



Gulf of Maine
Council on the
Marine Environment

Gulfwatch: **Blue Mussel Monitoring for Toxic Chemicals in the Gulf of Maine**

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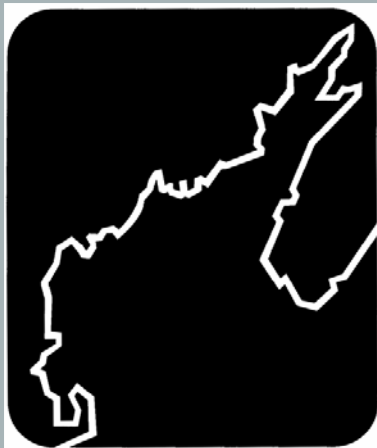


Gulf of Maine



The Gulfwatch Program

- Blue mussel monitoring program in GOM;
- Participation by volunteer environmental & resource managers and scientists in the two bordering countries and in all 5 jurisdictions:
 - US- MA, NH, ME
 - CA- NB, NS
- Supported (chemical analyses; data interpretation & report writing) by the-->



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Marine Environment**

The Gulfwatch Program

- GOM Council (1990) recognized significant gap in regional information on trans-boundary issue of toxic chemicals;
- Small pilot project initiated (1991-92) to determine feasibility/logistics of conducting coordinated Gulf-wide monitoring program;
- Geographically & temporally expanded program (1993-2004) objectives.
- New 12-year design (2005-2016) based on previous 12-year results and changing needs.



Program Goals & Objectives

Goals: Environmental Quality Monitoring Committee

1. *Provide information on the status, trends and sources of risks from chemical contaminants to the marine environment.*
2. *Provide information on the status, trends and sources of risks from chemical contaminants to human health.*
3. *Provide appropriate and timely information to environmental and resource managers that will allow efficient and effective management action.*

Objectives: Gulfwatch Program

- Monitor long-term trends in toxic contaminants in mussels at sites suspected of representing different levels of contamination;
- Identify areas of significant pollution and areal extent of contamination.



Sample Collection and Analysis

Sampling design (QAPP):

- maximizes spatial coverage, and
- generates data for long term temporal trends analysis.

38 collection sites consist of three types:

- ▲ **benchmark stations** *are sampled every year (5)*
- ▲ **rotational stations** *are sampled every third year (27)*
- ▲ **multi-year stations** *were sampled 4 - 6 years (6)*

On occasion, 18 other sites of interest to the program have been sampled on a less frequent basis during 1993 - 2004.



The Gulfwatch Program

- Ubiquitous *Mytilus edulis* used as indicator of habitat exposure to toxic (organic and trace metal) chemicals;
- Defined size range provides consistent measure of temporal exposure between sites;
- Long-term mussel sampling at sites on a rotational basis to provide temporal baseline of data.



The Gulfwatch Program

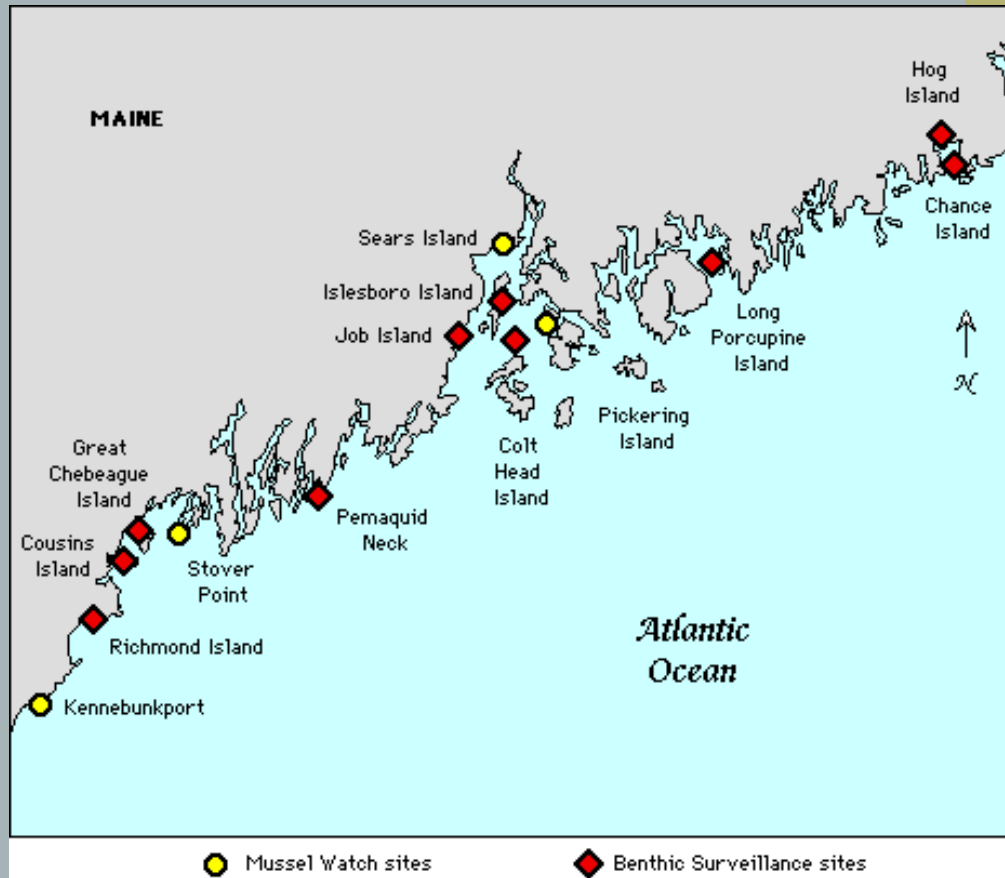
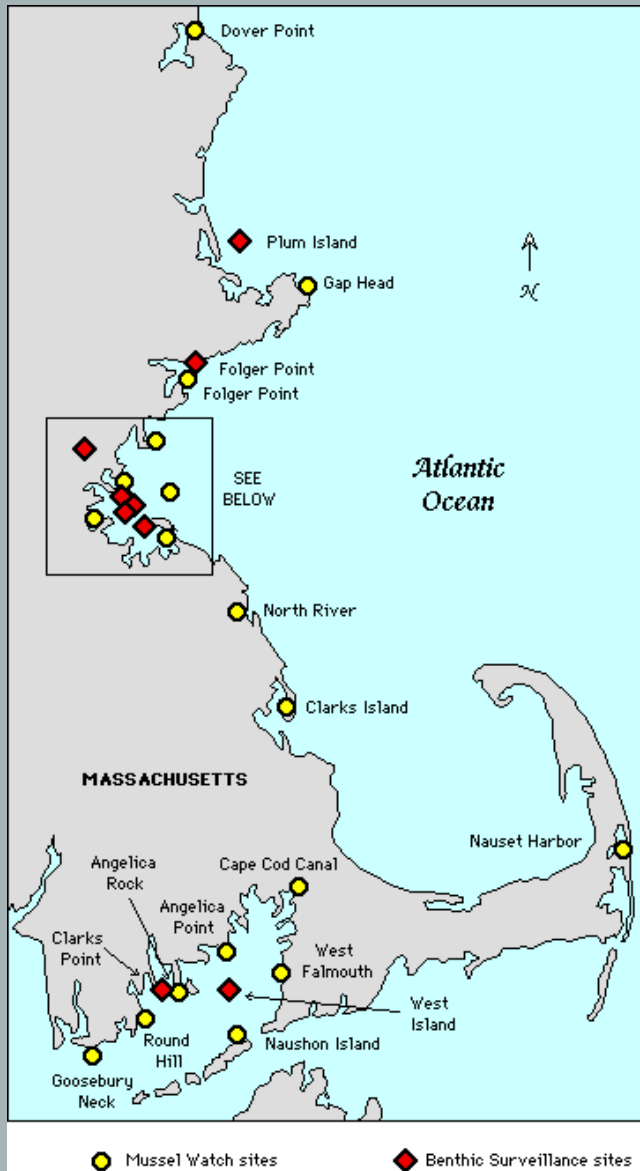
- Program design is almost the same as the NOAA NS&T Mussel Watch Program, with a few **exceptions**;

- sites in Canada included;
- sampling conducted in early autumn instead of spring to allow for sampling in Bay of Fundy;
- 3 year rotation of sites instead of 2 year rotation;
- Gulfwatch more geographically comprehensive in region:
 - GW= ~60 sites in GOM
 - MW= 14 sites in GOM

- Some overlap in sites (5) between programs.

