

Gulfwatch 2007 Data Report:

SEVENTEENTH YEAR OF THE GULF OF MAINE ENVIRONMENTAL MONITORING PROGRAM

Prepared for

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1.0 INTRODUCTION

This report summarizes the metals and organic contaminant data associated with the collection and analyses of blue mussel (*Mytilus edulis*) tissue from selected sites along the Gulf of Maine coast during the 2007 sampling season. Contaminant monitoring is conducted by the Gulfwatch Program for the Gulf of Maine Council on the Marine Environment (GOMC). A subset of these data is compared with analytical results from earlier Gulfwatch monitoring (2001-2006). Statistical analyses are limited to descriptive measures of replicates from selected sampling sites and include: arithmetic means and appropriate measures of variance. The primary purpose of this report is to present the current annual results, present graphical representation of spatial and temporal trends and identify potential outliers in order to provide investigators and other interested persons with contemporary information concerning water quality in the Gulf of Maine, as reflected by uptake into resident shellfish (mussels and clams).

1.1 PROGRAMMATIC RATIONALE

The Gulf of Maine is the region of the North Atlantic Ocean that extends from Cape Sable, Nova Scotia, through New Brunswick, Maine, and New Hampshire to Cape Cod, Massachusetts; and includes the Bay of Fundy and Georges Bank. The Gulf of Maine ecosystem is one of the world's most productive ecosystems with an extensive and diverse array of plants and animals (Census of Marine Life - Gulf of Maine Area, 2008) that support important economic activities including commercial catch and aquaculture fisheries, recreational fishing, shipping, and tourism. The Gulf of Maine ecosystem includes large watersheds draining from western Nova Scotia, southwestern New Brunswick, and the states of Maine, southern and eastern New Hampshire, and eastern Massachusetts. Several urban industrialized areas lie within those watersheds, including: Boston, Massachusetts; Portsmouth, New Hampshire; Portland and Bangor, Maine; and Saint John, New Brunswick.

Increases in industrial, commercial, and expanding residential development along the Gulf of Maine coast and the subsequent discharge of chemical contaminants have contributed to deterioration of water quality in some near shore areas (Dow and Braasch, 1996). Many of these contaminants have been shown to bioaccumulate and biomagnify throughout the food web, resulting in elevated concentrations in organisms, especially those at higher trophic levels (Chen et al., 2008; Shaw et al., 2006, 2005 and 2003; Mallory et al., 2005; Aguilar et al., 2002; Weisbrod et al., 2000). When critical body burdens are reached (exact concentrations differ with contaminant and organism) contaminants have been shown to adversely affect the growth, reproduction, and survival of marine organisms (Kawaguchi et al. 1999, Wells and Rolston 1991). Contaminant bioaccumulation serves therefore as an indicator of the status of ecosystem health with implications for human health, especially for those who derive the benefits of food, recreation, and other uses from the near shore marine environment (Dolan et al., 2005).

It is for this purpose that individual jurisdictions around the Gulf of Maine have implemented steps to control the discharge of chemical contaminants to the Gulf of Maine. The Gulfwatch monitoring program provides region-wide tracking of contaminant exposure (spatial status and time trends) for both urban and less populated areas within all five Gulf of Maine jurisdictions. Gulfwatch informs the GOMC member jurisdictions in the U.S. and Canada on the

status and trends of contaminant accumulation in mussels. The Gulfwatch monitoring program is thus responsive to the goals articulated by the Council that seek to balance environmental integrity and human uses in the Gulf of Maine. The GOMC (<http://www.gulfofmaine.org/>) was established by the *Agreement on the Conservation of the Marine Environment of the Gulf of Maine* which was signed in December 1989 by the premiers of Nova Scotia and New Brunswick and the governors of Maine, New Hampshire and Massachusetts. The GOMC's mission is to maintain and enhance the Gulf's marine ecosystem, its natural resources and environmental quality. To achieve the GOMC's mission statement, the Gulf of Maine Environmental Quality Monitoring Committee was formed and charged with the development of the Gulf of Maine Environmental Quality Monitoring Program. The program is based on the mission statement endorsed by the GOMC:

“Using mussel tissue monitoring of toxic chemical contaminants, the Gulfwatch Program will contribute to the provision of high quality and relevant data to allow for characterization of the condition of ecosystems in the GOM for enhancing marine resource management and protecting public health.”

The Gulfwatch program is charged with the assessment component of the GOMC's 2007-2012 Action Plan Goal 2 (of 3): *Environmental conditions in the Gulf of Maine support ecosystem and human health*. Two monitoring goals were established to help meet the goals of the current Action Plan and the mission of the Gulfwatch Program:

- (1) Conduct regional contaminant monitoring using the blue mussel (*Mytilus edulis*) as an indicator of exposure to organic and inorganic contaminants
- (2) Assess the status and trends of chemical contaminants in coastal habitats of the Gulf of Maine and Bay of Fundy.

The hypotheses that guide the Program are as follows:

- Concentrations of chemical contaminants in mussel tissues are the same at all sites in the Gulf of Maine;
- No changes in mussel tissue contaminant concentrations occur with time at each sampling site.

Gulfwatch uses the blue mussel, *Mytilus edulis*, as an indicator for habitat exposure to organic and inorganic contaminants. Bivalves, including blue mussel, have been successfully used as an indicator organism in environmental monitoring programs throughout the world (McIntosh et al., 2004; Glynn et al., 2004; Airas, 2003; Monirith et al., 2003; NAS, 1980; NOAA, 1991; Widdows et al., 1995, Widdows and Donkin, 1992; O'Connor and Lauenstein, 2006; O'Connor, 2002 and 1998). Blue mussels were selected because they are:

- (1) abundant within and across each of the five Gulf of Maine jurisdictions and are relatively easy to collect and process.
- (2) comparatively well studied and reported in the scientific and technical literature.
- (3) commercially harvested for food and may be used to evaluate human exposure to chemical contamination.
- (4) sedentary, thereby reducing sources of data variability associated with mobile species.

(5) suspension feeders that pump large volumes of water and concentrate many chemicals in their tissues both directly and indirectly from the water column. This increases the ability to measure chemical contaminants found at lower concentrations in other environmental matrices.

Contaminant accumulation in mussel tissue represents the biologically available proportion that is not always apparent from measurement of contaminants in other environmental matrices such as water, sediment, and suspended particles.

Gulfwatch also reports on shell size and the growth condition using the condition index (CI); the latter has a potential for use in normalizing the contaminant concentration data. CI is traditionally used as an indicator of the physiological status of mussels (Widdows, 1985). CI relates the tissue's wet weight to shell volume. The effect of gonadal weight on total body weight and CI values (i.e., high CI values can be due to ripe gonads present just prior to spawning), and implications to the interpretation of metal and organic contaminant tissue concentrations has been covered in other Gulfwatch reports (e.g., Gulfwatch, 2006 report, GOMC, 2009).

2.0 METHODS

2.1 SAMPLING DESIGN

The year 2007 is year two of the 12-year sampling design (2005-2016) developed by the Gulfwatch committee, which modified the original 9-year sampling strategy.

This design addresses the following two broad hypotheses:

1. No changes in mussel tissue contaminant concentrations occur with time at each sampling site.
2. Mussel tissue contaminant concentrations are the same at all sites.

The sampling design was modified from the tradition of four (4) replicate mussel tissue samples collected at all the sites, with the majority of sites having one sample, made from a composite from the four mussel site replicates. Two tiers of sampling were identified based on sampling intensity: once every two years (temporally intensive) and once every six years (spatial coverage). The sites are sampled on a rotating basis and repeated in each 6-year cycle resulting in three (3) "temporal" samples and one (1) "spatial" sample at the end of each 6-year cycle for designated sites. New Hampshire continued with sampling four site replicates for the temporally intensive sites sampled.

Sample Sites:

Sample sites were chosen after a review of all the sites sampled up to 2005. Opinions of environmental management and general scientific audiences from each jurisdiction were solicited, and new sites chosen, older sites retained or discarded based upon the following criteria:

- management interest or activity (sewage treatment, new industry, oil spill, dredging, locating aquaculture sites, etc.)
- a relatively pristine (reference) site in each jurisdiction,
- potential or suspect contamination of site,
- high population/industrial activity, or,
- other reasons articulated by the management and science communities why detecting a temporal trend or intensive scrutiny would be necessary.

2.2 2007 SAMPLING STATIONS

The 2007 Gulf of Maine Gulfwatch mussel survey followed the above mentioned survey plan by sampling all of the sites indicated, but also sampled other sites not slated for sampling in 2007 (Table 1). A total of 30 sites were visited during 2007. Additional sites included MAME, MAMH in Massachusetts, NHLH and NHPI in New Hampshire, MEBB, MESA and MEUR in Maine, NBSC in New Brunswick, and NSYR, NSAR and NSAG in Nova Scotia. Station NSBI (Brier Island), which was originally scheduled for sampling, was not sampled in 2007. Finally at a number of New Hampshire sites, other types of shellfish were sampled. Softshell clams (*Mya arenaria*) were sampled at Yankee Coop (NHYC), Middle Ground (NHMG) and Little Bay (NHLB), and oysters (*Crassostrea virginica*) were sampled at Nannie Island (NHNI). Locations of all sampling sites are presented, by state and province, in figures 1-5.

Table 1. Gulfwatch stations visited during the 2007 sampling year.

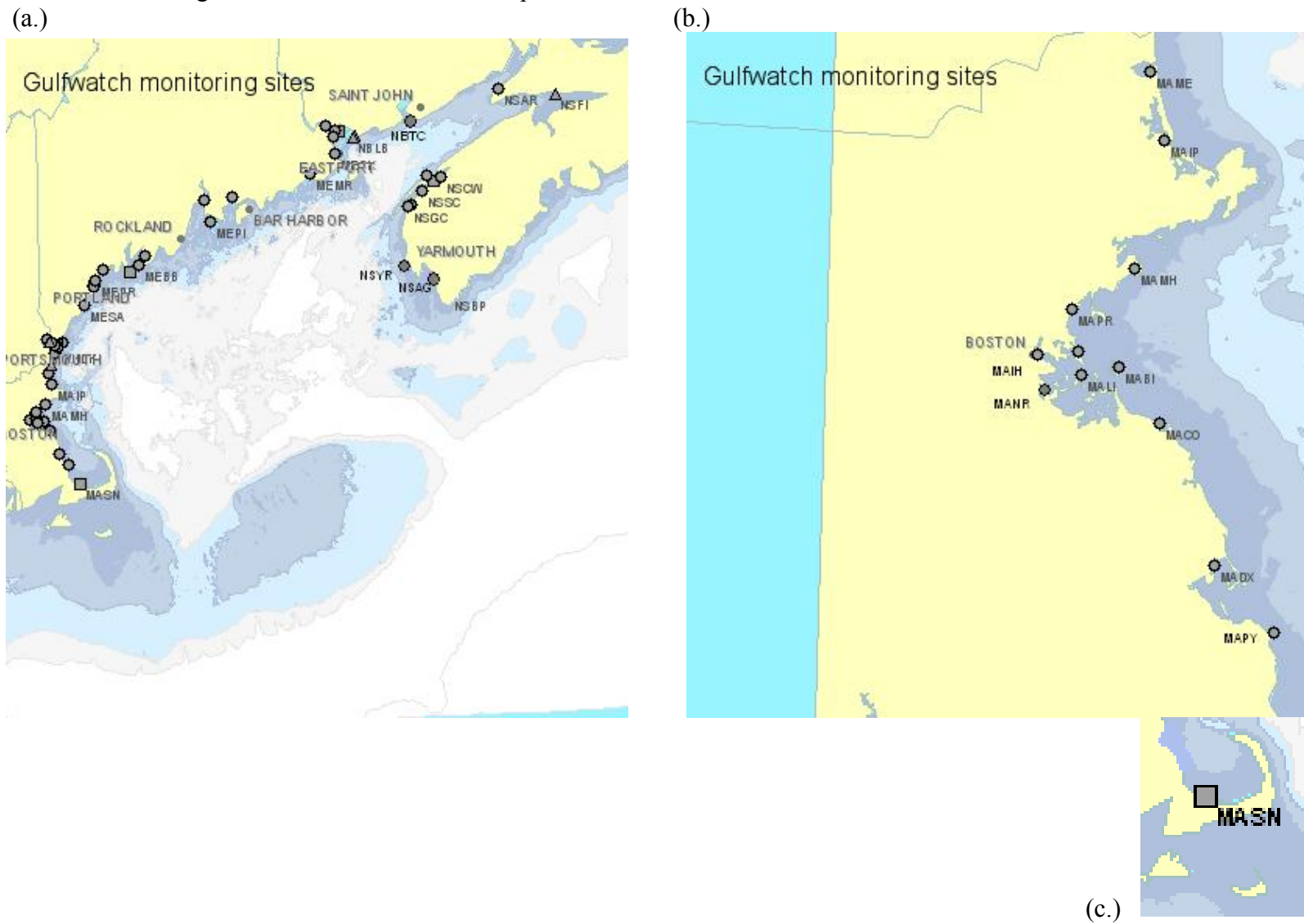
			Latitude	Longitude	Latitude	Longitude
Site Code	Site Name	Site type	decimal degrees		deg,min,sec	
Massachusetts						
MASN	Sandwich	Trend ¹ (Benchmark)	41.75000	70.40000	41° 45' 0"	70° 24' 0"
MAIH	Boston Inner Harbor	Rotational	42.35900	71.04900	42° 21' 32.4"	71° 2' 56.4"
MAMH	Marblehead	Rotational	42.49833	70.84833	42° 29' 53.988"	70° 50' 53.988"
MAME	Merrimack River	trend (multi-yr)	42.80833	70.82333	42° 48' 29.987"	70° 49' 23.987"
New Hampshire						
NHYC	Yankee Coop (clams)	Occasional	42.89000	70.81944	42° 53' 24"	70° 49' 9.984"
NHMG	Middle Ground (clams)	Expanded (GW)	42.89225	70.72255	42° 53' 32.099"	70° 43' 21.179"
NHHS	Hampton/Seabrook Harbor	trend (multi-yr)	42.89717	70.81633	42° 53' 49.812"	70° 48' 58.7874"
NHRH	Rye Harbor	Rotational	43.00000	70.74000	43° 0' 0"	70° 44' 23.9994"
NHLH	Little Harbor	Rotational	43.05810	70.7154	43° 3' 29.16"	70.7154
NHNI	Nannie Island (oysters)	Expanded (GW)	43.069775	70.86236	43° 4' 11.189"	70° 51' 44.495"
NHPI	Pierce Island	Rotational	43.07167	70.74333	43° 4' 18.0114"	70° 44' 35.988"
NHBC	Broad Cove	Occasional	43.11561	70.83622	43° 6' 56.1954"	70° 50' 10.3914"
NHBC	Broad Cove (clams)	Occasional	43.11561	70.83622	43° 6' 56.195"	70° 50' 10.391"
NHDP	Dover Point	trend (multi-yr)	43.1196	70.8267	43° 7' 10.5594"	70° 49' 36.12"
NHLB	Little Bay (clams)	Occasional	43.12171	70.83470	43° 7' 18.156"	70° 50' 4.9194"
Maine						
MECC	Clark's Cove	trend (Benchmark)	43.07740	70.72440	43° 4' 38.6394"	70° 43' 27.84"
MESA	Saco River	Rotational (6-yr)	43.45983	70.3743	43° 27' 35.387"	70° 22' 27.588"
MEPH	Portland Harbor	Trend	43.63917	70.25900	43° 38' 21.012"	70° 15' 32.4"
MEPR	Presumpscott River	Rotational	43.69217	70.24733	43° 41' 31.811"	70° 14' 50.388"
MEKN	Kennebec River	Trend (Benchmark)	43.78500	69.78450	43° 47' 5.999"	69° 47' 4.199"
MEBB	Boothbay Harbor	trend (multi-yr)	43.85067	69.67267	43° 51' 2.412"	69° 40' 21.6114"
MEUR	Union River	Rotational	44.5015	68.4322	44° 30' 5.4"	68° 25' 55.811"

Table 1 (cont'd)

			Latitude	Longitude	Latitude	Longitude
Site Code	Site Name	Site type	decimal degrees		deg,min,sec	
New Brunswick						
NBNR	Niger River (Niger reef)	Rotational	45.06633	67.06800	45° 3' 58.788"	67° 4' 4.7994"
NBSC	St. Croix River	trend (multi-yr)	45.1675	67.1638	45° 10' 2.9994"	67° 9' 49.6794"
NBTC	Tin Can Beach	trend (multi-yr)	45.2625	66.0570	45° 15' 45"	66° 3' 25.2"
Nova Scotia						
NSAR	Apple River	trend (multi-year)	45.47	64.835	45° 28' 11.9994"	64° 50' 5.9994"
NSDI	Digby	Trend (Benchmark)	44.6170	65.7523	44° 37' 1.1994"	65° 45' 8.28"
NSSC	Spechts Cove	Rotational	44.51533	65.9078	44° 30' 55.1874"	65° 54' 28.188"
NSYR	Yarmouth	trend (multi-yr)	43.81767	66.14483	43° 49' 3.6114"	66° 8' 41.3874"
NSAG	Argyle Sound	Rotational	43.699	65.81817	43° 41' 56.3994"	65° 49' 5.4114"

Trend sites are sites which, according to the 2005-20016 sampling plan are slated to be sampled every two years, and include sites formerly referred to as benchmark sites (as indicated) as well as other sites.

Figure 1. Locations of Gulfwatch sampling sites: (a.) Gulf of Maine (b.) Massachusetts. Tables 1 and A.2 in the appendix provide latitudinal and longitudinal coordinates for more precise site location.



(d.)



(e.)

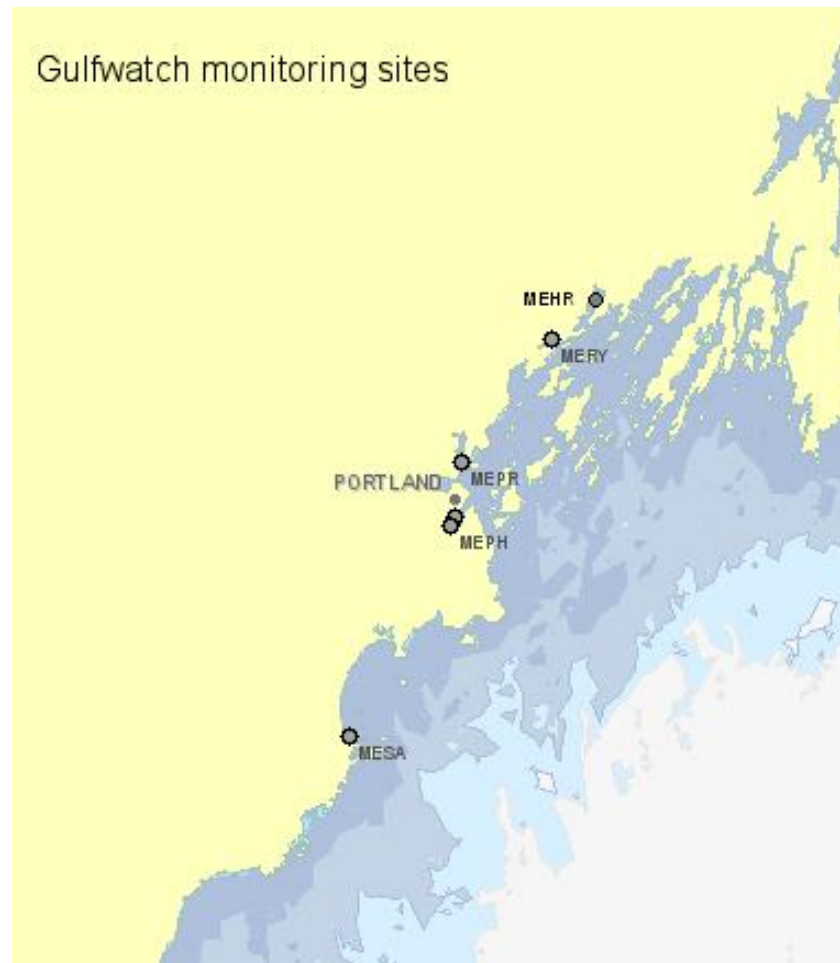
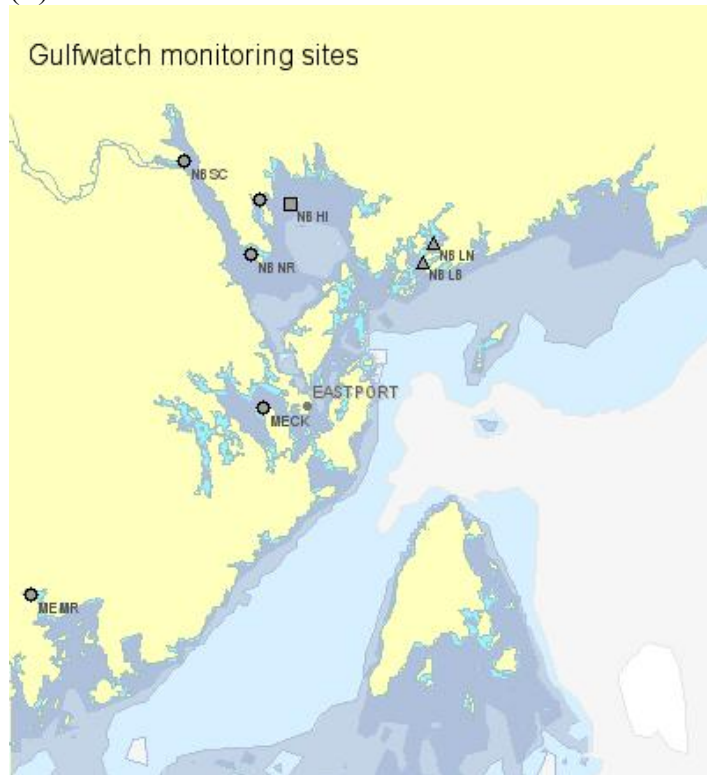
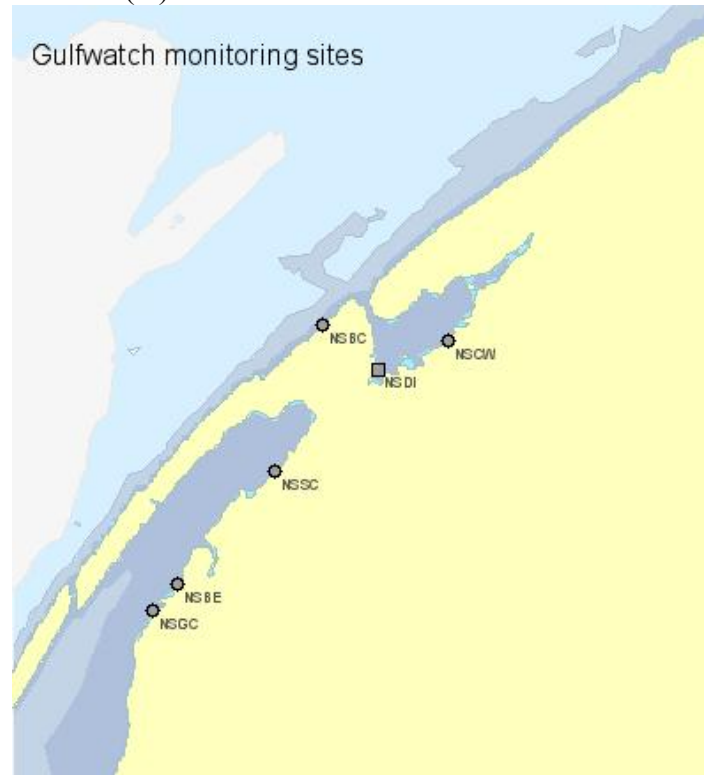


Figure 1 (cont'd). Locations of Gulfwatch sampling sites (d.) New Hampshire. (e.) Maine. Tables 1 and A.2 in the appendix provide latitudinal and longitudinal coordinates for more precise site location.

(f.)



(h.)



(g.)



(i.)



Figure 1 (cont'd). Locations of Gulfwatch sampling sites: (f.) sites in downeast Maine and New Brunswick (g.) closeup of station NBTC & sites in northeastern Nova Scotia (h.) southwest coast of Nova Scotia and (i.) on the southern tip of western Nova Scotia. Tables 1 and A.2 in the appendix provide latitudinal and longitudinal coordinates for more precise site location.

2.3 FIELD AND LABORATORY PROCEDURES

Details regarding the mussel collection, measurement, and sample preparation are published in Sowles et al. (1997) and are summarized briefly here. Field sampling occurred between October and November (Appendix A, Table A.1). In past years and in 2007 in New Hampshire sampling was conducted as follows: Mussels were collected from four discrete areas within a short stretch of shoreline to be representative of the mussel bed(s) at each site. Using a polycarbonate gauge or a ruler, four (4) replicates, each consisting of 45-50 mussels having shell lengths within the range of 50-60 mm, were placed in field containers and transported in coolers with ice packs to labs for processing. One half of those mussels predestined for organic analysis were wrapped in pre-combusted aluminum foil prior to placing in field containers. Mussels were not depurated prior to processing.

A somewhat different collection and processing procedure was used starting in 2007. For each site in Massachusetts, Maine, New Brunswick and Nova Scotia, three batches of 60 mussels were collected, each from a distinct area within the sampling site mussel bed. Each batch of 60 mussels was separated into 3 batches of 20, one for metals analysis, one for organics and one that was used to make up a composite sample for each site. Twenty mussels from each of the three distinct areas at each site were shucked for composite samples. Mussels were washed with deionized water in the laboratory while removing any loose external growth, sediment, and debris. If tissue sample processing was not logistically possible within 24 hours of sampling, excess seawater was drained from their mantles with either plexiglass or stainless steel spatulas and samples were frozen for later processing of metals or organics, respectively. Another 20 mussels from each of the three distinct samples were shucked for organics analysis. A composite sample composed of mussels from all three areas (20 total, 6 or 7 animals from each replicate) was processed for trace metal and another for organic chemical analyses. Mussel shell length was recorded for all mussels. Individual mussels were measured to the nearest 0.1mm for length (anterior umbo to posterior growing lip) and their soft tissue removed and combined in their respective organic or metals composite. In addition to shell length, shell height, width (mm), and soft tissue wet weight (to the nearest 0.01g) measurements were typically performed on three (3) subsets of ten mussels destined for the metal analysis composite for determining Condition index (CI). Also (wet weight-based) condition index (CI) measurements were conducted on each of 10 (out of the 20 total) individual mussels from two areas. This provided twenty total CI measurements per site.

The CI is calculated using the following formula (after Seed, 1968):

$$\text{Condition index (CI)} = \text{wet tissue weight (mg)} / [\text{length (mm)} * \text{width (mm)} * \text{height (mm)}]$$

All samples for trace metal and organic contaminant analyses were placed in pre-cleaned or quality-assured bottles (see Sowles et al., 1997). These composite samples (20 mussels/composite; 4 composites/station) were capped, labeled and stored at -15°C for 3-6 months prior to analysis. Gulfwatch sample identification numbers, field replicates, species, and dates collected are summarized in Appendix A.

2.4 ANALYTICAL PROCEDURES

Analytical procedures were the same as those reported in previous years (Sowles et al., 1997). An overview of the analytical methods used for the 2007 samples for both organic and inorganic analytes is described below. Table 2 contains a summary of trace metal and organic compounds determined from tissue samples of collected organisms.

2.4.1 Metals

Samples collected during 2007 for metals were analyzed by Battelle Marine Sciences Laboratory (MSL, Sequim, WA). The samples were analyzed for the ten metals chosen by the program: silver (Ag), aluminum (Al), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), mercury (Hg), nickel (Ni), and zinc (Zn).

Tissue samples were digested according to Battelle SOP MSL-I-024, *Mixed Acid Tissue Digestion*. An approximately 500-mg aliquot of each dried, homogeneous sample was combined with nitric and hydrochloric acids (aqua regia) in a Teflon vessel and heated in an oven at 130°C ($\pm 10^\circ\text{C}$) for a minimum of eight hours. After heating and cooling, deionized water was added to the acid-digested tissue to achieve analysis volume and the digestates were submitted for analysis by three methods.

Digested samples were analyzed for Hg by cold-vapor atomic absorption spectroscopy (CVAA) according to Battelle SOP MSL-I-016, *Total Mercury in Tissues and Sediments by Cold Vapor Atomic Absorption*, which is based on EPA Method 245.6, *Determination of Mercury in Tissue by Cold Vapor Atomic Absorption Spectrometry*. Digested samples were analyzed for Al, Cr, Cu, Fe, Ni, and Zn using inductively coupled plasma optical emissions spectroscopy (ICP-OES) according to Battelle SOP MSL-I-033, *Determination of Elements in Aqueous and Digestate Samples by ICPOES*. This procedure is based on two methods modified and adapted for analysis of low level samples: EPA Method 6010B and 200.7.

