold water caddisfly *Frenesia* (15%). Total Phosphorus and Orthophosphate at retrieval were still high at 60 and 30 ug/L respectively (Table 3.1.3a). Station 863 is downstream of Station 875 near the end of Lord's Lane. There is a dam and pond upstream of the sampling station. The macroinvertebrate community did not attain the goal of Class B at this station. Although there was an improvement in Generic Richness and EPT taxa, the dominant taxa were the snails *Musculium* (48%), *Amnicola*, and *Physa*. Total Phosphorus and Orthophosphate were high at 35 and 11 ug/L respectively (Table 3.1.3a), but were lower than the upstream station. This is probably due to nutrients being taken up in the upstream pond. Lord's Brook will be monitored periodically and hopefully Station 863 will improve.

Mare Brook – Brunswick Station 1064

Mare Brook in Brunswick is a cold (15 degrees Celsius) first order stream at Station 1064 and has a water quality goal of Class B. Station 1064 is a new station located below Barrows Street and above the former Brunswick Naval Air Station (BNAS). The canopy cover is dense with a good riparian area surrounding the stream and in-stream woody debris is numerous. Velocity at retrieval was not detected but one sampler was buried in sand, indicating a surge of water during the four-week incubation period. The aquatic community did not attain the minimum Class C aquatic life criteria. Although Total Mean Abundance was high the number of sensitive organisms was very low. Isopods, which are almost always found in shallow waters and are most common in seeps, springs, and small spring fed systems, dominate the community. If the substrate of a stream is complex with many hiding places, isopods can be very abundant. Isopods are somewhat tolerant, especially of organic wastes. They have been used as indicators of the zone where streams are beginning to recover from pollution by sewage. There were also two tolerant Chironomidae (midges) in the top five dominant taxa. It is possible there is an unknown discharge going into the system in the area and/or surges of water that make the substrate unstable at times and therefore doesn't allow certain taxa to establish themselves. Specific Conductance was not exceedingly high

at 272 us/cm at both sampler deployment and retrieval (Table 3.1.2a) and NO2-NO3-N was moderate at 45 mg/l at retrieval (Table 3.1.3a).

Mare Brook – Brunswick Station 143
Station 143 is an established station located above the former BNAS on Jonathan Street and has a water quality goal of Class B. The stream is second order at this location and the temperature is about four degrees (Celsius) higher than at Station 1064 (Table 3.1.2a). The substrate was similar to that at Station 1064, but water levels and Specific Conductance (297.8 uS/cm at deployment) were much higher (Table 3.1.2a). The aquatic macroinvertebrate community met the Class C criteria at this station but did not meet the water quality goal of Class B. The Total Mean Abundance was down but Generic Richness was similar to Station 1064. Isopods made up over 50% of the community, but EPT taxa (mayflies, stoneflies, and caddisflies) were higher by six taxa. The abundance of mayflies was also higher. This type of habitat favors Isopods, but the numbers decreased considerably from the upstream station, probably because the substrate was not as complex and the water depth increased at this station. This station has been sampled since 1991 and attained Class B criteria in 2002. It did not attain Class B criteria in 2003 (Table 3.1.4a).

Mare Brook – Unnamed Tributary – Brunswick Station 330
Station 330 is an established station located on an unnamed tributary below Picnic Pond on the former BNAS. The stream is second order at this location and has a water quality goal of Class B. There is an increase in gravel in the substrate at this location and the riparian area consists mainly of alders. The aquatic community did not meet the minimum Class C criteria for aquatic life. Although Generic Richness increased by over 20 taxa as compared to Station 1064 and 143, the abundance of mayflies dropped to a mean of 1.33 per sampler. Dominant taxa consisted of the tolerant midge *Polypedilum* and Isopods, which made up over 43% of the community. Compared to the other stations, there were more filter feeders present and there was an overall increase in taxa. This is probably due to the consistent flows below the pond. The water had a slightly milky color at deployment. This station was sampled every year from 1997 – 2003 and never attained the minimum Class C aquatic life criteria (Table 3.1.4a).

Mare Brook – Brunswick Station 457
Station 457 is located on the former BNAS and is sampled above the confluence with the unnamed tributary which discharges from Picnic Pond. Mare Brook is a second order stream at this location and has a water quality goal of Class B. The substrate is 100% sand at this station and the canopy is open. The aquatic community met the Class C aquatic life criteria but did not meet the goal of Class B. Isopods dominated the community (38%) while the number of EPT taxa was only five. Total Mean Abundance and Generic Richness were adequate but the number of sensitive organisms was low. At the time of retrieval one sampler was fully buried and there was a lot of silt deposited. Habitat is an issue at this location. In addition, the Total Phosphorus value in August was 100 ug/l (Table 3.1.3a). This station was sampled every year from 1997-2003 and has never attained its assigned Class (Table 3.1.4a).

Red Brook – Scarborough Station 219
Red Brook flows west to east from Scarborough to South Portland and has a water quality goal of Class C. It is a relatively cool first order stream measuring 18.5 degrees Celsius in August. Station

219 is located below Running Hill Road in Scarborough. The former RWS Landfill is located directly above the station. The specific conductance was not exceedingly high at this location (Table 3.1.2a) but the stream bottom was covered with silt at retrieval. The riparian area is good in this area and woody debris provides some stable habitat. Red Brook did not meet the Class C aquatic life criteria. The tolerant midge *Tanytarsus* and the cool water midge *Stempellinella* make up 64% of the macroinvertebrate community. Although there were 3 taxa of mayflies present, they were found in very low numbers. Total Mean Abundance was relatively low at 155 organisms per sampler but Generic Richness (number of different taxa) was adequate at 41. Most of the taxa were found at very low numbers, therefore the structure and function of the community requirement for a Class C waterbody was not met. This station was sampled in 2010 but there were not enough organisms present in the sample to make a determination (Table 3.1.4a).

Red Brook – South Portland Station 412

Station 412 is located 100 meters below the I-295 highway culvert. The brook in this area has a water quality goal of Class C. The Specific Conductance at this location was over 800 uS/cm at deployment (Table 3.1.2a) and the Total Dissolved Solids were very high at 930 mg/l at retrieval (Table 3.1.3a). The aquatic macroinvertebrate community did not meet the Class C aquatic life criteria. The amphipod *Gammarus* and the tolerant midge *Tanytarsus* make up 82% of the community. There were no mayflies and stoneflies present in the sample. The macroinvertebrate response is indicative of a toxic situation, possibly as a result of urban non-point sources (NPS).

Royal River – Gray Station 799

The Royal River in Gray is a fourth order system that has a water quality goal of Class B. The river flows north to south from Auburn to Yarmouth where it enters Casco Bay. Agriculture is the primary land use in the Gray area. In addition, several small tributary streams flow into Collyer Brook which flows into the Royal River just above the sampling station. Agricultural runoff and two fish hatcheries discharge into the tributary streams. The macroinvertebrate community of the Royal River met the Class C aquatic life criteria but did not meet Class B criteria. The macroinvertebrate community was highly enriched with Total Abundance of each sampler averaging 3000 organisms per sampler. The diversity of the community was low although there are 44 different genera in the sample. Dominant taxa were comprised of over 79% collector filterers made up of the caddisflies *Hydropsyche* and *Cheumatopsyche* and the midge *Rheotanytarsus*. The Nitrate + Nitrite as N level was high at 61 mg/l (Table 3.1.3a). This is the first time the station has been sampled for macroinvertebrates. It is recommended that this station be sampled again in the next few years to confirm the results.

Thacher Brook – Biddeford Station 451

Thacher Brook is a third order system that has a water quality goal of Class B. Station 451 is located above South Street in a small residential area. The brook flows northeast into the Saco River. Station 451 was sampled previously in 2000, 2005, and 2010 (Table 3.1.4a). Thacher Brook met at least the Class B aquatic life criteria for sampling events in 2000, 2005, and 2010. In 2015, Thacher Brook did not meet the minimum Class C aquatic life criteria. EPT taxa (mayflies, stoneflies, caddisflies) dropped steadily in each sampling event. In 2005, EPT taxa totaled 19 genera but dropped to 9 genera by 2015. In 2010, 63% of the community was made up

of the filter feeders *Hydropsyche* and *Chimarra* while in 2015 the community shifted to the more tolerant taxa *Dubiraphia* (beetle), *Caecidotea* (Isopods), and *Gammarus* (amphipod). Specific Conductance at retrieval was very high at 736 uS/cm (Table 3.1.2a). It is recommended that the station be sampled again in the next few years to confirm the dramatic change in the aquatic community.

Trout Brook – South Portland Station 675

Trout Brook is a cold second order stream with a water quality goal of Class C. The sampling station is located approximately 125 meters upstream of Boothby Avenue. The stream did not meet the minimum Class C aquatic life criteria. The dominant organisms in the aquatic community were the tolerant non-insect *Gammarus* (amphipod) and worms in the order *Tubificida*. There were no taxa present from the sensitive groups of mayflies and stoneflies. Caddisflies were represented by three taxa, the coldwater caddisflies *Frenesia*, *Hydatophylax*, and *Lepidostoma*. Specific Conductance during the sampling period was very high, with a reading at sampler deployment of 777 uS/cm (Table 3.1.2a). This station was last sampled in 2010 and did not meet the minimum Class C aquatic life criteria (Table 3.1.4a).

Table 3.1.1a 2015 SWAT Benthic Macroinvertebrate Biomonitoring Results

Waterbody	Town	Station	Log	Potential sources of pollution[1]	Statutory Class/ Final Determination	Attains Class?	Probable Cause
Back Brook	Limington	107	2368	Reference	B/A	Y	
Bear Brook	Saco	1041*	2389	NPS	B/NA	N	Urban Runoff/Habitat
Branch Brook	Sanford	106	2374	NPS	A/A	Y	

Capisic Brook	Portland	257	2373	Urban NPS	C/NA	N	Urban Runoff
Cole Brook	Gray	317	2353	Agricultural NPS	B/A	Y	
East Branch Wesserunsett Stream	Athens	486	2344	Long Term	B/A	Y	
Goodall Brook	Sanford	747	2375	NPS	B/NA	N	Urban Runoff/Habitat
Goodall Brook	Sanford	748	2376	NPS	B/B	Y	
Goosefare Brook	Saco	48	2385	Reference	B/B	Y	
Goosefare Brook	Saco	49*	2371	Urban NPS	B/NA	N	Urban Runoff
Goosefare Brook	Saco	271	2384	Urban NPS/In Place Contamination	B/NA	N	Urban Runoff/In-Place Contamination
Goosefare Brook	Saco	272	2387	Urban NPS	B/C	N	Urban Runoff/Habitat
Goosefare Brook	Saco	338*	2386	Urban NPS	B/NA	N	Urban Runoff/In-Place Contamination
Goosefare Brook	Saco	1065*	2388	Urban NPS	B/C	N	Urban Runoff/Habitat
Great Works River	North Berwick	439	2363	NPS	B/A	Y	
Halfmoon Stream	Thorndike	697	2345	Agricultural NPS/Long Term	A/B	N	Agricultural Runoff
Kennebunk River	Kennebunk	270	2380	Urban NPS	B/C	N	Urban Runoff
Libby Brook	Gray	221	2359	Agricultural Runoff	B/B	Y	
Little Ossipee River	Limington	446	2365	NPS/Impound-ment	B/B	Y	Impoundment Effect
Little Ossipee River	Limerick	447	2367	Reference	B/A	Y	
Little River	Lebanon	440	2364	NPS	B/A	Y	
Long Creek	South Portland	414	2399	Urban NPS	C/NA	N	Urban Runoff/Habitat
Long Creek	South Portland	752	2398	Urban NPS	C/NA	N	Urban Runoff/Habitat
Long Creek	Westbrook	411*	2397	Urban NPS	B/C	N	Urban Runoff/Habitat

[1] NPS, non-point source pollution
[*] Non-SWAT Station

Table 3.1.1a 2015 SWAT Benthic Macroinvertebrate Biomonitoring Results

Waterbody	Town	Station	Log	Potential sources of pollution[1]	Statutory Class/ Final Determination	Attains Class?	Probable Cause
Lord's Brook	Lyman	863	2393	Compost Facility	B/C	N	Nutrients
Lord's Brook	Lyman	875	2392	Compost Facility	B/A	Y	

Mare Brook	Brunswick	143	2348	Former BNAS[2]/ In Place Contamination	B/C	N	Urban Runoff/Habitat
Mare Brook	Brunswick	457	2349	Former BNAS[2]/ In Place Contamination	B/C	N	In Place Contamination /Habitat
Mare Brook	Brunswick	1064	2347	NPS	B/NA	N	Runoff/Habitat
Mare Brook – Unnamed Tributary	Brunswick	330	2346	Former BNAS[2]/ In Place Contamination	B/NA	N	In Place Contamination /Habitat
Merriland River	Wells	436	2382	Reference	A/A	Y	
Merriland River	Wells	437	2383	NPS/Turnpike	A/B	N	Class A (.11)
Mousam River	Sanford	259	2377	Urban NPS/ Landfill	C/C	Y	
Mousam River	Sanford	390	2379	Municipal	C/A	Y	
Mousam River	Sanford	391	2378	Municipal	C/A	Y	
North Branch Little River	Standish	70	2355	NPS/In Place Contamination	B/A	Y	
Piscataqua River	Cumberland	758	2361	Urban NPS	B/B	Y	
Piscataqua River	Falmouth	759	2360	Urban NPS	B/B	Y	
Presumpscot River	Westbrook	72	2372	Industrial/Municipal	C/B	Y	
Red Brook	Scarborough	219	2395	NPS/Landfill	C/NA	N	Runoff/ Landfill
Red Brook	South Portland	412	2396	Urban NPS	C/NA	N	Urban Runoff/Habitat
Royal River	Gray	799	2358	NPS	B/C	N	Agricultural Runoff
Salmon Falls River	Berwick	52	2362	Municipal	C/C	Y	
Sheepscot River	Whitefield	74	2341	Long Term	AA/A	Y	
South Branch Long Creek	South Portland	408	2400	Urban NPS	C/NA	N	Urban Runoff/Habitat
Tannery Brook	Gorham	562	2357	NPS	B/A	Y	
Thacher Brook	Biddeford	451	2391	Urban NPS	B/NA	N	Urban Runoff
Trout Brook	South Portland	675	2394	Urban NPS	C/NA	N	Urban Runoff
West Branch Sheepscot River	China	268	2342	Long Term	AA/A	Y	
West Brook	Biddeford	797	2390	Urban NPS	B/B	Y	

[1] NPS, non-point source pollution.
[2] BNAS, Brunswick Naval Air Station. *Non-SWAT Station

Table 3.1.2a 2015 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
Back Brook	107	2368	7/16/2015	15.2	9.84	68.1	6.98	8/13/2015	16.5	9.38	65.8	6.73
Bear Brook	1041*	2389	7/23/2015	18.9	**6.43**	**559**	7.28	8/20/2015	20.6	**6.39**	**491**	7.2
Branch Brook	106	2374	7/21/2015	17.1	8.64	82.2	6.98	8/18/2015	17.7	8.86	45.4	7.17
Capisic Brook	257	2373	7/20/2015	20.4	7.01	**246.6**	7.13	8/17/2015	21.7	**6.61**	**368.5**	7.27
Cole Brook	317	2353	7/9/2015	16.7	9.36	**285.6**	7.33	8/6/2015	17.9	9.35	**324.8**	7.45
East Branch Wesserunsett Stream	486	2344	7/7/2015	20	8.95	61.3	7.84	8/4/2015	20.4	9.32	66.9	8.13
Goodall Brook	747	2375	7/21/2015	13.2	8.75	**652**	6.32	8/18/2015	13.5	9.06	**419.7**	6.32
Goodall Brook	748	2376	7/21/2015	17.7	8.49	**443**	6.88	8/18/2015	18.5	8.85	**510**	6.88
Goosefare Brook	271	2384	7/23/2015	16.2	7.99	**691**	6.89	8/20/2015	19	7.44	**883**	7.05
Goosefare Brook	272	2387	7/27/2015	17.9	9.2	--	--	8/20/2015	20.1	7.67	**493**	7.06
Goosefare Brook	48	2385	7/23/2015	16.1	8.5	147.7	6.98	8/20/2015	18.8	7.45	185.9	7.07
Goosefare Brook	49*	2371	7/20/2015	18.6	7.48	**660**	--	8/19/2015	19.6	7.05	**1066**	--
Goosefare Brook	338*	2386	7/23/2015	17.1	8.22	**902**	7.31	8/20/2015	20.3	7.35	**435**	7.36
Goosefare Brook	1065*	2388	7/23/2015	19.6	7.03	**430.3**	7.15	8/20/2015	21.4	**5.31**	**861**	6.97
Great Works River	439	2363	7/15/2015	23	8.18	151	7.25	8/12/2015	21.3	8.74	145.8	7.32
Halfmoon Stream	697	2345	7/7/2015	24.9	10.51	128.4	8.9	8/4/2015	25.4	9.54	154.8	7.99
Kennebunk River	270	2380	7/22/2015	23.2	9.38	121.5	7.57	8/19/2015	25.5	9.28	130	7.58
Libby Brook	221	2359	7/14/2015	15	9.95	**245**	7.57	8/11/2015	14.3	9.81	**236.5**	7.57
Little Ossipee River	446	2365	7/16/2015	21	7.22	79.2	6.57	8/13/2015	23.2	**6.8**	75	6.7
Little Ossipee River	447	2367	7/16/2015	17.8	9.67	65.7	7.52	8/13/2015	21.2	9.28	65.7	7.61
Little River	440	2364	7/15/2015	21.9	8.9	74.2	7.3	8/12/2015	21.5	8.82	104.5	7.34

Table 3.1.2a 2015 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
Long Creek	411*	2397	7/30/2015	21.2	**4.94**	**1131**	7.52	8/27/2015	19.8	**6.12**	**760**	7.55
Long Creek	414	2399	7/30/2015	16.9	9.08	**592**	7.57	8/27/2015	16.6	9.2	**709**	7.78
Long Creek	752	2398	7/30/2015	21.4	**6.88**	**1287**	7.66	8/27/2015	20.1	6.97	**883**	7.64
Lord's Brook	863	2393	7/28/2015	21.3	7.94	99.3	6.85	8/25/2015	21	7.8	108.5	6.83
Lord's Brook	875	2392	7/28/2015	17.8	8.16	138.5	6.83	8/25/2015	19.2	7.77	136.9	6.89
Mare Brook	1064	2347	7/8/2015	15.1	8.53	**272**	6.79	8/5/2015	15.9	8.51	**271.9**	7.27
Mare Brook	143	2348	7/8/2015	19.2	8.45	**297.8**	6.99	8/5/2015	19.4	8.08	**279.2**	7.1
Mare Brook	457	2349	7/8/2015	19.4	8.76	**226**	7	8/5/2015	20.7	8.72	**195.6**	7.17
Mare Brook – Unnamed Tributary	330	2346	7/8/2015	19.8	7.74	**247**	6.9	8/5/2015	21.4	**6.8**	**221.7**	6.92
Merriland River	436	2382	7/22/2015	20.5	7.58	86.9	7.03	8/19/2015	22.8	6.96	100.6	7.19
Merriland River	437	2383	7/22/2015	20.8	8.1	108.9	7.12	8/19/2015	23	8.04	113.6	7.34
Mousam River	259	2377	7/21/2015	27	8.33	146.4	7.22	8/18/2015	27	8.25	131.6	7.05
Mousam River	390	2379	7/21/2015	25.6	9.18	157.4	7.55	8/18/2015	27.3	9.07	137	7.7
Mousam River	391	2378	7/21/2015	25.4	8.72	**201.1**	7.48	8/18/2015	26.7	8.2	**191.5**	7.26
North Branch Little River	70	2355	7/13/2015	20.6	**5.92**	107.8	6.79	8/10/2015	18.7	7.36	80.4	6.92
Piscataqua River	758	2361	7/14/2015	23.2	8.19	**203.2**	7.59	8/11/2015	20.7	8.54	**234.5**	7.4
Piscataqua River	759	2360	7/14/2015	21.7	9.34	**326.5**	7.68	8/11/2015	17.9	8.81	**367**	7.27
Presumpscot River	72	2372	7/20/2015	24.4	8.77	83	7.31	8/17/2015	24.7	8.8	98.6	7.46
Red Brook	219	2395	7/29/2015	19.1	8.72	163.6	7.39	8/26/2015	18.5	8.65	170.1	7.27
Red Brook	412	2396	7/29/2015	19.5	8.33	**828**	7.08	8/26/2015	19.6	8.36	**691**	7.19
Royal River	799	2358	7/14/2015	20.5	8	**192.2**	7.62	8/11/2015	18.3	8.61	**216.7**	7.51
Salmon Falls River	52	2362	7/15/2015	25.7	8.09	170.6	7.53	8/12/2015	24	8.56	95.9	7.39
Sheepscot River	74	2341	7/6/2015	21.7	8.18	58.1	7.29	8/3/2015	26	8.99	80.8	7.97
South Branch Long Creek	408	2400	7/30/2015	23.8	7.84	**1146**	7.62	8/27/2015	21	8.1	**1474**	7.7

Table 3.1.2a 2015 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
Tannery Brook	562	2357	7/13/2015	17.1	9.09	**238**	7.66	8/10/2015	17.1	9.11	170.2	7.76
Thacher Brook	451	2391	7/27/2015	20.2	8.51	--	--	8/24/2015	20.9	8.55	**736**	7.52
Trout Brook	675	2394	7/29/2015	14.3	**6.23**	**777**	6.79	8/26/2015	14.9	**6.25**	**398.8**	6.88
West Branch Sheepscot River	268	2342	7/6/2015	22.4	8.62	70.1	7.67	8/3/2015	19.6	8.69	94.9	7.77
West Brook	797	2390	7/27/2015	19.6	8.11	**208.9**	7.12	8/24/2015	21.2	7.56	178.5	7.06

Table 3.1.3a 2015 SWAT Water Chemistry Data

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

Waterbody	Station	Log	Sampling Date	DOC	TKN	NO2-NO3-N	Total P	SRP	TSS	TDS
				MG/L	MG/L	MG/L	UG/L	UG/L	MG/L	MG/L
Capisic Brook	257	2373	8/17/2015	2.6	**1**	0.39	**100**	**10**	32	**560**
East Branch Wesserunsett Stream	486	2344	8/4/2015	2.6	0.3	0.03	8	1	< 2	51
Goosefare Brook	271	2384	8/20/2015	2.3	0.5	0.35	**34**	3	27	**510**
Goosefare Brook	48	2385	8/20/2015	1.4	0.3	0.48	19	4	2.6	120
Goosefare Brook	272	2387	8/20/2015	2.2	0.3	0.3	23	2	3	280
Great Works River	439	2363	8/12/2015	1.8	0.3	0.04	11	2	< 2	92
Halfmoon Stream	697	2345	8/4/2015	1.3	0.3	**0.75**	12	1	< 2	92
Kennebunk River	270	2380	8/19/2015	3	0.4	0.01	30	3	3.4	98
Libby Brook	221	2359	8/11/2015	< 1	0.2	**0.84**	22	**10**	< 2	160
Lord's Brook	875	2392	8/25/2015	10	**0.7**	0.24	**60**	**30**	< 2	220
Lord's Brook	863	2393	8/25/2015	6.1	0.4	0.2	**35**	**11**	< 2	96
Mare Brook	1064	2347	8/5/2015	1.1	0.3	~0.45	21	5	< 2	180
Mare Brook	457	2349	8/5/2015	1.2	0.6	**0.61**	**100**	3	44	130
Merriland River	437	2383	8/19/2015	3.2	0.4	0.07	23	4	< 2	90
Presumpscot River	72	2372	8/17/2015	1.4	0.3	0.04	**40**	**25**	2.6	79
Red Brook	412	2396	8/26/2015	5.2	0.4	0.14	17	2	3.6	**930**
Royal River	799	2358	8/11/2015	1.6	0.2	**0.61**	21	5	2.8	140
Salmon Falls River	52	2362	8/12/2015	2.1	0.4	0.2	17	1	< 2	93
Sheepscot River	74	2341	8/3/2015	2.6	0.4	< 0.01	10	1	< 2	57
West Branch Sheepscot River	268	2342	8/3/2015	2.9	0.6	0.06	9	1	< 2	68

DOC = Dissolved Organic Carbon, NH_3-N = Ammonia-Nitrogen, TKN = Total Kjeldahl-Nitrogen, NO_2-NO_3-N = Nitrite-Nitrate-Nitrogen, SRP = Soluble Reactive Phosphorus (ortho-phosphate), Total P = Total Phosphorus, TSS = Total Suspended Solids, TDS = Total Dissolved Solids, "<" = constituent not detected at the reporting limit.