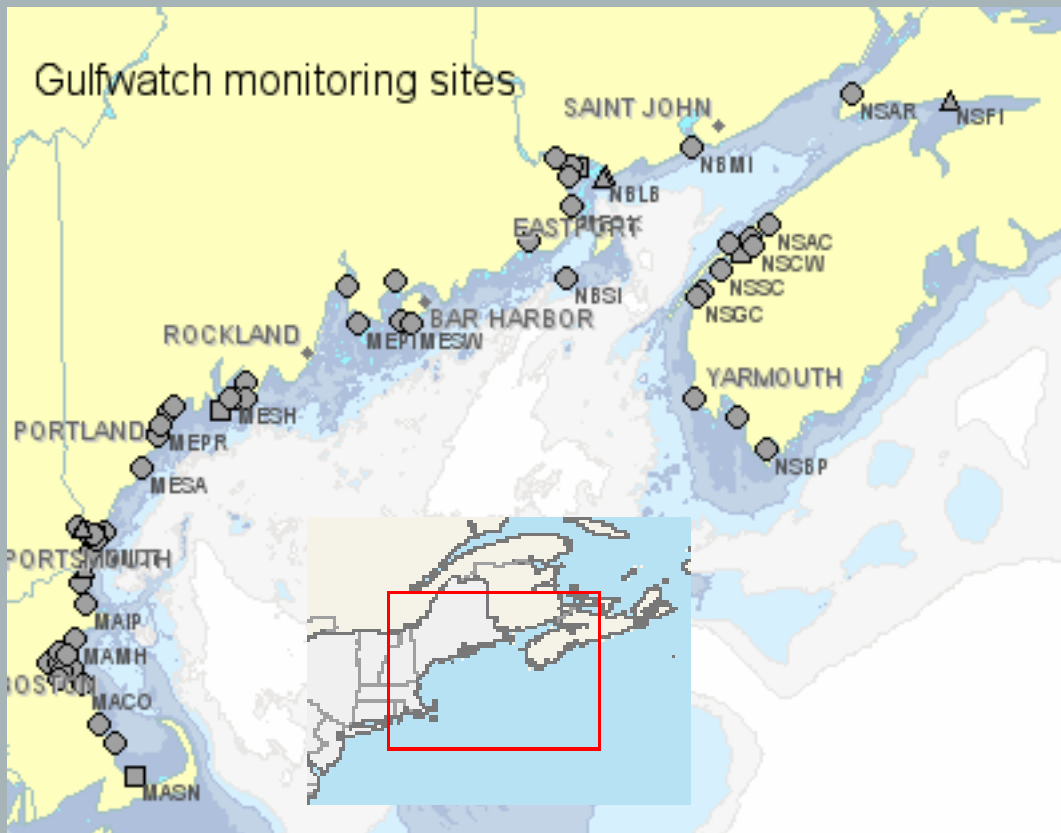


NOAA NS&T GOM Sites



Overview of Gulfwatch Sampling Sites

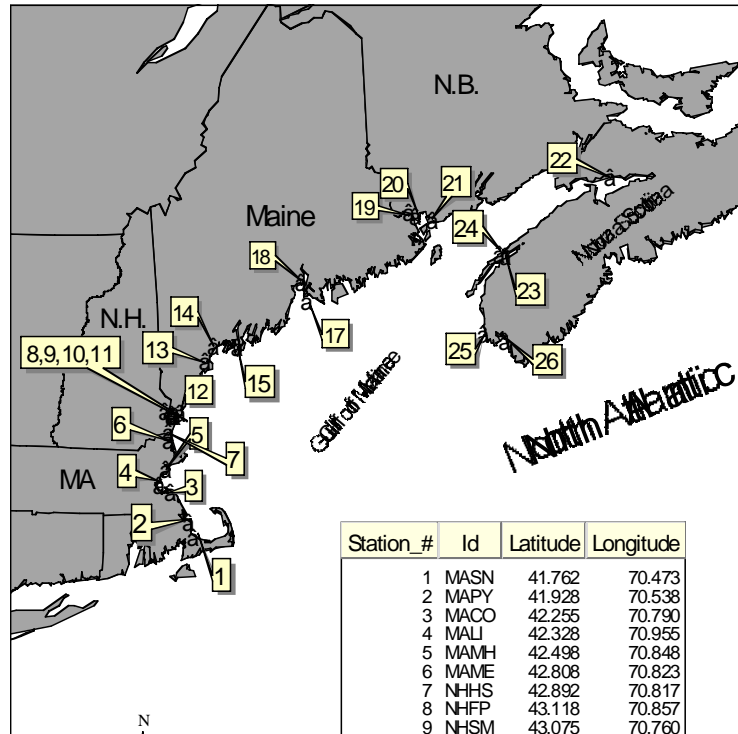
- international contaminants monitoring program involving three states and two provinces



Each fall, blue mussels (*Mytilus edulis*) are collected from inter-tidal areas in coastal embayments around the Gulf of Maine and Bay of Fundy.



1999 Gulfwatch sampling sites



Station #	Id	Latitude	Longitude
1	MASN	41.762	70.473
2	MAPY	41.928	70.538
3	MACO	42.255	70.790
4	MALI	42.328	70.955
5	MAMH	42.498	70.848
6	MAME	42.808	70.823
7	NHHS	42.892	70.817
8	NHFP	43.118	70.857
9	NHSM	43.075	70.760
10	NHPI	43.072	70.743
11	NHPA	43.085	70.758
12	MECC	43.067	70.723
13	MEBH	43.093	70.653
14	MERY	43.797	70.147
15	MEKN	43.792	69.793
16	MEFP	44.472	68.815
17	MEPI	44.260	68.730
18	MEFR	43.646	70.255
19	NBSC	45.167	67.162
20	NBHI	45.123	67.053
21	NBLN	45.077	66.800
22	NSFI	45.395	64.067
23	NSDI	44.635	65.745
24	NSBC	44.668	65.830
25	NSYR	43.818	66.143
26	NSAG	43.739	65.844



Methods

- ▶ *Four replicates of 50 mussels 50-60 mm in length collected from each site;*
- ▶ *Mussels collected from subtidal, protected shoreline during mid-September to mid-November;*
- ▶ *Shuck 20/rep for metals (plastic knife) and 20/rep for organics (metal knife);*
- ▶ *Sample at 21-22 sites each year, including 5 “benchmark” sites, one in each jurisdiction, that are sampled each year.*



INORGANIC CONTAMINANTS

Metals

Ag, Al, Cd, Cr, Cu, Fe, Hg, Ni, Pb, Zn

ORGANIC CONTAMINANTS

Aromatic Hydrocarbons

Naphthalene
1-Methylnaphthalene
2-Methylnaphthalene
Biphenyl
2,6-Dimethylnaphthalene
Acenaphthylene
Acenaphthalene
2,3,5-Trimethylnaphthalene
Fluorene
Phenanthrene
Anthracene
1-Methylphenanthrene
Fluoranthrene
Pyrene
Benzo[a]anthracene
Chrysene
Benzo[b]fluoranthrene
Benzo[k]fluoranthrene
Benzo[e]pyrene
Benzo[a]pyrene
Perylene
Indo[1,2,3-cd]pyrene
Dibenz[e,ah]anthracene
Benzo[ghi]perylene

Chlorinated Pesticides

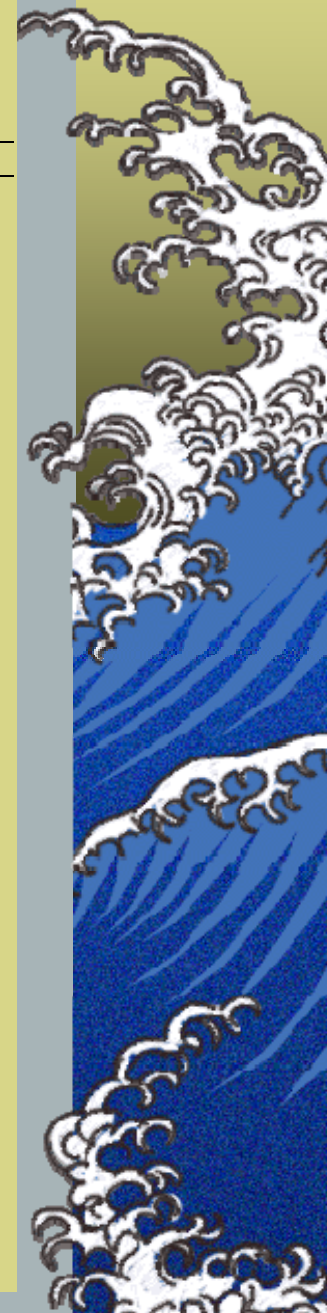
Hexachlorobenzene (HCB)
gamma-Benzenehexachloride (BHC)
Heptachlor
Heptachlor epoxide
Aldrin
Lindane
cis-Chlordane
trans-Nonachlor
Dieldrin
alpha-Endosulfan
beta-Endosulfan

DDT and Homologues

2,4'-DDE	4,4'-DDE
2,4'-DDD	4,4'-DDD
2,4'-DDT	4,4'-DDT

PCB Congeners

PCB 8, PCB 18, PCB 28, PCB 29,
PCB 44, PCB 50, PCB 52, PCB 66,
PCB 77, PCB 87, PCB 101, PCB 105,
PCB 118, PCB 126, PCB 128, PCB 138,
PCB 153, PCB 169, PCB 170, PCB 180,
PCB 187, PCB 195, PCB 206, PCB 209



Methods

- ▶ *Metals analyzed by atomic adsorption;*
- ▶ *Organics analyzed by HRGC/ECD (pesticides and PCBs) or HRGC/MS (PAHs);*
- ▶ *Dioxins & furans analyzed in subset of sites 1996-99.*



Uses of Gulfwatch Data and Information

- **Management and Policy**
- **Monitoring**
- **Aquaculture and Commercial Fishing**
- **Impact /Damage and Remediation Assessment**
- **Education**