Digested samples were analyzed for Ag, Cd, and Pb using inductively coupled plasma-mass spectrometry (ICP-MS) according to Battelle SOP MSL-I-022, *Determination of Elements in Aqueous and Digestate Samples by ICP/MS*. This procedure is based on two methods modified and adapted for analysis of low-level solid sample digestates: EPA Method 1638, *Determination of Trace Elements in Ambient Waters by Inductively Coupled Plasma-Mass Spectrometry* and EPA Method 200.8, *Determination of Trace Elements in Water and Wastes by Inductively Coupled Plasma – Mass Spectrometry*. All results were determined and reported in units of $\mu\text{g/g}$ on a dry weight basis.

The MSL-1-022 reported method detection limits (MDLs, $\mu\text{g/g}$ dry weight) are as follows; Ag, 0.01; Cd, 0.01; Cr, 0.1; Cu, 0.1; Fe, 0.5; Hg, 0.005; Ni, 0.05; Pb, 0.02; Zn, 0.6; and Al, 1.3. A summary of method detection limits and reporting limits are further described in Appendix B. A copy of the MSL-1-022 QA/QC report is reprinted in Appendix C.

2.4.2 Organic Contaminants

Organic contaminants in mussel samples were analyzed at the Environment Canada Atlantic Laboratory for Environmental Testing - Environmental Science Centre in Moncton, New Brunswick. The analyte detection limits ranged from 4 -15 ng/g for polycyclic aromatic hydrocarbons (PAHs) and from 1-4 ng/g for polychlorinated biphenyl (PCB) congeners and chlorinated pesticides (Appendix B).

Twenty one of the twenty four PCB congeners identified and quantified correspond to congeners monitored by the U.S. National Oceanographic and Atmospheric Administration's (NOAA) National Status and Trends (NS&T) Program. Other organic compounds (i.e., PAH and organochlorine compounds) selected for analysis are also consistent, for the most part, with NOAA National Status and Trends mussel monitoring (NOAA, 1989). The summed quantities ΣPAH_{24} and ΣPAH_{40} (= total PAHs), the sum of 24 PAH compounds and 40 PAH compounds respectively, are consistent with what is reported by the National Status and Trends program, as is the sum of 21 chlorinated pesticide analytes (ΣPEST_{21}).

A description of the full analytical protocol and accompanying performance-based QA/QC procedures are found in Sowles et al. (1997), and Jones et al. (1998). Briefly, tissue samples were extracted by homogenization with polytron ultrasonic probes using dichloromethane (DCM) solvent and filter-dried over sodium sulfate salt to remove residual water. Biomatrix interference was removed through automated size exclusion gel permeation chromatography using S-X3 Bio-Beads (200-400 mesh) resin. Purified extracts were then subjected to silica gel liquid chromatography for a better clean-up of macro molecular biomatrix effects prior to the initial analysis.

After clean-up, samples were calibrated to final volume with internal standards added for polyaromatic hydrocarbon (PAH) analysis. A 100uL aliquot was extracted from this calibrated final volume and analyzed for PAHs by high-resolution gas chromatography/mass spectrometry (HRGC/MS) in Single Ion Monitoring mode (SIM) for best sensitivity. Quantifying and Qualifier ions for each compound of interest can be found in Table 3.0.

The remaining volume of the extract was then further fractionated using a larger silica gel bed for the liquid chromatographic separation of non-polar and polar compounds. This final step provided a relatively non-polar PCB/chlorinated pesticides fraction using a hexane mobile phase, and a more polar chlorinated pesticide fraction using a 1:1 hexane:DCM mobile phase. PCBs and pesticides analysis were then performed on two calibrated fractions using high-resolution dual column gas chromatography/electron capture detection (HRGC/ECD). Simultaneous analysis of each fraction on a different polarity thin liquid phase chromatographic columns allowed for quantification and confirmation of target compounds via external calibration.

Table 2. Inorganic and organic compounds analyzed in mussel tissues from the Gulf of Maine, 2007.

INORGANIC CONTAMINANTS			
Ag, Al, Cd, Cr, Cu, Fe, Hg, Ni, Pb, Zn			
ORGANIC CONTAMINANTS			
Aromatic Hydrocarbons		Chlorinated	PCB
		Pesticides	Congeners
Naphthalene ^{1,2}	Fluoranthene ^{1,2}	α -BHC	8;5 ^{3,4}
C1-Naphthalenes ²	Pyrene ^{1,2}	HCB	18;15 ^{3,4}
C2-Naphthalene ²	C1-FP	γ -HCH(Lindane)	29 ^{3,4}
C-3 Naphthalene ²	C2-FP	Heptachlor	50 ^{3,4}
C4-Naphthalene	Benzo(a)Anthracene ^{1,2}	Aldrin	28 ^{3,4}
Biphenyl ^{1,2}	Chrysene ^{1,2}	Heptachlor Epoxide	52 ^{3,4}
Acenaphthylene ^{1,2}	C1-Chrysene	γ -Chlordane	44 ^{3,4}
Acenaphthene ^{1,2}	C2-Chrysene	o,p'-DDE	66;95 ⁴
Fluorene ^{1,2}	C3-Chrysene	α -Endosulfan	101;90 ^{3,4}
C1- Fluorene	C4-Chrysene	cis-Chlordane	87 ^{3,4}
C2-Fluorene	Benzo(b)Fluoranthene ^{1,2}	trans-Nonachlor	77 ^{3,4}
C3- Fluorene	Benzo(k)Fluoranthene ^{1,2}	p,p' DDE	118 ^{3,4}
C4- Fluorene	Benzo(e)Pyrene ¹	Dieldrin	153;132 ^{3,4}
Dibenzothiophene ^{1,2}	Benzo(a)Pyrene ^{1,2}	o,p'-DDD	105 ^{3,4}
C1-Dibenzothiophene	Perylene ^{1,2}	Endrin	138 ^{3,4}
C2- Dibenzothiophene	Indeno(1,2,3-cd)Pyrene ^{1,2}	β -Endosulfan	126 ⁴
C3-Dibenzothiophene	Dibenz(a,h)Anthracene ^{1,2}	p,p'-DDD	187 ^{3,4}
Phenanthrene ^{1,2}	Benzo(ghi)Perylene ^{1,2}	o,p'-DDT	128 ^{3,4}
Anthracene ^{1,2}		p,p'-DDT	180 ^{3,4}
C1-Phenanthrene ²		Metoxychlor	169 ⁴
C2-Phenanthrene		Mirex	170;190 ^{3,4}
C3-Phenanthrene		DDTs	195;208 ^{3,4}
C4-Phenanthrene		2,4'-DDT, 4, 4'-DDT	206 ^{3,4}
		2,4' DDE; 4,4'-DDE	209 ^{3,4}
		2,4'-DDD; 4, 4'-DDD	
Summed parameters and diagnostic ratios			
¹ Σ PAH ₁₉ (= the sum of the unsubstituted, i.e., non-alkylated PAH compounds)			
² Σ PAH ₂₄ (= the sum of the 19 unsubstituted PAHs, and a few alkyl-substituted PAHs, as indicated. This quantity is the total PAH number of previous Gulfwatch reports).			
Total PAH (= the sum of all 40 PAH compounds listed in Table 2, = Σ PAH ₄₀)			
Flu+Pyr/ Σ (C2-C4-Phen) = The sum of (fluoranthene+pyrene)/(fluoranthene+pyrene+C2-C4 alkylphenanthrene).			
Σ PEST ₂₁ = sum of all chlorinated pesticide and DDTs			
³ Σ PCB ₂₁ = the sum of 21 congeners, calculated to be consistent with the sum of PCBs calculated by NOAA National Status and Trends. ⁴ Σ PCB ₂₄ = sum of 24 congeners. Numbers represent IUPAC designation of individual PCB congeners. Double numbers represent co-elution or congeners that are quantified together as one peak on the GC.			

Table 3. List of target ions and quantification ions for GC/MS analysis of mussel tissue extracts for unsubstituted and alkyl-substituted polyaromatic hydrocarbons.

Compound¹	Target Ions²	Qions³
Naphthalene	128	127
C1-Naph	142	141
C2-Naph	156	141
C3-Naph	170	155
C4-Naph	184	169
Biphenyl	154	153
Acenaphthalene	152	151
Acenaphthene	153	154
Dibenzothiophene	184	185
C1-Dibenz	198	197
C2-Dibenz	212	197
C3-Dibenz	226	197
Fluorene	166	165
C1-Fluor	180	165
C2-Fluor	194	165
C3-Fluor	208	165
C4-Fluor	222	165
Anthracene	178	176
Phenanthrene	178	176
C1-Phen	192	191
C2-Phen	206	191
C3-Phen	220	205
C4-Phen	234	219
Fluoranthene/Pyrene	202	200
C1-FP	216	217
C2-FP	230	215
Pyrene	202	200
Benzo(a) Anthracene	228	226
Chrysene	228	226
C1-Chry	242	241
C2-Chry	256	241
C3-Chry	270	241
C4-Chry	284	241
benzo(b) Fluoranthene	252	250
benzo(k) Fluoranthene	252	250
benzo(e)Pyrene	252	250
benzo(a)Pyrene	252	250
Perylene	252	250
Indeno(1,2,3-cd)Pyrene	276	277
Dibenzo(a,h) Anthracene	278	276

¹Analytes in bold are summed to yield the quantity ΣPAH_{24} , ²Target ions are used in GC/MS analysis for compound identification, ³Q ions = quant ions are used for quantification in GC/MS analyses.

2.4.3 Ancillary parameters

Ancillary measurements and determinations from each site included as part of the annual Gulfwatch mussel monitoring are:

- individual shell length,;
- Tissue wet weight and shell width and height on a subset (~30) of individual mussels for condition index calculations;
- moisture content of tissue composites; and
- percent lipid content of tissue composites.

Moisture content was determined gravimetrically at the Battelle lab for each replicate composite either by freeze- or oven-drying. A tissue sub-sample (~5-20 g) was placed in a drying oven (at 105°C) for a minimum of 8 hrs, then placed in a dessicator, allowed to reach room temperature, and weighed until constant weight is achieved. For freeze-drying, the sub-sample is frozen to -68°C for two - four days and periodically weighed until a constant weight is observed. Percent moisture is determined from the ratio of tissue dry weight to tissue wet weight.

Lipid content of tissue samples was also determined gravimetrically. A sub-sample (~15 g) of each tissue sample was extracted with three portions of dichloromethane. The combined solvent extract was then reduced to a measured volume of 6 mL from which 1 mL was quantitatively removed and placed in a tared aluminum dish. The dish was then placed in a clean environment for solvent evaporation and dried to a constant weight. This residue represents one sixth (1/6) of the total extractable organics (TEO) in the original sample.

TEO was calculated as follows:

$$\%TEO = \frac{6 * WtR}{WtDry} * 100$$

Where WtR = the weight in grams of the residue and
Wt Dry = the dry weight of the original sample, calculated using the percent moisture. The lipid residue number is multiplied by 6 to correct for the 1/6th aliquot taken for the measurement.

Lipid-normalized concentrations of organic compounds can be used to interpret tissue concentration comparisons between sites or over time, since organic contaminants tend to partition into organism lipids. Normalizing to lipid weight can help minimize variability in chemical concentrations caused by differences in lipid content due to reproductive stage and other factors. Here we report these observations as percent lipids (or TEO).

2.5 QUALITY ASSURANCES / QUALITY CONTROL

Standard operating procedures for the analysis of mussel samples and related laboratory quality control performance criteria are described in *Gulfwatch Project Standard Procedures: Field and Laboratory* (Sowles et al., 1997). Quality assurance (QA) provisions described in the manual serve as a guide for generating acceptable analytical data by the Gulfwatch program. The quality control (QC) results, when compared to Gulfwatch data quality objectives, also present data users with measures of accuracy and precision when comparing among annual Gulfwatch monitoring results as well as a comparative measure for other environmental contaminant monitoring programs.

Appendix C contains the trace metal contaminant QC sample results and a brief QA/QC summary for the 2007 Gulfwatch samples, and Appendix D contains the organic contaminant QC sample results and summary for the 2007 Gulfwatch samples. Laboratory QC measures reported in Appendices C and D include procedural blanks, duplicate sample analyses, contaminant surrogate sample spikes, sample matrix spikes, and the analysis of certified reference material. The analytical organic laboratory performance of the 2007 National Institute of Standards and Technology organic contaminants inter-calibration exercise is available upon request.

2.6 DATA PRESENTATION

Summed parameters were calculated from the sum of all individual analytes that had values greater than compound detection limits. Summed parameters included ΣPAH_{19} , which is the sum of the unsubstituted (non-alkylated) aromatic ring compounds, ΣPAH_{24} , which is the total PAH quantity that has traditionally been used for the Gulfwatch program prior to 2007, and includes a few alkyl-substituted PAHs (such as methyl and ethyl-naphthalenes and methyl phenanthrenes) in addition to the unsubstituted (aromatic ring) PAH analytes. Starting in 2007, more alkyl-substituted PAH compounds have been included in the analysis, and so a new total PAH number (ΣPAH_{40}) has also been calculated. Inclusion of this larger PAH sum makes Gulfwatch data consistent with National Status and Trend reporting. Data for both ΣPAH_{24} and ΣPAH_{40} quantities for 2007 have been obtained from the NOAA National Status and Trends program. One important difference in the quantitation of PAHs in 2007 versus prior years, is that formerly, only two C1-naphthalene compounds (1-methylnaphthalene and 2-methylnaphthalene), one C2-naphthalene compound (2,6-dimethylnaphthalene) and one C3-naphthalene compound was quantified, whereas starting in 2007, the sum of all C1-naphthalenes, C2-naphthalenes and C3-naphthalenes were quantified. Likewise, formerly only one C1-phenanthrene analyte was quantified, while beginning in 2007, the sum of all detected methylphenanthrenes was quantified. This may result in slight differences in the summed parameter ΣPAH_{24} .

Other summed parameters include ΣDDT_6 , the sum of DDT and metabolites, ΣPEST_{21} , the sum of all the chlorinated pesticide analytes, and ΣPCB_{24} , the sum of the PCB congeners (congeners which co-elute on the GC column are summed together as one peak) quantified in the analysis. Since differences exist between the ΣPCB_{24} parameter calculated in Gulfwatch and the ΣPCB_{21} quantity provided by NS&T (PCB congeners 66, 126 and 169 are not quantified in the NS&T Program). To make a better comparison, these three congeners are eliminated from the Gulfwatch summed PCB values, and the quantity is called ΣPCB_{21} . Other differences which may exist between the two programs, due to differing co-elutions of congeners on different analytical columns, are expected to be very small. All of the target analytes are summarized in Table 2.

Inorganic and organic analytes in which all replicate measurements were below the detection limit were treated as zero and recorded as not detected (ND). However, if at least two of the replicates were greater than the detection limit, then the other replicates were treated as having a value equal to ½ the method detection limit (MDL) for simple statistical computations. From each site, arithmetic means, standard deviations (SD), and geometric means were calculated for all metal and organic contaminants. Analytical duplicates were not used in the computation of the above statistical parameters. Results of duplicate analyses are presented in the QA/QC section of the appendix. Graphs of arithmetic mean concentrations (\pm standard deviation) are presented for all stations and are compared with medians and 85th percentiles of data from the 2007 National Status and Trends Mussel Watch Program. These data are presented in tabular format as well in the next section. The medians and 85th percentiles for the Gulf of Maine have been calculated to allow comparison of Gulfwatch results with the National Musselwatch National Status and Trends (NS&T) program. The 85th percentiles are taken to represent “high” concentrations (O’Connor and Beliaeff, 1995; Cantillo, 1998; Lauenstein et al., 2002). ***In the Gulfwatch program, a target analyte is considered “elevated” and of concern if the concentration is equal to or greater than the NS&T national 85th percentile.***

For interpretive purposes, Clark Cove, Maine (MECC) serves as the trend (benchmark) site for the group of New Hampshire sites because of its location in the Great Bay / Piscataqua River watershed and, therefore, is more comparable to sites in New Hampshire. Gulfwatch mean data for the stations sampled in 2007 are summarized beginning from 2001 in graphic form, along with all annual data for the trend sites, in order to help evaluate potential temporal trends and spatial extent of contaminant exposure along the rim of the Gulf of Maine.

3.0 RESULTS AND DISCUSSION

3.1 2007 FIELD OPERATIONS AND LOGISTICS SUMMARY

Mussel samples were collected at 25 sites in 2007. Most of the stations slated for sampling in 2007 according to the Gulfwatch 12 year sampling design were sampled in 2007, with the exception of Brier Island (NSBI) in Nova Scotia. Twelve trend sites were sampled: Sandwich (MASN) and Merrimack River (MAME) in Massachusetts, Hampton/Seabrook Harbor (NHHS) and Dover Point (NHDP) from New Hampshire, Clark’s Cove (MECC), Portland Harbor (MEPH) and Boothbay Harbor (MEBB) in Maine, Tin Can Beach (NBTC) in New Brunswick, and Apple River (NSAR) and Yarmouth (NSYR) in Nova Scotia. All other sites were for spatial analysis, usually sampled on a regular (3 yr) or more occasional basis (Table 1). Samples of softshell clams (*Mya arenaria*) were collected at Yankee Coop (NHYC), Broad Cove (NHBC) and Little Bay (NHLB) in New Hampshire and samples of eastern oyster (*Crassostrea virginica*) were collected from Nannie Island (NHNI) in New Hampshire.

All 2007 tissue composites were frozen and delivered to the University of New Hampshire prior to shipping to the analytical laboratories. (Note, the Canadian samples destined for organic analyses were delivered directly to Environmental Canada in Moncton, since the 2007 organic analyses were performed there). Appropriate field and initial sample preparation information from each jurisdiction were forwarded to the Program Coordinators shortly after sample collection and composite preparations.

3.2 TRACE METAL CONCENTRATIONS

Table 4 contains the metal concentrations for site replicates (arithmetic means \pm SD, $\mu\text{g/g}$ dry weight) and site composite samples for mussels taken in 2007. Summary statistics were generated using the field replicate values. In only three cases (MECC, NHHS and NHDP) were field replicates taken. The mean and standard deviation of the three site replicates from these sites are compared with a fourth value which is a site composite in Table 4. At all other sites, replicates were composited as previously described to form one site composite (labeled in Table 4 as “site name-comp”). Metal analytes were detected in all samples. Metal concentrations in mussel tissue of each individual composite sample (field replicates) are further detailed in Appendix E.

In addition, metal concentrations for all mussels are also reported as medians and the 85th percentile (85th P) in Table 5 to allow for a program-level comparison with NOAA NS&T concentrations. Tables 4 and 5 provide the median and the 85th percentile data of the national Mussel Watch data for 2007. Most of the summarized Gulfwatch metals concentrations were lower than the NS&T median and 85th percentile summary data, with the exception of mercury and Pb, where several sites had higher concentrations than the 85th percentile value, indicated in red in Table 4. This has also been noted in previous data reports. Comparison of metal concentrations with NS&T median values shows that several sites had concentrations at or higher than median values for Hg, Pb, Al, Cr, and Fe (indicated in bold, Table 4). The range of concentrations over all sites are also presented in Table 5, and show concentrations of certain elements, such as Pb, Al, Cr, Cu, Fe, Ni and Zn can vary by a factor of 100 across sites sampled in 2007.

Table 4. Summary data of tissue metal concentrations ($\mu\text{g g}^{-1}$ dry wt) in mussels from Gulfwatch 2007 stations. Those sites with site replicates have calculated means and standard deviations, while site composites have only a single value. Values in red are higher than the 85th percentile values for national status and trends, those in bold are higher than median values. Stations in red have at least one analyte higher than the NOAA S&T 85th percentile value.

Station code		Ag	Cd	Cr	Cu	Fe	Ni	Pb	Zn	Al	Hg
NS&T median¹		0.248	2.43	0.872	17.5	368	2.1	0.887	153	167	0.097
NS&T 85th P¹		2.42	4.59	2.68	162	1114	7.15	2.49	2789	534	0.237
MAIH-comp²		0.0240	1.26	1.38	10.2	374	1.30	9.06	150	194	0.137
MAME-comp		0.079	1.64	1.55	8.76	364	1.34	2.37	90.1	201	0.151
MAMH-comp		0.030	0.759	2.34	8.70	202	1.23	6.26	75.0	108	0.172
MASN-comp		0.146	0.974	0.610	6.87	173	0.978	1.68	83.8	108	0.093
NHBC³ 1N-3N	Mean	0.046	1.64	2.21	7.58	530	1.26	1.62	94.5	371	0.273
	Stdev	0.013	0.13	0.06	1.64	17	0.06	0.17	4.09	75	0.013
NHDP 1N-3N	Mean	0.040	2.21	1.84	7.36	323	1.33	2.44	122	231	0.27
	Stdev	0.004	0.17	0.22	0.68	74	0.13	0.75	26.7	89	0.01
NHHS-comp		0.041	2.01	1.19	7.59	333	1.03	1.38	112	232	0.136
NHHS 1N-3N	Mean	0.038	1.96	1.20	7.36	310	0.98	1.60	123	244	0.13
	Stdev	0.005	0.16	0.04	0.15	57	0.08	0.11	8.35	43	0.01
NHLH-comp		0.047	2.12	1.50	7.43	350	1.30	2.54	126	164	0.281
NHPI-comp		0.039	1.97	2.43	8.25	538	1.31	2.96	121	297	0.302
NHRH-comp		0.020	1.56	1.68	7.75	466	1.59	1.95	126	300	0.256
MEBB-comp		0.012	0.916	0.905	9.29	254	0.592	8.08	119	144	0.205
MECC-comp		0.027	1.79	1.79	8.29	449	1.22	2.94	113	269	0.223
MECC 1N-3N	Mean	0.030	1.90	2.17	9.05	519	1.41	3.09	108	317	0.257
	Stdev	0.003	0.15	0.28	0.62	64	0.19	0.43	4.17	38	0.031
MEKN-comp		0.062	2.39	1.25	5.37	303	0.830	1.40	78.9	127	0.174
MEPH-comp		0.019	1.39	1.17	7.61	444	0.948	4.34	146	250	0.202
MEPR-comp		0.064	1.20	1.38	8.30	524	1.11	2.92	93.5	417	0.212
MESA-comp		0.049	1.81	1.25	5.91	267	0.767	1.18	66.4	142	0.112
MEUR-comp		0.034	1.62	0.927	5.15	384	0.913	1.18	64.6	142	0.110
NBNR-comp		0.033	1.20	0.933	5.37	410	0.845	0.830	79.8	411	0.092
NBSC-comp		0.027	1.71	1.69	5.94	704	1.46	1.44	85.6	544	0.168
NBTC-comp		0.019	2.46	3.34	8.03	1430	2.91	2.40	81.7	1541	0.332
NSAG-1N		0.016	1.21	1.20	6.46	428	1.21	2.65	74.3	291	0.132
NSAR-comp		0.038	2.97	2.08	6.66	872	2.27	1.42	86.2	979	0.207
NSDI-comp		0.046	1.28	1.18	6.47	353	0.964	1.63	64.6	322	0.0875
NSSC-comp		0.054	1.38	1.00	5.76	374	1.26	1.10	61.1	193	0.102
NSYR-comp		0.073	1.21	1.31	6.64	441	1.21	1.86	95.9	325	0.152

¹Data obtained from the NOAA National Status and Trends office, upon written request. ²comp refers to a site composite. Three areas within a site were sampled for mussels and composited, as described in section 2.3. ³For site NHBC, the mean and standard deviation are calculated from only two site composites.

Table 5. Gulf of Maine median and 85th percentile values, compared with 2007 National Status and trends data.

	Ag	Cd	Cr	Cu	Fe	Ni	Pb	Zn	Al	Hg
	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)
Gulfwatch 2007										
range	0.005-0.073	0.13-2.97	0.04-3.34	0.15-10.2	17-1430	0.06-1430	0.11-9.06	4.09-150	38-1541	0.01-0.33
median	0.037	1.75	1.50	7.43	384	1.22	1.95	97.4	269	0.202
85th P	0.055	2.14	2.24	8.76	542	1.46	3.29	126	406	0.280
2007 NS&T Musselwatch										
median	0.248	2.43	0.872	17.5	368	2.1	0.887	153	167	0.097
85th P	2.42	4.59	2.68	162	1114	7.15	2.49	2789	534	0.237

3.3 ORGANIC CONTAMINANTS CONCENTRATIONS

The total concentration of detectable polynuclear aromatic hydrocarbons (ΣPAH_{40}), along with other summations of PAH analytes (ΣPAH_{19} and ΣPAH_{24}) described in section 2.6, polychlorinated biphenyls (ΣPCB_{24}), and organochlorine pesticides (ΣPEST_{21}) measured in mussel tissue samples collected during 2007 are presented in Table 6. Individual analyte concentrations of each compound class for field replicates and composite samples are reported by station and given in Appendix F.

Pyrogenic (combustion-derived) PAH have high relative concentrations of unsubstituted PAH species relative to alkyl-substituted PAH species, while petrogenic (petroleum-derived) PAH are dominated by alkyl-substituted PAH (NRC, 1985). These characteristics can be used to differentiate between petrogenic and pyrogenic PAH sources in environmental samples. The concentration ratio: (fluoranthene + pyrene)/[(fluoranthene + pyrene) + (C2+C3+C4 phenanthrenes)], expressed as - FP:(FP+C24P), is a useful pyrogenic indicator for sediments and tissues (Burns et al., 1997; Neff et al., 2005) whose value varies from 0.00 (petrogenic) to 1.00 (pyrogenic). Samples with FP:(FP+C24P) ratios greater than ~0.2 are interpreted to have a pyrogenic PAH component. Petroleum-sourced PAHs generally have values <0.1 (Neff et al., 2005). Table 6 contains mean values of this ratio for site replicate samples, and individual values for site composites.

Table 6. Summary data of summed organic contaminant concentrations in tissues from Gulfwatch 2007 stations. Those sites with site replicates have calculated means and standard deviations, while site composites only have a single value. Values in red are higher than the NS&T 85th percentile, those in bold are higher than the NS&T median. Stations in red have at least one value higher than the NS&T 85th percentile value.

		ΣPAH_{19}	ΣPAH_{24}	ΣPAH_{40}	$\Sigma\text{FP/}$	ΣPCB_{21}	ΣPEST_{21}
		(ng/g)	(ng/g)	(ng/g)	$\Sigma\text{FPC}_{24\text{P}}$	(ng/g)	(ng/g)
NS&T median		118	167.3	249		21.6	20.8
NS&T 85th P		916	746	1326		146	76
MASN-comp ²		41.1	74.4	85.4	0.60	30.1	19.7
MAIH-comp		1563	1693	2268	0.75	387	44.3
MAME-comp		314	381	512	0.67	89	25.7
MAMH-comp		197	309	595	0.27	98	93.3
NHRH-comp		87.2	108	142	0.61	6.39	4.59
NHLH-comp		92.8	106	143	0.64	9.77	3.50
NHPI-comp		289	337	429	0.71	31.0	4.85
NHDP 1N-3N	mean	375	482	1101	0.45	29.9	12.0
	stdev	85.0	138	886	0.27	6.5	3.0
NHDP-comp		330	402	547	0.70	33.8	9.81
NHHS 1N-3N	mean	62	105	131	0.76	5.52	5.85
	stdev	13.4	24.0	19.9	0.21	0.73	1.54
NHHS-comp		84.5	129	156	0.65	6.3	7.7
NHBC 1N-2N ³	mean	288	341	470	0.68	39.7	15.7
	stdev	18.8	24.1	26.3	0.00	10.5	4.9
MECC 1N-3N	mean	210	265	352	0.63	31.2	4.17
	stdev	24.4	28.0	41.9	0.05	2.2	0.09
MECC-comp		192	241	339	0.59	31.8	4.2
MEPR-comp		242	308	433	0.66	27.8	18.4
MEPH-comp		691	778	1060	0.73	78.2	22.6
MEKN-comp		44.0	71.1	90.8	0.61	14.1	5.0
MESA-comp		43.0	51.8	72.6	0.72	17.5	2.8
MEBB-comp		909	1029	1580	0.60	45.0	37.9
MEUR-comp		47.3	75.1	94.6	0.57	0.0	1.8
NBTC-comp		229	309	389	0.62	18.3	14.1
NBNR-comp		34.3	60.8	66.5	0.58	4.7	3.4
NBSC-comp		58.4	91.6	91.6	1.00	0.0	2.9
NSDI-comp		48.3	60.5	79.5	0.49	0.0	1.5
NSSC-comp		30.5	30.5	59.9	0.15	0.0	3.7
NSYR-comp		108	130	177	0.70	0.0	2.1
NSAR-comp		26.4	26.4	26.4	0.00	0.0	0.0
NSAG-comp		37.9	66.6	54.2	0.46	0.0	0.0

¹Data obtained from the NOAA National Status and Trends office, upon written request. ²comp refers to a site composite. Four areas within a site were sampled for mussels and composited, as described in section 2.3. ³For site NHBC, the mean and standard deviation are calculated from only two site composites.