Figure 3.1.1a 2015 In-Stream Continuous Temperature Data

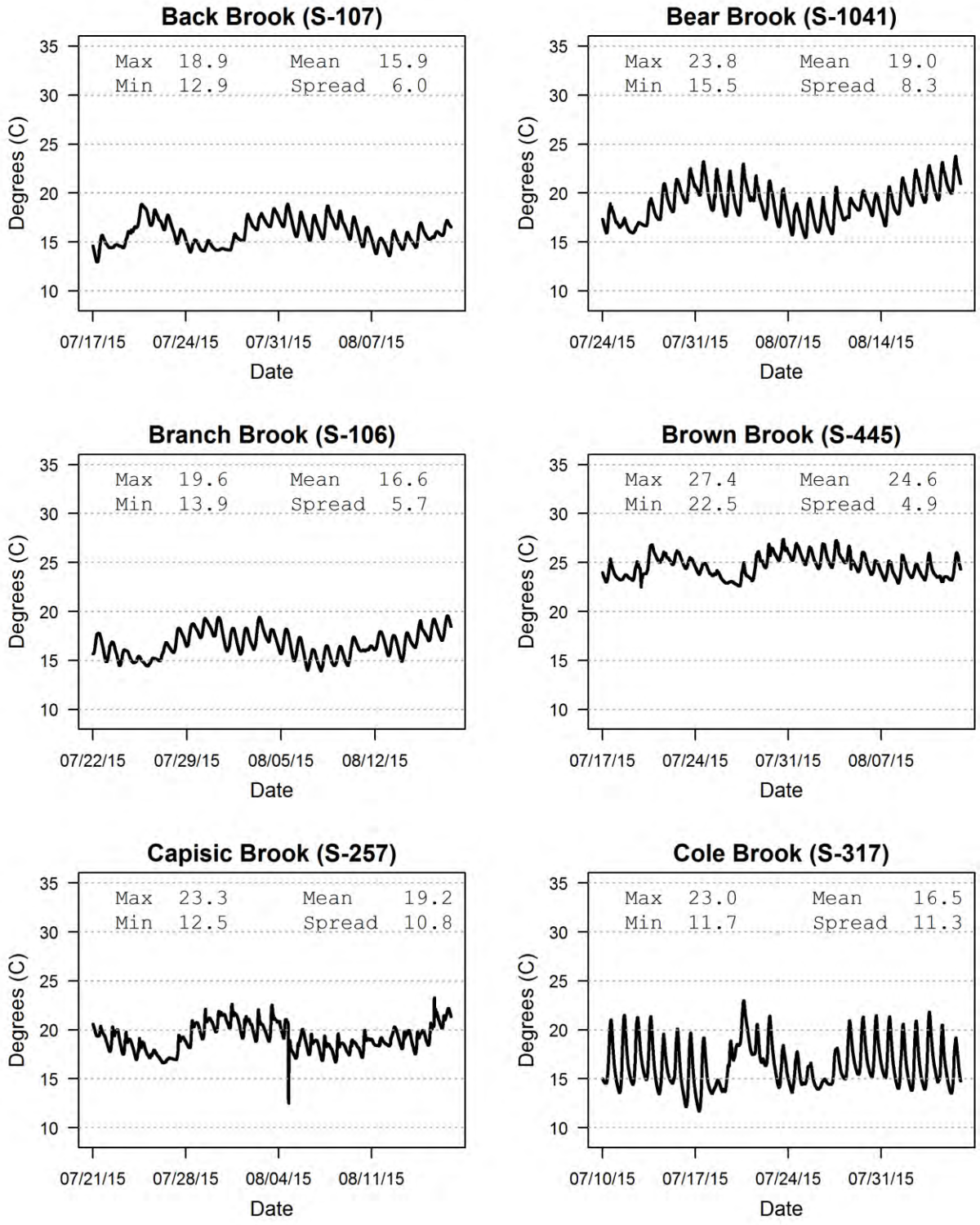


Figure 3.1.1a 2015 In-Stream Continuous Temperature Data (continued)

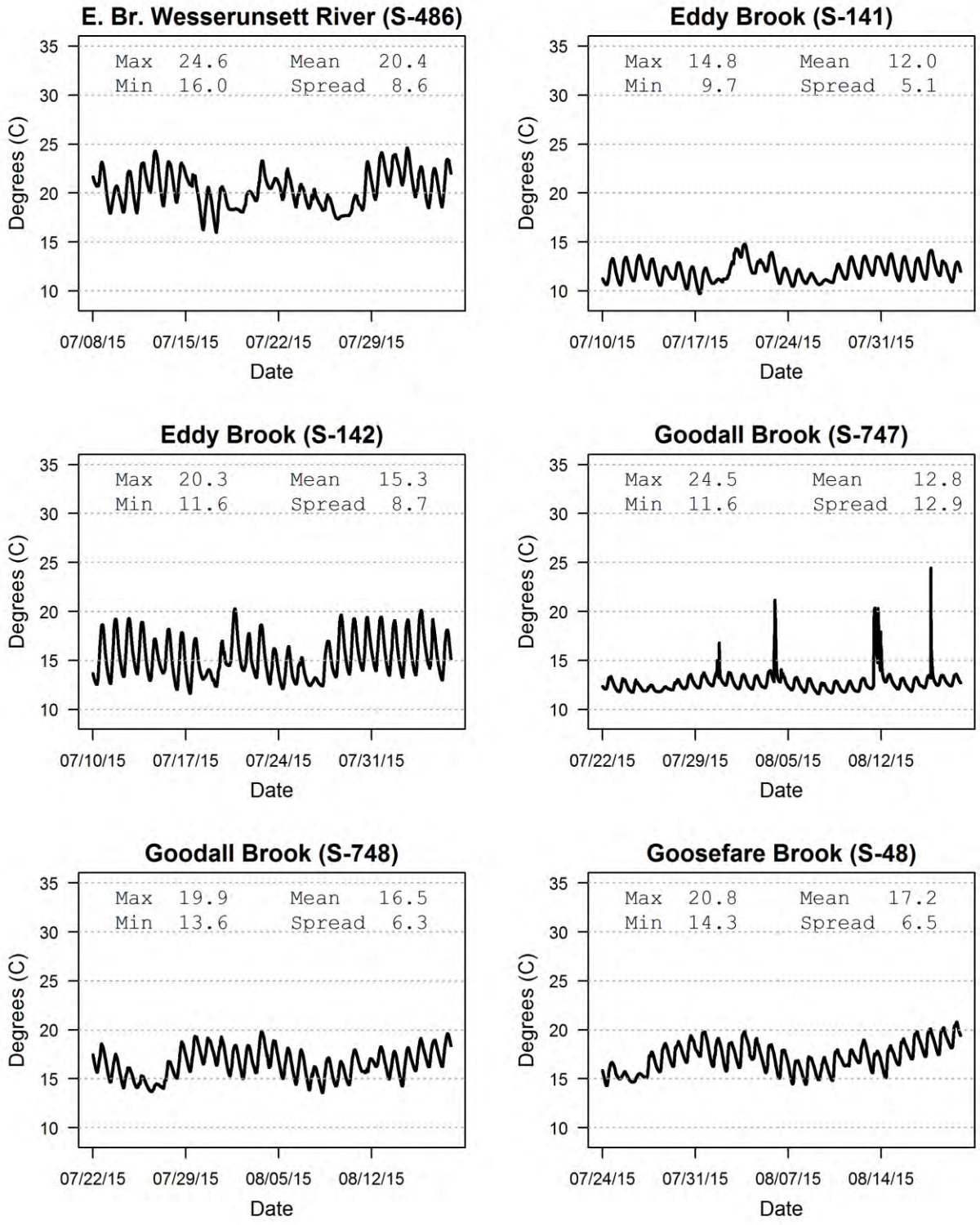


Figure 3.1.1a 2015 In-Stream Continuous Temperature Data (continued)

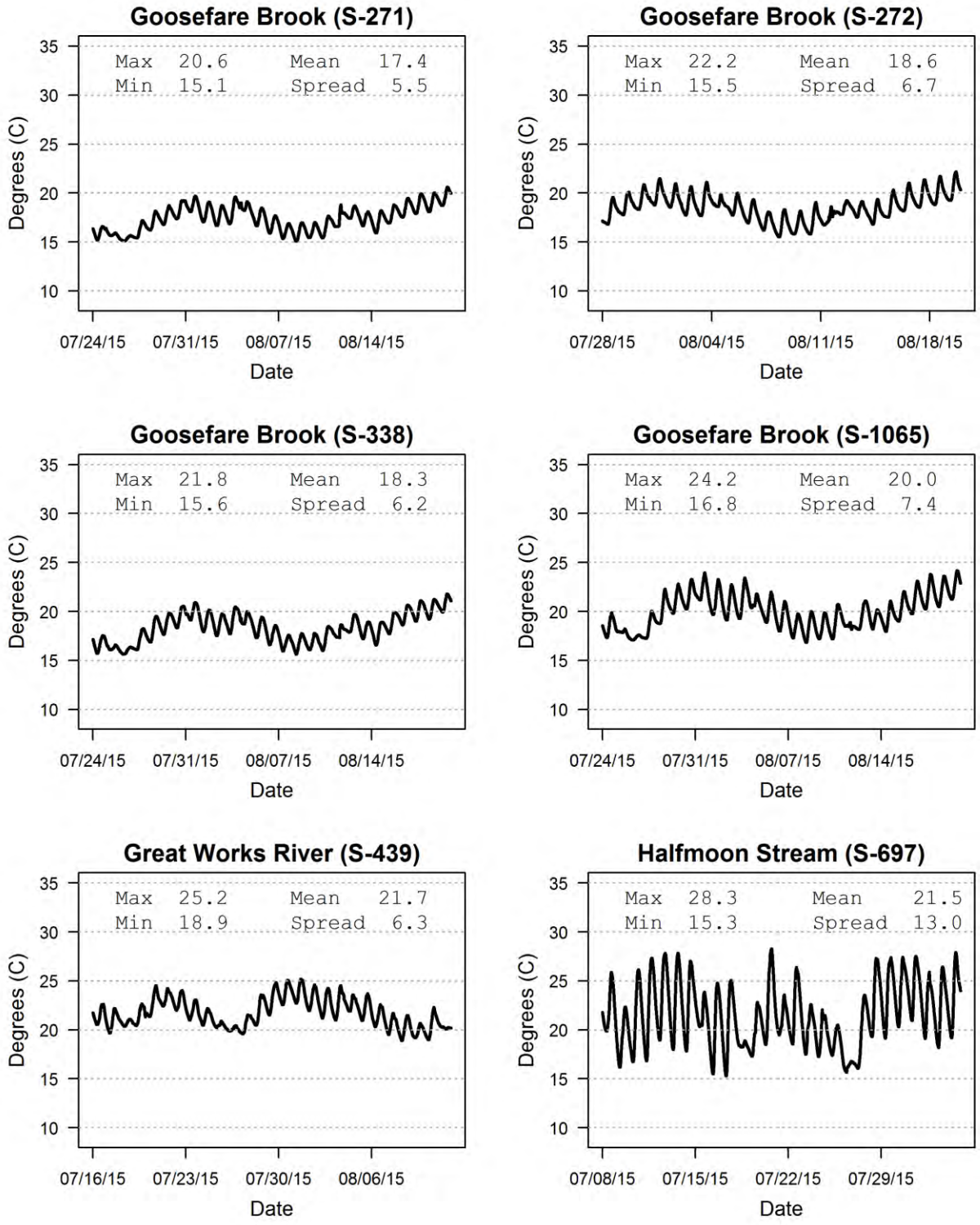


Figure 3.1.1a 2015 In-Stream Continuous Temperature Data (continued)

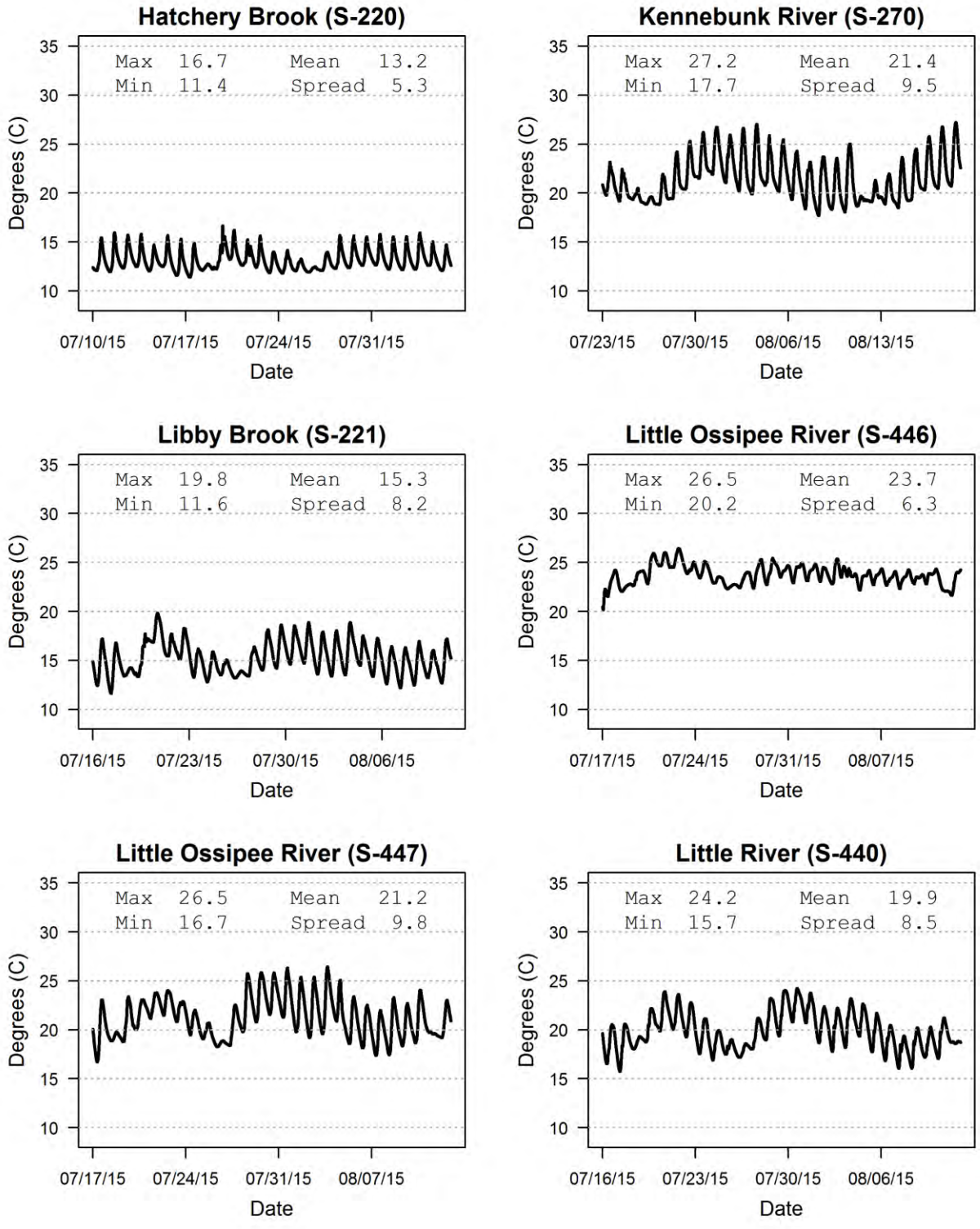


Figure 3.1.1a 2015 In-Stream Continuous Temperature Data (continued)

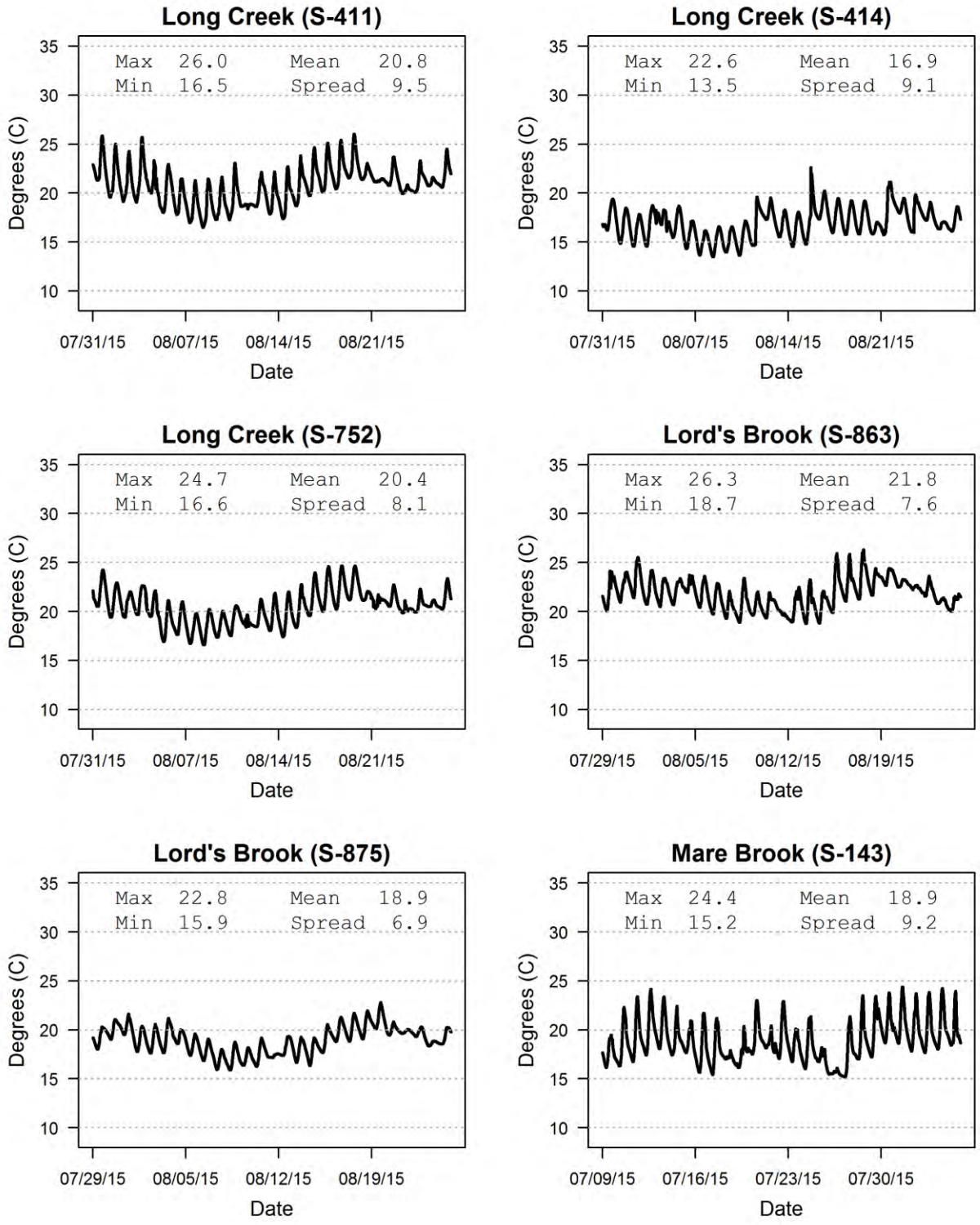


Figure 3.1.1a 2015 In-Stream Continuous Temperature Data (continued)

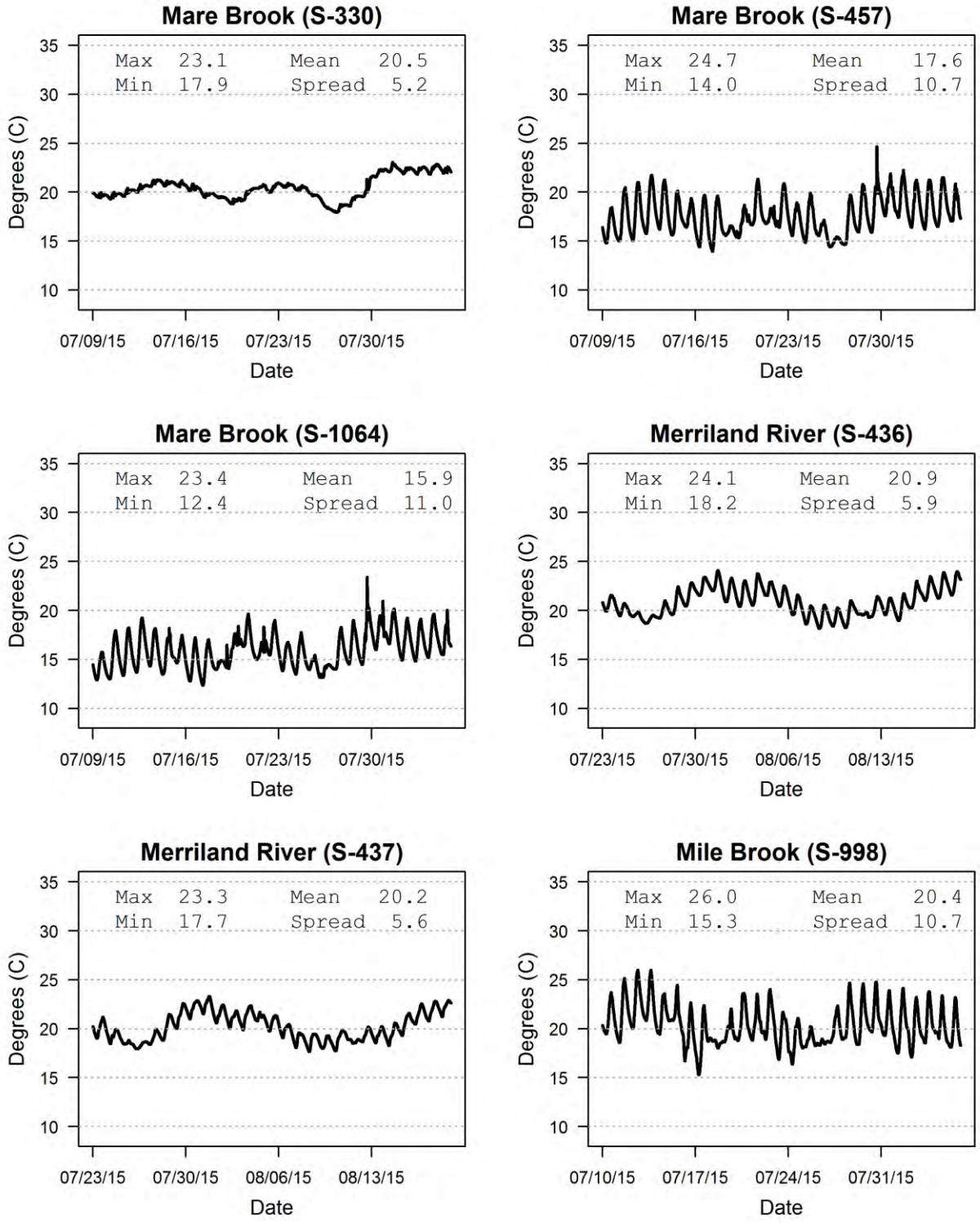


Figure 3.1.1a 2015 In-Stream Continuous Temperature Data (continued)

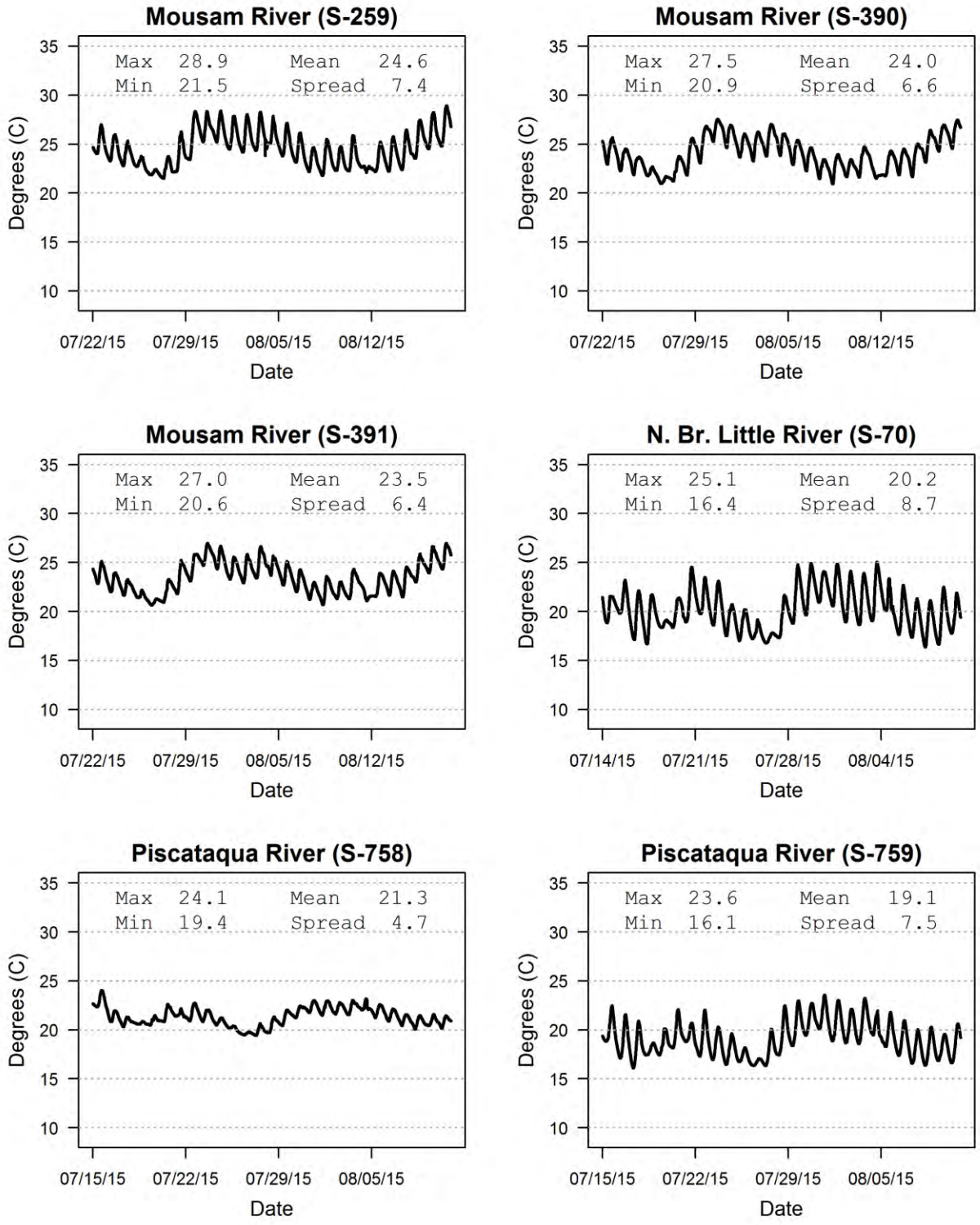


Figure 3.1.1a 2015 In-Stream Continuous Temperature Data (continued)