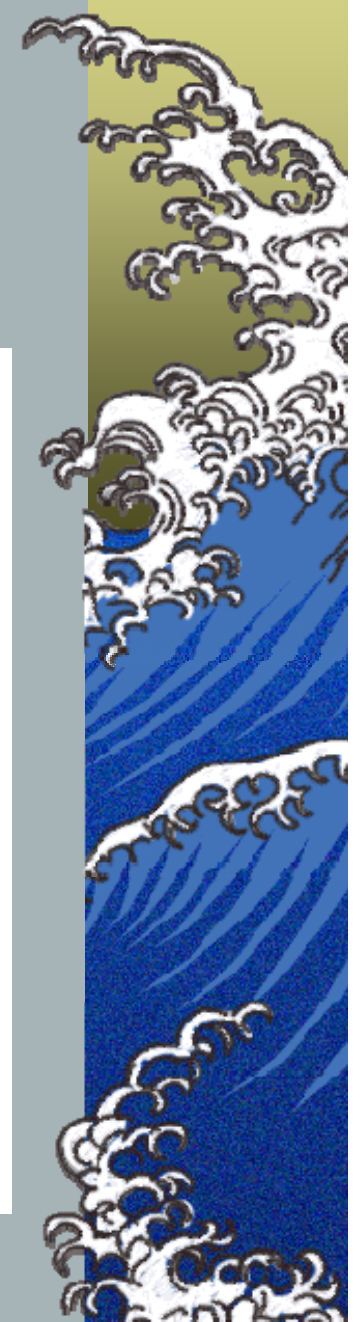
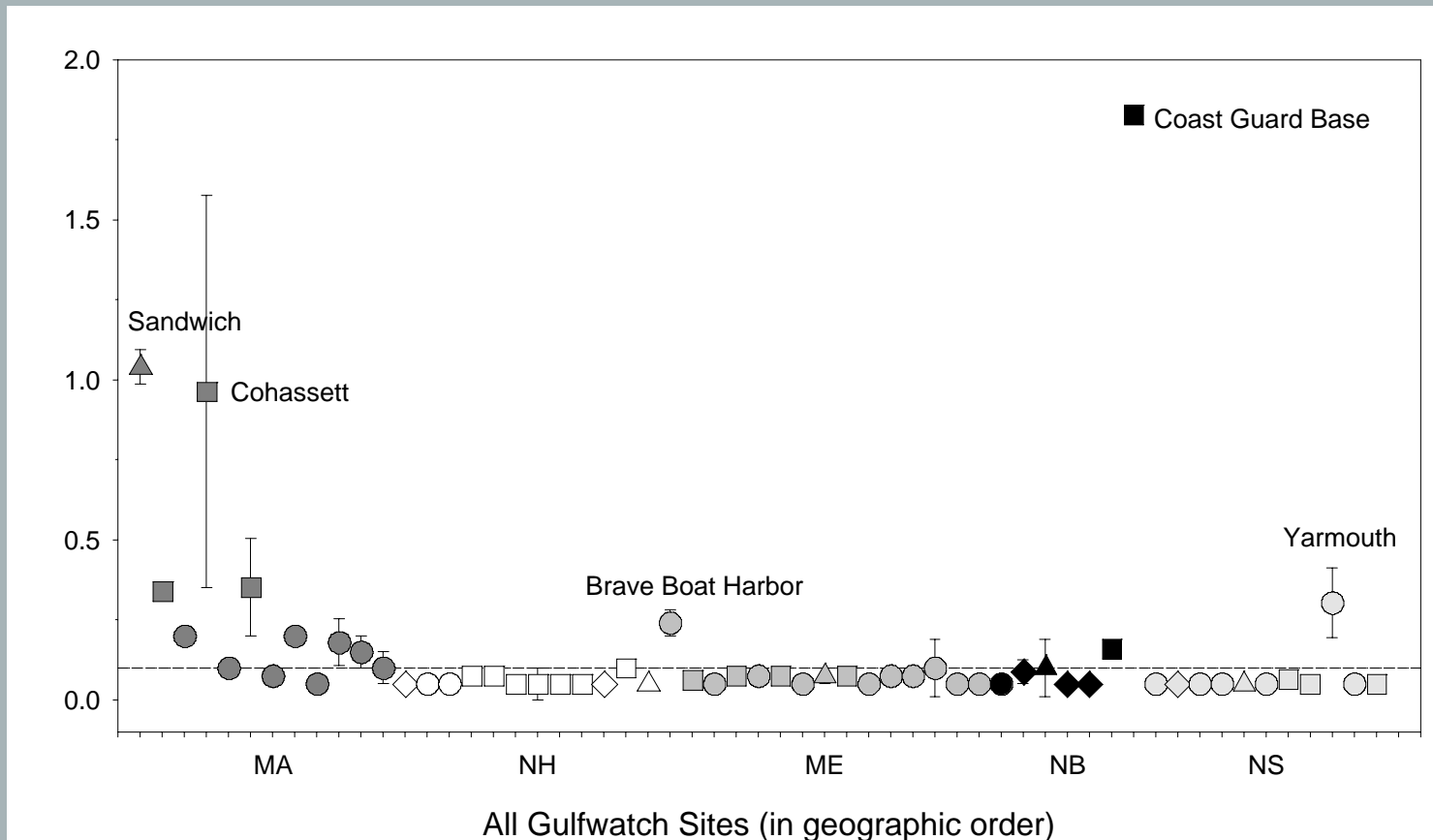


RESULTS

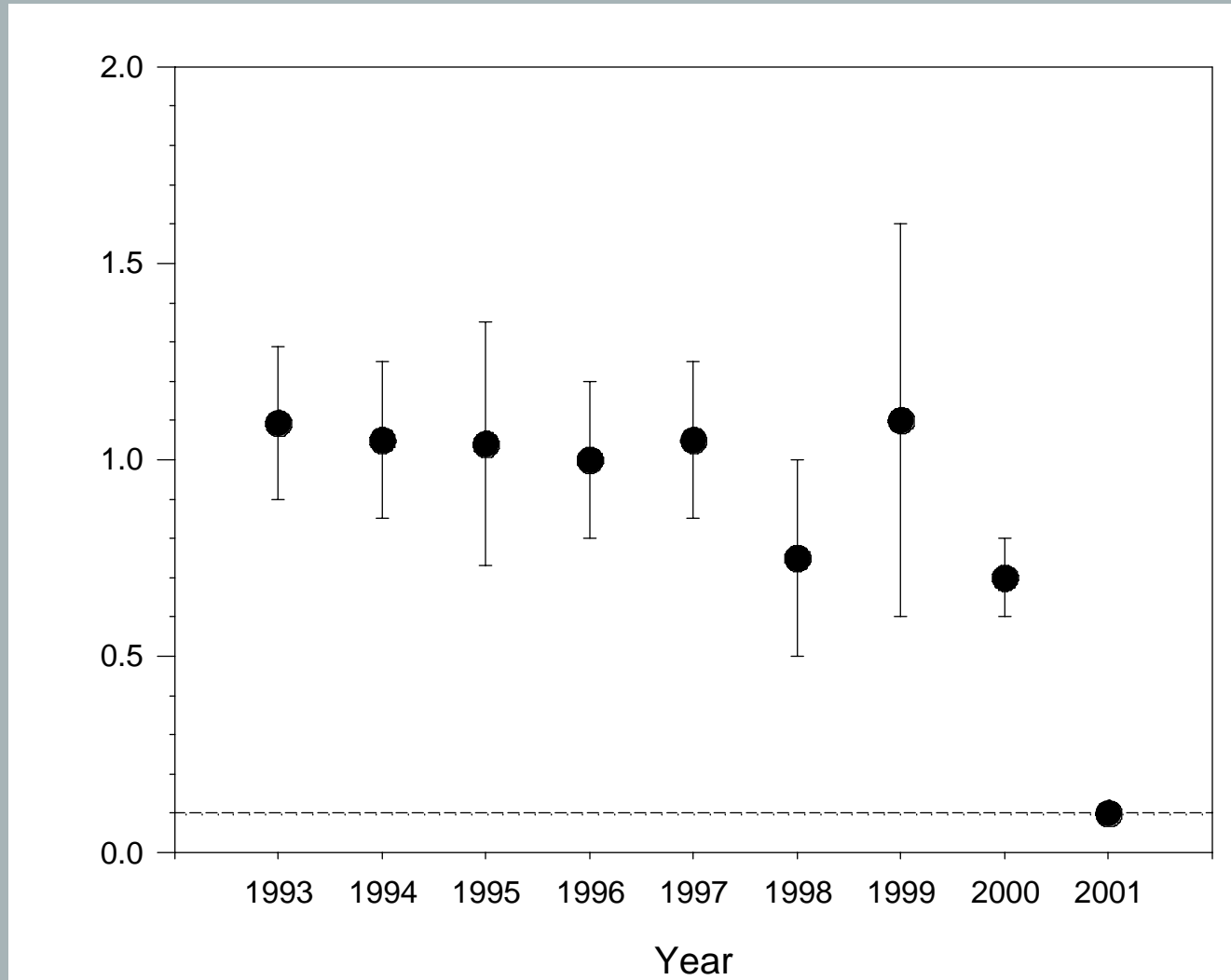
- 1993-2001/2004 spatial & temporal trends
- NH compared to regional program
- Oil spill effects