Overall gulf-wide medians and the 85th percentile of the organic contaminant concentrations for indigenous mussels are also presented to allow for program-level comparisons with NOAA NS&T concentrations (Table 7). The 2007 Gulfwatch concentrations (single composite values or arithmetic means) for summed organic contaminants (PAH, PCB, and chlorinated pesticides) were compared with 2007 NS&T median values and 85th percentile (Table 6). Two sites in Massachusetts, exceeded 85th percentile NS&T values. Boston Inner Harbor (MAIH) exceeded the 85th percentile value for the sum of PAHs (ΣPAH_{19} , ΣPAH_{24} and ΣPAH_{40}) and Marblehead (MAMH) exceeded the 85th percentile value for the sum of pesticides. In Maine, Portland Harbor exceeded the 85th percentile value for the sum of 21 PAHs, and Boothbay Harbor (MEBB) exceeded 85th percentile values for PAHs (ΣPAH_{21} and ΣPAH_{40}) and pesticides.

Mussel tissue PAH levels at the Boston Harbor site in Massachusetts and at the Boothbay Harbor site in ME (MEBB) were ten and six times the NS&T national median respectively and were the highest observed among 2007 samples. PCB levels at the Boston Inner Harbor site (MAIH) exceeded the NS&T national median and were the highest observed among 2007 samples.

Table 7. Comparison of median and 85 percentile values of tissue concentrations of summed organic analytes from Gulfwatch 2007 sites and National Status and Trends 2007 sites

Parameter	ΣPAH_{19} (ng/g)	ΣPAH_{24} (ng/g)	ΣPAH_{40} (ng/g)	ΣPCB_{24} (ng/g)	ΣPEST_{21} (ng/g)
Gulfwatch 2007					
median	186	240	315	22.3	5.0
85th percentile	326	397	583	45	20
National Status and Trends 2007					
Median	118	167.3	249	21.6	20.8
85th percentile	916	746	1326	146	76

Median values for summed PAHs in the Gulf of Maine exceed the National Status and Trends median values, but did not exceed 85th percentile values. Median PCB values were comparable and slightly higher than the 2007 Status and Trend national median. Gulfwatch 85th percentile values were lower than the corresponding Status and Trends 85th percentile values for all summed organic parameters.

3.4 Contaminant Concentrations In Other Shellfish

As part of the New Hampshire Gulfwatch 2007 program, and in cooperation with the regional Gulfwatch 2007 Program, softshell clams (*Mya arenaria*) were sampled at the following sites: Yankee Coop (NHYC), Middle Ground (NHMG), Broad Cove (NHBC) and Little Bay (NHLB). In addition, oysters (*Crassostrea virginica*) were sampled from Nannie Island (NHNI). Average and standard deviations concentrations from site replicates (two per site) are presented in Table 8 for metals and Table 9 for summed organic parameters.

Table 8. Averages and standard deviations for metals concentrations in site replicate samples taken at New Hampshire sites and analyzed for the 2007 Gulfwatch Monitoring Program.

		Ag	Cd	Cr	Cu	Fe	Ni	Pb	Zn	Al	Hg
GOM Site		(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)
NHLB	Avg ¹	1.49	0.36	4.89	17.23	5233	1.86	6.78	82.0	1977	0.23
(clams)	Stdev ²	0.82	0.01	0.77	1.63	1883	0.31	2.27	1.19	362	0.04
NHYC	Avg	0.32	0.68	3.44	19.01	1946	1.61	3.90	86.2	1360	0.14
(clams)	Stdev	0.050	0.01	0.28	1.47	23	0.06	0.58	3.47	36	0.02
NHBC	Avg	0.52	1.09	4.25	12.57	3576	2.54	3.43	93.0	1326	0.26
(clams)	Stdev	0.59	0.64	2.44	5.85	3589	1.74	2.12	3.00	1111	0.02
NHMG	Avg	0.57	0.53	2.38	19.15	1934	1.50	2.61	84.5	1054	0.10
(clams)	Stdev	0.31	0.04	0.03	3.87	801	0.06	0.43	0.88	46	0.01
NHNI	Avg	7.40	3.35	1.07	177	374	2.39	0.69	6888	308	0.26
(oysters)	Stdev	0.37	0.16	0.48	2.48	197	0.10	0.26	240	200	0.02

¹Avg = average of the concentration of 2 site replicates. ²Stdev = standard deviation of the concentration of 2 site replicates.

Table 9. Averages and standard deviations for summed PAH, PCB and chlorinated pesticide concentrations in site replicate samples taken at New Hampshire sites and analyzed for the 2007 Gulfwatch Monitoring Program.

GOM site		ΣPAH ₁₉	ΣPAH ₂₄	ΣPAH ₄₀	FP/FPC24P	ΣPCB24	ΣPEST21
		(ng/g)	(ng/g)	(ng/g)	(ng/g)	(ng/g)	(ng/g)
NHBC (clams)	Avg ¹	255	295	375	1	0	0
	std dev	16.1	14.5	8.4	0.0	0.0	0.0
NHMG (clams)	Avg	40	0.3	0.3	0.0	0.0	0.0
	Std ² dev	7.1	291	333	1	0	0
NHLB (clams)	Avg	262	7.2	10.9	0.0	0.0	0.0
	std dev	6.3	79.7	101.9	0.6	0.0	1.1
NHYC 1N (clams)	Avg	14.5	7.0	18.0	0.0	0.0	1.5
	std dev	1.5	2.8	0.2	0.0	3.4	0.6
NHNI (oysters)	Avg	131	152	207	1	52	23
	std dev	1.5	53.9	68.1	0.6	0.0	0.0

¹Avg = average of the concentration of 2 site replicates. ²Stdev = standard deviation of the concentration of 2 site replicates.

4.0 2007 DISTRIBUTIONS OF CONTAMINANTS IN *MYTILUS EDULIS*

4.1 SPATIAL PATTERNS

Figures 2 through 11 show the concentration of the metals determined in the tissue of *M. edulis* from the 2007 Gulfwatch sampling sites. The data are displayed geographically beginning clockwise around the GOM from Sandwich, Massachusetts, and ending with the southern-most station in Nova Scotia (See Fig. 1 above). Overall, the concentrations of most metals appear relatively evenly distributed around the Gulf of Maine, with no apparent spatial trends and an occasional hot spot of elevated concentrations. Exceptions to this general pattern and further details for individual metals and organic contaminant categories are noted in the following individual sections.

4.1.1 Silver (Ag)

Silver concentrations ranged from 0.012 $\mu\text{g/g}$ dry weight at the Boothbay Harbor, ME site (MEBB) to 0.146 $\mu\text{g/g}$ dry weight at the Sandwich, MA site (MASN) (Table 4; Figure 2). The 2007 levels were below the NOAA NS&T 1995 median and 85th percentile (Figure 2, dashed and solid lines, respectively). Higher silver concentrations in sediments and water column samples have been shown to coincide with regions receiving municipal sewage (Sanudo-Wilhelmy and Flegal, 1992; Buchholz ten Brink et al., 1997).

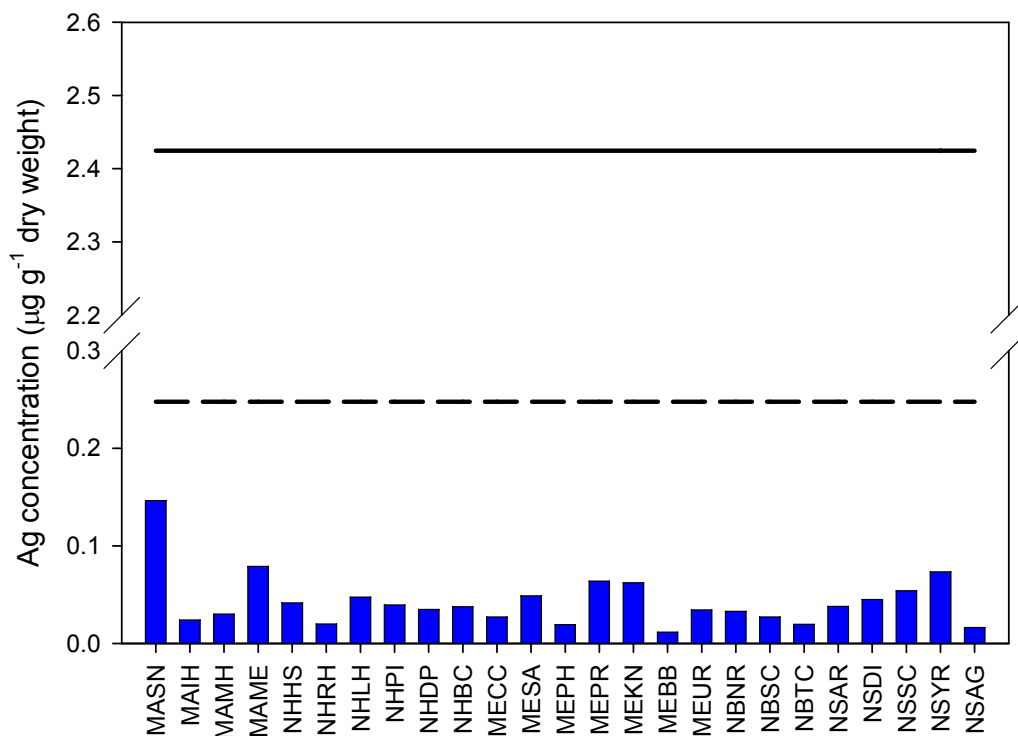


Figure 2. Distribution of silver tissue concentrations in mussel sample site composites (one per site) at Gulfwatch sites in 2007. Dashed line = 2007 Mussel Watch National median; Solid line = 2007 Mussel Watch 85th percentile.

4.1.2 Cadmium (Cd)

The concentration of cadmium in mussel tissue ranged from 0.76 $\mu\text{g/g}$ dry weight at Marblehead, MA (MAMH) to 2.97 $\mu\text{g/g}$ dry weight at the Apple River, NS site (NSAR, Table 4; Figure 3) and were generally comparable to the 2007 NS&T median. Differences were seen between stations which could reflect localized sources. Globally, about half of the Cd released to the environment occurs through weathering of rocks and subsequent transport by rivers; some Cd is released into air through forest fires and volcanoes. This would be expected to provide an even distribution across stations if these were the only sources. The remaining significant release occurs via human activities, such as manufacturing, fossil fuel combustion (including those from automotive use), and agriculture (Bruland and Lohan, 2004; Bruland and Franks, 1983). As can be seen, the MEKN and NBTC sites had Cd concentrations similar to the NS&T median value, and at the NSAR site tissue concentrations exceeded the NS&T median value. All sites had values below the NS&T 85th percentile value.

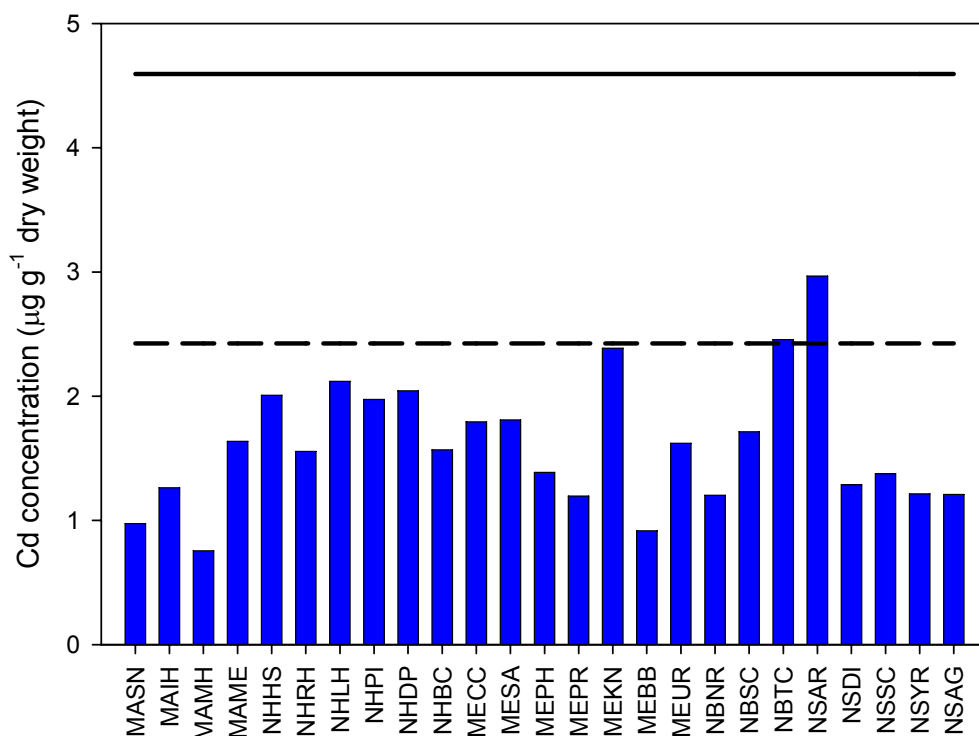


Figure 3. Distribution of cadmium tissue concentrations in mussel sample site composites (one per site) at Gulfwatch sites in 2007. Dashed line = 2007 Mussel Watch National median; Solid line = 2007 Mussel Watch 85th percentile.

4.1.3 Chromium (Cr)

Chromium concentration in mussel tissue for the Gulf of Maine for 2007 ranged from 0.61 $\mu\text{g/g}$ dry weight at the Sandwich, MA site (MASN) to 3.34 $\mu\text{g/g}$ at the Tin Can Beach, NB site (NBTC). Most sites were close to or exceeded the Musselwatch NS&T median tissue concentrations. One site, Tin Can Beach in New Brunswick (NBTC) exceeded the NS&T 85th percentile (Table 4, Figure 4). Chromium is the primary agent used in tanning processes and discharged with untreated tannery wastes throughout much of the nineteenth and twentieth centuries (Capuzzo, 1974). Chromium persists in the environment at elevated concentrations in the sediments near such sources (Capuzzo, 1974; NCCOSC, 1997).

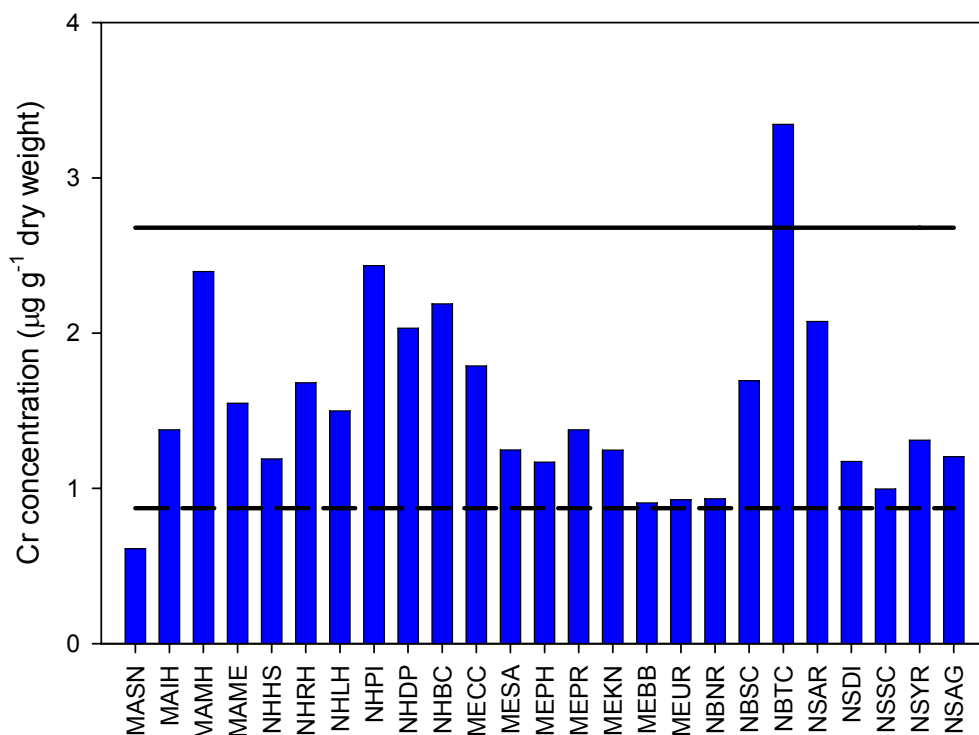


Figure 4. Distribution of chromium tissue concentrations in mussel sample site composites (one per site) at Gulfwatch sites in 2007. Dashed line = 2007 Mussel Watch National median; Solid line = 2007 Mussel Watch 85th percentile.

4.1.4 Copper (Cu)

The 2007 copper concentrations in *M. edulis* ranged from 5.15 µg/g dry wt at Union River, ME site (MEUR) to 10.2 µg/g dry wt at the Boston Inner Harbor, MA site (MAIH, Table 4, Figure 5). Cu levels in 2007 Gulfwatch samples were fairly uniform in distribution throughout the study region. No tissue concentrations exceeded NS&T median or 85th percentile concentrations.

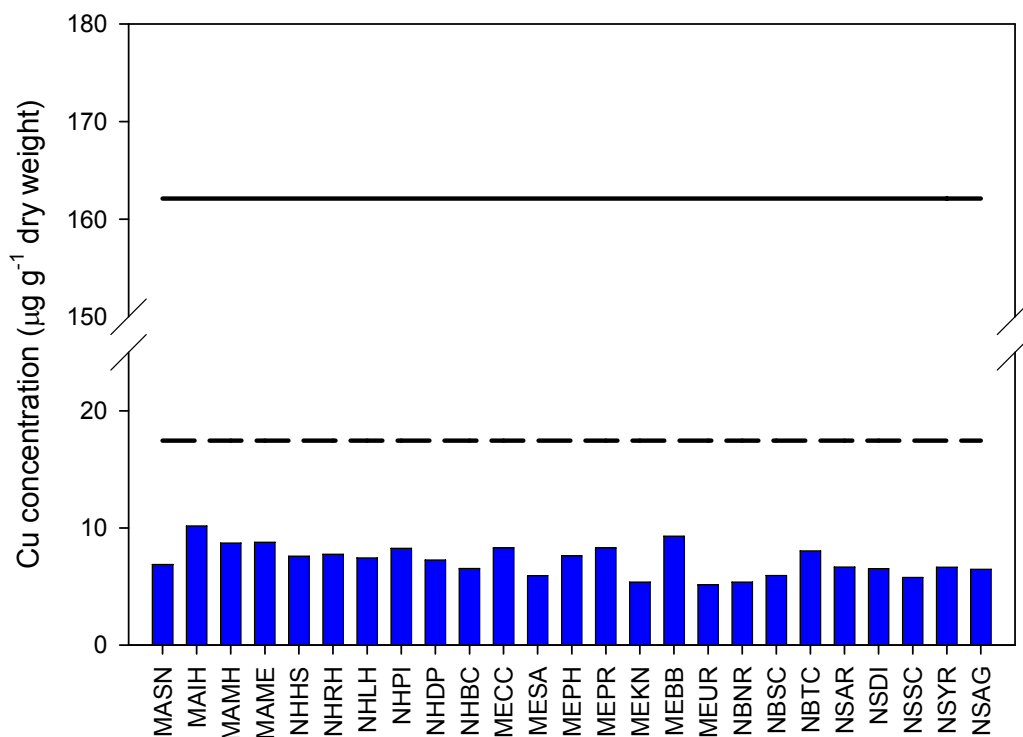


Figure 5. Distribution of copper tissue concentrations in mussel sample site composites (one per site) at Gulfwatch sites in 2007. Dashed line = 2007 Mussel Watch National median; Solid line = 2007 Mussel Watch 85th percentile.

4.1.5 Iron and Aluminum (Fe & Al)

For 2007, the highest concentrations for both iron and aluminum were found at sites in New Brunswick and Nova Scotia. Tin Can Beach, NB had the highest concentrations of Fe and Al, followed by the Apple River site in Nova Scotia (NSAR) and the St. Croix River site in New Brunswick (NBSC, Table 4; Figures 6 and 7). Concentrations of Fe ranged from 173 µg/g dry weight at MASN to 1429 µg/g dry wt at NBTC. Tissue concentrations of Al ranged from 108 µg/g dry wt at MASN and MAMH (Sandwich and Marblehead, MA) to 1541 µg/g dry wt at NBTC. Concentrations at Tin Can Beach exceeded the NS&T national 85th percentile for aluminum and iron. Because of their high abundance in crustal material (Burdige, 2006), Al and Fe may or may not represent bioaccumulated anthropogenic elements. Many of the Gulfwatch sites had tissue concentrations that were near to or exceeded NS&T median values, which may reflect the aluminosilicate composition sediments in northeastern North America. Aluminum concentrations can be valuable as a way to normalize to background concentrations derived from

continental crustal material and enhance differences in concentration due uptake of localized (non-crustal derived) sources. Previous reports have mentioned the greater exposure of mussels near the top of the Gulf of Maine to higher frequencies and intensities of tidally-induced sediment resuspension. Also mentioned was that such sediment may not truly be incorporated into tissues, since mussels are known to be particle-selective and will void undesirable ingested particulates as pseudofeces (Barnes, 1974) bypassing digestion in the gut. It is possible that non-depurated mussels may contain a sediment signal not reflective of true metal incorporation, and such a normalizing parameter may aid in the gulf-wide comparisons of tissue concentrations. Caution has been urged in prior reports to evaluate Al recoveries, which in 2007 were adequate (see Appendix C).

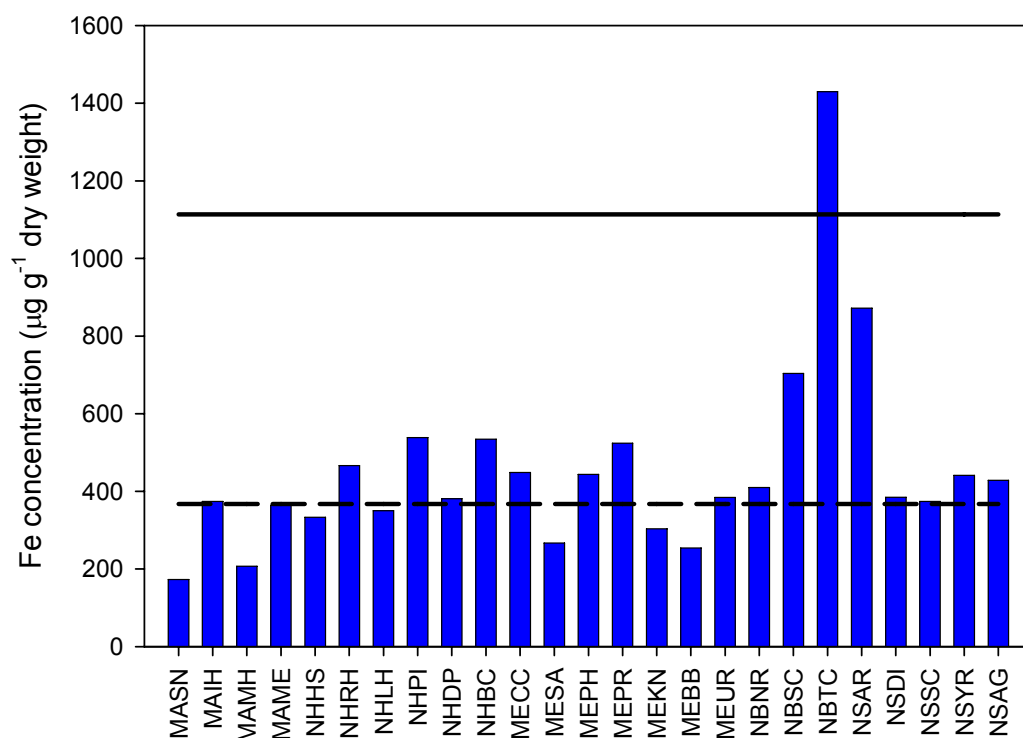


Figure 6. Distribution of iron tissue concentrations in mussel sample site composites (one per site) at Gulfwatch sites in 2007. Dashed line = 2007 Mussel Watch National median; Solid line = 2007 Mussel Watch 85th percentile.

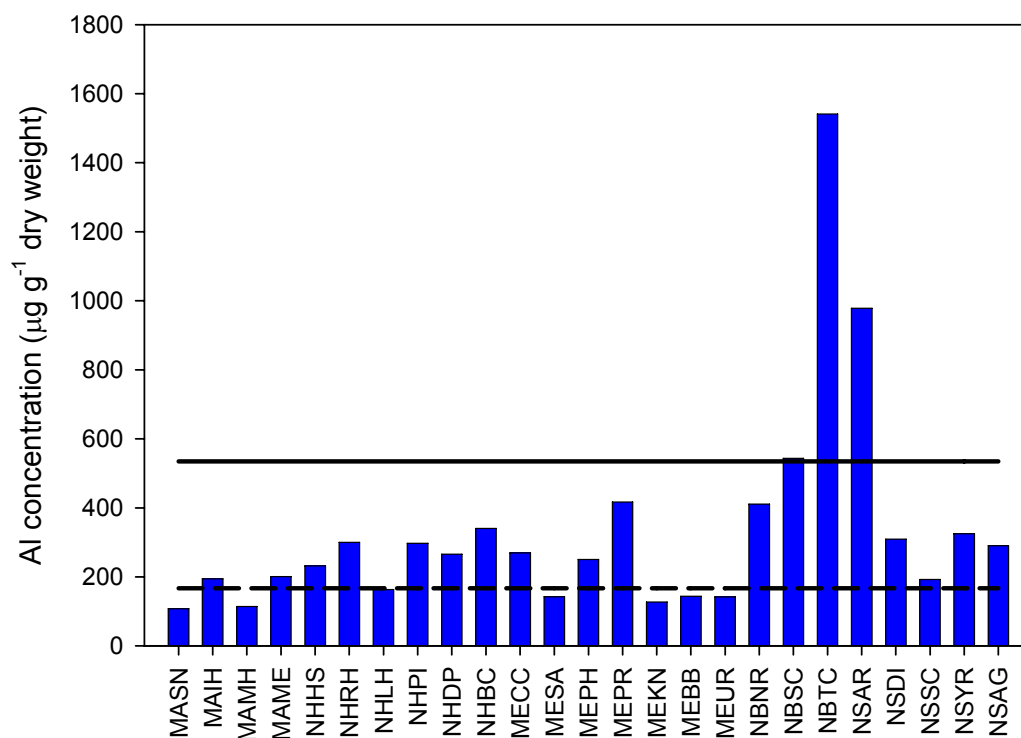


Figure 7. Distribution of aluminum tissue concentrations in mussel sample site composites (one per site) at Gulfwatch sites in 2007. Dashed line = 2007 Mussel Watch National median; Solid line = 2007 Mussel Watch 85th percentile.

4.1.6 Nickel (Ni)

The concentration of nickel ranged from 0.59 µg/g dry wt at MEBB to 2.9 µg/g dry wt at NBTC (Table 4; Figure 8). Higher levels of Ni observed at Tin Can Beach (NBTC) as well as NBSC and NSAR may reflect the differential uptake of sediments already mentioned. No concentrations exceed the NS&T 85th percentile values.

4.1.7 Lead (Pb)

As in 2006, all sites visited in 2007 had tissue concentrations that exceeded the 2007 NS&T median value of 0.89 µg/g dry wt. Lead concentrations ranged from 0.83 µg/g dry wt at Niger River, NB (NBNR) to 9.06 µg/g dry wt at Boston Inner Harbor, MA (MAIH, Table 4, Figure 9). Several of the sites (9 out of 25) visited by Gulfwatch were elevated for Pb, (i.e., above the NS&T 85th percentile of 2.49 µg/g dry wt). Tissue Pb concentrations from MAIH, MAMH and MEBB exceeded 85th percentile values by a factor of two or greater.