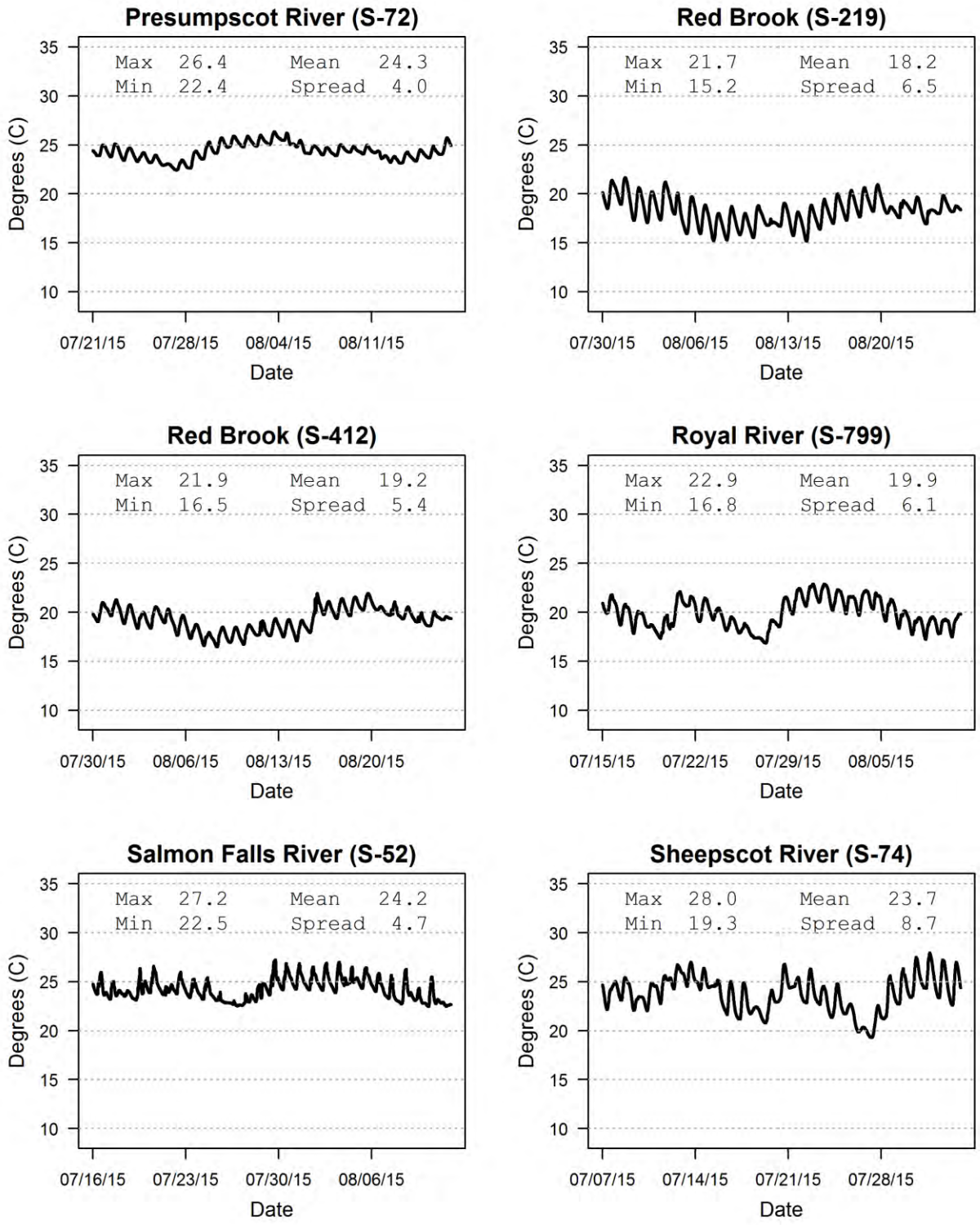


Figure 3.1.1a 2015 In-Stream Continuous Temperature Data (continued)

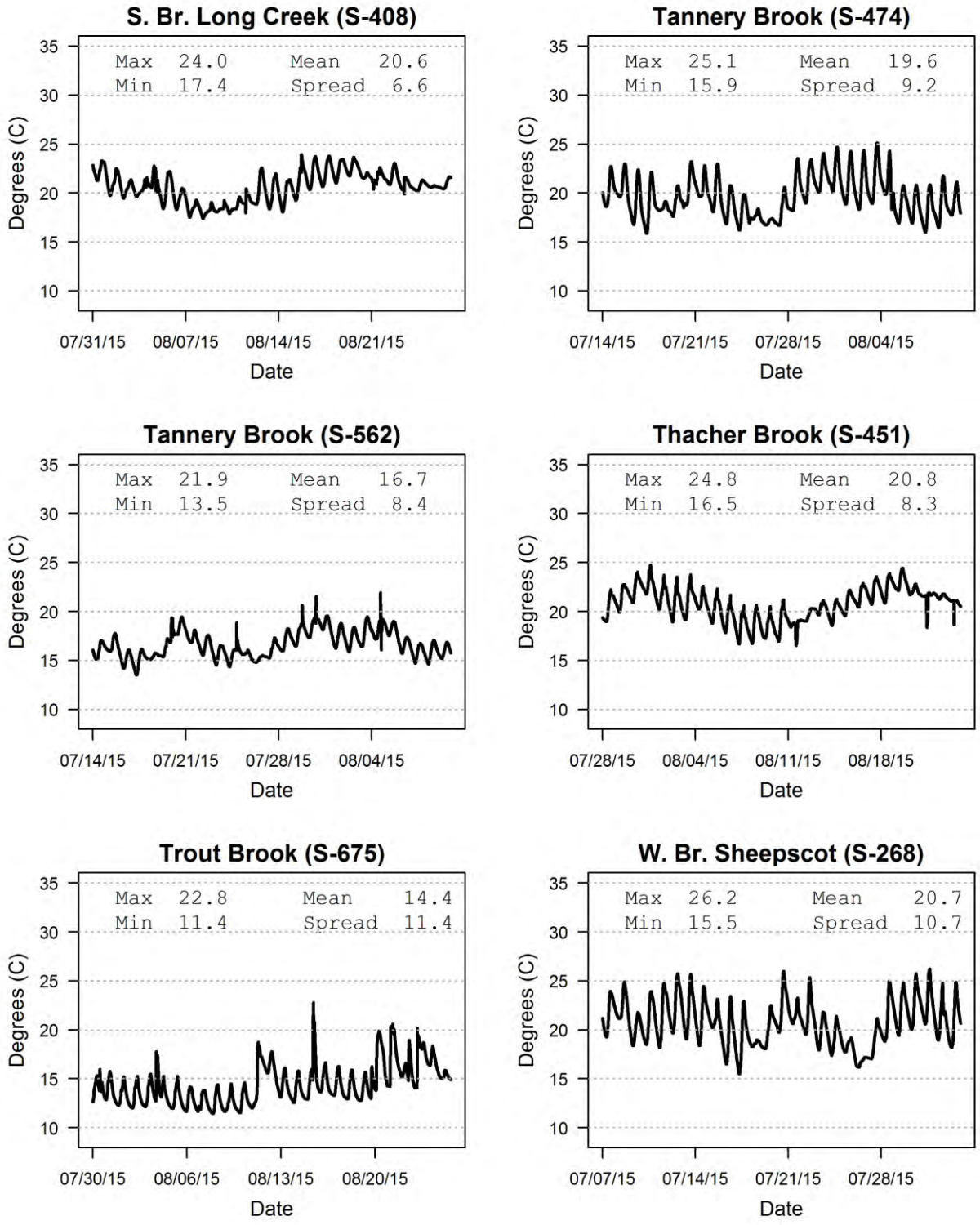
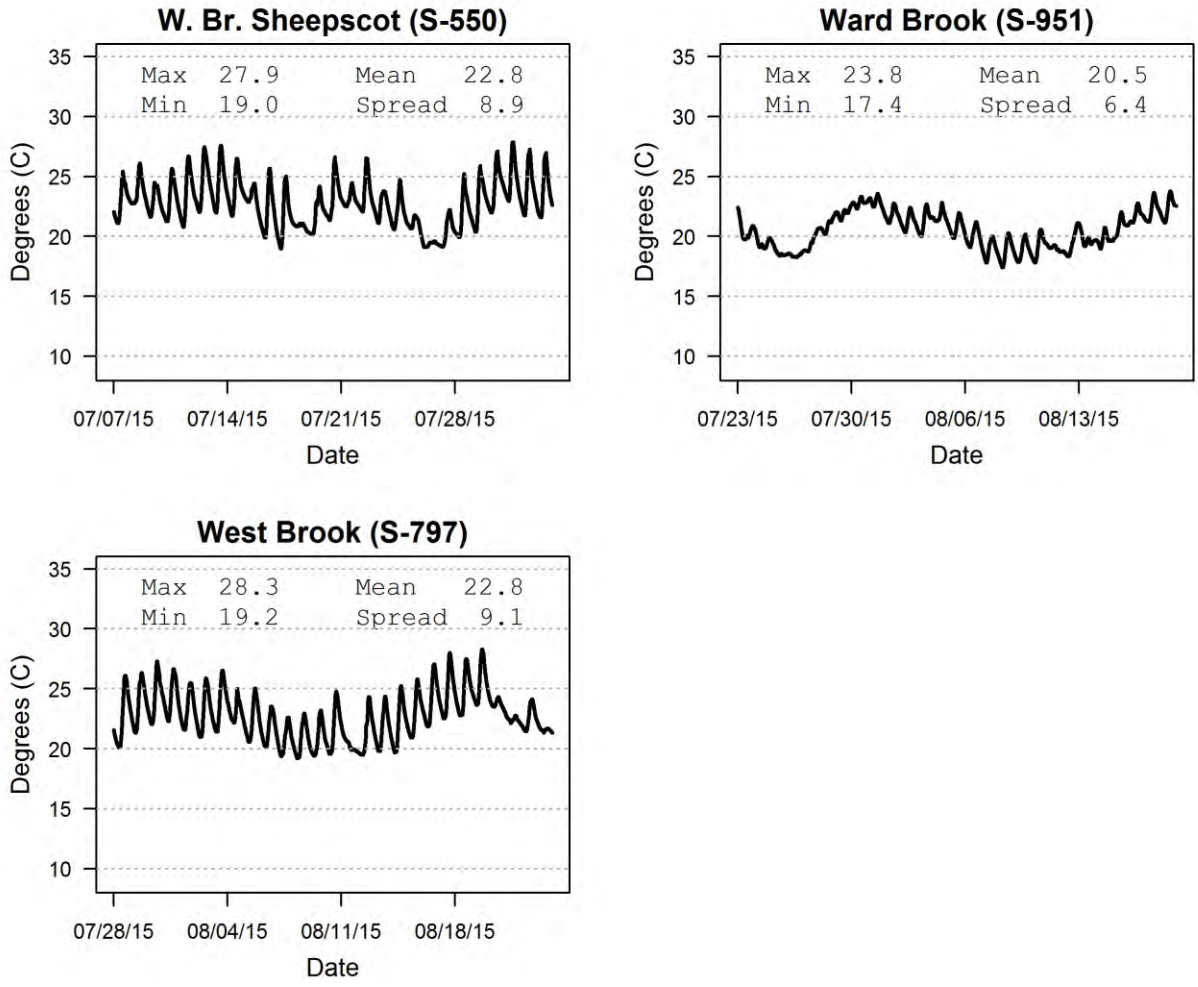


Figure 3.1.1a 2015 In-Stream Continuous Temperature Data (continued)



3.1.3a Attainment History of Sampling Stations Prior to 2015

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

Table 3.1.4a Past Attainment History

Waterbody	Station	Attained Class	Did not Attain Class	Indeterminate Result
Back Brook	107	1987, 2005, 2010		
Bear Brook	1041*		2014	
Branch Brook	106	1987, 2010	2000, 2005	
Capisic Brook	257	1995	1996, 1999, 2003, 2009	
Cole Brook	317	1997, 1998, 2010	1999, 2005	
East Branch Wesserunsett Stream	486	2001, 2007, 2012-2014		
Goodall Brook	747		2004	
Goodall Brook	748	2004		
Goosefare Brook	48	1984, 1986, 1994, 1998, 2000	1995, 2005, 2010	
Goosefare Brook	49*		1984, 1986, 1994, 1995	
Goosefare Brook	271	2005	1995, 1998, 2000	2010
Goosefare Brook	272		1995, 2014	
Goosefare Brook	338*			1998
Great Works River	439	2000, 2005, 2010		
Halfmoon Stream	697	2003, 2007	2012, 2013, 2014	
Kennebunk River	270	1995, 2000, 2010	2005	
Libby Brook	221	1994, 2005, 2010		
Little Ossipee River	446	2010	2000, 2005, 2012	
Little Ossipee River	447	2000, 2005, 2010		
Little River	440	2000, 2005, 2010		
Long Creek (South Branch)	408	1999		
Long Creek	411*		1999, 2010	
Long Creek	414		1999, 2010	2013
Long Creek	752		2004, 2010	
Lord's Brook	863		2008	
Lord's Brook	875		2008	

* Non-SWAT Station

Table 3.1.4a Past Attainment History (continued)

Waterbody	Station	Attained Class	Did not Attain Class	Indeterminate Result
Mare Brook	457		1998- 2003	
Mare Brook	143	1995, 1997-1999, 2002	1991, 2000, 2001, 2003	
Mare Brook	330		1997-2003	
Merriland River	436	2000, 2005, 2010		
Merriland River	437	2000, 2005, 2010		
Mousam River	259	1995, 1999, 2005, 2010		
Mousam River	390	1999, 2010		
Mousam River	391	1999, 2010		
North Branch Little River	70	1994	1984	
Piscataqua River	758	2004		
Piscataqua River	759	2004		
Presumpscot River	72	1984, 1994-1996	2005, 2010	
Red Brook	219	1994, 2005	1999	2010
Red Brook	412	1999, 2010		
Salmon Falls River	52	2005, 2010	1984, 1991, 1992, 1995	
Sheepscot River	74	1987-1990, 1992, 1995, 1996, 1998, 1999-2014	1984-1986, 1991, 1993, 1994, 1997	
Tannery Brook	562	2000, 2005, 2010		
Thacher Brook	451	2000, 2005, 2010		
Trout Brook	675		2003-2005, 2010	
West Branch Sheepscot River	268	1996-1999, 2001, 2002, 2005, 2007, 2009-2015	2000, 2003, 2004, 2006, 2008	1995
West Brook	797		2005, 2010	

* Non-SWAT Station

2016 Results

3.1.2b 2016 Results Summary

The Biological Monitoring Unit concentrated its sampling in 2016 in the Penobscot and Downeast basins. Forty-one stations were sampled under the SWAT Program (Table 3.1.1b).

Forty-one stations have been analyzed for aquatic life attainment with twenty-six of these stations in attainment of their statutory class. No licensing / relicensing issues have been found in waterbodies sampled below municipalities or industries. There were several waterbodies that had indeterminate results, see Table 3.1.1b for probable cause.

Birch Stream – Bangor Station 312

Birch Stream is a small first order stream located below Bangor International Airport and the Airport Mall with an aquatic life criteria of Class B. Sampling occurred downstream of the Ohio Street Crossing. Much of the headwaters of the stream have been altered throughout the years. The macroinvertebrate community did not attain the Class B aquatic life criteria. The aquatic community was comprised of over 50% snails from the genus *Gyraulus*. Total Abundance was high with a mean of 635 organisms/sampler, compared to 52 organisms/sampler during the 2011 sampling season. Generic Richness, or the number of different organisms collected, was good (49 taxa) but there were very few sensitive organisms present. Specific Conductance remained high (Table 3.1.2b). Altered hydrology and deicer from the airport continue to impact the benthic community. The stream bottom condition has improved as deicer has been contained. Sewage fungus has not been present since 2010. The stream has been listed on our 303(d) list and is a designated TMDL stream; it has not attained Class B aquatic life criteria since first being sampled in 1997 (Table 3.1.4b).

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 does not meet the Class A aquatic life criteria but does meet the Class B criteria. In 2006 and 2011, Class A aquatic life criteria were met (Table 3.1.4b). 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. In comparison, fifty-three different taxa were collected in 2011; this is a significant drop in diversity. 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. Cove Brook is an important aquatic resource and it is recommended that macroinvertebrate sampling be repeated next year.

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 does not meet the Class A aquatic life criteria but does meet the Class B criteria. In 2007 and 2012, Class A aquatic life criteria were met (Table 3.1.4b). 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. The Ducktrap River is a Class A midcoast 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 3.1.3b). 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 (Table 3.1.3b) 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. 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.

Northeast Brook – Devereaux Twp Station 1102

Northeast Brook is a first order stream located between Mopang Lake and the Pleasant River. The stream has a water quality goal of Class A. There are considerable beaver activities and blow downs in the system. Flow at both the placement and retrieval of samplers was very low. Dissolved Oxygen (DO) was 2.69 mg/l at deployment and 4 mg/l at retrieval (Table 3.1.2b). The pH at retrieval was 5.56 (Table 3.1.2b). The macroinvertebrate community did not meet the minimum Class C aquatic life criteria. The amphipod, *Hyalella*, made up almost 57% of the community. Amphipods can be very abundant in small habitats without fish, although small fish were present. The Generic Richness, or number of different taxa, was low with only 29 different taxa present and the community lacked several sensitive organisms. There were no stoneflies present. The combination of poor habitat, very low dissolved oxygen, and low pH has impacted the biological community significantly.

Penjajawoc Stream – Bangor Station 511, 513, and 315 (from upstream to downstream)
Penjajawoc Stream is a Class B waterbody flowing southeast through the Bangor Mall area and crossing Route 2 before entering the Penobscot River. Station 511 is below a large wetland area and above Stillwater Avenue. The station is adjacent to a large medical office park and receives runoff from Walmart. Station 513 is located just below the Hogan Road crossing and further downstream. Station 315 is located just upstream of the Route 2 crossing close to where the stream enters the Penobscot River. All three stations did not meet the minimum Class C aquatic life criteria. The only station to attain Class B aquatic life criteria was Station 315 in 2001 (Table 3.1.4b). In 2016, specific conductance was very high at sampler retrieval at all stations, measuring well over 1000 us/cm (Table 3.2.1b). Total Mean Abundance and Generic Richness were adequate at all stations but there were few sensitive organisms found at all stations, especially in the orders Ephemeroptera (mayflies) and Plecoptera (stoneflies). Over 30% of the taxa at Station 511 consisted of the amphipod *Hyalella* and tolerant Isopods. The most prevalent taxa in the system consisted of the tolerant chironomids *Microtendipes*, *Tanytarsus*, and *Parametricocnemus* as well as the non-insect taxa described above. The high conductivity may reflect high salt content in the system from groundwater and runoff.

Sucker Brook – Hampden Station 624
Sucker Brook is a small Class B stream originating near Bangor International Airport. It flows southeast through a highly-developed area, through Hampden, and finally into the Penobscot River. Station 624 did not meet the Class C aquatic life criteria. The tolerant midges *Polypedilum, Rheotanytarsus*, and *Tanytarsus* were the dominant taxa making up 63% of the aquatic community. The number of sensitive organisms in the community was very low. The stream bottom was covered by silt and the Specific Conductance of the stream was very high (Table 3.1.2b). Sucker Brook has been sampled periodically since 2002 and has never attained aquatic life criteria goals (Table 3.1.4b).

Trout Brook – Columbia Station 1101
Trout Brook is a third order system located in Columbia. The stream has a water quality goal of Class A. Samplers were placed 17 meters above the Sacarap Road crossing. At the time of sampler deployment, it was noted that Trout Brook had a milky color and the stream was very cloudy. The stream did not meet the Class A aquatic life criteria. It did attain the Class C aquatic life criteria indicating that the structure and function of the community was maintained. The Total Mean Abundance and Generic Richness (number of different taxa) of the three samplers were adequate, but the number of sensitive taxa present in the community was low. The dominant organism present in the community was the tolerant midge *Microtendipes* which made up 18% of the community. This was the first time Trout Brook was sampled and it is recommended that the stream be resampled to determine if an unknown discharge or a non- point source issue continues to affect the aquatic community.

Table 3.1.1b 2016 SWAT Benthic Macroinvertebrate Biomonitoring Results

Waterbody	Town	Station	Log	Potential sources of pollution[1]	Statutory Class/ Final Determination	Attains Class?[2]	Probable Cause
Allen Stream	Exeter	308	2497	Agricultural NPS	B/B	Y	
Babel Brook	Ebeemee (T5R9)	305	2491	Reference	A/A	Y	
Birch Stream	Bangor	312	2469	Urban NPS/Airport	B/C	N	Urban Runoff/ Airport.
Card Brook	Ellsworth	815	2482	Urban NPS	B/I	N	Low Numbers. Resample.
Carleton Stream	Blue Hill	526	2476	In-Place Contamination	C/I	N	Beaver Activity. Resample.
Cove Brook	Winterport	813	2496	NPS	AA/B	N	Low Flow; Siltation.
Crooked Brook	Corinth	510	2500	Agricultural NPS	B/A	Y	
Ducktrap River	Lincolnville	626	2475	Reference	AA/B	N	Low Flow.
East Branch Wesserunsett Stream	Athens	486	2481	Long Term Monitoring	B/A	Y	
East Machias River	Crawford	494	2509	Reference	AA/A	Y	
French Stream	Exeter	505	2498	Agricultural NPS	B/B	Y	
Great Falls Branch – Schoodic Brook	Deblois	504	2506	Agricultural NPS	AA/A	Y	
Great Marsh Stream	Columbia	1100	2502	NPS	A/A	Y	
Halfmoon Stream	Thorndike	697	2465	Agricultural NPS/Long Term Monitoring	A/B	N	Class A (.46); Enriched.
Kenduskeag Stream	Corinth	508	2499	Agricultural NPS	B/A	Y	
Kenduskeag Stream	Bangor	829	2473	Urban NPS	C/C	Y	
Martin Stream	Dixmont	755	2467	Agricultural NPS	A/B	N	Class A (.23); Very low flow.
Martin Stream	Dixmont	756	2466	Agricultural NPS	A/B	N	Class A (.19); Very low flow.
Mopang Stream	T30 MD BPP	501	2510	Reference	AA/A	Y	

[1] NPS, non-point source pollution.

[2] This field is completed only for stations for which sampling results have been obtained as of the time of this report.

Table 3.1.1b 2016 SWAT Benthic Macroinvertebrate Biomonitoring Results

Waterbody	Town	Station	Log	Potential sources of pollution[1]	Statutory Class/ Final Determination	Attains Class?[2]	Probable Cause
Narraguagus River	Deblois	111	2507	Agricultural NPS	AA/A	Y	
Narraguagus River	Beddington	112	2508	Reference	AA/A	Y	
Narraguagus River	Cherryfield	81	2503	Agricultural NPS	B/B	Y	
Northeast Brook	Devereaux TWP	1102	2511	Reference	A/NA	N	Low DO/ Low pH/ Habitat.
Passadumkeag River	Grand Falls TWP	1098	2489	Reference	AA/A	Y	
Passagassawakeag River	Belfast	430	2474	Agricultural NPS	B/B	Y	
Penjajawoc Stream	Bangor	315	2472	Urban NPS	B/NA	N	Urban runoff
Penjajawoc Stream	Bangor	511	2470	Urban NPS	B/NA	N	Urban runoff
Penjajawoc Stream	Bangor	513	2471	Urban NPS	B/NA	N	Urban runoff
Schoodic Brook	Cherryfield	1099	2505	Agricultural NPS	AA/B	N	Beaver Activity
Sebec River	Milo	827	2490	Urban NPS	B/B	Y	
Seboeis Stream	Howland	665	2486	NPS	A/A	Y	
Sedgeunkedunk Stream	Orrington	972	2493	NPS	B/A	Y	
Sheepscot River	Whitefield	74	2341	Long Term Monitoring	AA/A	Y	
Souadabscook Stream	Hampden	291	2495	In-Place Contamination	AA/A	Y	
Sucker Brook	Hampden	624	2494	Urban/Agricultural NPS	B/NA	N	Urban runoff/ Habitat.
Trout Brook	Columbia	1101	2501	NPS	A/C	N	NPS/ Unknown Discharge
Tunk Stream	Cherryfield	148	2484	Reference	B/B	Y	
Tunk Stream	T10 SD	159	2485	Reference	B/B	Y	
West Branch Narraguagus River	Cherryfield	502	2504	Agricultural NPS	AA/A	Y	
West Branch Sheepscot River	China	268	2464	Long Term Monitoring/ Agricultural NPS	AA/A	Y	
West Seboeis Stream	T4 R9	818	2492	NPS	A/A	Y	

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

Table 3.1.2b 2016 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
Allen Stream	308	2497	7/25/2016	21.3	8.59	**215.5**	7.75	8/22/2016	18.4	9.17	**192.88**	7.88
Babel Brook	305	2491	7/20/2016	17.1	10.27	31.9	7.15	8/17/2016	17.5	10.48	26	7.19
Birch Stream	312	2469	7/11/2016	17	10.2	**370.9**	8.12	8/8/2016	19.7	9.3	**490**	7.97
Card Brook	815	2482	7/18/2016	21.4	9.68	**480**	7.81	8/15/2016	22	9.87	**667**	7.71
Carleton Stream	526	2476	7/13/2016	21.6	9.3	69.5	6.79	8/10/2016	21.4	9.27	76.7	6.97
Cove Brook	813	2496	7/21/2016	19.7	10.8	**230.1**	8.48	8/18/2016	19.4	10.77	**240.3**	8.35
Crooked Brook	510	2500	7/25/2016	24.2	10.53	**215.3**	8.31	8/22/2016	21.7	10.95	**188.8**	8.43
Ducktrap River	626	2475	7/12/2016	18.8	9.3	51.2	7.02	8/9/2016	21.3	7.35	50.2	6.85
East Branch Wesserunsett Stream	486	2481	7/14/2016	23.6	9.75	88.4	8.27	8/11/2016	24.3	10.35	118.1	8.5
East Machias River	494	2509	7/28/2016	27.6	9.43	29.5	7.36	8/24/2016	22.7	10.19	30.9	7.08
French Stream	505	2498	7/25/2016	22.5	8.39	**209.6**	7.65	8/22/2016	20.4	8.82	**249.6**	7.95
Great Falls Branch-Schoodic Brook	504	2506	7/26/2016	23.9	8.26	47.3	6.98	8/23/2016	19.3	9.27	43.9	6.56
Great Marsh Stream	1100	2502	7/27/2016	25.7	8.45	46.4	6.87	8/23/2016	19.6	9.45	41.8	6.73
Halfmoon Stream	697	2465	7/7/2016	19.5	8.9	149.3	7.63	8/3/2016	20	10.14	158.8	7.69
Kenduskeag Stream	508	2499	7/25/2016	21.7	10.28	**176.2**	8.02	8/22/2016	19.8	10.07	**171.7**	7.91
Kenduskeag Stream	829	2473	7/11/2016	23.1	10.45	**250.5**	8.73	8/8/2016	25.5	10.91	**276.6**	8.79
Martin Stream	755	2467	7/7/2016	18.6	9.94	137.5	7.88	8/3/2016	24.5	10.13	151.4	7.37
Martin Stream	756	2466	7/7/2016	18.6	9.6	121.4	7.8	8/3/2016	23.3	12.45	149.9	8.24
Mopang Stream	501	2510	7/28/2016	26.1	9.17	24.5	6.62	8/24/2016	22.1	10.22	26.4	6.62
Narraguagus River	111	2507	7/26/2016	25.3	9.19	34.5	7.12	8/23/2016	20.5	10.47	35.4	7.15
Narraguagus River	112	2508	7/26/2016	28.3	8.95	38.1	7.48	8/23/2016	23.5	9.78	36.3	7.43