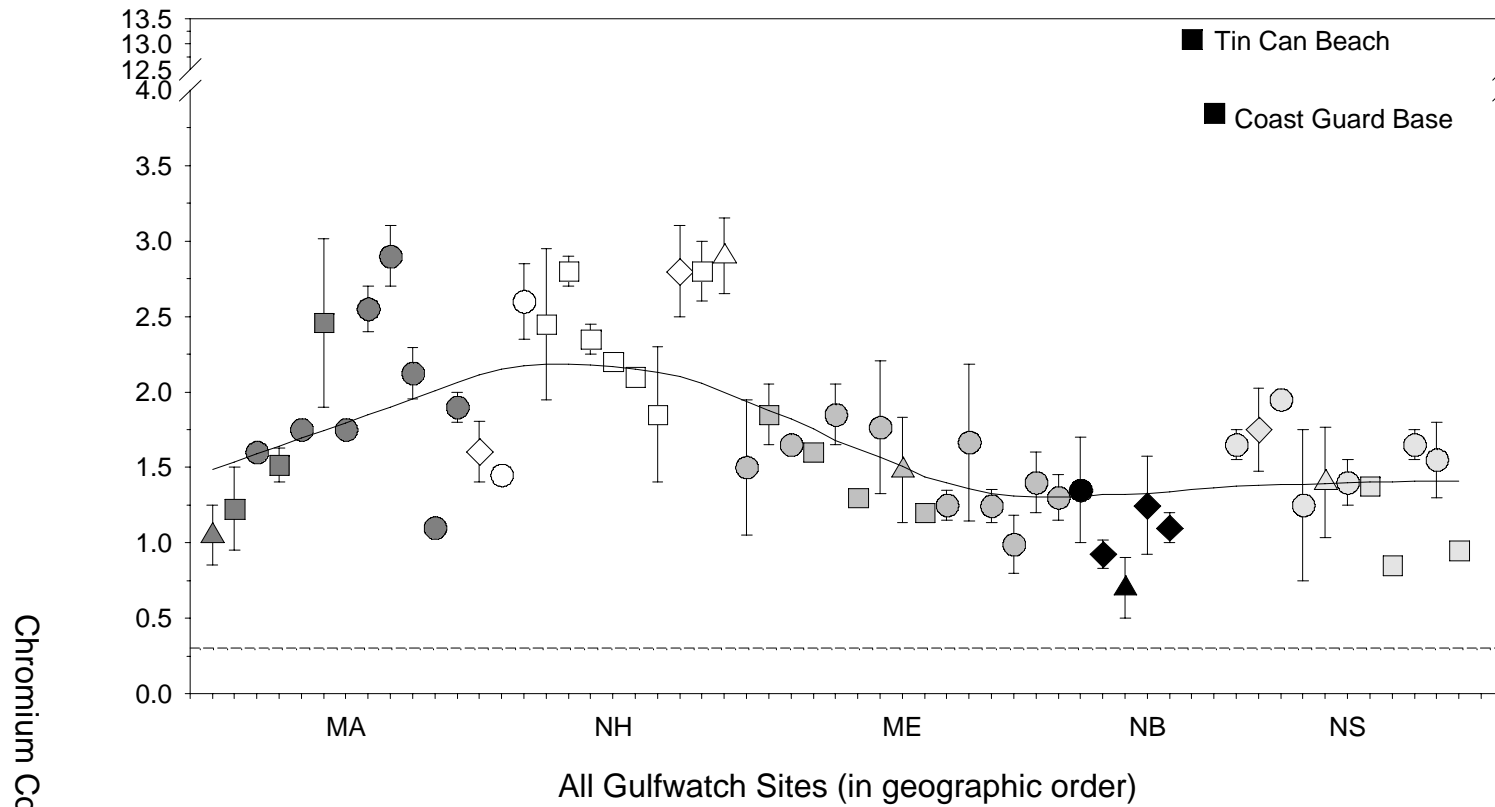
Silver concentrations (ppm) in blue mussels at all GOM sites: Site median values 1993-2001



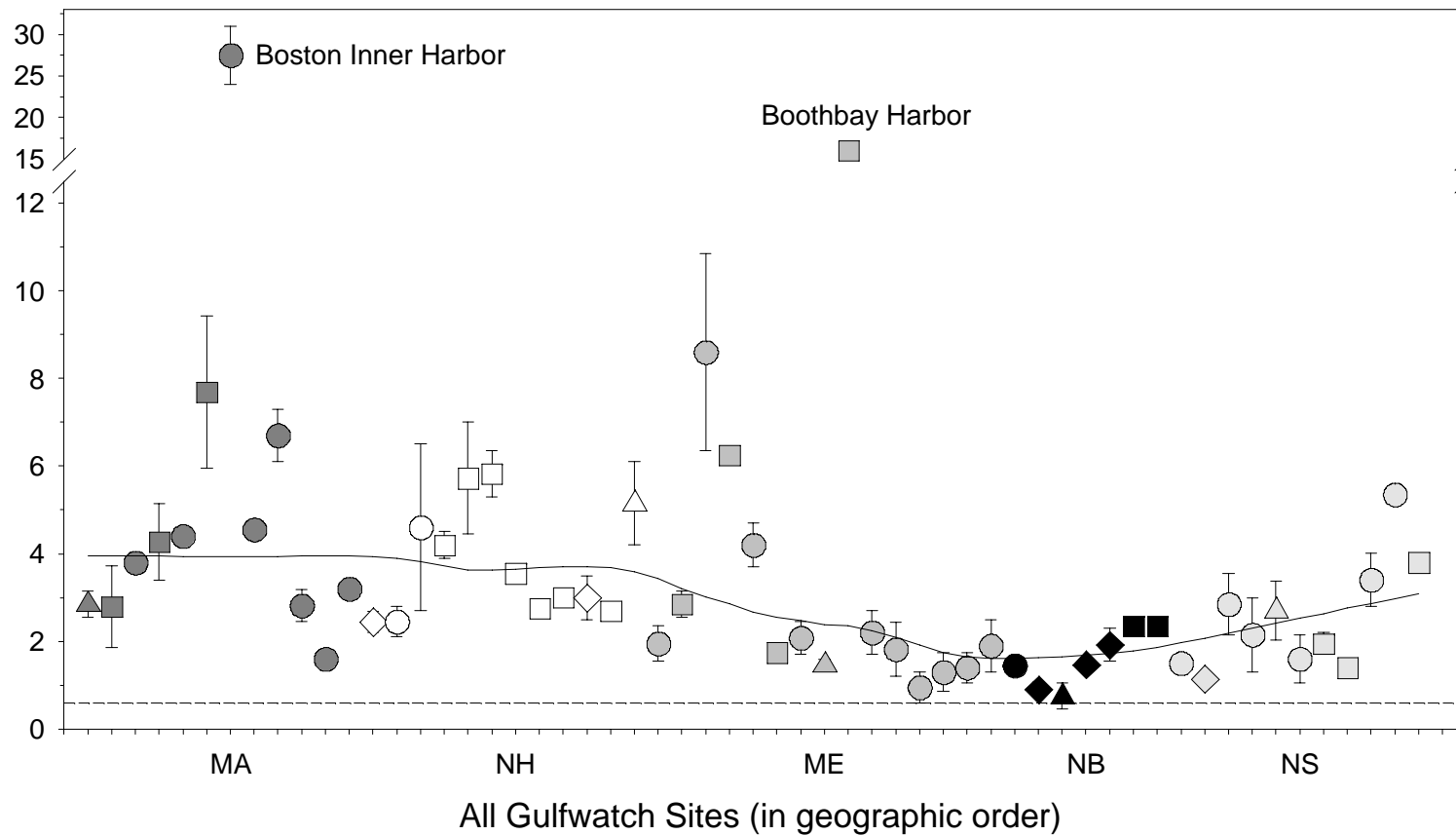
Silver concentrations (ppm) in mussels with time at Sandwich, MA