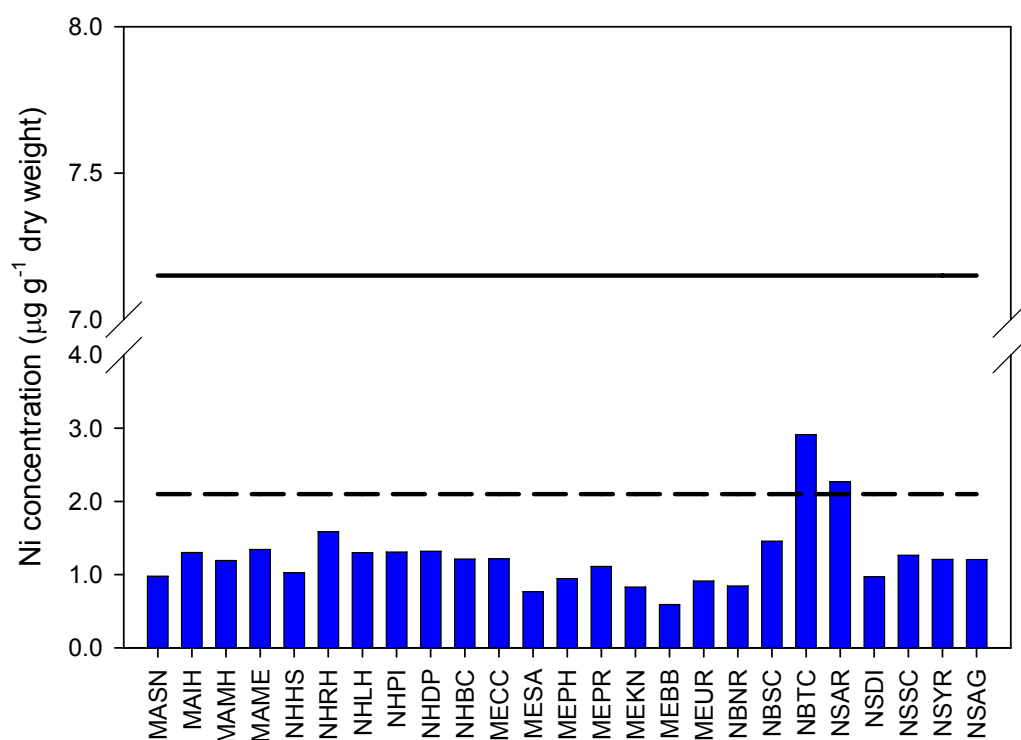


Figure 8. Distribution of nickel tissue concentrations in mussel sample site composites (one per site) at Gulfwatch sites in 2007. Dashed line = 2007 Mussel Watch National median; Solid line = 2007 Mussel Watch 85th percentile.

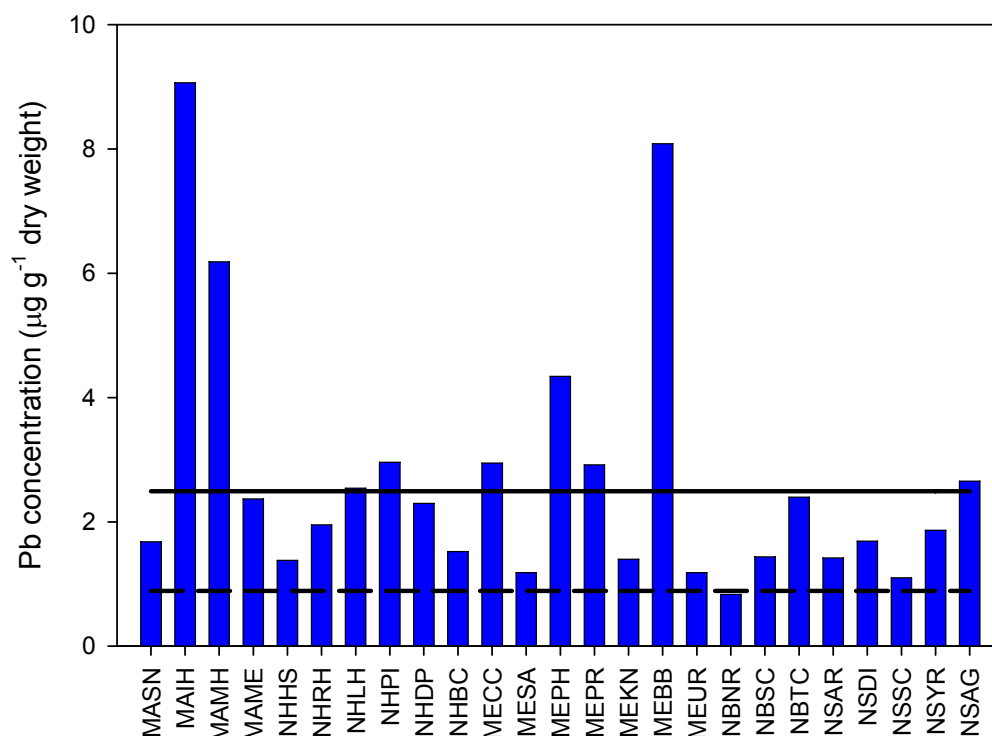


Figure 9. Distribution of lead tissue concentrations in mussel sample site composites (one per site) at Gulfwatch sites in 2007. Dashed line = 2007 Mussel Watch National median; Solid line = 2007 Mussel Watch 85th percentile.

4.1.8 Zinc (Zn)

Concentrations of zinc ranged from a low value of 61.1 µg/g dry wt in mussels from Spechts Cove, NS (NSSC) to a high of 150 µg/g dry wt in mussels from the Boston Inner Harbor, MA (MAIH) site (Table 4, Figure 10). No sites had zinc concentrations exceeding the 85th percentile value from the 2007 NS&T sampling program. Zinc is a ubiquitous environmental contaminant generally reflecting a wide range of land-based activities (tire wear, galvanized materials, industrial waste discharges, etc.).

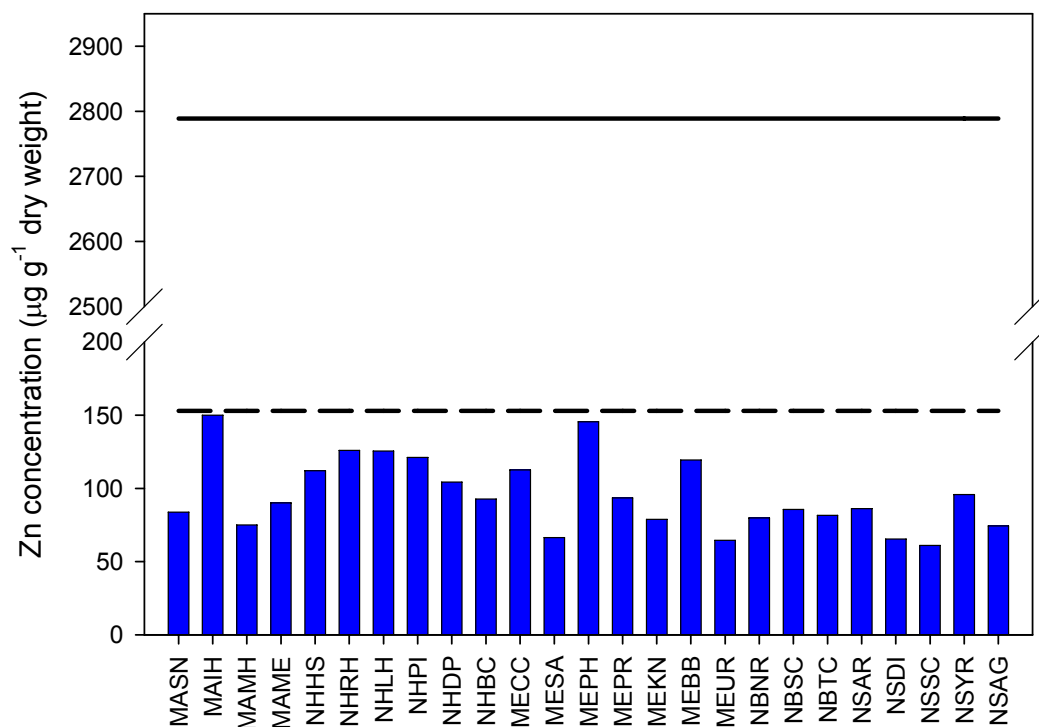


Figure 10. Distribution of zinc tissue concentrations in mussel sample site composites (one per site) at Gulfwatch sites in 2007. Dashed line = 2007 Mussel Watch National median; Solid line = 2007 Mussel Watch 85th percentile.

4.1.9 Mercury (Hg)

Mercury was detected in mussels collected at all 2007 Gulfwatch stations. Concentrations ranged from a low of 0.088 µg/g dry wt at the Digby Island, NS site (NSDI) to a high of 0.332 µg/g dry wt at the Tin Can Beach, NB (NBTC) site. All 2007 site concentrations except for three (MASN, NBNR, and NSDI) were above the NS&T 2007 median concentration of 0.097 µg Hg/g dry wt. Seven out of 25 sites exceeded the NS&T 85th percentile value of 0.237 µg Hg/g dry wt (Table 4, Figure 11).

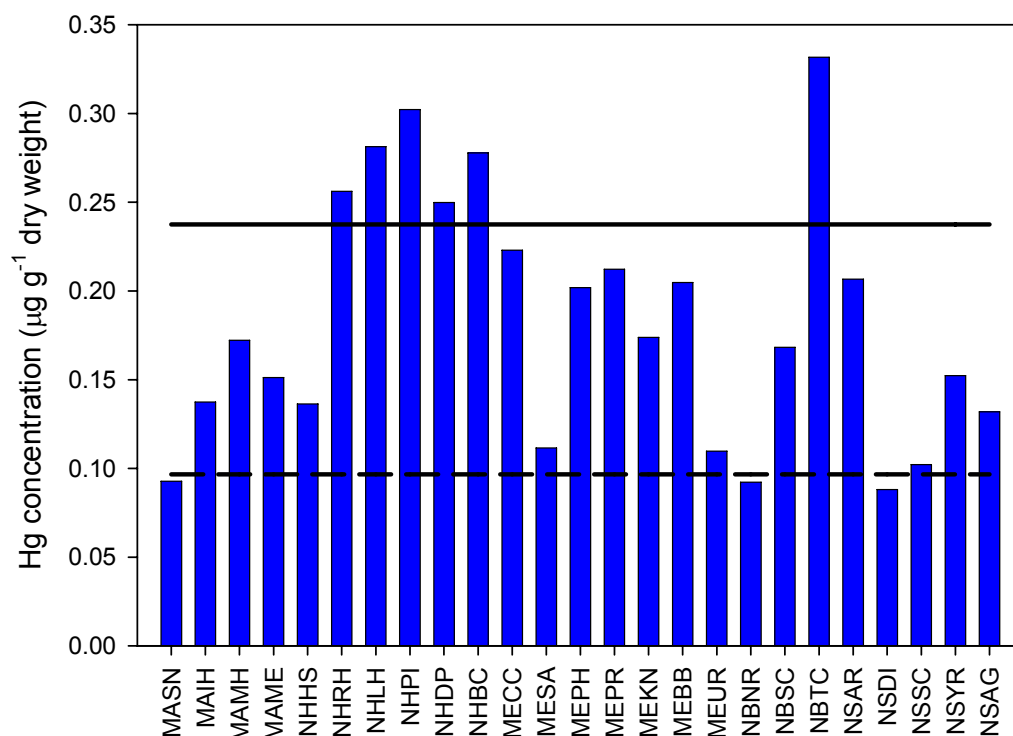


Figure 11. Distribution of mercury tissue concentrations in mussel sample site composites (one per site) at Gulfwatch sites in 2007. Dashed line = 2007 Mussel Watch National median; Solid line = 2007 Mussel Watch 85th percentile.

4.1.10 Organic Contaminants

For 2007 samples, enough target analytes were present in sufficient quantity such that with the exception of Nova Scotia, most sites had values for the summed quantities (Table 6 and Figures 12-14). There is a pattern of higher concentrations of ΣPAH_{24} , ΣPAH_{40} , and ΣPCB_{24} in the New England States, compared to the Canadian Provinces, with the Boston Inner Harbor site in Massachusetts consistently having the highest of all the summed analytes. Concentrations exceeding the NS&T 85th percentile also occurred at New Hampshire and Maine sites. Three sites exceeded the NS&T 85th percentile concentrations for the quantity ΣPAH_{24} : Boston Inner Harbor, MA (MAIH), Portland Harbor, ME (MEPH) and Boothbay Harbor, ME (MEBB, Figure 12, and Table 6). The pattern seen for the sum of 40 PAH analytes (which includes a greater quantity of alkyl-substituted PAHs) is similar, although only two sites (MAIH and MEBB) had concentrations which exceeded the NS&T 85th percentile concentration. Concentrations of ΣPAH_{24} ranged from 26.4 ng/g Apple River, NS (NSAR) to 1693 ng/g at Boston Inner Harbor, MA (MAIH). Similarly, concentrations of ΣPAH_{40} ranged between 26.4 ng/g at NSAR and 2268 ng/g at MAIH and from 26.4 ng/g to 1563 ng/g for the ΣPAH_{19} .

Composite samples from Massachusetts had higher PCB concentrations than those collected from ME, NH, NB and NS, although concentrations from sites throughout the New England

states were close to, or exceeded NS&T median PCB values. ΣPCB_{24} concentrations ranged from not detected (mostly at sites in NS) to 420 ng/g at the Boston Inner Harbor site (MAIH).

Tissue concentrations of ΣPEST_{21} ranged from ND at Apple River and Argyle Sound, NS (NSAR and NSAG) to 93.3 ng/g dry wt at the Marblehead, MA site (MAMH, Table 6, Figure 15). The sum of the DDTs (ΣDDT_6), most notably p, p'-DDE, a degradation product of DDT, were the main contributors to the sum of the chlorinated pesticide target analytes. The distribution pattern was somewhat bimodal, with the highest levels observed in Massachusetts, but with maxima also observable at some of the Maine sites, particularly Boothbay Harbor (MEBB). Two sites exceeded the NS&T 85th percentile criteria (Marblehead, MA or MAMH and Boothbay Harbor, ME or MEBB). Several Massachusetts sites (MASN, MAIH, MAME, MAMH,) and a few Maine sites (MEPR, MEPH, MEBB) were close to or higher than the median NS&T value.

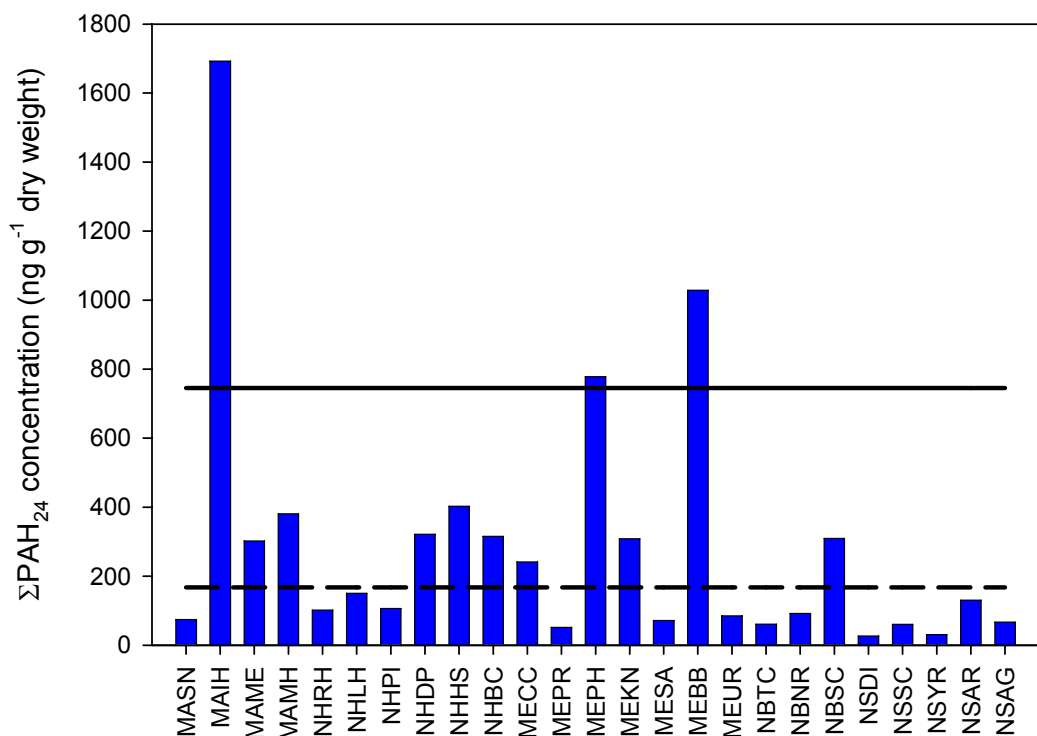


Figure 12. Distribution the sum of 24 PAHs in tissues from mussel sample site composites (one per site) at Gulfwatch sites in 2007. Dashed line = 2007 Mussel Watch National median; Solid line = 2007 Mussel Watch 85th percentile.

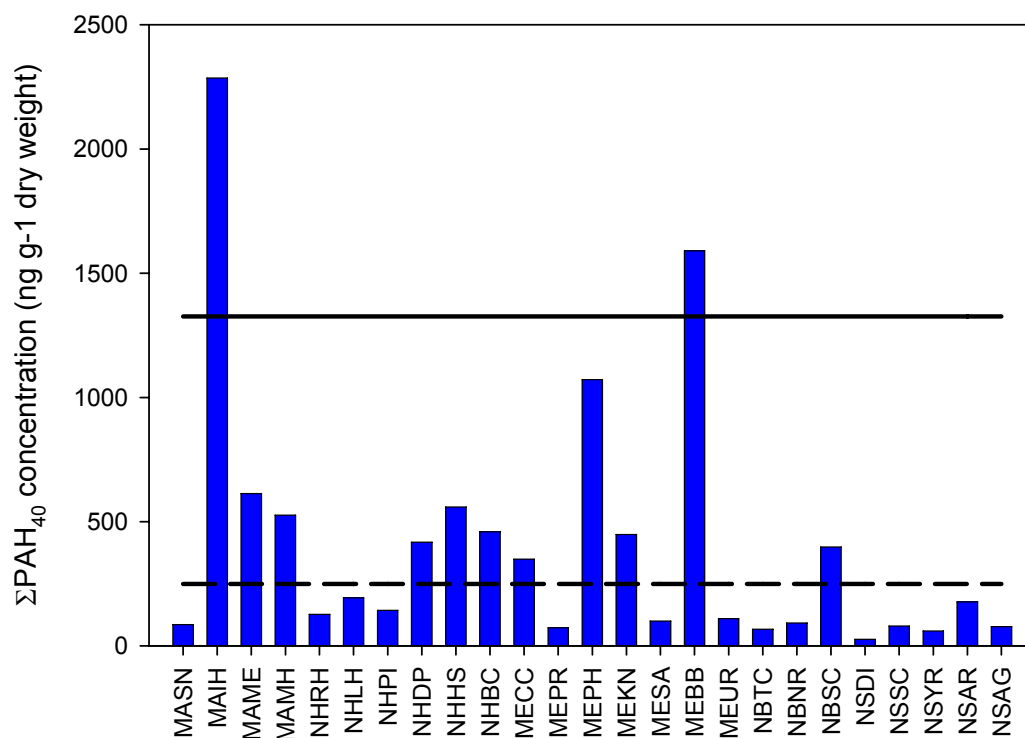


Figure 13. Distribution the sum of 40 PAHs in tissues from mussel sample site composites (one per site) at Gulfwatch sites in 2007. Dashed line = 2007 Mussel Watch National median; Solid line = 2007 Mussel Watch 85th percentile.

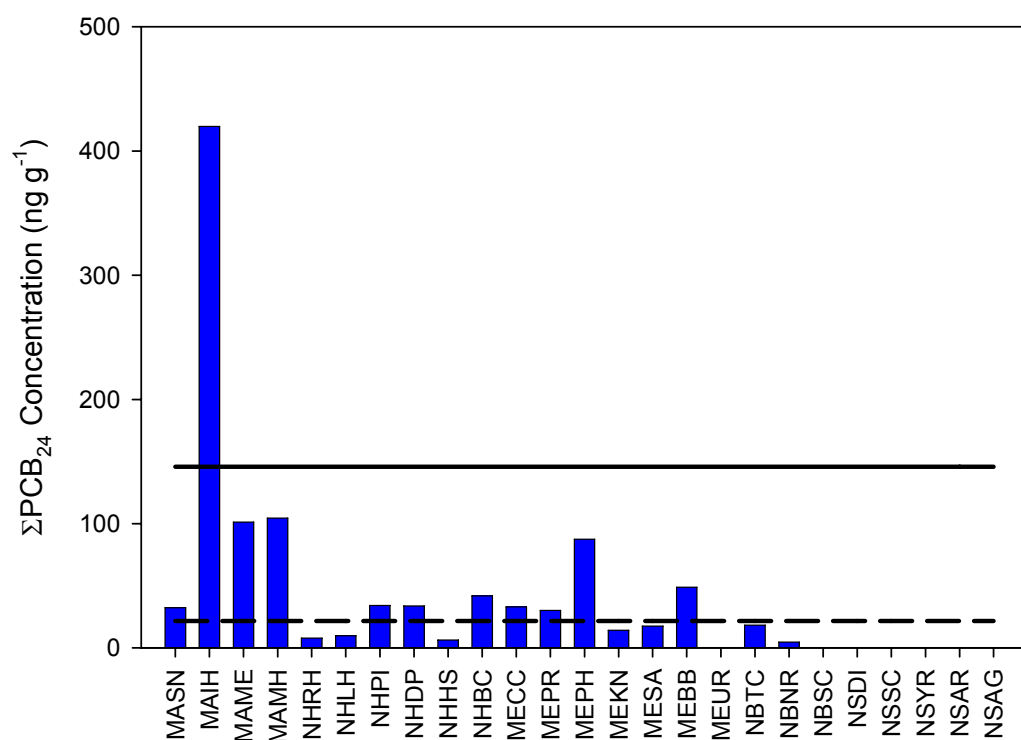


Figure 14. Distribution the sum of 24 PCB congeners in tissues from mussel sample site composites (one per site) at Gulfwatch sites in 2007. Dashed line = 2007 Mussel Watch National median; Solid line = 2007 Mussel Watch 85th percentile (for the sum of 21 PCB congeners).

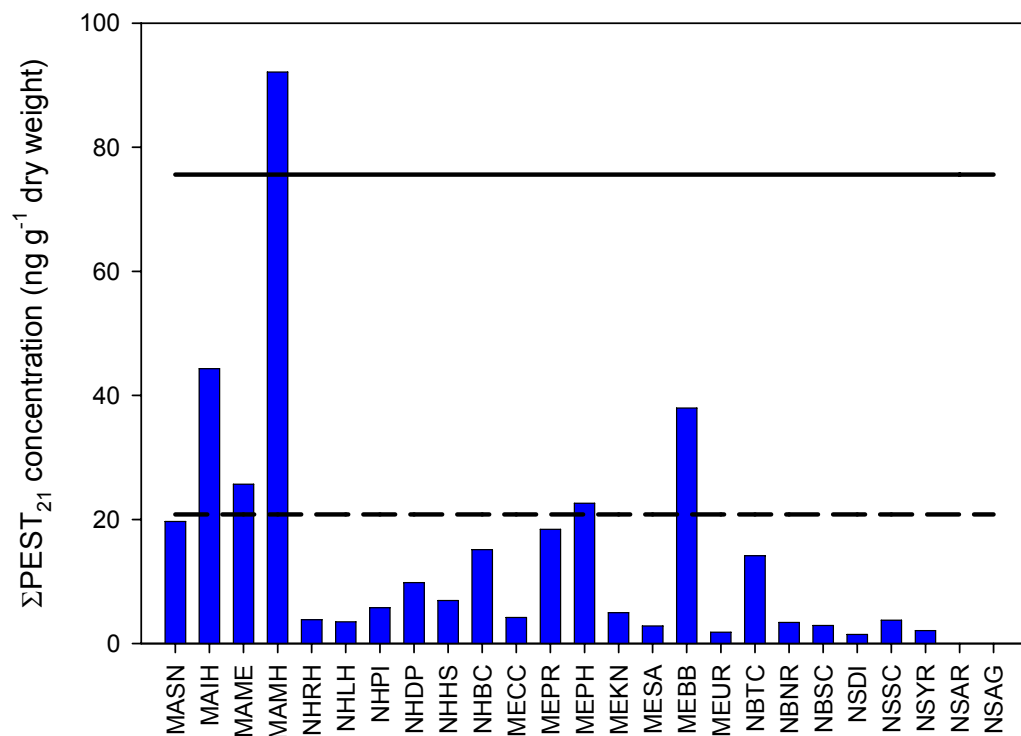


Figure 15. Distribution the sum of 21 chlorinated pesticides in tissues from mussel sample site composites (one per site) at Gulfwatch sites in 2007. Dashed line = 2007 Mussel Watch National median; Solid line = 2007 Mussel Watch 85th percentile.

4.2 TEMPORAL PATTERNS

This section presents the distribution of inorganic and organic contaminants in mussel tissue collected trend sites along the Gulf of Maine, from 2001 to 2007. The temporal distribution of station means is plotted for each contaminant or class of contaminants, and compared to individual tissue concentrations from year 2007 site composite samples in Figures 16-26. All individual replicate results for each 2007 site are provided in Appendices E and F. The distribution of contaminants in mussels from the four of the five traditional benchmark sites (MASN, MECC, MEKN, and NSDI) and 9 trend sites (MAME, NHHS, NHDP, MEBB, MEPH, NBSC, NBTC, NSAR and NSYR) is updated with data from mussels collected in 2007.

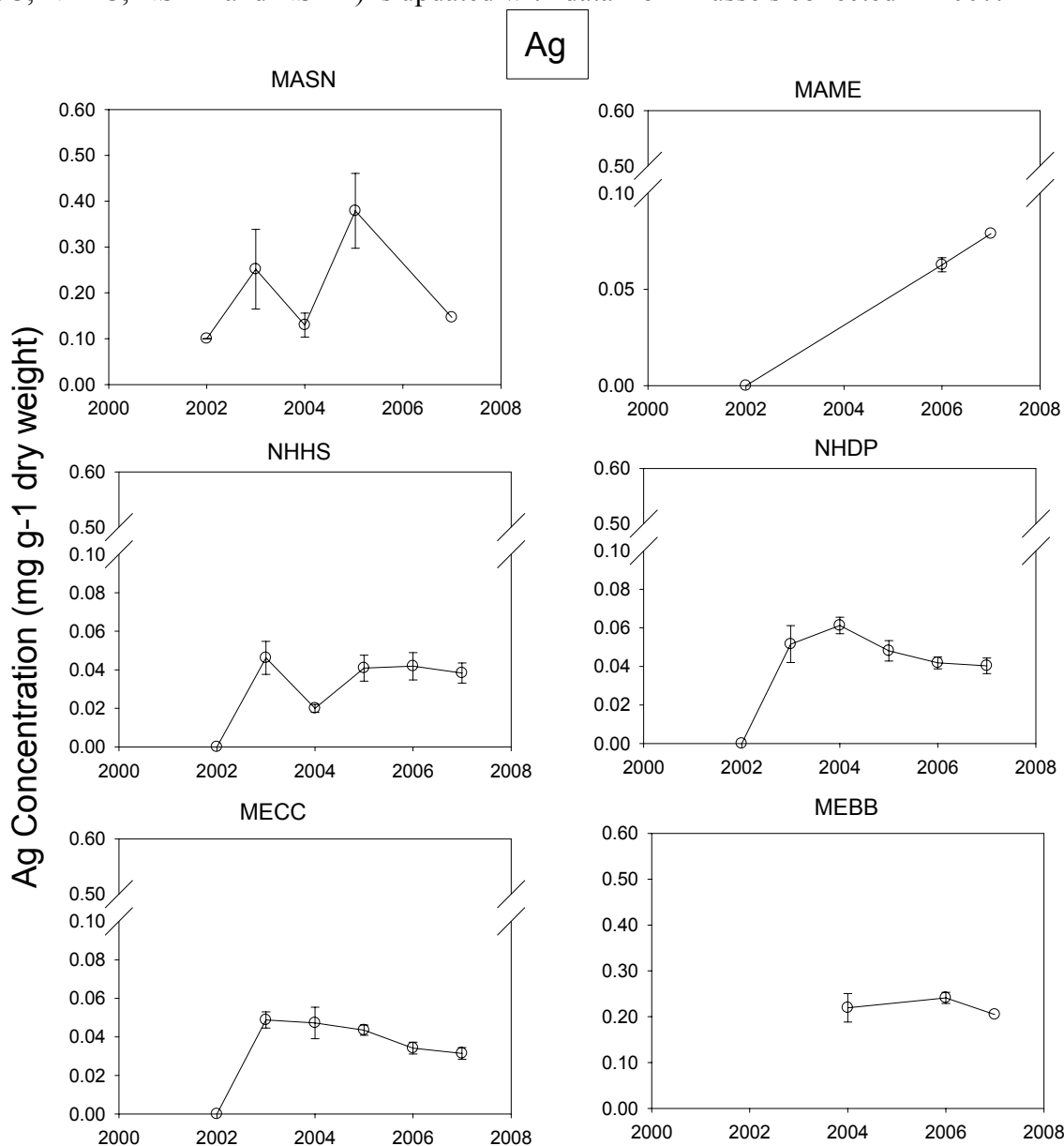


Figure 16. Distribution of silver tissue concentrations in $\mu\text{g/g}$ dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