Table 3.1.2b 2016 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
Narraguagus River	81	2503	7/27/2016	28.4	9.11	39.8	7.58	8/23/2016	24.3	9.6	41	6.92
Northeast Brook	1102	2511	7/28/2016	20.8	**2.69**	35.5	**5.83**	8/24/2016	16.8	**4**	33.1	**5.56**
Passadumkeag River	1098	2489	7/19/2016	24.2	9.18	31.2	7.27	8/16/2016	22.7	9.77	36.8	7.39
Passagassawakeag River	430	2474	7/12/2016	21.6	10.75	66.1	8.19	8/9/2016	21.4	10.93	74.8	8.02
Penjajawoc Stream	315	2472	7/11/2016	19.9	10.62	**805**	8.17	8/8/2016	22.1	11.55	**1168**	8.26
Penjajawoc Stream	511	2470	7/11/2016	17.6	9.96	**314.2**	7.7	8/8/2016	20.2	9.58	**1706**	7.65
Penjajawoc Stream	513	2471	7/11/2016	19.2	11.2	**797**	8.22	8/8/2016	23.5	13.51	**1452**	8.54
Schoodic Brook	1099	2505	7/26/2016	23.3	8.57	36.8	7.2	8/23/2016	18.1	9.58	33.5	6.72
Sebec River	827	2490	7/20/2016	24.6	9.19	30.8	7.34	8/17/2016	22.9	9.36	29.5	7.22
Seboeis Stream	665	2486	7/19/2016	24.4	9.62	27.4	7.42	8/16/2016	21.7	10.17	28.9	7.43
Sedgeunkedunk Stream	972	2493	7/21/2016	20.4	9.95	36.5	7.5	8/18/2016	18.9	9.47	114.5	7.48
Sheepscot River	74	2463	7/6/2016	23.4	8.42	82.8	7.54	8/2/2016	23.1	8.49	70	7.3
Souadabscook Stream	291	2495	7/21/2016	22.7	10.19	156.9	8.27	8/18/2016	21.4	10.44	**328.5**	8.18
Sucker Brook	624	2494	7/21/2016	17.9	9.31	**720**	8.01	8/18/2016	18.2	8.6	**579**	7.81
Trout Brook	1101	2501	7/27/2016	24.7	7.06	41	6.59	8/23/2016	17.8	8.54	36.7	6.55
Tunk Stream	148	2484	7/18/2016	24.5	8.67	29	6.24	8/15/2016	24.1	7.32	34	**6.04**
Tunk Stream	159	2485	7/18/2016	24	9.39	21.5	6.57	8/15/2016	24.5	9.31	21.6	6.42
West Branch Narraguagus River	502	2504	7/27/2016	26.5	7.55	34.7	6.84	8/23/2016	22.3	8.58	33.7	**5.75**
West Branch Sheepscot River	268	2464	7/6/2016	20.9	9.3	93.8	7.57	8/2/2016	20.7	10.6	137.5	7.59
West Seboeis Stream	818	2492	7/20/2016	20.2	10.24	36	7.15	8/17/2016	20	10.13	38.6	9.98

Table 3.1.3b 2016 SWAT Water Chemistry Data

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

Waterbody	Station	Log	Sampling Date	DOC	TKN	NO2-NO3-N	Total P	SRP	TSS	TDS
				MG/L	MG/L	MG/L	UG/L	UG/L	MG/L	MG/L
Allen Stream	308	2497	8/22/2016	4.6	0.4	0.14	**42**	2	17	120
Babel Brook	305	2491	8/17/2016	4.5	0.2	0.03	14	3	0.8	18
Birch Stream	312	2469	8/8/2016	4.7	0.3	0.25	18	3	1	280
Carleton Stream	526	2476	8/10/2016	5.7	0.2	0.01	5	1	< 2	47
Crooked Brook	510	2500	8/22/2016	3.2	0.4	0.13	21	2	3.4	100
Ducktrap River	626	2475	8/9/2016	5.9	0.3	0.02	26	1	8.7	35
East Machias River	494	2509	8/24/2016	4.7	0.3	0.01	8	< 1	<2	18
French Stream	505	2498	8/22/2016	4.7	0.4	0.23	**46**	**13**	4.2	140
Halfmoon Stream	697	2465	8/3/2016	1.9	0.4	**0.83**	13	1	1.6	82
Kenduskeag Stream	829	2473	8/8/2016	5.7	0.4	0.01	12	2	<2	180
Kenduskeag Stream	508	2499	8/22/2016	2.1	0.1	**0.97**	12	2	2.6	93
Martin Stream (Dixmont)	756	2466	8/3/2016	2.3	0.2	0.01	14	1	3.6	98
Martin Stream (Dixmont)	755	2467	8/3/2016	2	0.3	0.02	15	1	6.9	81
Mopang Stream	501	2510	8/24/2016	4.7	0.3	< 0.01	9	1	< 2	41
Passagassawakeag River	430	2474	8/9/2016	5.3	0.4	0.02	16	4	< 2	58
Penjajawoc Stream	511	2470	8/8/2016	4.2	0.3	0.57	25	5	8.8	**980**
Penjajawoc Stream	315	2472	8/8/2016	4.6	0.3	0.03	11	2	< 2	**620**
Sebec River	827	2490	8/17/2016	3.4	0.2	0.01	6	1	0.8	25
West Seboeis Stream	818	2492	8/17/2016	8.9	0.5	0.03	16	1	4.7	40

DOC = Dissolved Organic Carbon, NH_3-N = Ammonia-Nitrogen, TKN = Total Kjeldahl-Nitrogen, NO_2-NO_3-N = Nitrite-Nitrate-Nitrogen, SRP = Soluble Reactive Phosphorus (ortho-phosphate), Total P = Total Phosphorus, TSS = Total Suspended Solids, TDS = Total Dissolved Solids, "<" = constituent not detected at the reporting limit.

Figure 3.1.1b 2016 In-Stream Continuous Temperature Data

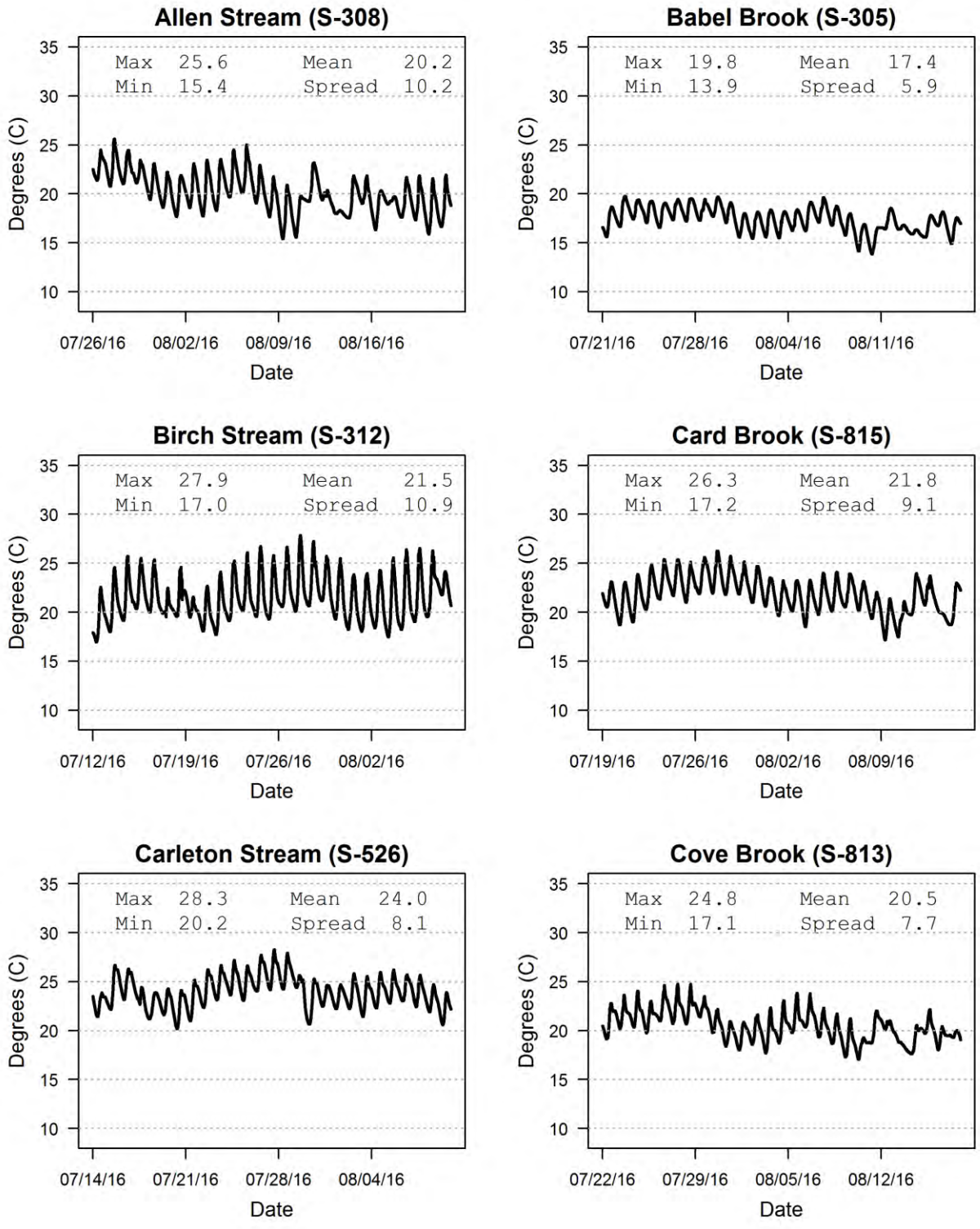


Figure 3.1.1b 2016 In-Stream Continuous Temperature Data (continued)

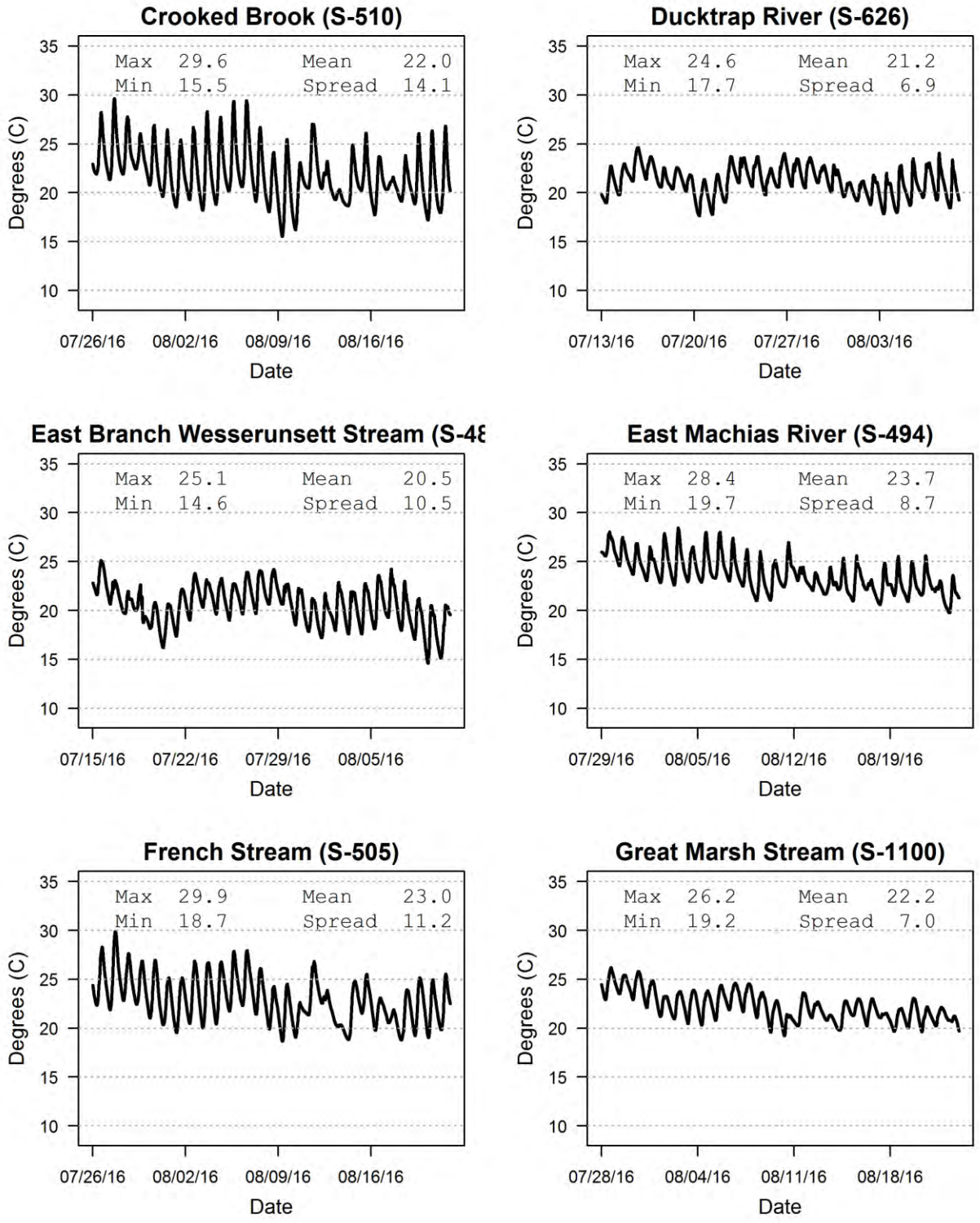


Figure 3.1.1b 2016 In-Stream Continuous Temperature Data (continued)

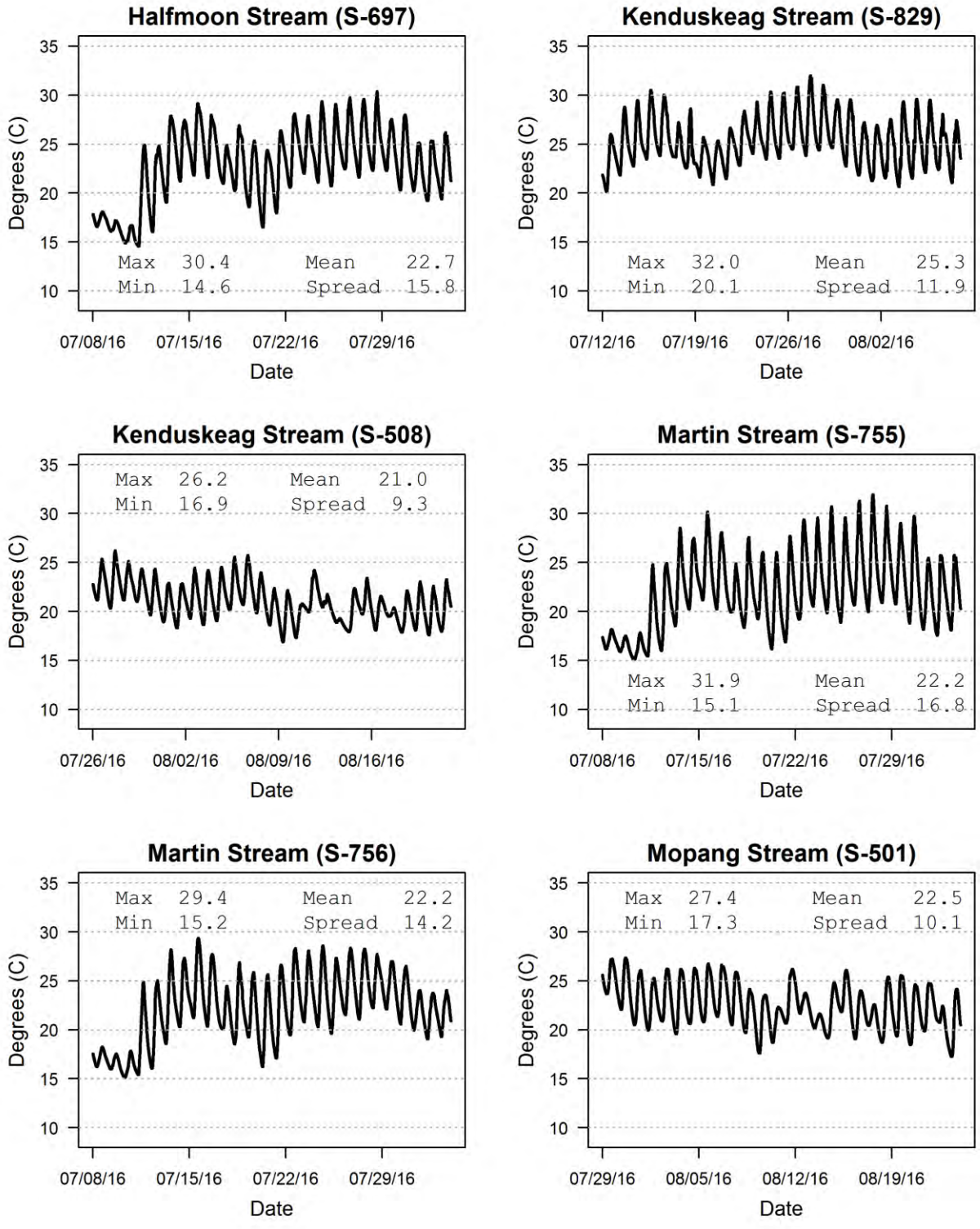


Figure 3.1.1b 2016 In-Stream Continuous Temperature Data (continued)

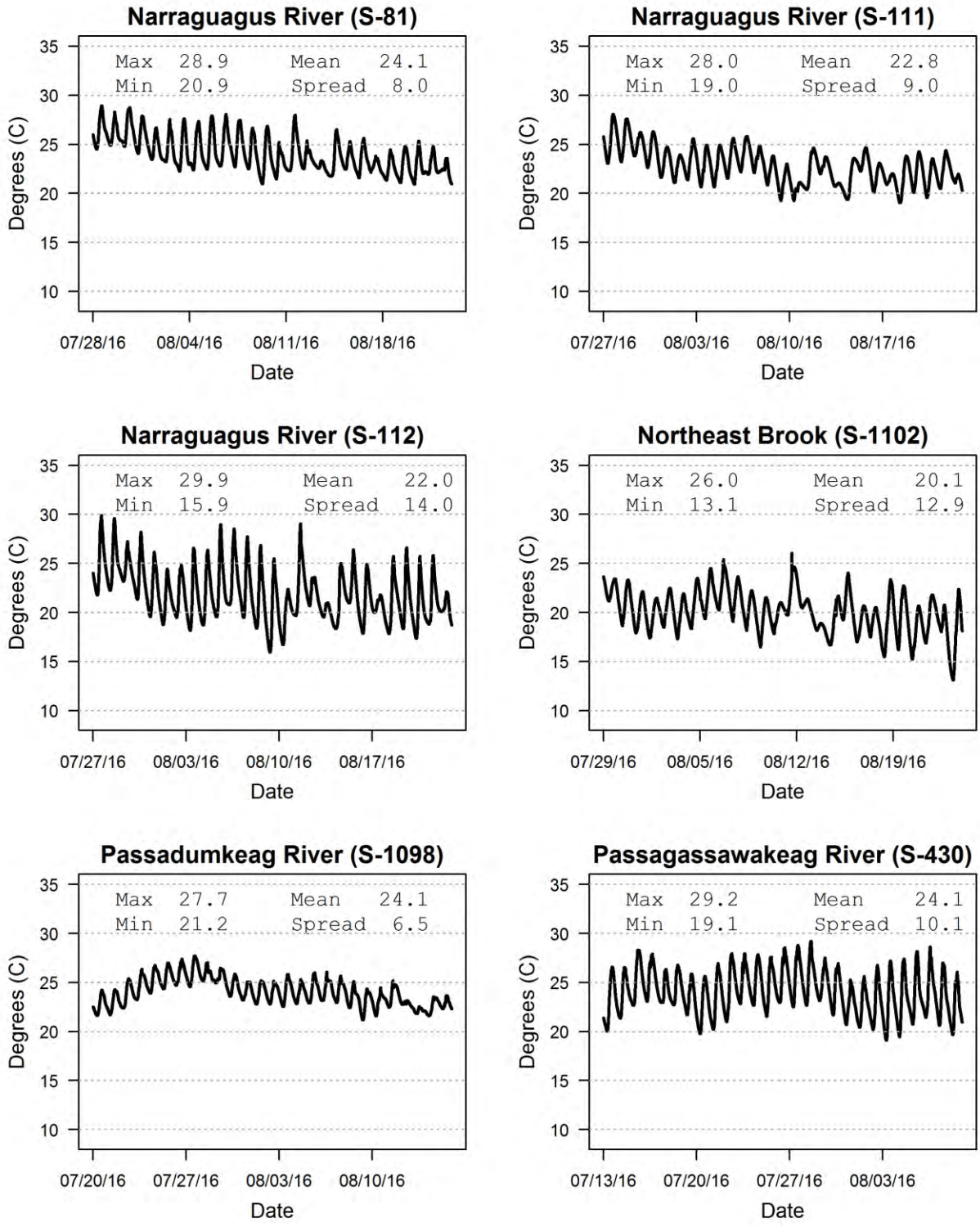


Figure 3.1.1b 2016 In-Stream Continuous Temperature Data (continued)

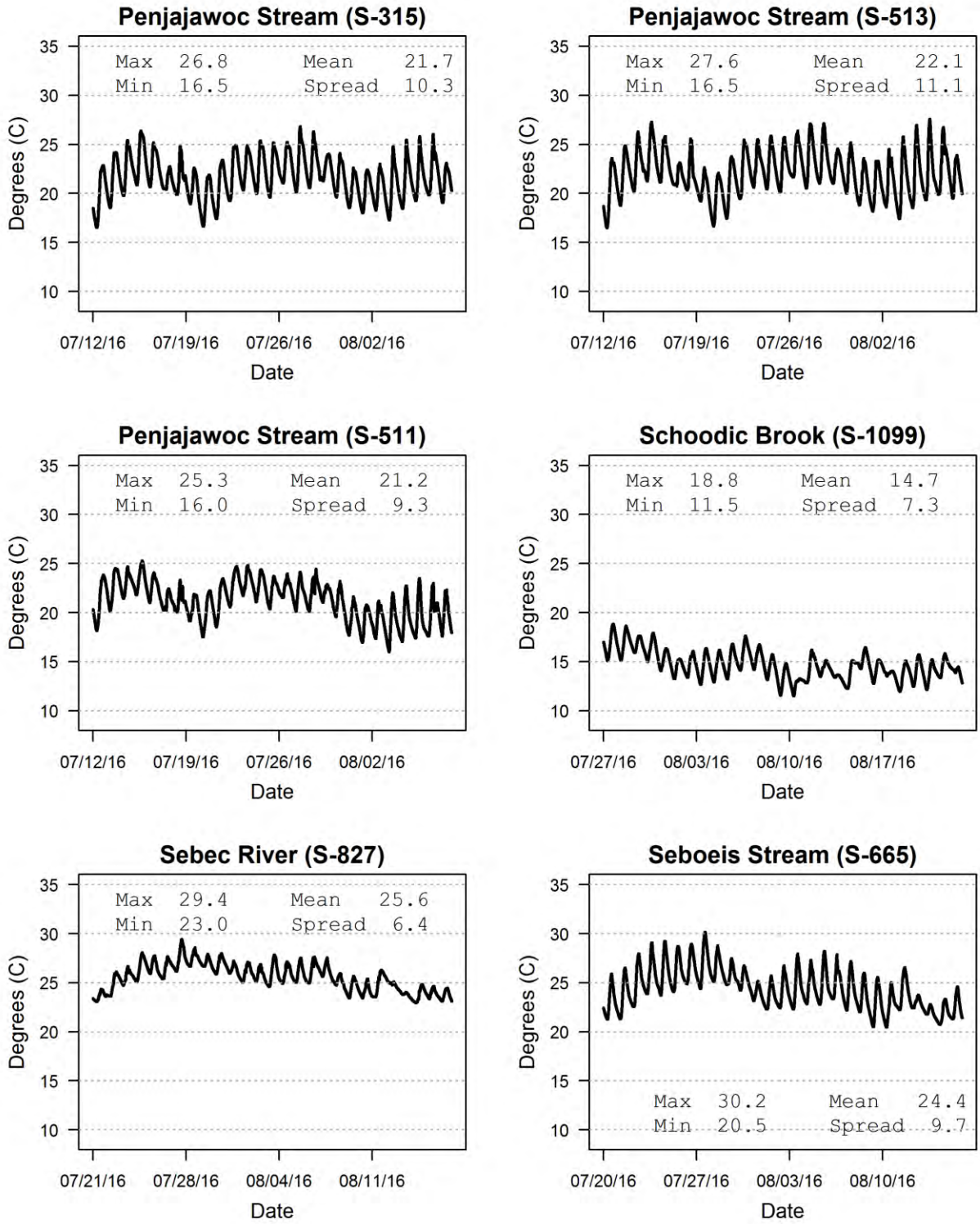


Figure 3.1.1b 2016 In-Stream Continuous Temperature Data (continued)

