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SURFACE WATER AMBIENT TOXIC MONITORING PROGRAM

DRAFT REPORT 2008

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

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INTRODUCTION

This 2008 Surface Water Ambient Toxic (SWAT) monitoring program final report is organized into an Executive Summary (with introduction and table of contents) and 4 modules, 1) Marine & Estuarine 2) Lakes, 3) Rivers & Streams.

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

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

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

EXECUTIVE SUMMARY

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

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

The SWAT program is divided into 4 modules, 1) Marine and Estuarine, 2) Lakes, 3) Rivers and Streams, and 4) Special Studies. This annual report follows the outline of the 2008 workplan recommended by the SWAT TAG in a meeting June 13, 2008. Following is a summary of key findings from the 2008 SWAT program for each module.

1. MARINE AND ESTUARINE

- This report includes 2007 and 2008 blue mussel tissue metals data from 26 sites (13 per year) along the Maine coast. Elevated lead levels were detected at ten sites, but the lead levels appear stable or reduced when compared to past data. Elevated mercury levels were detected at four sites. Comparison to historic mercury data is difficult due to data quality issues with older data. Additional sampling should be undertaken to provide trend analyses for all metals of interest..

- Additional analyses on mussels included PAHs, pesticides, PCBs, and Dioxin/Furan and PFCs (at selected sites). Four sediment sites were also sampled for the same suite of analytes. These data are presented in two separate appendices due to the volume of data. See Appendix 1 (sediment data) and Appendix 2 (blue mussel tissue data) on this same web page.

- Eggs from common loons and peregrine falcons from several locations in Maine were contaminated with mercury above adverse effects thresholds. A peregrine falcon egg from Mount Desert Island had the highest contaminant load. Deca BDE, a flame retardant, was found in loons, falcons, and piping plovers at some sites. Perflourinated compounds in loons were found above adverse thresholds, the highest being from Androscoggin Lake.

- Bluefish caught in Saco Bay contained PCBs well above the Maine Center for Disease Control and Prevention's (MCDC) Fish Tissue Action Level.

2. LAKES

No monitoring was conducted in 2008.

3. RIVERS AND STREAMS

- Forty stations were assessed for the condition of the benthic macroinvertebrate community. Fifteen of the forty stations failed to attain the aquatic life standards of their assigned class.

- Dioxins and coplanar PCBs analyzed under Maine's Dioxin Monitoring Program and SWAT program continue to show reductions in some rivers, but exceed the MCDC's new fish tissue action level (0.4 pptr) in others. MCDC expects to revise the fish consumption advisories this year. Data are reported in Maine's 2008 Dioxin Monitoring Program report available at http://www.maine.gov/dep/blwq/docmonitoring/dioxin/index.htm

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

- There is a fish consumption advisory for several Aroostook County rivers and streams issued by the MCDC because of residuals of DDT used decades ago. Samples of trout from four of eight Aroostook County rivers and streams sampled in 2008 exceeded MCDC's FTAL used for setting the advisories.

- A cumulative effects assessment (collectively looking at survival, growth, and reproduction) of a fish population in the Presumpscot River found some impacts below Westbrook. Data yet to be reported by the laboratory will be needed before final conclusions can be made as to the cause and will be reported in the 2009 report.

1.0 MARINE MODULE

1.1

SHELLFISH TISSUE AND SEDIMENT ANALYSIS

1.1 Assessment of Contaminant Levels in Blue Mussels

(funded by BRWM Maine Coastal and Inland Surface Oil Clean-up Fund)

1.1.1 Introduction

This report presents and summarizes metals contaminant data from the collection and analysis of blue mussel (*Mytilus edulis*) tissue collected from 26 selected sites along the Maine coast. Mussel tissue samples were collected at 13 sites in 2007 and 13 sites in 2008. This work was conducted as part of the marine portion of the Surface Water Ambient Toxic Monitoring Program (SWAT) of the Maine Department of Environmental Protection (MDEP). Funding for laboratory analyses was provided by the MDEP oil research Surface Water Fund. Blue mussel contaminant levels from the SWAT program can also be compared to blue mussel contaminant levels in other programs including the Gulfwatch program (Gulf of Maine Council on the Marine Environment) and the Mussel Watch Program (National Oceanographic and Atmospheric Administration), which give a regional and national context to the Maine SWAT data.

Additional analyses on blue mussels included PAHs, pesticides, PCBs, and Dioxin/Furan and PFCs (at selected sites). Four sediment sites were also sampled for the same suite of analytes. These data are presented in two separate appendices due to the volume of information they contain. See Appendix 1 (sediment data) and Appendix 2 (blue mussel tissue data) on this same web page.

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

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

1.1.2 Methods

Blue mussels were collected from 13 sites in 2007 and an additional 13 sites in 2008, distributed across the coast of Maine. Twenty sites had been sampled previously as part of the SWAT program, but had not been visited in between five and twenty-one years (mean of 10 years). Six sites had never been sampled previously. Sites were selected to provide new information about contaminants along the coast, either to update older data or to fill in geographical gaps in areas sampled. Names and locations of blue mussel collection sites for 2007 are presented by municipality and latitude and longitude in Table 1.1.2.1. A map of the 2007 sites is presented in Figure 1.1.2.1. Names and locations of blue mussel collection sites for 2008 are presented by municipality and latitude and longitude in Table 1.1.2.2. A map of the 2008 sites is presented in Figure 1.1.2.2.

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

Sampling occurred from mid-October to mid-December and sampling dates are included for specific sites in Table 1.1.2.1 and Table 1.1.2.2. In order to characterize the contaminants present in a general area at the sampling station, mussels were collected from four distinct areas (replicates) along the shoreline at each site whenever possible. Gauges were used to sort mussels by shell length in the field and mussels were selected for analysis within a size range of 50-60 mm. For metals analysis, a minimum of 20 mussels were selected from within the target size range from each of the four intra site locations and placed in separate containers. Replicates were washed in ambient sea water in a mesh or open bucket at the collection site to remove external debris and attached sediments. Mussel replicates were then transported to the laboratory in coolers (supplemented with ice packs in warmer weather). Collecting 20 mussels per replicate met the laboratory tissue requirements to meet detection limits for metals analysis. Mussels were not depurated prior to shucking to remove tissue for analysis.

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

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

TABLE 1.1.2.1: 2007 SWAT Blue Mussel Sites

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

TABLE 1.1.2.2: 2008 SWAT Blue Mussel Sites

Site Name	Municipality	Station Code	West Longitude	North Latitude	Date Sampled
Piscataqua, I-95	Kittery	PQISIS	-70.7798	43.0986	10/9/2008
Piscataqua, Back Channel	Kittery	PQBCBC	-70.7233	43.0829	11/12/2008
Piscataqua, Pepperell Cove	Kittery	PQPCPC	-70.7027	43.0777	11/5/2008
Piscataqua, Fort Foster	Kittery	PQFFFF	-70.6969	43.0646	11/5/2008
Perkins Cove, Ogunquit	Ogunquit	SCPCPC	-70.5881	43.2357	10/6/2008
Kennebunk River	Kennebunkport	SCKBMT	-70.4743	43.3475	10/6/2008
Scarborough River	Scarborough	SCSRRR	-70.3441	43.5542	10/23/2008
Presumpscot River	Falmouth	CBPRMT	-70.2471	43.6925	11/18/2008
Middle Bay, Harpswell	Harpswell	CBMBMB	-70.0537	43.7656	10/21/2008
Lincolnville, Ferry Terminal	Lincolnville	PBLNFT	-69.0058	44.2786	10/6/2008
Saturday Cove, Northport	Northport	PBNPSC	-68.9530	44.3380	10/20/2008
Belfast Harbor	Belfast	PBBFTD	-68.9987	44.4251	10/21/2008
Sears Island, Searsport	Searsport	PBSIWS	-68.8902	44.4468	9/22/2008

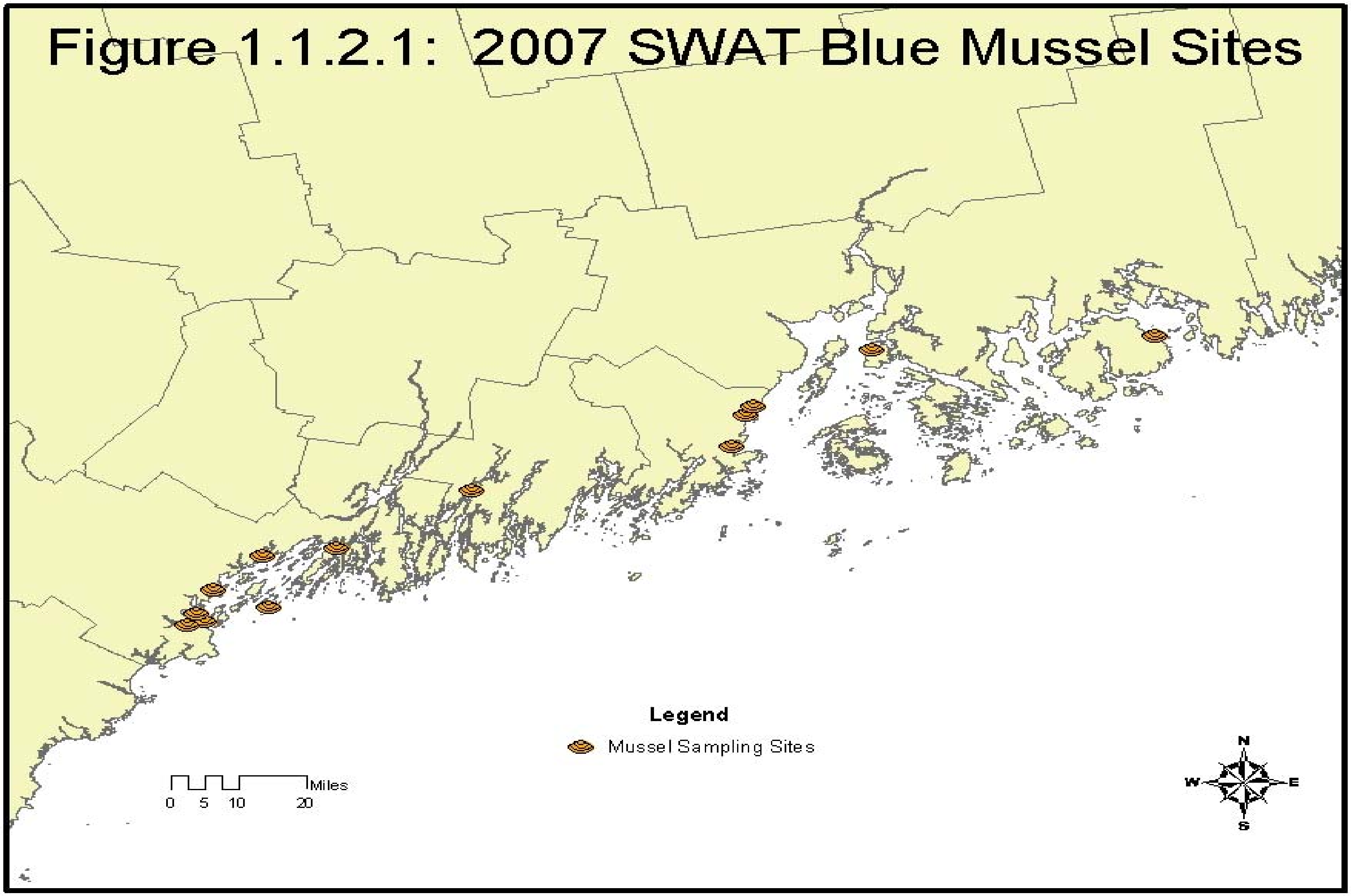
Figure 1.1.2.1: 2007 SWAT Blue Mussel Sites
Legend
Mussel Sampling Sites
Miles
0 5 10 20
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W
E
S

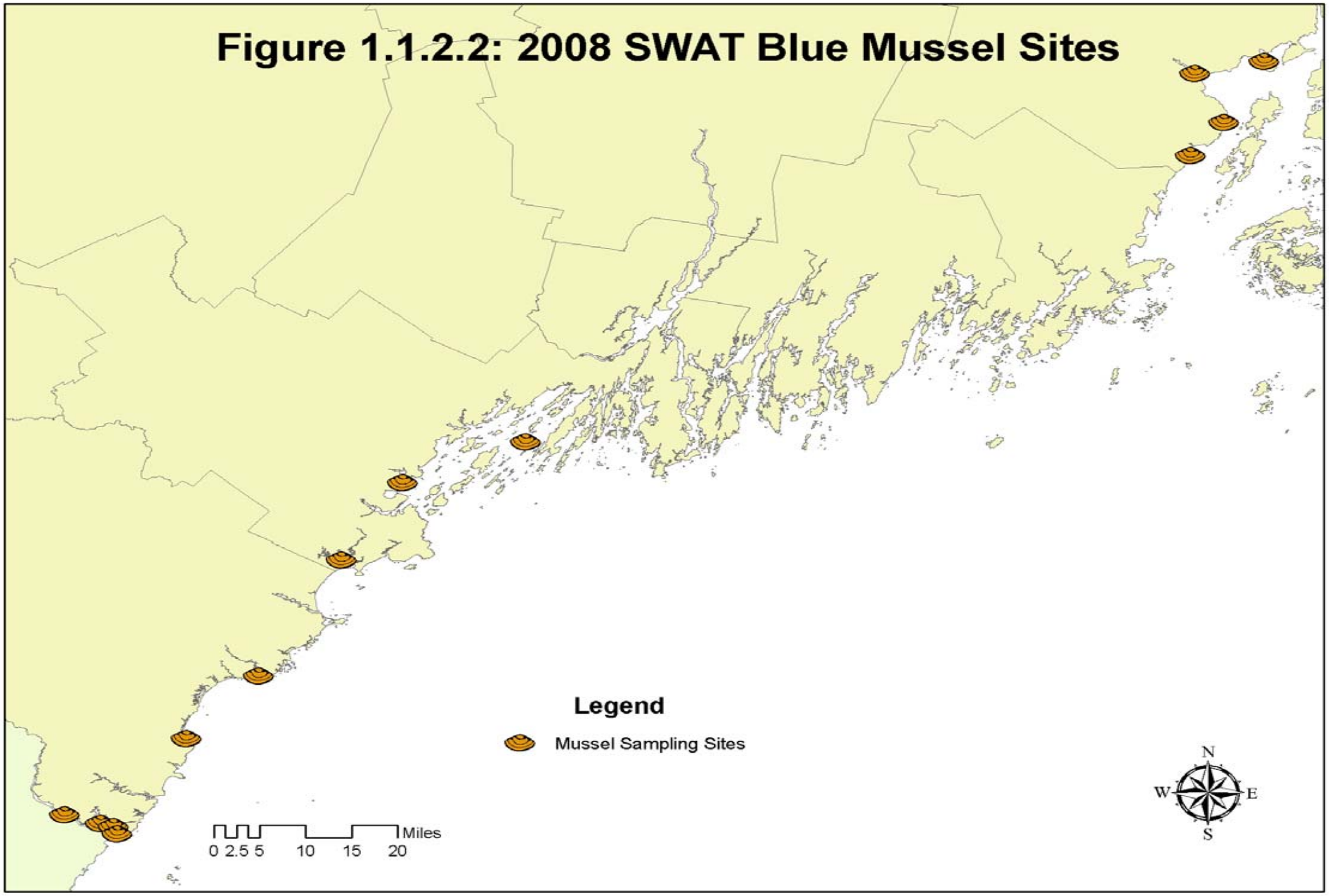


Figure 1.1.2.2: 2008 SWAT Blue Mussel Sites
Legend
Mussel Sampling Sites
0 2.5 5 10 15 20
Miles
N
W
E
S

1.1.3 Results

Mussel tissue samples collected in 2007 and 2008 were analyzed by Brooks Rand Labs, Seattle, WA. The samples were analyzed for 12 metals: Silver (Ag), aluminum (Al), arsenic (Ar), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), mercury (Hg), nickel (Ni), selenium (Se), and zinc (Zn). Selenium results will not be presented in this report. Results were compared to national (NOAA National Status & Trends, see Kimbrough, 2008) and Gulf of Maine (Gulfwatch, see Krahforst, 2009) blue mussel monitoring program data (when available) in an effort to place Maine SWAT data set in a national and regional context.

1.1.3.1 Silver (Ag)

Silver concentrations across all 13 sample locations in 2007 and 2008 (and all 4 associated replicates) were in the non-detect range. The minimum quantitation limit for silver at Brooks Rand (the subcontracted laboratory used by AXYS Analytical for metals analyses) was much higher than for mussel tissue silver detection limits and actual results from the Gulfwatch program, for example. Minimum detection limits will need to be lowered to obtain comparable results for silver concentrations in the SWAT samples. If possible, samples will be reanalyzed to allow quantitiation of silver concentrations. No silver results will be presented for 2007 and 2008 SWAT mussel sites at this time, pending reanalysis of samples.

1.1.3.2 Arsenic (As)

2007

Arsenic was detected in all 13 sample locations visited in 2007. Arsenic levels detected in mussels ranged from a low mean concentration of 5.4 mg/kg dry wt. at Bar Harbor to a high mean concentration of 12.5 mg/kg dry wt. at Jewell Island, Cumberland (Figure 1.1.3.2.1). While Gulfwatch does not monitor arsenic concentrations, they are tracked regionally and nationally by NOAA's Mussel Watch program. In blue mussels, Mussel Watch considers 5-11 parts per million dry wt. (directly comparable to SWAT mg/kg data) to be in the lowest of three ranges of arsenic concentration (Kimbrough, 2008). While six of the sites examined in 2007 show levels above 11 mg/kg dry wt. only one exceeded 12 mg/kg dry wt. (Jewell Island, Cumberland), and all six were at the lowest end of the Musselwatch mid-range. The remaining seven sites fall in the lowest range delineated by Musselwatch, below 11 parts per million (ppm) dry wt.

2008

Similarly, arsenic was detected in all 13 sample locations visited in 2008. Arsenic levels detected in mussels ranged from a low mean concentration of 7.8 mg/kg dry wt. at Saturday Cove, Northport, to a high mean concentration of 15.6 mg/kg dry wt. at Pepperell Cove, Piscataqua River and at Scarborough River (Figure 1.1.3.2.2). Nine of the sites examined in 2008 show levels above 11 mg/kg dry wt., and so these nine sites fall into the Mussel Watch national mid-range of 12 – 22 mg/kg dry wt. concentration. All nine fall in the lower half of this mid-range. The remaining four sites sampled in 2008 fall in the lowest range delineated by Mussel Watch, below 11 parts per million (ppm) dry wt.

Nationally, the primary source for elevated levels of arsenic is crustal rock. Other than natural sources, industrial pollution can contribute arsenic to the environment from preserved wood, semiconductors, pesticides, defoliants, pigments, antifouling paints, and veterinary medicines. Atmospheric sources include smelting, fossil fuel combustion, power generation, and pesticide application (Kimbrough, 2008). From a human health perspective, the FDA action level (2001) for arsenic in clams, oysters, and mussels is 86 ppm wet wt. (Kimbrough, 2008). The highest scoring Maine site, Scarborough River (2008), had a mean arsenic result of 2.3 mg/kg wet wt., or more than an order of magnitude less than the FDA action level.

FIGURE 1.1.3.2.1: SWAT 2007 Blue Mussel Tissue Arsenic Concentrations

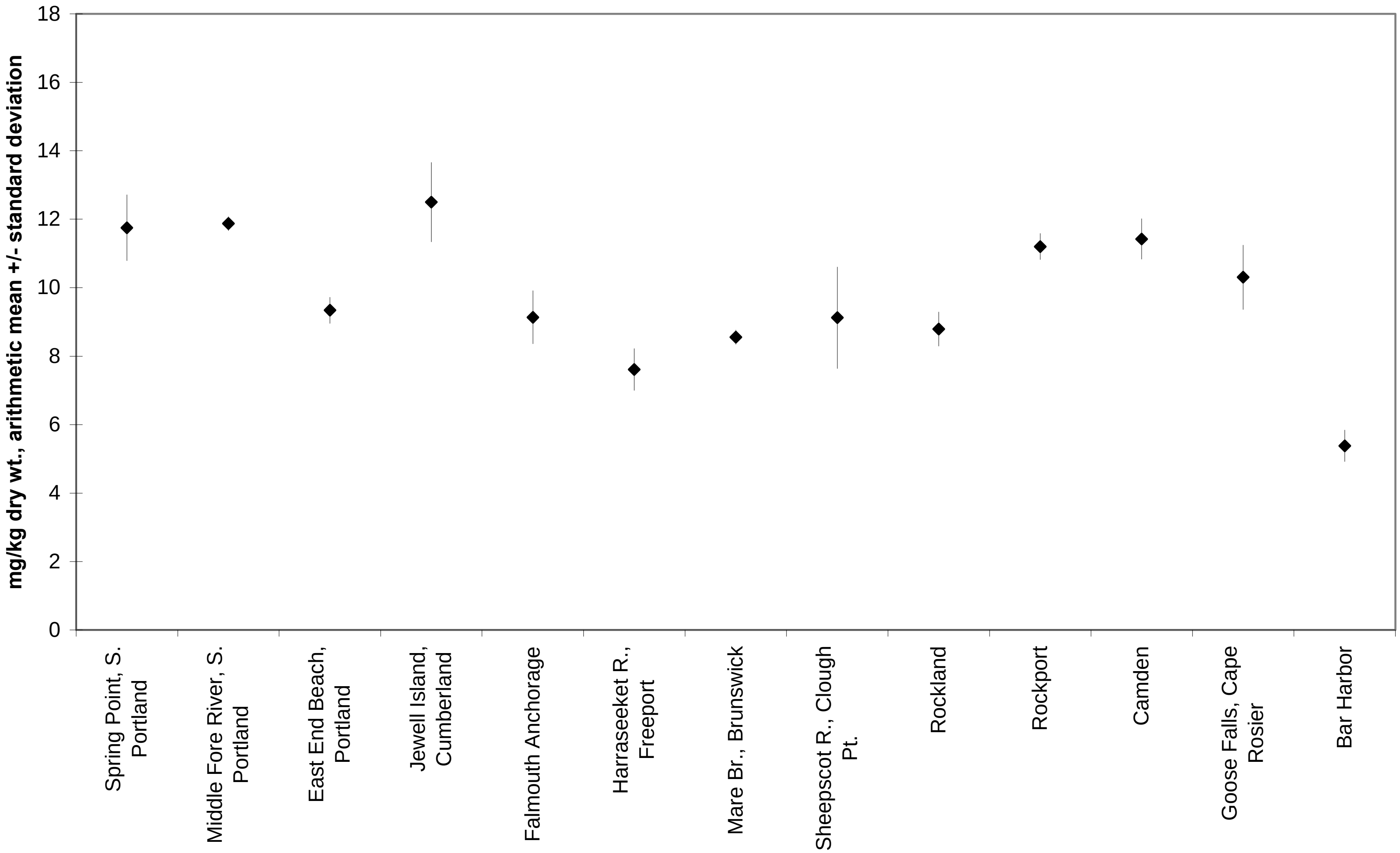
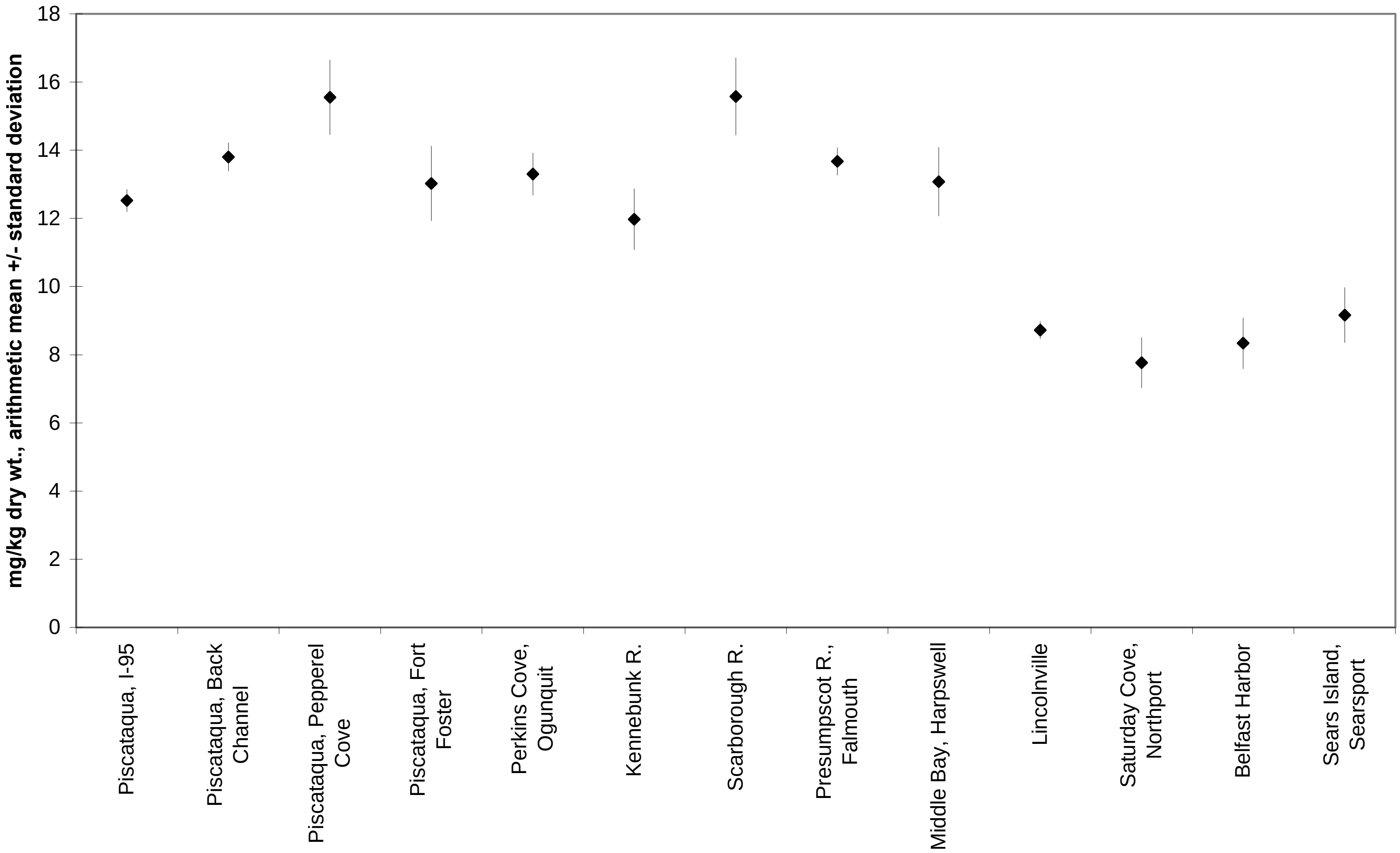


FIGURE 1.1.3.2.2: SWAT 2008 Blue Mussel Tissue Arsenic Concentrations



1.1.3.3 Cadmium (Cd)

2007

Cadmium was detected in all 13 sample locations visited in 2007. Cadmium levels detected in mussels ranged from a low mean concentration of 0.86 mg/kg dry wt. at Rockland to a high mean concentration of 3.49 mg/kg dry wt. at Goose Falls, Brooksville (Figure 1.1.3.3.1) Maine concentrations were comparable to or below the Mussel Watch median with the exception of Goose Falls, Brooksville (Kimbrough, 2008). Maine concentrations also were comparable to Gulf of Maine concentrations (1.5 to 2.0 mg/kg, 2003-06) from Gulfwatch with the exception of Goose Falls, Brooksville. Though Goose Falls had the highest concentrations found in Maine in 2007, the mean cadmium concentration for all SWAT samples fell below the Mussel Watch 85th percentile (Figure 1.1.3.3.1).

2008

Cadmium was detected in all 13 sample locations visited in 2008. Cadmium levels detected in mussels ranged from a low mean concentration of 1.39 mg/kg dry wt. at Saturday Cove, Northport, to a high mean concentration of 3.42 mg/kg dry wt. at Piscataqua River, Fort Foster (Figure 1.1.3.3.2). Concentrations for six sites were below the Mussel Watch national median (Kimbrough, 2008). Arsenic concentrations at seven sites ranged from just above the Mussel Watch national median up to the highest concentration noted above at Piscataqua River, Fort Foster. The lowest six sites had concentrations which were comparable to Gulf of Maine concentrations (1.5 to 2.0 mg/kg, 2003-06) from Gulfwatch. The seven with the exception of Goose Falls, Brooksville. Though Piscataqua River, Fort Foster had the highest cadmium concentration found in Maine in 2007 and 2008, the mean cadmium concentration for all SWAT samples fell below the Mussel Watch 85th percentile (Figure 1.1.3.3.2).

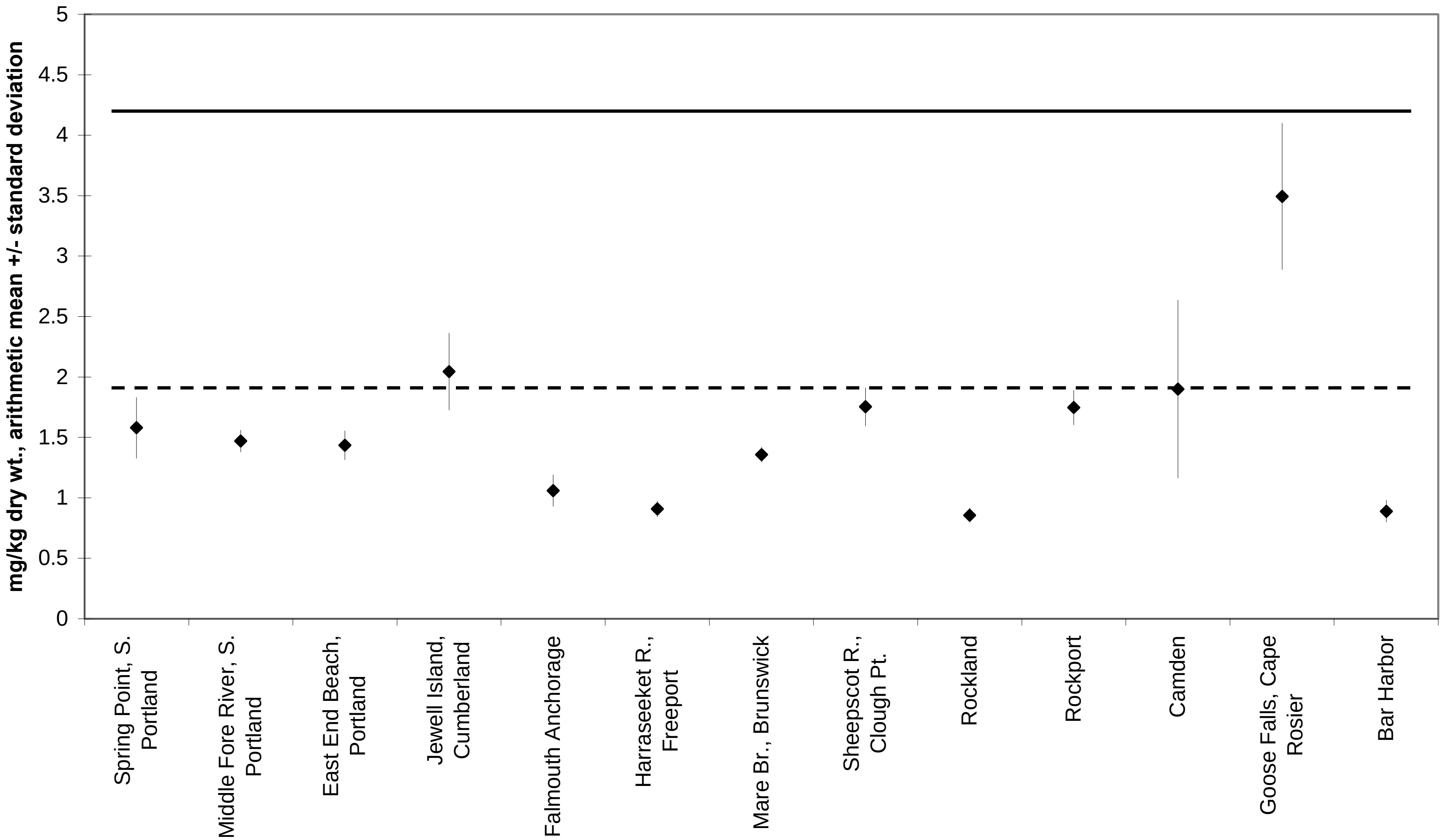
Cadmium originates from crustal elements as rocks weather and is transported seaward by rivers, which account for approximately half of worldwide cadmium sources. Cadmium is also released naturally through forest fires and volcanic activity, with anthropogenic sources including manufacturing, fossil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

Elevated cadmium levels in mussels at Goose Falls (2007) may be associated with high sediment ingestion by mussels, but this does not appear to be the case due to relatively low levels of iron, aluminum, and nickel in the Goose Falls samples. These elements provide a good approximation of sediment intake, scoring high with high sediment ingestion by mussels. Since these three metals results are relatively low, the cadmium source is likely not related to sediment intake alone. Goose Falls is also the site of a historic mining operation, which may offer increased input of cadmium to the local environs through the increased availability of rock for weathering or through other sources related to the mining operation.

Elevated cadmium levels in mussels at Piscataqua River, Fort Foster (2008), also do not appear to be the result of high sediment ingestion by mussels as iron, aluminum, and nickel concentrations in the Fort Foster samples are not extremely high. One of the four mussel tissue replicates obtained at the Fort Foster site had a cadmium concentration of 5.08 mg/kg dry wt., compared to somewhat lower concentrations determined for the other replicates (mean of lower three = 2.87 mg/kg dry wt.). The increased variability is visible in the standard deviation plotted in Figure 1.1.3.3.2 around the sample point for Fort Foster. Fort Foster was sampled once in 1987 and with only one replicate, with the cadmium concentration reported at 2.00 mg/kg dry wt. With very little historical data at this site and some high variation among the 2008 replicates, future sampling at the site will yield more insight into the variability associated with the 2008 replicates.

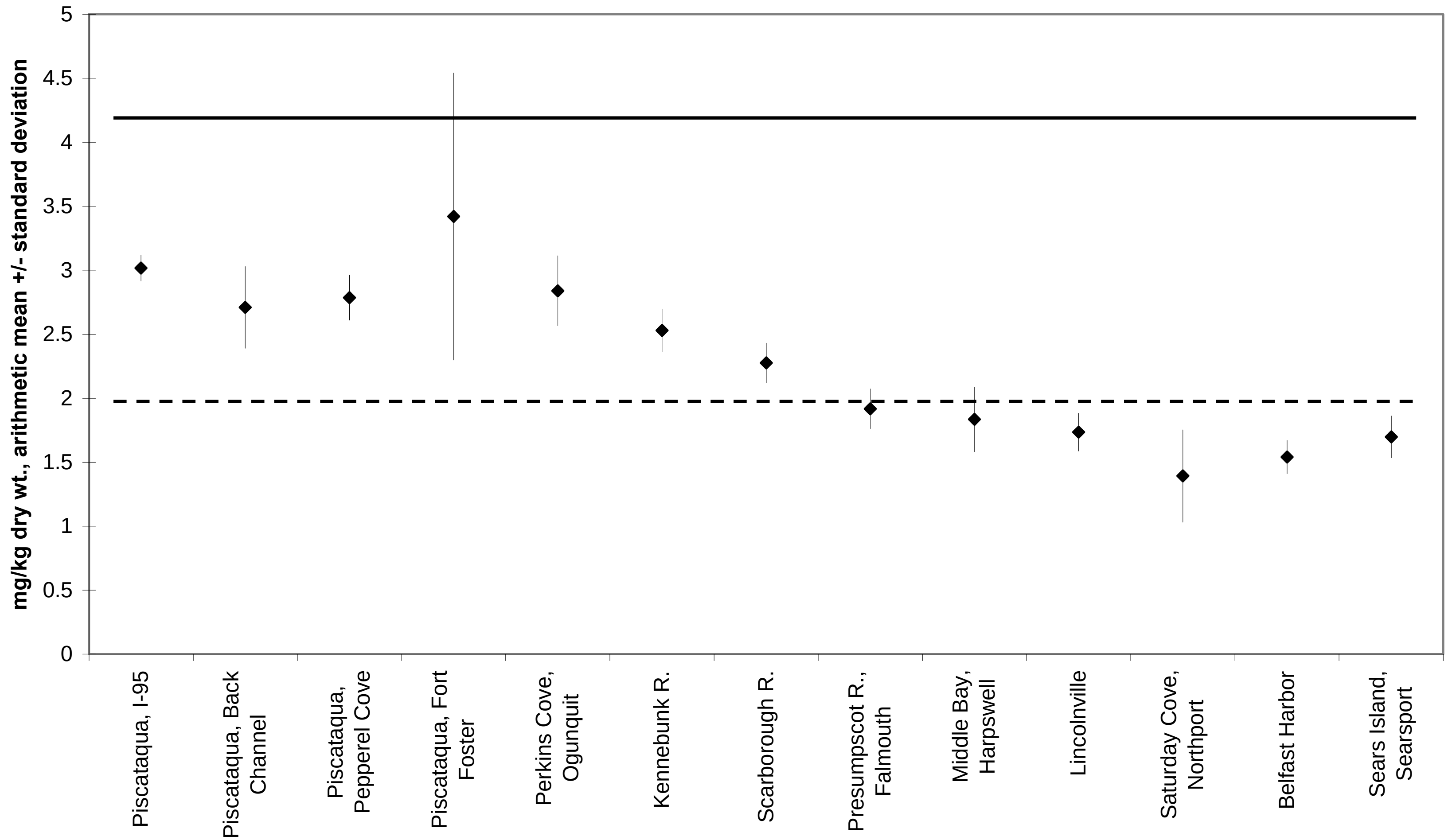
From a human health perspective, the FDA action level (2001) for cadmium in clams, oysters, and mussels is 4 ppm wet wt. (Kimbrough, 2008). The highest scoring Maine site in 2007, Goose Falls, Brooksville, had a mean arsenic result of 0.60 mg/kg wet wt., nearly an order of magnitude less than the FDA action level. Similarly, the highest scoring site sampled in 2008, Piscataqua River, Fort Foster, had a mean arsenic concentration of 0.48 mg/kg wet wt.

FIGURE 1.1.3.3.1: SWAT 2007 Blue Mussel Tissue Cadmium Concentrations



Dashed line = 1996 Mussel Watch National Median; Solid line = 1996 Mussel Watch National 85th Percentile.

FIGURE 1.1.3.3.2: SWAT 2008 Blue Mussel Tissue Cadmium Concentrations



Dashed line = 1996 Mussel Watch National Median; Solid line = 1996 Mussel Watch National 85th Percentile.

1.1.3.4 Chromium (Cr)

2007

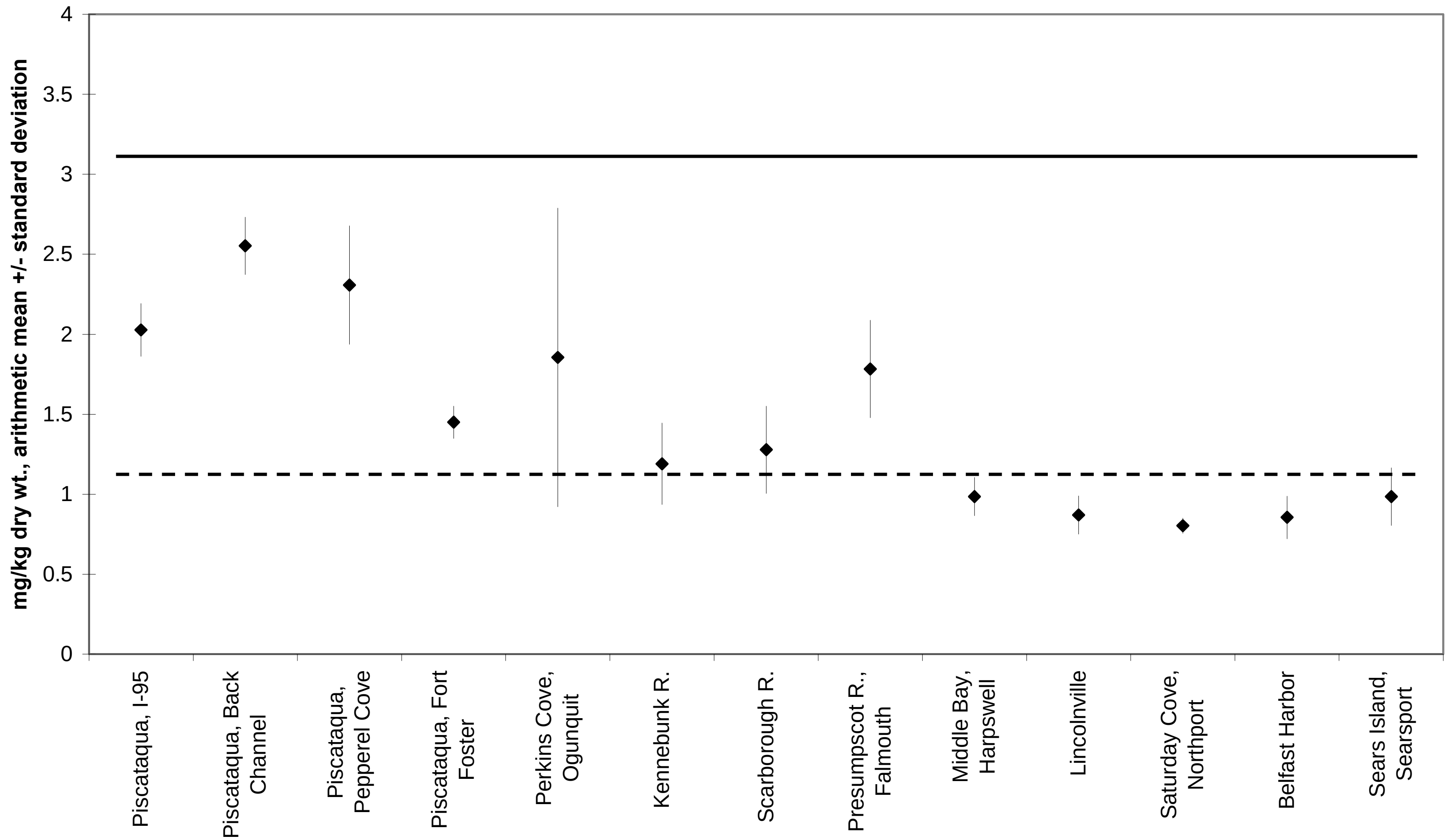
Chromium data from 2007 samples will not be presented in this report. Chromium mussel tissue levels across all 13 stations sampled appeared to be at elevated levels when compared to Mussel Watch and Gulfwatch data, with nearly all stations except one exceeding the Mussel Watch 85^{th} national percentile. No Gulfwatch stations sampled in 2006 exceeded the Mussel Watch 85^{th} national percentile, though all were above the Mussel Watch median. Given this significant departure of the 2007 SWAT sampling for Cr from the prior years' datasets, it is suspected that laboratory samples were contaminated with chromium, perhaps during processing, contributing to the consistently elevated scores. This issue will be explored with the contracted laboratory to determine potential causes.

2008

Chromium was detected in all 13 locations sampled in 2008. Chromium levels detected in mussel tissue ranged from a low mean concentration of 0.80 mg/kg dry wt. at Saturday Cove, Northport, to a high mean concentration of 2.55 mg/kg dry wt. at Piscataqua River, Back Channel (Figure 1.1.3.4.1). Maine concentrations were comparable to the Mussel Watch median, with the more westerly, southern Maine sites exceeding the median while the eastern Maine sites fell below the national median. None of the chromium concentrations in mussel samples obtained in 2008 exceeded the Mussel Watch national 85^{th} percentile (Kimbrough, 2008). Maine 2008 concentrations also were comparable to Gulf of Maine mean concentrations (1.8 to 2.6 mg/kg dry wt., 2003-06) from Gulfwatch, with the central and eastern Maine sites falling below the Gulf of Maine mean (Krahforst, 2009).