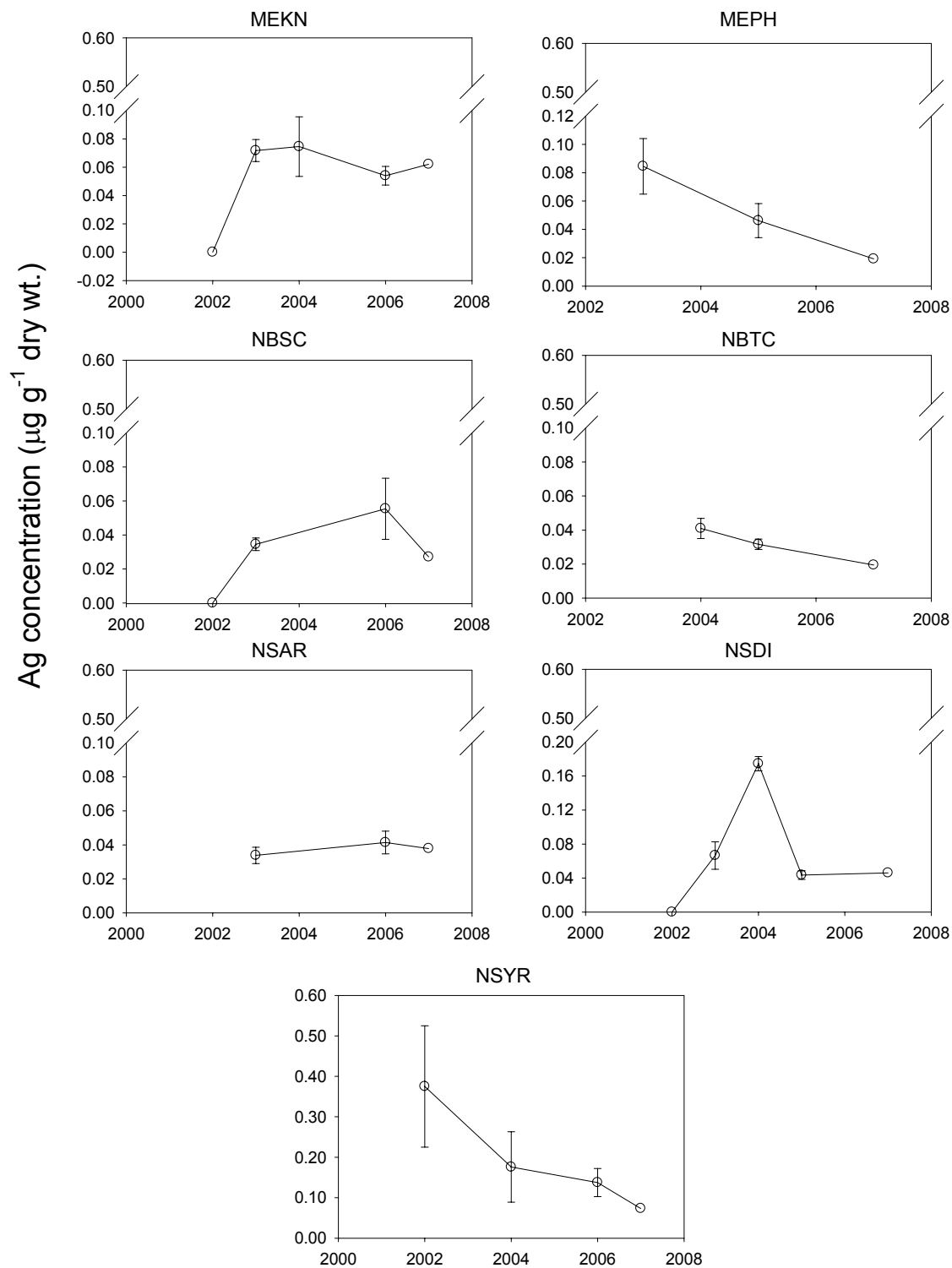


Figure 16 (cont'd). Distribution of silver tissue concentrations in $\mu\text{g/g}$ dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

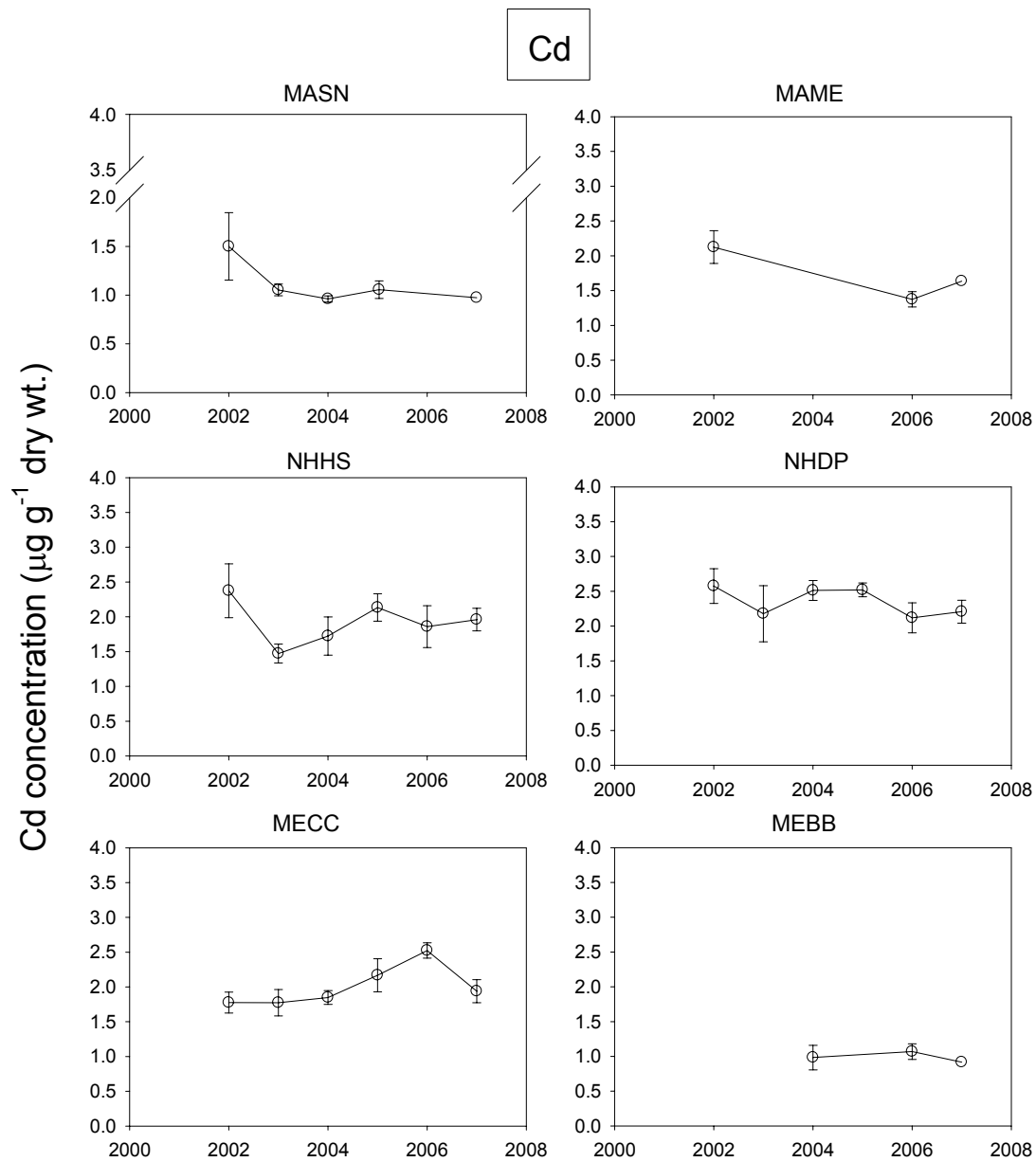


Figure 17. Distribution of cadmium tissue concentrations in $\mu\text{g/g}$ dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

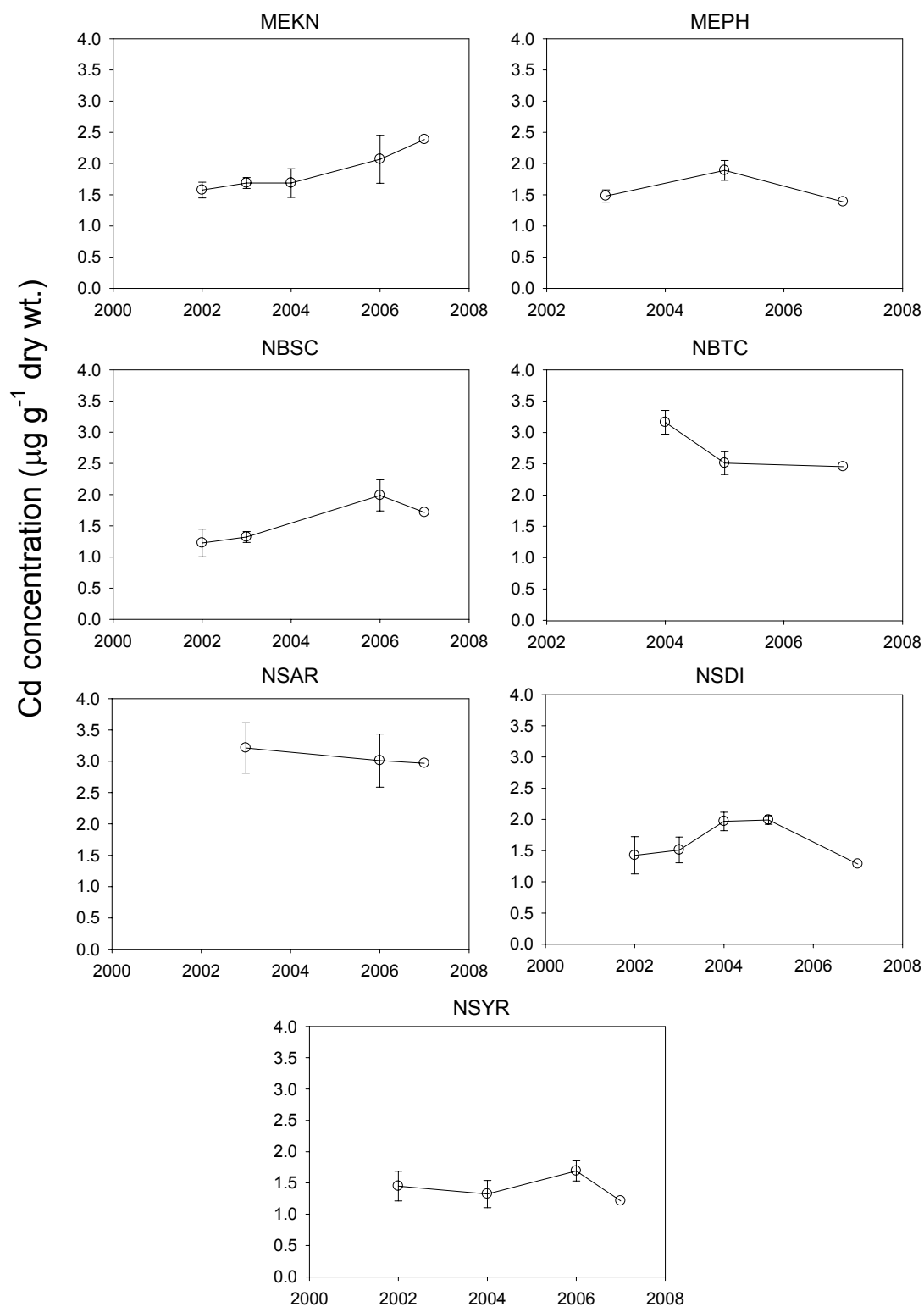


Figure 17 (cont'd). Distribution of cadmium tissue concentrations in $\mu\text{g/g}$ dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

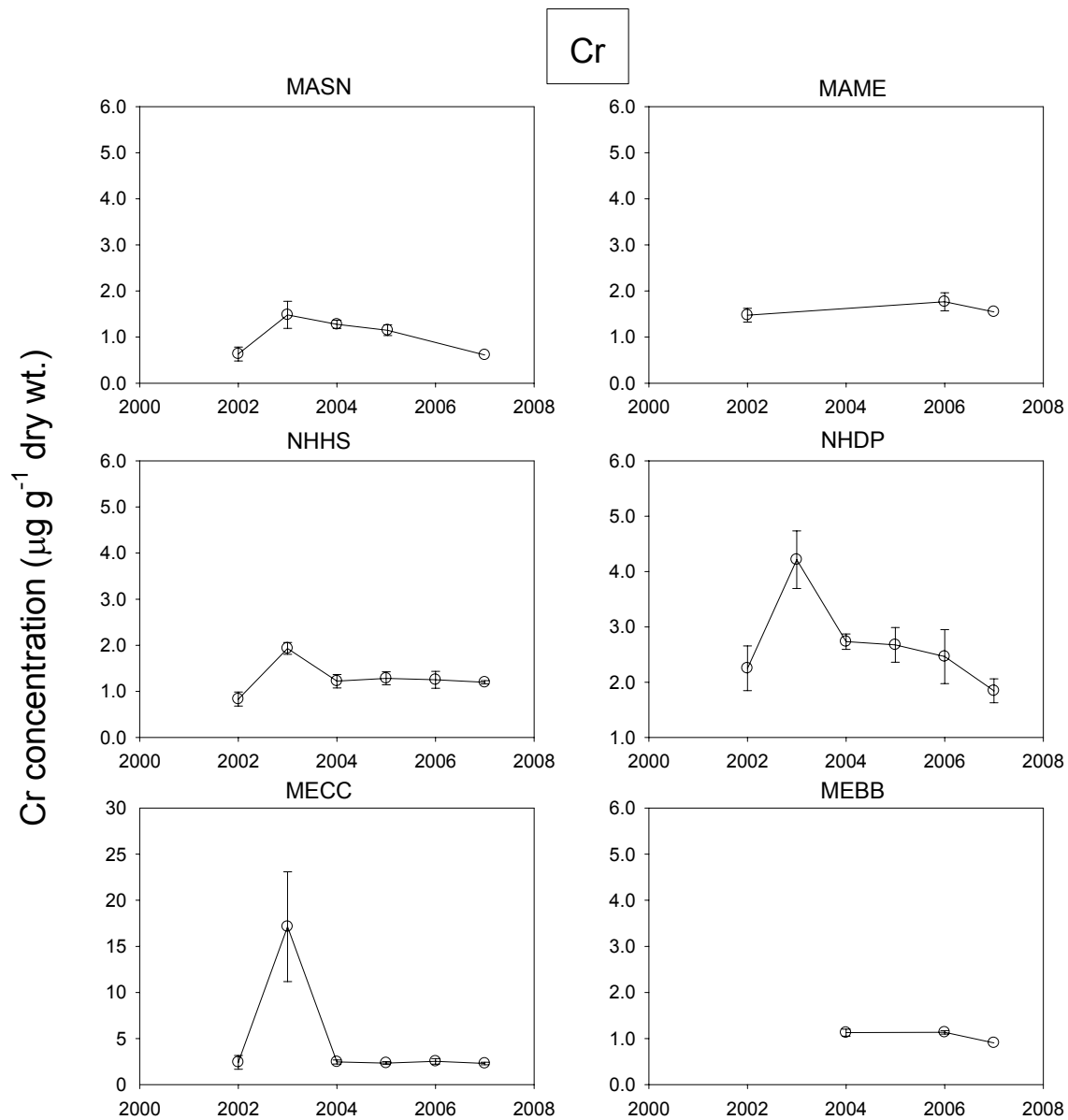


Figure 18. Distribution of chromium tissue concentrations in $\mu\text{g/g}$ dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

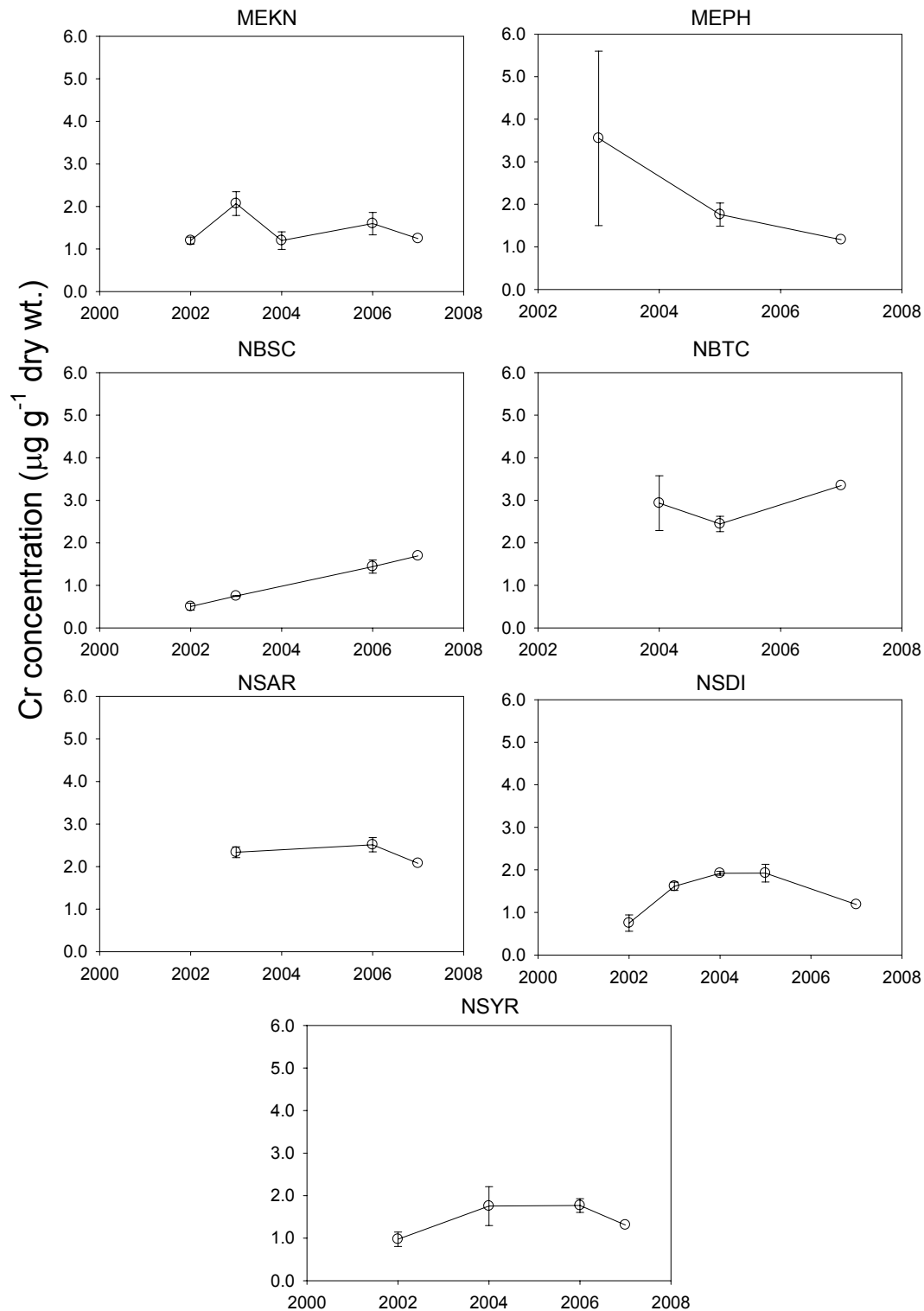


Figure 18 (cont'd). Distribution of chromium tissue concentrations in $\mu\text{g/g}$ dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

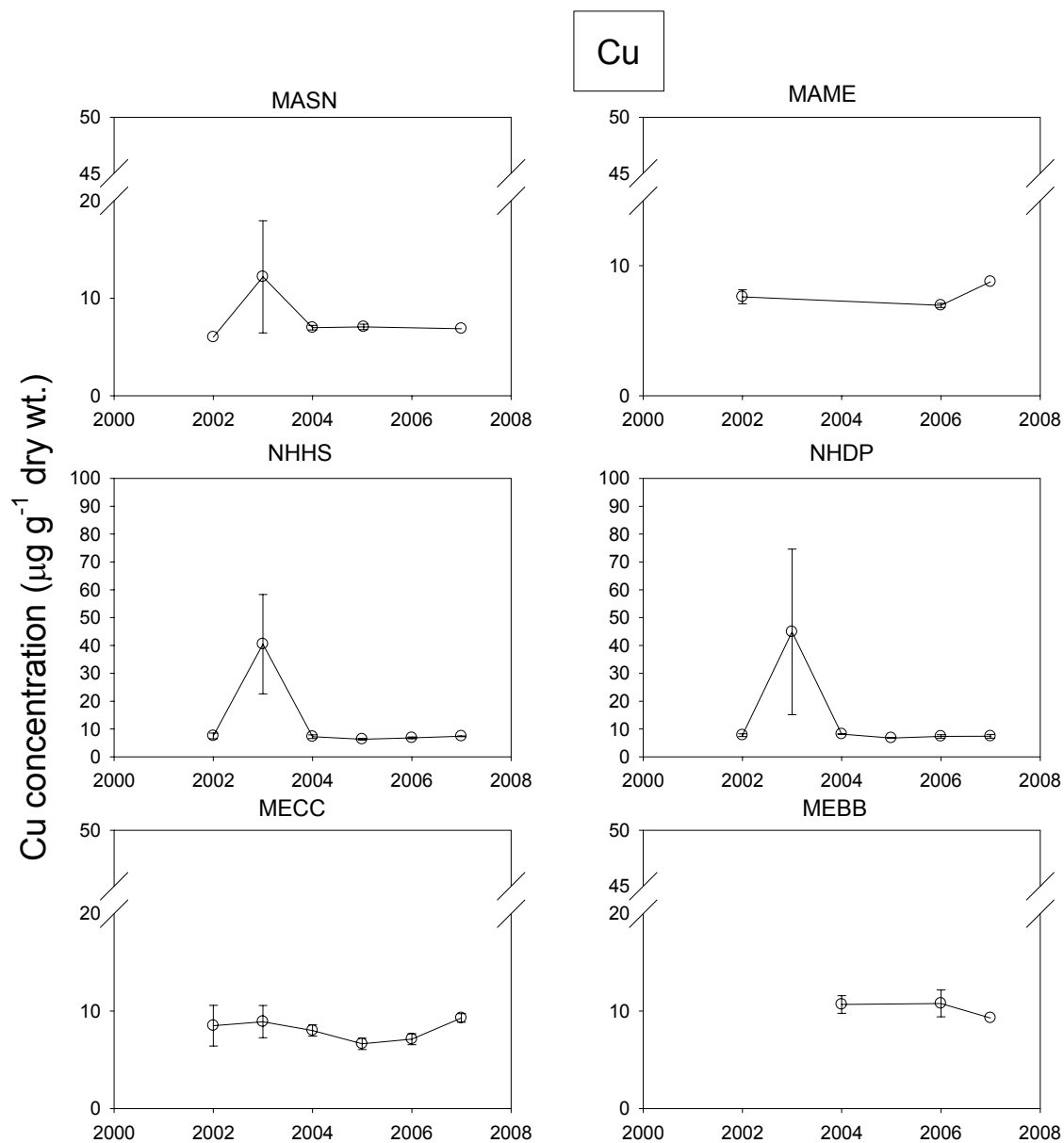


Figure 19. Distribution of copper tissue concentrations in $\mu\text{g/g}$ dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

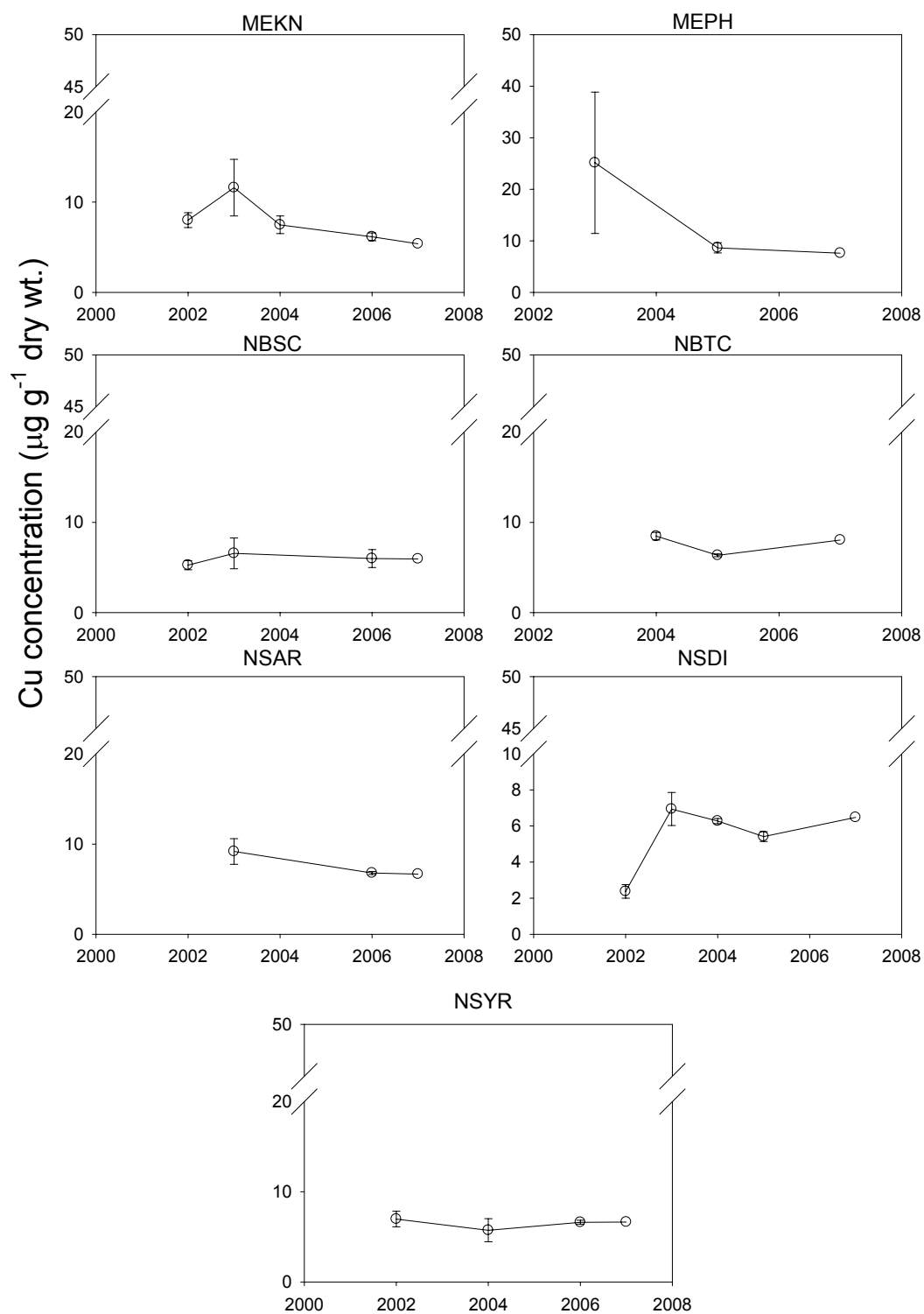


Figure 19 (cont'd). Distribution of copper tissue concentrations in µg/g dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

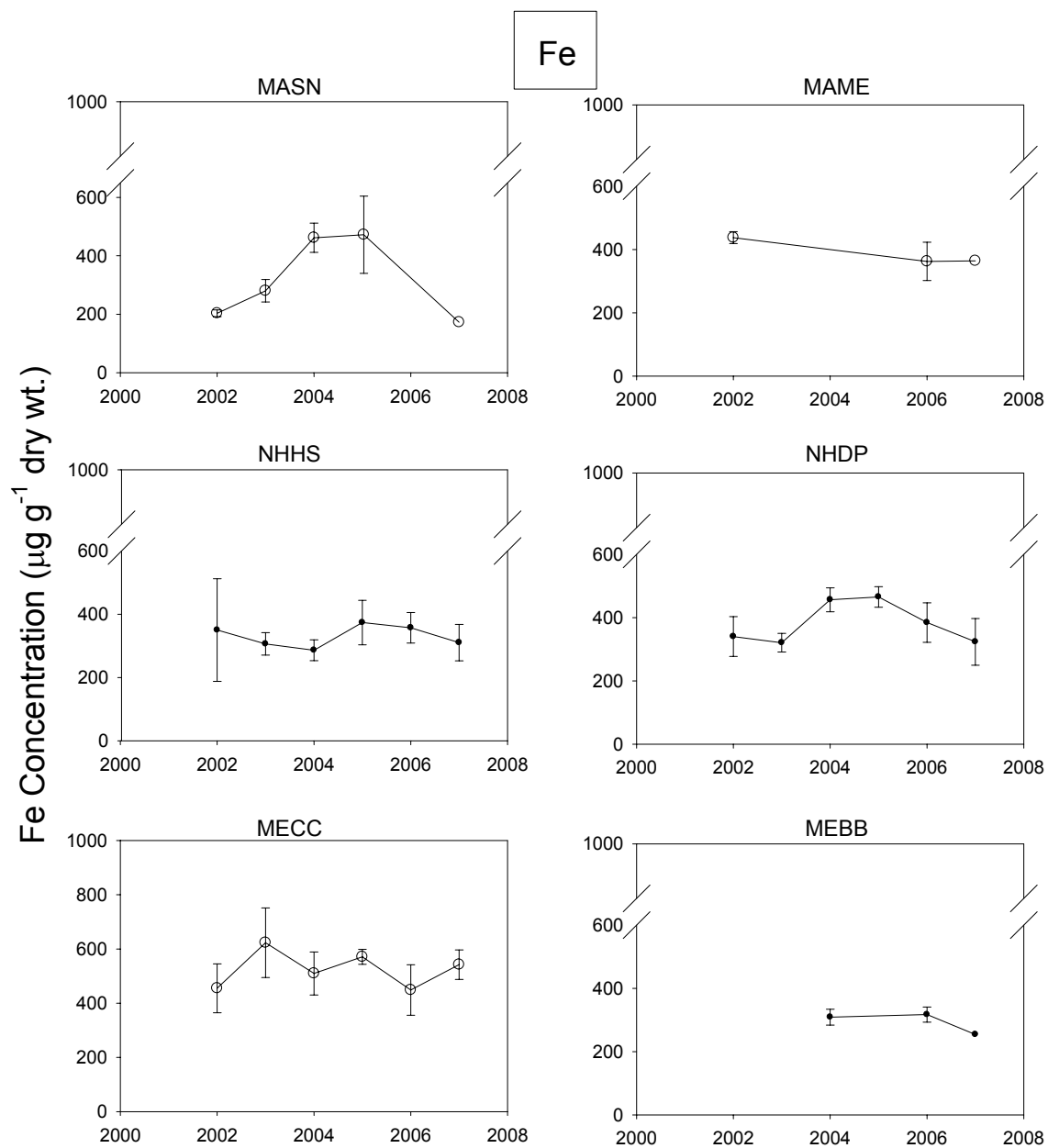


Figure 20. Distribution of iron tissue concentrations in $\mu\text{g/g}$ dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