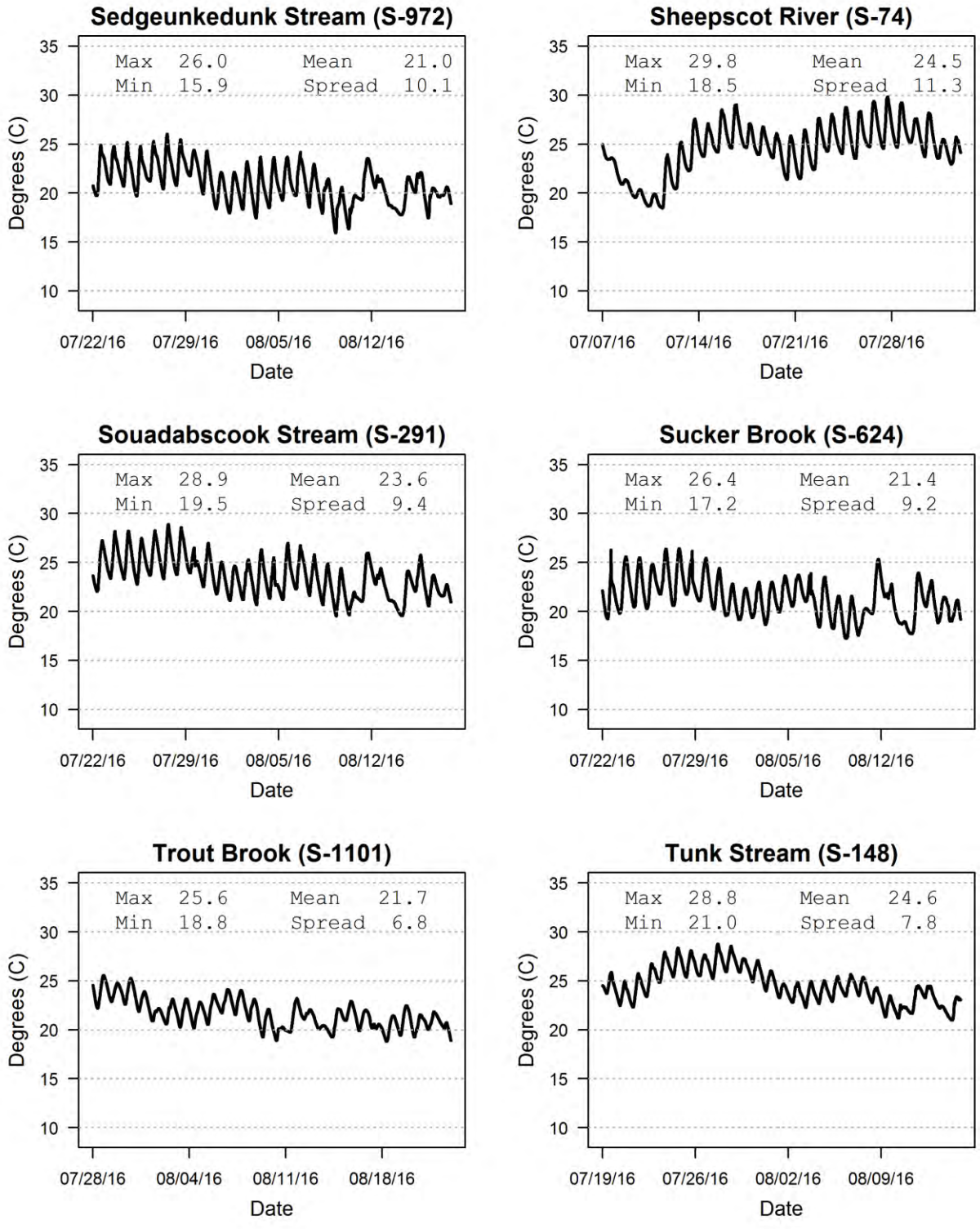
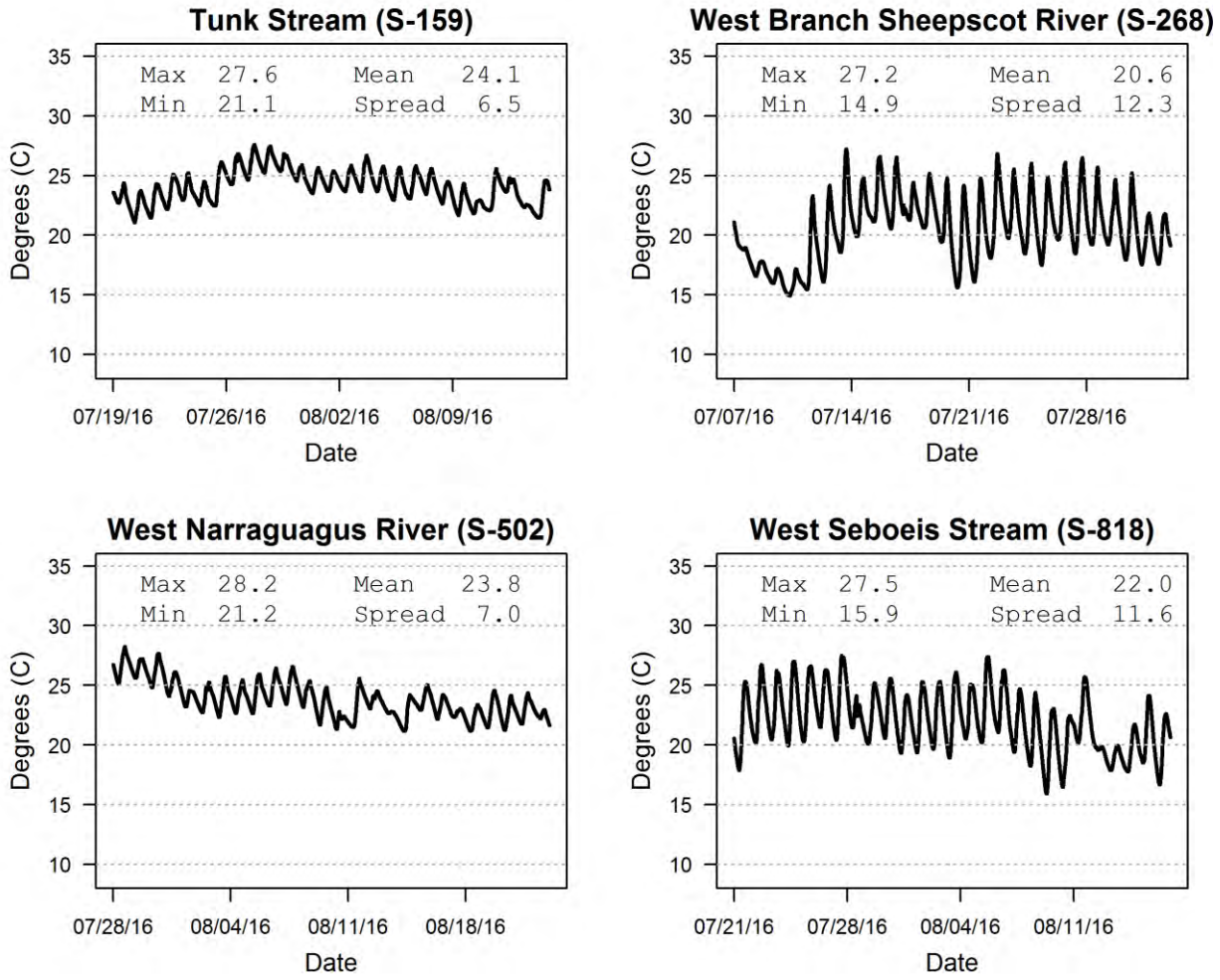


Figure 3.1.1b 2016 In-Stream Continuous Temperature Data (continued)



3.1.3b Attainment History of Sampling Stations prior to 2016

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

Table 3.1.4b Past Attainment History

Waterbody	Station	Attained Class	Did not Attain Class	Indeterminate Result
Allen Stream	308	1997, 2001, 2011		
Babel Brook	305	1997, 2001, 2011		
Birch Stream	312		1997, 1999, 2001, 2003, 2004, 2005, 2006, 2007, 2010, 2011	
Card Brook	815		2006, 2011	
Carleton Stream	526	2000	2009, 2011	
Cove Brook	813	2006, 2011		
Crooked Brook	510	2001, 2003, 2011		
Ducktrap River	626	2007, 2012	2002	
East Branch Wesserunsett Stream	486	2001, 2007, 2012, 2013, 2014, 2015		
East Machias River	494	2006, 2011	2001	
French Stream	505	2001, 2011		
Great Falls Branch – Schoodic Brook	504		2001, 2006, 2011	
Halfmoon Stream	697	2003, 2007	2012, 2013, 2014, 2015	
Kenduskeag Stream	508	1988, 2001, 2011		
Kenduskeag Stream	829	2006, 2011		
Martin Stream	755	2006	2004, 2005	2007
Martin Stream	756	2012	2005, 2006, 2007	2004
Mopang Stream	501	2001, 2006, 2011		
Narraguagus River	81	2001, 2006, 2011	1984, 1993	
Narraguagus River	111	1987, 2001, 2006, 2011	1989, 1996	
Narraguagus River	112	1987, 2006, 2011		
Passagassawakeag River	430	2000, 2007, 2012		
Penjajawoc Stream	315	2001	1997, 2002, 2003, 2006, 2008, 2011	

Table 3.1.4b Past Attainment History (continued)

Waterbody	Station	Attained Class	Did not Attain Class	Indeterminate Result
Penjajawoc Stream	511		2001, 2002, 2003, 2006, 2008, 2009, 2011	
Penjajawoc Stream	513		2001, 2002, 2003, 2005, 2008, 2012	
Sebec River	827	2006		
Seboeis Stream	665	2006, 2011		
Sedgeunkedunk Stream	972	2011		
Sheepscot River	74	1987-1990, 1992, 1995, 1996, 1998, 1999-2015	1984-1986, 1991, 1993, 1994, 1997	
Souadabscook Stream	291	2006, 2011	1996	
Sucker Brook	624		2002, 2004, 2011	
Tunk Stream	148	1991		
Tunk Stream	159	1991, 2011		
West Branch Narraguagus River	502	2001	2011	
West Branch Sheepscot River	268	1996-1999, 2001, 2002, 2005, 2007, 2009-2015	2000, 2003, 2004, 2006, 2008	1995
West Seboeis Stream	818	2006, 2011		

3.2 FISH CONTAMINANTS

3.2.1 PFCs in Fish Tissue (requested by Maine Center for Disease Control and Prevention)

Perfluorochemicals (PFCs) are a large (>200) class of highly persistent and mobile chemicals composed of fully fluorinated straight or branched carbon chains with different functional groups at one end. Consequently they may be hydrophilic, hydrophobic, and/or lipophilic. They have many specialized industrial and commercial uses for products that resist heat, stains, water, oil and grease, including hair conditioners, non-stick coatings, wetting agents, insulation, dust repellants, cleaners, anti-static agents, antifogging agents, and fire-fighting foams among others (Qi et al., 2011; Yingling, 2013).

PFCs are continuously emitted into the environment from point and nonpoint sources such as sewage treatment plants and atmospheric deposition, respectively (Ahrens and Bundschuh, 2014). In a study of sources of PFCs in major rivers of the world, Kimacjeva et al. (2012) found higher levels in industrial areas than in non-industrial areas. The most commonly detected PFCs are perfluorooctane sulfonate (PFOS) and to a lesser extent perfluorooctanoic acid (PFOA). Beginning in 2002, PFOS has been phased out in the US, Canada, and Europe, but its use has been increasing in China (Yingling, 2013).

PFCs have been found in humans and wildlife all over the world including the artic and deep seas (Yingling, 2013), which suggests atmospheric sources (Houde et al., 2011). They have been correlated with increased cancers, thyroid disease, interference with normal growth and development, and endocrine disruption in humans (Yingling, 2013). There are also reports in the literature of high concentrations in invertebrates, fish, reptiles, and marine mammals worldwide (Houde et al. 2011). Laboratory animal studies on the toxic effects of PFCs (primarily PFOS and PFOA) show various effects on development, reproduction, and immune function of birds fish and mammals (Murphy et al., 2012 as cited by Stahl et al. 2014).

PFCs with 8 or more carbons are considered bioaccumulative with sulfonates (e.g. PFOS) having a greater bioaccumulation rate than PFOA and other PFCs, indicating that the functional group is also important (Martin et al., 2013). Bioaccumulation of PFOS is considered similar to that of a moderately lipophilic substance (Houde et al., 2011). Bioaccumulation is higher in some tissues than others (liver>kidneys>whole blood>gill>carcass) but bioaccumulation factors in the carcass range up to ~2400 (Sharpe et al., 2010). PFC concentrations have been reported as high as 1900 ng/g wet wt. (Houde et al., 2011). Adverse effects in fish are not well known, but mortality, decreased fecundity, and histopathological alterations have been reported (Ahrens and Bundschuh, 2014; Sharpe et al. 2010).

MCDC derived human health risk-based screening levels for PFOS and PFOA in 2014 and updated them in 2016 following new toxicological data published by EPA. Screening levels (SLs) were developed for exposures to soil, sediment, groundwater, surface water, and for the ingestion of fish. Health risk-based SLs for these PFCs are based on non-cancer effects because cancer toxicity values have not been established (Wadman, 2014, 2016). In a Maine study of streams near Loring

Air Force Base (LAFB), where fire-fighting foams have been used, DEP found brook trout to have concentrations of PFOS ranging from 41-1080 ng/g wet wt. in exposed sites, all but one of which exceeded MCDC's 2014 SL for subsistence fishers (42 ng/g) and many of which exceeded MCDC's SL for a Maine recreational angler (175 ng/g), all based on upper level fish consumption rates for each group. Concentrations of PFOS in brook trout (0-43 ng/g) were at or below the SLs at a reference site (Akladiss, 2014).

To gather data from more reference sites and from other species, in 2014 DEP collected six to ten brook trout, smallmouth bass, and brown bullhead from each of three lakes or ponds, which receive no direct discharges of pollutants. Fish were combined into two composites of three to five fish each and analyzed for a suite of PFCs. Results showed that concentrations of most PFCs were undetected. PFOS and perfluoroundecanoate were the most commonly detected, at four and five of nine sites respectively. Both compounds were detected at one or two of the three sites for all three species. PFOS concentrations (1-4.7 ng/g) were well below MCDC's 2014 SLs and the concentrations found near LAFB. The magnitude of detected concentrations was no greater in the benthic omnivorous species brown bullhead (BBH) than in pelagic predators brook trout (BKT) and smallmouth bass (SMB).

High levels of PFCs have been found in surface waters near wastewater treatment plants and urban centers (Zushi et al. 2012 as cited in Stahl et al. 2014). In U.S. Environmental Protection Agency's (EPA's) 2008–2009 National Rivers and Streams Assessment (NRSA) and the Great Lakes Human Health Fish Tissue Study component of the 2010 EPA National Coastal Condition Assessment, analyses of PFCs in fish from randomly selected locations in the US (164 urban river sites and 157 nearshore Great Lake sites) showed that PFOS dominated in frequency of occurrence, followed by three other longer-chain PFCs (perfluorodecanoic acid, perfluoroundecanoic acid, and perfluorododecanoic acid) (Stahl et al. 2014). Maximum PFOS concentrations were 127 and 80 ng/g in urban river samples and Great Lakes samples, respectively. As part of the study, single composite samples of up to 5 fish each from three urban rivers in Maine were analyzed. No PFCs were detected in chain pickerel from the Saco River above Saco, but concentrations of PFOS in smallmouth bass were 16 ng/g in the Androscoggin River at Lisbon and 28 ng/g in the Kennebec River at Waterville. There were a few other PFCs detected at lower concentrations at both sites.

In 2015, in order to more fully assess the occurrence of PFCs in Maine, DEP targeted ten samples of both predator and omnivore fish for collection from five rivers below major municipal sewage treatment plants (STPs). The fish were analyzed for PFCs as two composites of five fish each for each river and species. Despite considerable effort, sample collection was not completely successful. Only ten white perch were collected from the Mousam River at the entrance to Estes Lake downstream of the Sanford STP. Ten smallmouth bass and ten white catfish were collected from the Kennebec River below the Augusta STP. Ten fallfish and ten smallmouth bass were collected from the Sandy River below the Farmington STP. Only six smallmouth bass were collected from the Meduxnekeag River at Lowery Bridge below the Houlton STP. And only three brook trout and eight fallfish were collected below the Caribou STP. All fish were collected by angling. Following DEP standard protocol, fish were rapidly euthanized, placed in a clean plastic bag in a cooler on ice until all samples were obtained, then measured for length and weight, rinsed in stream water, wrapped in aluminum foil shiny side out, labeled and placed in a cooler on ice for transport to the DEP lab where they were then frozen until shipped frozen overnight to the analytical lab for analyses. All fish were analyzed as two composites of three to five fish each

(except for the Aroostook River Brook trout which were analyzed separately) by AXYS Method MLA-043, a modification of EPA Method 537 by AXYS Analytical Services in Sidney, British Columbia, Canada.

The 2015 results show that concentrations of PFCs were low (1 ng/g or less) (Table 3.2.1) similar to levels found in fish from lakes and ponds with no discharges in 2014 except for perflourooctane sulfonate (PFOS). The variance between the two composites at each site was low (Appendix 3.2.3). PFOS was well below MCDC's 2014 SL for subsistence fishers (42 ng/g) for all samples except for white perch in the Mousam River below Sanford where the mean concentration was at the SL. The ratio of the STP discharge to size of the river is much larger for Sanford than any of the other rivers in this study, which may explain these results.

Table 3.2.1. PFCs (ng/g ww) in fish from rivers below municipal sewage treatment plants, 2015

PFC	MSE-WHP	KGD-SMB	KGD-WHC	SRF-FLF	SRF-SMB	MXW-SMB	ACB-BKT	ACB-FLF
PERFLUOROBUTANE SULFONATE	1.0	1.0	0.9	1.0	1.0	1.0	0.9	1.0
PERFLUOROBUTANOATE	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
PERFLUORODECANOATE	0.6	0.8	0.5	0.5	0.5	0.5	0.5	0.5
PERFLUORODODECANOATE	1.0	0.7	0.5	0.5	0.5	0.5	0.5	0.5
PERFLUOROHEPTANOATE	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
PERFLUOROHEXANE SULFONATE	1.0	1.0	0.9	1.0	1.0	1.0	0.9	1.0
PERFLUOROHEXANOATE	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
PERFLUORONONANOATE	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
PERFLUOROOCTANE SULFONATE	42.9	7.0	1.0	2.0	2.6	4.9	4.1	2.3
PERFLUOROOCTANE SULFONAMIDE	0.6	0.6	0.5	0.6	0.6	0.6	0.6	0.6
PERFLUOROOCTANOATE	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
PERFLUOROPENTANOATE	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
PERFLUOROUNDECANOATE	0.8	0.8	0.5	0.5	0.5	0.6	0.5	0.5
MOISTURE %	77	78	80	77	76	77	73	76

MSE-WHP = Mousam River white perch at entrance to Estes Lake below Sanford STP (Sewage Treatment Plant)
KGD-SMB = Kennebec River smallmouth bass below Augusta STP
KGD-WHC = Kennebec River white catfish below Augusta STP
SRF-FLF = Sandy River fallfish below Farmington STP
SRF-SMB = Sandy River smallmouth bass below Farmington STP
MXW-SMB = Meduxnekeag River smallmouth bass at Lowrey Bridge below Houlton STP
ACB-BKT = Aroostook River brook trout below Presque Isle and Caribou STPs
ACB-FLF = Aroostook River fallfish below Presque Isle and Caribou STPs

In 2016, to confirm the elevated level in the Mousam River fish with respect to consumption by anglers, ten white perch and ten bass from Estes Lake were collected and analyzed as two composites of five fish each for PFCs. In addition, given recent detection of PFCs in groundwater nearby, the same species of fish were also to be sampled from stations upstream at Number One Pond in downtown Sanford, a popular fishing spot above the STP and at Mousam Lake, a regional reference water upstream of Sanford. Again, and despite assistance from the Department of Inland Fisheries and Wildlife Regional Fishery Biologists, sample collection was not completely

successful. While ten white perch were again captured at Estes Lake and ten largemouth bass were also collected there, only ten largemouth bass were collected in Number One Pond and only 8 largemouth bass were collected from Mousam Lake.

Although the 2016 fish were collected from Estes Lake proper rather than from the Mousam River 100 m upstream of the lake as was the case in 2015, the fish, particularly the white perch, are expected to be from the same population in both sample locations, as they are pelagic likely roaming the entire pond and into the Mousam River. Results show that 2016 concentrations of PFCs in white perch from Estes Lake were similar to those from 2015 (Table 3.2.2). Concentrations of most congeners were undetected. PFOS was the only congener detected at significant levels. Concentrations of PFOS in white perch in the Mousam River below Sanford were similar to those from 2015 near MCDC's new 2016 SL for Maine Recreational Anglers (44 ng/g) and well above the 2016 SL for subsistence fishers (11 ng/g). Concentrations in largemouth bass from the same site were similar to those of the white perch. Concentrations of PFOS were much lower in largemouth bass from Number One Pond in downtown Sanford, approaching the SL for subsistence fishers, and even lower above Sanford at Mousam lake in Acton, well below MCDC's SL for subsistence fishers. The variance between the two composites at each site was small and there was no relationship between fish PFC concentrations and fish size (Appendices 3.2.3 -3.3.4).

Table 3.2.2. PFCs (ng/g ww) in fish from Estes Lake, Number 1 Pond, and Mousam Lake, 2016

PFC	MSE-WHP	MSE-LMB	NUM 1 P-LMB	MOUSAM L-LMB
PERFLUOROBUTANE SULFONATE	1.0	1.0	1.0	1.0
PERFLUOROBUTANOATE	0.5	0.5	0.5	0.5
PERFLUORODECANOATE	0.5	0.5	0.5	0.5
PERFLUORODODECANOATE	0.5	0.5	0.6	0.6
PERFLUOROHEPTANOATE	0.5	0.5	0.5	0.5
PERFLUOROHEXANE SULFONATE	1.0	1.0	1.0	1.0
PERFLUOROHEXANOATE	0.5	0.5	0.5	0.5
PERFLUORONONANOATE	0.5	0.5	0.5	0.5
PERFLUOROOCTANE SULFONATE	41.9	38.1	9.6	1.1
PERFLUOROOCTANE SULFONAMIDE	0.5	0.5	0.5	0.5
PERFLUOROOCTANOATE	0.5	0.5	0.5	0.5
PERFLUOROPENTANOATE	0.5	0.5	0.5	0.5
PERFLUOROUNDECANOATE	0.5	0.6	0.5	0.8
MOISTURE	76.7	79.3	80.1	79.2

MSE-WHP = Mousam River white perch at entrance to Estes Lake below Sanford STP (Sewage Treatment Plant)
MSE-LMB = Mousam River largemouth bass at entrance to Estes Lake below Sanford STP (Sewage Treatment Plant)
NUM 1 P LMB = Number One Pond largemouth bass in downtown Sanford
MOUSAM L - LMB = Mousam Lake largemouth bass in Acton

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3.2.2. Red Brook PCBs

Red Brook in Scarborough had, on its bank, a recycling facility that became contaminated with PCBs. There is also a landfill adjacent to the brook that was used for disposal of pulp and paper

mill waste as well as other commercial and municipal waste. Previous analyses of brook trout from Red Brook have documented fluctuating levels of PCBs, all above the MeCDC's Fish Tissue Action Level (FTAL=11 ng/g) resulting in a Fish Consumption Advisory for the brook. Since 2009, the recycling facility has been remediated. Contaminated soil adjacent to the brook has been removed or consolidated into concrete on site. There was a desire to determine if the remediation has resulted in lower concentrations in fish. Consequently, 10 brook trout were collected and analyzed for total PCBs as two composites of five fish.

In 2015, ten brook trout were collected by electrofishing Red Brook at DEP's macroinvertebrate sampling station below Running Hill Road as part of a fish community assessment for development of an Index of Biotic Integrity for fish (Table 3.2.3). Following DEP standard protocol, fish were kept alive in a bucket until the sampling event was completed, then rapidly euthanized, measured for length and weight, rinsed in stream water, wrapped in aluminum foil shiny side out, labeled and placed in a cooler on ice for transport to the DEP lab where they were then frozen until shipped frozen overnight to the analytical lab for analyses. The fish were analyzed as two composites of five fish by EPA method 1668A at AXYS Analytical Services.

The 2015 results show that concentrations were not lower, but in fact much higher than in previous years (Table 3.2.2). Consequently, as a check on the veracity of the data, in 2016, the study was repeated. The 2016 results showed that concentrations were intermediate of the 2015 and earlier levels. Note that the 2016 brook trout were slightly smaller than those in 2015, which might account for the difference between years, although with only 2 composite samples for each year, it is difficult to determine if the concentrations are affected by size or are significantly different. In either case, all samples exceeded the FTAL.

Table 3.2.2. Total PCBs in brook trout from Red Brook , mean (max)

Year	Species	PCB ng/g
1994	BKT	60 (70)
2000	BKT	22 (25)
2009	BKT	53 (59)
2015	BKT	244 (247)
2016	BKT	107 (118)

Lengths and weights of brook trout sampled 2015 & 2016

SAMPLE ID	LENGTH mm	WEIGHT g
2015		
RBS-BKT1	156	47.1
RBS-BKT2	168	47.2
RBS-BKT3	185	60.9
RBS-BKT4	215	102.2
RBS-BKT5	220	104.8
RBS-BKT6	154	37.4
RBS-BKT7	165	53.5
RBS-BKT8	165	49.4
RBS-BKT9	170	55.5
RBS-BKT10	186	63.7
mean	**178**	**62**
2016		
RBS-BKT1	176	56
RBS-BKT2	190	73
RBS-BKT3	175	57
RBS-BKT4	158	45
RBS-BKT5	163	47
RBS-BKT6	156	37
RBS-BKT7	160	40
RBS-BKT8	152	33
RBS-BKT9	150	35
RBS-BKT10	154	40
mean	**163**	**46**

3.2.3 Goosefare Brook Metals and PCBs

Goosefare Book in Saco is listed by DEP as an urban impaired stream and has a long history of contamination due to urban runoff, a current firearms manufacturing facility, and a former metal Remediation and Waste Management (BRWM). BRWM continues implementation of clean-up projects at the metal recycling facility including monitoring of water and sediment at the site. The City of Saco, York County Soil and Water Conservation District, and DEP are developing a watershed management plan to address the water quality problems. Recent discovery of brook trout in the stream have led to the questions of ecological effects and safety of human consumption of the trout. Therefore, 6-10 brook trout were to be collected and analyzed as 2 composites for metals and PCBs, both of which have been found elevated in the stream. A total of 6 brook trout were collected.

Six brook trout of legal size (>150 mm) were collected by electrofishing Goosefare Brook at DEP's macroinvertebrate sampling station at the Park and Ride on Industrial Park Road as part of a fish community assessment for development of an Index of Biotic Integrity for fish (Table 3.2.3). Following DEP standard protocol, fish were kept alive in a bucket until the sampling event was completed, then rapidly euthanized, measured for length and weight, rinsed in stream water, wrapped in aluminum foil shiny side out, labeled and placed in a cooler on ice for transport to the DEP lab where they were then frozen until shipped frozen overnight to the analytical lab for analyses. The fish were analyzed as two composites of three fish each by AXYS Analytical Services for the PCBs and by the Battelle Marine Sciences Laboratory in Sequim, Washington for silver, arsenic, cadmium, lead and selenium via ICP-MS – EPA Method 1638 and EPA Method 200.8 and for aluminum, chromium, copper, iron, nickel, and zinc via ICP-OES – EPA Method 6010B and EPA Method 200.7.