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

FIGURE 1.1.3.4.1: 2008 SWAT Blue Mussel Tissue Chromium Concentrations



Dashed line = 1996 Mussel Watch National Median; Solid line = 1996 Mussel Watch National 85th Percentile.

1.1.3.5 Copper (Cu)

2007

Copper was detected in all 13 sample locations visited in 2007. Copper levels detected in mussels ranged from a low mean concentration of 6.35 mg/kg dry wt. at Bar Harbor to a high mean concentration of 10.91 mg/kg dry wt. at Goose Falls, Brooksville (Figure 1.1.3.5.1). Maine concentrations were comparable to the Mussel Watch median with the exceptions of Rockland and Goose Falls, Brooksville, which exceeded the Mussel Watch 85th percentile (Kimbrough, 2008). Maine 2007 concentrations also were comparable to Gulf of Maine mean concentrations (1.8 to 7.2 mg/kg dry wt., 2004-06) from Gulfwatch with the exceptions of Rockland and Goose Falls, Brooksville (Krahforst, 2009). Gulfwatch also recorded an elevated copper level for Boothbay Harbor in 2006 at 10.8 mg/kg dry wt., which is consistent with past Gulfwatch records for this site and helps to put the Goose Falls and Rockland results in context.

2008

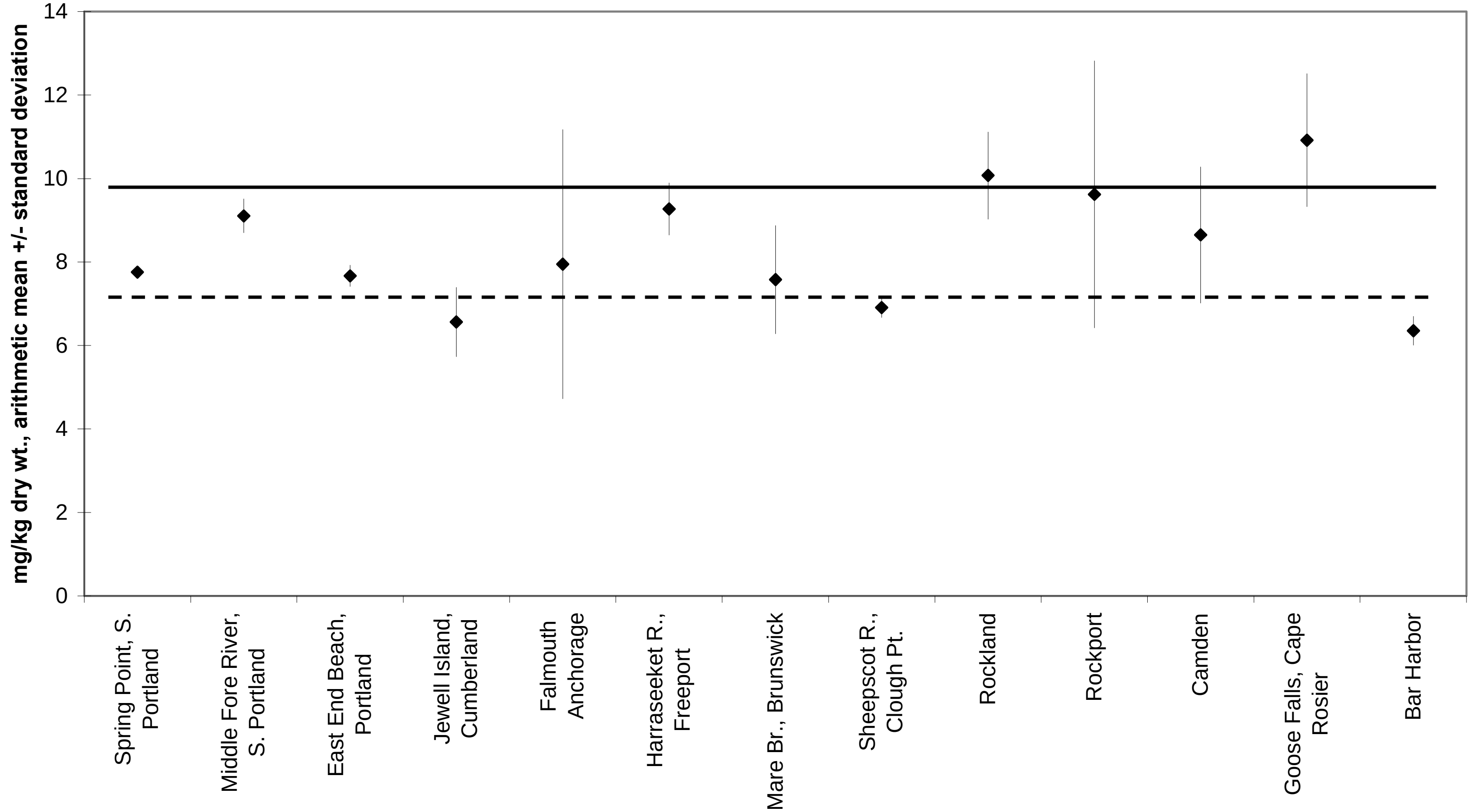
Copper was detected in all 13 sample locations visited in 2008. Copper levels detected in mussels ranged from a low mean concentration of 5.15 mg/kg dry wt. at Saturday Cove, Northport to a high mean concentration of 9.39 mg/kg dry wt. at Piscataqua River, Back Channel (Figure 1.1.3.5.2). Maine concentrations were comparable to or below the Mussel Watch median with the exception of Piscataqua River, Back Channel, which approached but did not exceed the Mussel Watch 85th percentile (Kimbrough, 2008). Maine 2008 concentrations also were comparable to Gulf of Maine mean concentrations (1.8 to 7.2 mg/kg dry wt., 2004-06) from Gulfwatch with the exception of two sites: Piscataqua River, Back Channel, and Presumpscot River (Krahforst, 2009).

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

Goose Falls (2007) is also a Superfund site, a historic mining operation, which may offer increased input of copper to the sediments and blue mussels through the increased availability of rock for weathering or through other sources related to the mining operation. Elevated copper levels at Rockland in 2007 (and levels between the national Mussel Watch median and 85th percentile at other Maine sites) are most likely associated with marine activity in those areas, including heavy boat usage and the presence of boatyards where the boats are refinished and maintained. Copper concentrations at Piscataqua River, Back Channel (2008) may be a result of the naval shipyard adjacent to the sampling site, from other marine activities, or a result of urban runoff (or a combination of all three). Prior sampling at Back Channel in 1987 (only one replicate taken) showed a similar copper concentration of 8.90 mg/kg dry wt., which is comparable to the 2008 mussel sample concentrations.

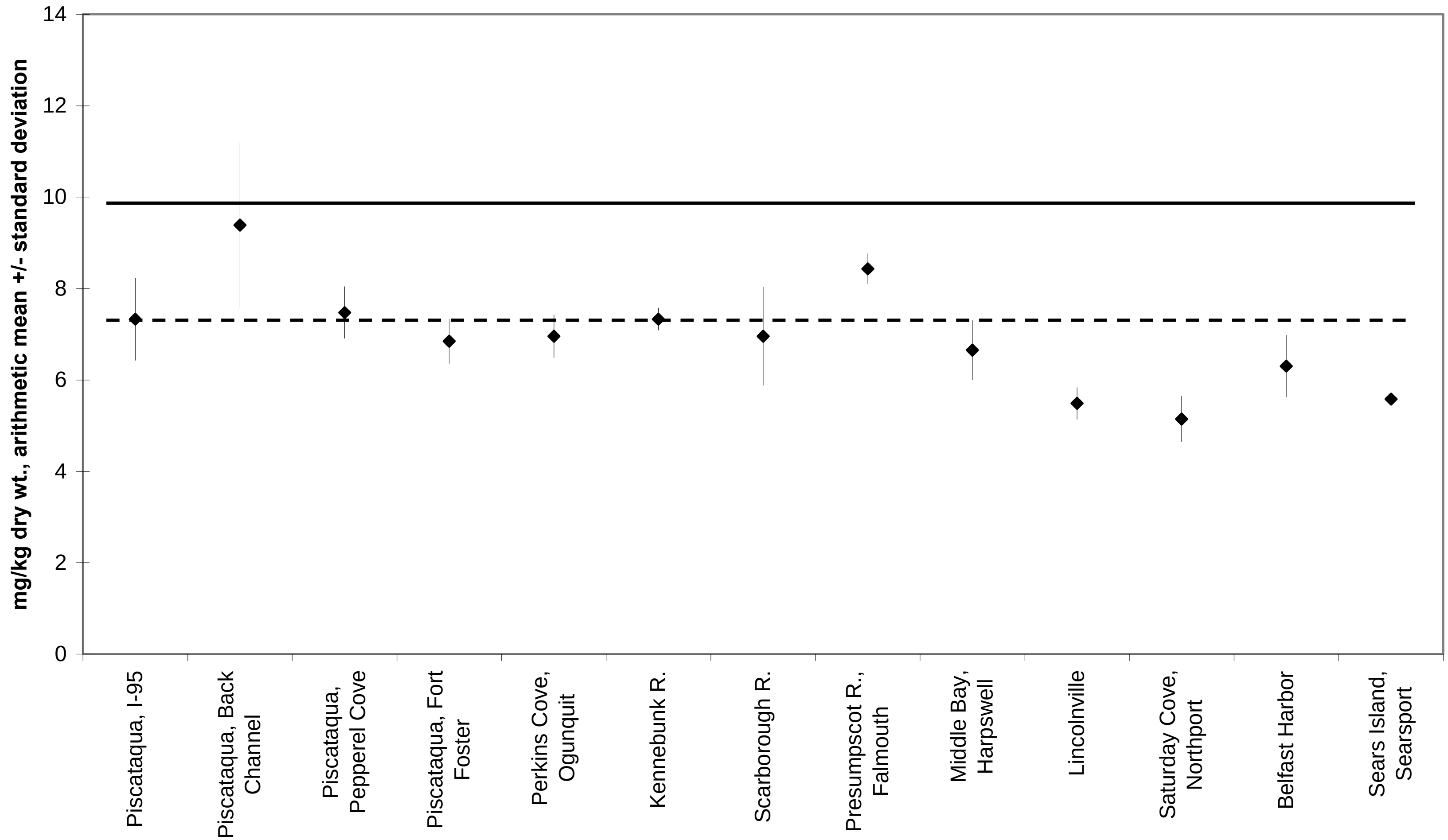
From a human health perspective, copper is not highly toxic to humans, though there are some chronic effects. There is no recommended FDA safety level for human consumption for copper in fish or shellfish (Kimbrough, 2008).

FIGURE 1.1.3.5.1: 2007 SWAT Blue Mussel Tissue Copper Concentrations



Dashed line = 1996 Mussel Watch National Median; Solid line = 1996 Mussel Watch National 85th Percentile.

FIGURE 1.1.3.5.2: 2008 SWAT Blue Mussel Tissue Copper Concentrations



Dashed line = 1996 Mussel Watch National Median; Solid line = 1996 Mussel Watch National 85th Percentile.

1.1.3.6 Iron (Fe) and Aluminum (Al)

2007

Iron was detected in all 13 sample locations visited in 2007. Iron concentrations detected in mussels ranged from a low mean concentration of 176 mg/kg dry wt. at Jewell Island, Cumberland to a high mean concentration of 754 mg/kg dry wt. at Sheepscot River, Clough Point (Figure 1.1.3.6.1). Aluminum concentrations detected in mussels ranged from a low mean concentration of 39 mg/kg dry wt. at Jewell Island, Cumberland to a high mean concentration of 319 mg/kg dry wt. at Sheepscot River, Clough Point (Figure 1.1.3.6.2). Maine iron and aluminum concentrations were comparable to the Mussel Watch medians in at all sampling sites (Kimbrough, 2008). Maine iron and aluminum concentrations also were comparable to Gulf of Maine mean concentrations (407 to 521 mg/kg dry wt. (Fe) and 375 to 490 mg/kg dry wt. (Al), from 2004-06) from Gulfwatch (Krahforst, 2009).

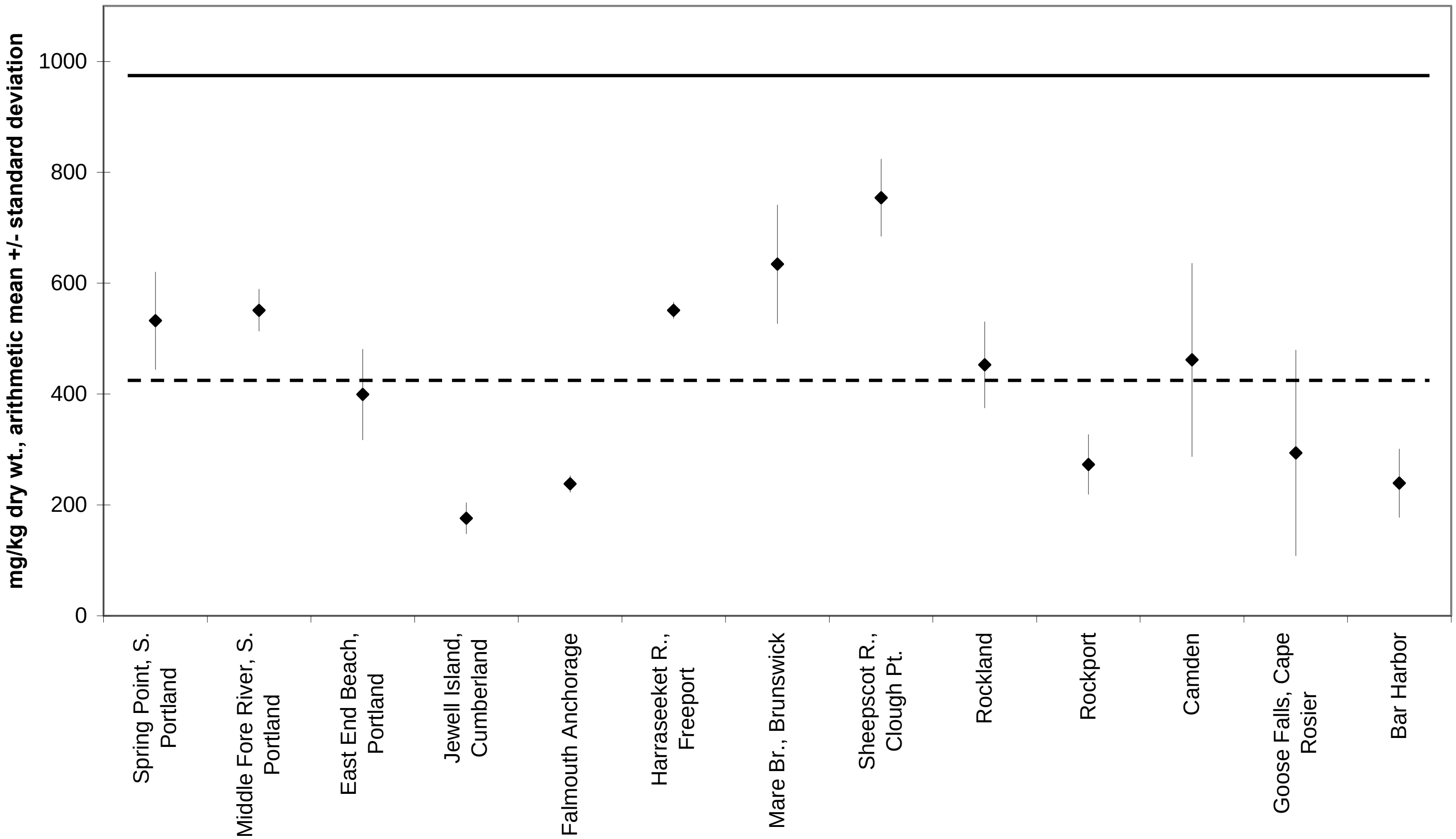
2008

Iron was detected in all 13 sample locations visited in 2008. Iron concentrations detected in mussels ranged from a low mean concentration of 218 mg/kg dry wt. at Belfast Harbor to a high mean concentration of 771 mg/kg dry wt. at Piscataqua River, Back Channel (Figure 1.1.3.6.3). Aluminum concentrations detected in mussels ranged from a low mean concentration of 65 mg/kg dry wt. at Perkins Cove, Ogunquit to a high mean concentration of 202 mg/kg dry wt. at Presumpscot River, Falmouth (Figure 1.1.3.6.4). Maine iron concentrations generally were comparable to the Mussel Watch national median (Kimbrough, 2008). The Piscataqua River, Back Channel iron concentration was notably higher than the Mussel Watch national mean, but did not exceed the Mussel Watch national 85th percentile. Maine aluminum concentrations all fell below the Mussel Watch national mean. Maine iron concentrations also were comparable to Gulf of Maine mean concentrations (407 to 521 mg/kg dry wt.). Maine aluminum concentrations all fell below the Gulf of Maine mean range of 375 to 490 mg/kg dry wt. (from 2004-06) from Gulfwatch (Krahforst, 2009).

High iron and aluminum concentrations are usually associated with the intake of high levels of suspended sediments by mussels at sampled sites. This has also been shown with gut depuration experiments conducted as part of Gulfwatch in previous years, indicating that some of the iron and aluminum is associated with gut contents and not bioaccumulated loads. This theory appears to be consistent with 2007 Maine results, with the highest scoring iron and aluminum sites located in the Sheepscot River system and associated with available sediments and faster current velocities and perhaps heightened re-suspension of sediments. Conversely, the lowest scoring sight in 2007 for both iron and aluminum is located on the exposed shoreline of an offshore island, Jewell Island, Cumberland, which is a largely exposed rock substrate and largely devoid of fine sediments due to its high energy, offshore environment. The 2008 Maine iron results also appear to be consistent with this theory, with the highest iron concentrations found at Piscataqua River, Back Channel and Presumpscot River. Both sites are dominated by fine sediments which are more easily suspended and ingested by mussels.

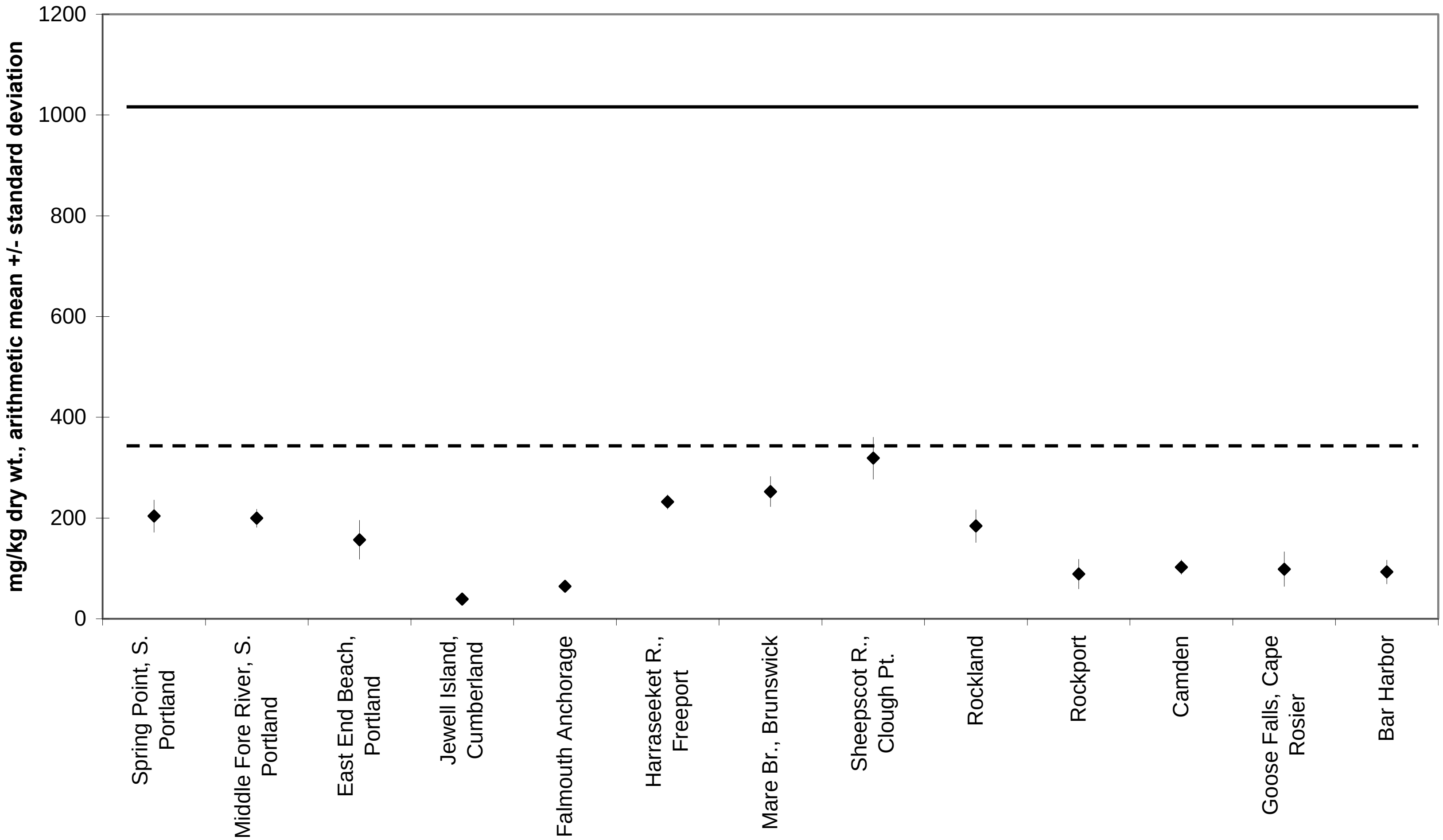
Monitoring for iron and aluminum provides an important reference to gauge sediment intake by mussels, allowing iron and aluminum levels to be referenced if other more toxic metals or contaminants are detected in mussel tissue. If iron and aluminum concentrations are high, it is likely that a fraction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

FIGURE 1.1.3.6.1: 2007 SWAT Blue Mussel Tissue Iron Concentrations



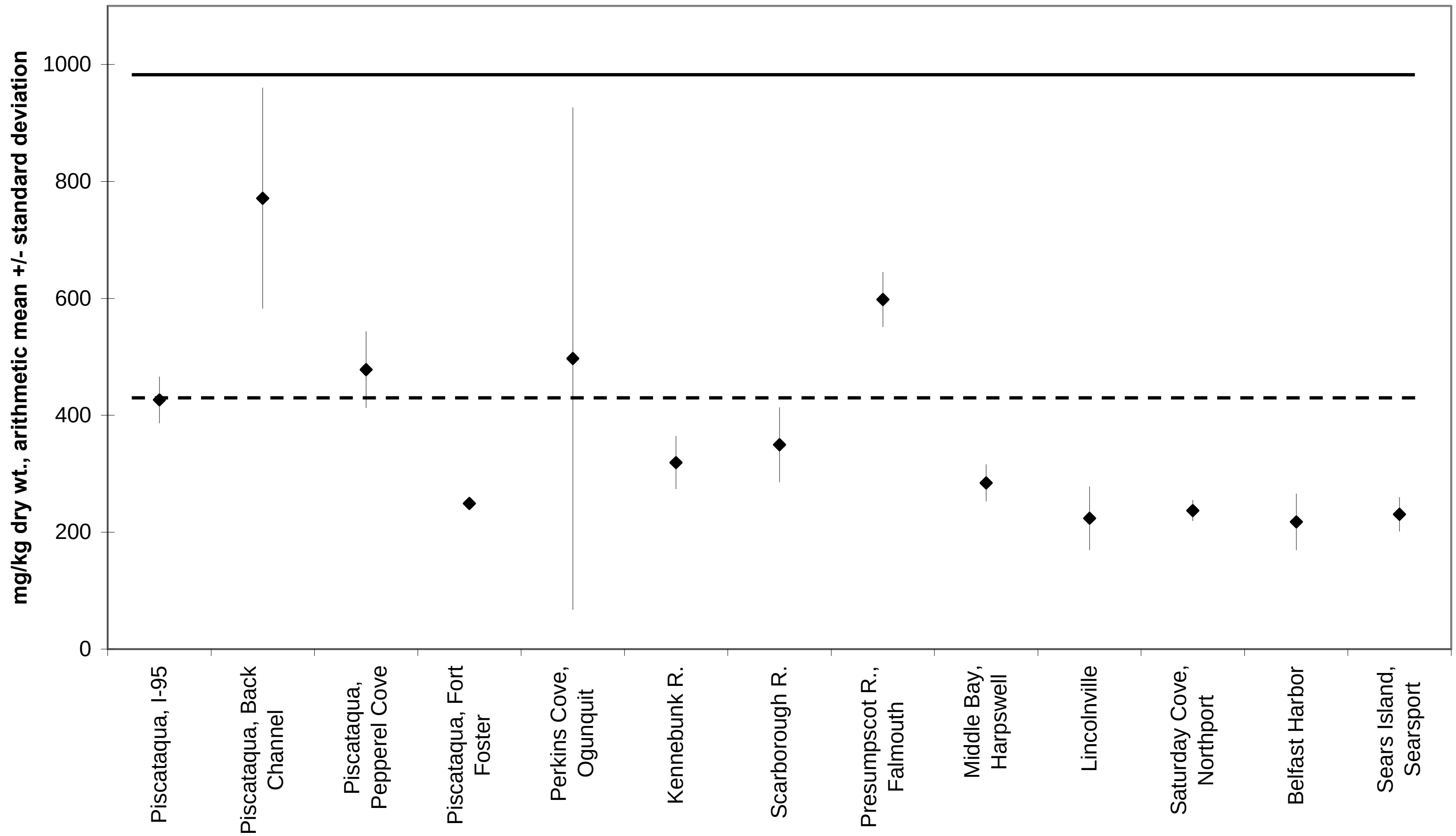
Dashed line = 1996 Mussel Watch National Median; Solid line = 1996 Mussel Watch National 85th Percentile.

FIGURE 1.1.3.6.2: 2007 SWAT Blue Mussel Tissue Aluminum Concentrations



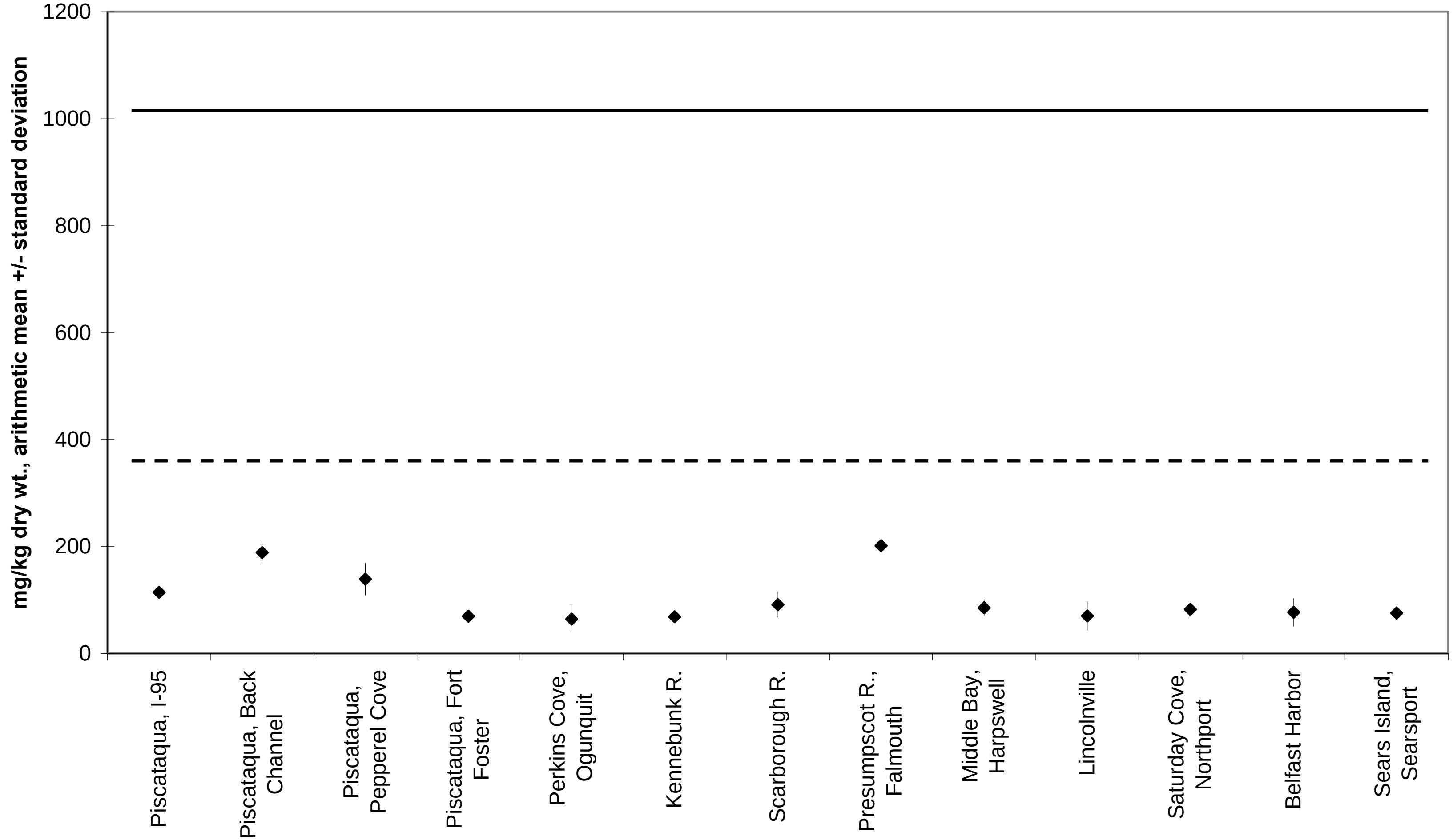
Dashed line = 1996 Mussel Watch National Median; Solid line = 1996 Mussel Watch National 85th Percentile.

FIGURE 1.1.3.6.3: 2008 SWAT Blue Mussel Tissue Iron Concentrations



Dashed line = 1996 Mussel Watch National Median; Solid line = 1996 Mussel Watch National 85th Percentile.

Figure 1.1.3.6.4: 2008 SWAT Blue Mussel Tissue Aluminum Concentrations



Dashed line = 1996 Mussel Watch National Median; Solid line = 1996 Mussel Watch National 85th Percentile.

1.1.3.7 Nickel (Ni)

2007

Nickel was detected in all 13 sample locations visited in 2007. Nickel levels detected in mussels ranged from a low mean concentration of 0.44 mg/kg dry wt. at Goose Falls, Brooksville to a high mean concentration of 1.50 mg/kg dry wt. at Sheepscot River, Clough Point (Figure 1.1.3.7.1). Nickel concentrations appear to be uniformly distributed across the 2007 SWAT sampling stations. Maine concentrations were comparable to and all below the national Mussel Watch median (Kimbrough, 2008). Maine 2007 concentrations also were comparable to Gulf of Maine mean concentrations (1.4 to 6.9 mg/kg dry wt., 2004-06) from Gulfwatch with all Maine 2007 samples falling near the bottom of that range (Krahforst, 2009). Higher nickel concentrations are probably associated with sediment ingestion, similar to iron and aluminum concentrations and the highest nickel concentration site, Sheepscot River, Clough Point also scored highest for iron and aluminum concentrations.

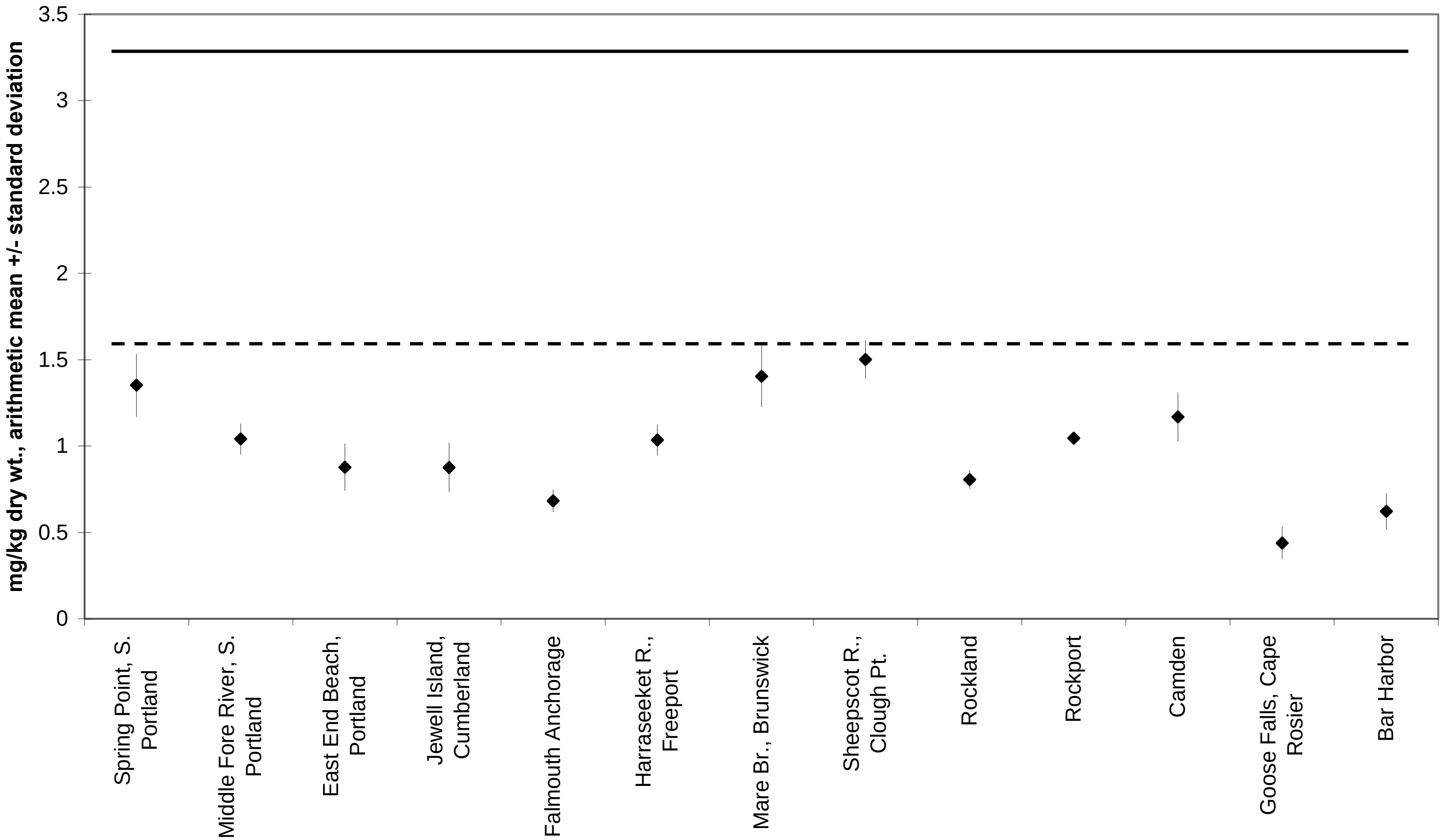
2008

Nickel was detected in all 13 sample locations visited in 2008. Nickel levels detected in mussels ranged from a low mean concentration of 0.81 mg/kg dry wt. at Saturday Cove, Northport to a high mean concentration of 1.88 mg/kg dry wt. at Perkins Cove, Ogunquit (Figure 1.1.3.7.2). Nickel concentrations appear to be uniformly distributed across the 2008 SWAT sampling stations. Maine concentrations were comparable to and predominantly below the national Mussel Watch median (Kimbrough, 2008). Maine 2008 concentrations also were comparable to Gulf of Maine mean concentrations (1.4 to 6.9 mg/kg dry wt., 2004-06) from Gulfwatch with all Maine 2008 samples falling near the bottom of that range (Krahforst, 2009).

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

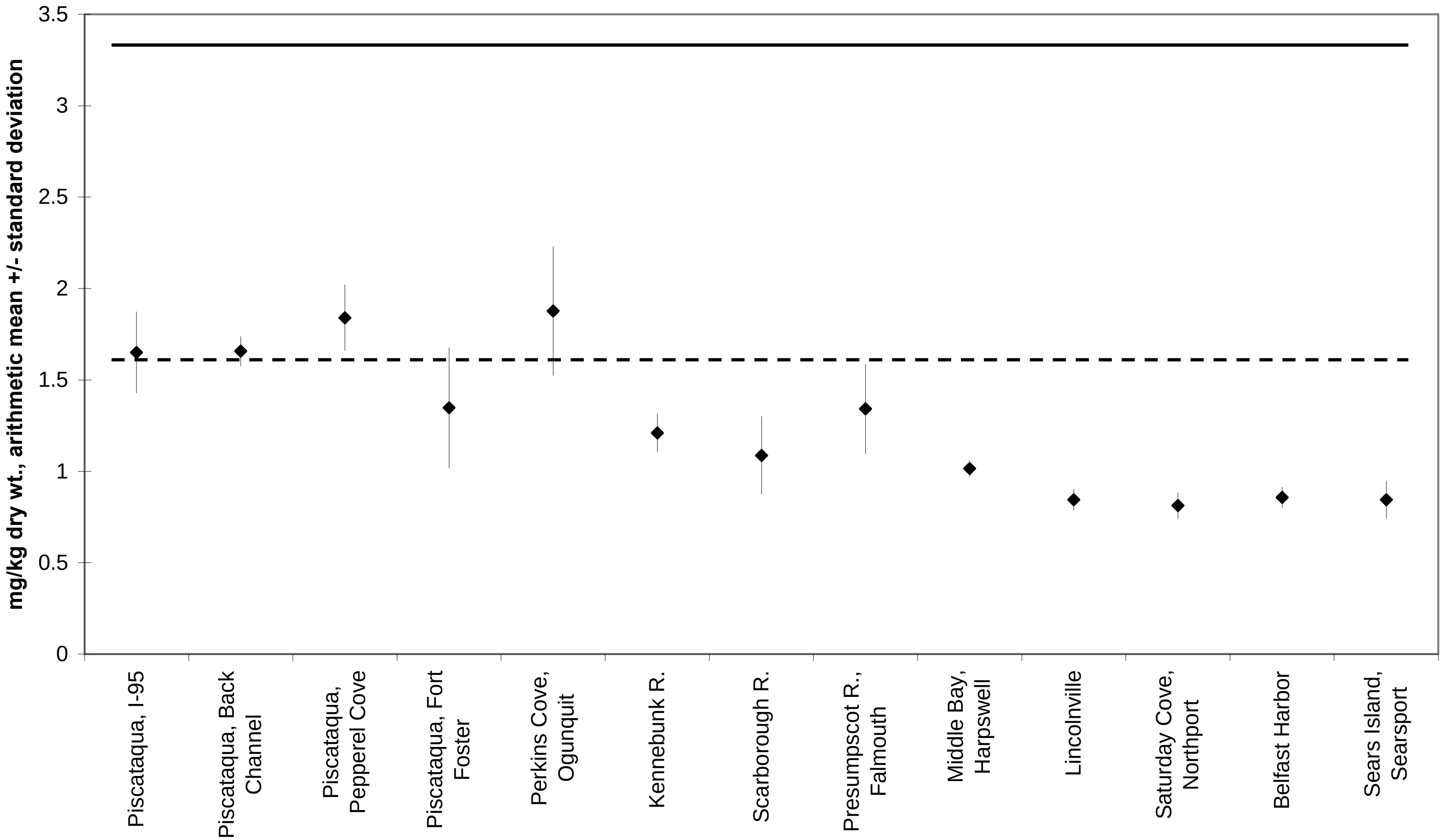
Nickel is not thought to bioaccumulate in the food chain, however nickel can be harmful to humans in large doses, inducing effects including bronchitis and even cancer from long term exposure (Kimbrough, 2008). The FDA action level for nickel in shellfish is 80 ppm wet weight, which is well above the maximum mean concentration detected by SWAT in 2007 of 0.21 ppm (mg/kg) wet weight at Sheepscot River, Clough Point.

FIGURE 1.1.3.7.1: 2007 SWAT Blue Mussel Tissue Nickel Concentrations



Dashed line = 1996 Mussel Watch National Median; Solid line = 1996 Mussel Watch National 85th Percentile.

FIGURE 1.1.3.7.2: 2008 SWAT Blue Mussel Tissue Nickel Concentrations



Dashed line = 1996 Mussel Watch National Median; Solid line = 1996 Mussel Watch National 85th Percentile.

1.1.3.8 Lead (Pb)

2007

Lead was detected in all 13 sample locations visited in 2007. Lead levels detected in mussels ranged from a low mean concentration of 0.87 mg/kg dry wt. at Jewell Island, Cumberland to a high mean concentration of 2.13 mg/kg dry wt. at Goose Falls, Brooksville (Figure 1.1.3.8.1). Six of the 13 Maine sites collected in 2007 were considered elevated in lead (above the Mussel Watch 1996 85^{th} percentile = 2.4 mg Pb/kg dry wt.) (Kimbrough, 2008). Maine sites were comparable to Gulf of Maine concentrations (means of 1.3 to 2.6 mg/kg, 2003-06) from Gulfwatch (Krahforst, 2009). The Gulfwatch 85^{th} percentile ranged from 1.8 to 6.2 mg/kg dry wt. (2003-06), indicating that some Gulf of Maine sites show elevated levels of lead in mussel tissue. These are associated with historic mine site (Goose Falls) and significant seaport areas along the coast. Prior samples from four of the six elevated Maine sites suggest that lead levels are not increasing but have been relatively stable at these four sites.