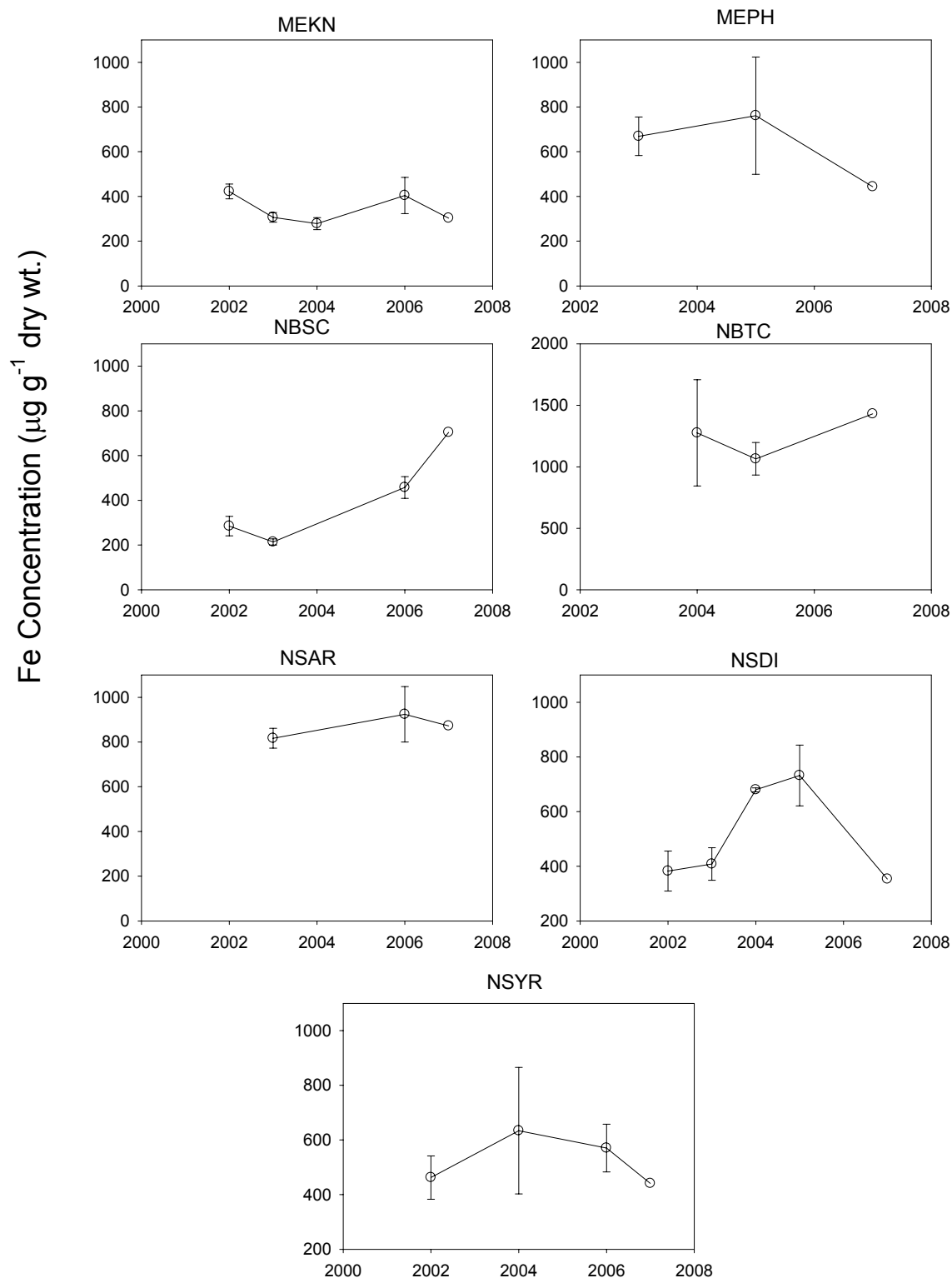


Figure 20 (cont'd). Distribution of iron tissue concentrations in $\mu\text{g/g}$ dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

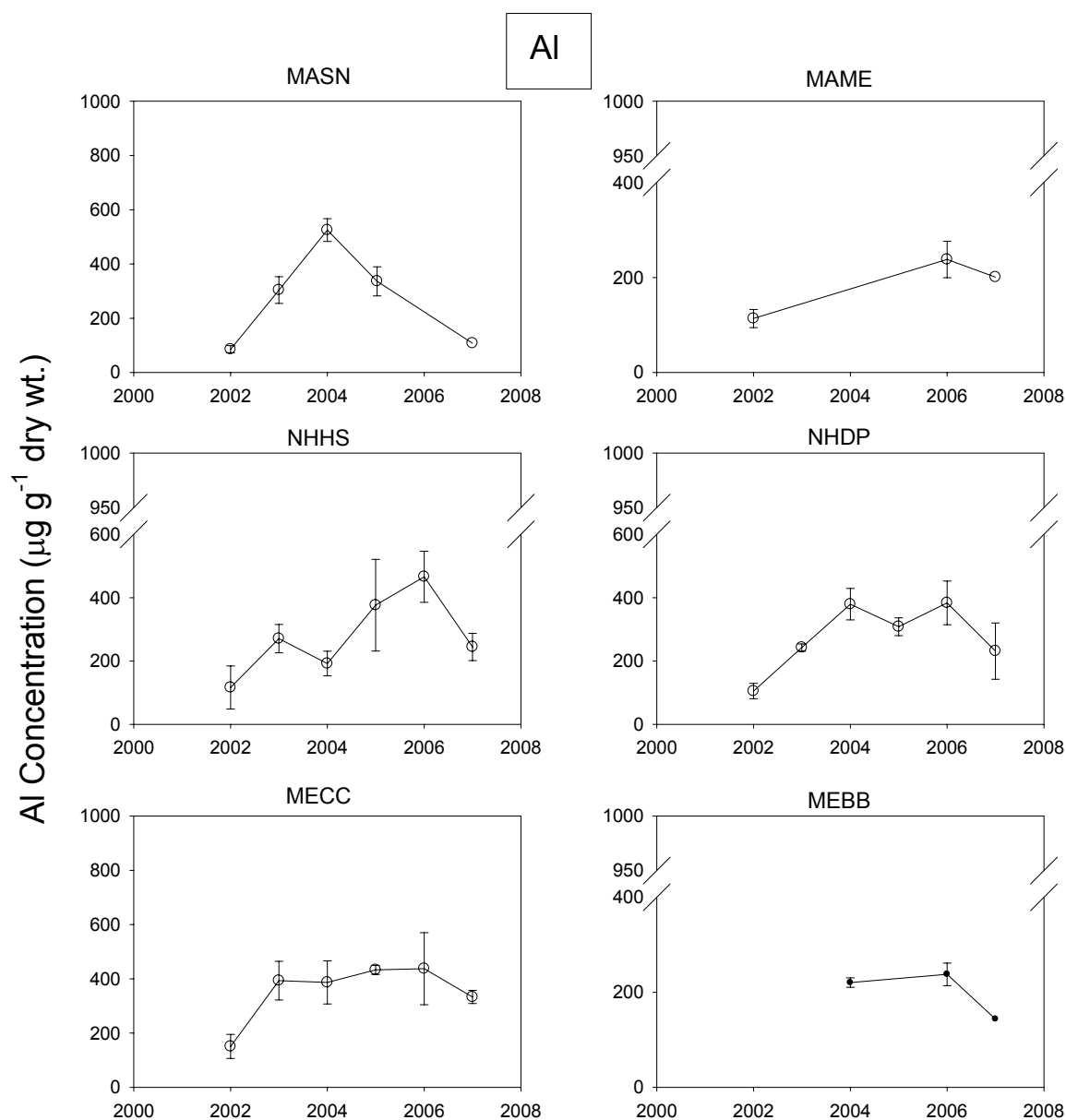


Figure 21. Distribution of aluminum tissue concentrations in $\mu\text{g/g}$ dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

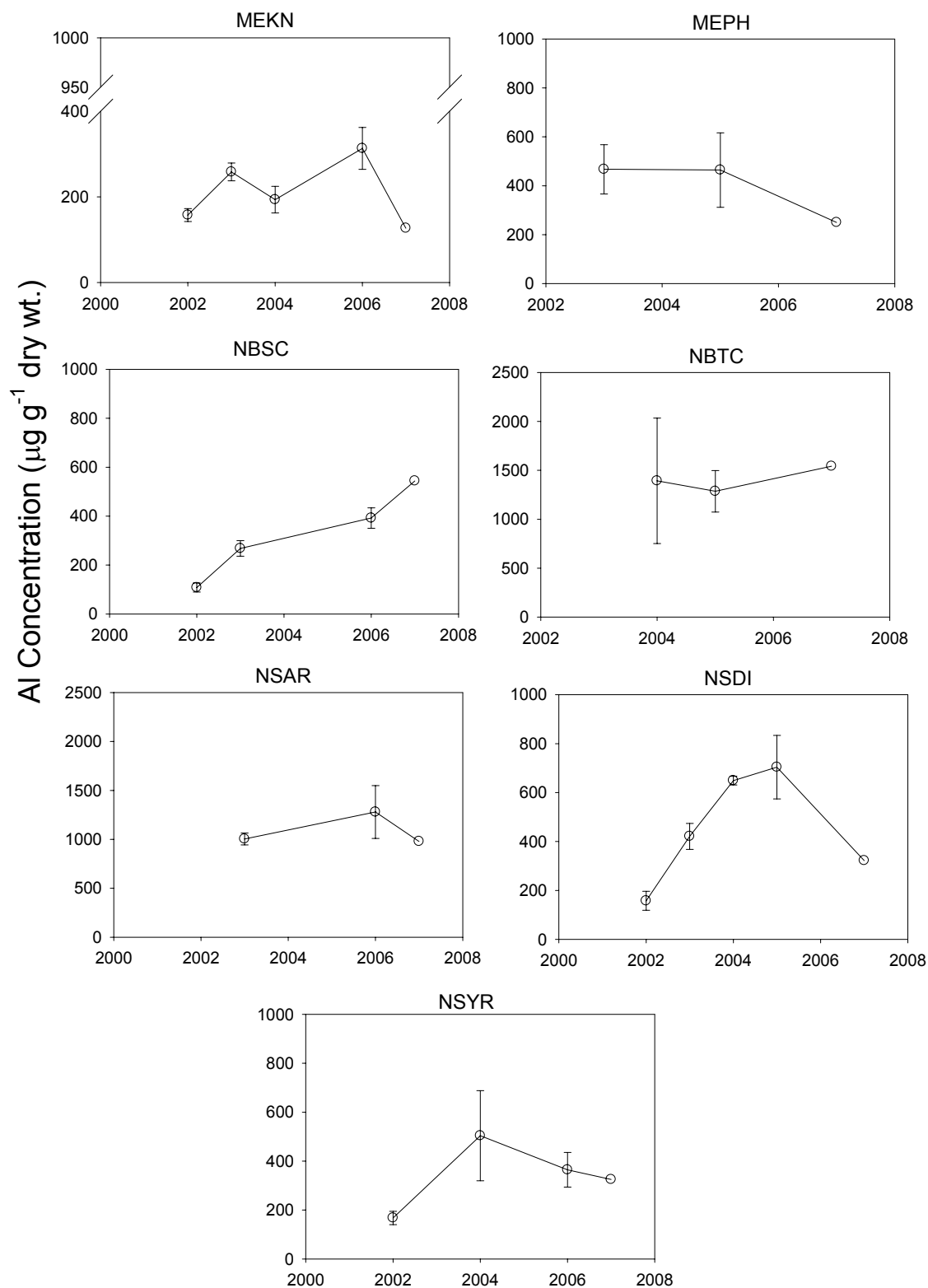


Figure 21 (cont'd). Distribution of aluminum tissue concentrations in $\mu\text{g/g}$ dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

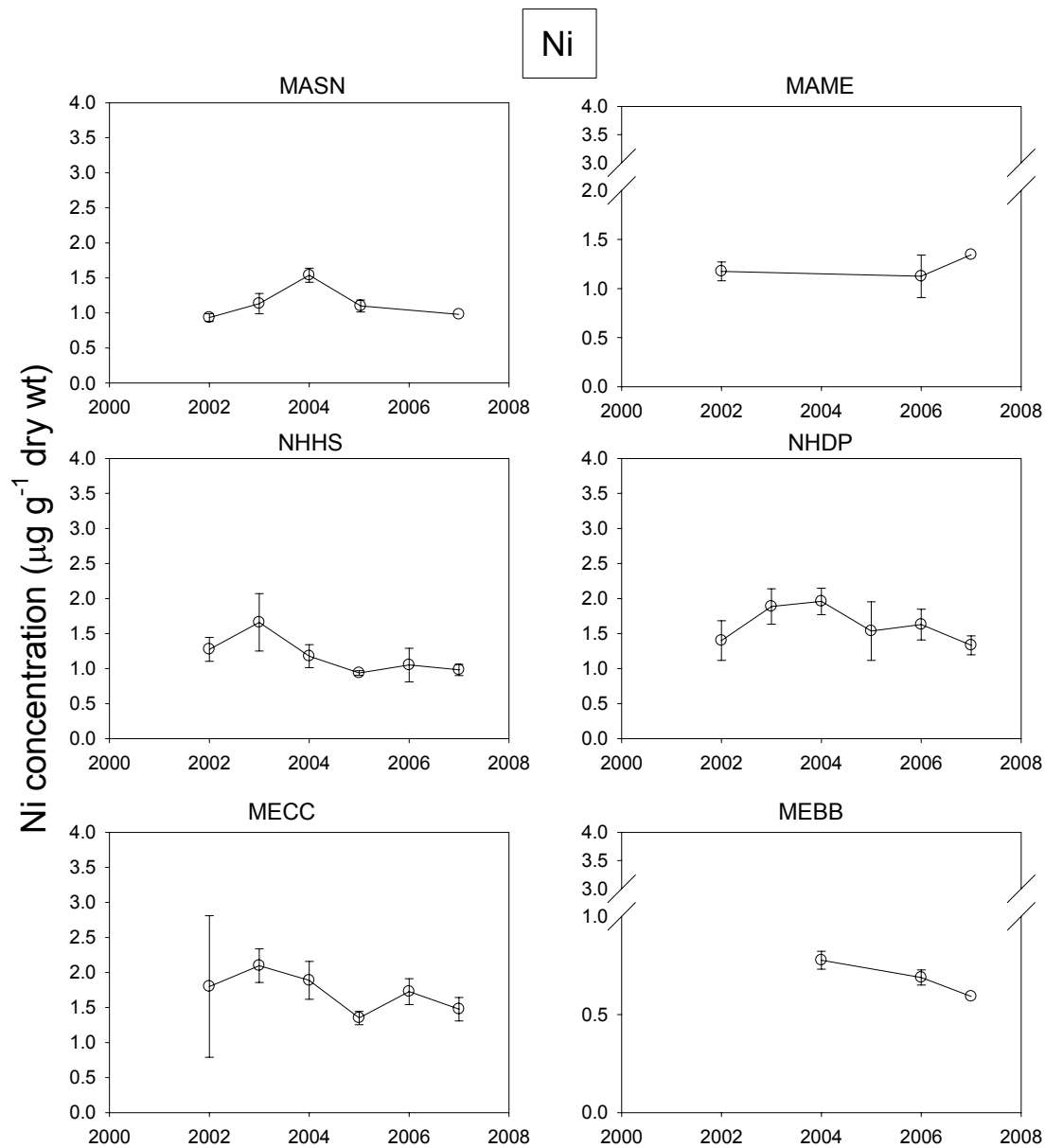


Figure 22. Distribution of nickel tissue concentrations in µg/g dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

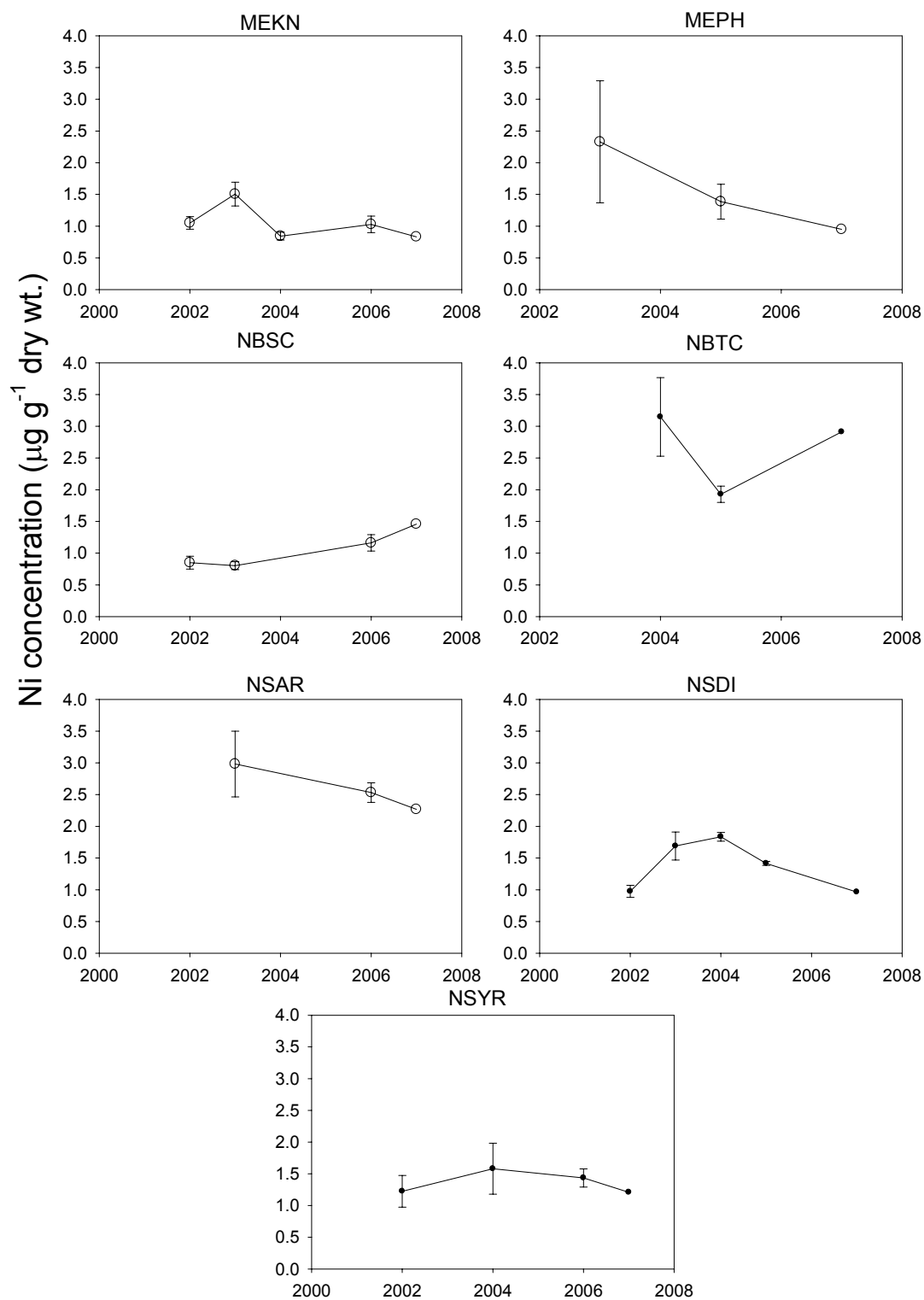


Figure 22 (cont'd). Distribution of nickel tissue concentrations in µg/g dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

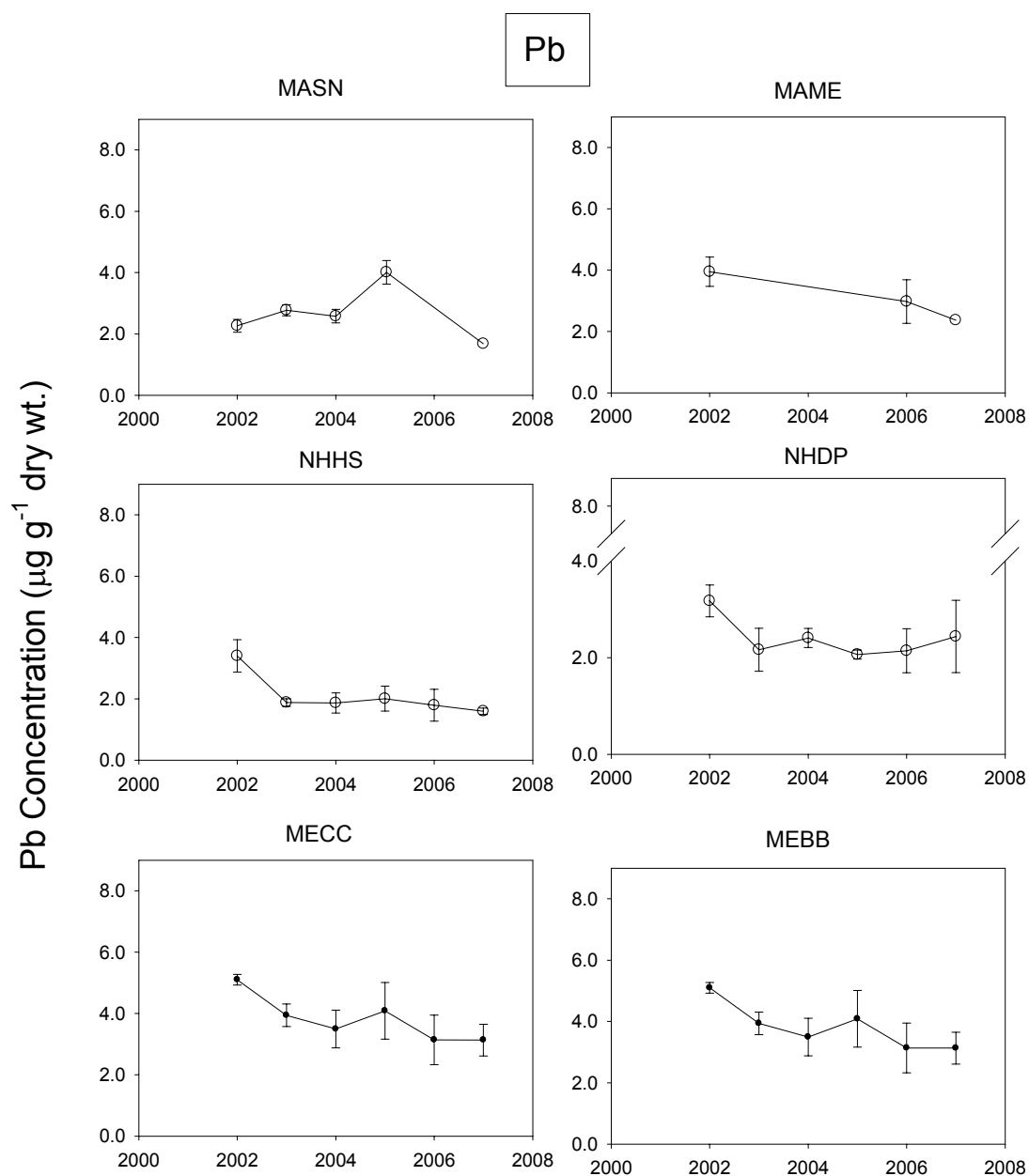


Figure 23. Distribution of lead tissue concentrations in $\mu\text{g/g}$ dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

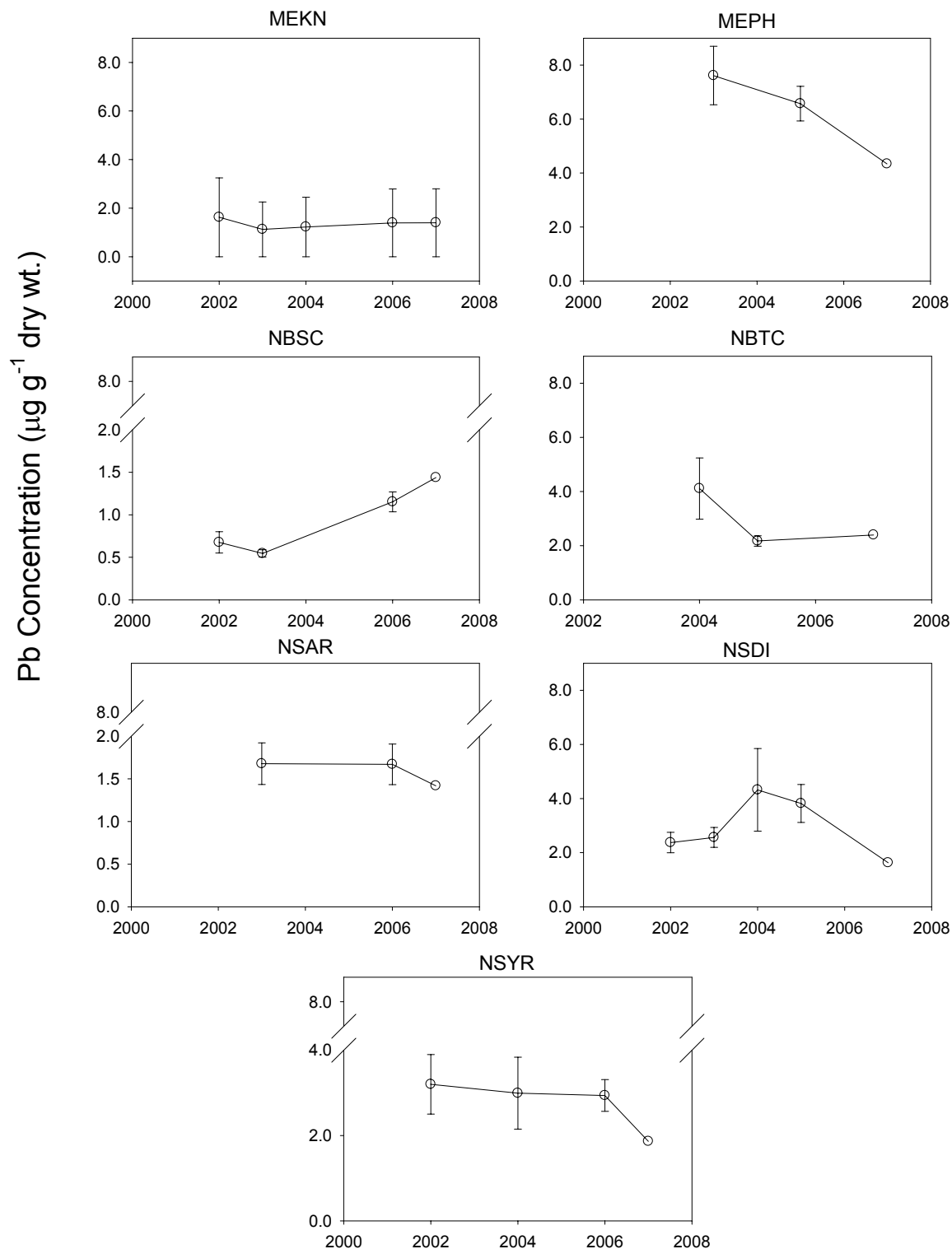


Figure 23 (cont'd). Distribution of lead tissue concentrations in $\mu\text{g/g}$ dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