Results show that mean concentrations of metals in Goosefare Brook brook trout (GFS-BKT) were below No Observable Effects Concentrations (NOEC) for fish for all metals with such NOECs except for copper (Table 3.2.3). Given that the concentrations of copper exceeded the NOEC for only one of the two composites and that there was a wide variation in concentrations between the two composites, these data should not be considered as definitive. In fact, since these NOECs were based on syntheses of limited studies, this assessment of GFS-BKT should be considered a screening level analysis. These fish tissue residue data do not address potential toxicity to other aquatic organisms from exposure to heavy metals in the sediments or water column, which can be better addressed by other methods. Mean concentrations in GFS-BKT were also below the MeCDC's Fish Tissue Action Levels (FTALs) for human consumers, where there are any, for all but arsenic (As). Arsenic was measured as total As, but it is inorganic As that is the toxic species, estimated as ~10% of total in fish tissue, making the estimate of toxic As only slightly higher than the FTAL. Concentrations of most metals were also lower than those in brook trout from two streams with no direct discharges or significant non-point sources, Cold Brook in Skowhegan and the Pleasant River in Deblois, considered as background levels. Concentrations of chromium, copper, and zinc in Goosefare Brook trout were slightly higher than background concentrations, but well within an order of magnitude and not considered significant.

Table 3.2.3. Lengths, Weights, and Heavy Metals in Brook Trout from Goosefare Brook, Saco (ww)

DEP Sample ID	GFS-BKT-C1(1,5,6) ug/g	GFS-BKT-C2(2,3,4) ug/g	**GFS-BKT MEAN** ug/g	NOEC* ug/g	FTAL ug/g	BACKGROUND ug/g
ALUMINUM	30.6	6.45	**18.53**	1000		
ARSENIC	0.276	0.142	**0.21**	1.5	0.014	<0.05
CADMIUM	0.0146	0.0246	**0.02**	0.13	2.2	<0.013
CHROMIUM	0.449	0.71	**0.58**		11	<0.06-0.29
COPPER	0.357	3.33	**1.84**	1.17		0.62-1.10
IRON	0.0897	0.456	**0.27**			
LEAD	0.0201	0.103	**0.06**	2.54		<0.05
MERCURY	0.12	0.172	**0.15**	0.2	0.2	
NICKEL	0.184	1.15	**0.67**		43	
SELENIUM	0.259	0.13	**0.19**	0.6		0.09-0.36
SILVER	0.000649	0.00184	**0.0012**	0.06	11	<0.06
ZINC	17.7	16.9	**17.30**	41.4	648	5.6-10.5

* CH2MHill, 2015.

SAMPLE	LENGTH mm	WEIGHT g
GFS-BKT1	230	136
GFS-BKT2	194	75.6
GFS-BKT3	204	77.0
GFS-BKT4	193	69.5
GFS-BKT5	155	39.7
GFS-BKT6	153	38.5

Concentrations of PCBs (Table 3.2.3b) were well below those from Red Brook but above the FTAL (11 ng/g) for recreational anglers similar to those in fish from many other rivers and streams in populated watersheds in Maine.

Table 3.2.3b. Total PCBs lengths and weights in fish from Goosefare Brook
mean and (max value if n=2 or 95th upper confidence level if n>2) ng/g

Year	Species	Saco
2015	BKT	31 (37)

Reference

CH2MHill, 2015. Summary of Literature-Derived Fish Tissue Toxicity Data for the Baseline Ecological Risk Assessment Halaco Superfund Site, Oxnard, California Remedial Investigation. Prepared for USEPA Region 9 by CH2MHILL, 325 East Hillcrest Drive, Suite 125, Thousand Oaks, California 91360

4.0 SPECIAL STUDIES

PAGE

PRINCIPAL INVESTIGATOR Rebecca Van Beneden, U. Maine

TECHNICAL ASSISTANTS

4.1 **MERCURY TOLERANCE IN MUMMICHOGS FROM THE PENOBSCOT RIVER**

Final Report
Maine Department of Environmental Protection
May 30, 2017
Revised October 20, 2017

Have Mummichog (*Fundulus heteroclitus*) from the lower Penobscot River, Maine,

Develop d Tolerance to the Toxic Effects of Mercury?

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Abstract
Fish populations that are chronically exposed to mercury (Hg) can develop resistance to the toxic effects of this metal, including mummichog (*Fundulus heteroclitus;* Weis 2002). Such resistance allows them to potentially accumulate very high levels of this contaminant (Stefansson et al. 2013). Mercury is a neurotoxin that affects behavior in fish, including swimming and the ability to capture prey (Samson et al. 2001, Zhou et al. 2001), and behavior, reproduction and immune function in birds (Evers et al. 2008, Hawley et al. 2009). Ingestion of mercury-contaminated prey could have significant, and severe, effects on migratory fish and piscivorous birds, including loons (Evers et al. 2008). We found that mercury concentrations in resident mummichog collected from sites in the lower Penobscot River in 2011 were 9 to 16 times higher than Hg levels in mummichog from a control site in Wells, Maine (Elskus 2012). For part one of this study, reproductively mature male and female mummichog were collected in Fall 2015 from two sites in Maine: Bald Hill Cove, a mercury-contaminated site along the mercury gradient of the Penobscot River, and Drake, a reference site at the Wells National Estuarine Research Reserve. These parental fish were housed at the US EPA laboratory (Narragansett, RI). Beginning in Spring 2016, these fish were fed diets containing either low or high concentrations of mercury for 28 days. Embryos were collected from these parents and divided into subsets. One subset was used to measure the mercury concentrations in the embryos, the second subset was shipped to the University of Maine where they were hatched, and the larval fish evaluated for behavioral effects. For part two of this study, adult mummichog were collected from Hg-contaminated Bald Hill Cove and from a reference site, Wells, in the Wells National Estuarine Reserve and evaluated for mercury body burdens and behavior. In Study 1, mercury was maternally transferred to the progeny demonstrating this is one pathway of generational exposure to mercury. Unfortunately, all larvae from the mercury-contaminated Bald Hill Cove population died before behavioral analysis could be done. Behavioral studies of the reference Drake population, however, demonstrated no significant differences between offspring of parents fed high mercury diets and offspring of parents fed low mercury diets. In Study 2, adult fish from the mercury contaminated BHC population had mercury body burdens that were four times higher than those in the reference Wells population, but while fewer BHC adults performed prey strikes than the Wells adults, there were no other significant behavioral differences between the two populations. In conclusion, the main hypothesis, that fish from the site receiving chronic mercury exposure had developed resistance to mercury toxicity, could not be definitively determined due to the death of embryos from the chronically exposed population. However, the present study did reveal some behavioral effects associated with mercury exposure that warrant further study. Behavioral approaches are important because they address some of the basic and difficult questions surrounding contaminant exposures; namely that sub-lethal effects are important to evaluate because they may have consequences for individual and perhaps population survival.

Objective
The goal of the study was to assess the tolerance of the mummichogs from a mercury (Hg)-contaminated region of the Penobscot River (downstream for the Holtachem mercury spill; Rudd et al., 2013) to the toxicity of mercury. It has been shown that killifish fed diets composed of fish that are naturally contaminated with mercury (such as tuna), become highly contaminated with mercury from that diet. There is evidence that fish transfer mercury to their eggs (maternal transfer; Stefansson et al., 2014). But what are the effects on progeny of high levels of maternally-transferred Hg? And, are fish populations resident to/adapted to high Hg environments less

vulnerable to these effects than unexposed (reference) populations? To test these hypotheses, we used killifish resident to two Maine locations known to vary in the concentration of mercury in their sediments and their resident fish populations: Bald Hill Cove (Penobscot River) with elevated mercury concentrations in sediment and resident killifish and Drake (Wells National Estuarine Research Reserve) which has low Hg concentrations in its sediments and resident fish and is considered a reference site (Chen et al., 2016). Fish from these sites were held at the EPA Laboratory in Narragansett, RI and used in a large, multi-faceted study that varied in dietary Hg concentration. The objectives of the present study were to evaluate 1) whether mercury in the diet was transferred from mother to offspring (maternal transfer); and 2) if the transferred mercury affected the behavior of the offspring (progeny), and 3) In a second related study, our objective was to determine whether adult fish from a mercury contaminated population and a reference population differ in their response to behavioral tests that evaluate stress. For this study, we compared the behaviors of a separate group of adult *F. heteroclitus* from Bald Hill Cove compared to adults from a reference site in Wells National Estuarine Research Reserve.

Methods

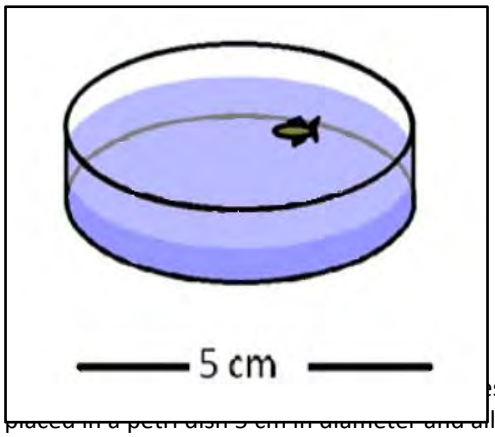
Study 1: Mercury Contamination, Maternal Transfer and Effects on Progeny

Laboratory Exposures

Dietary exposures to mercury were carried out at the US EPA Laboratory (Narragansett, RI). Bald Hill Cove (BHC) fish (mercury contaminated site) and Drake fish (reference site) were used for these studies. Prior to initiation of the dietary study, sub-samples of the diets and the fish were archived for measurement of % lipid and mercury content by US EPA personnel. For the dietary study**,** two replicate tanks of each population were fed either a low Hg diet (flake food supplemented with pink salmon, a fish naturally low in Hg) or a high Hg diet (flake food supplemented with tuna, a fish naturally high in Hg). The dietary exposure study ran for 28 days during which time the fish were strip spawned at intervals associated with lunar cycling. Sub-sets of embryos from all treatment groups were stored at US EPA for later analysis of mercury content. A sub-set of embryos from all four treatment groups were shipped to Maine for morphological assessment, hatching and behavioral analysis of the progeny (5 days post hatch (dph).

Progeny Behavioral analysis: Spontaneous Movement

Embryos received were from: 1) female fish from Drake fed tuna (high Hg diet); 2) female fish from Drake fed salmon (low Hg diet); 3) female fish from BHC fed tuna (high Hg diet); 4) female fish from BHC fed salmon (low Hg diet). Embryos were placed into individual wells in a 24-well plate. Each well held 2mL of 30ppt salt water. Water changes were done daily. After the first embryo hatched, hatching was stimulated for the remaining embryos to synchronize development. All water was removed from the wells for one hour then replaced. The plates were then placed on a rocker overnight to assist in hatching. After hatching, fish were fed 1-3 day-old brine shrimp daily.



st. Fish are placed in a petri dish 5 cm in diameter and allowed to swim freely while their movements are video recorded.

At 5 dph the spontaneous movement test was performed. Individual fish were placed in a petri dish (~5 cm in diameter) and allowed to swim freely for 3 minutes and filmed for the duration of the test. These videos were then analyzed using idTracker to track the fish's location within the arena at every frame. This information was then used to calculate the total distance traveled over the course of the test. After testing was complete, the fish were sacrificed per IACUC approved protocols (Univ. of Maine, A2016-03-11).

Study 2: Environmental Exposures

Collection and maintenance of fish

Adult *F. heteroclitus* were collected from two locations in Maine. Bald Hill Cove on the Penobscot River, ME, is known to have heavy metal contamination, and fish collected from this site were used as experimental targets in this study. Fish were also collected from a public boat dock in Wells, ME, a site considered to have relatively low heavy metal contamination. Fish were trapped using baited minnow traps. Approximately equal numbers of males and females (35 fish were taken from Bald Hill Cove and 30 fish from Wells Reserve) were brought back to the lab. Fish were held in two separate 40 gallon tanks (one for the Bald Hill Cove fish and one for the Wells fish) at the Aquaculture Research Center at the University of Maine, Orono, for approximately two weeks prior to experimental testing and fed a diet of Mazuri gel fish food once a day. Water quality was checked every other day and 50% water changes were made as needed. Following the two-week acclimation period, fish were divided into smaller, 10 gallon tanks (~5 fish per tank) to keep track of individual fish without the need to mark or tag them.

Tissue sampling for mercury analysis

For Study 2, biopsies were collected from adult *F. heteroclitus* collected in 2016 at Bald Hill Cove, Penobscot River and Wells Reserve in Wells, Maine as described previously (Elskus 2012). Muscle tissue was immediately frozen and maintained at – 80°C until analysis. Muscle biopsy samples were analyzed at the Sawyer Environmental Chemistry Research Laboratory at the University of Maine, Orono, by a Milestone DMA-80 Direct Mercury Analyzer. All analyses were accompanied by appropriate QA/QC samples, including analyzing 10% of the samples in duplicate, 10% of the samples for matrix spikes, procedural blanks, standards, and mercury reference materials.

Behavioral Analysis: Predator Avoidance (environmentally exposed fish)

In the wild, there are a number of important behavioral characteristics killifish must exhibit in order to evade predation. This experiment observes how groups of killifish react in response to a bird attack from overhead. A large aquarium was elevated above the ground with a clear bottom in order for a camera to be placed underneath. The cutout of a bird figure was then attached to a line over the tank. When the string was pulled, the bird would glide over the tank at a constant

speed, simulating a bird swooping over the water. Groups of 4-5 fish were given an acclimation period of 10 minutes in the test tank before the bird was flown over the tank. After the "attack", fish behavior was recorded for another 10 minutes. Control and experimental trials were divided into three groups each (n=6 groups of 5 fish). Each group was subjected to three trials with at least 24 hours of recovery between each trial.

Behavioral Analysis: Scototaxis (environmentally exposed fish)
To measure light/dark preference as an indicator of anxiety, one half of a testing aquarium was subjected to a bright, white light; the other half of the aquarium was covered on the outside with black fabric and was dimly lit. Fish were allowed to acclimate in the testing aquarium for five minutes before video cameras were turned on and the trial began. The fish were free to swim anywhere in the tank for 10 minutes. The percent of time a fish spent on either side of the tank was calculated to determine a dark/light preference.

Behavioral Analysis: Foraging (environmentally exposed fish)
Approximately one week before testing, fish from either the control or experimental group were moved into smaller holding aquaria in order to identify a single fish over multiple test trials. Two fish were held in each aquarium with one male and one female in each. Fish were introduced to a new diet of mealworms before the foraging trial. Fish were starved 24 hours prior to testing.

Fish were tested individually during this experiment in a separate testing aquarium with a camera positioned above the tank. Each fish was given an acclimation period of five minutes before dropping in three pieces of mealworm. Once the food entered the testing area, fish were given 10 minutes for the trial. The duration of the trial continued until either all three pieces of food were finished or until the trial reached the full 10 minutes. Data were collected for total number of strikes on the "prey". A "successful strike" occurred when a fish fully engulfed a piece of food in its mouth. "Unsuccessful strikes" were recorded when a fish missed or did not fully engulf a piece of food. The time of the first strike after the start of the trial and the time of completion were also recorded. Each fish was subjected to three trials over the course of the experiment. After all three trials, fish length and sex were recorded before placing them back into the large holding aquarium.

Results

Survival of embryos shipped to U Maine

Larvae from the Bald Hill Cove population (high Hg site) did not survive to 5 days post hatch (dph) while larvae from the Drake population (reference site) were unimpaired. The reason for the mortality of the Bald Cove larvae is not clear as there was no sign of fungus, or physical damage. Colleagues at the US EPA laboratory who shipped the larvae to us saw no mortality in the Bald Hill Cove offspring that remained in their facility. The cause of the BHC embryo-larval mortality remains unidentified.

Study 1: Laboratory Exposure

Uptake of mercury in adult female fish and eggs in the laboratory study

Analysis of total mercury in adult females fed tuna revealed that they did accumulate mercury at significantly higher levels than did control fish fed salmon (**Table I, Fig 1**) and that the mercury was transferred to their offspring (eggs, **Table II, Fig 1**). Embryos sent to the University of Maine for behavioral analysis were also examined for gross morphological abnormalities (*i.e.*, heart, spinal cranial facial deformities). No morphological abnormalities were observed.

Table I Adult Total Hg concentration

population	food	ave total Hg (ppb DW)	s.d. total Hg	n
Bald Hill	pre	403	112.2	6
Drakes	pre	187	32.7	6
Bald Hill	tuna	1351	349.7	6
Bald Hill	salmon	370	59.5	6
Drakes	tuna	1069	198.3	6
Drakes	salmon	238	33.5	6

Table II MeHg in Unfertilized Eggs

tank ID	MeHg (ppb DW)	population	feed
1	13.84	Bald Hill	tuna
2	8.73	Drakes	tuna
3	11.68	Bald Hill	salmon
5	25.64	Bald Hill	tuna
6	4.39	Drakes	tuna
7	12.60	Bald Hill	salmon
8	7.29	Drakes	salmon
9	11.75	Bald Hill	tuna
10	5.97	Drakes	tuna
11	8.76	Bald Hill	salmon
12	12.87	Drakes	salmon
1	34.15	Bald Hill	tuna
2	39.25	Drakes	tuna
3	10.35	Bald Hill	salmon
4	10.49	Drakes	salmon
5	35.02	Bald Hill	tuna
6	36.31	Drakes	tuna
7	8.76	Bald Hill	salmon
8	8.67	Drakes	salmon
9	37.47	Bald Hill	tuna
10	40.16	Drakes	tuna
11	11.12	Bald Hill	salmon
12	9.68	Drakes	salmon
1	103.34	Bald Hill	tuna
5	27.75	Bald Hill	tuna
6	17.95	Drakes	tuna
7	10.45	Bald Hill	salmon
8	10.13	Drakes	salmon
9	61.71	Bald Hill	tuna
10	50.01	Drakes	tuna
11	24.68	Bald Hill	salmon

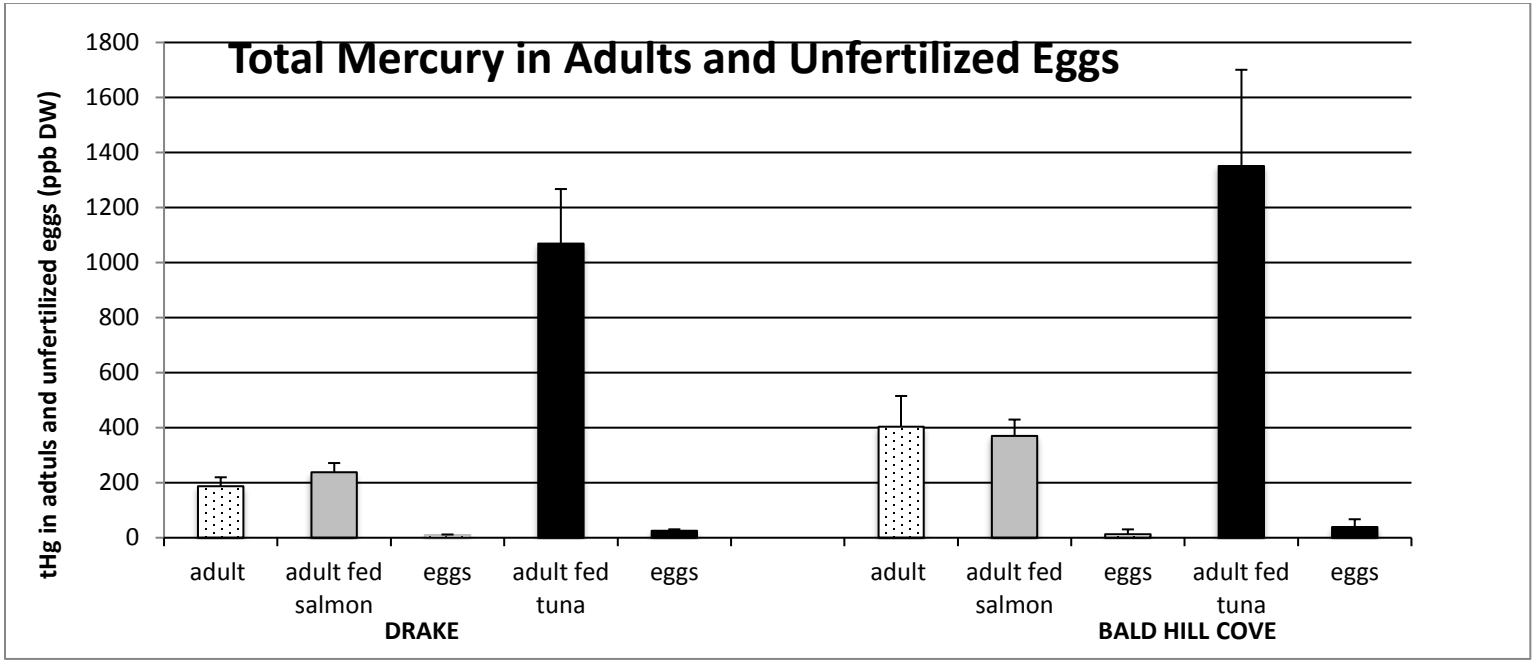


Fig. 1. Total mercury concentrations in adult *F. heteroclitus* from Drake (a reference site in Wells Estuarine Reserve) and Bald Hill Cove (a mercury contaminated site in the Penobscot River). Values were measured in fish after approximately 9 months of depuration (adult) and after 28 days of exposure to dietary mercury (low mercury salmon, or high mercury tuna), and in eggs stripped from the fed fish. Values are n=6 (adults) and n=6 to 9 (eggs) ± SD.

Spontaneous movement:

As noted above, larvae from Bald Hill Cove females (high Hg site) did not survive to 5 days post hatch (dph) and, therefore, were not tested. The spontaneous movement test was run only on 5 dph larvae from Drake females (reference site) fed either salmon (low Hg diet) or tuna (high Hg diet). There was no significant difference between these two groups in total distance traveled (**Fig. 2, 3**). These data were normally distributed so a student's t-test was used to check for significance ($p=0.504$). Using MATLab we were also able to calculate how long each fish spent in the center of the arena. The arena was divided into two parts of equal area, an outer ring and the center (**Fig. 3**). Time in the center is calculated as the number of frames spent in the center of the arena divided by 30 frames per second. There was no significant difference between these two groups in time spent in the center ($p = 0.9$) although there appears to be a trend in progeny of fish fed a high Hg diet to spend more time around the outer edge of the arena (**Fig. 4**).

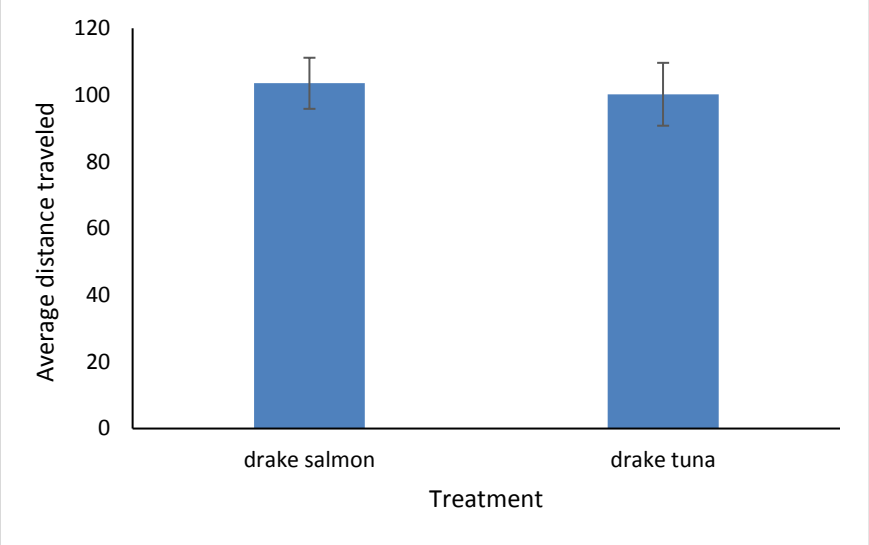


Fig. 2. Average distance traveled (cm) over a three-minute period in the spontaneous movement test. There was no significant difference in distance moved. Progeny (5 dph) from Drake female fish fed salmon (low Hg diet) n=22; for those fed tuna, n=38. Error bars are standard error.

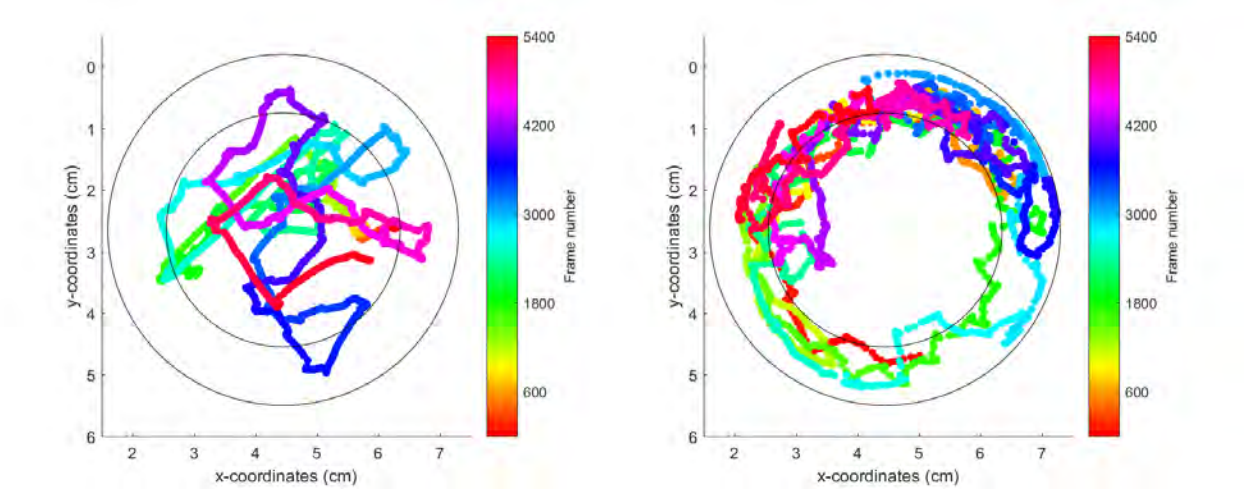


Fig. 3. Representative swimming patterns from a reference fish (left) and an exposed fish (right) in the spontaneous movement test. Each point on the graph represents the fish's location in one frame of the video (30 frames per second) over a three-minute period. The black circles show the approximate location of the arena wall (the outer circle) and the center of the arena (the inner circle). The color bar shows passing time starting with **red** and ending with **magenta**. Over time, the later positions overlay the earlier ones.