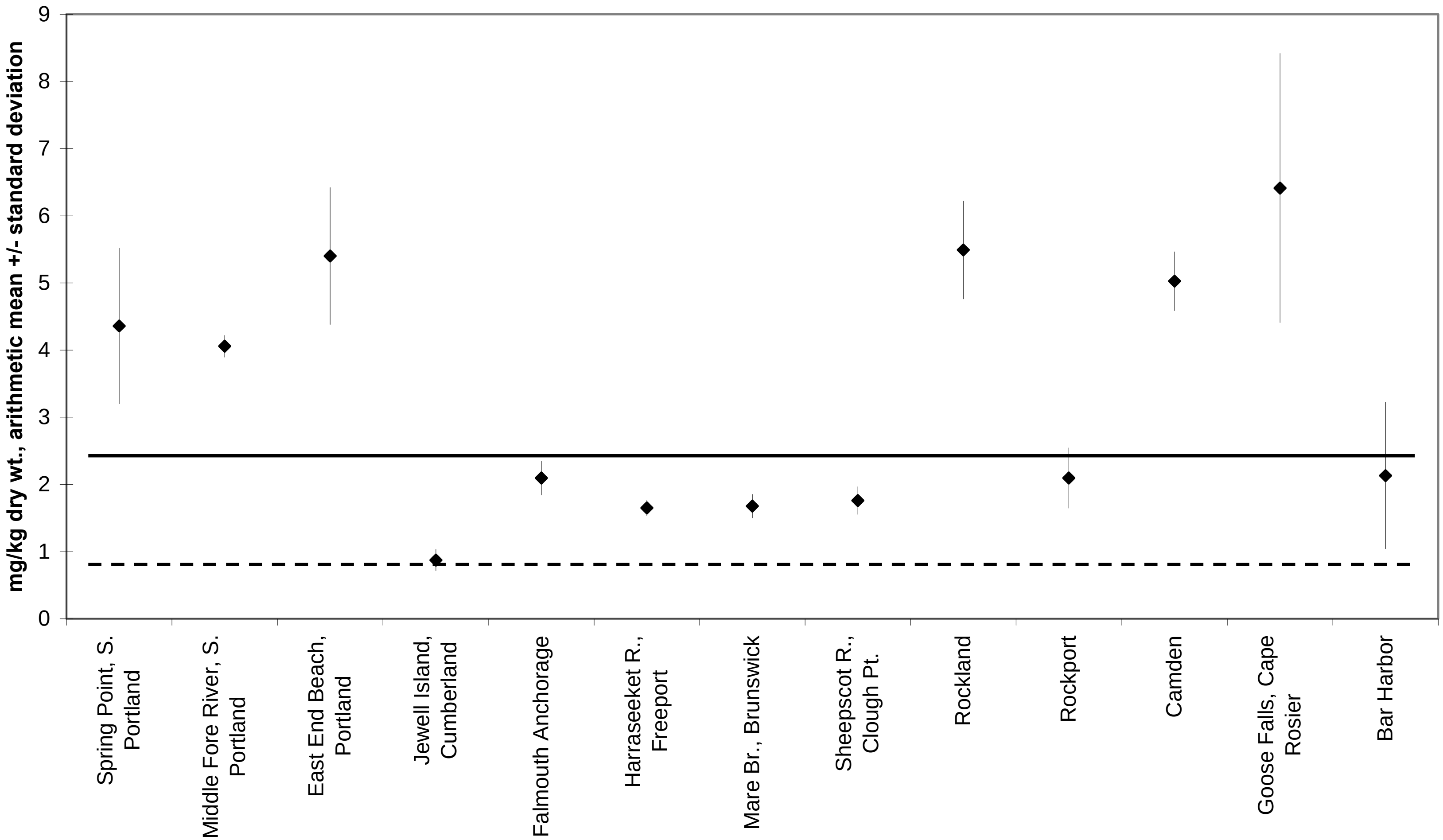
2008

Lead was detected in all 13 sample locations visited in 2008. Lead levels detected in mussels ranged from a low mean concentration of 0.61 mg/kg dry wt. at Lincolnville to a high mean concentration of 6.28 mg/kg dry wt. at Piscataqua River, Back Channel (Figure 1.1.3.8.2). Four of the 13 Maine sites collected in 2008 were considered elevated in lead (above the Mussel Watch 1996 85^{th} percentile = 2.4 mg Pb/kg dry wt.) (Kimbrough, 2008). These four sites elevated in lead were Piscataqua River at: I-95, Back Channel, and Pepperell Cove; and Presumpscot River, Falmouth. Maine sites generally were comparable to Gulf of Maine concentrations (means of 1.3 to 2.6 mg/kg, 2003-06) from Gulfwatch (Krahforst, 2009). The Gulfwatch 85^{th} percentile ranged from 1.8 to 6.2 mg/kg dry wt. (2003-06), indicating that some Gulf of Maine sites show elevated levels of lead in mussel tissue similar to the four elevated sites tested in 2008 as part of SWAT. Three of these sites are located within the Piscataqua River estuary, which is heavily industrialized and features Portsmouth Naval Shipyard and substantial urban runoff. Prior sampling in the Piscataqua at two of these three sites was limited to one replicate each, while the Pepperell Cove site was sampled with four replicates and more recently. Lead concentrations in mussel tissue appear to have dropped from three to two times less than previously sampled concentrations at these three sampling locations. Presumpscot River estuary, the fourth elevated lead site based on 2008 sampling, features moderate development within the watershed and includes treated waste discharges from the city of Westbrook, the town of Falmouth, and a pulp and paper mill. Prior mussel tissue sampling for lead suggests that lead levels are not increasing but have been relatively stable at the Presumpscot River estuary site over the last decade.

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

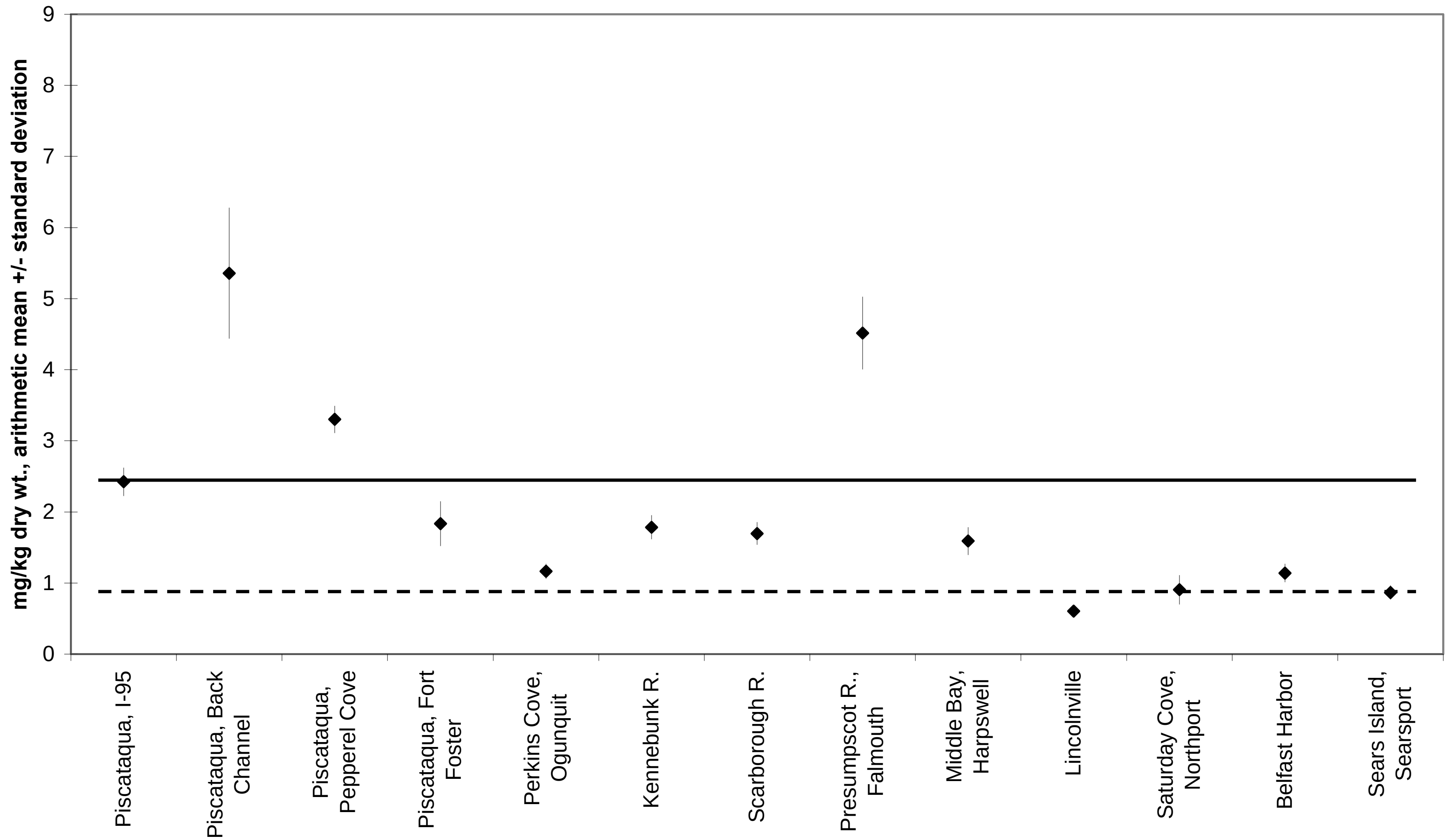
From a human health perspective, the FDA action level for lead in clams, oysters, and mussels is 1.7 ppm wet wt. (Kimbrough, 2008). The highest concentration of 1.1 ppm (mg/kg wet wt. at Goose Falls, Brooksville) in the 2007 Maine data falls below the FDA action level for lead in shellfish. In 2008, the highest concentration of 0.65 ppm (mg/kg wet wt. at Piscataqua, Back Channel) also falls well below the FDA action level for lead in shellfish.

FIGURE 1.1.3.8.1: 2007 SWAT Blue Mussel Tissue Lead Concentrations



Dashed line = 1996 Mussel Watch National Median; Solid line = 1996 Mussel Watch National 85th Percentile.

FIGURE 1.1.3.8.2: 2008 SWAT Blue Mussel Tissue Lead Concentrations



Dashed line = 1996 Mussel Watch National Median; Solid line = 1996 Mussel Watch National 85th Percentile.

1.1.3.9 Mercury (Hg)

2007

Mercury was detected in all 13 blue mussel sample locations visited in 2007. Mercury levels detected in mussels ranged from a low mean concentration of 39 µg/kg dry wt. at Bar Harbor to a high mean concentration of 443 µg/kg dry wt. at Sheepscot River, Clough Point (Figure 1.1.3.9.1). Maine concentrations were comparable to the Mussel Watch 1996 median with the exceptions of Sheepscot River, Middle Fore River, Camden, and Spring Point, which exceeded the Mussel Watch 85th percentile (Kimbrough, 2008). Spring Point and Camden concentrations were quite close to the Mussel Watch 85th percentile. Maine mercury concentrations generally were comparable to Gulf of Maine median concentrations (140 to 220 µg/kg, 2003-06) (Krahforst, 2009). The Gulfwatch 2006 85th percentile, 280 µg/kg, was exceeded in the 2007 Maine SWAT data only by the Sheepscot River, Clough Point concentration.

2008

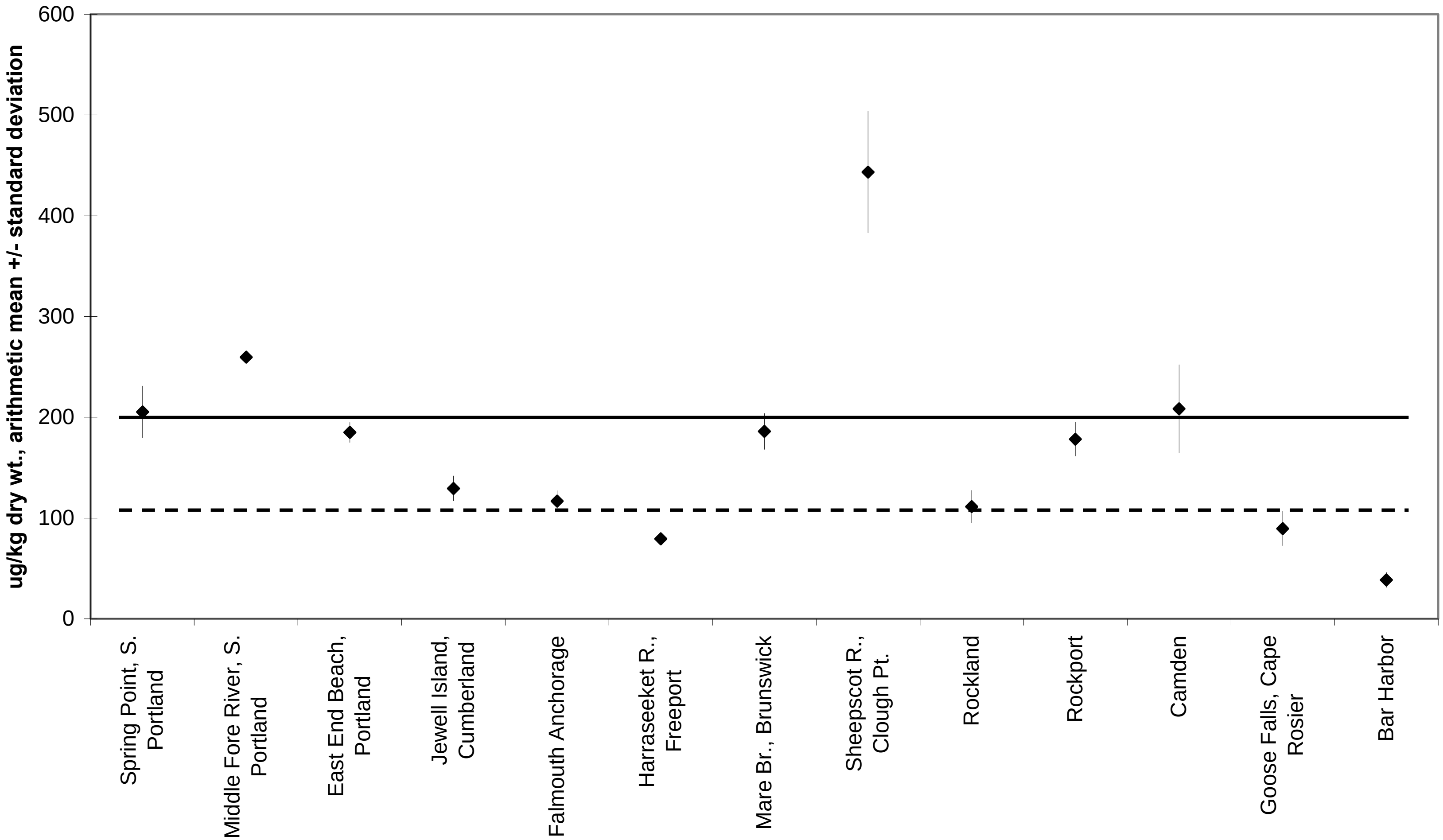
Mercury was detected in all 13 blue mussel locations sampled in 2008. Mercury levels detected in mussels ranged from a low mean concentration of 111 µg/kg dry wt. at Middle Bay, Harpswell to a high mean concentration of 366 µg/kg dry wt. at Piscataqua River, I-95 (Figure 1.1.3.9.2). Maine concentrations in 2008 were near or above the Mussel Watch 1996 median with the highest concentrations occurring in the Piscataqua River estuary at: I-95, Back Channel, and Pepperell Cove. In all, six sites sampled in 2008 exceeded the Mussel Watch 85th percentile (Kimbrough, 2008). Maine mercury concentrations generally were comparable to Gulf of Maine median concentrations (140 to 220 µg/kg, 2003-06) (Krahforst, 2009). The Gulfwatch 2006 85th percentile, 280 µg/kg, was exceeded in the 2008 Maine SWAT data only by the Piscataqua River estuary at: I-95, Back Channel, and Pepperell Cove, which could be considered to have elevated mercury concentrations. Mercury has been associated with the Portsmouth Naval Shipyard as a contaminant, although other historical sources documented in the estuary include coal ash, which may also contribute to tissue mercury levels in the Piscataqua. In 2008, tissue concentrations appear to be somewhat lower than previously sampled levels, although many of these previous samples include only one replicate so that variability can not be ascertained.

Mercury occurs naturally, however elevated levels are associated with anthropogenic sources. United States sources of mercury to the air include coal fired electrical power generation, incinerators, mining, landfills, and sewage sludge (Kimbrough, 2008).

From a human health perspective, the FDA has set an action level for methyl mercury of 1.0 ppm wet wt. (Kimbrough, 2008). The Mussel Watch, Gulfwatch, and Maine SWAT programs measure total mercury in mussels, rather than methyl mercury identified in the FDA action level. Total mercury is a more conservative measurement of mercury content, reflecting both the biologically active methyl mercury and the elemental mercury components in the sample. Recognizing this, the more conservative highest total mercury measured in blue mussels in Maine in 2007 was a mean of 0.061 µg/g wet wt. (ppm)

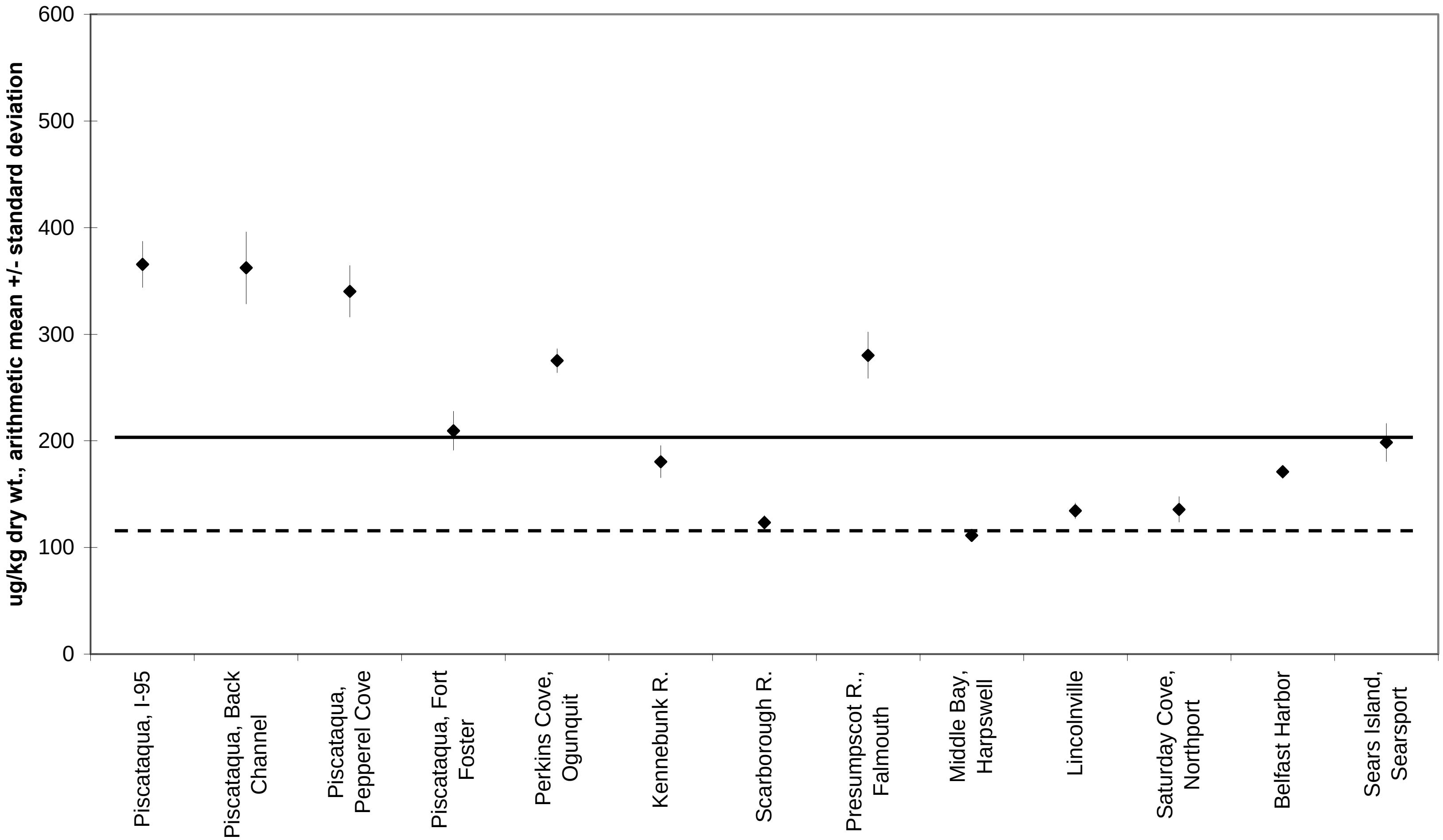
(Sheepscot River, Clough Point), compared to the 1.0 µg/g (ppm) wet weight FDA action level for methyl mercury. The highest total mercury measurement in mussel tissue in 2008 was a mean of 0.041 µg/g wet wt. (ppm) at Piscataqua River, I-95. The Maine blue mussel tissue levels are well below the FDA action level.

FIGURE 1.1.3.9.1: 2007 SWAT Blue Mussel Tissue Mercury Concentrations



Dashed line = 1996 Mussel Watch National Median; Solid line = 1996 Mussel Watch National 85th Percentile.

FIGURE 1.1.3.9.2: 2008 SWAT Blue Mussel Tissue Mercury Concentrations



Dashed line = 1996 Mussel Watch National Median; Solid line = 1996 Mussel Watch National 85th Percentile.

1.1.3.10 Zinc (Zn)

2007

Zinc was detected in all 13 sample locations visited in 2007. Zinc levels detected in mussels ranged from a low mean concentration of 70.82 mg/kg dry wt. at Bar Harbor to a high mean concentration of 164.50 mg/kg dry wt. at Goose Falls, Brooksville (Figure 1.1.3.10.1). Maine concentrations were comparable to the Mussel Watch median with the exception of Goose Falls, Brooksville (Kimbrough, 2008). Maine concentrations also were comparable to Gulf of Maine concentrations (71 to 116 mg/kg, 2003-06) from Gulfwatch with the exception of Goose Falls, Brooksville (Krahforst, 2009).

2008

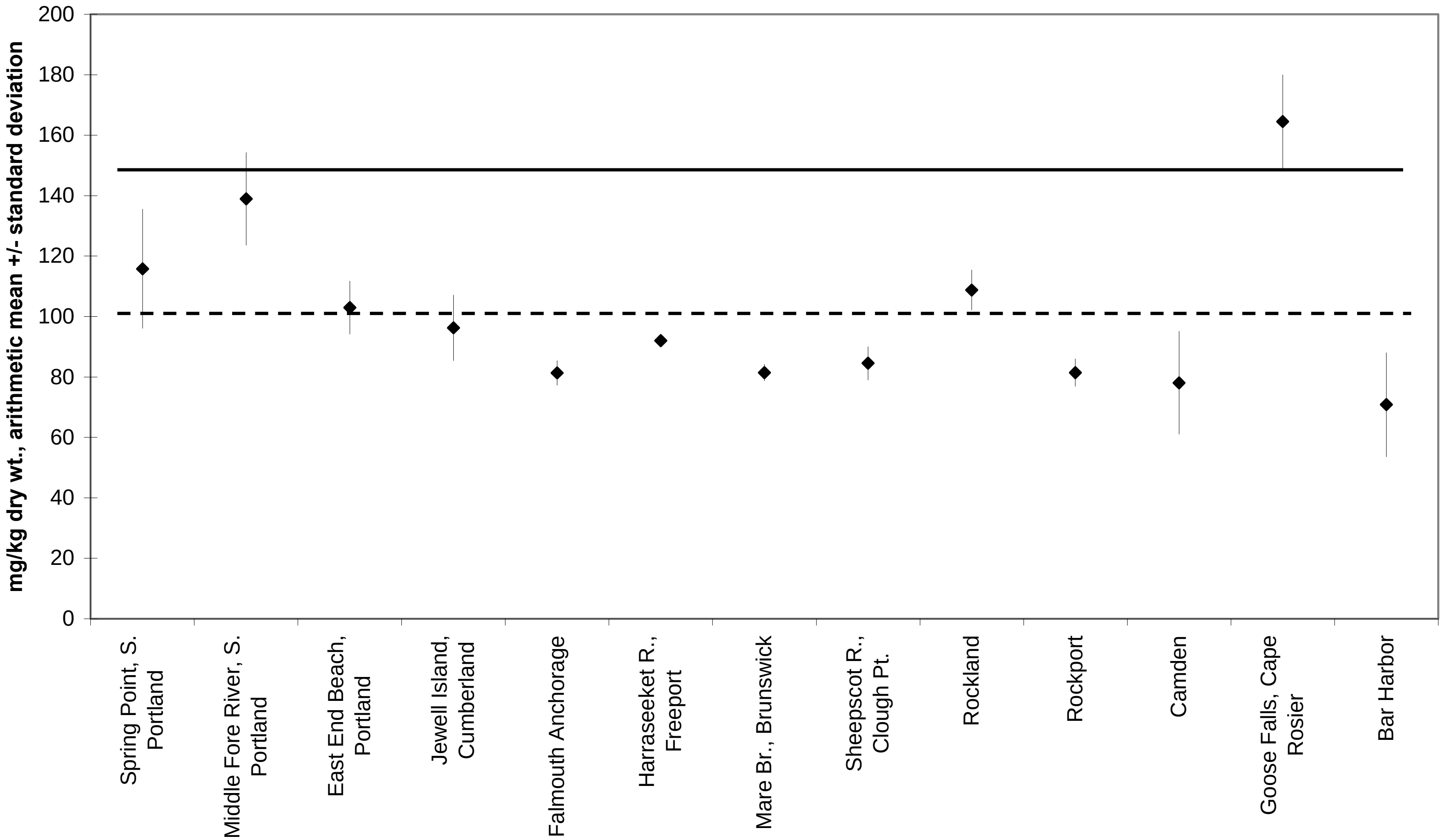
Zinc was detected in all 13 sample locations visited in 2008. Zinc levels detected in mussels ranged from a low mean concentration of 67.45 mg/kg dry wt. at Saturday Cove, Northport to a high mean concentration of 136.75 mg/kg dry wt. at Piscataqua River, Pepperell Cove (Figure 1.1.3.10.2). Maine concentrations were comparable to the Mussel Watch median with the exception of Piscataqua River, Pepperell Cove, which was similar to the Mussel Watch national 85^{th} percentile (Kimbrough, 2008). Maine concentrations generally were comparable to Gulf of Maine concentrations (71 to 116 mg/kg, 2003-06) from Gulfwatch with the exceptions of the Piscataqua River Pepperell Cove and Back Channel sites (Krahforst, 2009).

Zinc is a widespread in its distribution but elevated levels primarily originate from a variety of human activities including vehicle tire wear, electroplating and galvanized metals, industrial wastes, and drainage from mining (Kimbrough, 2008). Though an essential nutrient at low levels, higher doses to humans can cause anemia or pancreatic and kidney damage. Since humans do not bioaccumulate zinc, health impacts are normally associated with high doses. From a human health perspective, there is no recommended FDA safety level for zinc in fish (Kimbrough, 2008).

In 2007, elevated zinc levels in mussels at Goose Falls may be associated with high sediment ingestion by mussels, but this does not appear to be the case due to relatively low levels of iron, aluminum, and nickel in the Goose Falls samples. These elements provide a good approximation of sediment intake, scoring high with high sediment ingestion by mussels. Since these three metals results are relatively low, the zinc source is likely not related to sediment intake alone. Goose Falls is also the site of a historic mining operation, which may offer increased input of zinc to the local environs through sources related to the mining operation.

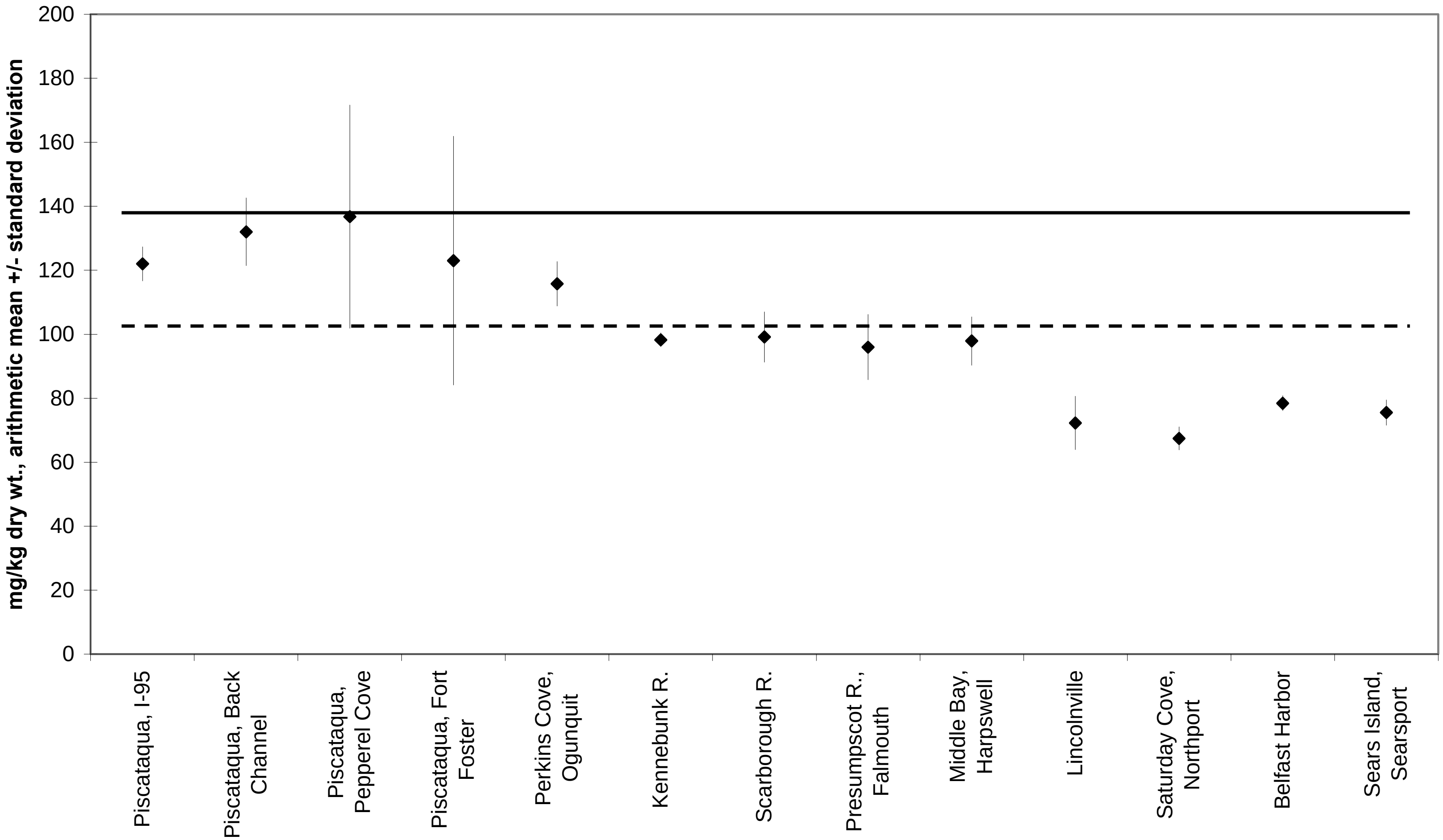
In 2008, elevated zinc concentrations in mussels at sites in the Piscataqua River may be related to urban runoff or to galvanization or plated metals associated with industry or shipyard activities in the area. Zinc concentrations are in the same general range in the 2008 samples as concentrations were when the sites were last sampled many years ago in 1987, although most sites were only sampled with one replicate. Pepperell Cove, which was sampled again in 2001, also appears to have a similar concentration of zinc in mussel tissue over time (although variability in the 2001 samples was very high).

FIGURE 1.1.3.10.1: 2007 SWAT Blue Mussel Tissue Zinc Concentrations



Dashed line = 1996 Mussel Watch National Median; Solid line = 1996 Mussel Watch National 85th Percentile.

FIGURE 1.1.3.10.2: 2008 SWAT Blue Mussel Zinc Concentrations



Dashed line = 1996 Mussel Watch National Median; Solid line = 1996 Mussel Watch National 85th Percentile.

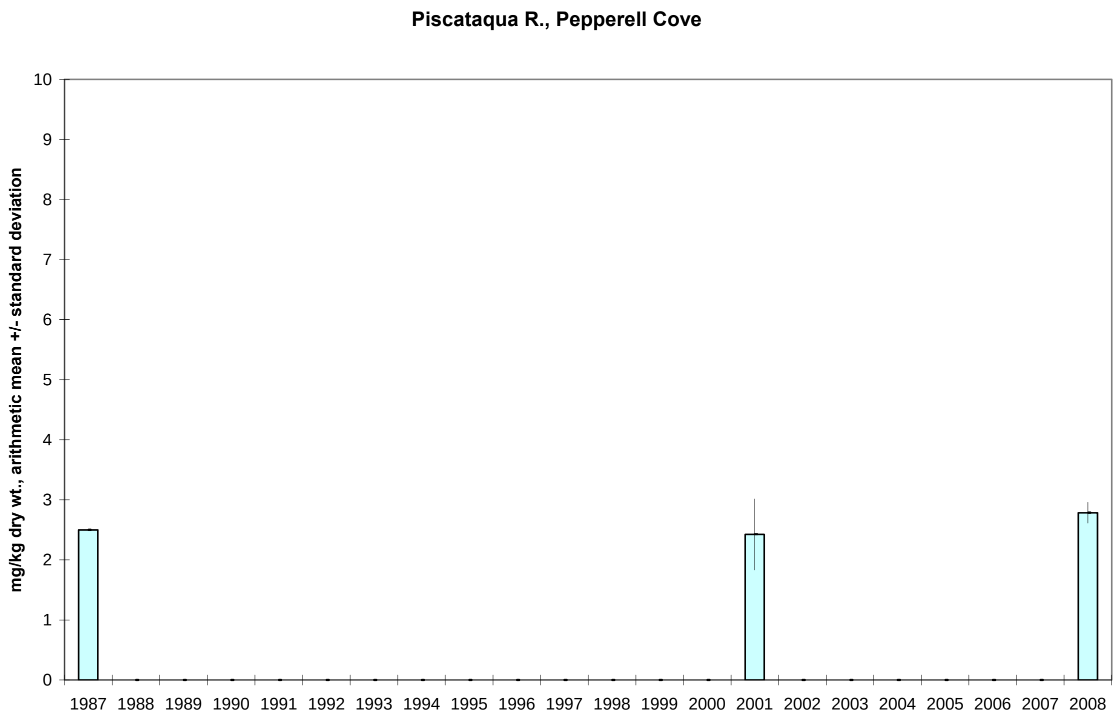
1.1.4 Temporal Variation

Selected metals data from blue mussel stations sampled in 2007-08, including cadmium, copper, lead, mercury, and zinc, is presented by sampling station over sampling years to show apparent visual trends in metals concentrations through time. No statistical analyses were performed to quantify apparent visual trends. Quantitative trend analysis is of interest but will not be possible until sufficient data points are collected at sites to allow a robust analysis of trend. Within each metal grouping, sites are presented in order moving along the coast in a roughly southwest to northeast direction.

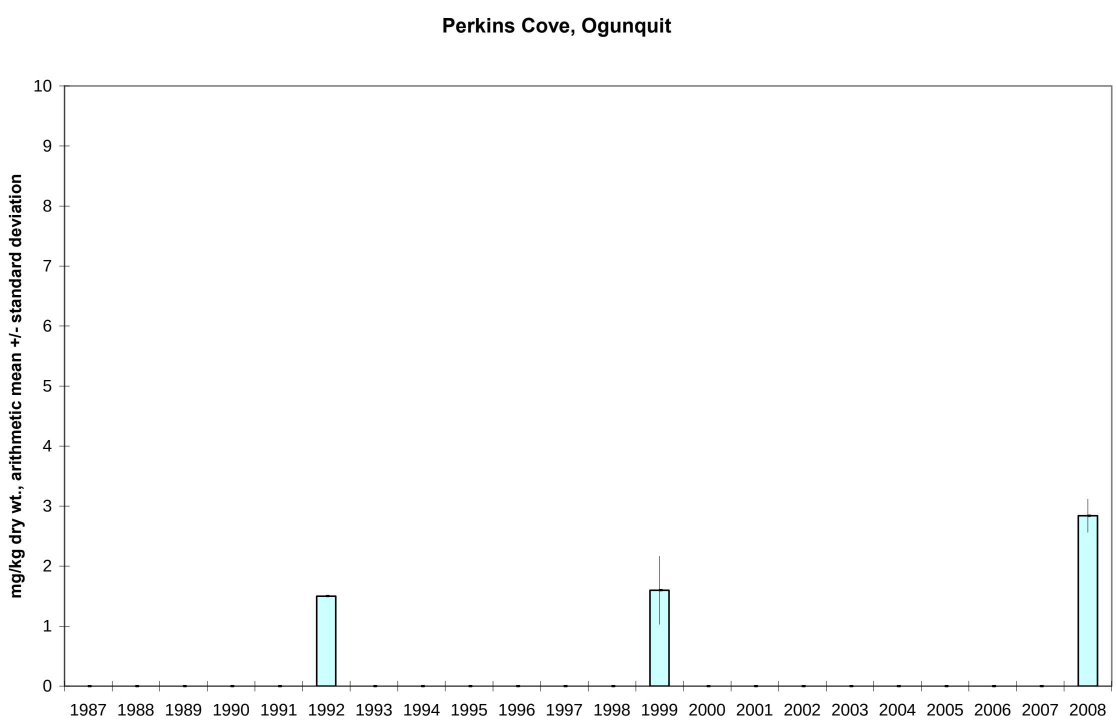
1.1.4.1 Cadmium (Cd)

Cadmium concentrations through time at ten sampling stations are presented in Figure 1.1.4.1. Sampling stations show apparent trends of stable or decreasing cadmium concentrations in blue mussel tissue. In some cases, variability between years in sampled concentrations obscures any visual trend (see East End Beach, Portland and Sears Island, Searsport). While apparent slight increasing trend may be visually interpreted at Perkins Cove, Ogunquit, Kennebunk River, and Scarborough River, the first samples taken at these stations include but one replicate and so make any analysis of variance in these early samples impossible. This fact, coupled with the very slight apparent trend and long sampling intervals, suggests that more data is needed to assess any cadmium trend at these sites. Apparent decreasing trend in mussel tissue cadmium concentration is visible at Goose Falls, Cape Rosier. Again, it must be noted that only one replicate was analyzed in 1989 at Goose Falls, making any analysis of variance impossible in that year. Mussel tissue cadmium concentrations at the remaining sites appear to be stable through time.

Figure 1.1.4.1 Distribution of SWAT Blue Mussel Tissue Cadmium Concentrations

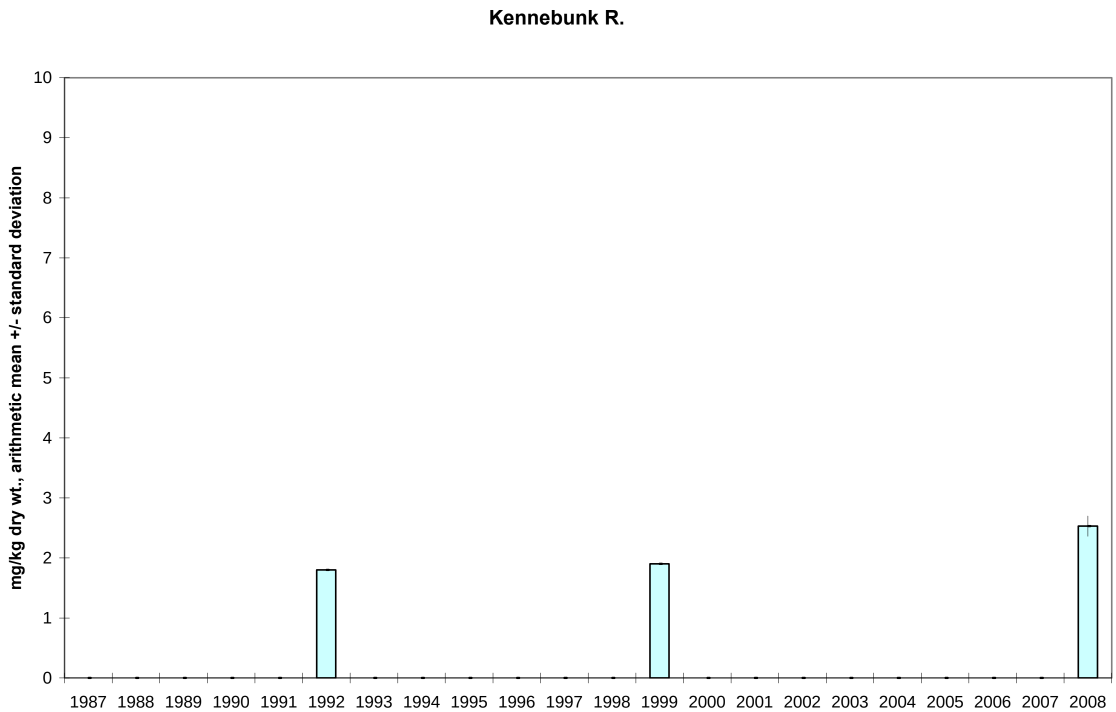


One repliate was tested in 1987.

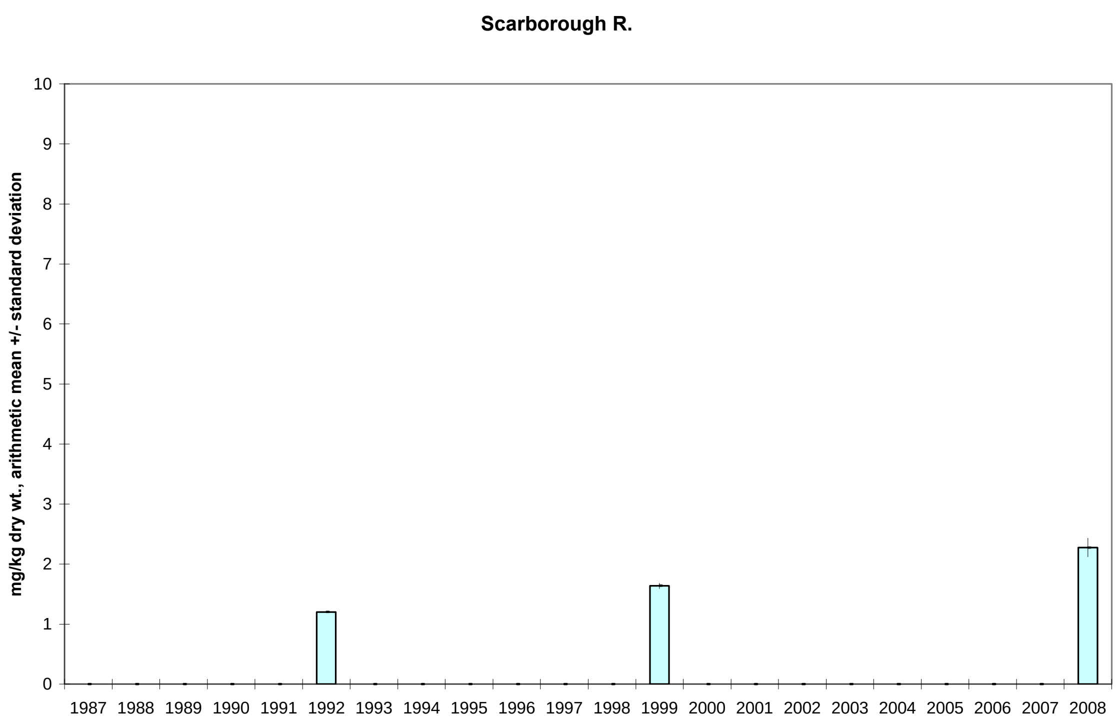


One replicate was tested in 1992.

Figure 1.1.4.1 Distribution of SWAT Blue Mussel Tissue Cadmium Concentrations (cont.)

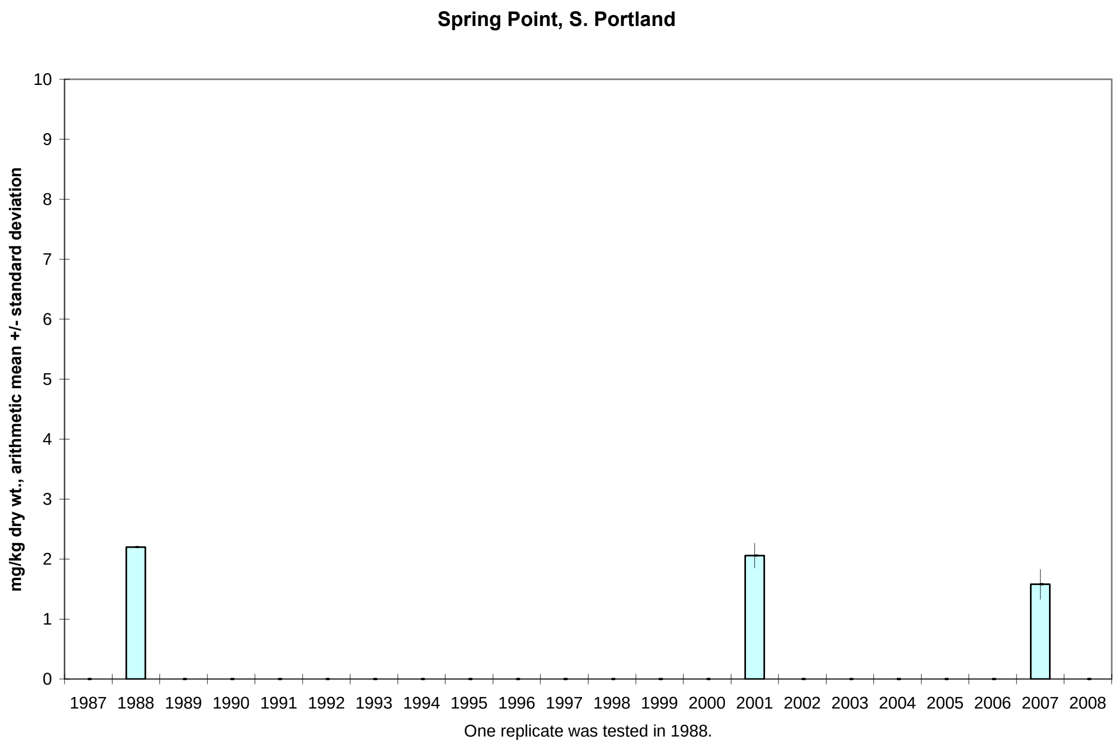


One replicate was tested in 1992 and 1999.