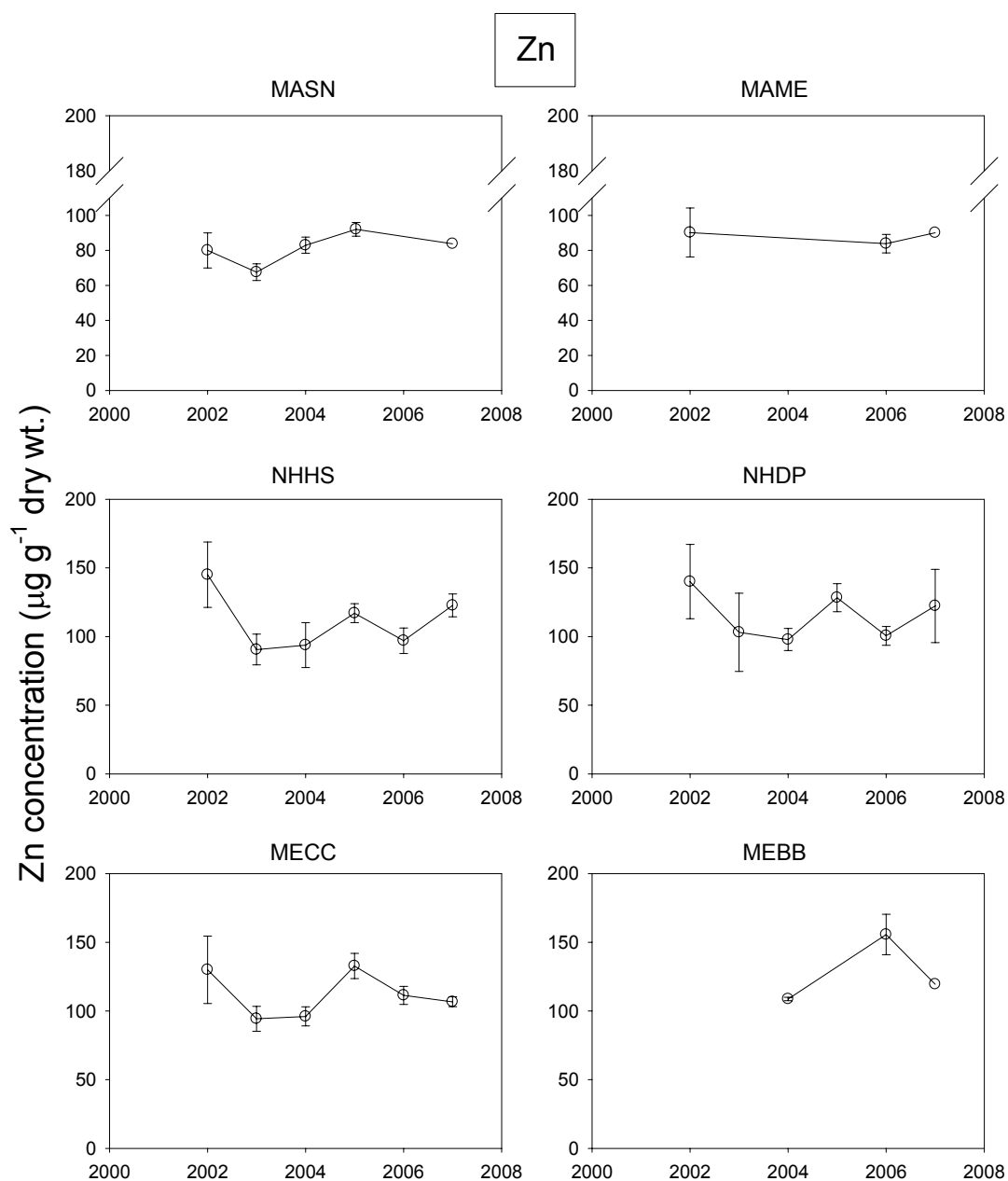


Figure 24. Distribution of zinc tissue concentrations in µg/g dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

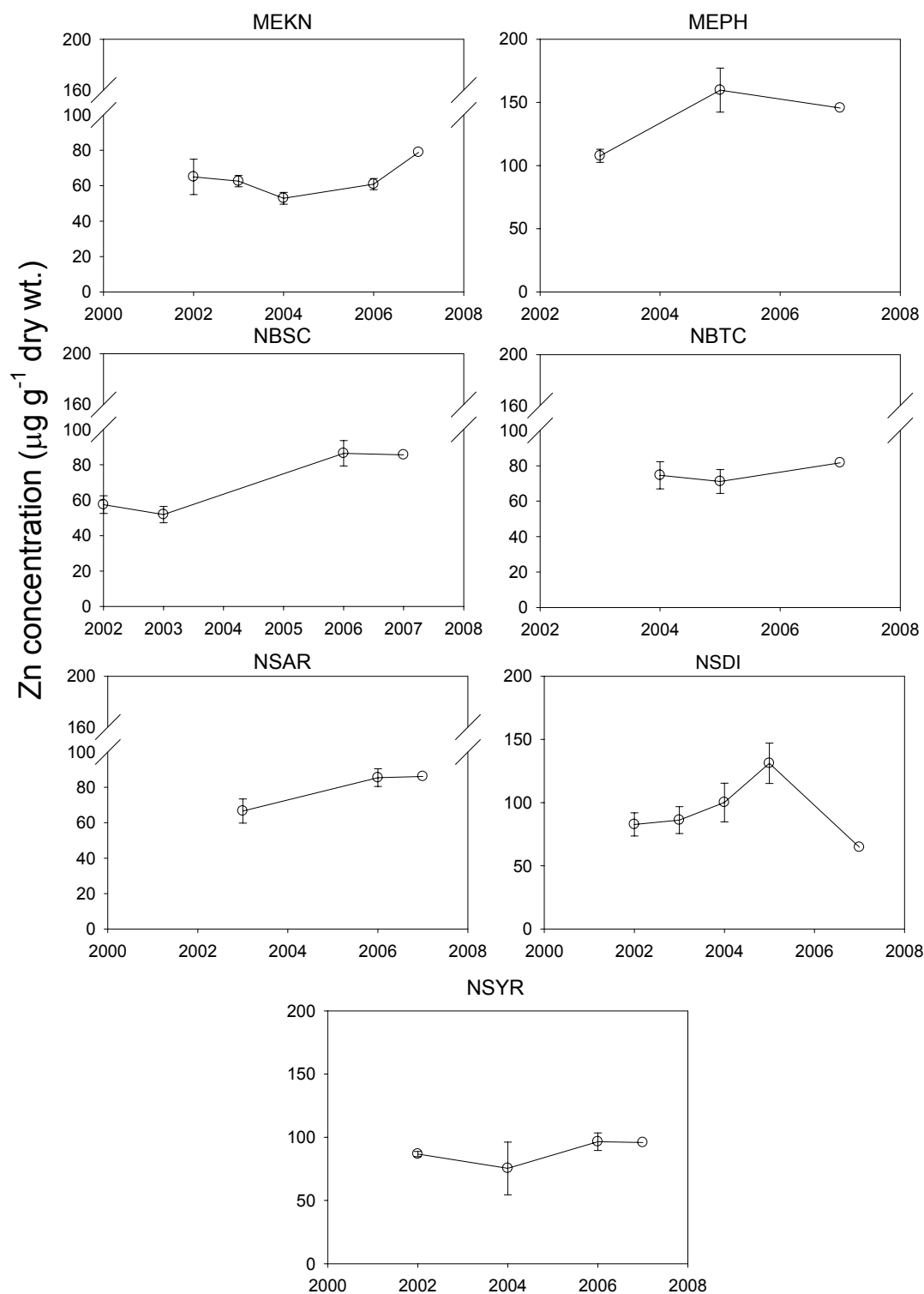


Figure 24 (cont'd). Distribution of zinc tissue concentrations in µg/g dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

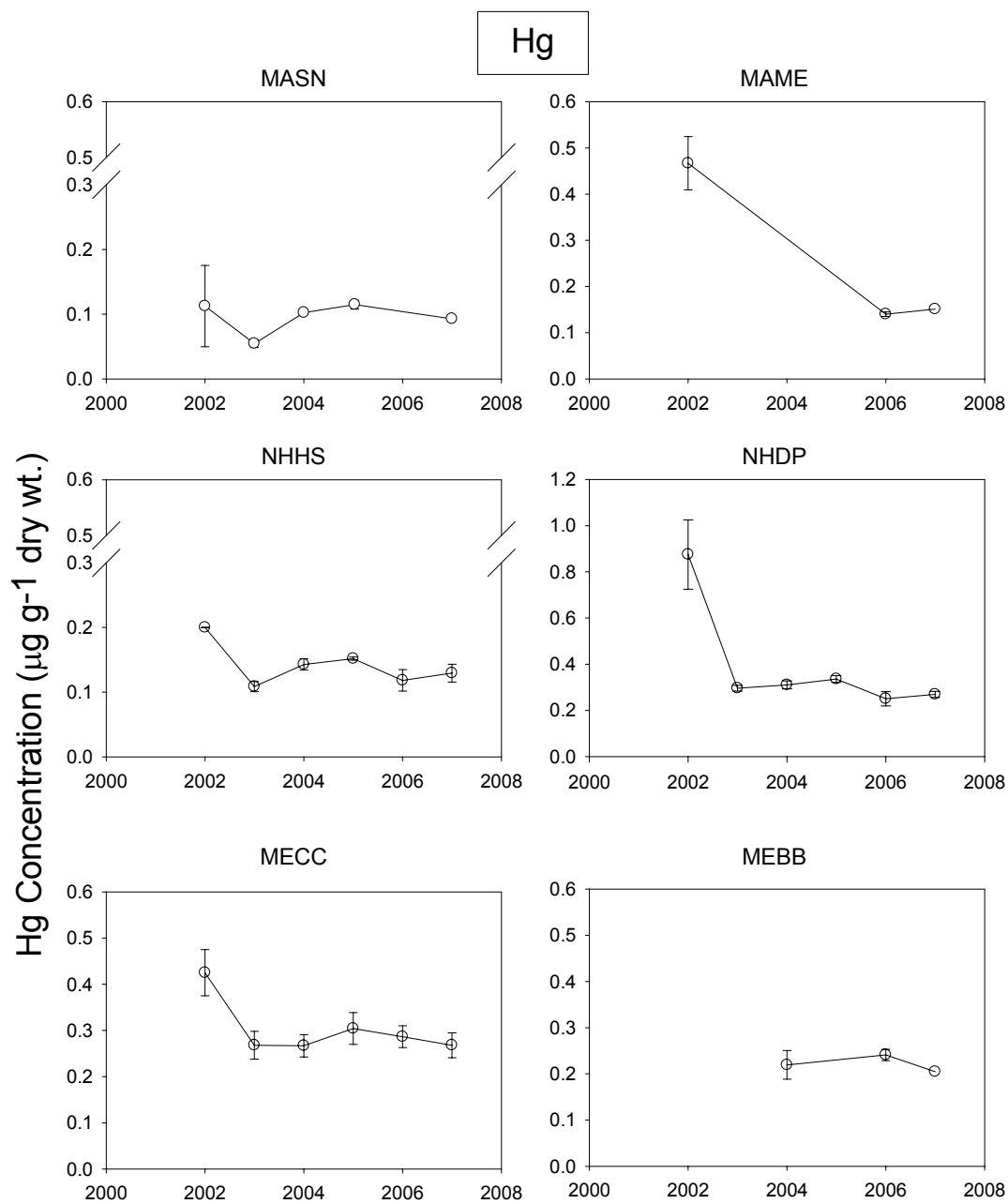


Figure 25. Distribution of mercury tissue concentrations in µg/g dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

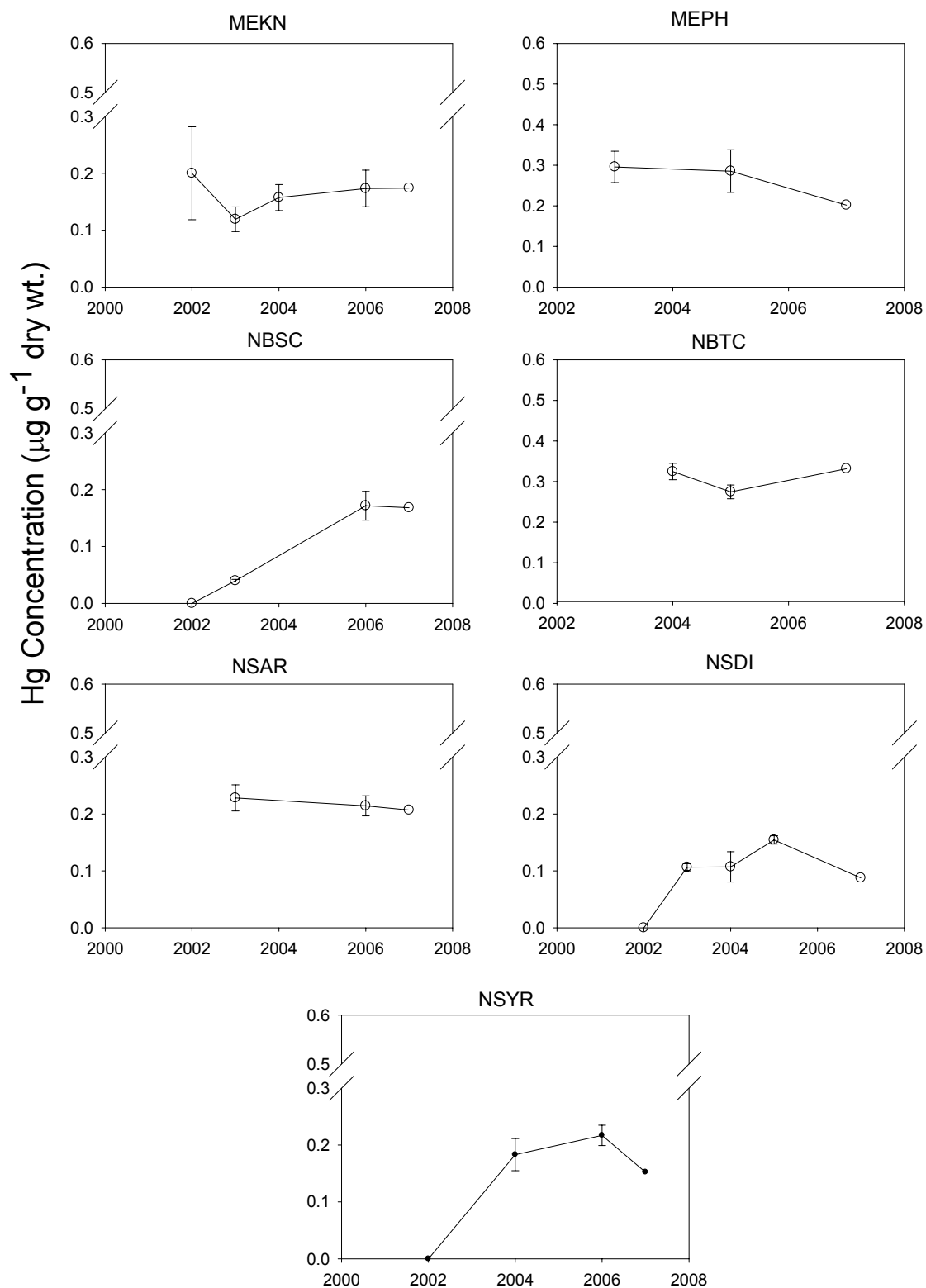


Figure 25 (cont'd). Distribution of mercury tissue concentrations in $\mu\text{g/g}$ dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

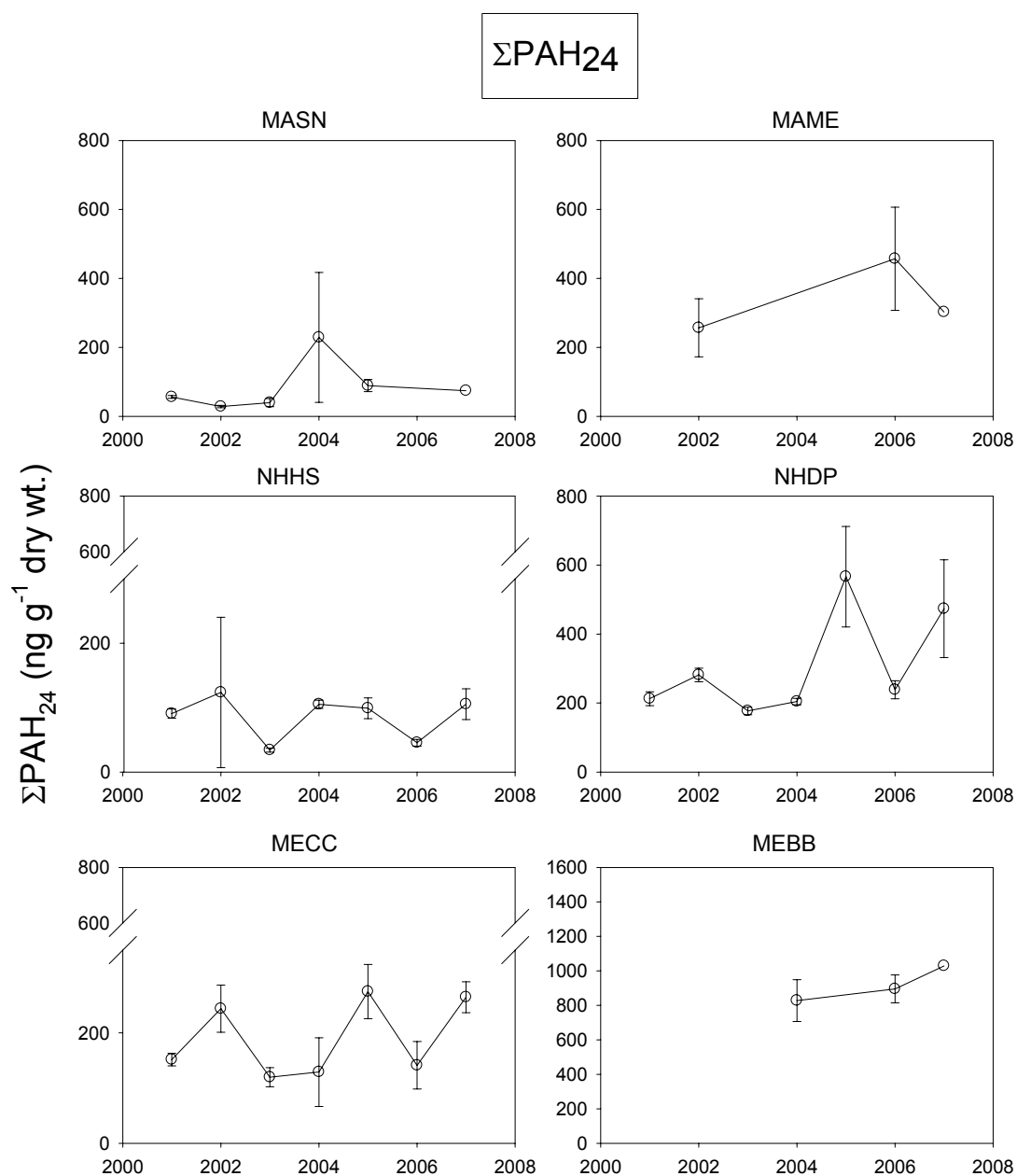


Figure 26. Distribution of the sum of 24 PAH compounds in $\mu\text{g/g}$ dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

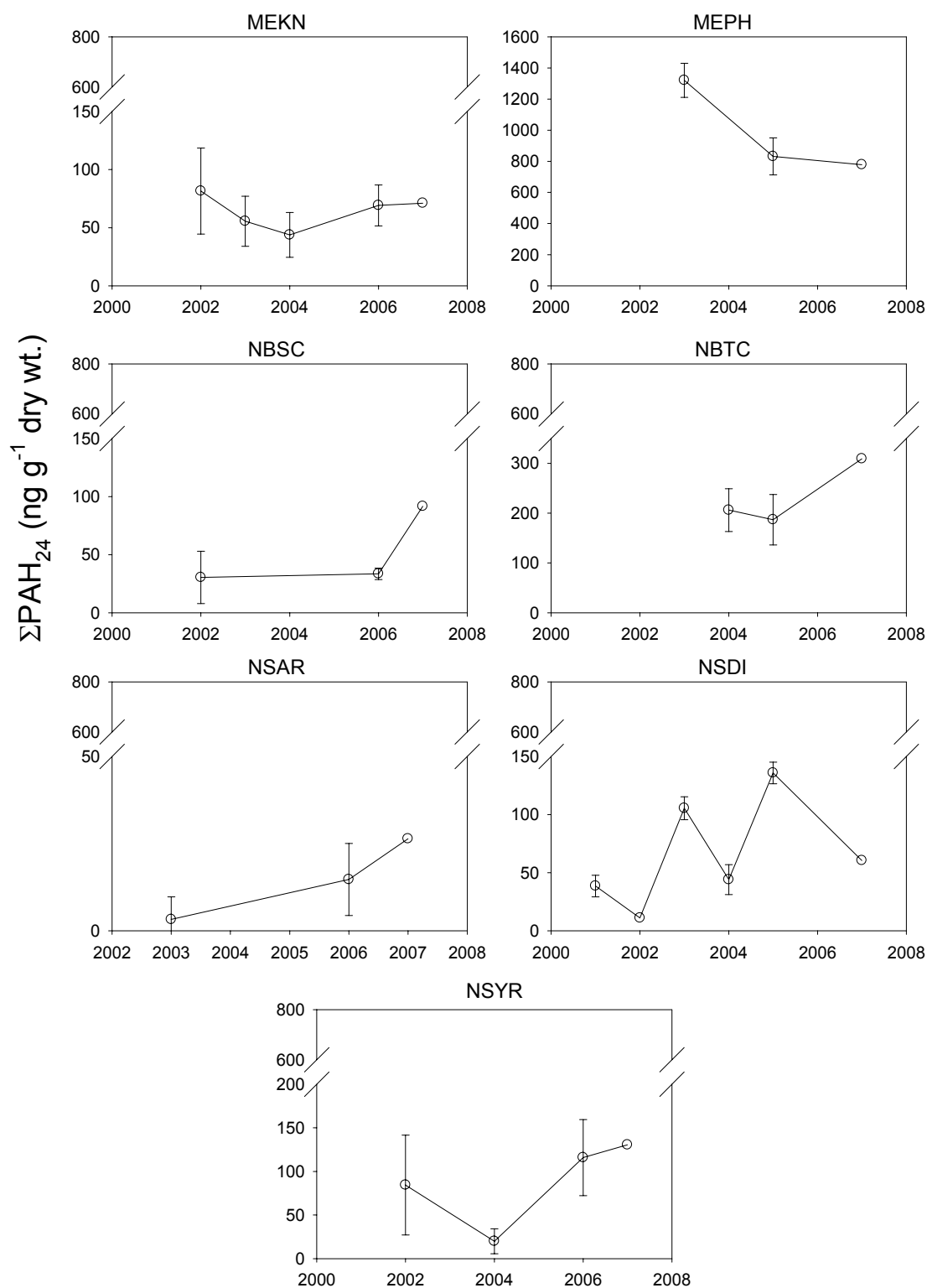


Figure 26 (cont'd). Distribution of the sum of 24 PAH compounds in $\mu\text{g/g}$ dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

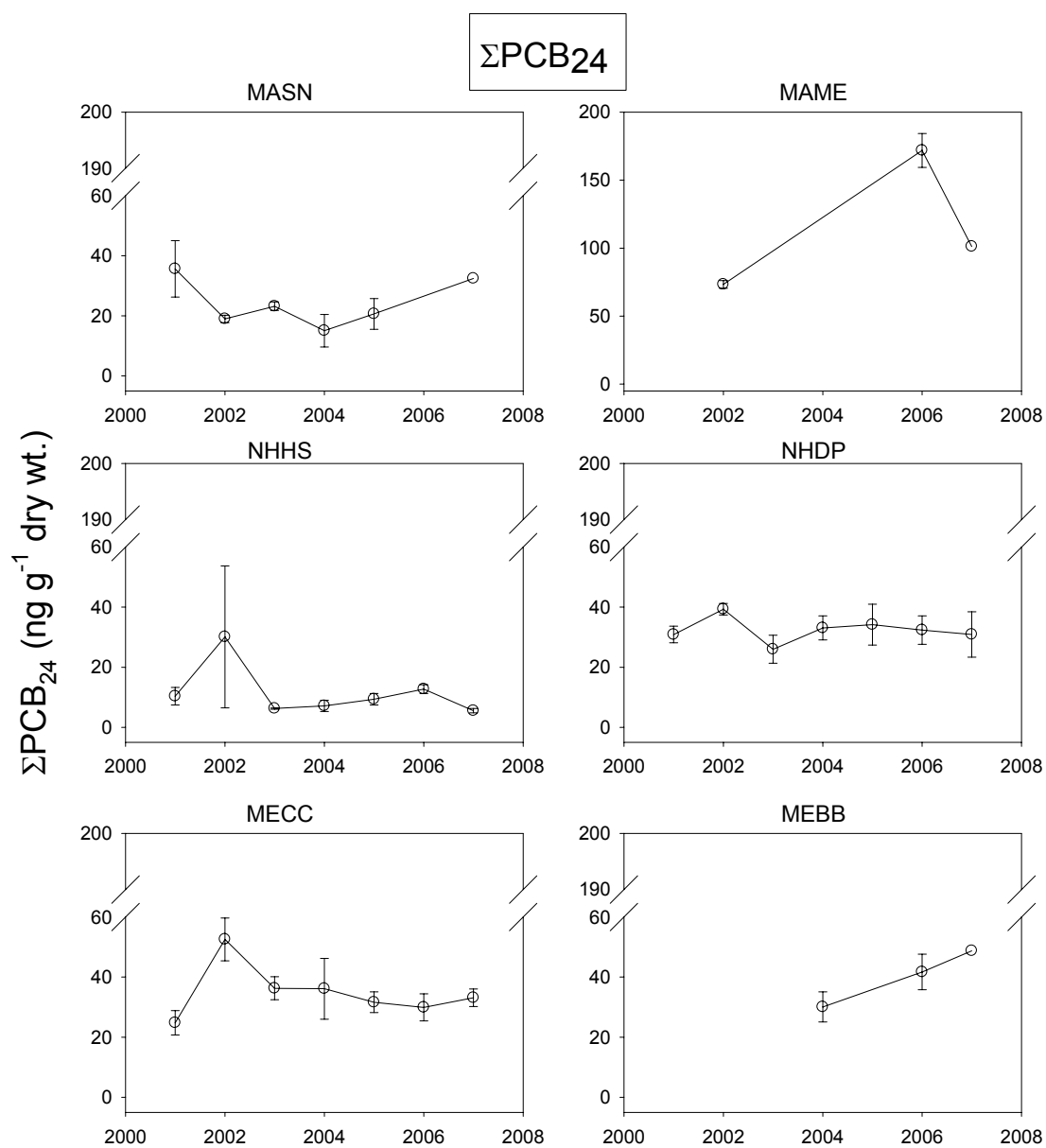


Figure 27. Distribution of the sum of 24 PCB congeners in $\mu\text{g/g}$ dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