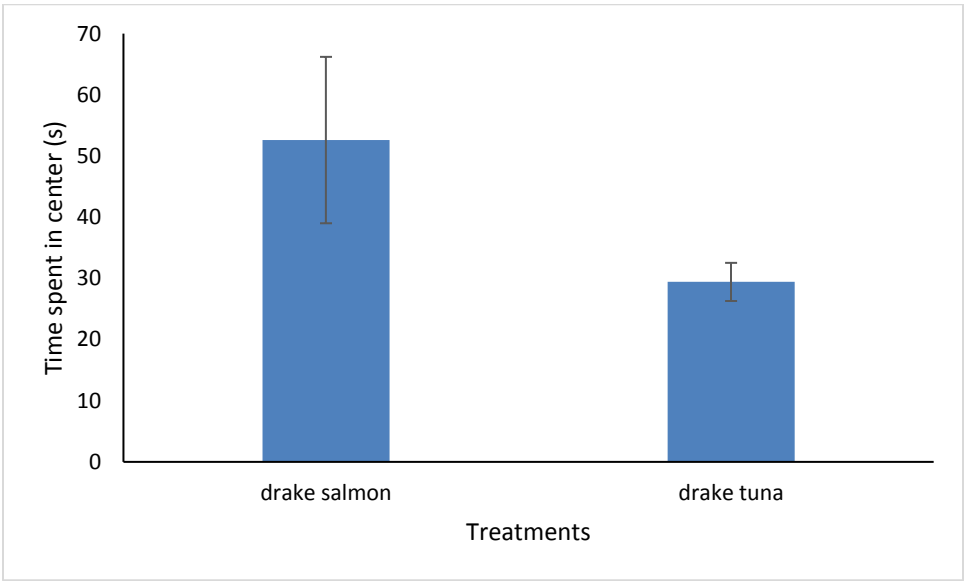


Fig. 4. Average time spent in the center of the arena in the spontaneous movement test. Center of the arena is defined at the center half of the total area. Sample size is 22 for Drake salmon and 38 for drake tuna. Error bars are standard error

Study 2: Environmentally exposed adult fish

Mercury concentrations in adult *F. heteroclitus* used in Study 2 ranged from an average of 147 ppb Hg dry weight (males) to 157 ppb Hg dry weight (females) for fish from the reference population in Wells, Maine and an average of 641 ppb (males) to 761 ppb (females) for the mercury contaminated, Bald Hill Cove population (Table III). Because there were no sex differences within populations, statistical analyses were carried out on combined sexes. These analyses indicated that average mercury concentrations in Bald Hill Cove fish were over 4 times higher than average mercury levels in Wells fish.

Predator avoidance

Shoals of 5 fish from each experimental (BHC) and control (Wells) groups were subjected to a simulated predator attack and observed over the course of three trials. There was no statistical correlation across individual trials (data not shown). The results indicate that the movements of the fish in each frame were not significant and that the distance between individual fish in the shoal was not affected by the introduction of the bird (predator).

Foraging behavior

Significantly more control individuals were striking at prey items than individuals from BHC. A total of 20 fish for each trial group were placed in the tank and given prey items. Only half (n=10) of the experimental fish attempted to strike at prey items, compared to 17 of 20 control fish ($p=0.018$). These results suggest lower motivation for the mercury-exposed fish to feed, even though all fish were starved 24 hours before each foraging trial.

Despite differences in the number of fish from each population that made prey strikes noted above, there was no significant difference between successful and unsuccessful strikes (Fig. 5). A successful strike was defined as the entire food particle is engulfed; unsuccessful strike, attempted to eat but "missed" acquiring food.

Table III: Adult male and female *F. heteroclitus* collected in Maine from Wells Reserve and from Bald Hill Cove in the Penobscot River for Study 2.

site	ID#	Length(cm)	Weight (g)	w/l	Gender	ppg Hg (dw)	% moisture
Wells	W-81516-01	9	7.35	0.82	female	170	73.99
Wells	W-81516-03	8	4.69	0.59	female	164	75.52
Wells	W-81516-05	8	4.68	0.59	female	162	75.01
Wells	W-81516-06	8.2	3.99	0.49	female	171	75.79
Wells	W-81516-08	8.2	5.22	0.64	female	115	70.26
Wells	W-81516-10	6.9	3.65	0.53	female	159	75.02
average females Wells		**8.05**	**4.93**	**0.61**		**157**	**74.26**
Wells	W-81516-02	5.6	1.46	0.26	male	168	71.71
Wells	W-81516-04	7	3.15	0.45	male	121	73.70
Wells	W-81516-07	6.3	1.66	0.26	male	156	76.99
Wells	W-81516-09	6	1.84	0.31	male	144	76.12
average males Wells		**6.23**	**2.03**	**0.32**		**147**	**74.63**
BHC	BH-81516-02	6.6	1.9	0.29	female	936	72.54
BHC	BH-81516-03	6.3	2.08	0.33	female	753	74.22
BHC	BH-81516-05	7	3.04	0.43	female	597	73.34
BHC	BH-81516-06	7.1	2.56	0.36	female	639	77.45
BHC	BH-81516-08	6.6	1.9	0.29	female	880	78.86
average females BHC		**6.72**	**2.3**	**0.34**		**761**	**75.28**
BHC	BH-81516-01	8.4	5.55	0.66	male	953	73.56
BHC	BH-81516-04	6.8	2.85	0.42	male	505	73.91
BHC	BH-81516-07	5.9	1.66	0.28	male	*	*
BHC	BH-81516-09	6.6	2.78	0.42	male	503	74.92
BHC	BH-81516-10	5.8	1.42	0.24	male	605	77.10
average males BHC		**6.7**	**2.852**	**0.41**		**641**	**74.87**

*** sample lost**

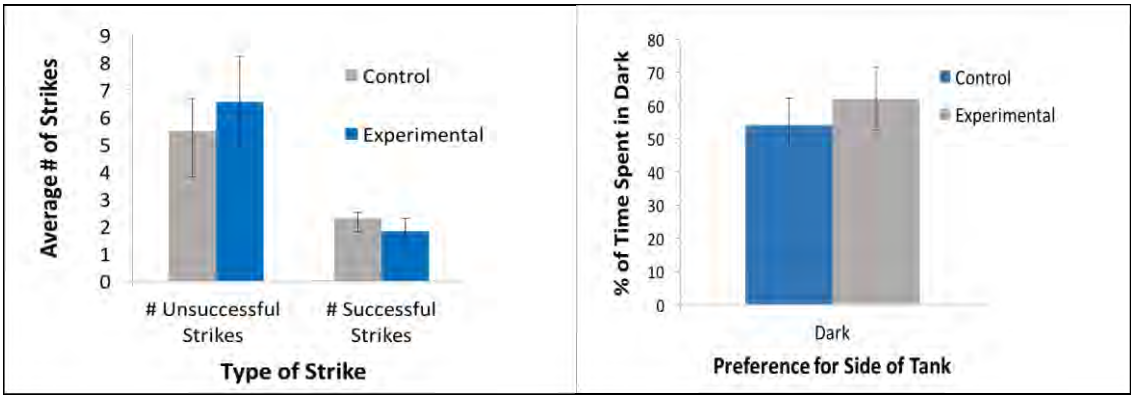


Fig 5. Average number of strikes on prey based on the type of strike compared across control and experimental groups. Error bars represent standard
standard error. Unsuccessful strikes, p= 0.946; Successful strikes, p=0.075; n= 20 fish/group.

Fig 6. Percent of time individuals spent on darkened side of tank compared to lightened side of tank. Error bars represent

error. p= 0.532; n=10 fish/group.

Scototaxis: Dark/Light Preferences

Results show no significant difference between control and experimental groups for preference of darkened side of tank (Fig.6). Fish (n=10) were chosen at random from each group and therefore, do not correlate with individual behavior across trials. Future studies may benefit if multiple behaviors are compared across individuals.

Discussion

The ability of fish to develop resistance to toxic chemicals has been well established. There have been numerous reports of fish acquiring tolerance to a variety of toxins, including dioxins, polychlorinated biphenyls, polynuclear aromatic hydrocarbons and mercury. Although other fish species are capable of developing tolerance, mummichogs have been the most intensively studied (Nacci et al., 1999; Meyer and Di Giulio, 2003; Greytak et al., 2005; Brown et al., 2016).

As a neurotoxin, mercury adversely affects a wide range of systems, including growth, physiological processes, and behavior. In fish, it provokes severe cranial-facial and spinal abnormalities, alters swimming, prey capture and feeding, and affects immune response, among other endpoints (Samson et al. 2001; Zhou et al. 2001; Weis 2002; Wang et al. 2011). Mercury-resistant populations of *F. heteroclitus* remain unaffected by exposure to mercury at concentrations that cause skeletal deformities and abnormal behavioral in non-resistant reference populations (Weis 2002). Costs associated with mercury tolerance include reduced tolerance to changes in salinity, slower growth rate, slower prey capture rate and a general weakness in adults (Weis and Weis 1989).

In this study, we compared the effects of mercury exposure on populations of mummichogs that were collected from a mercury contaminated site to those from relatively "clean" sites. In Study I,

we observed that mercury was transferred from Hg–laden feed (tuna steaks) to gravid female mummichogs and subsequently into their eggs. We did not observe gross morphological abnormalities in the embryos that we used for behavioral tests. In the spontaneous movement tests, the total distance traveled is an indicator of agitation, and the center of the arena is considered analogous to open water and a stressed fish would be less likely to spend time in open water (Zhou and Weiss, 1998). Based on this, when fish are initially placed into the arena we would expect to see a quick burst of movement (escape response) followed by a period of little movement (alertness for danger) and, finally, movement around the entire arena (exploratory behavior). Although there was a tendency for Drake offspring of the exposed fish (tuna-fed parents, high Hg diet) to spend less time in the center of the arena than the control fish (salmon-fed parents, low Hg diet), there was no significant difference between the 2 groups. In the adult studies, one behavioral test demonstrated a significant response to Hg exposure, with reference site adults (Wells) making more prey strikes than mercury site adults (Bald Hill Cove). The importance of behavioral approaches is demonstrated by Brown et al. (2016) who found that early embryonic exposure to polynuclear aromatic hydrocarbon-contaminated sediment pore water caused long-term locomotor and behavioral alterations in *F. heteroclitus*, and that locomotor alterations could be observed in early larval stages.

Mercury body burdens were similar in adult fish from reference sites in Study 1 (Drake, 187+/-32 ppb) and Study 2 (Wells, 153+/-20 ppb). For the mercury contaminated Bald Hill Cove site, mercury body burdens were slightly lower in Study 1 (403+/-112) than in Study 2 (708+/-178), likely due to Study 1 BHC fish depurating some of their Hg body burdens during the several months the fish were held at the USEPA laboratory prior to the start of the feeding study.

The behavior of adult fish from Hg- contaminated Bald Hill Cove (BHC) was compared to those from the relatively "clean" Wells Reserve. No differences between groups were observed in predator avoidance or light/dark preference, a classic measure of anxiety. Control individuals, however, were significantly more active in foraging for prey than were fish from Hg-contaminated BHC. Curiously, the female fish from Wells were significantly larger than male fish from Wells and larger than both genders from BHC. The significance of this size difference is not known.

In conclusion, the hypothesis that fish from the site receiving chronic mercury exposure had developed resistance to mercury toxicity could not be definitively determined due to the death of embryos from that population prior to testing. However, the present study did reveal some behavioral effects associated with mercury exposure that warrant further study. Behavioral approaches are important because they address some of the basic and difficult questions surrounding contaminant exposures; namely that sub-lethal effects are important to evaluate because they may have consequences for individual and perhaps population survival.

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Appendix 2.1. Lengths, weights, & mercury levels in Black Crappie in Maine Lakes & Ponds, 2015			
LAKE/ SAMPLE	L mm	W g	Hg ug/g
THREEMILE P LK5416			
LK5416-BLC1	309	315	0.17
LK5416-BLC2	284	336	0.14
LK5416-BLC3	330	469	0.19
LK5416-BLC4	302	410	0.26
LK5416-BLC5	256	264	0.25
LK5416-BLC6	277	285	0.07
LK5416-BLC7	311	391	0.13
LK5416-BLC8	318	477	0.36
LK5416-BLC9	294	356	0.22
LK5416-BLC10	291	399	0.19
MEAN	**297**	**370**	**0.20**
STD	**22**	**72**	**0.08**
UNITY P LK 5172			
LK5172-BLC1	234	177	0.54
LK5172-BLC2	304	436	0.19
LK5172-BLC3	283	319	0.36
LK5172-BLC4	243	192	0.37
LK5172-BLC5	243	200	0.19
LK5172-BLC6	270	273	0.52
LK5172-BLC7	290	374	0.27
LK5172-BLC8	285	344	0.28
LK5172-BLC9	268	304	0.37
LK5172-BLC10	257	259	0.23
MEAN	**268**	**288**	**0.33**
STD	**23**	**84**	**0.13**
MEAN of all 50 fish	**297**	**416**	**0.26**

Appendix 2.2. Lengths, weights & mercury levels in Black Crappie from Maine Lakes & Ponds, 2016

LAKE SAMPLE	LENGTH mm	WEIGHT g	Hg µg/g ww
COBBOSSEECONTE LAKE LK5236			
LK5236-BLC1	320	440	0.168
LK5236-BLC2	285	285	0.124
LK5236-BLC3	278	290	0.155
LK5236-BLC4	352	625	0.249
LK5236-BLC5	270	210	0.145
LK5236-BLC6	260	225	0.160
LK5236-BLC7	324	450	0.218
LK5236-BLC8	306	350	0.203
LK5236-BLC9	316	405	0.259
LK5236-BLC10	344	480	0.278
MEAN	**306**	**376**	**0.196**
STD	**31**	**129**	**0.053**
HERMON POND LK 2286			
LK2286-BLC1	237	190	0.176
LK2286-BLC2	237	180	0.228
LK2286-BLC3	246	190	0.281
LK2286-BLC4	240	170	0.145
LK2286-BLC5	221	150	0.158
LK2286-BLC6	245	180	0.615
LK2286-BLC7	225	140	0.151
LK2286-BLC8	243	180	0.254
LK2286-BLC9	250	210	0.172
LK2286-BLC10	236	170	0.712
MEAN	**238**	**176**	**0.289**
STD	**9**	**20**	**0.204**
LITTLE COBBOSSEECONTE LAKE LK8065			
LK8065-BLC1	332	530	0.304
LK8065-BLC2	325	485	0.308
LK8065-BLC3	352	600	0.248
LK8065-BLC4	344	565	0.277
LK8065-BLC5	320	480	0.228
LK8065-BLC6	277	290	0.155
LK8065-BLC7	265	260	0.141
LK8065-BLC8	269	280	0.148
LK8065-BLC9	348	520	0.302
LK8065-BLC10	332	460	0.291
MEAN	**316**	**447**	**0.240**
STD	**33**	**125**	**0.069**

Appendix 2.2. Lengths, weights & mercury levels in Black Crappie from Maine Lakes & Ponds, 2016			
LAKE SAMPLE	**LENGTH mm**	**WEIGHT g**	**Hg µg/g ww**
PLEASANT POND LK5254			
LK5254-BLC1	254	200	0.458
LK5254-BLC2	271	265	0.331
LK5254-BLC3	254	195	0.486
LK5254-BLC4	303	315	0.583
LK5254-BLC5	282	260	0.563
LK5254-BLC6	258	195	0.541
LK5254-BLC7	244	175	0.293
LK5254-BLC8	276	245	0.495
LK5254-BLC9	260	220	0.238
LK5254-BLC10	236	170	0.131
MEAN	**264**	**224**	**0.412**
STD	**20**	**46**	**0.154**
SAND POND LK5238			
LK5238-BLC1	270	285	0.296
LK5238-BLC2	263	250	0.256
LK5238-BLC3	282	335	0.401
LK5238-BLC4	199	115	0.092
LK5238-BLC5	290	335	0.310
LK5238-BLC6	250	260	0.235
LK5238-BLC7	222	160	0.107
LK5238-BLC8	252	240	0.255
LK5238-BLC9	308	415	0.399
LK5238-BLC10	264	275	0.315
MEAN	**260**	**267**	**0.267**
STD	**32**	**86**	**0.104**
SIBLEY POND LK2612			
LK2612-BLC1	270	270	0.374
LK2612-BLC2	310	300	0.958
LK2612-BLC3	246	200	0.177
LK5326-BLC8	260	225	0.318
LK2612-BLC5	278	290	0.451
LK2612-BLC6	266	240	0.287
LK2612-BLC7	266	230	0.434
LK2612-BLC8	243	195	0.193
LK2612-BLC9	268	240	0.620
LK2612-BLC10	272	280	0.403
MEAN	**268**	**247**	**0.421**
STD	**18**	**37**	**0.229**

Appendix 2.2. Lengths, weights & mercury levels in Black Crappie from Maine Lakes & Ponds, 2016			
LAKE SAMPLE	**LENGTH mm**	**WEIGHT g**	**Hg µg/g ww**
WOODBURY POND LK5240			
LK5240-BLC1	288	320	0.375
LK5240-BLC2	280	300	0.268
LK5240-BLC3	300	360	0.368
LK5240-BLC4	286	350	0.314
LK5240-BLC5	335	580	0.475
LK5240-BLC6	252	240	0.214
LK5240-BLC7	272	310	0.259
LK5240-BLC8	264	250	0.205
LK5240-BLC9	266	270	0.242
LK5240-BLC10	284	320	0.343
MEAN	**283**	**330**	**0.306**
STD	**23**	**96**	**0.085**
MEAN of all 70 fish	**276**	**295**	**0.30**

Appendix 3.2.1. Perfluoronated Compounds in fish from some Maine rivers, 2015 (ng/g ww)					
DEP Sample ID	MSE-WHP-C1(2,5,6,7,8)		MSE-WHP-C2(1,3,4,9,10		MSE-WHP
Lab Sample ID	L24243-1		L24243-2		mean
Sample Date	7/21/2015		7/21/2015		
Dilution Factor	1		1		
Species					
PERFLUOROBUTANE SULFONATE	0.995	U	0.995	U	0.995
PERFLUOROBUTANOATE	0.4975	U	0.4975	U	0.4975
PERFLUORODECANOATE	0.4975	U	0.7516		0.62455
PERFLUORODODECANOATE	0.8034		1.126		0.9647
PERFLUOROHEPTANOATE	0.4975	U	0.4975	U	0.4975
PERFLUOROHEXANE SULFONATE	0.995	U	0.995	U	0.995
PERFLUOROHEXANOATE	0.4975	U	0.4975	U	0.4975
PERFLUORONONANOATE	0.4975	U	0.4975	U	0.4975
PERFLUOROOCTANE SULFONATE	38.78		47.06		42.92
PERFLUOROOCTANE SULFONAMIDI	0.597	U	0.597	U	0.597
PERFLUOROOCTANOATE	0.4975	U	0.4975	U	0.4975
PERFLUOROPENTANOATE	0.4975	U	0.4975	U	0.4975
PERFLUOROUNDECANOATE	0.7038		0.9078		0.8058
LIPIDS					
MOISTURE	78		76.3		77.15
SOLIDS-TOTAL RESIDUE (TS)					
MSE-WHP = Mousam River white perch at entrance to Estes Lake below Sanford STP (Sewage Treatment Plant)					
KGD-SMB = Kennebec River smallmouth bass below Augusta STP					
KGD-WHC = Kennebec River white catfish below Augusta STP					
SRF-FLF = Sandy River fallfish below Farmington STP					
SRF-SMB = Sandy River smallmouth bass below Farmington STP					
MXW-SMB = Meduxnekeag River smallmouth bass at Lowrey Bridge below Houlton STP					
ACB-BKT = Aroostook River brook trout below Presque Isle and Caribou STPs					
ACB-FLF = Aroostook River fallfish below Presque Isle and Caribou STPs					

Appendix 3.2.1. Perfluoronated Compounds in fish from some Maine rivers, 2015 (ng/g ww)					
DEP Sample ID	KGD-SMB-C1(2,4,5,6,7)		KGD-SMB-C2(1,3,8,9,10		KGD-SMB
Lab Sample ID	L24243-12		L24243-13		mean
Sample Date	8/24/2015		8/24/2015		
Dilution Factor	1		1		
Species					
PERFLUOROBUTANE SULFONATE	0.939	U	0.9804	U	0.9597
PERFLUOROBUTANOATE	0.4695	U	0.4902	U	0.47985
PERFLUORODECANOATE	0.622		1.064		0.843
PERFLUORODODECANOATE	0.5368		0.8056		0.6712
PERFLUOROHEPTANOATE	0.4695	U	0.4902	U	0.47985
PERFLUOROHEXANE SULFONATE	0.939	U	0.9804	U	0.9597
PERFLUOROHEXANOATE	0.4695	U	0.4902	U	0.47985
PERFLUORONONANOATE	0.4695	U	0.4902	U	0.47985
PERFLUOROOCTANE SULFONATE	6.436		7.54		6.988
PERFLUOROOCTANE SULFONAMIDE	0.5634	U	0.5882	U	0.5758
PERFLUOROOCTANOATE	0.4695	U	0.4902	U	0.47985
PERFLUOROPENTANOATE	0.4695	U	0.4902	U	0.47985
PERFLUOROUNDECANOATE	0.6835		1.014		0.84875
LIPIDS					
MOISTURE	77.4		78.3		77.85
SOLIDS-TOTAL RESIDUE (TS)					
MSE-WHP = Mousam River white perch at entrance to Estes Lake below Sanford STP (Sewage Treatment Plant)					
KGD-SMB = Kennebec River smallmouth bass below Augusta STP					
KGD-WHC = Kennebec River white catfish below Augusta STP					
SRF-FLF = Sandy River fallfish below Farmington STP					
SRF-SMB = Sandy River smallmouth bass below Farmington STP					
MXW-SMB = Meduxnekeag River smallmouth bass at Lowrey Bridge below Houlton STP					
ACB-BKT = Aroostook River brook trout below Presque Isle and Caribou STPs					
ACB-FLF = Aroostook River fallfish below Presque Isle and Caribou STPs					

Appendix 3.2.1. Perfluoronated Compounds in fish from some Maine rivers, 2015 (ng/g ww)					
DEP Sample ID	KGD-WHC-C1(1,4,5,8,10)		KGD-WHC-C2(2,3,6,7,9)		KGD-WHC
Lab Sample ID	L24243-14		L24243-15		mean
Sample Date	8/24/2015		8/24/2015		
Dilution Factor	1		1		
Species					
PERFLUOROBUTANE SULFONATE	0.9217	U	0.905	U	0.91335
PERFLUOROBUTANOATE	0.4608	U	0.4525	U	0.45665
PERFLUORODECANOATE	0.4608	U	0.4525	U	0.45665
PERFLUORODODECANOATE	0.4608	U	0.4525	U	0.45665
PERFLUOROHEPTANOATE	0.4608	U	0.4525	U	0.45665
PERFLUOROHEXANE SULFONATE	0.9217	U	0.905	U	0.91335
PERFLUOROHEXANOATE	0.4608	U	0.4525	U	0.45665
PERFLUORONONANOATE	0.4608	U	0.4525	U	0.45665
PERFLUOROOCTANE SULFONATE	1.087		0.905	U	0.996
PERFLUOROOCTANE SULFONAMIDE	0.553	U	0.543	U	0.548
PERFLUOROOCTANOATE	0.4608	U	0.4525	U	0.45665
PERFLUOROPENTANOATE	0.4608	U	0.4525	U	0.45665
PERFLUOROUNDECANOATE	0.4608	U	0.4525	U	0.45665
LIPIDS					
MOISTURE	79.4		79.9		79.65
SOLIDS-TOTAL RESIDUE (TS)					
MSE-WHP = Mousam River white perch at entrance to Estes Lake below Sanford STP (Sewage Treatment Plant)					
KGD-SMB = Kennebec River smallmouth bass below Augusta STP					
KGD-WHC = Kennebec River white catfish below Augusta STP					
SRF-FLF = Sandy River fallfish below Farmington STP					
SRF-SMB = Sandy River smallmouth bass below Farmington STP					
MXW-SMB = Meduxnekeag River smallmouth bass at Lowrey Bridge below Houlton STP					
ACB-BKT = Aroostook River brook trout below Presque Isle and Caribou STPs					
ACB-FLF = Aroostook River fallfish below Presque Isle and Caribou STPs					

Appendix 3.2.1. Perfluoronated Compounds in fish from some Maine rivers, 2015 (ng/g ww)					
DEP Sample ID	SRF-FLF-C1(2,3,5,8,10)		SRF-FLF-C2(1,4,6,7,9)		SRF-FLF
Lab Sample ID	L24243-3		L24243-4		mean
Sample Date	7/30/2015		7/30/2015		
Dilution Factor	1		1		
Species					
PERFLUOROBUTANE SULFONATE	0.9709	U	0.9662	U	0.96855
PERFLUOROBUTANOATE	0.4854	U	0.4831	U	0.48425
PERFLUORODECANOATE	0.4854	U	0.4831	U	0.48425
PERFLUORODODECANOATE	0.4854	U	0.4831	U	0.48425
PERFLUOROHEPTANOATE	0.4854	U	0.4831	U	0.48425
PERFLUOROHEXANE SULFONATE	0.9709	U	0.9662	U	0.96855
PERFLUOROHEXANOATE	0.4854	U	0.4831	U	0.48425
PERFLUORONONANOATE	0.4854	U	0.4831	U	0.48425
PERFLUOROOCTANE SULFONATE	1.889		2.063		1.976
PERFLUOROOCTANE SULFONAMIDE	0.5825	U	0.5797	U	0.5811
PERFLUOROOCTANOATE	0.4854	U	0.4831	U	0.48425
PERFLUOROPENTANOATE	0.4854	U	0.4831	U	0.48425
PERFLUOROUNDECANOATE	0.4854	U	0.4831	U	0.48425
LIPIDS					
MOISTURE	77.5		76.8		77.15
SOLIDS-TOTAL RESIDUE (TS)					
MSE-WHP = Mousam River white perch at entrance to Estes Lake below Sanford STP (Sewage Treatment Plant)					
KGD-SMB = Kennebec River smallmouth bass below Augusta STP					
KGD-WHC = Kennebec River white catfish below Augusta STP					
SRF-FLF = Sandy River fallfish below Farmington STP					
SRF-SMB = Sandy River smallmouth bass below Farmington STP					
MXW-SMB = Meduxnekeag River smallmouth bass at Lowrey Bridge below Houlton STP					
ACB-BKT = Aroostook River brook trout below Presque Isle and Caribou STPs					
ACB-FLF = Aroostook River fallfish below Presque Isle and Caribou STPs					