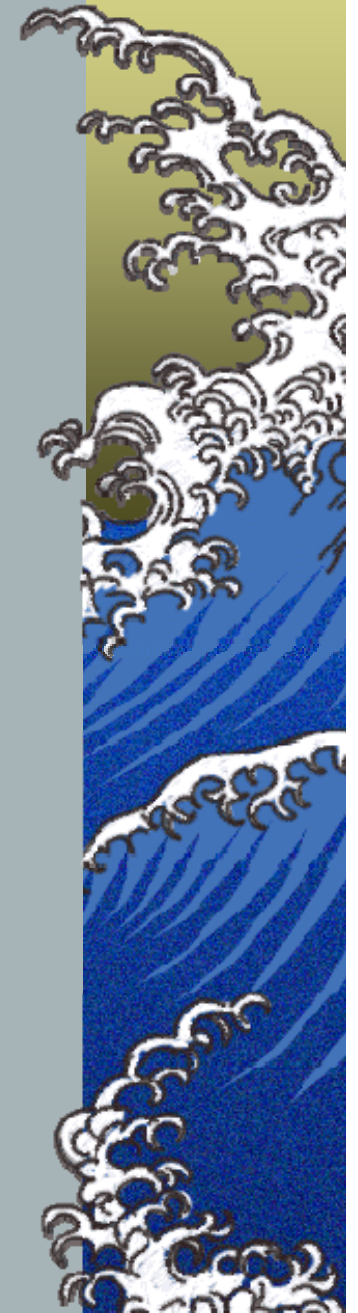
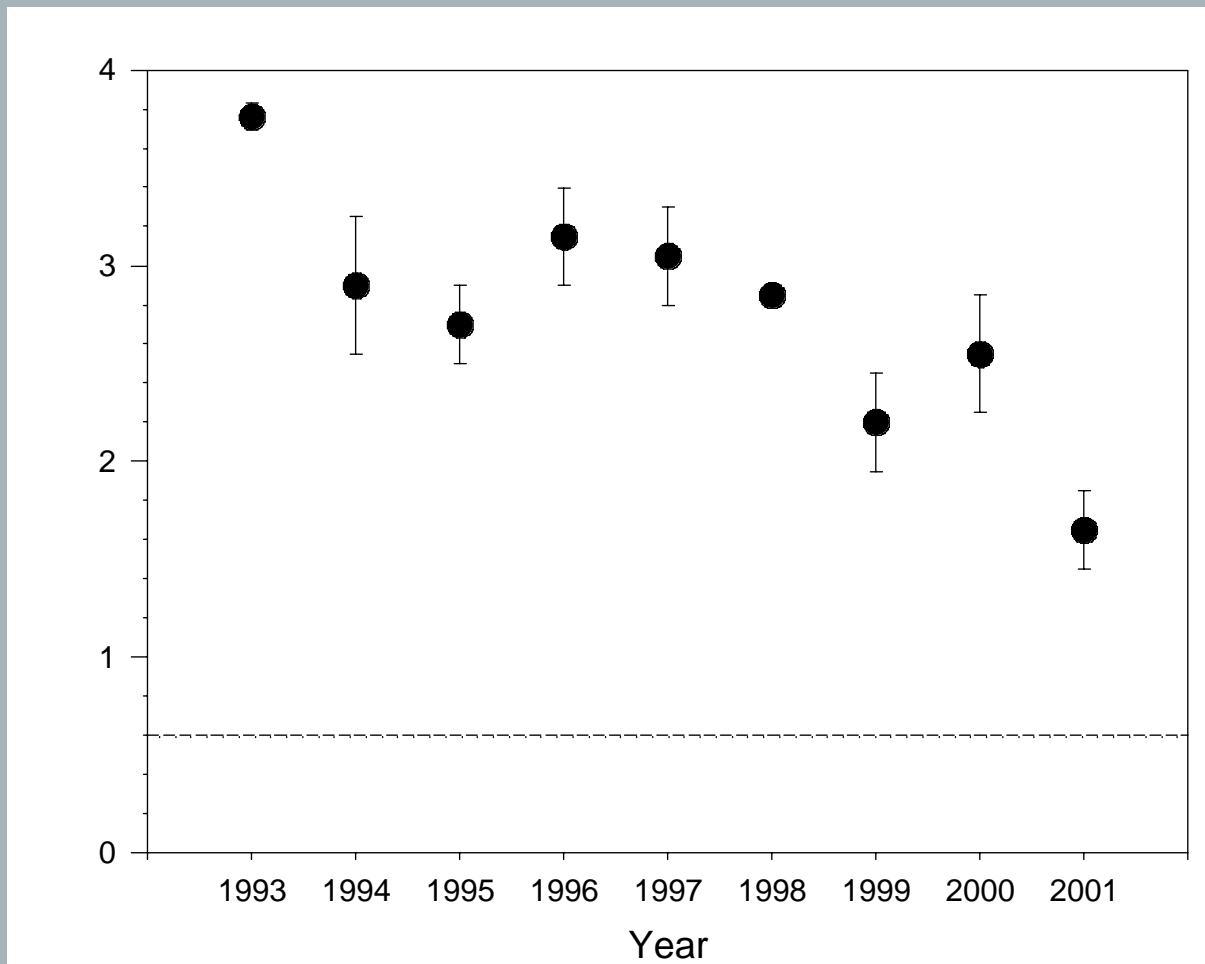
Chromium concentrations (ppm) in blue mussels at all GOM sites: Site median values 1993-2001



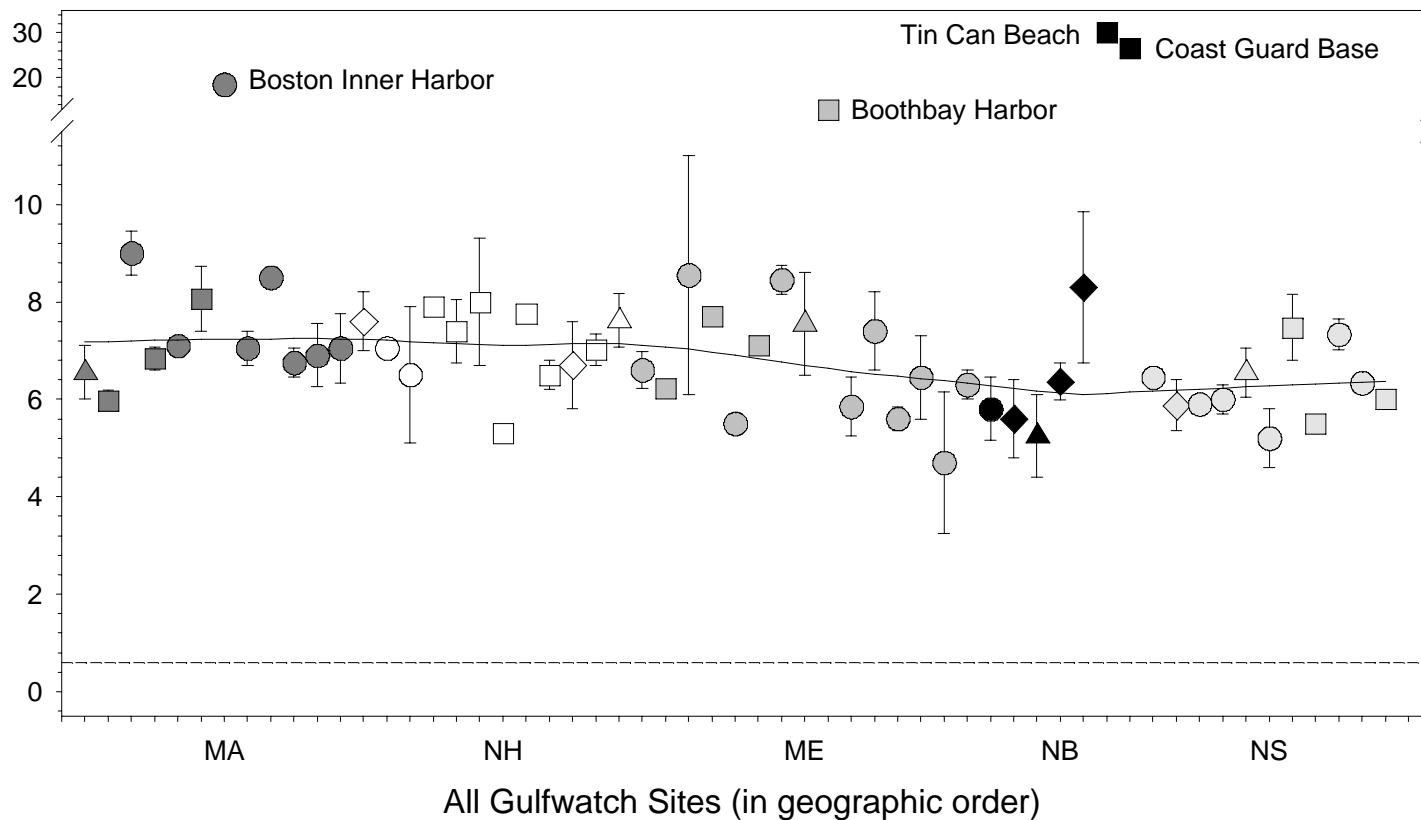
Lead concentrations (ppm) in blue mussels at all GOM sites: Site median values 1993-2001



Lead concentrations (ppm) with time in mussels at Sandwich, MA

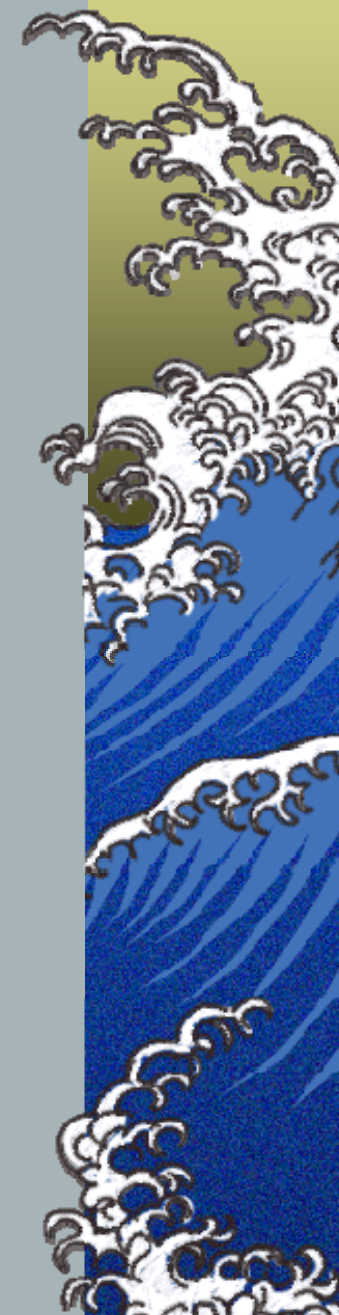


Copper concentrations (ppm) in blue mussels at all GOM sites: Site median values 1993-2001