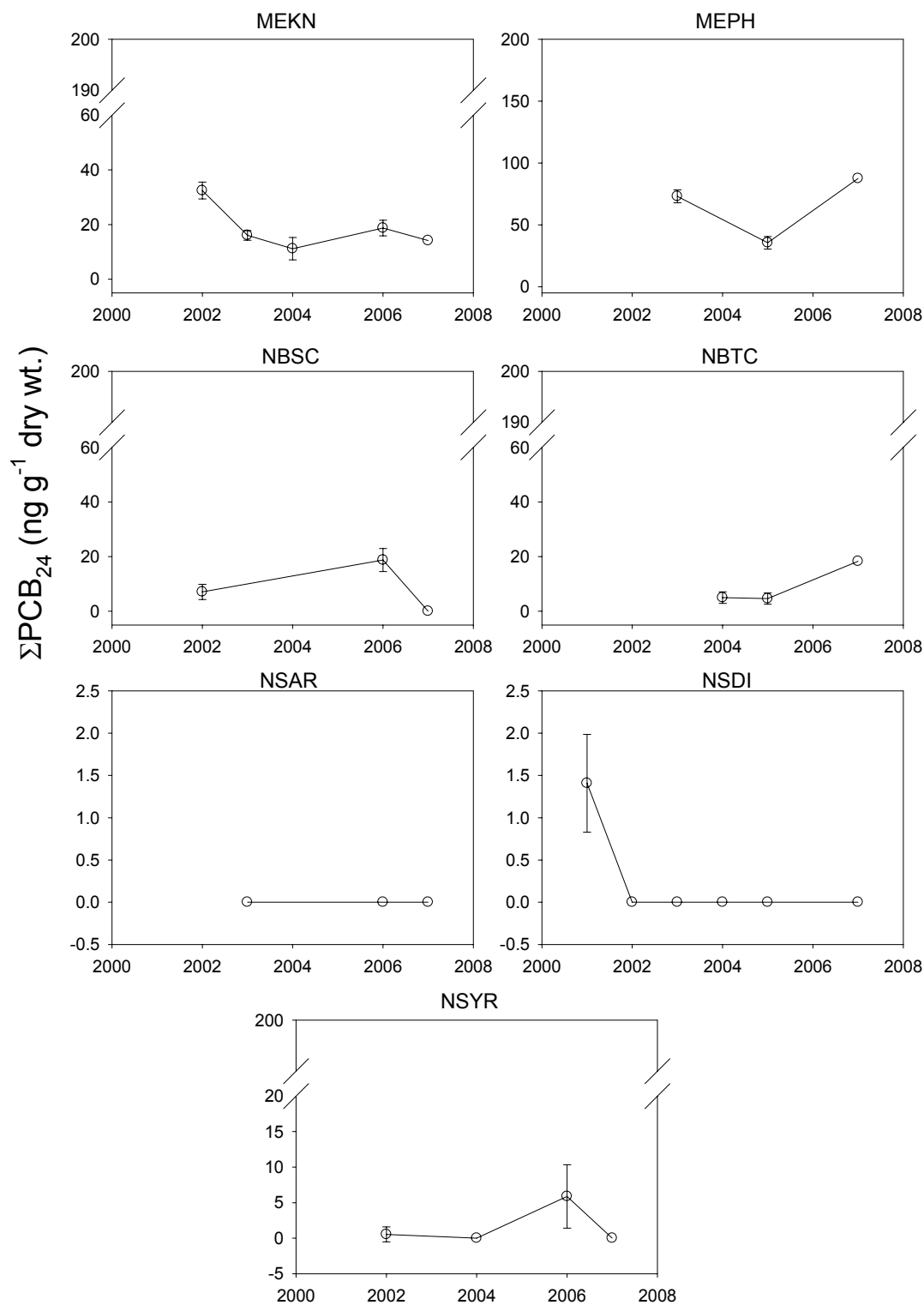


Figure 27 (cont'd). Distribution of the sum of 24 PCB congeners in $\mu\text{g/g}$ dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

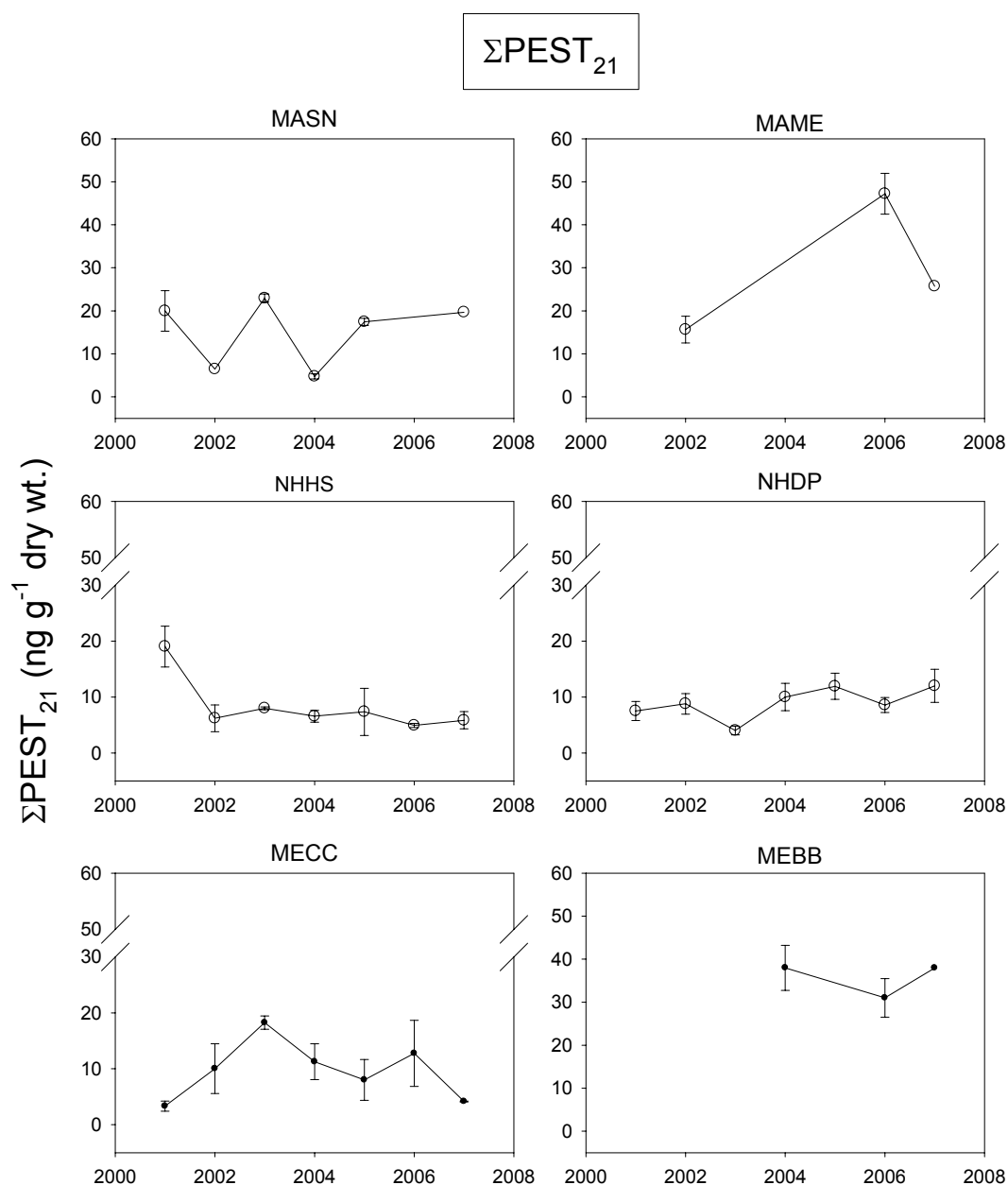


Figure 28. Distribution of the sum of 21 chlorinated pesticide compounds in $\mu\text{g/g}$ dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

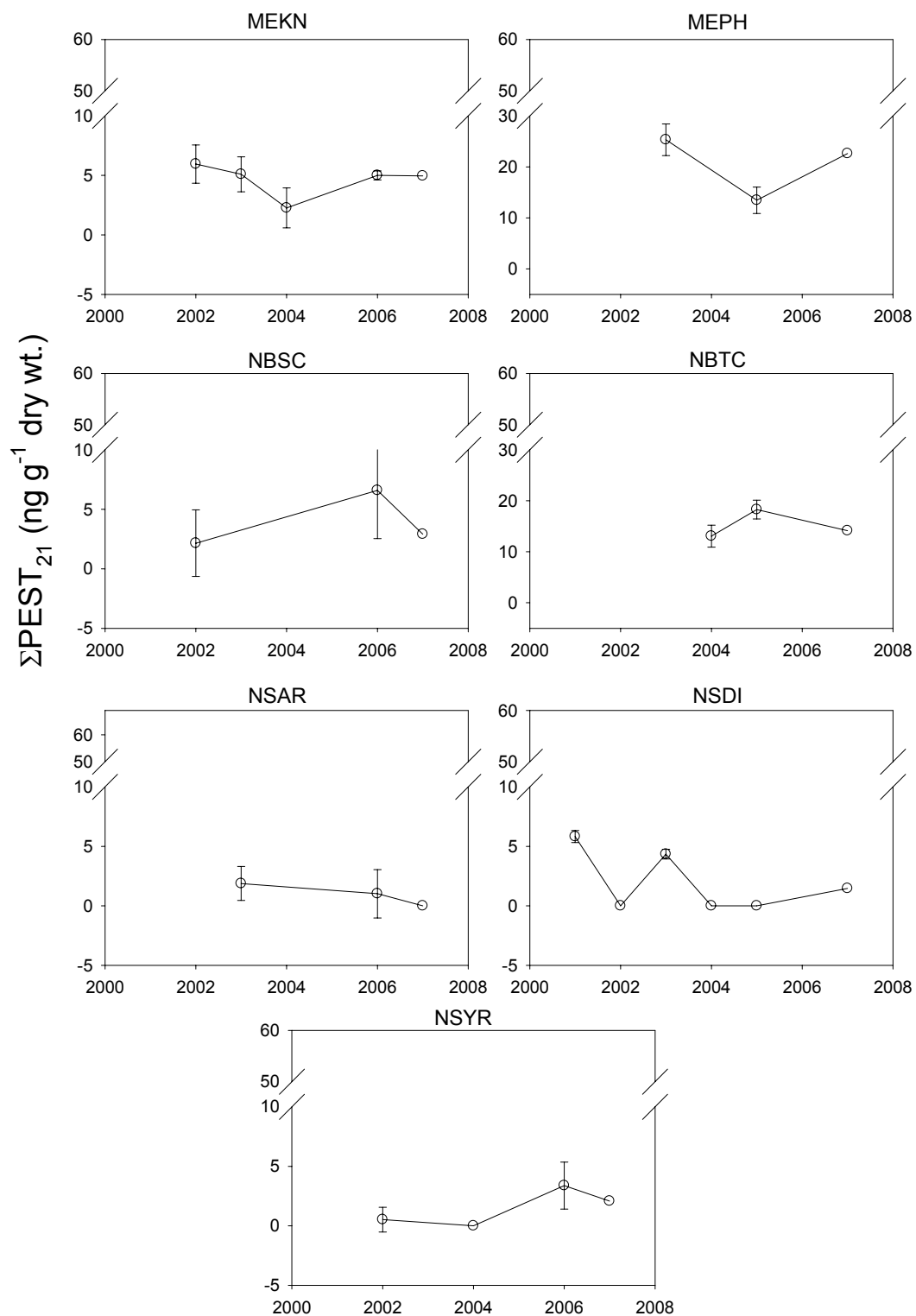


Figure 28 (cont'd). Distribution of the sum of 21 chlorinated pesticide compounds in $\mu\text{g/g}$ dry weight (arithmetic mean \pm standard deviation) in mussels at Gulfwatch trend sites in 2001-2007. For 2007 there are only single site composite values except for stations NHBC, NHDP, NHHS and MECC.

4.3 DRY WEIGHT AND LIPID FRACTIONS

Lipid content and percent wet weight (represented as % moisture) were determined on subsamples of composites, typically between 5-15 g of wet tissue, after drying to a constant weight (See §2.4.3). The mean (\pm one standard deviation) % moisture and % lipids as a function of tissue mass are plotted in Figs. 29 and 30, respectively. Percent moisture was between 82.1% - 90.3% of the overall tissue mass in 2007. Percent lipid content ranged from a low of 4.7% at Apple River (NSAR) to a high of 11.4% at Sandwich (MASN). O'Conner and Lauenstein (2006) reported an average of 8% lipid content for the mussels collected by the NOAA Mussel Watch program which is similar to the observed mean of 6.3 ± 1.8 % for the Gulfwatch Program for 2007.

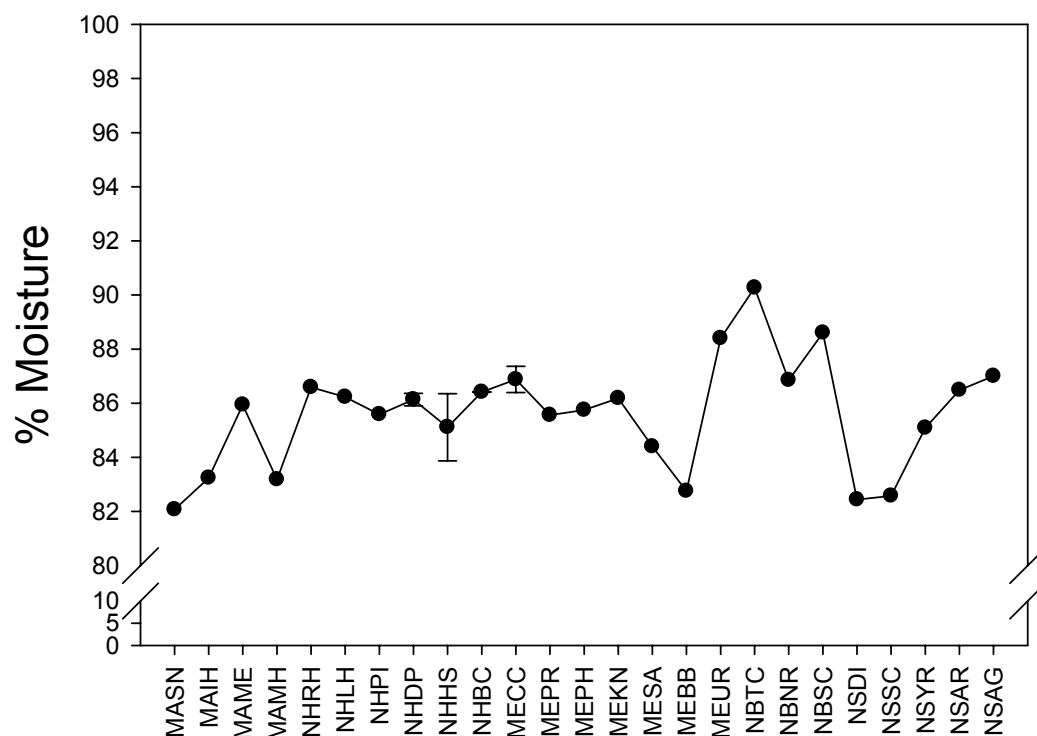


Figure 29. Mean and standard deviation of % moisture in Gulfwatch mussels collected during 2007.

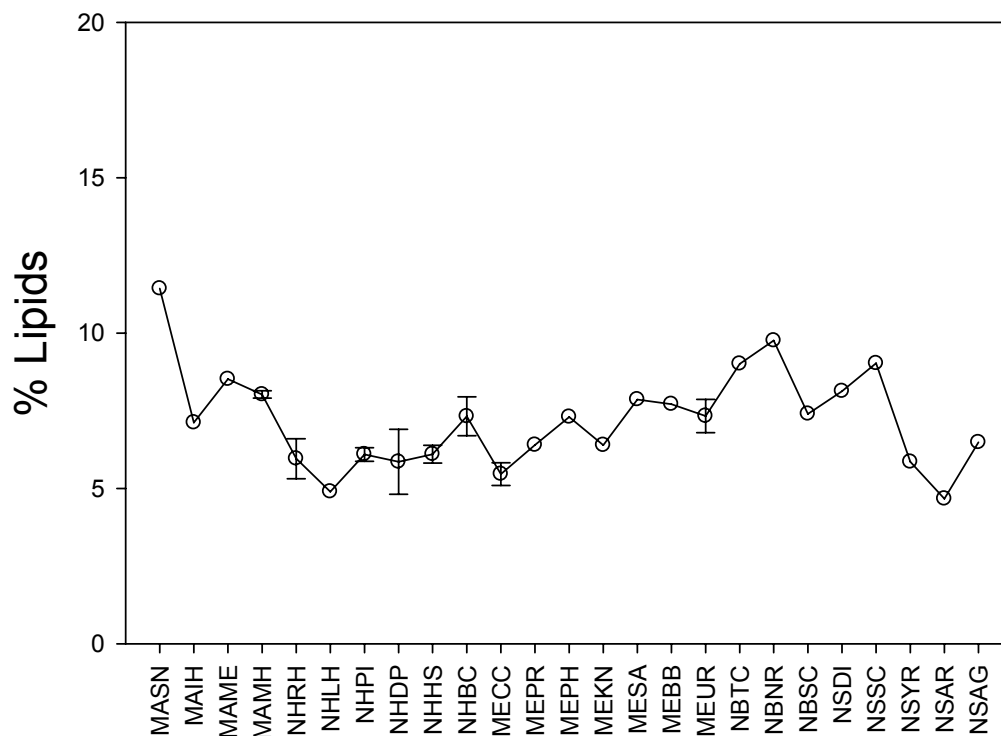


Figure 30. Mean and standard deviation of lipid content (% of tissue dry weight) in Gulfwatch mussels collected during 2007.

4.4 SHELL LENGTH AND CONDITION INDEX

Table 10 contains a summary of the morphological measurements and condition indices for mussels collected at each site in 2007. Mean condition index is plotted for all of the 2007 stations in Figure 32. Take note of the large error bars, surrounding Maine station MEUR, due to some anomalously low tissue weights.

4.4.1 Shell Morphology

Gulfwatch field collection protocol recommends collecting *M. edulis* within the length range of 50-60 mm. The gulf-wide mean shell length (\pm SD) from the 2007 sites was 55.0 ± 3.5 mm.

Table 10. Morphometric determinations and statistics (arithmetic mean, standard deviation) on mussels collected along the Gulf of Maine, 2007 Gulfwatch.

	CI ¹		Length (mm)		Height ³ (mm)		Width (mm)		n ⁴
Station	Mean	Stdev ²	Mean	Stdev	Mean	Stdev	Mean	Stdev	
MASN	0.193	0.049	55.0	4.30	29.4	2.31	24.8	2.32	20
MABI	0.150	0.059	53.2	2.79	25.2	2.56	23.5	3.35	20
MAIH	0.165	0.049	55.2	2.75	23.8	1.80	29.2	1.75	20
MAME	0.205	0.024	56.1	2.86	23.5	1.82	27.3	1.74	20
MAMH	0.239	0.028	58.8	3.81	24.1	2.46	30.3	1.62	20
NHBC	0.165	0.044	52.7	3.88	28.6	2.23	5.9	1.91	20
NHDP	0.150	0.0147	55.7	2.74	28.42	1.82	23.12	2.05	20
NHHS	0.150	0.0165	52.4	2.35	26.8	2.1	25.9	2.6	18
NHRH	0.113	0.0198	54.9	2.24	28.9	1.4	20.9	1.4	20
NHLH	0.118	0.0142	54.6	2.27	28.7	2.2	23.1	2.1	20
NHPI	0.143	0.0216	54.0	2.83	28.3	2.5	22.1	2.0	18
MECC	0.142	0.0215	53.1	2.44	28.2	1.52	22.3	2.49	17
MEBB	0.605	0.0606	55.1	2.97	30.3	1.7	22.3	2.3	60
MEPH	0.148	0.0202	55.5	2.65	28.6	1.7	22.3	2.1	60
MESA	0.171	0.0206	53.7	2.15	26.8	1.8	22.8	1.5	60
MEKN	0.176	0.0242	55.7	2.58	28.4	1.9	22.5	1.8	60
MEPR	0.156	0.0248	55.7	2.55	28.3	1.8	22.4	2.0	60
MEUR	0.220	0.3796	55.1	2.80	29.1	1.9	22.1	3.4	60
NBNR	0.194	0.045	55.6	3.72	23.5	3.36	27.3	2.99	40
NBSC	0.186	0.051	55.0	5.02	23.7	2.67	28.8	3.30	38
NBTC	0.136	0.046	57.3	4.05	21.9	1.97	26.7	1.97	40
NSYR	0.202	0.121	52.4	7.85	20.9	2.36	28.8	1.91	20
NSDI	0.193	0.030	55.4	2.71	23.3	2.00	29.5	2.33	30
NSAR	0.145	0.031	54.5	2.59	20.9	1.51	27.4	1.92	40
NSSC	0.167	0.067	55.5	5.95	23.1	2.25	28.9	1.98	40
NSAG	0.175	0.043	54.2	3.10	20.8	1.95	29.8	1.82	20

¹CI = condition index = individual tissue weight (mg)/length (mm) * height (mm) * width (mm).

²Stdev = standard deviation, ³Ht. = height (mm), ⁴n = number of mussels measured for CI determinations

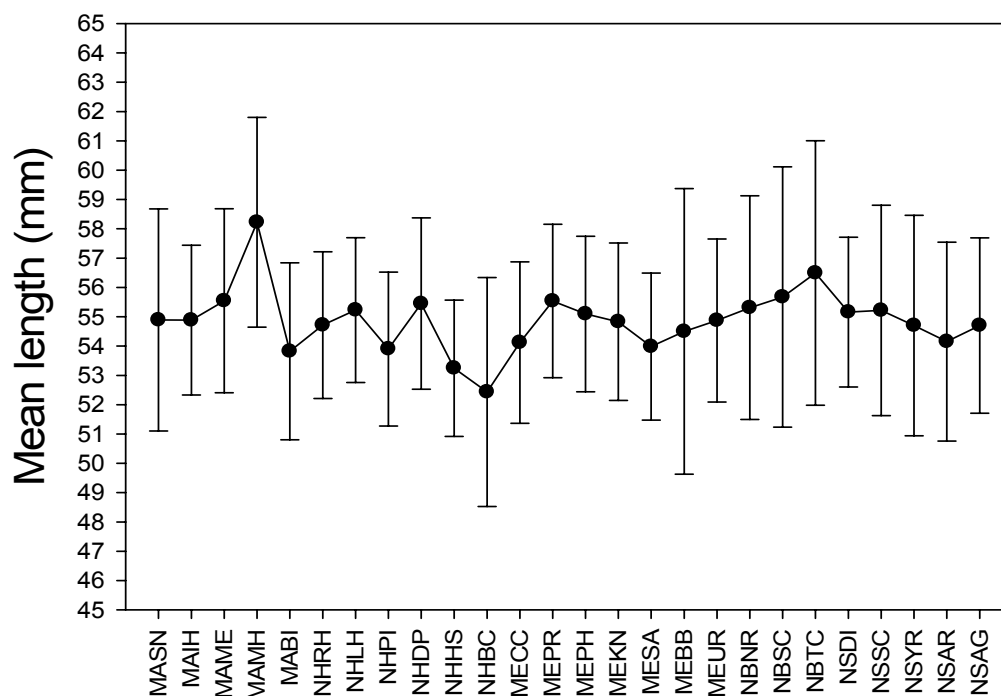


Figure 31. Mean and standard deviation of length (mm) in all Gulfwatch mussels collected for trace metal and organic analysis and archival during 2007.

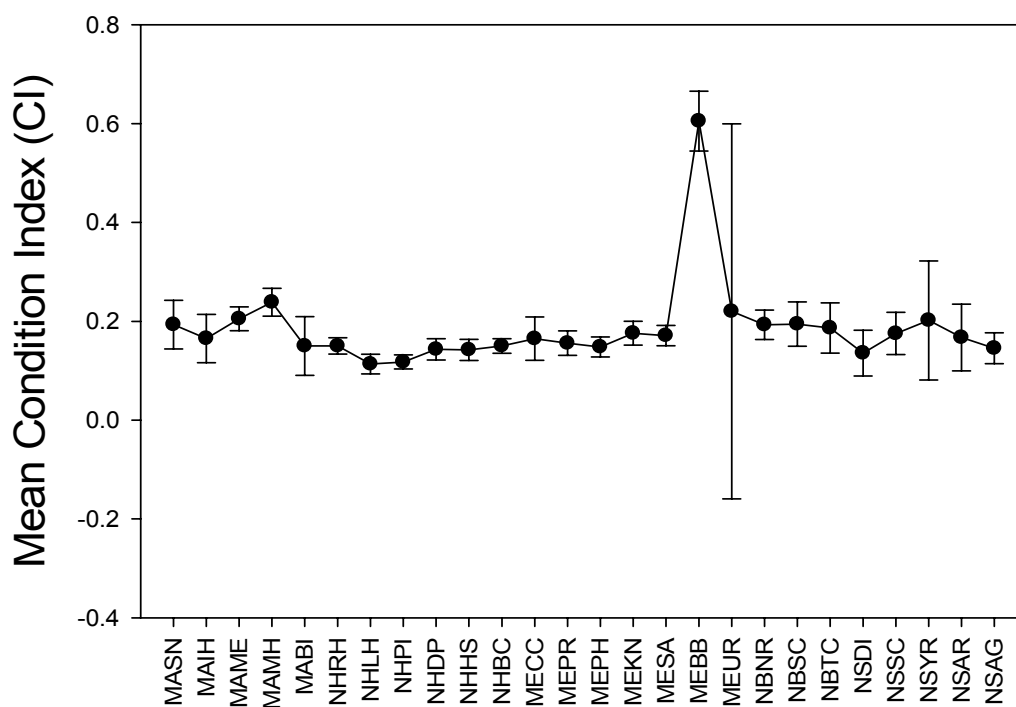


Figure 32. Mean and standard deviation condition index of Gulfwatch mussels collected during 2007.

5.0 2007 GULFWATCH SUMMARY

Monitoring of contaminants in the soft tissues of *M. edulis* from Massachusetts to Nova Scotia in the 17th year of the monitoring program continues to add information for the evaluation of temporal and spatial trends of contaminant exposure of aquatic organisms in the Gulf of Maine and, in part, meets the Goals (particularly #2) articulated in the 2007-2012 GOMC Action Plan. The 2007 Gulfwatch field season continues the modified sampling design begun in 2006, and includes four benchmark sites now re-classified as trend sites based on their unique sampling frequency (visited once every two years), nine other trend sites and twelve rotational sites (to be visited once every 6 years). As part of the New Hampshire Gulfwatch program, softshell clams were sampled at 4 sites and oysters at one site. Samples were collected, processed, and analyzed in accordance with program QC/QA protocols. All data associated with the 2007 samples are provided in the accompanying appendices.

The Gulfwatch 2007 results were qualitatively reviewed in comparison to the NOAA National Status and Trends national median concentrations. The data were additionally examined relative to the 85th percentile of the NOAA national median for 2007 which is used by Gulfwatch as the criteria for a tissue concentration to be elevated and of concern.

Temporal distributions were reviewed for some analytes across the entire region for the designated trend sites. Beginning in 2003, quality assurance and control improved and were better documented for some metals, i.e. aluminum, chromium, nickel, and mercury when Gulfwatch acquired analytical services from Battelle Marine Science Laboratory, Sequim, WA. Where noted, the change in analyte concentrations should be taken into consideration for any future time trend analysis relative to pre-2003 QC/QA data quality objectives. Quantitative temporal and spatial analysis of the data is beyond the scope of this report.

Given the above caveats, the status of contaminants in near shore areas around the Gulf of Maine suggests the more heavily populated/industrialized coastal areas of the Gulf of Maine have higher contaminant levels compared to locations with smaller communities and less industrial activity. High concentrations are not confined solely to the south and western regions of the Gulf, as elevated concentrations were also observed at sites throughout the region. Lead and mercury exceeded the 85th percentile of the NOAA national median at several sites, mostly located in MA, NH, and ME. Lead was elevated at MAIH and MAMH in Massachusetts, NHLH and NHPI in New Hampshire and MEPH and MEPR in Maine. Mercury was found to be elevated at NHBC, NHLH, NHPI and NHRH in New Hampshire, MECC in Maine, and NBTC in New Brunswick. Kimbrough, et al., (2008) reported the status of lead and mercury contamination in blue mussel tissue on a regional and national basis. Overall, contaminants in mussels were considered high among sites in MA, and NH, and low in ME. However Gulfwatch monitoring detected elevated concentrations of lead at 4 sites and mercury at one site in Maine. In Canada, elevated levels of aluminum were found in two New Brunswick sites (NBSC and NBTC) and one Nova Scotia site (NSAR). Elevated chromium and mercury was found at Tin Can Beach (NBTC) in New Brunswick, and elevated lead at Argyle Sound (NSAG-1N) in Nova Scotia. However, it should be noted that sites in the northernmost portions of the Gulf are highly turbid and high metals concentrations (especially aluminum and iron) are believed to be primarily from natural (crustal) sources.

Organic contaminants exceeded the 85th percentile of the NOAA national median at sites in Massachusetts for PAHs (MAIH and MAMH), PCBs (MAMH) and chlorinated pesticides (MAMH). In Maine elevated levels of PAHs were seen at sites MEPH and MEBB, and elevated pesticide concentrates at MEBB. Sites throughout New England had concentrations that exceeded the NS&T median values. ΣPAH_{24} and ΣPAH_{40} exceeded median NS&T values at Tin Can Beach (NBTC), New Brunswick. No sites in New Brunswick or Nova Scotia exceeded either of these criteria for organic contaminants.

Hot spots were apparent, with Boston Inner Harbor (MAIH) being especially elevated in PAHs and PCBs and lead, Marblehead being elevated in chlorinated pesticides and lead, Portland Harbor (MEPH) and Boothbay Harbor (MEBB) being elevated in PAHs and lead. Readers may wish to examine contaminant results in the appendices for further analyses.

When the Gulf of Maine Council was formed, it recognized the need to provide all jurisdictions with contaminant information to enable improved capability to assess, understand, and, where necessary, respond to issues involving contaminants, ecosystem health, and human health. Thus, the GOMC created the Gulfwatch Program, the only marine contaminant monitoring program conducted jointly by the United States and Canada. Gulfwatch continues to monitor contaminants in the Gulf of Maine to address the goals established by the Council and articulated in their 2007-2012 Action Plan. The program continues to refine temporal and spatial sampling and analytical protocols to provide information for coastal resource managers who make decisions on issues related to contaminants in near shore waters of the Gulf of Maine. The Gulfwatch 2007 data report provides contaminant information for this purpose and to inform researchers and others living around the Gulf of Maine Environment.

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