Appendix 3.2.1. Perfluoronated Compounds in fish from some Maine rivers, 2015 (ng/g ww)					
DEP Sample ID	SRF-SMB-C2(2,7,8,9,10)		SRF-SMB-C2(2,7,8,9,10) (I		SRF-SMB-C2
Lab Sample ID	L24243-6 (A)		WG53285-103 (D)		
Sample Date	8/31/2015		8/31/2015		ave
Dilution Factor	1		1		
Species					
PERFLUOROBUTANE SULFONATE	1.01	U	0.9434	U	0.9767
PERFLUOROBUTANOATE	0.5051	U	0.4717	U	0.4884
PERFLUORODECANOATE	0.5051	U	0.4717	U	0.4884
PERFLUORODODECANOATE	0.5051	U	0.4717	U	0.4884
PERFLUOROHEPTANOATE	0.5051	U	0.4717	U	0.4884
PERFLUOROHEXANE SULFONATE	1.01	U	0.9434	U	0.9767
PERFLUOROHEXANOATE	0.5051	U	0.4717	U	0.4884
PERFLUORONONANOATE	0.5051	U	0.4717	U	0.4884
PERFLUOROOCTANE SULFONATE	3.079		2.809		2.944
PERFLUOROOCTANE SULFONAMIDI	0.6061	U	0.566	U	0.58605
PERFLUOROOCTANOATE	0.5051	U	0.4717	U	0.4884
PERFLUOROPENTANOATE	0.5051	U	0.4717	U	0.4884
PERFLUOROUNDECANOATE	0.5051	U	0.5007		0.5029
LIPIDS					
MOISTURE	75.8		76		75.9
SOLIDS-TOTAL RESIDUE (TS)					
MSE-WHP = Mousam River white perch at entrance to Estes Lake below Sanford STP (Sewage Treatment Plant)					
KGD-SMB = Kennebec River smallmouth bass below Augusta STP					
KGD-WHC = Kennebec River white catfish below Augusta STP					
SRF-FLF = Sandy River fallfish below Farmington STP					
SRF-SMB = Sandy River smallmouth bass below Farmington STP					
MXW-SMB = Meduxnekeag River smallmouth bass at Lowrey Bridge below Houlton STP					
ACB-BKT = Aroostook River brook trout below Presque Isle and Caribou STPs					
ACB-FLF = Aroostook River fallfish below Presque Isle and Caribou STPs					

Appendix 3.2.1. Perfluoronated Compounds in fish from some Maine rivers, 2015 (ng/g ww)			
DEP Sample ID	SRF-SMB-C1(1,3,4,5,6)		SRF-SMB
Lab Sample ID	L24243-5		mean
Sample Date	7/30/2015		
Dilution Factor	1		
Species			
PERFLUOROBUTANE SULFONATE	0.9662	U	0.9662
PERFLUOROBUTANOATE	0.4831	U	0.4831
PERFLUORODECANOATE	0.4831	U	0.4831
PERFLUORODODECANOATE	0.4831	U	0.4831
PERFLUOROHEPTANOATE	0.4831	U	0.4831
PERFLUOROHEXANE SULFONATE	0.9662	U	0.9662
PERFLUOROHEXANOATE	0.4831	U	0.4831
PERFLUORONONANOATE	0.4831	U	0.4831
PERFLUOROOCTANE SULFONATE	2.228		2.228
PERFLUOROOCTANE SULFONAMIDE	0.5797	U	0.5797
PERFLUOROOCTANOATE	0.4831	U	0.4831
PERFLUOROPENTANOATE	0.4831	U	0.4831
PERFLUOROUNDECANOATE	0.4831	U	0.4831
LIPIDS			
MOISTURE	75.9		75.9
SOLIDS-TOTAL RESIDUE (TS)			
MSE-WHP = Mousam River white perch at entrance to Estes Lake below Sanford STP (Sewage Treatment Plant)			
KGD-SMB = Kennebec River smallmouth bass below Augusta STP			
KGD-WHC = Kennebec River white catfish below Augusta STP			
SRF-FLF = Sandy River fallfish below Farmington STP			
SRF-SMB = Sandy River smallmouth bass below Farmington STP			
MXW-SMB = Meduxnekeag River smallmouth bass at Lowrey Bridge below Houlton STP			
ACB-BKT = Aroostook River brook trout below Presque Isle and Caribou STPs			
ACB-FLF = Aroostook River fallfish below Presque Isle and Caribou STPs			

Appendix 3.2.1. Perfluoronated Compounds in fish from some Maine rivers, 2015 (ng/g ww)					
DEP Sample ID	MXW-SMB-C1(1,2,5)		MXW-SMB-C2(3,4,6)		MXW-SMB
Lab Sample ID	L24243-16		L24243-17		mean
Sample Date	8/21/2015		8/21/2015		
Dilution Factor	1		1		
Species					
PERFLUOROBUTANE SULFONATE	1	U	0.9804	U	0.9902
PERFLUOROBUTANOATE	0.5	U	0.4902	U	0.4951
PERFLUORODECANOATE	0.5	U	0.4902	U	0.4951
PERFLUORODODECANOATE	0.5	U	0.4902	U	0.4951
PERFLUOROHEPTANOATE	0.5	U	0.4902	U	0.4951
PERFLUOROHEXANE SULFONATE	1	U	0.9804	U	0.9902
PERFLUOROHEXANOATE	0.5	U	0.4902	U	0.4951
PERFLUORONONANOATE	0.5	U	0.4902	U	0.4951
PERFLUOROOCTANE SULFONATE	5.616		4.129		4.8725
PERFLUOROOCTANE SULFONAMIDE	0.6	U	0.5882	U	0.5941
PERFLUOROOCTANOATE	0.5	U	0.4902	U	0.4951
PERFLUOROPENTANOATE	0.5	U	0.4902	U	0.4951
PERFLUOROUNDECANOATE	0.666		0.6241		0.64505
LIPIDS					
MOISTURE	77.6		76.6		77.1
SOLIDS-TOTAL RESIDUE (TS)					
MSE-WHP = Mousam River white perch at entrance to Estes Lake below Sanford STP (Sewage Treatment Plant)					
KGD-SMB = Kennebec River smallmouth bass below Augusta STP					
KGD-WHC = Kennebec River white catfish below Augusta STP					
SRF-FLF = Sandy River fallfish below Farmington STP					
SRF-SMB = Sandy River smallmouth bass below Farmington STP					
MXW-SMB = Meduxnekeag River smallmouth bass at Lowrey Bridge below Houlton STP					
ACB-BKT = Aroostook River brook trout below Presque Isle and Caribou STPs					
ACB-FLF = Aroostook River fallfish below Presque Isle and Caribou STPs					

Appendix 3.2.1. Perfluoronated Compounds in fish from some Maine rivers, 2015 (ng/g ww)						
DEP Sample ID	ACB-BKT1		ACB-BKT2		ACB-BKT3	
Lab Sample ID	L24243-7		L24243-8		L24243-9	
Sample Date	8/17/2015		8/17/2015		8/20/2015	
Dilution Factor	1		1		1	
Species						
PERFLUOROBUTANE SULFONATE	0.9302	U	0.9434	U	0.9174	U
PERFLUOROBUTANOATE	0.4651	U	0.4717	U	0.4587	U
PERFLUORODECANOATE	0.4651	U	0.4717	U	0.4587	U
PERFLUORODODECANOATE	0.4651	U	0.4717	U	0.4587	U
PERFLUOROHEPTANOATE	0.4651	U	0.4717	U	0.4587	U
PERFLUOROHEXANE SULFONATE	0.9302	U	0.9434	U	0.9174	U
PERFLUOROHEXANOATE	0.4651	U	0.4717	U	0.4587	U
PERFLUORONONANOATE	0.4651	U	0.4717	U	0.4587	U
PERFLUOROOCTANE SULFONATE	2.741		5.931		3.583	
PERFLUOROOCTANE SULFONAMIDE	0.5581	U	0.566	U	0.5505	U
PERFLUOROOCTANOATE	0.4651	U	0.4717	U	0.4587	U
PERFLUOROPENTANOATE	0.4651	U	0.4717	U	0.4587	U
PERFLUOROUNDECANOATE	0.4651	U	0.4717	U	0.4587	U
LIPIDS						
MOISTURE	71.5		72.9		74.1	
SOLIDS-TOTAL RESIDUE (TS)						
MSE-WHP = Mousam River white perch at entrance to Estes Lake below Sanford STP (Sewage Treatment Plant)						
KGD-SMB = Kennebec River smallmouth bass below Augusta STP						
KGD-WHC = Kennebec River white catfish below Augusta STP						
SRF-FLF = Sandy River fallfish below Farmington STP						
SRF-SMB = Sandy River smallmouth bass below Farmington STP						
MXW-SMB = Meduxnekeag River smallmouth bass at Lowrey Bridge below Houlton STP						
ACB-BKT = Aroostook River brook trout below Presque Isle and Caribou STPs						
ACB-FLF = Aroostook River fallfish below Presque Isle and Caribou STPs						

Appendix 3.2.1. Perfluoronated Compounds in fish from some Maine rivers, 2015 (ng/g ww)					
DEP Sample ID	ACB-FLF-C1(2,3,5,7)		ACB-FLF-C2(1,4,6,8)		ACB-FLF
Lab Sample ID	L24243-10		L24243-11		mean
Sample Date	8/17/2015		8/17/2015		
Dilution Factor	1		1		
Species					
PERFLUOROBUTANE SULFONATE	0.995	U	0.9302	U	0.9626
PERFLUOROBUTANOATE	0.4975	U	0.4651	U	0.4813
PERFLUORODECANOATE	0.4975	U	0.4651	U	0.4813
PERFLUORODODECANOATE	0.4975	U	0.4651	U	0.4813
PERFLUOROHEPTANOATE	0.4975	U	0.4651	U	0.4813
PERFLUOROHEXANE SULFONATE	0.995	U	0.9302	U	0.9626
PERFLUOROHEXANOATE	0.4975	U	0.4651	U	0.4813
PERFLUORONONANOATE	0.4975	U	0.4651	U	0.4813
PERFLUOROOCTANE SULFONATE	1.626		2.945		2.2855
PERFLUOROOCTANE SULFONAMIDE	0.597	U	0.5581	U	0.57755
PERFLUOROOCTANOATE	0.4975	U	0.4651	U	0.4813
PERFLUOROPENTANOATE	0.4975	U	0.4651	U	0.4813
PERFLUOROUNDECANOATE	0.4975	U	0.4651	U	0.4813
LIPIDS					
MOISTURE	75.4		76.7		76.05
SOLIDS-TOTAL RESIDUE (TS)					
MSE-WHP = Mousam River white perch at entrance to Estes Lake below Sanford STP (Sewage Treatment Plant)					
KGD-SMB = Kennebec River smallmouth bass below Augusta STP					
KGD-WHC = Kennebec River white catfish below Augusta STP					
SRF-FLF = Sandy River fallfish below Farmington STP					
SRF-SMB = Sandy River smallmouth bass below Farmington STP					
MXW-SMB = Meduxnekeag River smallmouth bass at Lowrey Bridge below Houlton STP					
ACB-BKT = Aroostook River brook trout below Presque Isle and Caribou STPs					
ACB-FLF = Aroostook River fallfish below Presque Isle and Caribou STPs					

Appendix 3.2.2 Lengths and weights of fish sampled from Maine rivers for PFC analyses, 2015		
RIVER/SAMPLE	LENGTH	WEIGHT
AROOSTOOK R CARIBOU		
ACB-BKT1	406	860
ACB-BKT2	305	344
ACB-BKT3	292	303
ACB-FLF1	330	520
ACB-FLF2	305	441
ACB-FLF3	318	496
ACB-FLF4	343	590
ACB-FLF5	337	523
ACB-FLF6	318	476
ACB-FLF7	318	490
ACB-FLF8	305	444
KENNEBEC R GARDINER		
KGD-SMB1	290	296
KGD-SMB2	263	227
KGD-SMB3	296	288
KGD-SMB4	292	293
KGD-SMB5	322	378
KGD-SMB6	287	258
KGD-SMB7	281	274
KGD-SMB8	332	404
KGD-SMB9	282	279
KGD-SMB10	265	214
KGD-WHC1	410	1121
KGD-WHC2	408	1016
KGD-WHC3	414	1105
KGD-WHC4	403	1152
KGD-WHC5	381	930
KGD-WHC6	400	911
KGD-WHC7	357	732
KGD-WHC8	357	670
KGD-WHC9	370	714
KGD-WHC10	342	530
MEDUXNEKEAG R LOWERY BRIDGE		
MXW-SMB1	330	461
MXW-SMB2	279	309
MXW-SMB3	330	529
MXW-SMB4	292	348
MXW-SMB5	267	269
MXW-SMB6	267	255

Appendix 3.2.2 Lengths and weights of fish sampled from Maine rivers for PFC analyses, 2015		
MOUSAM R ESTES L		
MSE-WHP1	247	217
MSE-WHP2	260	249
MSE-WHP3	263	238
MSE-WHP4	260	238
MSE-WHP5	264	259
MSE-WHP6	246	200
MSE-WHP7	261	266
MSE-WHP8	252	247
MSE-WHP9	257	280
MSE-WHP10	265	246
SANDY R FARMINGTON		
SRF-SMB1	475	1505
SRF-SMB2	468	1376
SRF-SMB3	445	1154
SRF-SMB4	460	1276
SRF-SMB5	345	596
SRF-SMB6	430	1287
SRF-SMB7	440	1288
SRF-SMB8	485	1721
SRF-SMB9	422	1185
SRF-SMB10	445	1360
SRF-FLF1	243	148
SRF-FLF2	229	114
SRF-FLF3	263	167
SRF-FLF4	258	188
SRF-FLF5	250	152
SRF-FLF6	310	290
SRF-FLF7	264	194
SRF-FLF8	270	190
SRF-FLF9	272	221
SRF-FLF10	277	230
GOOSEFARE BK		
GFS-BKT1	230	136
GFS-BKT2	194	75.6
GFS-BKT3	204	77.0
GFS-BKT4	193	69.5
GFS-BKT5	155	39.7
GFS-BKT6	153	38.5

Appendix 3.2.3. Perfluoronated Compounds in fish from Estes Lake, Number One Pond, & Mousam Lake for PFC analyses, 2016, (ng/g ww)						
DEP Sample ID	LK0007-LMB-C1(1,2,4,9,10)		LK0007-LMB-C1(1,2,4,9,10) (D)		LK0007-LMB-C1	
Lab Sample ID	L26103-39 (A)		WG57197-104 (D)			
Sample Date	6/15/2016		6/15/2016			
Dilution Factor	1		1		AVE	
Species						
Weight Basis: WET						
PERFLUOROBUTANE SULFONATE	0.9756	U	0.9615	U	0.96855	U
PERFLUOROBUTANOATE	0.4878	U	0.4808	U	0.4843	U
PERFLUORODECANOATE	0.4878	U	0.4808	U	0.4843	U
PERFLUORODODECANOATE	0.5283		0.4808	U	0.50455	U
PERFLUOROHEPTANOATE	0.4878	U	0.4808	U	0.4843	U
PERFLUOROHEXANE SULFONATE	0.9756	U	0.9615	U	0.96855	U
PERFLUOROHEXANOATE	0.4878	U	0.4808	U	0.4843	U
PERFLUORONONANOATE	0.4878	U	0.4808	U	0.4843	U
PERFLUOROOCTANE SULFONATE	35.93		36.89		36.41	
PERFLUOROOCTANE SULFONAMIDE	0.4878	U	0.4808	U	0.4843	U
PERFLUOROOCTANOATE	0.4878	U	0.4808	U	0.4843	U
PERFLUOROPENTANOATE	0.4878	U	0.4808	U	0.4843	U
PERFLUOROUNDECANOATE	0.669		0.6914		0.6802	
LIPIDS						
MOISTURE	78.7		78.5		78.6	
SOLIDS-TOTAL RESIDUE (TS)						
LK007-LMB = Estes Lake Largemouth Bass						
LK0007-WHP= Estes Lake White Perch						
LK3848-LMB = Number One Pond Largemouth Bass						
LK3838-LMB = Mousam Lake Largemouth Bass						

Appendix 3.2.3. Perfluoronated Compounds in fish from Estes Lake, Number One Pond, & Mousam Lake for PFC analyses, 2016, (ng/g ww)					
DEP Sample ID	LK0007-LMB-C2(3,5,6,7,8)		**LK0007-LMB**		
Lab Sample ID	L26103-40				
Sample Date	6/15/2016				
Dilution Factor	1		**MEAN**		
Species					
Weight Basis: WET					
PERFLUOROBUTANE SULFONATE	0.9479	U	**1.0**	U	
PERFLUOROBUTANOATE	0.4739	U	**0.5**	U	
PERFLUORODECANOATE	0.4739	U	**0.5**	U	
PERFLUORODODECANOATE	0.4739	U	**0.5**	U	
PERFLUOROHEPTANOATE	0.4739	U	**0.5**	U	
PERFLUOROHEXANE SULFONATE	0.9479	U	**1.0**	U	
PERFLUOROHEXANOATE	0.4739	U	**0.5**	U	
PERFLUORONONANOATE	0.4739	U	**0.5**	U	
PERFLUOROOCTANE SULFONATE	39.74		**38.1**		
PERFLUOROOCTANE SULFONAMIDE	0.4739	U	**0.5**	U	
PERFLUOROOCTANOATE	0.4739	U	**0.5**	U	
PERFLUOROPENTANOATE	0.4739	U	**0.5**	U	
PERFLUOROUNDECANOATE	0.4739	U	**0.6**	U	
LIPIDS					
MOISTURE	80		**79.3**		
SOLIDS-TOTAL RESIDUE (TS)					
LK007-LMB = Estes Lake Largemouth Bass					
LK0007-WHP= Estes Lake White Perch					
LK3848-LMB = Number One Pond Largemouth Bass					
LK3838-LMB = Mousam Lake Largemouth Bass					

Appendix 3.2.3. Perfluoronated Compounds in fish from Estes Lake, Number One Pond, & Mousam Lake for PFC analyses, 2016, (ng/g ww)						
DEP Sample ID	LK0007-WHP-C1(1,3,5,7,9)		LK0007-WHP-C2(2,4,6,8,10)		**LK0007-WHP**	
Lab Sample ID	L26103-41		L26103-42			
Sample Date	6/15/2016		6/15/2016			
Dilution Factor	1		1		**MEAN**	
Species						
Weight Basis: WET						
PERFLUOROBUTANE SULFONATE	1.0	U	0.9756	U	**1.0**	U
PERFLUOROBUTANOATE	0.5	U	0.4878	U	**0.5**	U
PERFLUORODECANOATE	0.5	U	0.4878	U	**0.5**	U
PERFLUORODODECANOATE	0.5	U	0.4878	U	**0.5**	U
PERFLUOROHEPTANOATE	0.5	U	0.4878	U	**0.5**	U
PERFLUOROHEXANE SULFONATE	1	U	0.9756	U	**1.0**	U
PERFLUOROHEXANOATE	0.5	U	0.4878	U	**0.5**	U
PERFLUORONONANOATE	0.5	U	0.4878	U	**0.5**	U
PERFLUOROOCTANE SULFONATE	41.63		42.19		**41.9**	
PERFLUOROOCTANE SULFONAMIDE	0.5	U	0.4878	U	**0.5**	U
PERFLUOROOCTANOATE	0.5	U	0.4878	U	**0.5**	U
PERFLUOROPENTANOATE	0.5	U	0.4878	U	**0.5**	U
PERFLUOROUNDECANOATE	0.5	U	0.5084		**0.5**	
LIPIDS						
MOISTURE	77		76.3		**76.7**	
SOLIDS-TOTAL RESIDUE (TS)						
LK007-LMB = Estes Lake Largemouth Bass						
LK0007-WHP= Estes Lake White Perch						
LK3848-LMB = Number One Pond Largemouth Bass						
LK3838-LMB = Mousam Lake Largemouth Bass						

Appendix 3.2.3. Perfluoronated Compounds in fish from Estes Lake, Number One Pond, & Mousam Lake for PFC analyses, 2016, (ng/g ww)						
DEP Sample ID	LK3848-LMB-C1(1,4,5,6,10)		LK3848-LMB-C2(2,3,7,8,9)		**LK3848-LMB**	
Lab Sample ID	L26103-43		L26103-44			
Sample Date	6/13/2016		6/13/2016			
Dilution Factor	1		1		**MEAN**	
Species						
Weight Basis: WET						
PERFLUOROBUTANE SULFONATE	0.9709	U	1	U	**1.0**	U
PERFLUOROBUTANOATE	0.4854	U	0.5	U	**0.5**	U
PERFLUORODECANOATE	0.4854	U	0.5	U	**0.5**	U
PERFLUORODODECANOATE	0.7014		0.5	U	**0.6**	U
PERFLUOROHEPTANOATE	0.4854	U	0.5	U	**0.5**	U
PERFLUOROHEXANE SULFONATE	0.9709	U	1	U	**1.0**	U
PERFLUOROHEXANOATE	0.4854	U	0.5	U	**0.5**	U
PERFLUORONONANOATE	0.4854	U	0.5	U	**0.5**	U
PERFLUOROOCTANE SULFONATE	9.661		9.489		**9.6**	
PERFLUOROOCTANE SULFONAMIDE	0.4854	U	0.5	U	**0.5**	U
PERFLUOROOCTANOATE	0.4854	U	0.5	U	**0.5**	U
PERFLUOROPENTANOATE	0.4854	U	0.5	U	**0.5**	U
PERFLUOROUNDECANOATE	0.4854	U	0.5	U	**0.5**	U
LIPIDS						
MOISTURE	80.4		79.7		**80.1**	
SOLIDS-TOTAL RESIDUE (TS)						
LK007-LMB = Estes Lake Largemouth Bass						
LK0007-WHP= Estes Lake White Perch						
LK3848-LMB = Number One Pond Largemouth Bass						
LK3838-LMB = Mousam Lake Largemouth Bass						

Appendix 3.2.3. Perfluoronated Compounds in fish from Estes Lake, Number One Pond, & Mousam Lake for PFC analyses, 2016, (ng/g ww)						
DEP Sample ID	LK3838-LMB-C1(1,5,7,8)		LK3838-LMB-C2(2,3,4,6)		LK3838-LMB	
Lab Sample ID	L26103-45		L26103-46			
Sample Date	7/7/2016		7/7/2016			
Dilution Factor	1		1		**MEAN**	
Species						
Weight Basis: WET						
PERFLUOROBUTANE SULFONATE	0.9901	U	0.9804	U	**1.0**	U
PERFLUOROBUTANOATE	0.4951	U	0.4902	U	**0.5**	U
PERFLUORODECANOATE	0.4951	U	0.5645		**0.5**	
PERFLUORODODECANOATE	0.6886		0.5267		**0.6**	
PERFLUOROHEPTANOATE	0.4951	U	0.4902	U	**0.5**	U
PERFLUOROHEXANE SULFONATE	0.9901	U	1.098	U	**1.0**	U
PERFLUOROHEXANOATE	0.4951	U	0.4902	U	**0.5**	U
PERFLUORONONANOATE	0.4951	U	0.4902	U	**0.5**	U
PERFLUOROOCTANE SULFONATE	1.268		0.9804	U	**1.1**	U
PERFLUOROOCTANE SULFONAMIDE	0.4951	U	0.4902	U	**0.5**	U
PERFLUOROOCTANOATE	0.4951	U	0.4902	U	**0.5**	U
PERFLUOROPENTANOATE	0.4951	U	0.4902	U	**0.5**	U
PERFLUOROUNDECANOATE	0.8185		0.6837		**0.8**	
LIPIDS						
MOISTURE	79.8		78.6		**79.2**	
SOLIDS-TOTAL RESIDUE (TS)						
LK007-LMB = Estes Lake Largemouth Bass						
LK0007-WHP= Estes Lake White Perch						
LK3848-LMB = Number One Pond Largemouth Bass						
LK3838-LMB = Mousam Lake Largemouth Bass						

Appendix 3.3.4. Lengths and weights of fish sampled from Estes Lake, Number One Pond, and Mousam Lake for PFC analyses, 2016			
LAKE/SAMPLE	DATE	LENGTH	WEIGHT
		mm	g
ESTES LAKE LK0007			
LK0007-LMB1	6/15/2016	286	320
LK0007-LMB2	6/15/2016	385	415
LK0007-LMB3	6/15/2016	300	360
LK0007-LMB4	6/15/2016	322	480
LK0007-LMB5	6/15/2016	244	210
LK0007-LMB6	6/15/2016	284	310
LK0007-LMB7	6/15/2016	383	850
LK0007-LMB8	6/15/2016	338	520
LK0007-LMB9	6/15/2016	260	260
LK0007-LMB10	6/15/2016	374	710
MEAN		318	444
LK0007-WHP1	6/15/2016	288	310
LK0007-WHP2	6/15/2016	244	200
LK0007-WHP3	6/15/2016	251	220
LK0007-WHP4	6/15/2016	232	185
LK0007-WHP5	6/15/2016	226	170
LK0007-WHP6	6/15/2016	212	140
LK0007-WHP7	6/15/2016	236	185
LK0007-WHP8	6/15/2016	278	310
LK0007-WHP9	6/15/2016	232	190
LK0007-WHP10	6/15/2016	227	175
MEAN		243	209
NUMBER ONE POND LK3848			
LK3848-LMB1	6/13/2016	354	615
LK3848-LMB2	6/13/2016	280	300
LK3848-LMB3	6/13/2016	390	800
LK3848-LMB4	6/13/2016	338	540
LK3848-LMB5	6/13/2016	280	380
LK3848-LMB6	6/13/2016	214	145
LK3848-LMB7	6/13/2016	298	360
LK3848-LMB8	6/13/2016	271	280
LK3848-LMB9	6/13/2016	340	400
LK3848-LMB10	6/13/2016	288	380
MEAN		305	420

Appendix 3.3.4. Lengths and weights of fish sampled from Estes Lake, Number One Pond, and Mousam Lake for PFC analyses, 2016			
LAKE/SAMPLE	DATE	LENGTH	WEIGHT
		mm	g
MOUSAM LAKE LK3838			
LK3838-LMB1	7/7/2016	332	460
LK3838-LMB2	7/7/2016	318	400
LK3838-LMB3	7/7/2016	336	550
LK3838-LMB4	7/7/2016	420	1000
LK3838-LMB5	7/8/2016	402	885
LK3838-LMB6	7/8/2016	356	575
LK3838-LMB7	7/8/2016	314	390
LK3838-LMB8	7/8/2016	340	480
MEAN		**352**	**593**