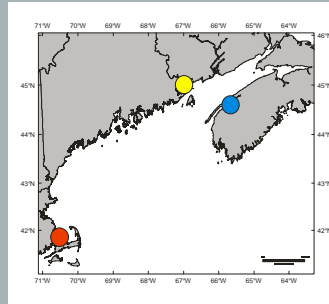
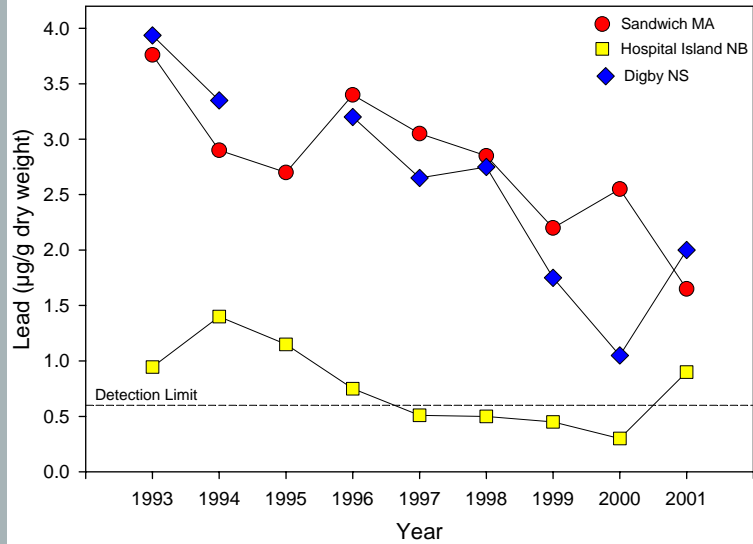


Temporal trends (1993-2001) for metals at benchmark sites

Site	Metal	Direction of Significant Trend	Significance of Trend (P<)	Range in Annual Median Concentrations (µg/g DW)
Benchmark				
Sandwich MA	silver	decreasing	0.10	1.1 - 0.1
	chromium	decreasing	0.01	1.9 - 0.60
	iron	decreasing	0.05	350 - 140
	lead	decreasing	0.01	3.8 - 1.7
Clarks Cove ME				
Kennebec River ME				
Hospital Island	lead	decreasing	0.01	1.4 - 0.30
	zinc	decreasing	0.05	91 - 57
Digby NS	chromium	decreasing	0.05	1.9 - 0.70
	iron	decreasing	0.05	644 - 215
	lead	decreasing	0.01	3.9 - 1.1
Multi-year				
Dover Point NH				
Five Islands NS	iron	decreasing	0.05	1400 - 215
	lead	decreasing	0.05	1.6 - 1.1



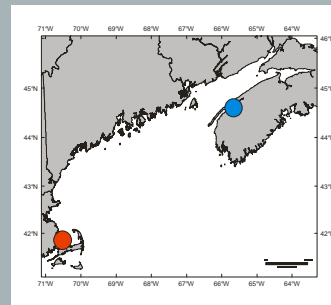
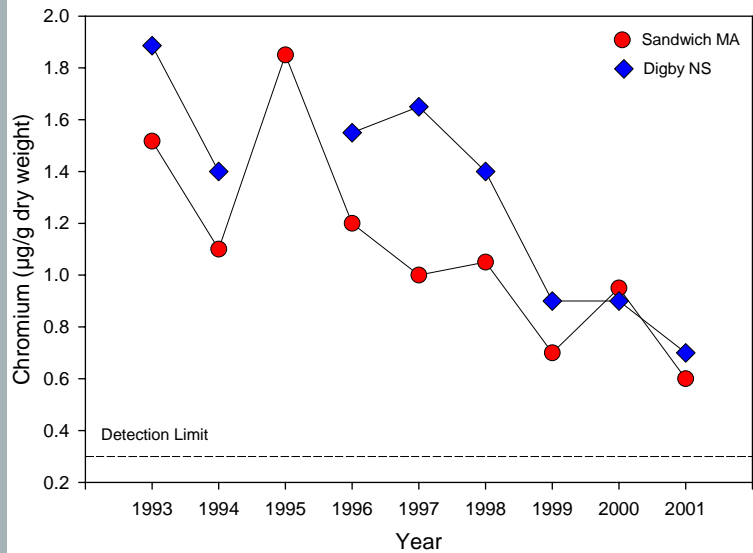
**Annual median lead concentrations
at Sandwich MA, Hospital Island NB, and Digby NS**



Lead

- ▲ MASN - $P < 0.05$
- ▲ NBHI - $P < 0.05$
- ▲ NSDI - $P < 0.01$

**Annual median chromium concentrations
at Sandwich MA and Digby NS**



Chromium

- ▲ MASN - $P < 0.01$
- ▲ NSDI - $P < 0.05$



Toxic organic compounds are resistant to **biodegradation** because of chlorines, complex structures & other properties

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TIFF (Uncompressed) decompressor
are needed to see this picture.

DDT

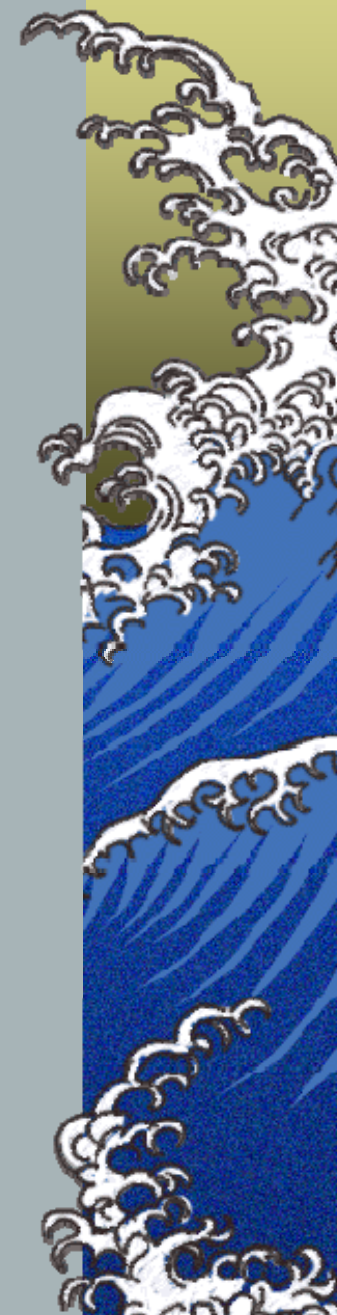
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QuickTime™ and a
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PAH