One repliate was tested in 1992.

Figure 1.1.4.1 Distribution of SWAT Blue Mussel Tissue Cadmium Concentrations (cont.)



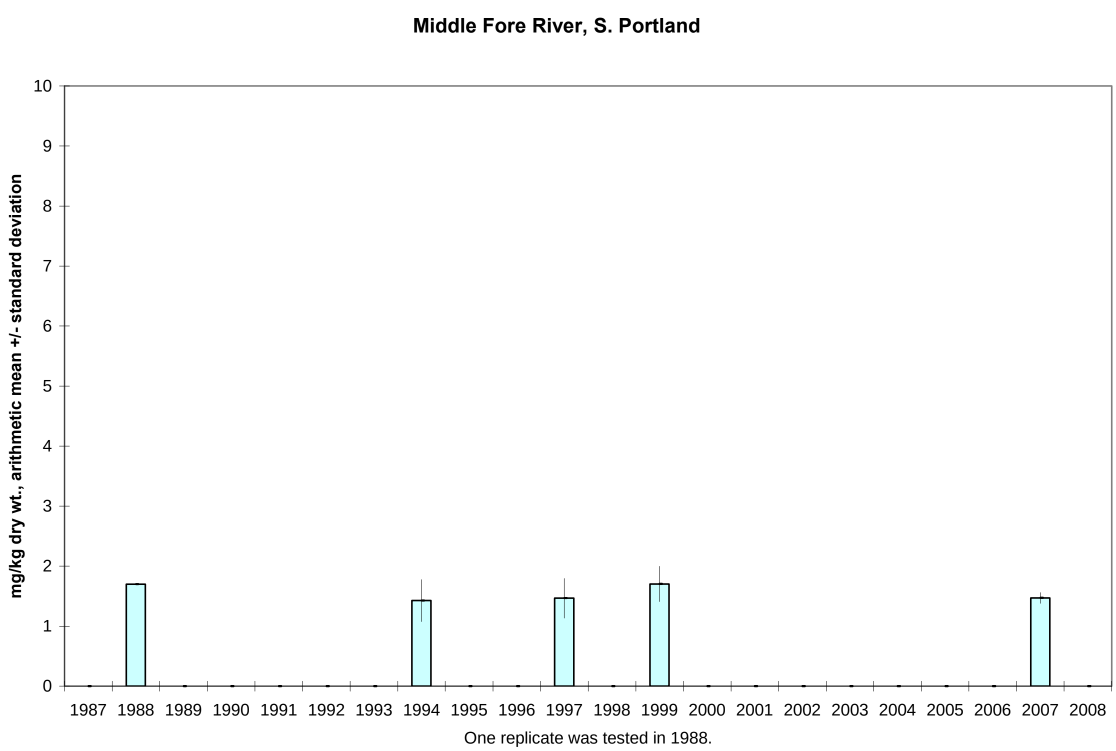
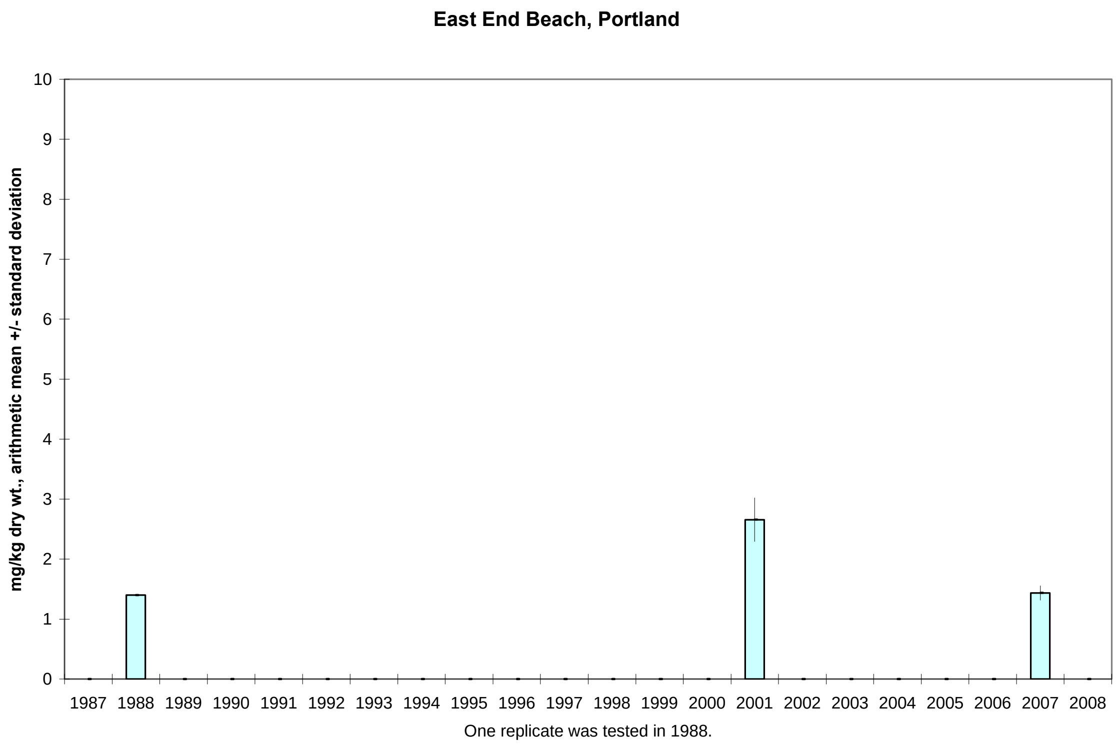


Figure 1.1.4.1 Distribution of SWAT Blue Mussel Tissue Cadmium Concentrations (cont.)



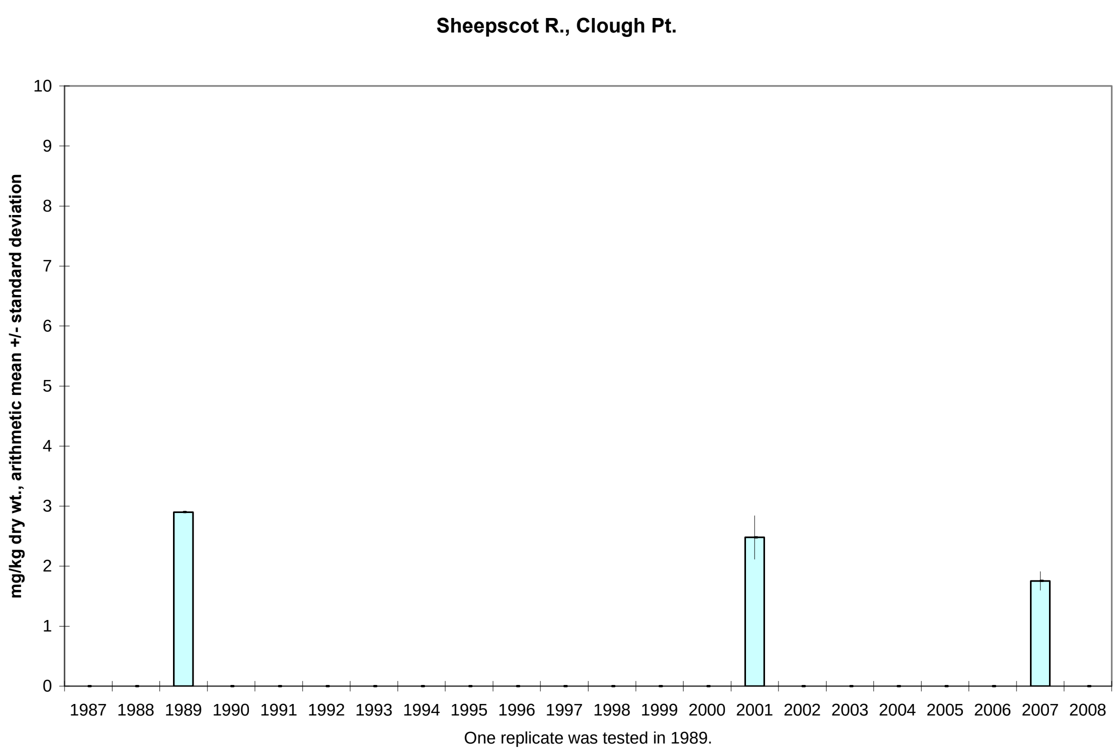
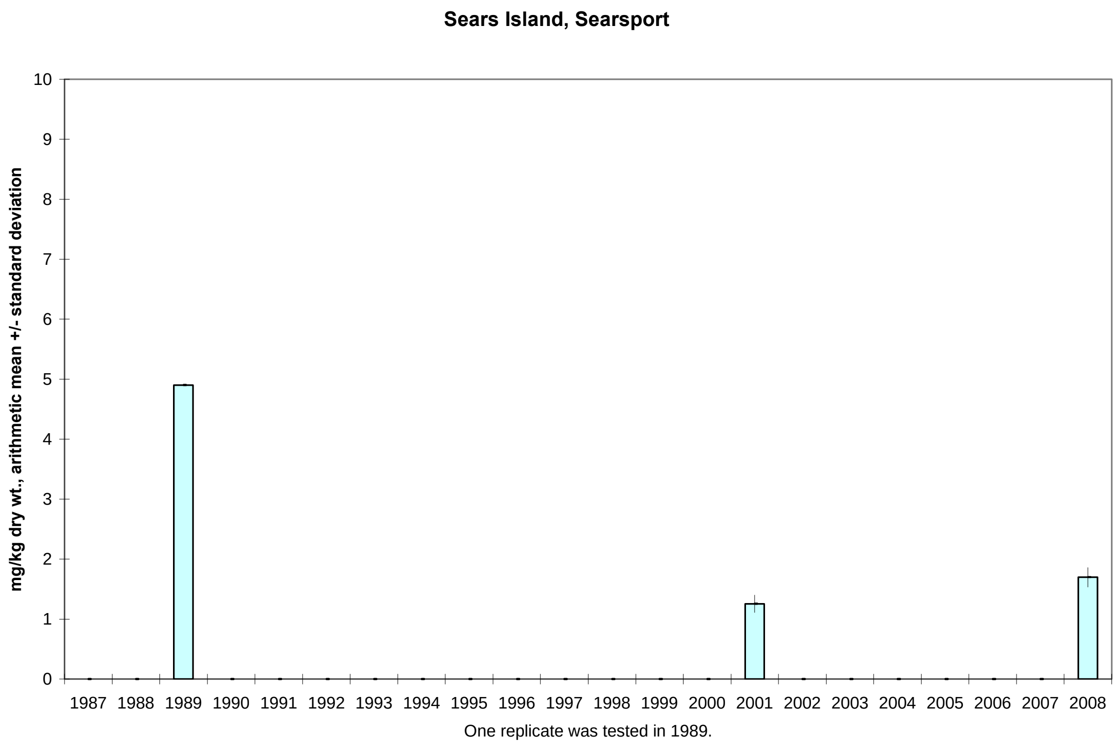
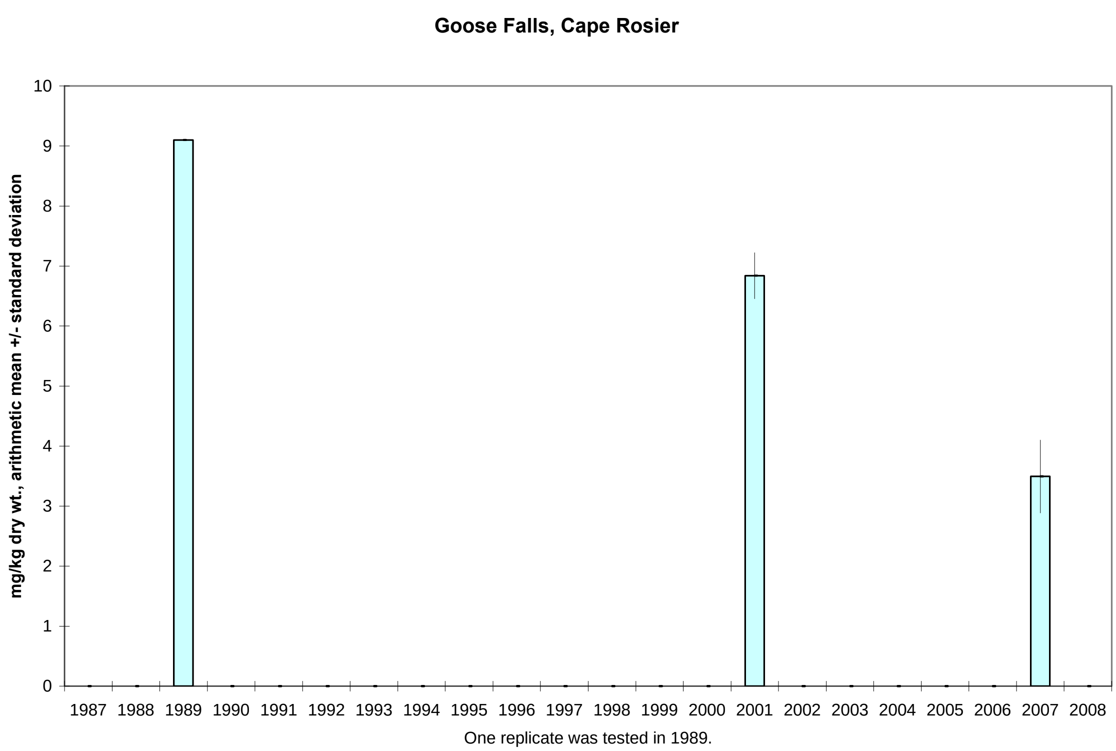


Figure 1.1.4.1 Distribution of SWAT Blue Mussel Tissue Cadmium Concentrations (cont.)

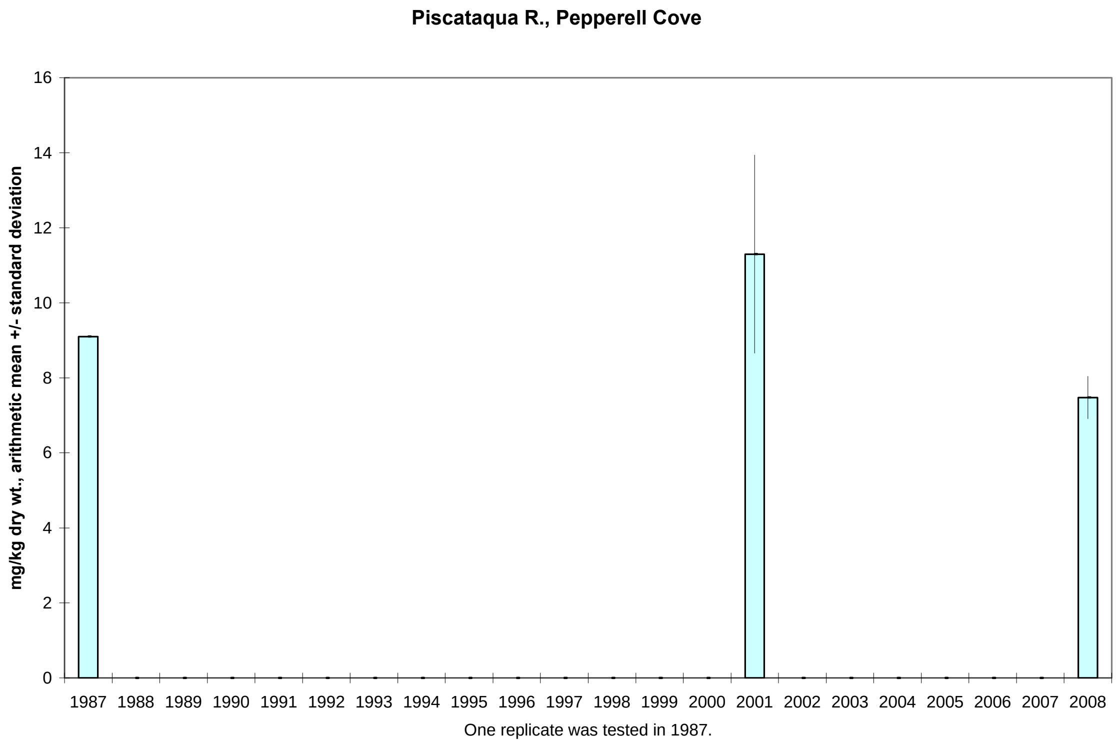




1.1.4.2 Copper (Cu)

Copper concentrations through time at seven sampling stations are presented in Figure 1.1.4.2. Sampling stations show apparent trends of stable or decreasing copper concentrations in blue mussel tissue. In some cases, variability between years in sampled concentrations obscures any visual trend (see Piscataqua River, Pepperell Cove; East End Beach, Portland; and Goose Falls, Cape Rosier). At some sites, high within site variability among replicates confounds temporal analyses (see Piscataqua River, Pepperell Cove; Middle Fore River, S. Portland; East End Beach, Portland; and Goose Falls, Cape Rosier). Apparent decreasing trend in mussel tissue copper concentration is visible at Sears Island, Searsport. It must be noted that only one replicate was analyzed in 1989 at Sears Island, making any analysis of variance impossible in that year. Copper concentrations appear lower but similar within subsequent sampling years. Mussel tissue copper concentrations at the remaining sites appear to be stable through time (see Spring Point, S. Portland; Middle Fore River, S. Portland; and Sheepscot River, Clough Point).

Figure 1.1.4.2 Distribution of SWAT Blue Mussel Tissue Copper Concentrations



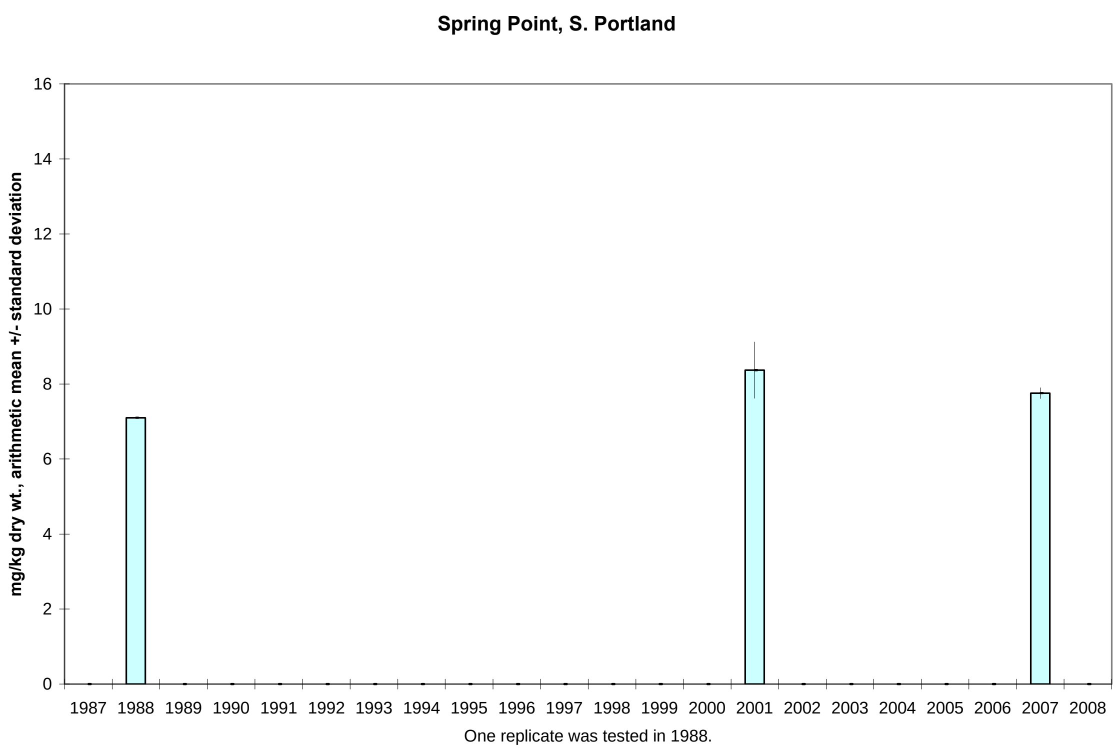
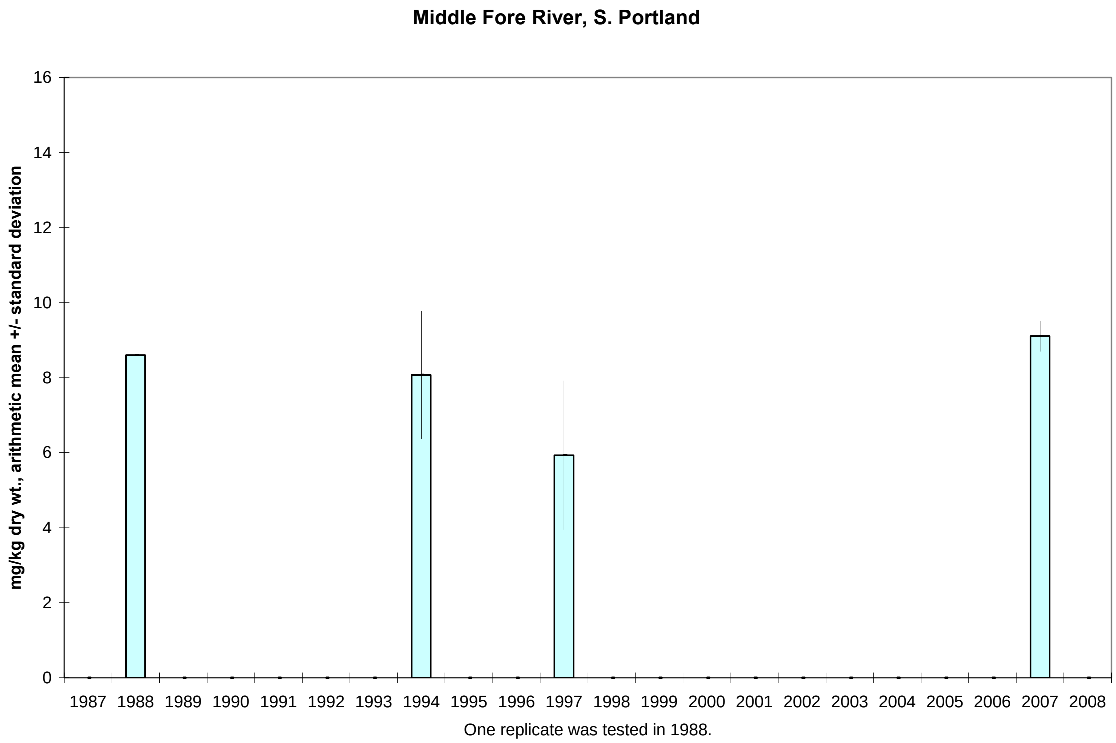


Figure 1.1.4.2 Distribution of SWAT Blue Mussel Tissue Copper Concentrations (cont.)



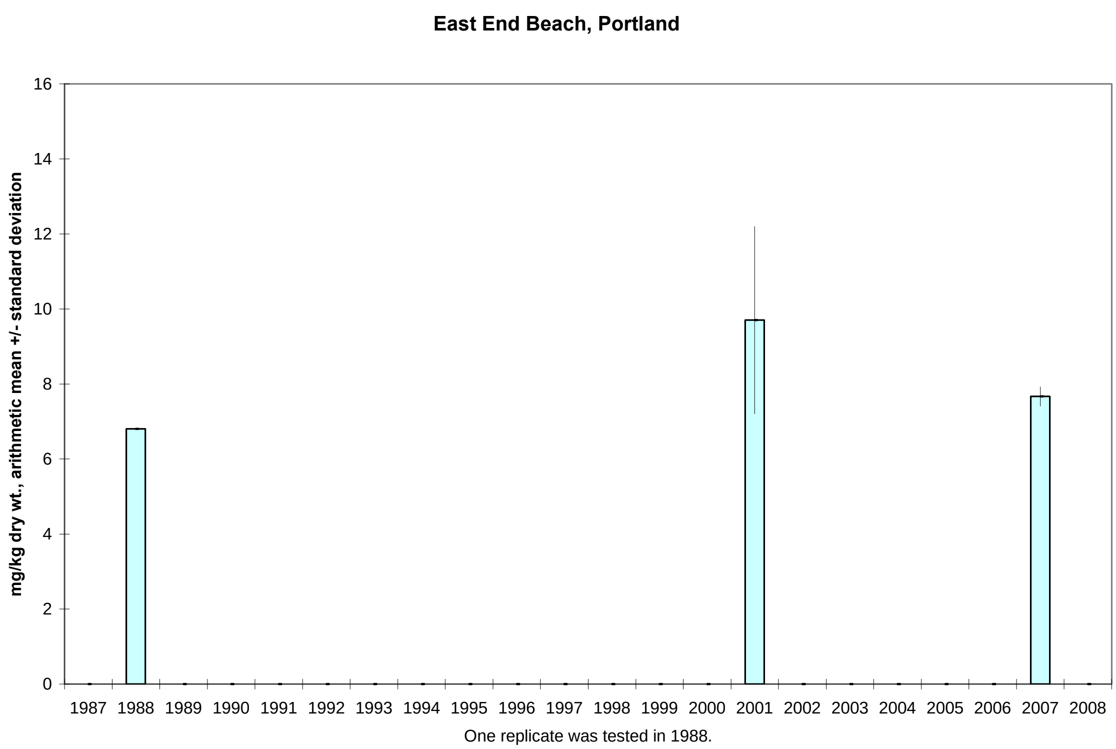
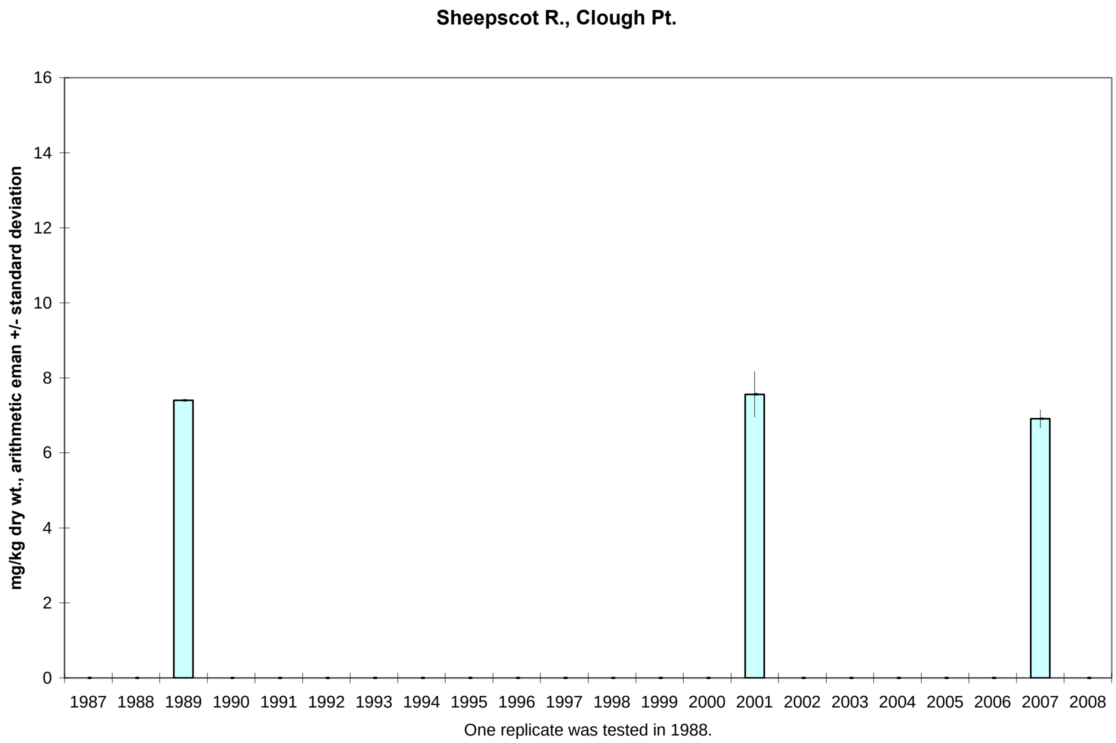


Figure 1.1.4.2 Distribution of SWAT Blue Mussel Tissue Copper Concentrations (cont.)



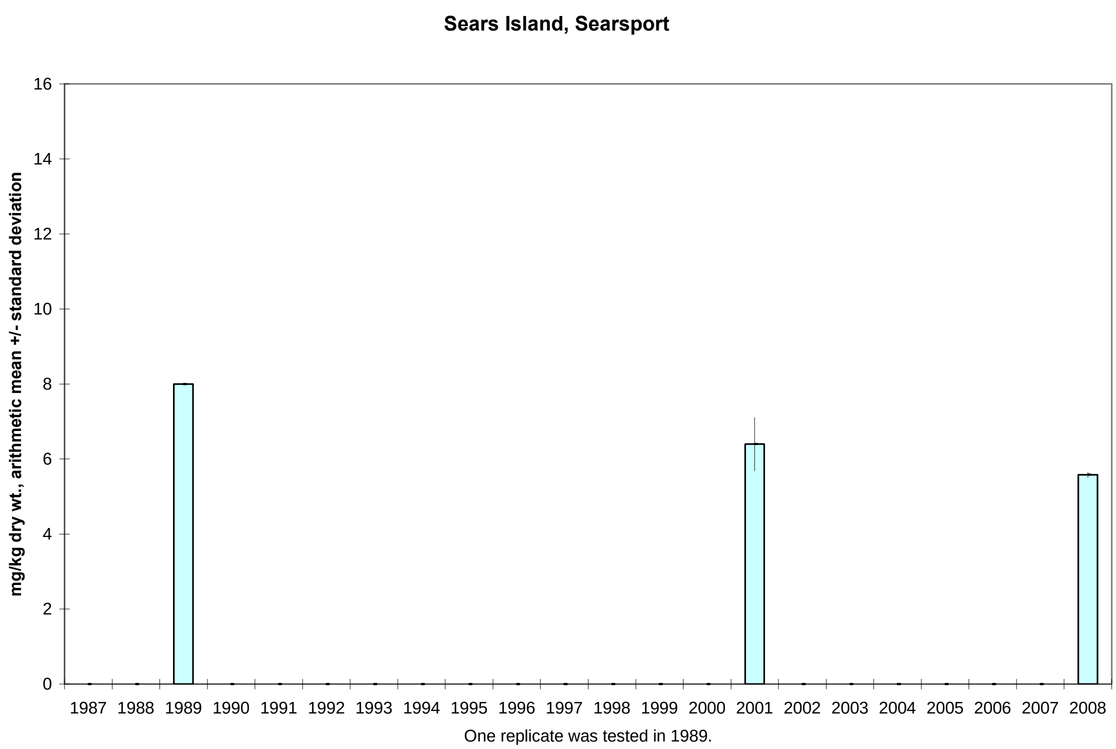
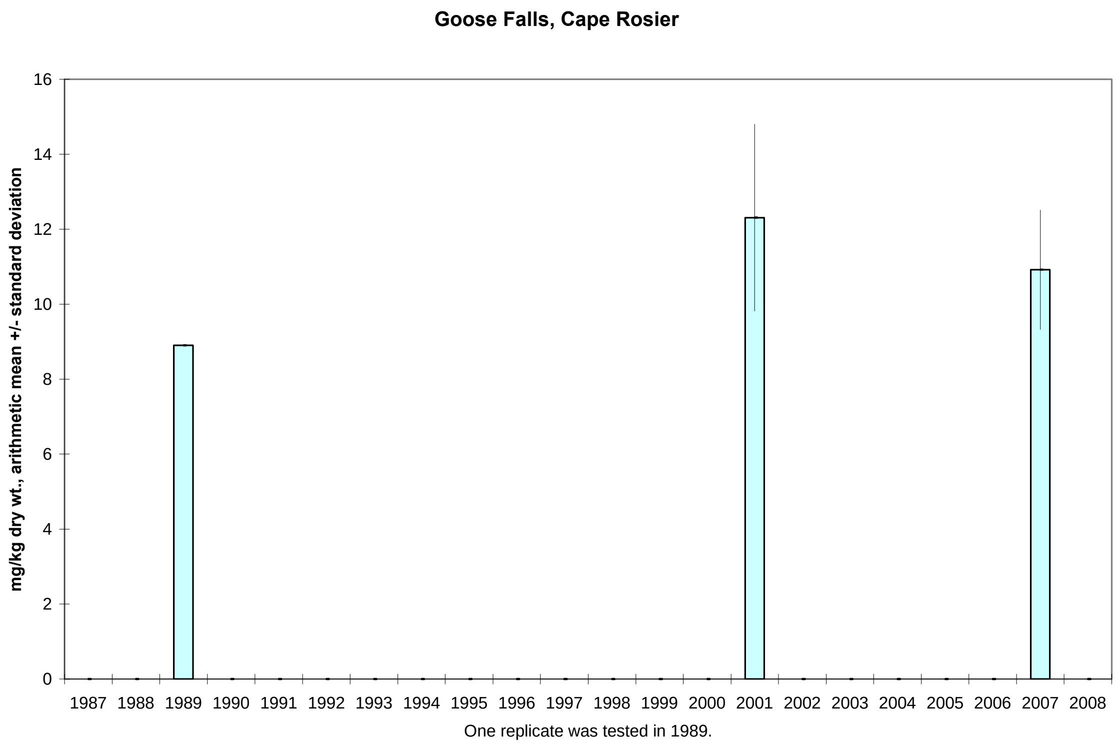


Figure 1.1.4.2 Distribution of SWAT Blue Mussel Tissue Copper Concentrations (cont.)

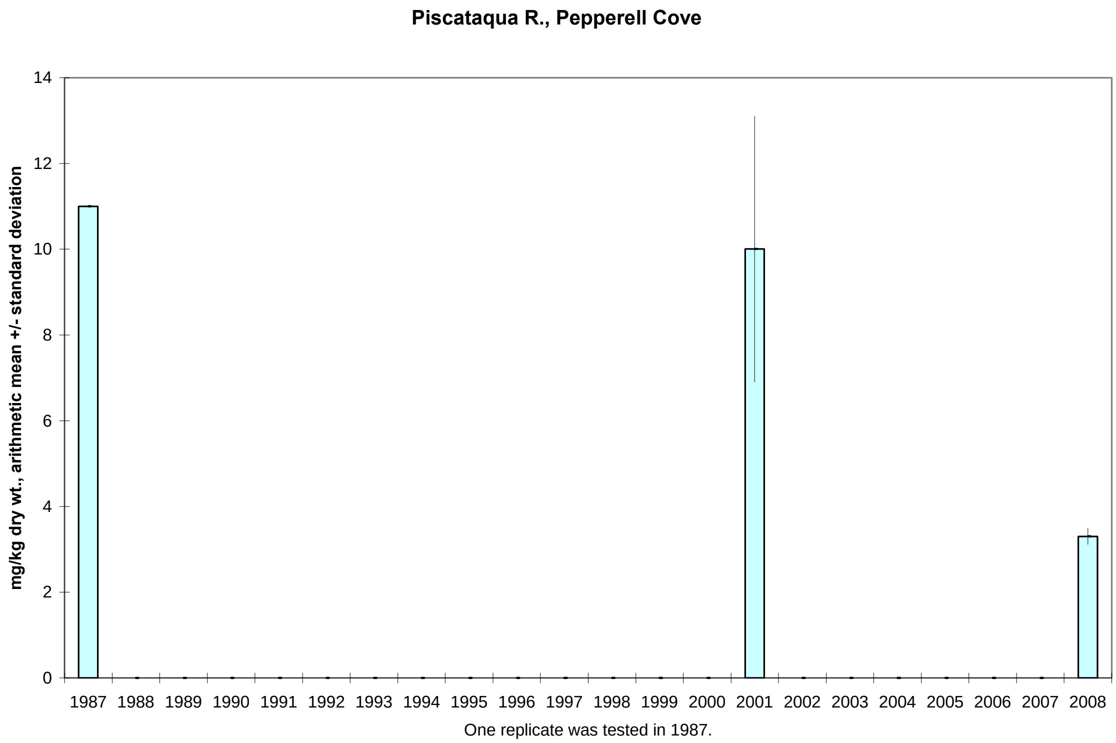


1.1.4.3 Lead (Pb)

Lead concentrations through time at ten sampling stations are presented in Figure 1.1.4.3. Sampling stations show apparent trends of stable or decreasing lead concentrations in blue mussel tissue. In some cases, variability between years in sampled concentrations obscures any visual trend (see Piscataqua River, Pepperell Cove; East End Beach, Portland; and Goose Falls, Cape Rosier). At some sites, high within site variability among replicates confounds temporal analyses (see Piscataqua River, Pepperell Cove; Middle Fore River, S. Portland; East End Beach, Portland; and Goose Falls, Cape Rosier). It appears that the highest within year variability (within replicates) occurs at the sampling stations with higher lead mussel tissue concentrations, perhaps indicating a patchy distribution of the lead within the sampling station. This reinforces the need to sample multiple sites within the sampling station to generate some measure of variance, particularly if trend analysis is an important need. Sampling at a station with one replicate will provide high variation between sampled years and confound any attempt at trend analysis.

Apparent decreasing trend in mussel tissue lead concentration is visible at Piscataqua River, Pepperell Cove, and Perkins Cove, Ogunquit (very slight). It must be noted that only one replicate was analyzed in 1987 at Piscataqua River, Pepperell Cove, making any analysis of variance impossible in that year. Pepperell Cove mussel tissue lead concentrations appear lower over time despite the high within replicate variability associated with 2001 samples. Perkins Cove, Ogunquit shows a very slight apparent trend toward lower lead mussel tissue concentrations, however the first samples taken at Perkins Cove (1992) include but one replicate and so make any analysis of variance in that year impossible. This fact, coupled with the very slight apparent trend and long sampling intervals, suggests that more data is needed to assess any lead trend at Perkins Cove. Mussel tissue lead concentrations at the remaining sites appear to be stable through time (see Kennebunk River; Scarborough River; Spring Point, S. Portland; Middle Fore River, S. Portland; Sheepscot River, Clough Point; and Sears Island, Searsport).

Figure 1.1.4.3 Distribution of SWAT Blue Mussel Tissue Lead Concentrations



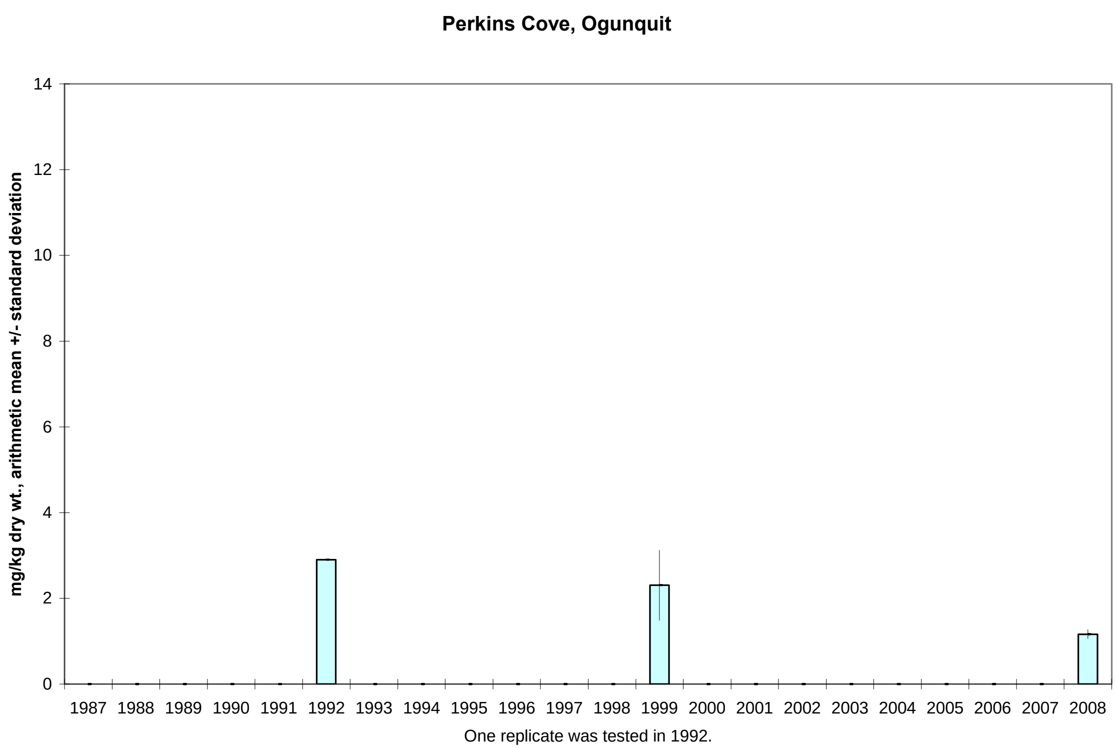
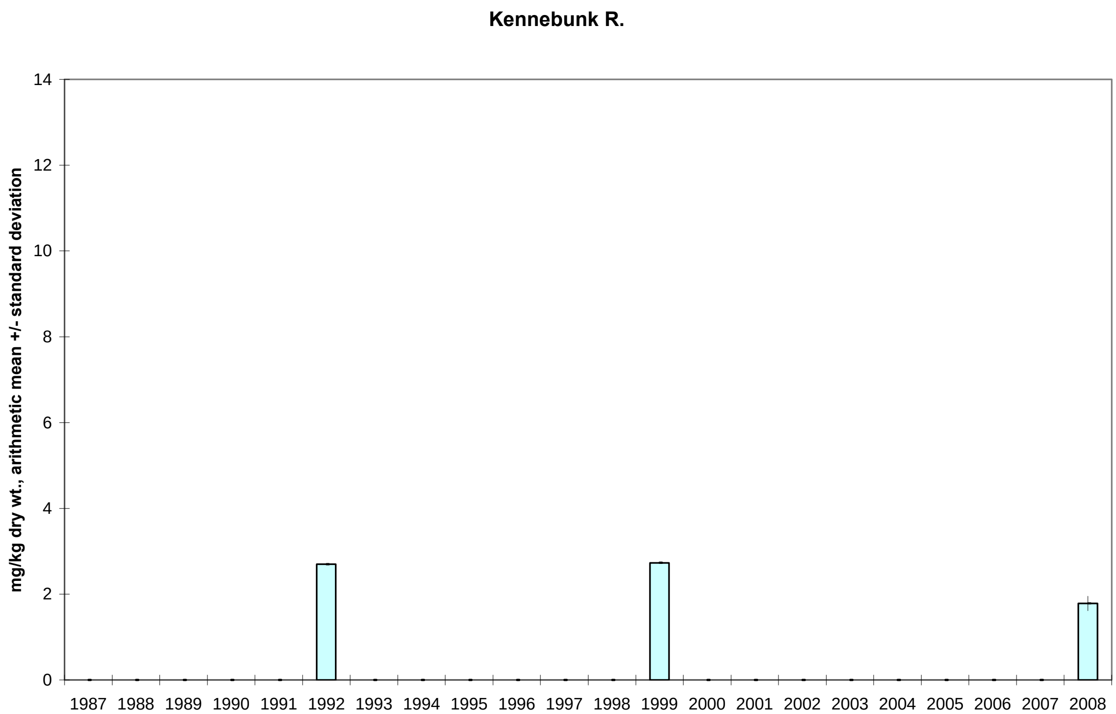
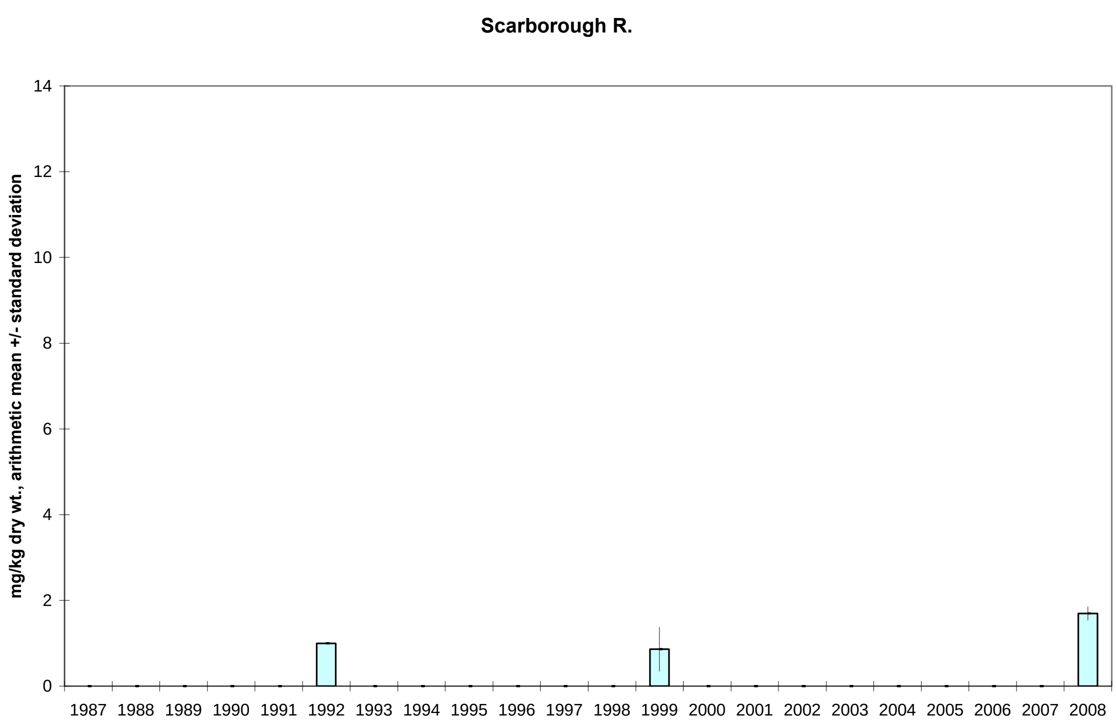


Figure 1.1.4.3 Distribution of SWAT Blue Mussel Tissue Lead Concentrations (cont.)

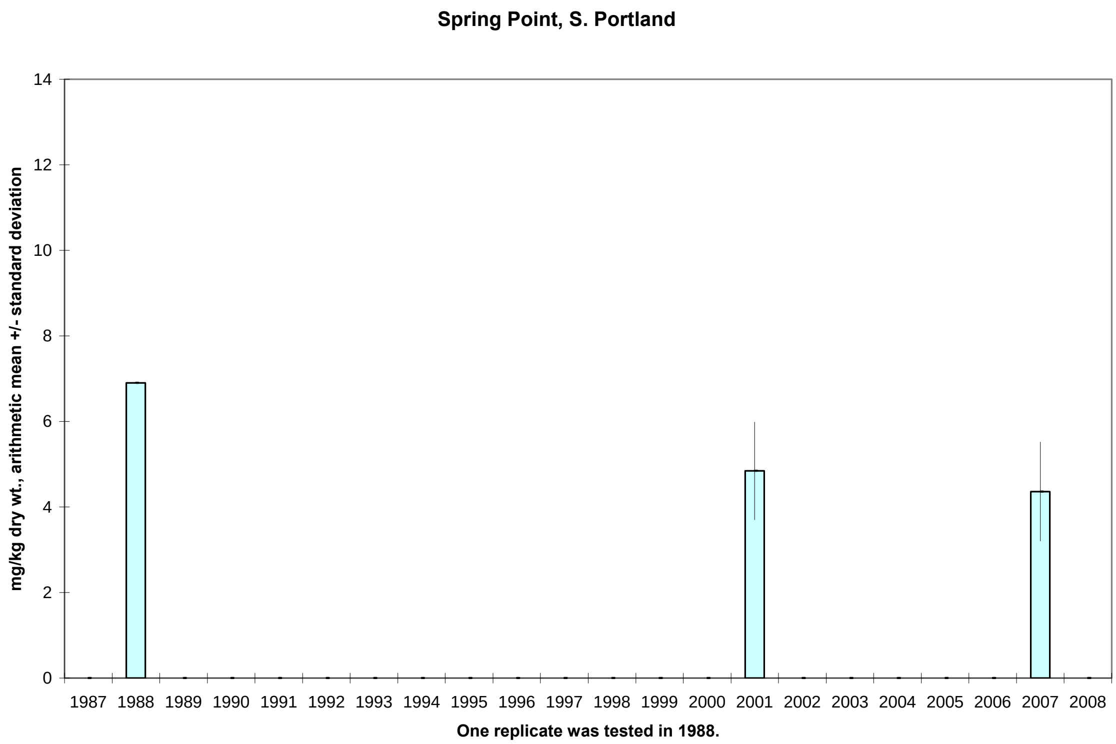


One replicate was tested in 1992 and 1999.



One replicate was tested in 1992.

Figure 1.1.4.3 Distribution of SWAT Blue Mussel Tissue Lead Concentrations (cont.)



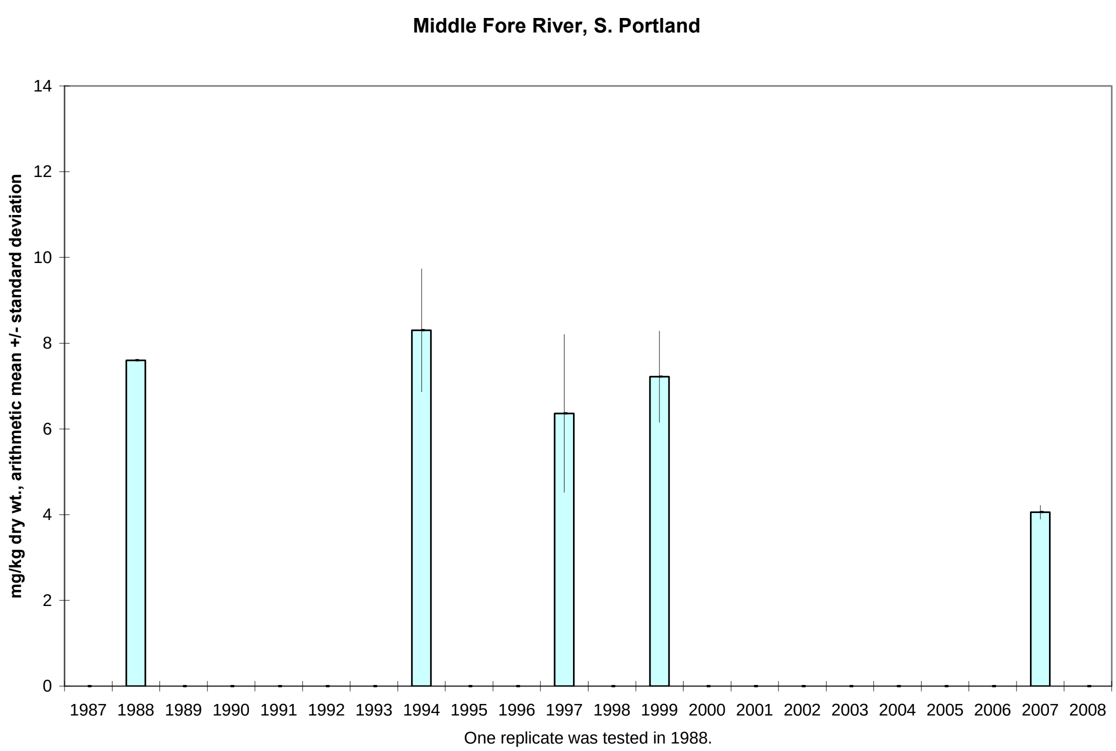
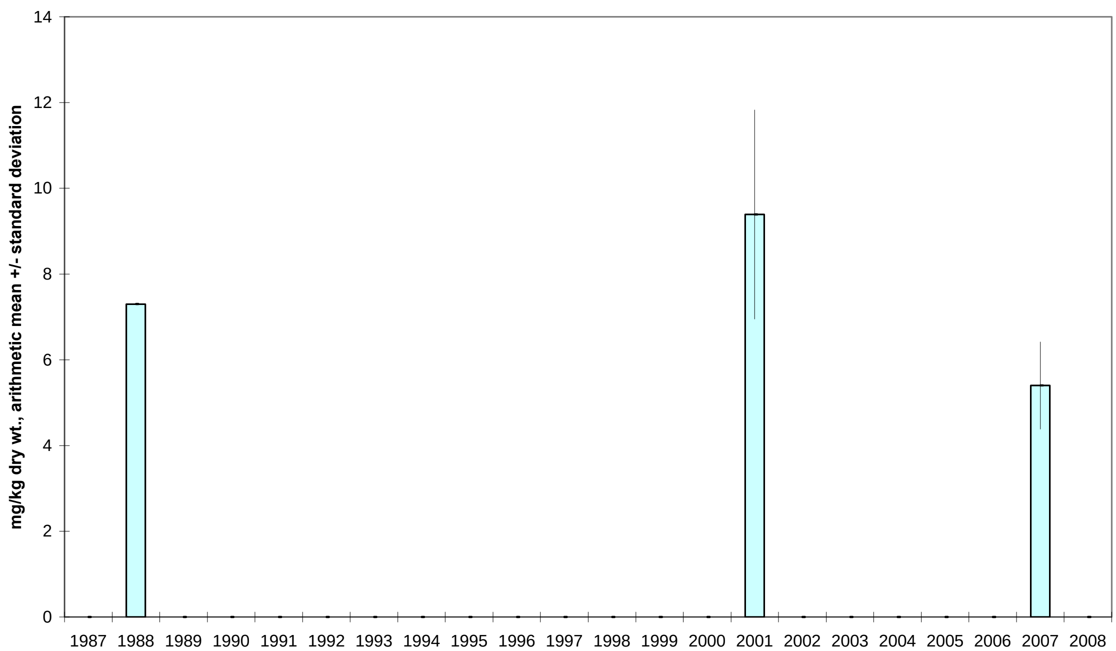


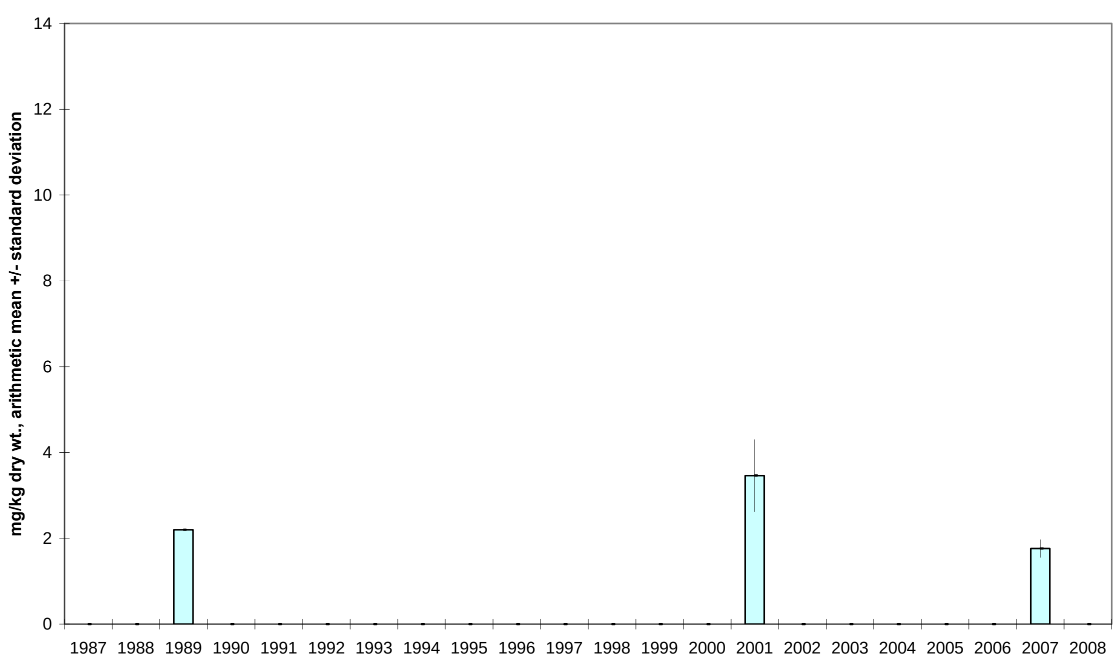
Figure 1.1.4.3 Distribution of SWAT Blue Mussel Tissue Lead Concentrations (cont.)

East End Beach, Portland



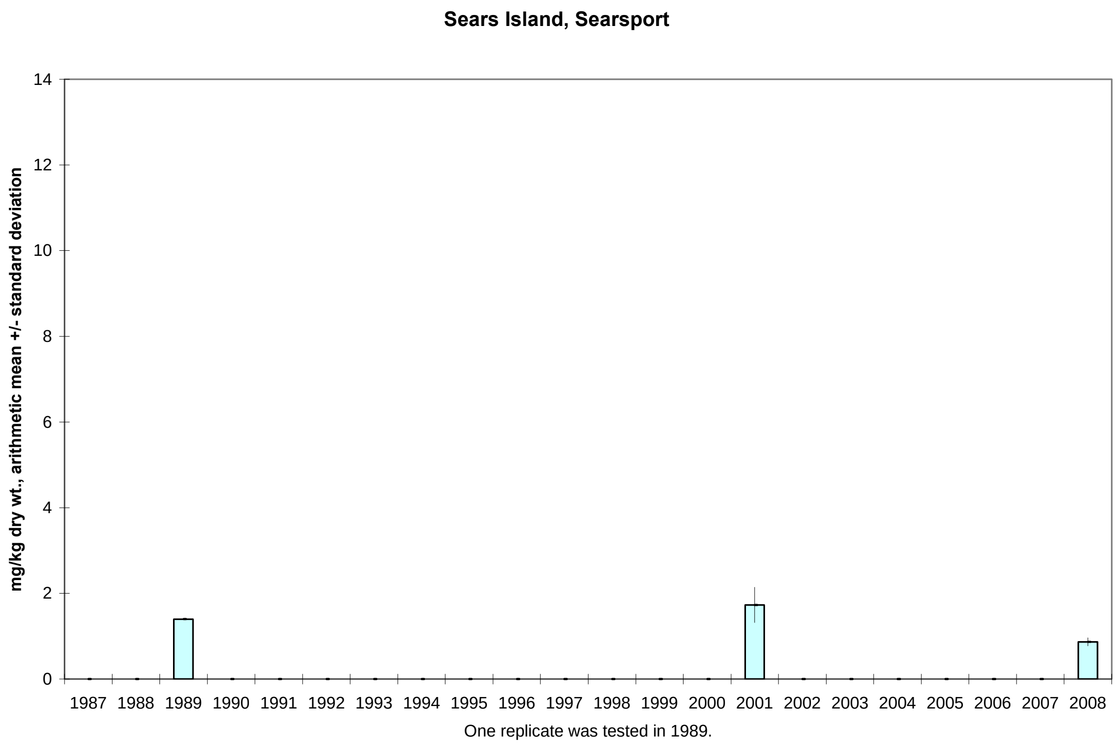
One replicate was tested in 1988.

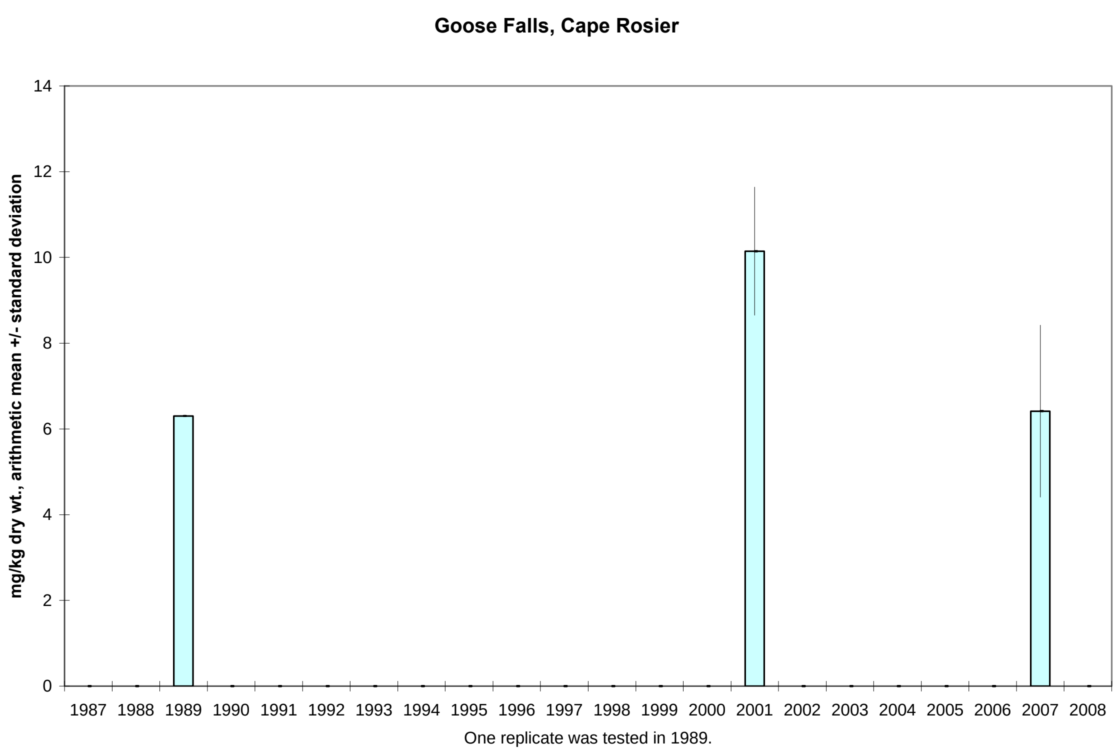
Sheepscot R., Clough Pt.



One replicate was tested in 1989.

Figure 1.1.4.3 Distribution of SWAT Blue Mussel Tissue Lead Concentrations (cont.)

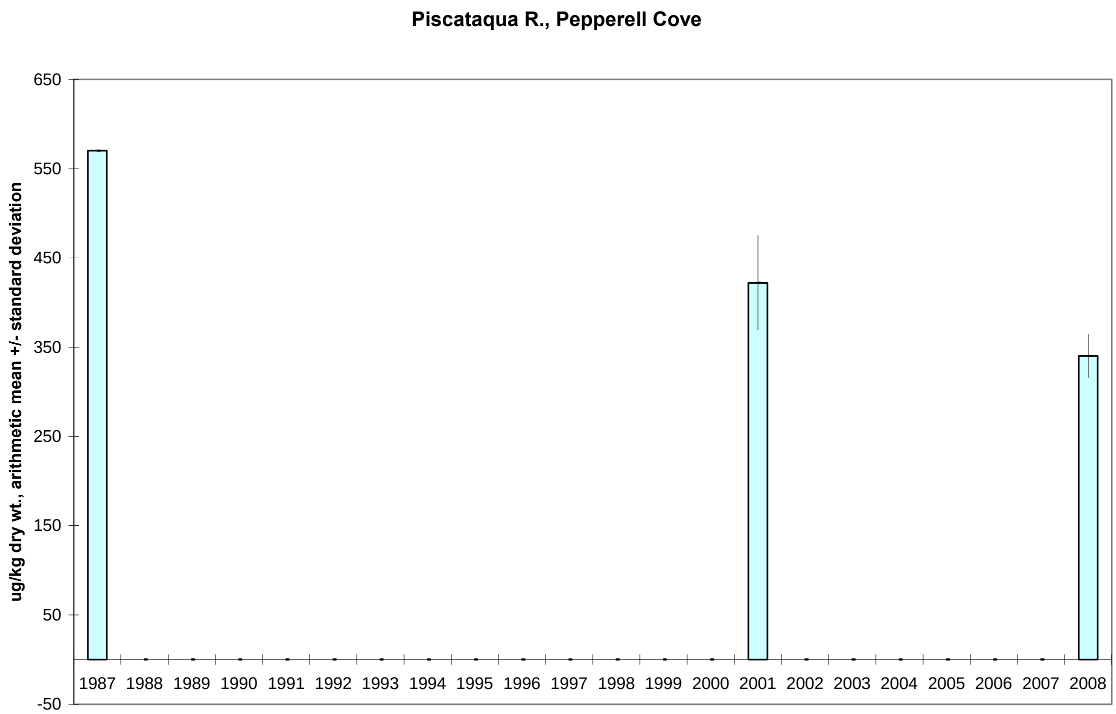




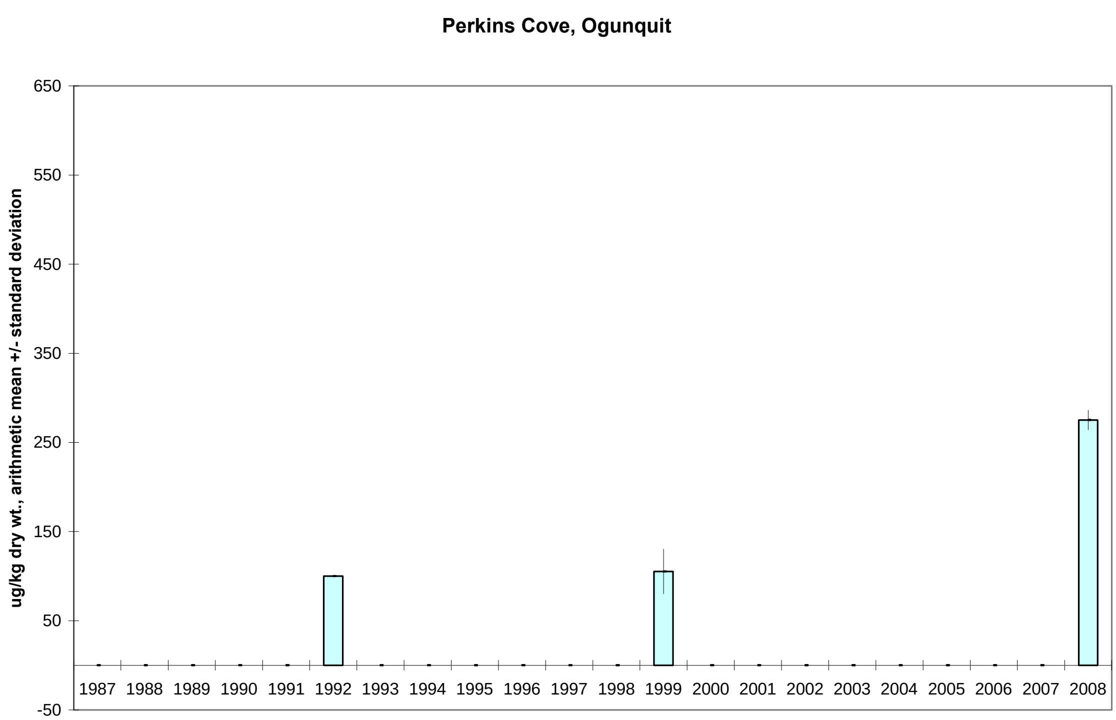
1.1.4.4 Mercury (Hg)

Mercury data prior to 2003 is shown but should be interpreted with caution. Analytical artifacts, including high detection limits and high variability, were common in analyses completed prior to and including 2002. As Figure 1.1.4.4 shows, no more than one sample point exists for each sampling station after 2002, such that trend would be impossible to assess, even visually, until such time as additional sampling and analysis are completed in the future. If blue mussel mercury tissue concentration results prior to 2003 are considered, only two sites show anything other than stable or very noisy and variable tissue concentrations for mercury. Piscataqua River, Pepperell Cove appears to show a declining trend, while Perkins Cove, Ogunquit, appears to show a very weak increasing trend. More sampling will be required to produce meaningful trend analyses (even apparent visual trend analyses) from the mercury mussel tissue data set.

Figure 1.1.4.4 Distribution of SWAT Blue Mussel Tissue Mercury Concentrations

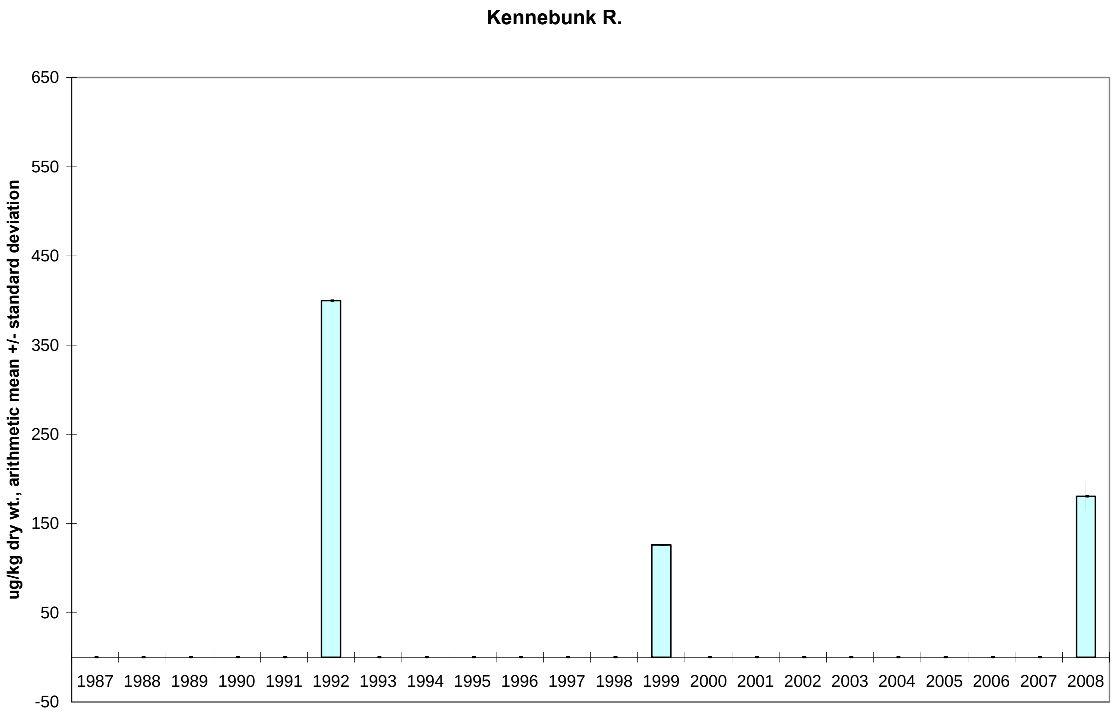


One replicate was tested in 1987.

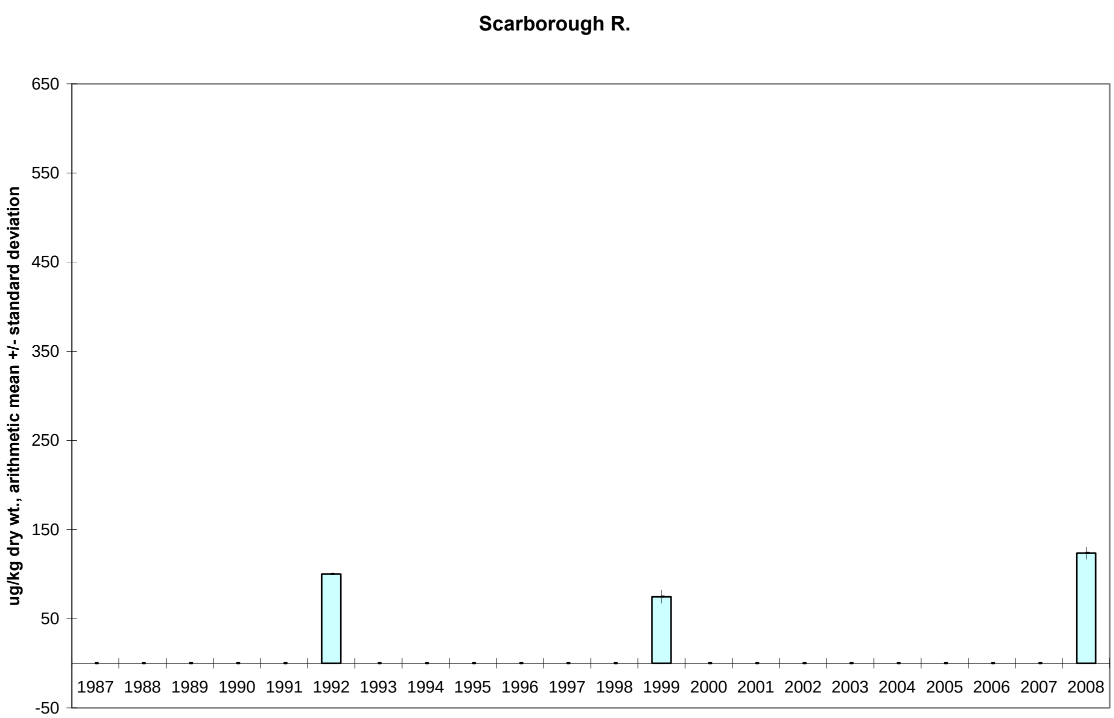


One replicate was tested in 1992.

Figure 1.1.4.4 Distribution of SWAT Blue Mussel Tissue Mercury Concentrations (cont.)

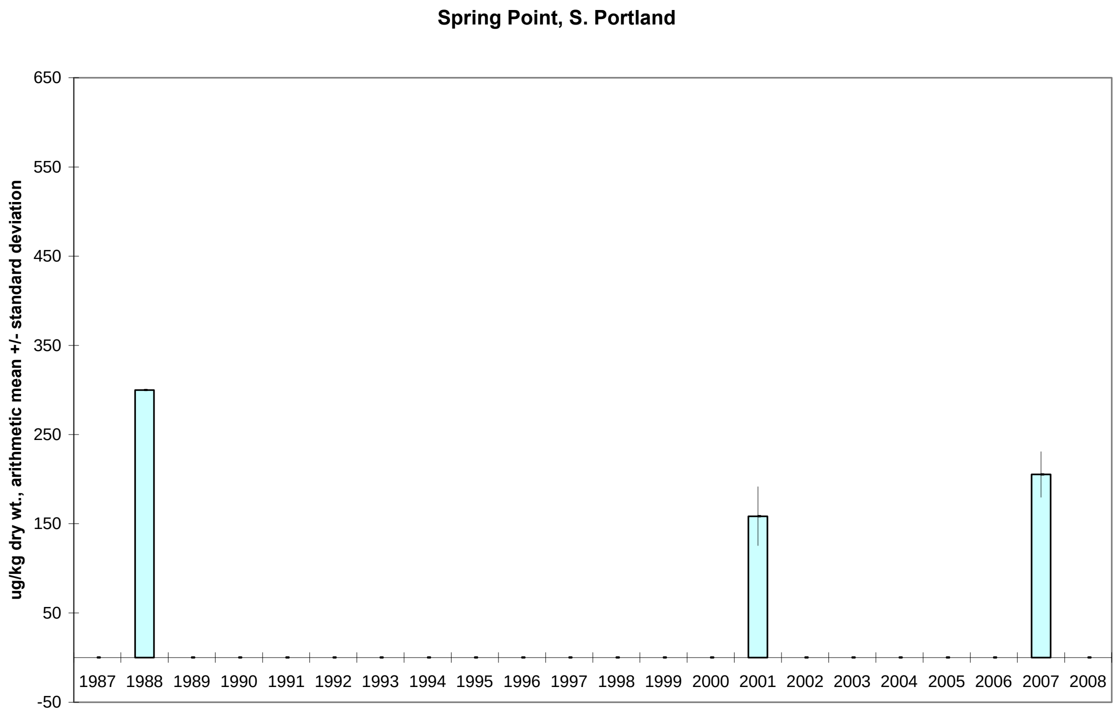


One replicate was tested in 1992 and 1999.

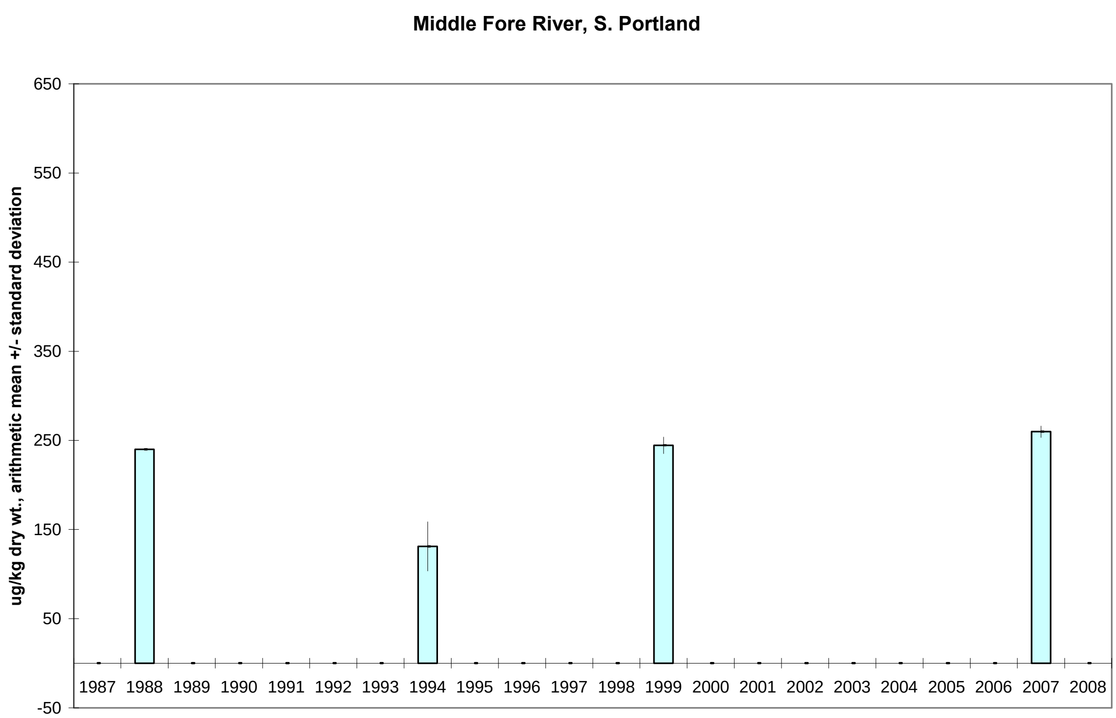


One replicate was tested in 1992.

Figure 1.1.4.4 Distribution of SWAT Blue Mussel Tissue Mercury Concentrations (cont.)

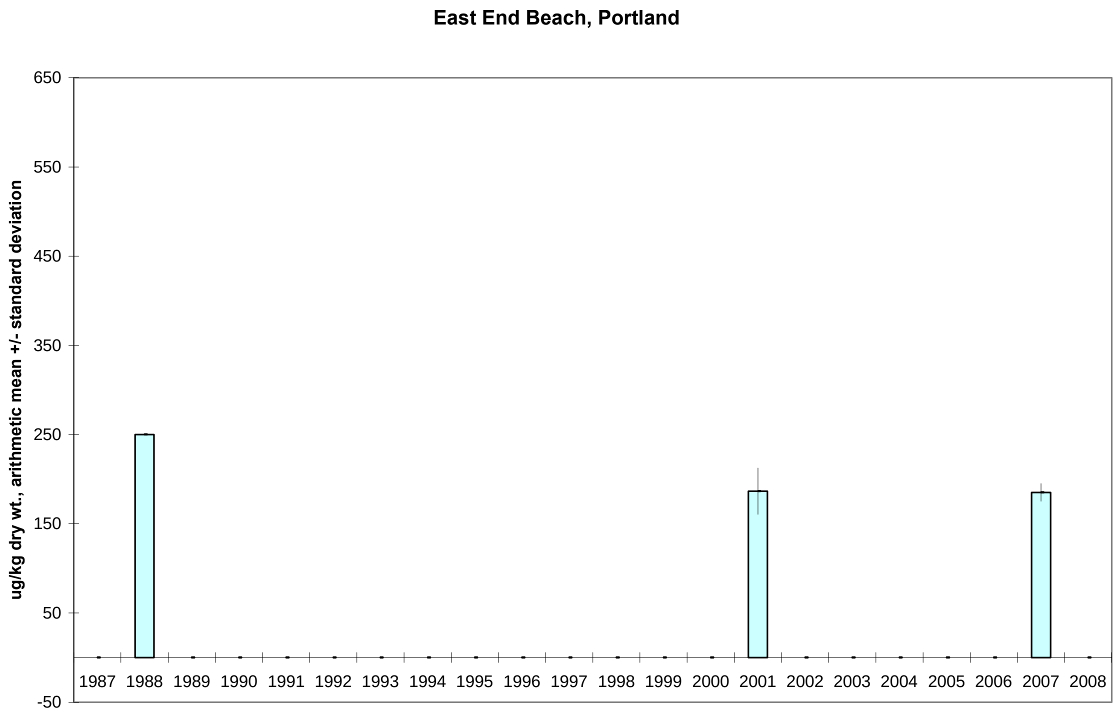


One replicate was tested in 1988.

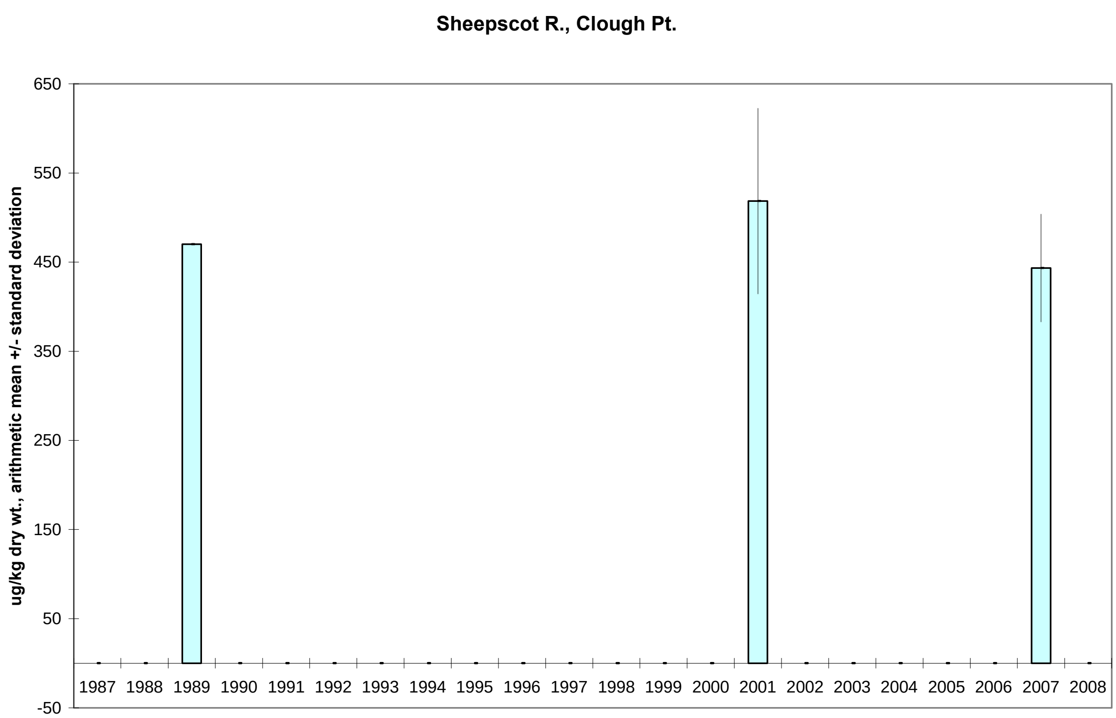


One replicate was tested in 1988.

Figure 1.1.4.4 Distribution of SWAT Blue Mussel Tissue Mercury Concentrations (cont.)

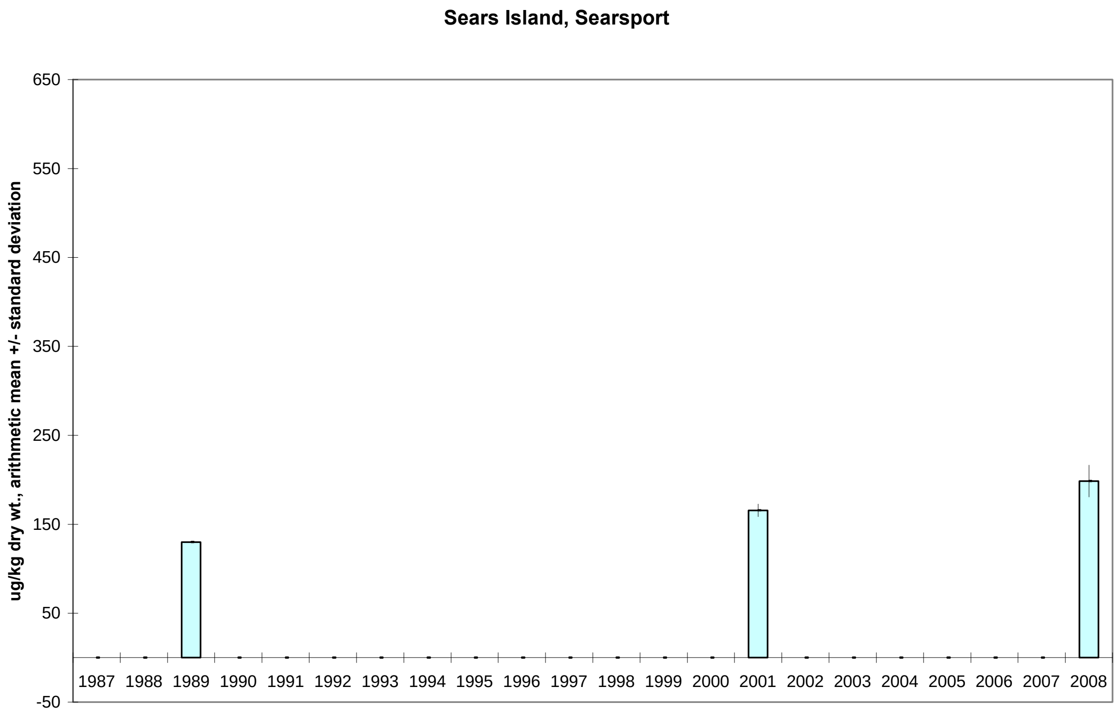


One replicate was tested in 1988.

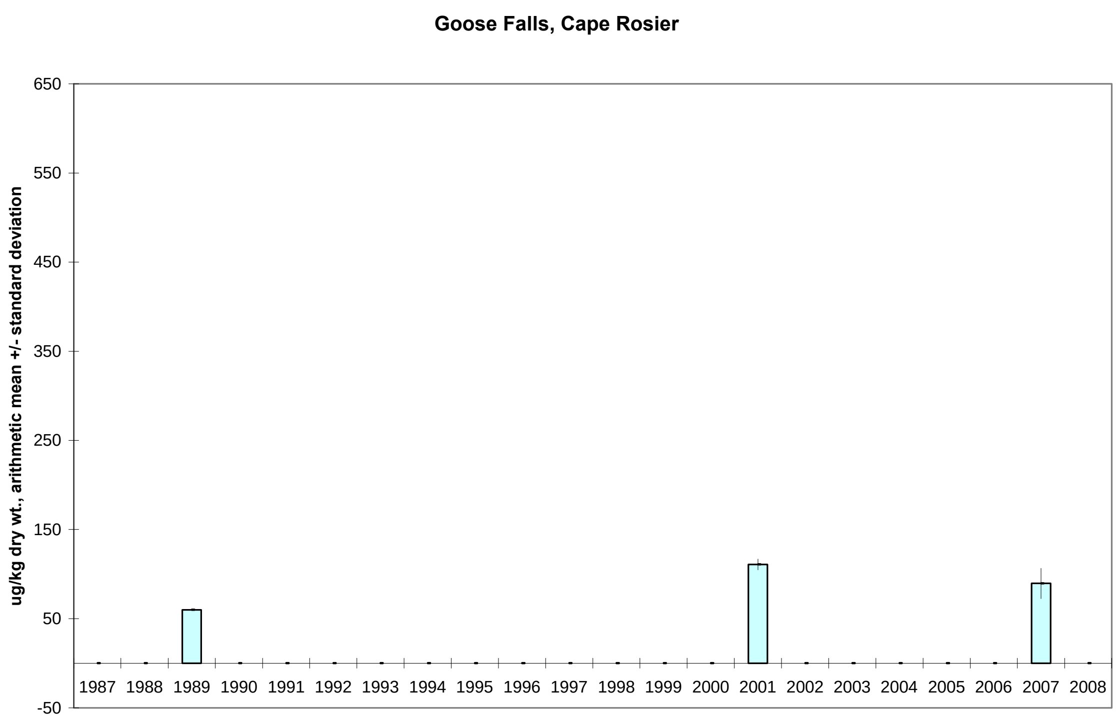


One replicate was tested in 1989.