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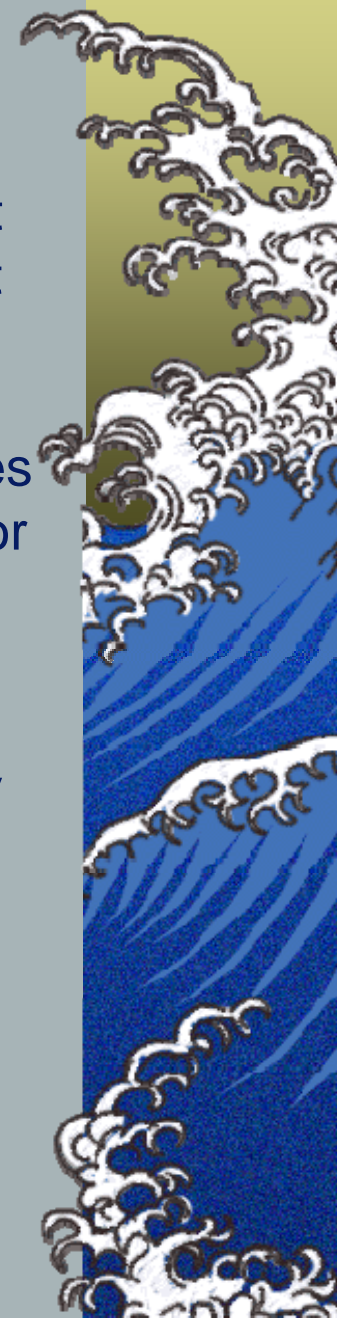
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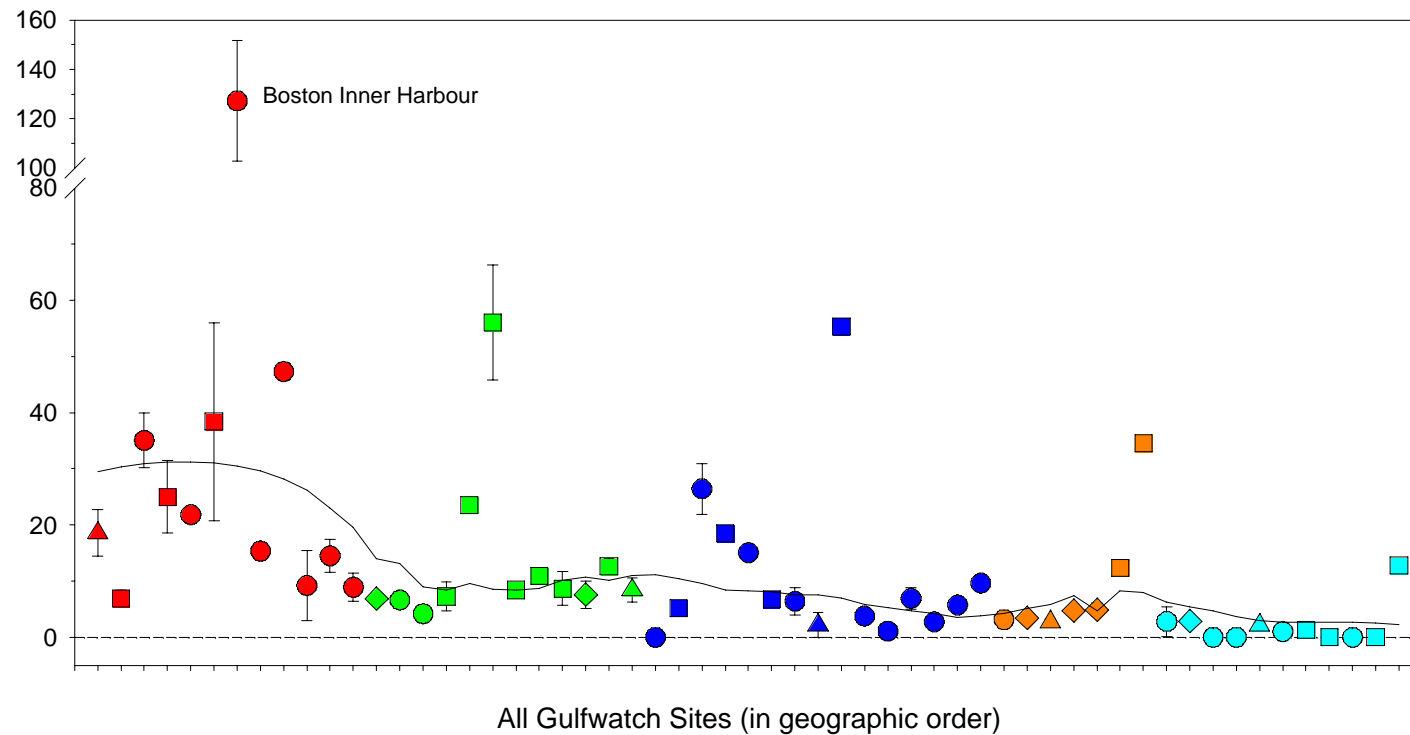
Chlorinated Pesticides

<i>Pesticide</i>	<i>% Frequency at All Sites</i>
<i>p,p'-DDE</i>	97
<i>p,p'-DDD</i>	62
<i>cis-Chlordane</i>	51
<i>Dieldrin</i>	51
<i>o,p'-DDD</i>	49
<i>Lindane</i>	41
<i>trans-Nonachlor</i>	35
<i>p,p'-DDT</i>	27
<i>o,p'-DDE</i>	22
<i>a-endosulfan</i>	14
<i>o,p'-DDT</i>	14
<i>hepta-epoxide</i>	11
<i>b-endosulfan</i>	5
<i>heptachlor</i>	3
<i>mirex</i>	0
<i>aldrin</i>	0

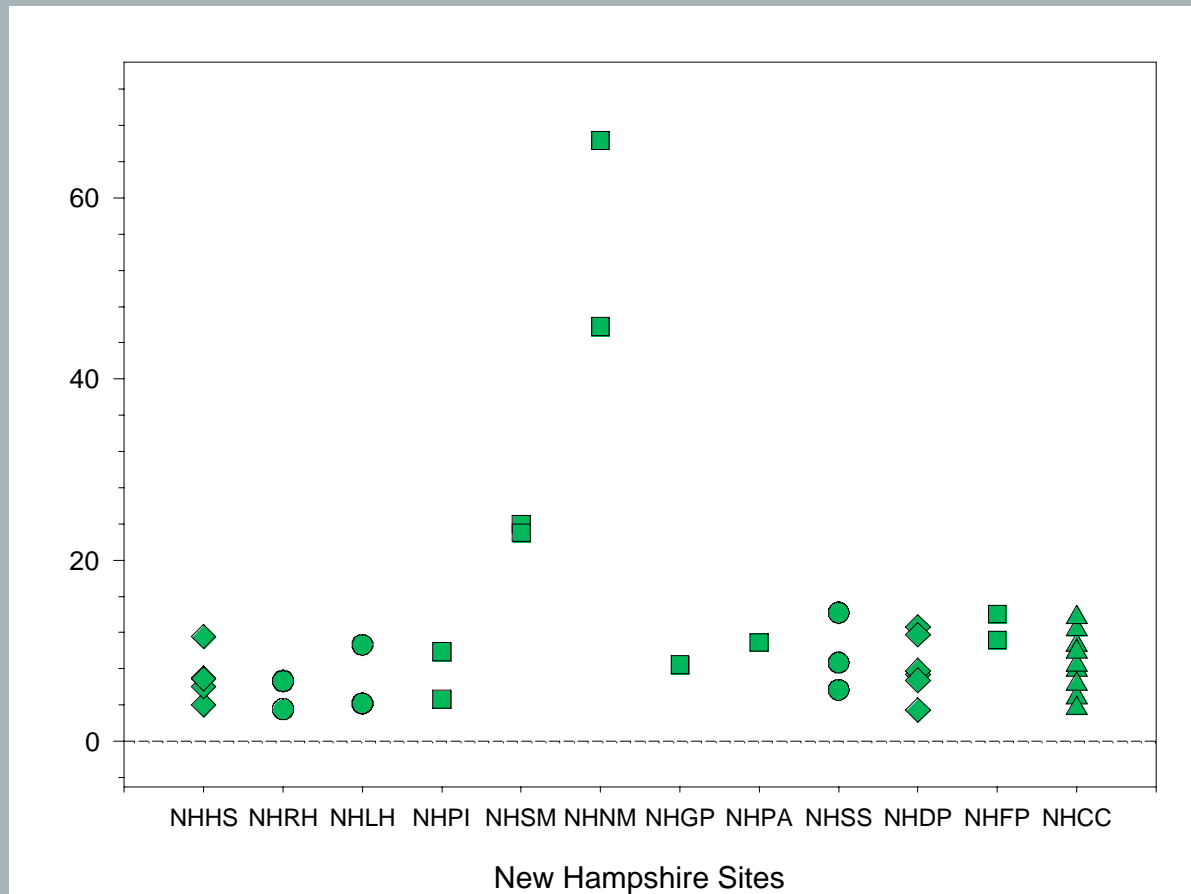
- Of 16 pesticides, pp'DDE was the most frequently detected at Gulfwatch sites.
- Only 4 other pesticides were found at ~50% or more of the sites.
- Mirex and aldrin were never detected at any site in any sample during 1993 – 2001.



Total DDT concentrations (ppb) in blue mussels at all GOM sites: Site median values 1993-2001



Total DDT concentrations (ppb) in blue mussels at NH sites: Site median values 1993-2001