Figure 1.1.4.4 Distribution of SWAT Blue Mussel Tissue Mercury Concentrations (cont.)



One replicate was tested in 1989.

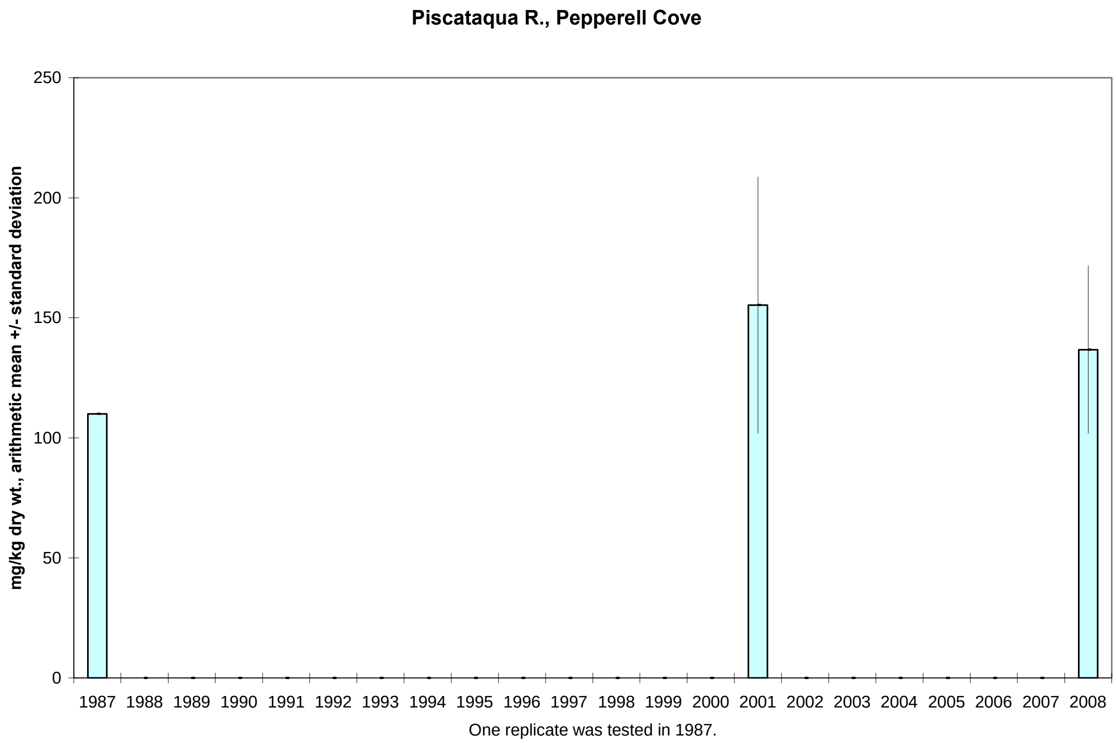


One replicate was tested in 1989.

1.1.4.5 Zinc (Zn)

Zinc concentrations through time at ten sampling stations are presented in Figure 1.1.4.5. Sampling stations show apparent trends of stable or excessively noisy zinc concentrations in blue mussel tissue. In some cases, variability between years in sampled concentrations obscures any visual trend (see Piscataqua River, Pepperell Cove; Perkins Cove, Ogunquit; Kennebunk River; Scarborough River; and East End Beach, Portland). Four sites also showed high variability within replicates in a sampling year (see Piscataqua River, Pepperell Cove; Spring Point, S. Portland; Middle Fore River, S. Portland; and Goose Falls, Cape Rosier). Mussel tissue zinc concentrations at the remaining sites appear to be stable through time.

Figure 1.1.4.5 Distribution of SWAT Blue Mussel Tissue Zinc Concentrations



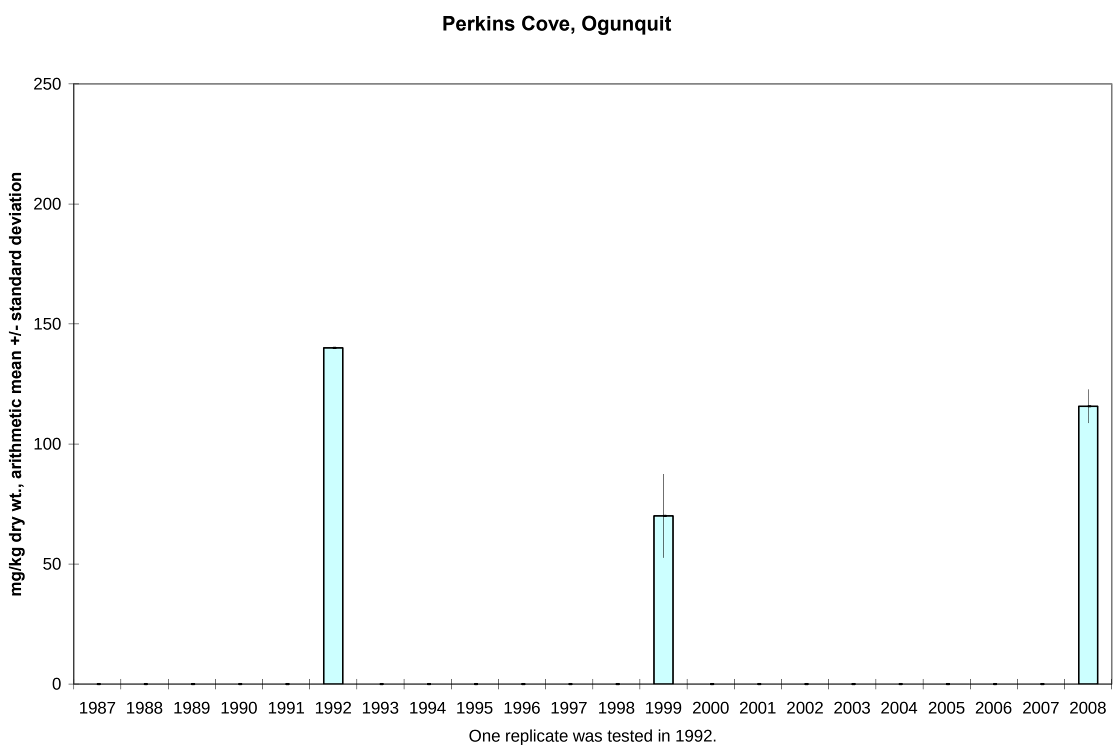
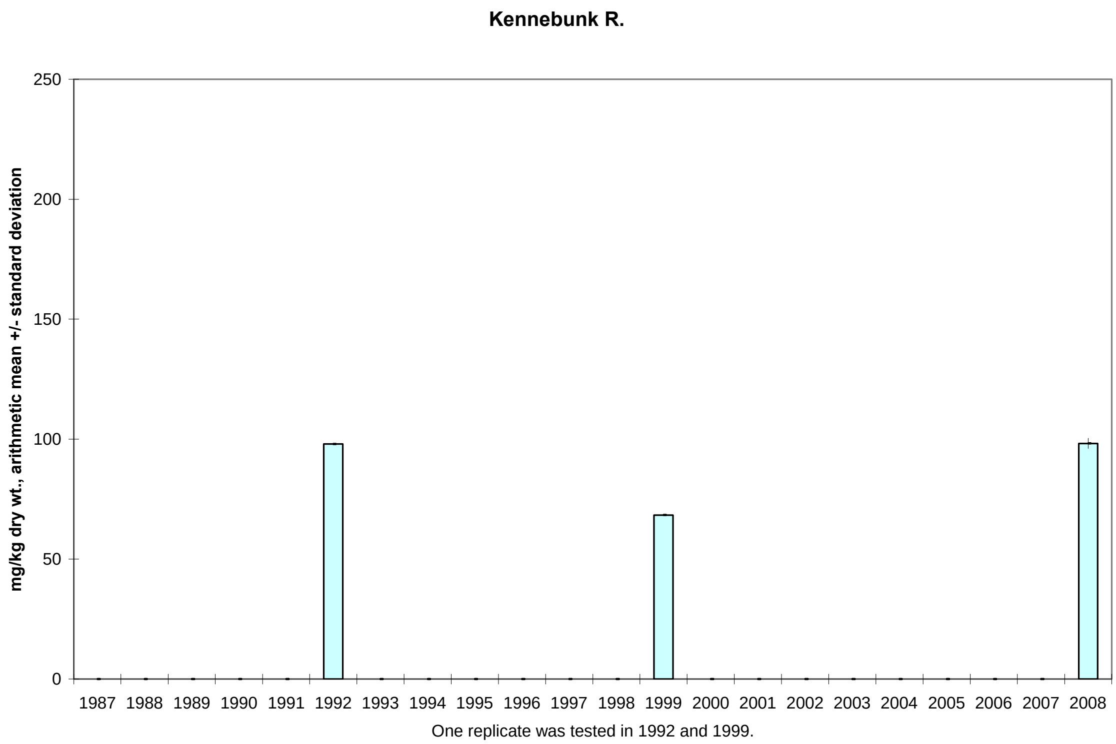


Figure 1.1.4.5 Distribution of SWAT Blue Mussel Tissue Zinc Concentrations (cont.)



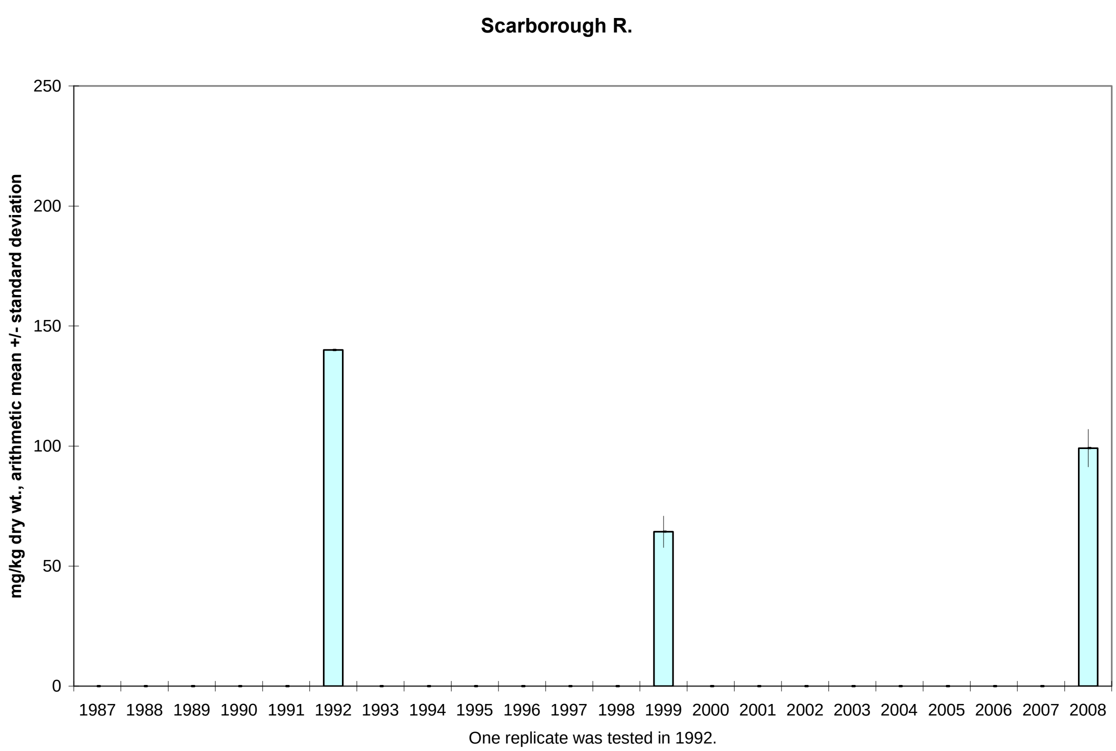
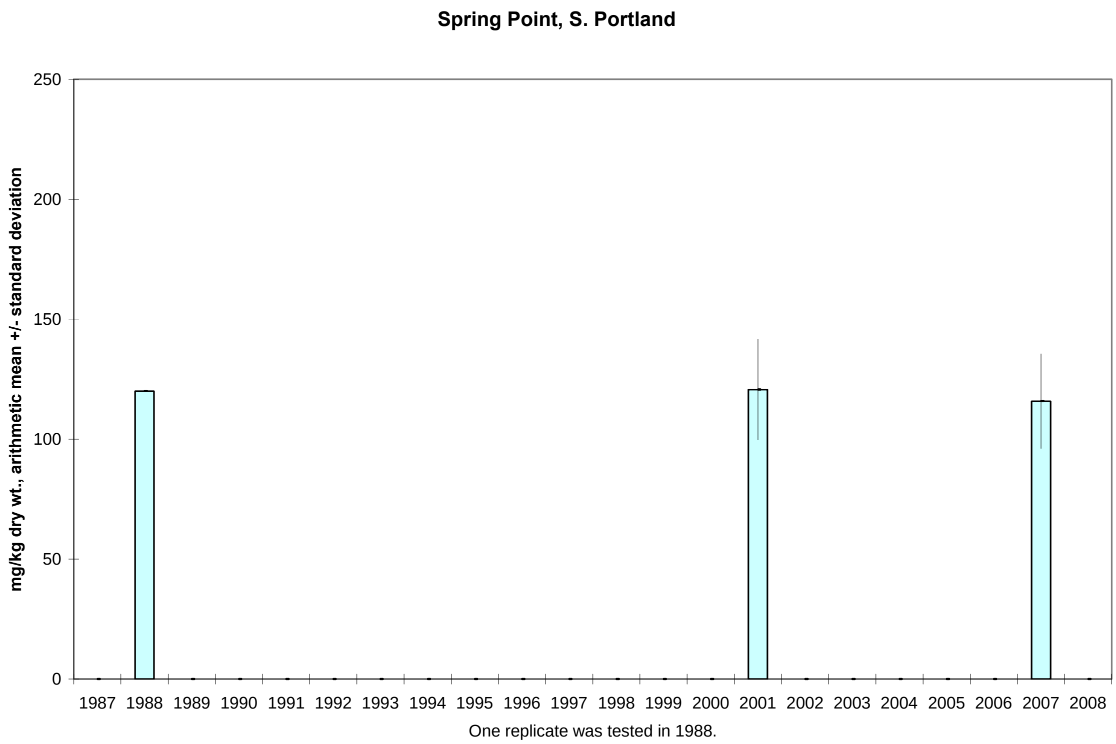


Figure 1.1.4.5 Distribution of SWAT Blue Mussel Tissue Zinc Concentrations (cont.)



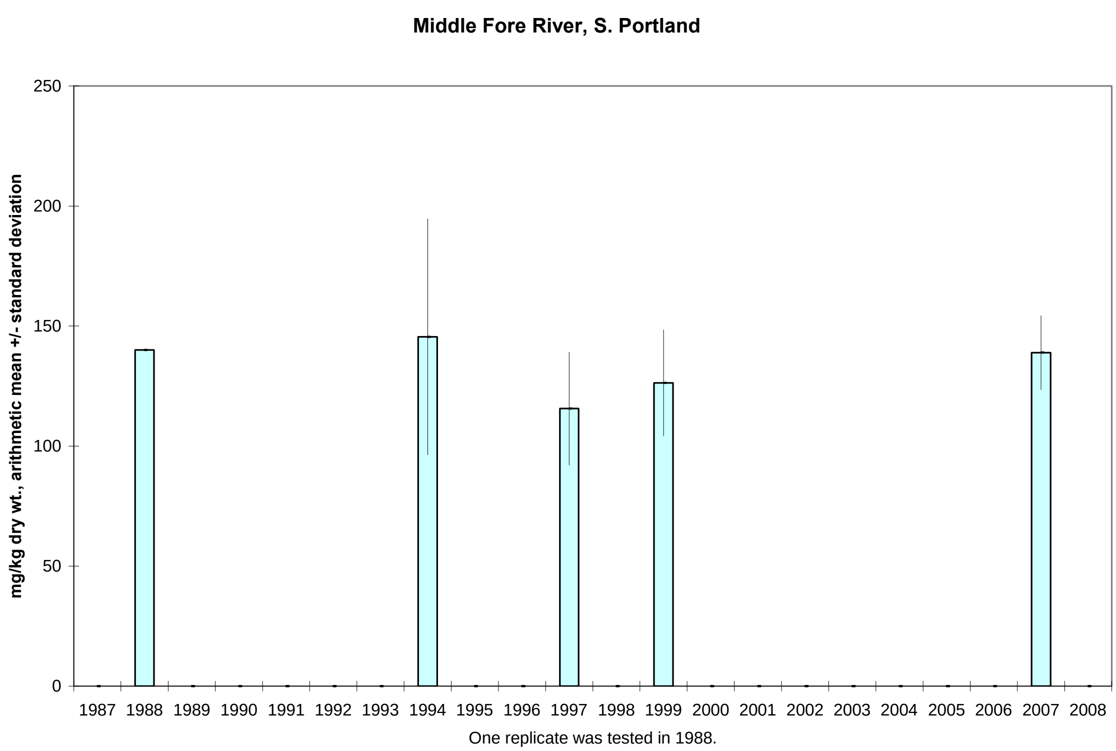
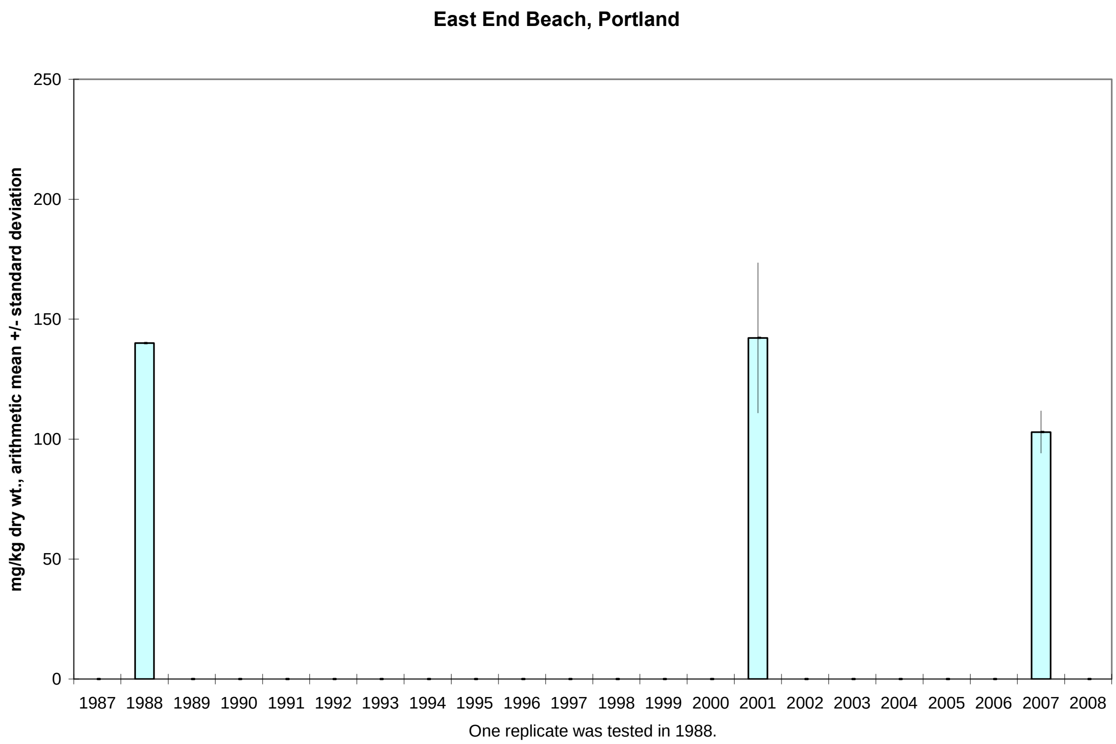


Figure 1.1.4.5 Distribution of SWAT Blue Mussel Tissue Zinc Concentrations (cont.)



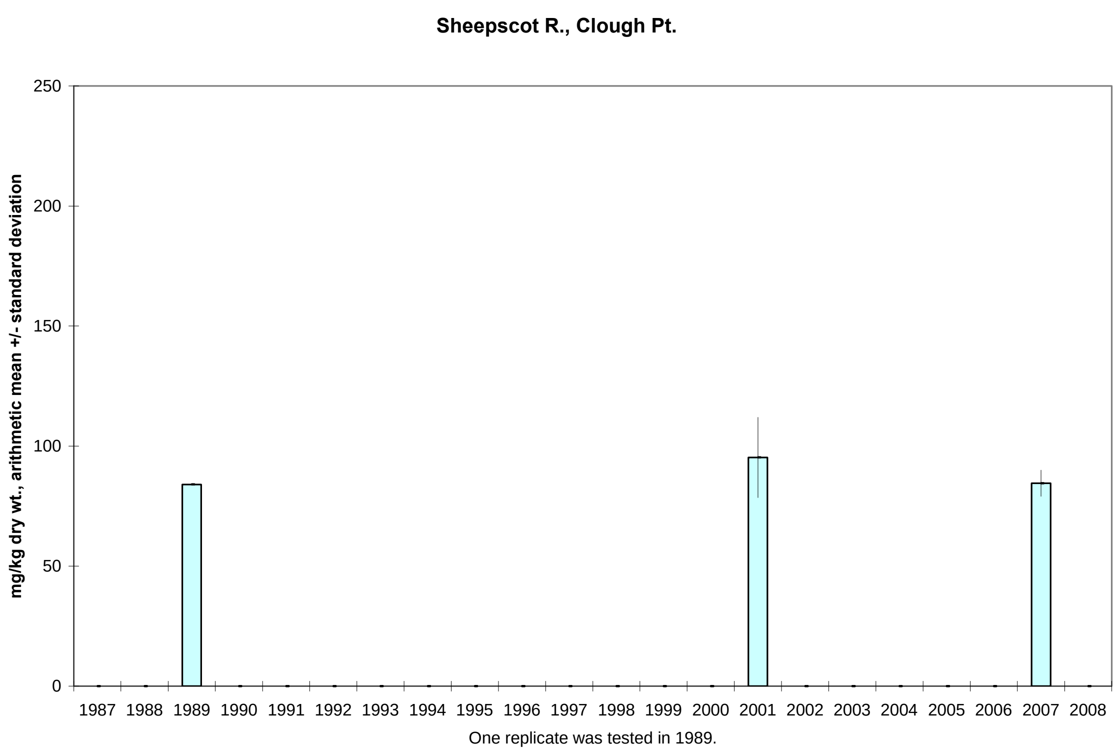
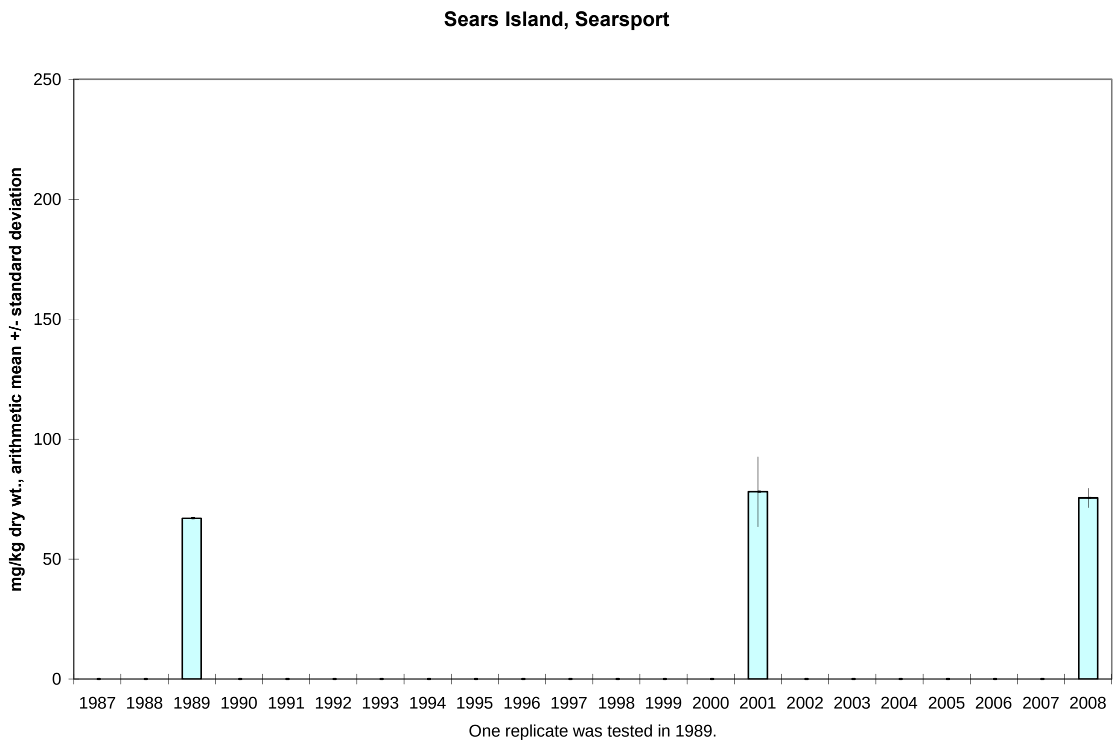
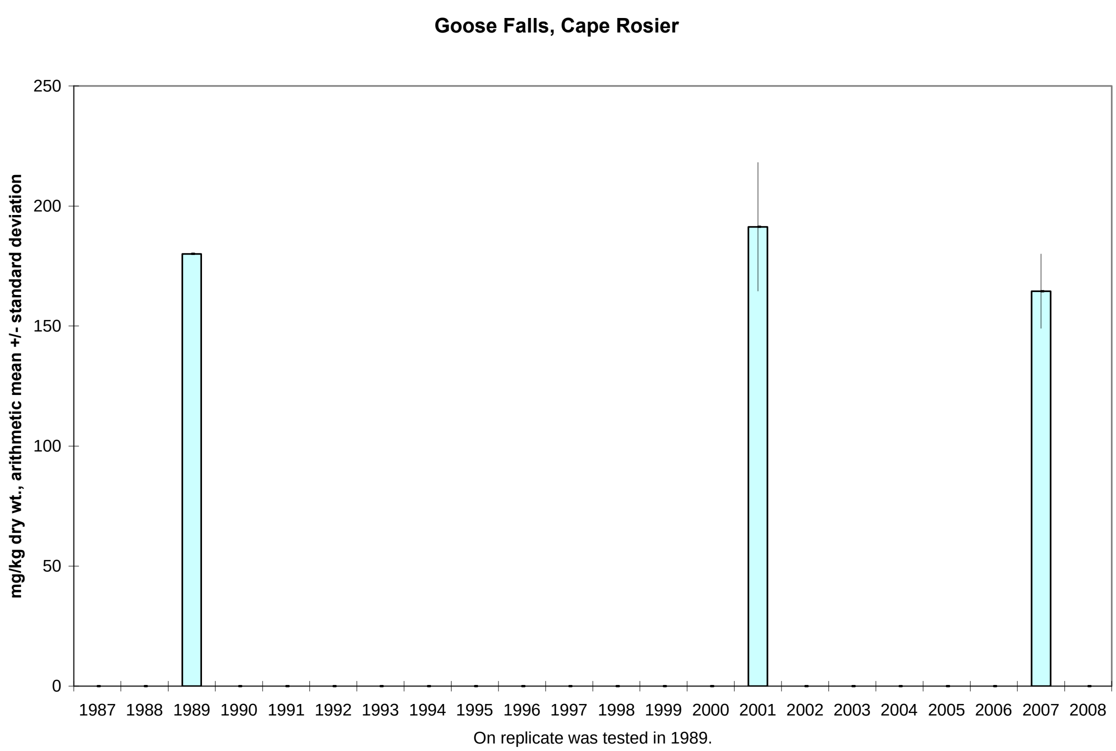


Figure 1.1.4.5 Distribution of SWAT Blue Mussel Tissue Zinc Concentrations (cont.)





1.1.5 References

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

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

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

1.2

CONTAMINANTS IN COMMON LOON, PIPING PLOVER, AND PEREGRINE FALCON EGGS

1.2 MONITORING OF CONTAMINANTS IN COMMON LOON AND PEREGRINE FALCON EGGS

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1. EXECUTIVE SUMMARY AND PRIMARY FINDINGS

Starting in May 2008, BioDiversity Research Institute (BRI) and collaborators expanded upon the 2007 broad-based contaminant study on Maine birds, measuring both historical and emerging chemicals. Out of the 23 species studied in the first year, we determined that three required additional study in 2008: common loon (*Gavia immer*), peregrine falcon (*Falco peregrines*), and piping plover (*Charadrius melodus*). We selected these species because loons act as bioindicators of lacustrine habitat throughout Maine, and peregrines and plovers are potentially at risk of bioaccumulating contaminants at levels above adverse effects thresholds. The compounds we analyzed in nine egg composites were mercury (Hg), polychlorinated biphenyls (PCBs, including coplanar congeners), polybrominated diphenyl ethers (PBDEs), perfluorinated compounds (PFCs), and organochlorine pesticides (OCs). Our preliminary findings are:

1. Hg, PCBs, PBDEs, PFCs, and OCs continue to be detected in birds living in diverse habitats across Maine; PFCs were detected in all samples.
2. Hg was detected in loons and peregrine falcons at levels above adverse effects thresholds.
3. PFOS (perfluorooctane sulfonate, used as a fabric protector and in paints and cleaning agents) in common loons was detected at levels above adverse effects thresholds suggested for chickens. Androscoggin Lake had the highest level.
4. The peregrine falcon sample from Mount Desert Island had the highest contaminant load, potentially from feeding on terns.
5. Piping plovers continue to have contaminant levels higher than we expected for an invertivore, a animal that feeds on insects and other invertebrates.
6. The loon samples did not show a specific spatial pattern, suggesting that within the lacustrine ecosystem, contaminant levels may be dictated by point sources, watershed characteristics, and/or food web dynamics.
7. Like the 2007 results, PCB, PBDE, PFC, and OC levels are positively correlated, indicating that birds with high levels of one compound tend to have higher levels of the others. PBDEs and PCBs have one of the strongest relationships.
8. DecaBDE is found in all three species, but not within each sample.

The full report can be found at
http://www.maine.gov/dep/blwq/docmonitoring/swat/index.htm

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Table 1. Samples collected.

State	Species	Site
ME	COLO	Androscoggin Lake
		Brassua Lake
		Ebeemee Lake
		Mooselookmeguntic Lake
		Sysladobsis Lake
	Peregrine Falcon	Casco Bay
		Bar Harbor
	PIPL	Scarborough Beach
		Goose Rocks Beach
NY	COLO	Dry Channel Pond
		Moss Lake
		Squam Lake

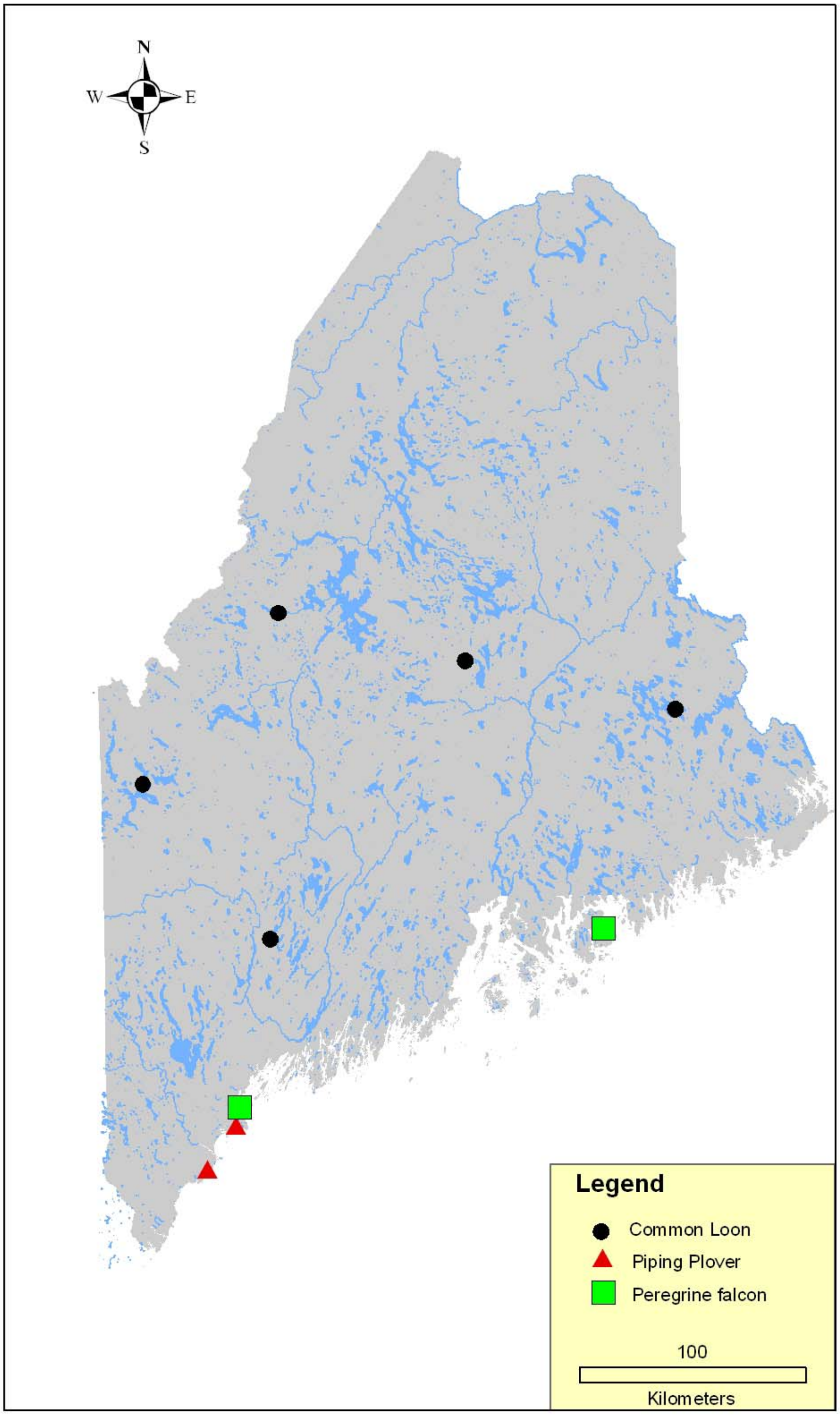


Figure 1. Sampling locations by species.

1.3

PCBS IN BLUEFISH

PCBS IN BLUEFISH

The MCDC has issued a fish consumption advisory recommending people consume no more than 2 meals per month of striped bass and bluefish. In the past few years MCDC has led an Eastern Coastal Striped Bass and Bluefish Consumption Advisory Workgroup reviewing the fish consumption advisories in all coastal states to see if a single common advisory could be developed. The Workgroup produced a 'Report of the Interstate Workgroup on Evaluating Atlantic Coastal Advisories for Recreationally Caught Striped Bass and Bluefish based on PCBs, 10/1008' available at http://www.maine.gov/dhhs/eohp/fish/9_08Final.pdf .

Since bluefish all along the Atlantic coast seem to be of the same population, feeding in local regions may affect contaminant levels. There are much fewer data for bluefish than for striped bass. MCDC has requested additional data for bluefish for several years. But since bluefish are not always abundant in Maine each year, it has been difficult to collect samples. In 2008, we were able to collect 5 bluefish in Saco Bay near Old Orchard Beach. Results show that the concentration was well above MCDC's Fish Tissue Action Level (FTAL) of 11 ng/g (Table 1.3.1). The concentrations were also similar to previous data from Saco Bay and all recent data since 2001 in Maine (Table 1.3.2).

Table 1.3.1. PCBs in bluefish from Old Orchard Beach area in Saco Bay.

FISH ID	**LENGTH mm**	**PCB ng/g**
OOB-BLF-1	813	406
OOB-BLF-2	711	104
OOB-BLF-3	686	143
OOB-BLF-6	737	674
OOB-BLF-7	762	328
MEAN	**742**	**331**
95th UCL (Upper Confidence Level)		**532**

Table 1.3.2 PCBs in bluefish from Maine estuaries, ng/g average (95th ucl on the mean)

bluefish Year		Kennebec	Saco	Scarboro	York
1995	spring	48.8			
1998	spring			42.2	
2001	spring	276			
2002	spring	232	320		
2004	spring		161		
2005	spring		313(479)		
2008	fall		331(532)		

2.0 LAKES MODULE

(NO ACTIVITY IN 2008)

3.0 RIVERS AND STREAMS MODULE

3.1.

AMBIENT BIOLOGICAL MONITORING

3.1 AMBIENT BIOLOGICAL MONITORING

3.1.1 Background

As part of the SWAT program, DEP's Biological Monitoring Unit evaluates benthic macroinvertebrate communities of Maine streams and rivers to determine if they are impaired by toxic contamination. For reasons of comparability, a small number of unimpaired reference sites are also evaluated. Benthic macroinvertebrates are animals without backbones that can be seen with the naked eye and live on the stream bottom, such as mayflies, stoneflies, caddisflies, crayfish, snails, and leeches. In 2008, we evaluated the condition of 40 sample locations, primarily in the Androscoggin River basin.

The Biological Monitoring Unit uses a multivariate statistical model to analyze a benthic macroinvertebrate sample and predict if a waterbody is attaining the biological criteria associated with its statutory class (DEP rule Chapter 579). If a waterbody does not meet minimum state aquatic life criteria, Class C, then the model class is predicted as Non-Attainment (NA). Classes AA and A are treated the same in the model. Final decisions on aquatic life attainment of a waterbody are made accounting for factors that may allow adjustments to the model outcome. This is called the final determination.

Table 3.1.1 summarizes the results of biological monitoring activities for the 2008 SWAT Program, sorted by waterbody name. Column headings of Table 3.1.1 are described below:

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

Data reports for each sampling event, known as Aquatic Life Classification Attainment Reports, are available in electronic format with the web version of this report.

Supporting water chemistry data are given in Table 3.1.2. Water temperature data are given in Figure 3.1.1. For more information about the Biological Monitoring Unit, please e-mail us at biome@maine.gov or visit our web site: http://www.state.me.us/dep/blwq/docmonitoring/biomonitoring/index.htm. The Data and Maps page of this website provides access to station information and available data via Google Earth.

3.1.2 Results Summary

- Forty stations were assessed for the condition of the benthic macroinvertebrate community.
- Fifteen of the forty stations failed to attain the aquatic life standards of their assigned class.

TABLE 3.1.1 - 2008 SWAT Benthic Macroinvertebrate Biomonitoring Results

Waterbody	Town	Station	Log	Issue[1]	Statutory Class/ Final Determination[1]	Attains Class?	Probable Cause[1]
Androscoggin River	Bethel	355	1743	Municipal	B / B	Y	
Aunt Hannah Brook	Dixfield	343	1751		B / A	Y	
Bean Brook	Rumford	349	1737		B / A	Y	
Bear River	Newry	866	1742	Reference	AA / A	Y	
Bird Brook	Norway	340	1750	Urban NPS	B /B	Y	
Bobbin Mill Brook	Auburn	357	1746	Urban NPS	B / B	Y	
Burnham Brook	Big Moose TWP	869	1730	Reference/ Lake Outlet	A / B	N	32% prob. Class A
Cupsuptic River	Upper Cupsuptic TWP	360	1719		AA / A	Y	
East Outlet Stream	Lyman	867	1710	Reference	B / A	Y	
Gully Brook	Auburn	695	1745	Urban NPS	B / B	Y	
Hart Brook	Lewiston	341	1747	Urban NPS	B / NA	N	NPS Toxics; Habitat
Kennebago River	Rangeley	868	1718		AA / A	Y	
Kennebec River	Augusta	785	1753		B / A	Y	
Little Androscoggin River	Paris	43	1727	Urban NPS	C / B	Y	
Little Androscoggin River	Paris	79	1728	Municipal / Urban NPS	C / A	Y	
Little Androscoggin River	Mechanic Falls	122	1729		C / B	Y	
Lord's Brook	Lyman	875	1708	Compost Facility	B / NA	N	Severe Enrichment
Lord's Brook	Lyman	863	1709	Compost Facility	B / C	N	Severe Enrichment
Martin Stream	Turner	693	1717		B / B	Y	
Merrill Brook	Newry	350	1739		A / A	Y	

[1] NPS, non-point source pollution; prob., probability.

TABLE 3.1.1 - 2008 SWAT Benthic Macroinvertebrate Biomonitoring Results (cont.)

Waterbody	Town	Station	Log	Issue[1]	Statutory Class/ Final Determina-tion[1]	Attains Class?	Probable Cause[1]
Penjajawoc Stream	Bangor	511	1711	Urban NPS; Wetland	B / C	N	Low DO
Penjajawoc Stream	Bangor	513	1712	Urban NPS	B / C	N	NPS Toxics
Penjajawoc Stream	Bangor	315	1713	Urban NPS	B / NA	N	NPS Toxics
Sabattus River	Sabattus	629	1724	Municipal; Lake Outlet	C / C	Y	
Sabattus River	Sabattus	359	1725	Agric. NPS	C / C	Y	
Sabattus River	Lisbon	170	1726	Urban NPS	C / NA (BPJ)	N	NPS Toxics
Sheepscot River	Whitefield	74	1706	Reference	AA / A	Y	
Snowman Brook	Weld	874	1752		B / A	Y	
Stetson Brook	Lewiston	356	1744	NPS	B / A	Y	
Sunday River	Newry	444	1714	Reference	A / A	Y	
Sunday River	Bethel	354	1715	NPS	A / A	Y	
Unnamed Stream (Big Moose Twp)	Big Moose TWP	870	1731	Reference	A / A	Y	
Unnamed Stream (Brunswick 2)	Brunswick	641	1722		B / NA	N	NPS Toxics; Habitat
Unnamed Stream (Brunswick4)	Brunswick	643	1723		B / C	N	NPS Toxics; Habitat
Unnamed Stream (Lewiston)	Lewiston	856	1748	Landfill; Urban NPS	B / C	N	NPS Toxics; Landfill Toxics
Unnamed Stream (Lewiston)	Lewiston	857	1749	Landfill; Urban NPS	B / NA	N	Landfill Toxics; NPS Toxics
Unnamed Stream (Topsham 2)	Topsham	633	1720		B / I	N	NPS Toxics; Habitat
Unnamed Stream (Topsham 4)	Topsham	634	1721		B / NA	N	NPS Toxics; Habitat
West Branch Sheepscot River	China	268	1707	Reference	AA / B	N	34% prob. Class A
Wild River	Gilead	103	1741		A / A	Y	

[1] DO, Dissolved Oxygen; NPS, non-point source pollution; BPJ, Best Professional Judgment; I, indeterminate class; prob., probability.

3.1.3 Attainment History of Sampling Stations prior to 2008

- Androscoggin River (Station 355) attained class in 1998 and 2003.
- Aunt Hannah Brook (Station 343) attained class in 1998 and 2003.
- Bean Brook (Station 349) attained class in 1998.
- Bird Brook (Station 340) failed to attain class in 1998 and 2003.
- Bobbin Mill Brook (Station 357) attained class in 2003. It failed to attain class in 1998.
- Cupsuptic River (Station 360) attained class in 1998 and 2003.
- Gully Brook (Station 695) attained class in 2003.
- Hart Brook (Station 341; previously called Dill Brook) failed to attain class in 1988 and 2003.
- Kennebec River (Station 785) attained class in 1999, 2000, 2001, 2002, and 2007.
- Little Androscoggin River (Station 122) attained class in 1988 and 1998.
- Little Androscoggin River (Station 43) attained class in 1983, 1984, 1985, 1986, 1987, 1992, 1998, and 2002.
- Little Androscoggin River (Station 79) attained class in 1998 and 2003. It failed to attain class in 1984.
- Martin Stream (Station 693) attained class in 2003.
- Merrill Brook (Station 350) attained class in 1998 and 2003.
- Penjajawoc Stream (Station 315) attained class in 1997 and 2001. It failed to attain class in 2002, 2003, and 2006.
- Penjajawoc Stream (Station 511) failed to attain class in 2001, 2002, 2003, and 2006.
- Penjajawoc Stream (Station 513) failed to attain class in 1997, 2001, 2002, 2003, and 2005.
- Sabattus River (Station 170) attained class in 1992 and 1998. It failed to attain class in 2003.
- Sabattus River (Station 359) attained class in 1998.
- Sabattus River (Station 629) attained class in 2002 and 2003.
- Sheepscot River (Station 74) attained class in 1985, 1987, 1988, 1989, 1990, 1992, 1995, 1996, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006 and 2007. It failed to attain class in 1984, 1986, 1991, 1993, 1994, and 1997.
- Stetson Brook (Station 356) attained class in 1998.
- Sunday River (Station 354) attained class in 2000. It failed to attain class in 1998 and 2003.
- Sunday River (Station 444) failed to attain class in 2000 and 2003.
- Unnamed Stream (Brunswick 2) (Station 641) failed to attain class in 2002.
- Unnamed Stream (Brunswick 4) (Station 643) failed to attain class in 2002.
- Unnamed Stream (Topsham 2) (Station 633) attained class in 2006. It failed to attain class in 2002.
- Unnamed Stream (Topsham 4) (Station 634) attained class in 2002 and 2006.
- West Branch Sheepscot River (Station 268) attained class in 1996, 1997, 1998, 1999, 2001, 2002, 2005, and 2007. It failed to attain class in 2000, 2003, 2004, and 2006.
- Wild River (Station103) attained class in 1987.

TABLE 3.1.2 - 2008 SWAT Water Chemistry Data

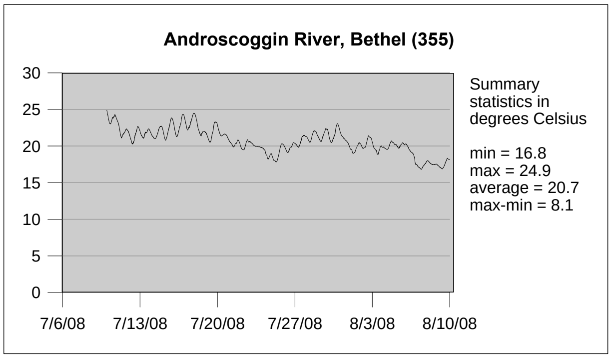
Please note that data for dissolved oxygen, specific conductance and pH (where available) are shown in the Aquatic Life Classification Attainment Report (pdf format) for each log number.

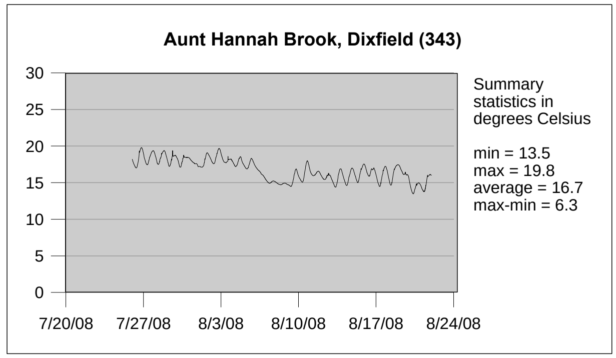
Waterbody	Log	Sampling Date	DOC	NH_3-N	TKN	NO_2-NO_3-N	SRP	Total P	TSS	TDS
			mg/L	mg/L	mg/L	mg/L	ug/L	mg/L	mg/L	mg/L
Androscoggin River	1743	8/20/2008	5.5	0.02	0.2	0.07	2	0.015	<2	23
Bean Brook	1737	8/19/2008	4.8	0.01	0.2	0.04	3	0.025	5.6	52
Bear River	1742	8/20/2008	3.2	<0.01	0.1	0.02	2	0.005	<2	29
Cupsuptic River	1719	8/12/2008	5.9	<0.01	0.2	0.04	2	0.009	<2	25
Hart Brook	1747	8/21/2008	5.3	0.1	0.4	0.08	3	0.034	4.2	52
Kennebago River	1718	8/12/2008	7.1	<0.01	0.3	0.03	2	0.009	<2	29
Little Androscoggin River	1728	8/11/2008	7.8	0.01	0.3	0.03	2	0.012	<2	45
Penjajawoc Stream	1711	8/5/2008	13	0.01	0.6	0.01	3	0.029	2.7	95
Penjajawoc Stream	1712	8/5/2008	12	0.02	0.8	0.09	5	0.038	7.9	190
Penjajawoc Stream	1713	8/5/2008	12	0.01	0.6	0.09	5	0.034	5.1	230
Sabattus River	1724	8/14/2008	4.9	<0.01	0.6	<0.01	2	0.055	7.7	50
Sabattus River	1726	8/14/2008	6.8	<0.01	0.7	0.03	1	0.074	14	65
Sheepscot River	1706	8/4/2008	8.6	0.01	0.4	0.04	2	0.021	<2	72
Sunday River	1715	8/6/2008	4.5	<0.01	0.1	0.02	~1	0.025	9.7	32
Swift River	1738	8/19/2008	3.9	<0.01	0.1	0.02	1	0.006	<2	17
Unnamed Stream (Brunswick 4)	1723	8/13/2008	5.5	0.02	0.3	0.42	5	0.018	3.5	140
Unnamed Stream (Lewiston)	1749	8/21/2008	5.2	0.26	0.5	0.33	5	0.015	<2	24
Unnamed Stream (Newry)	1740	8/20/2008	2.2	0.01	0.1	0.08	2	0.004	7.2	78
Unnamed Stream (Topsham 2)	1720	8/13/2008	5.1	0.03	0.3	0.61	5	0.056	9.2	160
Unnamed Stream (Topsham 4)	1721	8/13/2008	4.1	0.07	0.3	0.3	2	0.016	6.2	380
West Branch Sheepscot River	1707	8/4/2008	8.7	0.01	0.5	0.03	1	0.013	<2	51

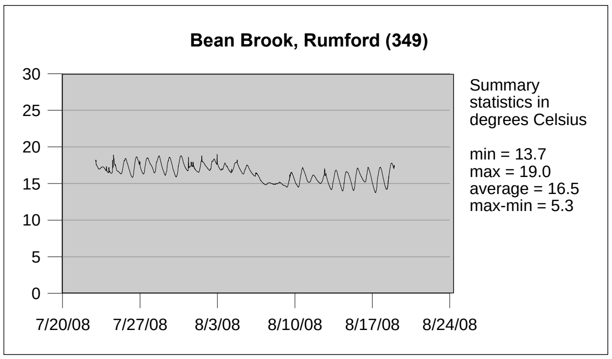
DOC = dissolved organic carbon, NH_3-N = ammonia-nitrogen, TKN = total Kjeldahl-nitrogen, NO_2-NO_3-N = nitrite-nitrate-nitrogen, SRP = soluble reactive phosphorus (ortho-phosphate), Total P = total phosphorus, TSS = total suspended solids, and TDS = total dissolved solids.

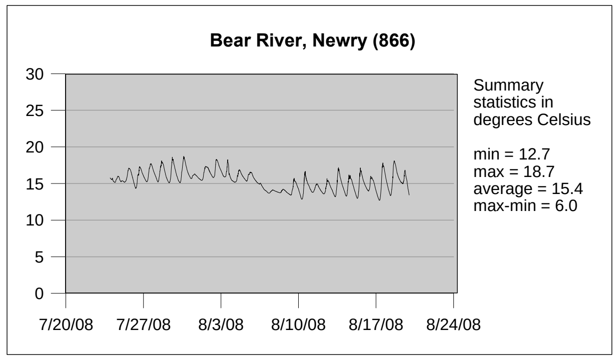
Figure 3.1.1 – 2008 In-Stream Temperature Data

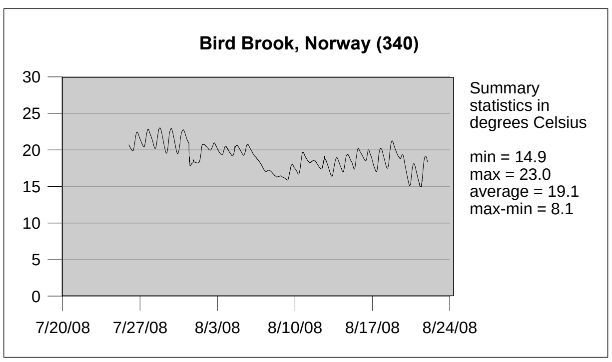
Please note: all data are in degrees Celsius

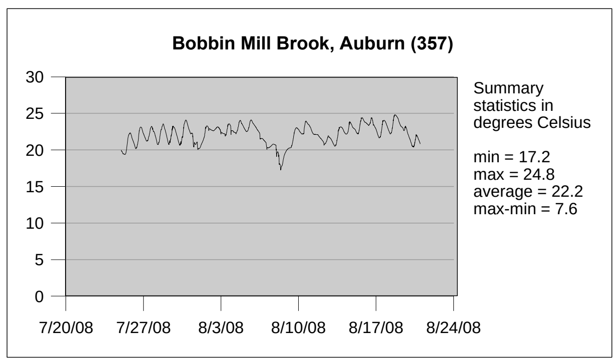


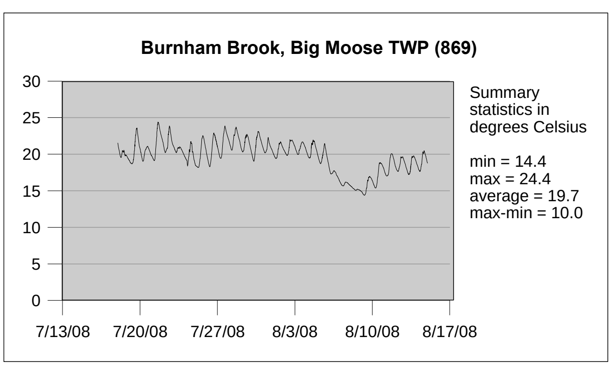












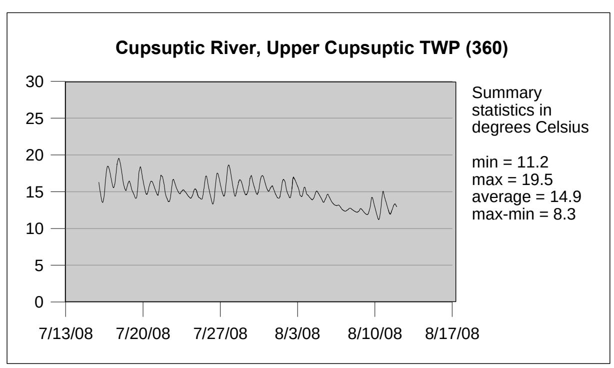


Figure 3.1.1 – 2008 In-Stream Temperature Data

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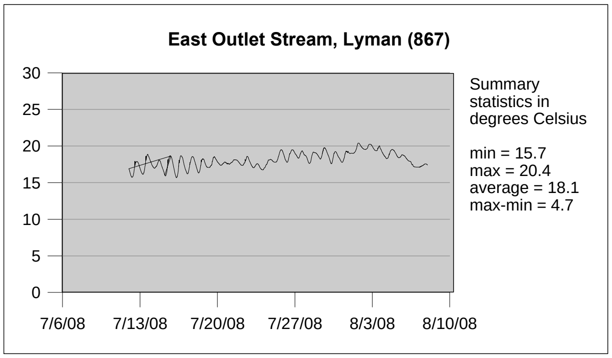

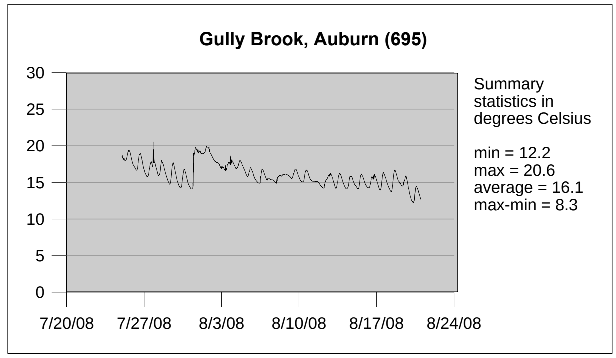

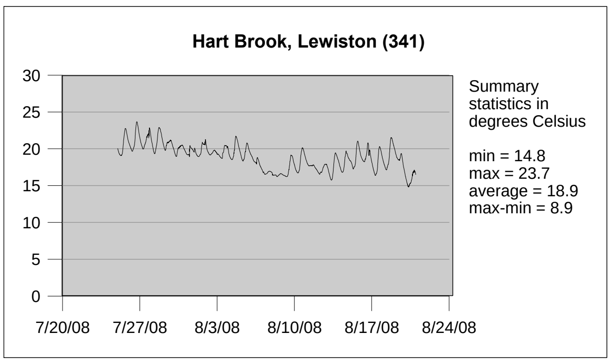

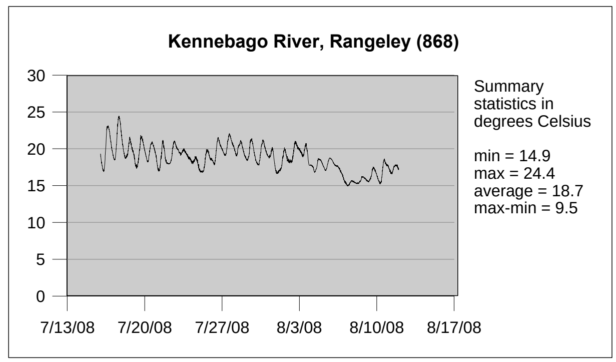

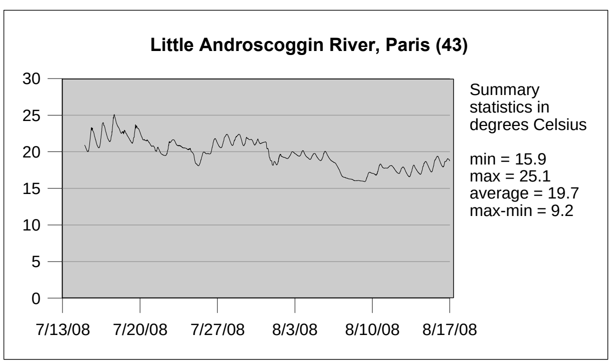

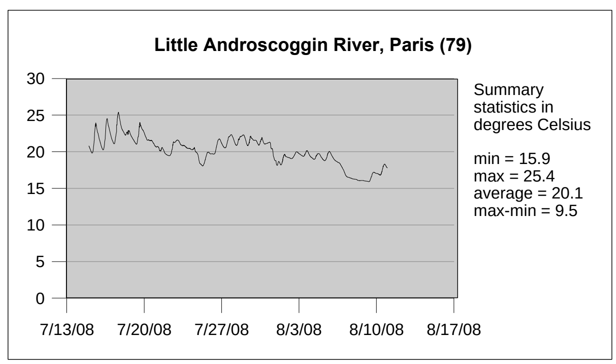

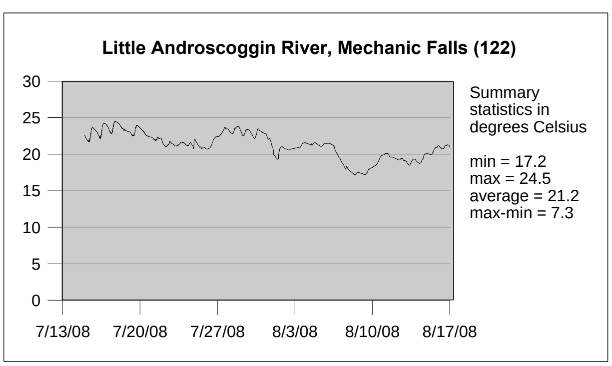

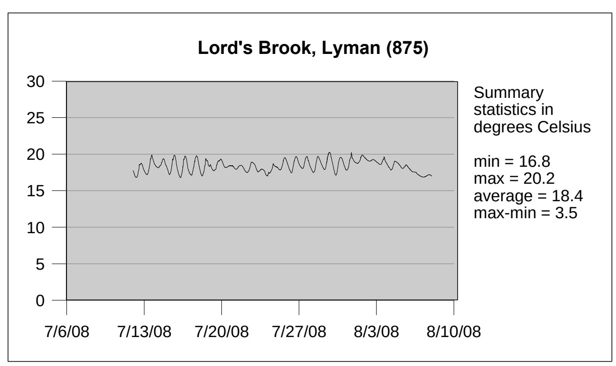

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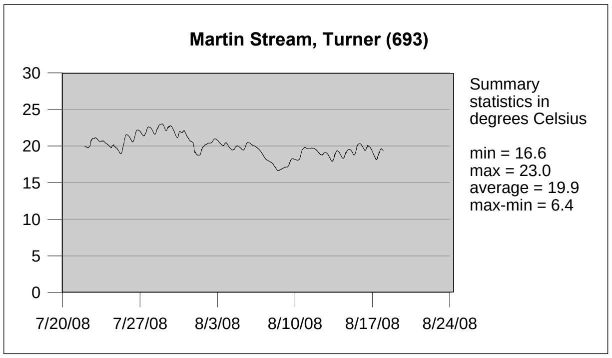
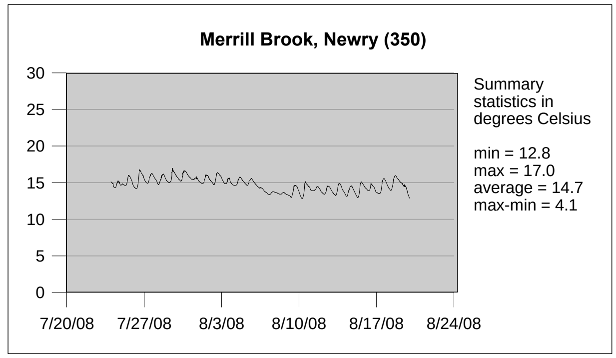
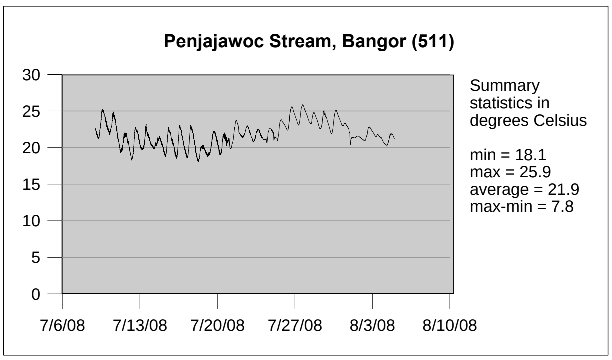
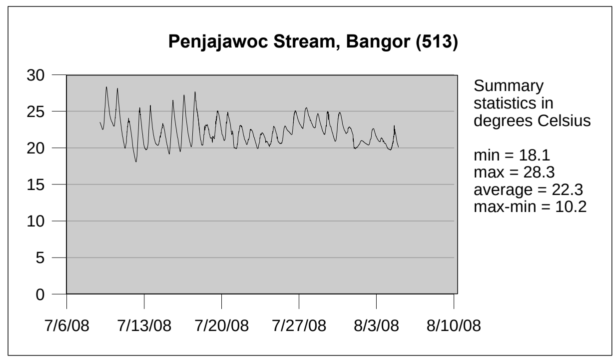
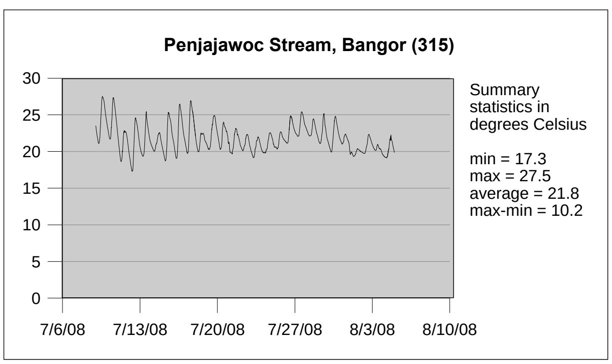
Please note: all data are in degrees Celsius

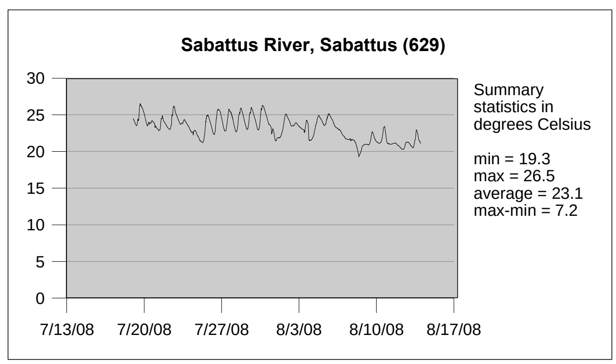


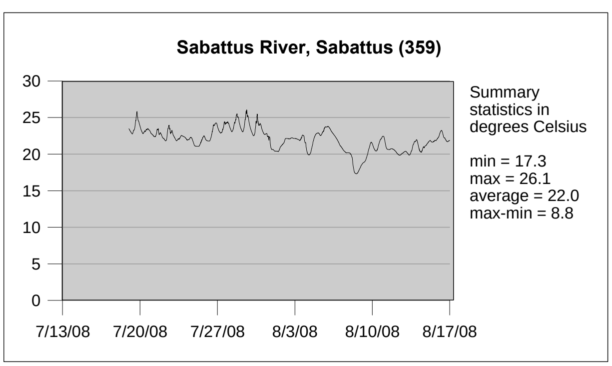












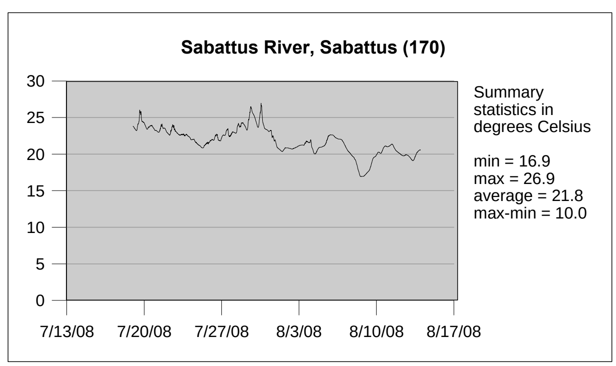


Figure 3.1.1 – 2008 In-Stream Temperature Data

Please note: all data are in degrees Celsius

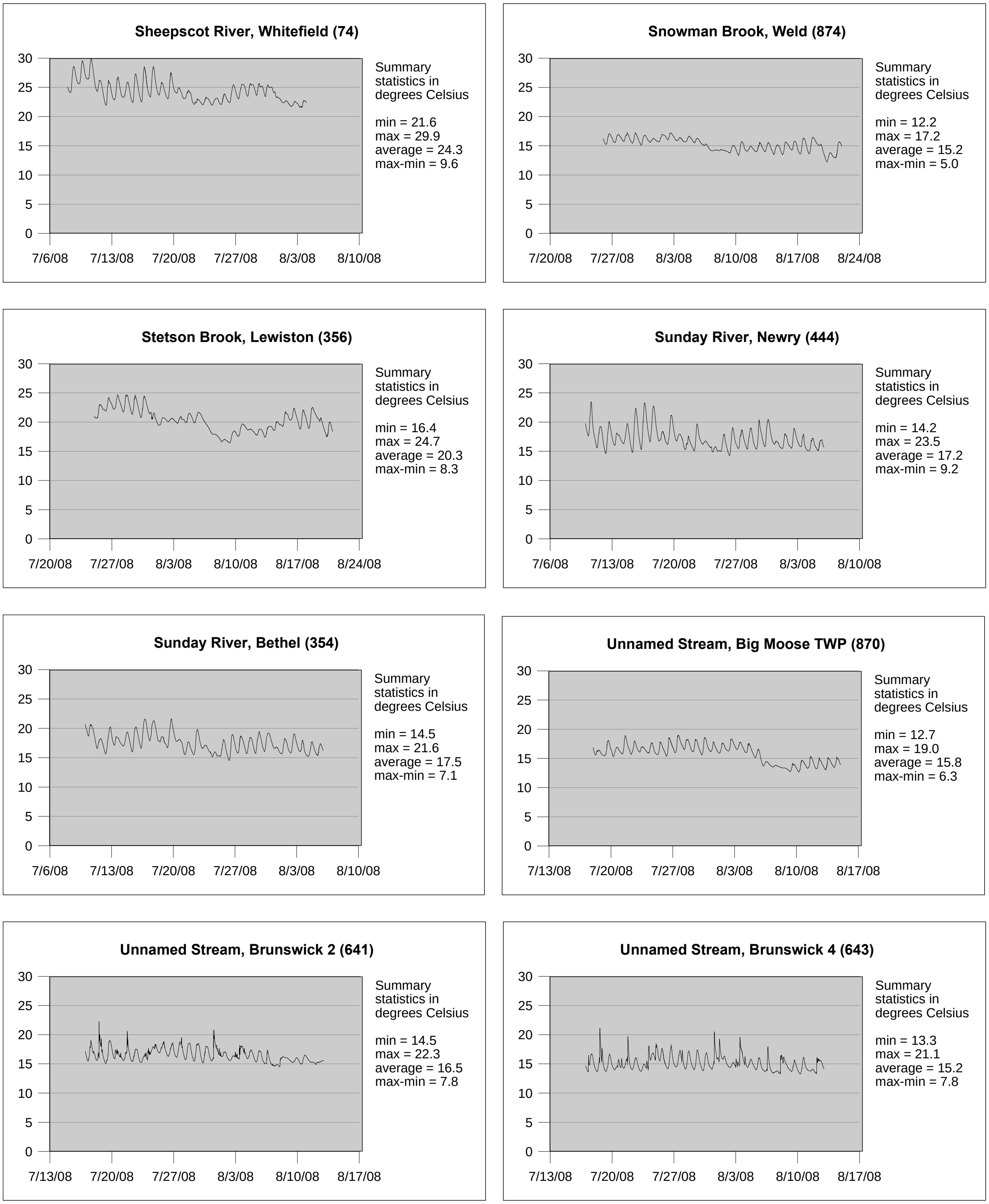
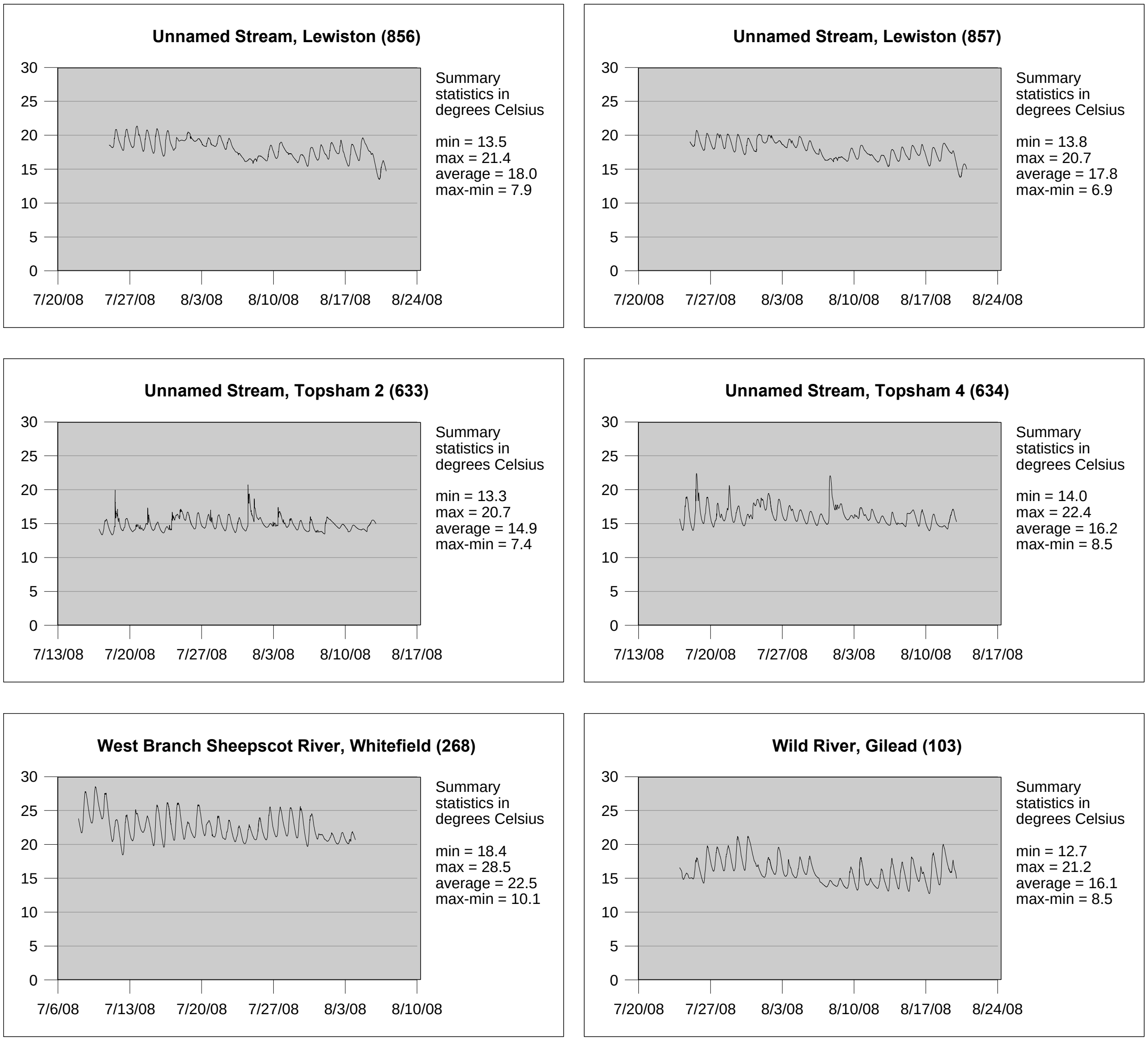


Figure 3.1.1 – 2008 In-Stream Temperature Data

Please note: all data are in degrees Celsius



3.2

FISH CONSUMPTION ADVISORIES

3.2 FISH CONSUMPTION ADVISORIES

The Maine Center for Disease Control and Prevention (MCDC) requested monitoring of fish from several river stations for contaminants to be used for the assessment of risk to human consumers of fish and the need for fish consumption advisories. Due to the deepening state budget deficit and resulting continuing cuts in the SWAT budget, some of the requests were not funded. Of those that were funded, we successfully collected the desired samples for most, but not all stations as described in the following sections. All data in this section are based on wet weight.

Dioxins and CoPlanar PCBs

In 2008, the SWAT program was again integrated with the Dioxin Monitoring Program (DMP) that has been in effect since 1988. Fish samples collected at 7 DMP stations for dioxin analyses were also analyzed for dioxin-like coplanar PCBs in the SWAT program (Table 1). Additional samples were collected from 2 of these stations and samples were collected from an additional 7 stations for dioxin and dioxin-like coplanar PCB analyses in the SWAT program. We were able to collect only 4 brown trout and 5 rainbow trout from the Kennebec River at Fairfield.

The results have been published in the 2008 Dioxin Monitoring Program report at http://www.maine.gov/dep/blwq/docmonitoring/dioxin/index.htm

Table 1 DMP/SWAT 2008 Workplan

RIVER	STATION	FISH predators samples	FISH omnivores samples	DMP PCDD/F samples	DMP facility	SWAT PCDD/F samples	SWAT CPCB samples
ANDROSCOGGIN	GILEAD	2C5 RBT				2	2
	RUMFORD						
	RILEY						
	LIVERMORE FALLS						
	TURNER GIP	2C5 SMB	2C5 WHS	4	RPC, VERSO		4
	LISBON						
	ANDROSCOGGIN L	2C5 WHP		2	RPC, VERSO		2
KENNEBEC	FAIRFIELD	2C5 BNT/RBT		2	SAPPI SOMERSET		2
	WINSLOW						
	AUGUSTA	2C5 SMB		2	KSTD		2
	GARDINER	2C5 SMB				2	2
	RICHMOND	2C5 SMB				2	2
PENOBSCOT	WOODVILLE	2C5 SMB	2C5 WHS	2	KATAHDIN PAPER	2	4
	S LINCOLN	2C5 SMB	2C5 WHS	2	LINCOLN PAPER	2	4
	VEAZIE	2C5 SMB	2C5 WHS	0	RED SHIELD	0	0
PRESUMPSCOT	WINDHAM	2C5 SMB	2C5 WHS			4	4
	WESTBROOK	2C5 SMB	2C5 WHS			4	4
SALMON FALLS	S BERWICK	2C5 SMB	2C5 WHS	4	BERWICK		4
SEBASTICOOK	BURNHAM	2C5 SMB	2C5 WHS			4	4
EAST BRANCH	NEWPORT	2C5 SMB	2C5 WHS			4	4
WEST BRANCH	PALMYRA						
TOTAL				**18**		**26**	**44**

2C5 = 2 composites of 5 fish each
FISH SPECIES CODES: BNT=brown trout, RBT=rainbow trout, SMB=smallmouth bass, WHP=white perch, WHS=white sucker
DMP = Dioxin Monitoring Program
SWAT= Surface Water Ambient Toxics monitoring program
PCDD/F=dioxins and furans
CPCB=(dioxin-like) coplanar PCBs+A32
RPC=Rumford Paper Company
KSTD=Kennebec Sanitary Treatment District (Waterville)

Total PCBs

Fish for total PCB (TPCB) analysis were successfully collected at all stations targeted. Results show that TPCB concentrations varied among species, stations, and years (Table 3.2.2). Generally results are similar among years, but there is some variability. Most concentrations exceeded MCDC's fish tissue action level (FTAL = 11 ng/g).

Table 3.2.2 Total PCBs in fish from some Maine rivers, mean ng/g
(95th upper confidence level on the mean or max if n=2)

ANDROSCOGGIN

Year	Species	Gilead	Rumford	Jay	Livermore	Auburn	Lisbon	Andro. Lk
2000	BNT	84.6						
1998	RBT	10.8						
2000	RBT	28.1						
2008	RBT	74.5 (86.2)						
1994	SMB		97.2	42.4	48.6	76.6	97.9	
1998	SMB		8.9	7	15.4	20.3	27.1	
2000	SMB		21	15	38.2	29.4	52.3	
2002	SMB		22	18.4	18.4	21.7	16.7	
2008	SMB					30.4 (34.6)		
2008	WHP							18.4 (23)
1994	WHS		79.5	129	39.1	114	145	
1996	WHS				30.8			
1998	WHS		20.5	24	32.6			
2000	WHS				48.1			
2008	WHS					80.2 (84.6)		

KENNEBEC

Year	Species	Norridgewock	Skowhegan	Fairfield	Sidney	Augusta	Hallowell	Gardiner	Richmond
1994	BNT			300					
1997	BNT			93 (107)		54.6 (70.9)			
1999	BNT					55 (71)			
2000	BNT	3.1			34 (45)				
2002	BNT	7.9		10.2					
2007	BNT	9.5 (14)							
1994	SMB			4.5	8.6	604			
1997	SMB		3.7 (4.5)	4.0 (4.9)	6.1 (7.2)	342 (357)			
1999	SMB					263 (323)		179 (227)	
2000	SMB				32 (42)				
2002	SMB	1.6		1.7	19.5	111		47.5	
2006	SMB				7.5 (10)	83 (142)		51 (75)	
2007	SMB							52 (70)	44 (64)
2002	EEL								377
2005	SLT						46 (64)		
2007	SLT						60 (83)		
1996	WHS					850			

PENOBSCOT

Year		Grindstone	Woodville	Mattawamke	S Lincoln	Costigan	Veazie	Bangor	Bucksport
2000	ATS						18.9		
1996	EEL							37.4	
2000	EEL							253	
2002	EEL							98.3	
2007	SLT								27 (27)
1994	SMB				8.6		10.1		
1996	SMB	4.5							
2008	SMB		9.4		6.9 (7.7)				
1994	WHS				95		65.1		
1996	WHS	6.7							
2008	WHS		28.9 (30)		29 (49)				

SALMON FALLS

Year		Acton		Northeast P	Spaulding P		Berwick		S. Berwick
1994	SMB								90.6
1994	WHS								576
1995	SMB	4.8							29.8
1997	SMB	5 (6)							75
1997	CHP								47 (53)
2000	SMB								83 (100)
2002	SMB								110
2002	WHP			23.4					
2006	LMB				25.5 (49)				33.2 (44)
2007	LMB								47 (61)
2008	LMB								47.2 (58.8)
2008	WHS								115 (150)

ATS	Atlantic salmon
BNT	brown trout
LMB	largemouth bass
SLT	rainbow smelt
SMB	smallmouth bass
WHP	white perch
WHS	white sucker

Mercury and metals

The statewide Fish Consumption Advisory is based on mercury concentrations in fish. Previous data indicate that fish from the Androscoggin River have higher levels of mercury than fish from other rivers. Therefore MCDC requested fish from the Androscoggin River to be sampled and analyzed for mercury and also for lead, another metal with human health risks. In 2008 samples collected from stations for dioxin and PCB analyses were also analyzed for mercury, lead, and also for other metals, since the laboratory method for lead (EPA method 1638) includes analysis for other metals for no extra charge. Results show that mercury levels in fish from selected stations on the Androscoggin River and from Androscoggin Lake were similar to those from previous years (Table 3.2.4).

Table 3.2.4. Mercury concentrations in Androscoggin River fish, 1998-2008

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

In 2008 rainbow trout (RBT) at Gilead had concentrations of mercury similar to those from 1998, both of which were below MCDC's Fish Tissue Action Level (FTAL = 0.2 ppm). Concentrations in smallmouth bass (SMB) at Gulf Island Pond (AGI) in Auburn in 2008 were elevated well above the FTAL as were those from 1998 and 2002. Concentrations in white suckers at AGI were much lower as is expected for this species which does not feed at a high trophic level, conducive to increased bioaccumulation of mercury, as do bass. Concentrations in white perch (WHP) from Androscoggin Lake (ALW) were similar to those in white perch, smallmouth bass, and chain pickerel (PKL) from previous years, all of which were well above the FTAL.

The 2008 samples were also analyzed for lead and other metals. The data show that concentrations of arsenic exceeded MCDC's FTAL (Table 3.2.6). Concentrations of other metals did not exceed FTALs or there were no FTALs and will be assessed by MCDC.

Table 3.2.6 Concentrations of heavy metals in fish from the Androscoggin River, 2008

DEP Sample ID→	FTAL	AGL-RBT	AGI-SMB	AGI-WHS	ALW-WHP
METALS ↓	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MERCURY	0.2	0.14	1.26	0.30	0.79
LEAD		0.04	0.04	0.01	0.04
ALUMINUM		0.87	1.88	1.50	1.15
ARSENIC	0.014	0.08	0.06	0.07	0.06
CADMIUM	2.2	0.006	0.010	0.010	0.010
CHROMIUM	7	0.13	0.11	0.12	0.15
COPPER		0.43	0.54	0.37	0.31
IRON		4.38	2.32	8.18	2.82
NICKEL	43	0.18	0.09	0.20	0.20
SELENIUM		0.59	0.31	0.40	0.93
SILVER	11	0.09	0.09	0.10	0.09
ZINC	648	6.89	4.59	7.56	5.50
% SOLIDS		23.4	21.6	21.4	22.4

Other than mercury, concentrations of metals were not significantly different from those from other rivers in Maine sampled in previous years.

Mercury method development

The results above were from fish caught, sacrificed, and filleted. Frozen filets were then sent to a commercial lab in British Columbia. A promising new method allows use of non-lethal sampling by taking small (< 1 g) biopsies of tissue for analysis using a Milestone Direct Mercury Analyzer (DMA80). The US Environmental Protection Agency and several states are beginning to use this new technology. There is an issue of comparability to more traditional methods such as the method used by our commercial lab (AXYS Analytical Services, EPA Method 1631, CVAAS, cold vapor atomic fluorescence atomic spectroscopy) primarily due to greater dehydration of the small biopsy samples which can skew results based on wet weight. To investigate the potential for use of this new method in Maine, small sub-samples of filet were taken from the ten smallmouth bass and ten white suckers from AGI and sent to the University of Maine's Sawyer Environmental Research Chemistry Lab (SERCL) that houses a DMA 80 purchased by DEP for use by researchers statewide, for mercury analysis. Samples of each species were analyzed as composites of five fish each in the same manner they were also analyzed by AXYS. In addition, five smallmouth bass were analyzed individually, and the mean (0.852 ppm) compared well to the composite value of the same fish (0.858 ppm). Correspondence between AXYS and SERCL for bass were just outside the acceptable range (relative percent difference RPD<30%) (Table 3.2.5). Additional experiments with smaller biopsy mass did produce concentrations for bass that were well within the acceptable range. Correspondence between the two labs for white suckers did fall within the acceptable range.

Table 3.2.5. Comparison of HG in fish from AXYS and UMO SERCL DMA 80

STATION	SPECIES	SAMPLE	HG AXYS	HG SERCL	RPD %
AGI	SMB	C1	1126	858	27.0
AGI	SMB	C2	1385	854	47.4
AGI	WHS	C1	309	274	12.0
AGI	WHS	C2	283	282	0.4

The use of the DMA 80 allows quicker and less expensive analysis of fish and other environmental samples. Further development of the proper technique is needed and will be pursued with SERCL.

DDT in Aroostook County Rivers

Detectable concentrations of DDE, a breakdown product of DDT, are still found throughout the United States, 40 years after it was banned. It is still manufactured and sold to third world countries for control of human disease vectors, and some may travel back to the US via evasion, long-range transport, and atmospheric deposition. Based on previous data collected in the SWAT program, levels exceeding the MCDC's cancer based FTAL for total DDTs (64 ppb) were found in several rivers and streams in Aroostook County, a legacy from past use. Consequently, in 2000 MCDC has issued fish consumption advisories (FCAs) for the Meduxnekeag River, North Branch Presque Isle Stream, and Prestile Stream. Since then additional data have shown exceedances of the FTAL in additional streams. To provide a current assessment of DDT levels in Aroostook County rivers and streams for potential revisions to the FCAs, MCDC requested sampling of additional rivers and streams in 2008.

Total DDT concentrations were calculated as the sum of 2,4'-DDD, 4,4'-DDD, 2,4'-DDE, 4,4'-DDE, 2,4'-DDT, and 4,4'-DDT. Results show that concentrations were relatively similar in 2008 to previous results in 2000 for the only waterbody resampled in 2008, Beaver Brook in Portage (Table 3.2.3). Concentrations in both years were below MCDC's fish tissue action level (FTAL) for DDTs (64 ng/g). Concentrations in Clark Brook in Presque Isle and Libby Brook in Ft. Fairfield exceeded the FTAL, while Hamlin Brook in Hamlin and Limestone Stream in Limestone greatly exceeded the FTAL.

Table 3.2.3 Total DDT (DDD+DDE+DDT) in Fish from Aroostook Co. Rivers and Streams, ng/g

	Year	1995	1995	1996	1997	2000	2003	2007	2008
	Species	BKT	BNT	BKT	BKT	BKT	BKT	BKT	BKT
STREAM	Town								
Beaver Bk	Portage					13.0			21.2
Caribou Str	Caribou					3.0			
Clark Bk	Presque Isle								95.6
Everett Bk	Ft. Fairfield					242		196	
Hammond Bk	Hamlin								234
Hockenhull Bk	Ft Fairfield					3.0			
Libby Bk	Ft Fairfield								106
Limestone Str	Limestone								229
Meduxnekeag R N Br	Bridgewater					4.7			
Meduxnekeag R S Br	Hodgdon							25	
Meduxnekeag R	Houlton	82	98						45.4
Presque Str N Br	Mapleton	142				43.8		65	
Presque Isle Str	Mapleton					3.0			
Prestile Str	Mars Hill			260				88	
Prestile Str	Westfield					96.0			
Prestile Str	Caribou						170	140	
Salmon Bk	Washburn					37.6			
Violette Str	Van Buren								27.8

BKT = brook trout
BNT = brown trout

3.3

CUMULATIVE EFFECTS DRIVEN ASSESSMENT OF FISH POPULATIONS

CUMULATIVE EFFECTS ASSESSMENT OF FISH POPULATIONS

INTRODUCTION

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

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

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

With the assistance of Environment Canada (EC), DEP conducted CEAs of fish populations on the St John River in 1999-2001 that indicated probable impacts to fish populations and identified a previously unknown source of pollution (a poultry processing plant) in Canada that negatively affected fish populations in the river. In 2000, similar studies of the North Branch of Presque Isle Stream and Prestile Stream in Maine, where high concentrations of DDT, a known endocrine disruptor, have been previously found, indicated potential population level effects by a significant reduction in gonad size in both streams compared to two reference streams with much lower DDT levels in fish. Although a population estimate of brook trout in Prestile Stream found an abundance of trout, it is not known whether negative effects were mitigated by the high natural productivity of this limestone stream and anthropogenic nutrient enrichment as there is no suitable reference stream in the area with limestone and without DDT.

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

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

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

Another method of determining the impact of stressors on fish populations is through studies of fish communities. For the last several years, Chris Yoder, Midwest Biodiversity Institute, and Brandon Kulik, Kleinschmidt Associates, have been conducting fish assemblage studies on large rivers in Maine and the rest of New England, for the purpose of developing an Index of Biological Integrity of fish communities, under an EPA grant in consultation with Maine DEP and the Department of Inland Fisheries and Wildlife, In their 2006 study of the Presumpscot River field observations noted reduced catch rates of fish in the Presumpscot River below Westbrook compared to the river above the city. Consequently, it was decided that further investigation was necessary and in 2007, a CEA was conducted on the Presumpscot River. The SD Warren pulp mill in Westbrook closed in 1999, leaving the paper mill and city of Westbrook as the major dischargers into the river. The Presumpscot River much is smaller than the Androscoggin, Kennebec, and Penobscot recently studied and consequently wastewater is a larger proportion of the Presumpscot River than the other 3 rivers previously studied, and more likely to have an effect on fish populations. As reported in the 2007 SWAT report, at the downstream stations, GSI and K were elevated consistent with nutrient enrichment and general observations of eutrophication due to the two discharges and urban runoff. Also, field data from 2007 indicated that catch rates were lower and there were fewer (3) males captured below Westbrook. One possible explanation for such unusual responses was a suggestion by mill personnel that the habitat at the sampling stations above Westbrook at PWD and below at PWB are different, with the latter being more influenced by marine clay deposits than the former. Consequently, the study was repeated in 2008 with an additional station (PGO), in the area sampled by Chis Yoder immediately upstream of the Saccarappa dam in Westbrook near the Gorham town line, that was more similar in habitat to the station below Westbrook (PWB).

METHODS

In September 2008, white suckers were collected from the Presumpscot River at Windham (PWD) and in the Saccarappa impoundment near the Gorham/Westbrook town line (PGO) above the discharges from the SD Warren paper mill and municipal wastewater treatment plant in the city of Westbrook and at Westbrook (PWB) below the discharges. Previous studies in Canada have determined that a sample size of 20 is sufficient to reduce the variance enough to detect a difference of ~25% in the variables measured between stations. Therefore, the target was to collect 20 males and 20 females from each station.

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

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

Later the same day in the lab, the samples were placed in proper storage to await analyses. Plasma was collected from the blood samples after centrifugation in the lab and then frozen at –20 ° C for radioimmunoassay (RIA) analysis for circulating sex steroids (testosterone T, 11 ketotestosterone 11-KT, and estradiol E2) following the method of McMaster, et al. (1992) and F following the method of

Jardine (1996). Liver samples were stored at –80 ° C for MFO (CYP1A) analysis as outlined by Munkittrick et al (1992). Gonad samples remained in formalin for further analyses. Histological samples of gonads were prepared and examined for the presence of testis-ova as outlined in Gray and Metcalf (1997) or analysis of gonadal staging (McMaster, 2001). All laboratory analyses were performed at Environment Canada's National Water Research Institute in Burlington, Ontario, Canada. Samples for aging were stored at –20 ° C until prepared and read in the DEP lab in Augusta, Maine.

RESULTS

Due to heavy fall rains and flow regulation at the headwaters at Sebago Lake, river flow increased to flood stage during sampling at PWB. The result was that only 18 live females and 20 live males were captured during 3 days of netting. A total of 23 live females and 23 live males were captured at PWD and a total of 20 live females and 21 live males were captured at PGO, also in 3 day sampling periods.

Water Quality

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

Table 3.3.1. Water quality of the Presumpscot River 2008

STATION	FLOW[1]	BOD[1]	NITROGEN[2]	NITROGEN[3]	PHOSPHORUS[2]	PHOSPHORUS[3]
	1000 m3/d	kg/d	mg/l	kg/d	mg/l	kg/d
PWD			0.230		0.005	
PGO						
PR1			0.250		0.009	
WESTBROOK STP	13.0	117	16.967	220	3.700	48
PR2			0.355		0.039	
SAPPI	19.2	124	2.503	48	0.437	8
PWB PR3			0.447		0.053	
PWB PR4			0.350		0.043	
Mill Stream			0.650		0.082	
PWB PR5			0.350		0.048	
PWB PR6			0.390		0.053	
Piscataqua R West			0.640		0.023	
Piscataqua R East			0.940		0.029	
PR8			0.437		0.061	

discharges or tributaries to the river

[1] mean monthly for 2007-2008

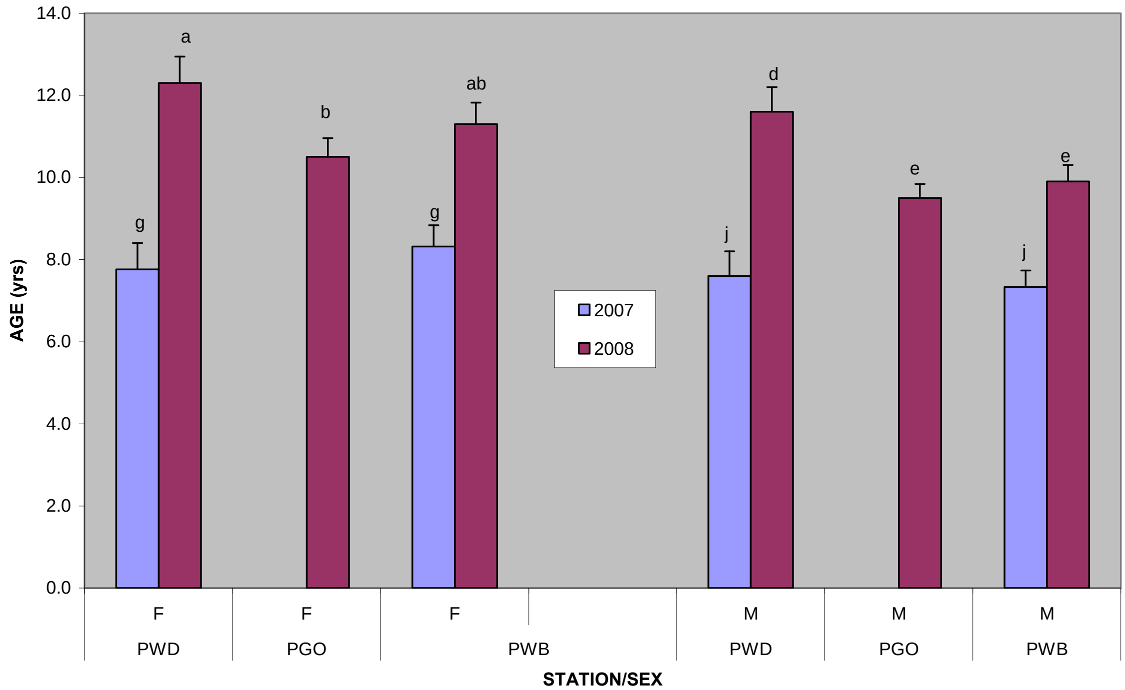
[2] mean August 2,4,5, 2008

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

Age

Comparisons of absolute ages between the two years are not appropriate, given the difference in net mesh size between the two years, but it is important to determine if relative differences in age between sexes and among stations within years are repeated the next year. In 2008 there was no difference in mean age between PWD and PWB for females as was the case for both sexes in 2007 (Figure 3.3.1). But in 2008 mean age of males was lower at PWB than at the upstream station PWD although similar to that at PGO.

Figure 3.3.1. Mean age (+S.E. bars, letters show significant differences by each sex and year) of female (F) and male (M) white suckers above (PWD, PGO) and below (PWB) a sewage treatment plant and paper mill in Westbrook, 2007-2008



Length

Comparisons of absolute lengths between the two years are not appropriate, given the difference in net mesh size between the two years, but it is important to determine if relative differences in length between sexes and among stations within years are repeated the next year. In 2008 female white sucker at PWB were shorter than those at both stations above Westbrook, while males were shorter than those only at PWD (Figure 3.3.2). In 2007 there was no significant difference between PWD and PWD for females. There was also no significant difference with males due to a small (n=3) sample size and high variance, but the fish at PWB (mean = 410 mm) appeared to be shorter than those at PWD (mean = 439 mm). These results are contrary to the expected greater length below Westbrook due to nutrient enrichment and eutrophication.

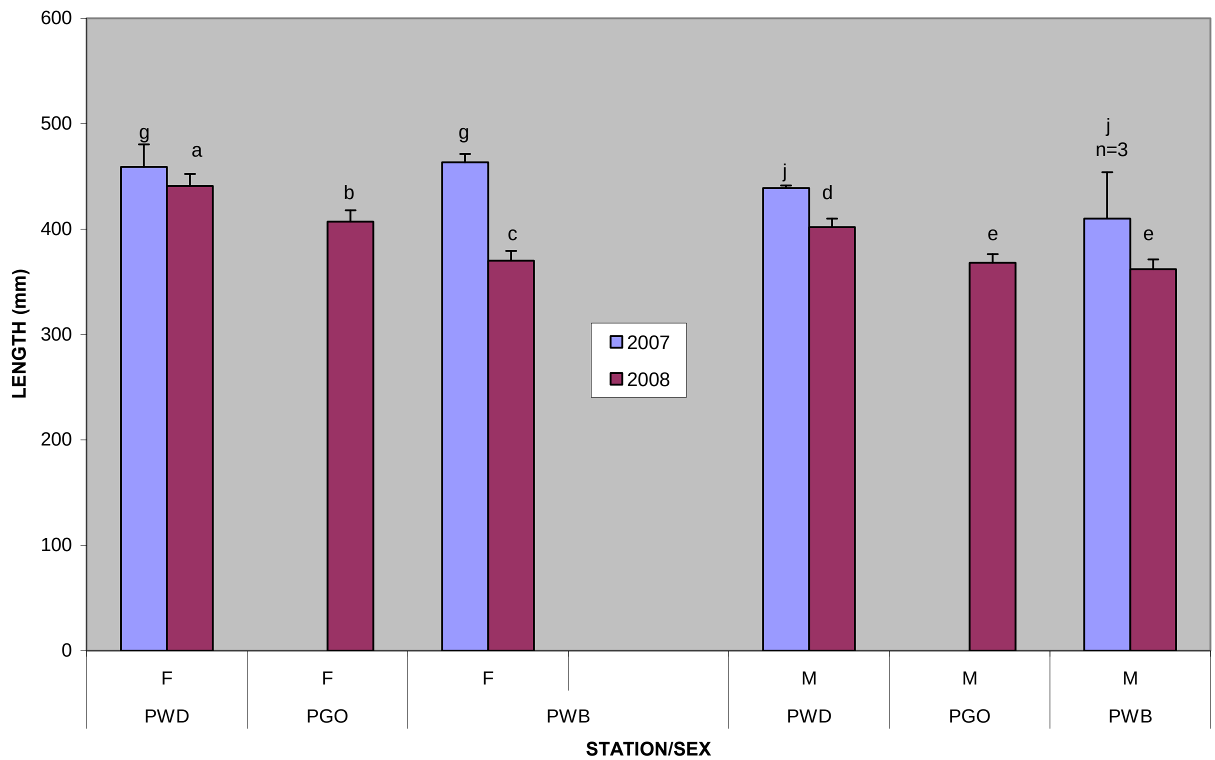
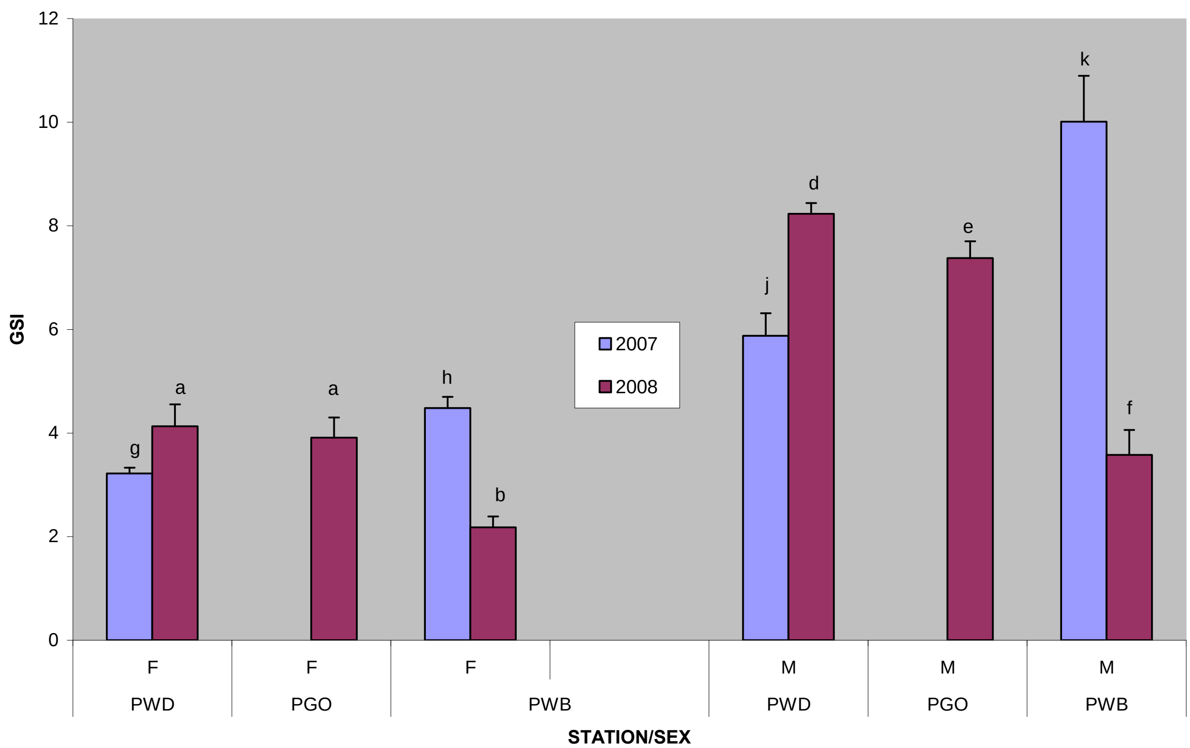


Figure 3.3.2. Mean length (+S.E. bars, letters show significant differences by each sex and year) of female (F) and male (M) white suckers above (PWD, PGO) and below (PWB) a sewage treatment plant and paper mill in Westbrook, 2007-2008

GSI

In 2008 GSI was lower at PWB than at both upstream stations for both sexes (Figure 3.3.3). This is different than 2007 when GSI at PWB was higher than the upstream station for both sexes. It is difficult to compare between years given the difference in net mesh size for each year, but since GSI is normalized to body size, it should be less affected than age or length. Nevertheless, there is no consistent response between the two years.

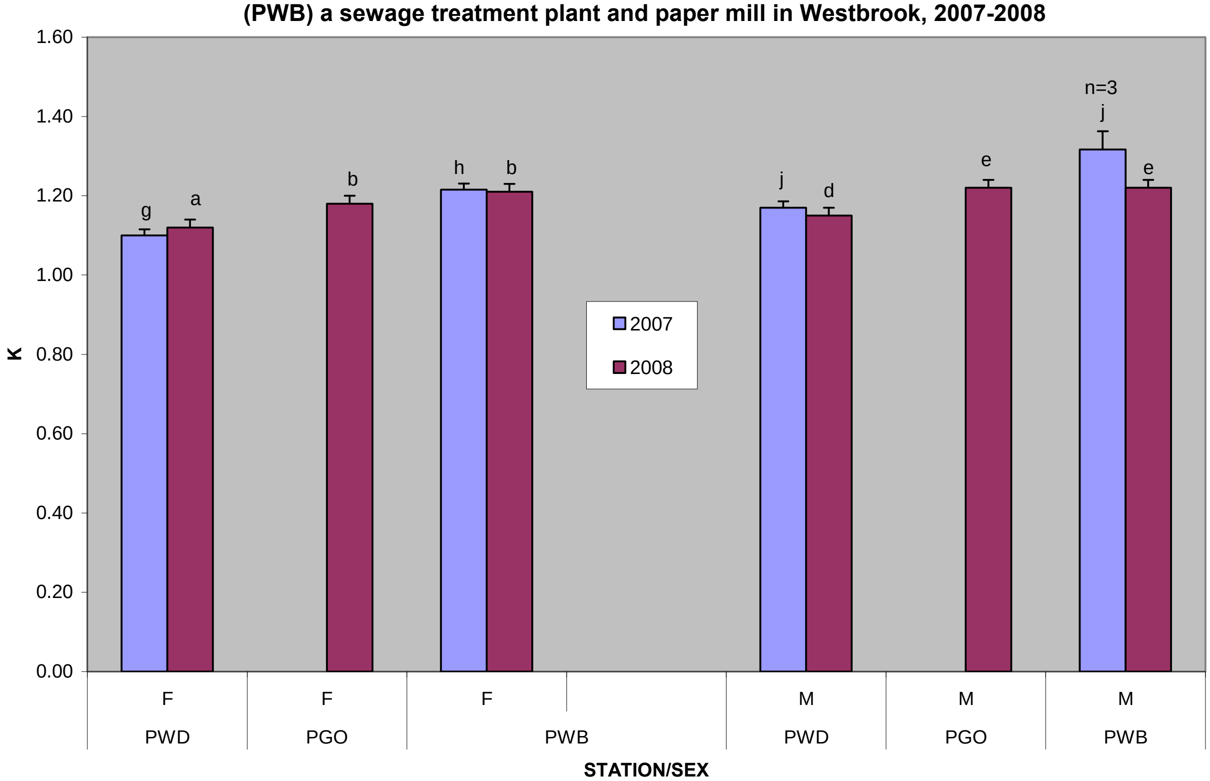
Figure 3.3.3. Mean GSI (+S.E. bars, letters show significant differences by each sex and year) of female (F) and male (M) white suckers above (PWD, PGO) and below (PWB) a sewage treatment plant and paper mill in Westbrook, 2007-2008



Condition Factor

In 2008 condition factor (K) for both sexes was similar at PWB to that of PGO, both of which were higher than the most upstream station at PWD (Figure 3.3.4). This was interesting given the greater enrichment at PWB than either PWD or PGO. This was similar to that of 2007 for females and likely so for males if sample size had not been so low.

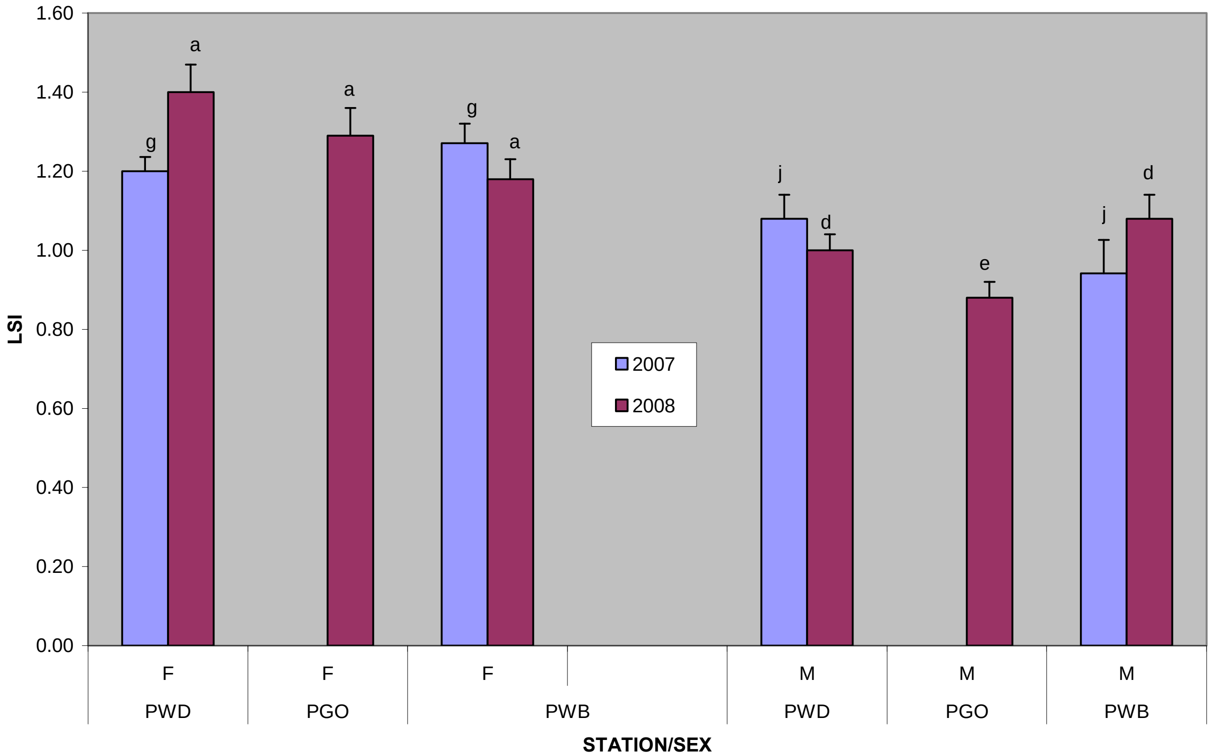
Figure 3.3.4. Mean condition factor (K) (+S.E. bars, letters show significant differences by each sex and year) of female (F) and male (M) white suckers above (PWD, PGO) and below (PWB) a sewage treatment plant and paper mill in Westbrook, 2007-2008



Liver Size

In 2008 mean normalized liver size (LSI, liver somatic index) was similar at all stations for females and similar at PWD and PWB for males (Figure 3.3.5). Only at PGO in males was liver size different (lower) than at other stations. In 2007 there was no difference between stations for either sex. This was unexpected since LSI usually responds similarly to K, and increases in eutrophic waters, such as occurs below Westbrook.

Figure 3.3.5. Mean LSI (+S.E. bars, letters show significant differences by each sex and year) of female (F) and male (M) white suckers above (PWD, PGO) and below (PWB) a sewage treatment plant and paper mill in Westbrook, 2007-2008



In 2008 normalized spleen size, a potential indicator of immune system dysfunction, was lower at PWB than upstream for females, but there was no difference for males among the stations (not shown). Nor was there any difference between stations in 2007 for either sex. There is no clear indication of immune system dysfunction.

Laboratory results for plasma steroids from 2007 and steroids and liver detoxification enzymes (MFO) from 2008 have not yet been received from the Environment Canada lab.

Gonad Development

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

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

A gonadal staging study compared the developmental stage of the male and female germ cells in white sucker collected at PWD and PWB in 2007 was conducted by Environmental Canada. Results showed that there was no significant difference in percentage of previtellogenic, endovitellogenic, and vitellogenic oocytes between stations (Figure 3.3.6). Nor was there any difference in mean size of vitellogenic oocytes between stations (Figure 3.3.7).

Figure 3.3.6. Percentage of previtellogenic (P), endovitellogenic (E), and vitellogenic (V) oocytes in white suckers from above (PWD) and below (PWB) a municipal sewage treatment plant and a paper mill discharge to the Presumpscot River, 2007.

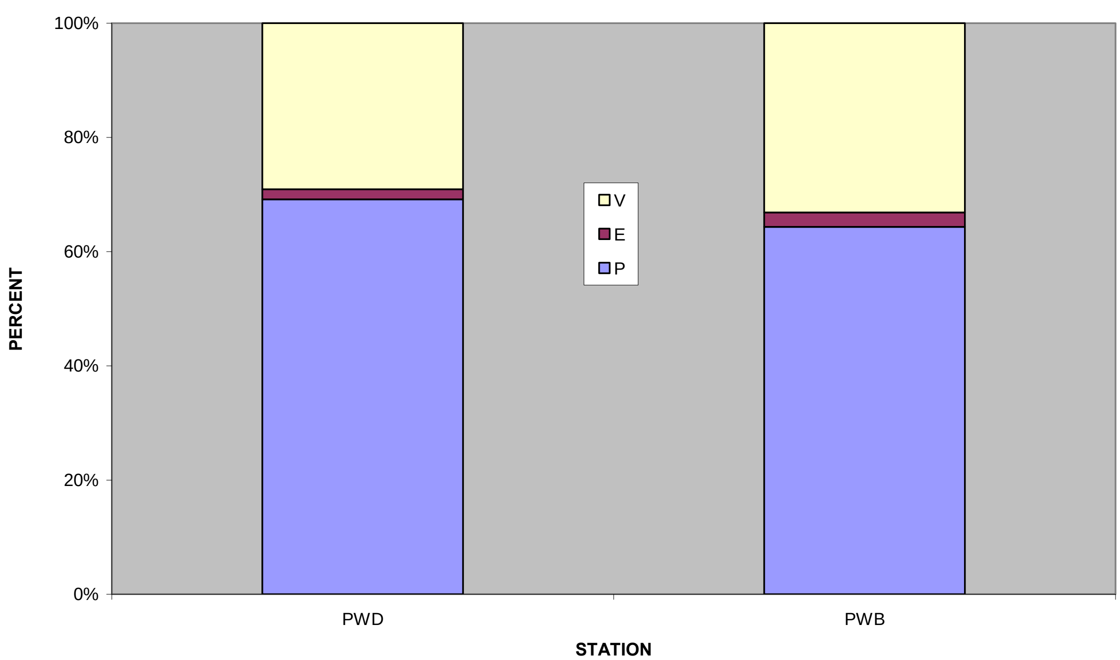
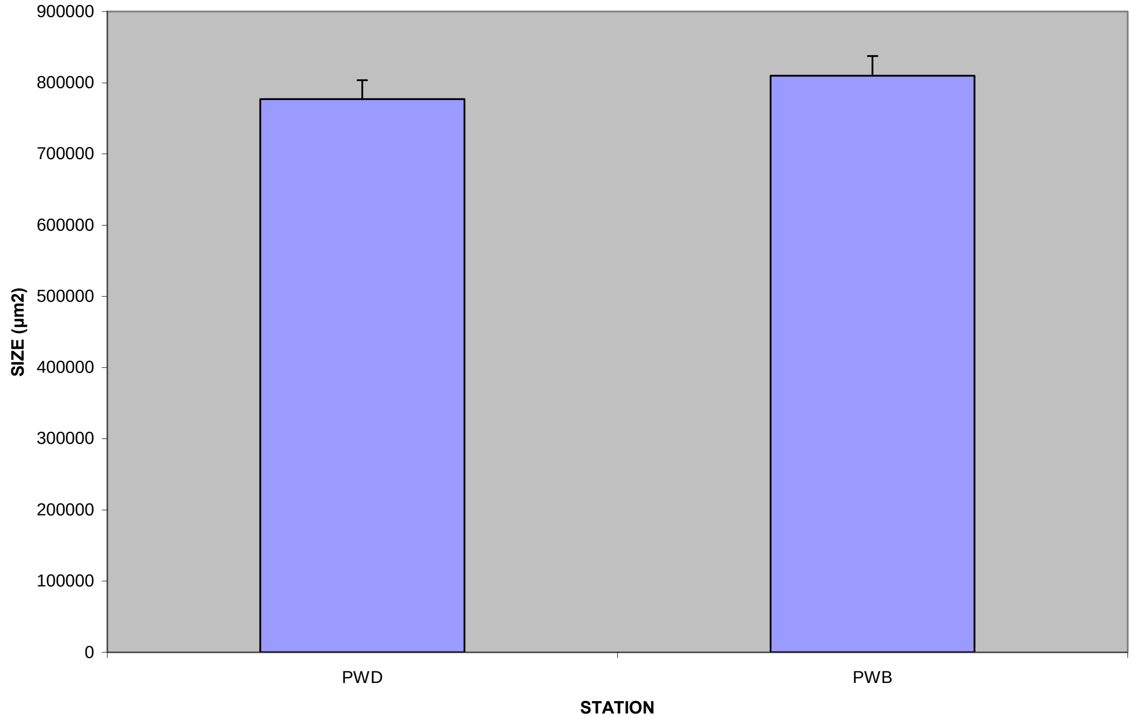
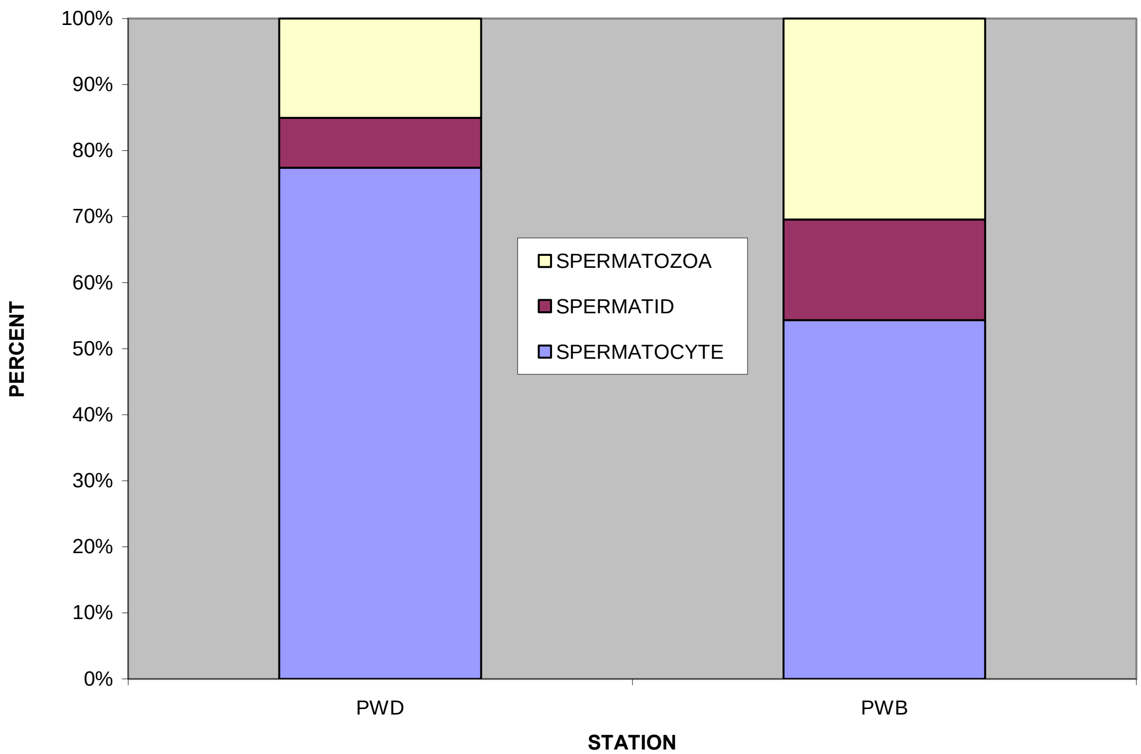


Figure 3.3.7. Mean size (µm2) of vitellogenic oocytes from white suckers above (PWD) and below (PWB) a municipal wastewater and and paper mill discharge to the Presumpscot River, Westbrook, Maine, 2007



Gonadal development of male sperm cells was not significantly (p=0.104) different between stations (Figure 3.3.8), but sample size of male suckers was limited (n=3). Results of the 2008 gonad sample analysis have not yet been received from the lab and will be important for a final conclusion.

Figure 3.3.8. Percentage of spermatocytes, spermatids, and spermatozoa in testes of male white suckers from above (PWD) and below (PWB) a municipal sewage treatment plant and paper mill discharge to the Presumpscot River in Westbrook, Maine, 2007.



Vitellogenin and Intersex

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

In 2007 measurement of VTG in plasma of white suckers from the Presumpscot River above (PWD) and below (PWB) the Westbrook sewage treatment plant discharge and SD Warren paper mill discharge showed measurable levels of VTG in females and only trace amounts in males. VTG was significantly elevated in females at PWB (Figure 3.3.9) consistent with the increase in GSI (Figure 3.3.3). This may be a result of increased nutrition shown by condition factor (weight to length) which was greater at PWB than at PWD as a result of increased eutrophication due to the two discharges. There was no significant difference between stations for males (Figure 3.3.10), signaling that endocrine disruption was an unlikely factor in this river. But sample size was small (n=3) at the downstream station, so results of the 2008 collection will be important for final conclusions. No intersex was observed in male gonads.

Figure 3.3.9. Mean concentrations of vitellogenin (VTG) in female white sucker above (PWD) and below (PWB) a municipal sewage treatment plant and paper mill discharge to the Presumpscot River in Westbrook, Maine, 2007

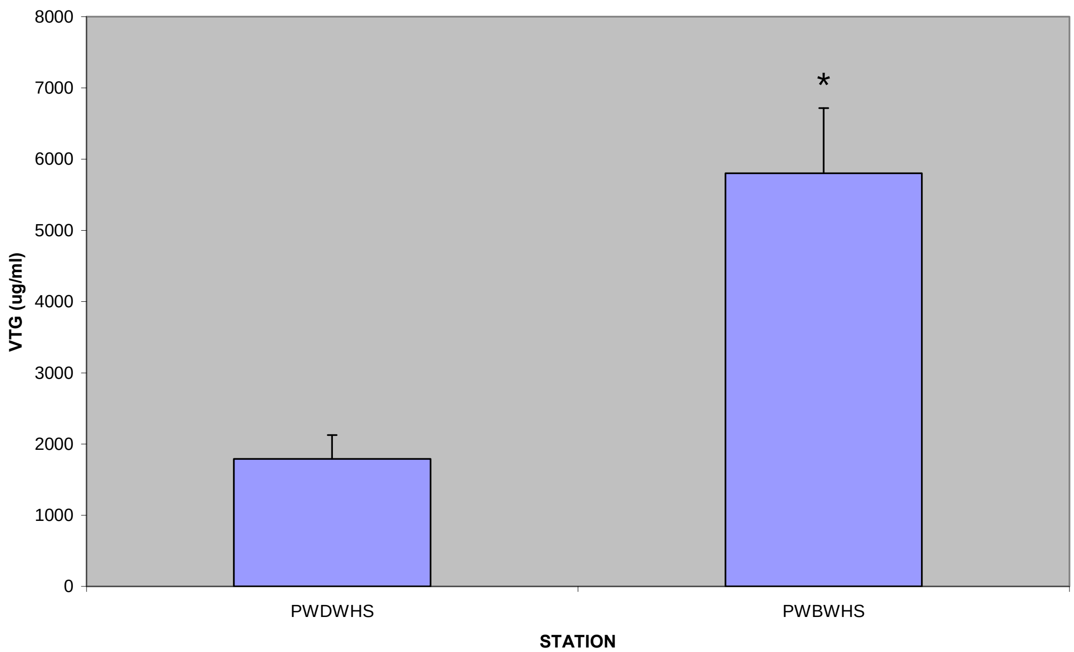
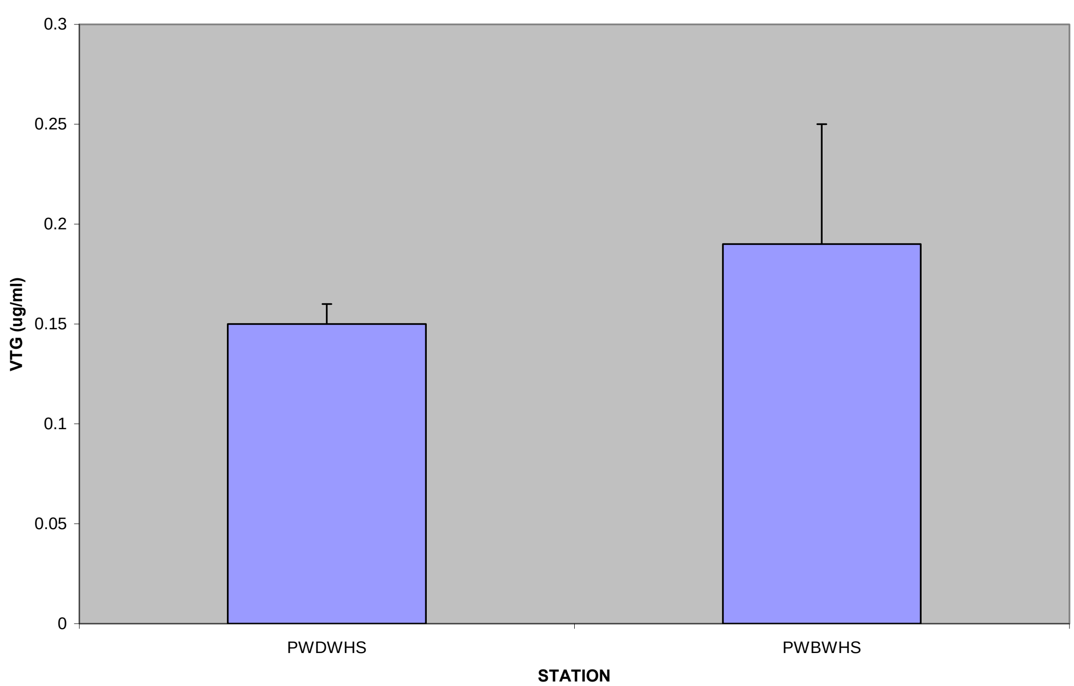


Figure 3.3.10. Mean concentrations of vitellogenin (VTG) in male white sucker above (PWD) and below (PWB) a municipal sewage treatment plant and paper mill discharge to the Presumpscot River in Westbrook, Maine, 2007

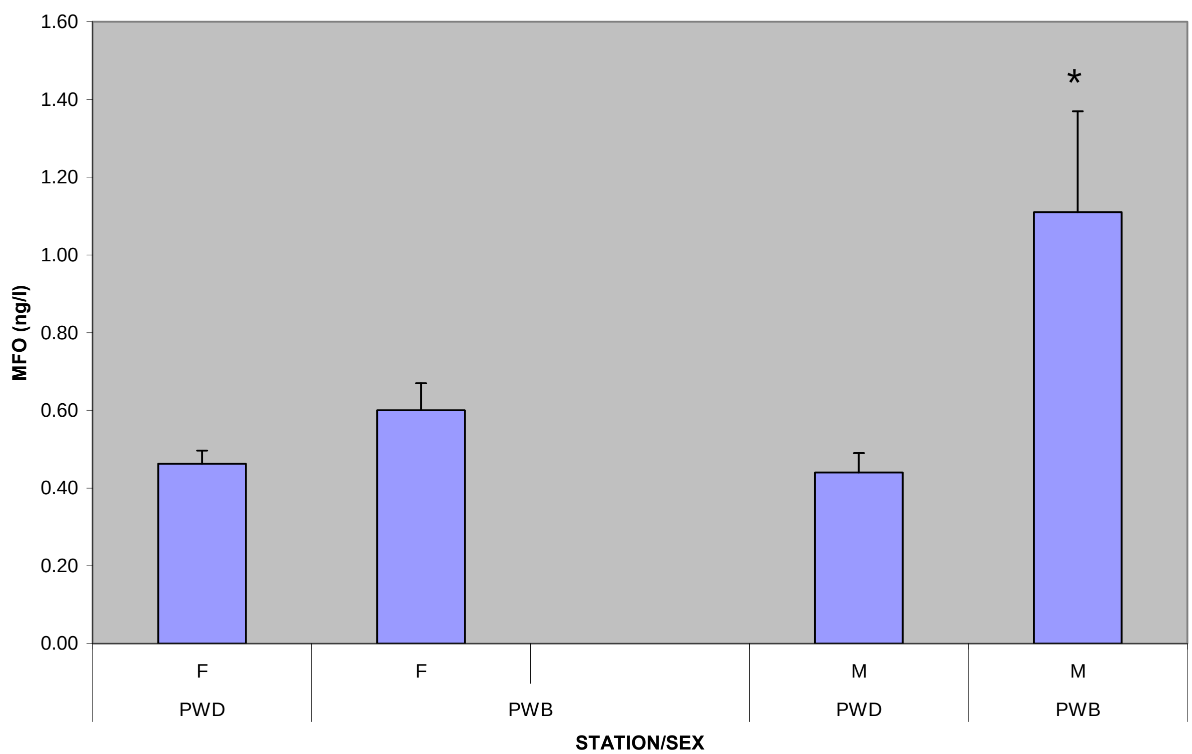


Mixed function oxidase (MFO) enzymes.

Mixed function oxidase (MFO) enzymes are a family of enzymes found in the liver functioning to aid metabolism of normal physiological compounds such as steroids, bile salts, prostaglandins, and fatty acids. One enzyme, CYP 1A or p450, also is involved the first stage in biotransformation of xenobiotics (chemicals foreign to biological systems) to compounds more easily eliminated from the body (detoxification) and is often increased with exposure to chemicals in various discharges such as those from sewage treatment plants and pulp and paper mills. Thus, a difference in CYP1A above and below a discharge can be a biomarker of exposure to physiological important levels of xenobiotics. The most common method of measurement of MFO is specific to CYP1A and so the terms are usually interchangeable.

In 2007, there was no difference in MFO in female white sucker above and below the discharges in Westbrook (Figure 3.3.11). MFO in males were elevated below Westbrook, results should be viewed with caution as the sample size (n=3) was low at PWB. Data from 2008 have not yet been reported by the lab.

Figure 3.3.11. MFO in male and female white sucker above (PWD) and below (PWB) municipal sewage treatement plant and paper mill discharges to the Presmumscot River in Westbrook, Maine 2007



CONCLUSIONS

The apparent lower catch rate and fewer male white sucker captured in 2007 below Westbrook may have been due to gear size. Catch rates in 2008, when smaller mesh size nets were included in the sampling methods and when a second station above but closer to Westbrook was included, appeared generally similar above and below Westbrook, although it is not certain given flood flows during the study which interrupted sample collections. Female white sucker were shorter below Westbrook in 2008. This is contrary to expectations, given the eutrophication of the river below Westbrook due to the discharges from the Westbrook sewage treatment plant, SD Warren paper mill, and urban runoff. Although induction of MFO in males below Westbrook in 2007 and lower GSI in both males and females in 2008 indicate some endoocrine disruption in suckers below Westbrook, there is no repeated pattern for both 2007 and 2008. Even though gonad size increased for both sexes below Westbrook in 2007, there was no difference in development of eggs or sperm. In 2008 gonad size decreased below Westbrook for both sexes, which is atypical of eutrophic conditions like those below Westbrook and is a common indicator of endocrine or metabolic disruption. There was no evidence of intersex observed in gonads. Condition factor (fatness) increased below Westbrook compared to above at Windham for both years, an expected result of nutrient enrichment, but was no different from that of the new station near the Gorham/Westbrook town line, where suckers have access to the impoundment beginning in Westbrook and which may be enriched by urban runoff.

Whole effluent toxicity (WET) tests from both the Westbrook Sewage Treatment Plant and SD Warren Paper mill do not show potential toxicity with the effluent, but WET tests typically detect only relatively gross effects. And there is a possibility of toxic effects from urban runoff from the highly developed city of Westbrook. Most likely the cause of any impaired fish population is a combination of factors.

Neither data for plasma sex steroids and liver detoxification enzymes from both years, nor gonad and vitellogenin data from 2008 have yet been received from the lab. Those data will be necessary before final conclusions can be made. A 2006-2007 study of fish assemblages and relative abundance in the Presumpscot River may also be useful for assessing fish populations in this river (Yoder, 2009).

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