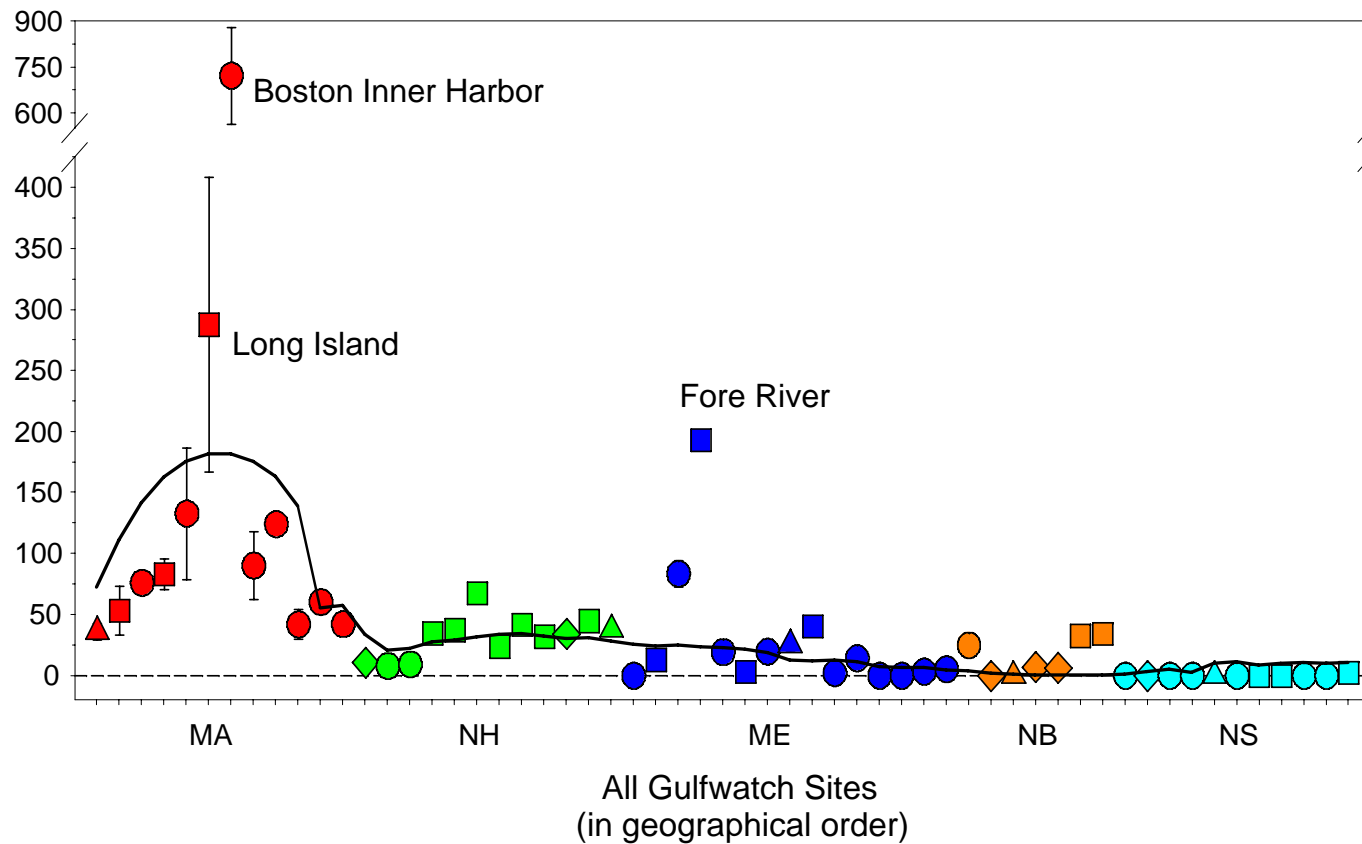


Detection (%) of total PCBs in mussels at all GOM sites: 1993-2001

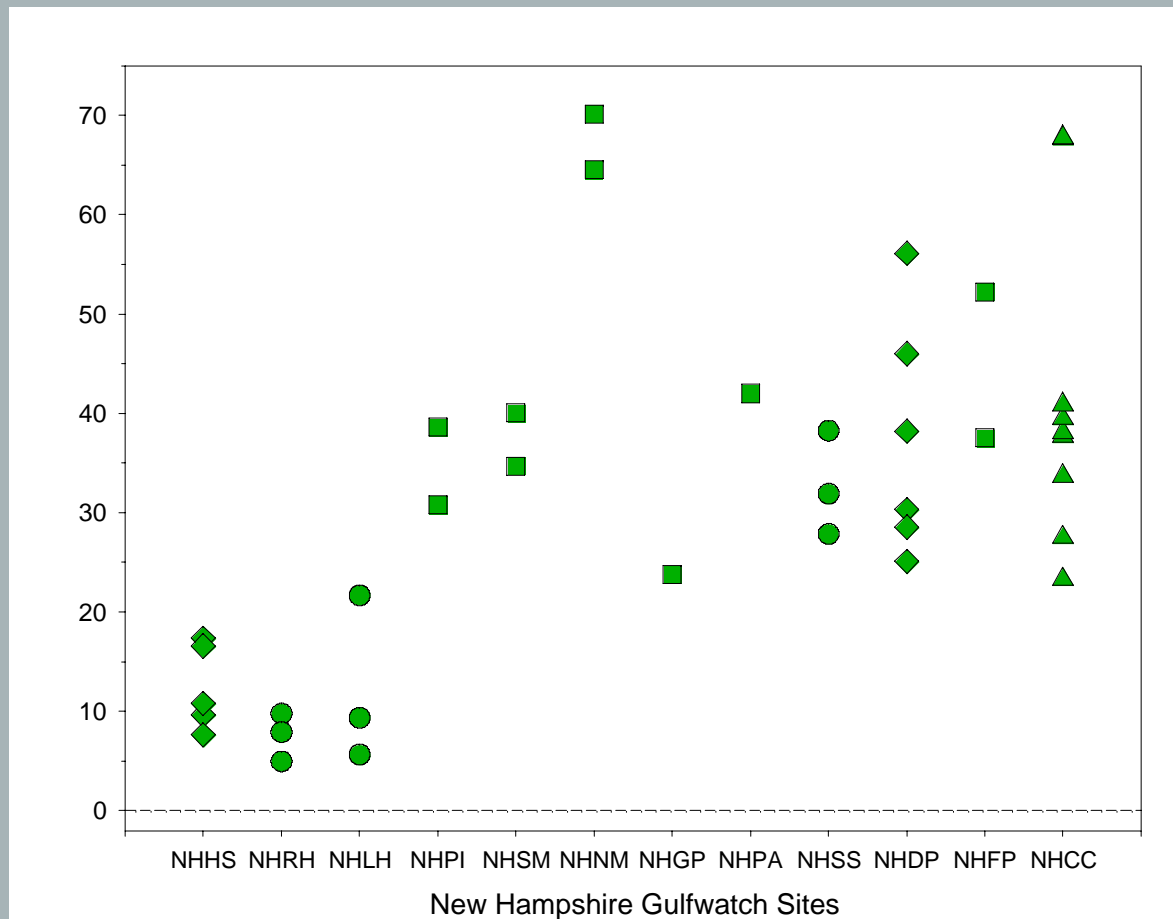
Jurisdiction	N	% Detected
MA	149	100
NH	158	100
ME	172	75
NB	111	59
NS	134	13



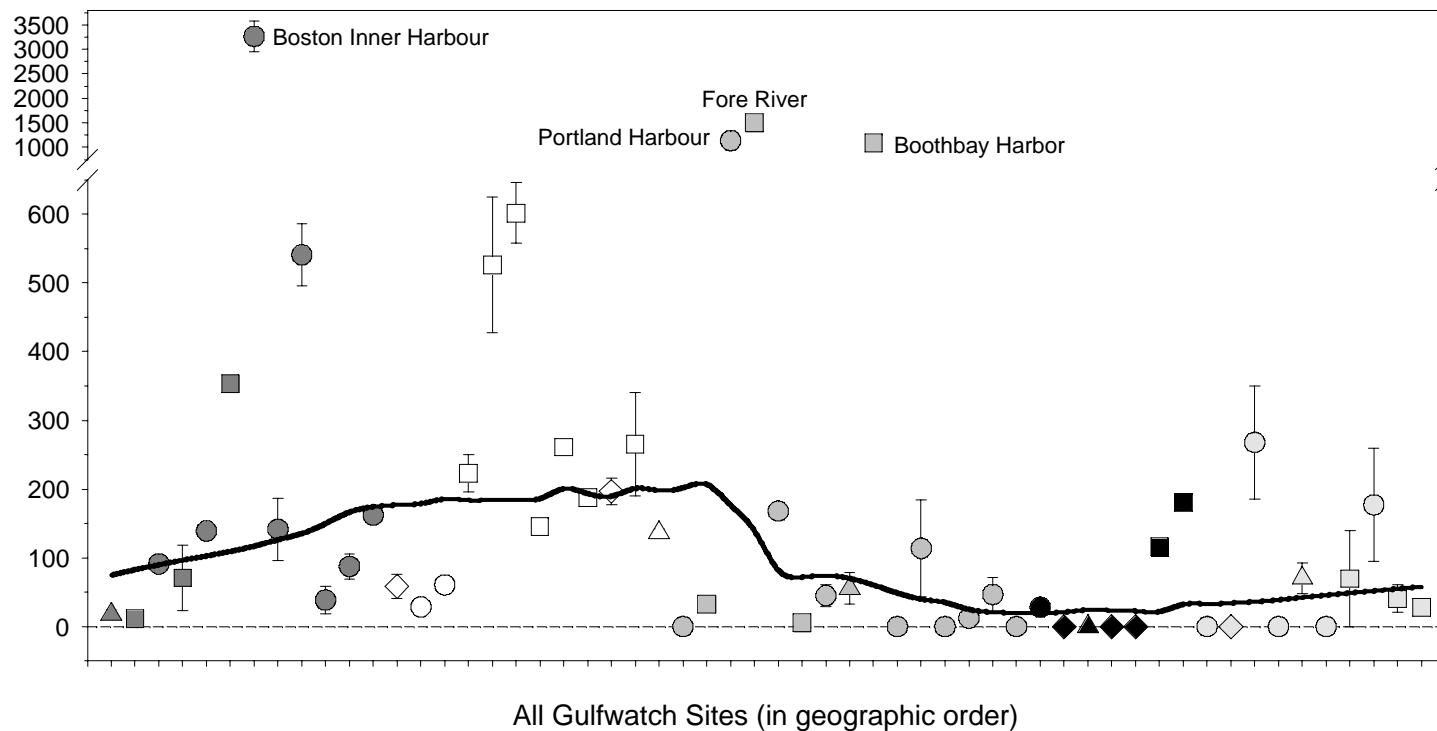
Total PCB concentrations (ppb) in blue mussels at all GOM sites: Site median values 1993-2001



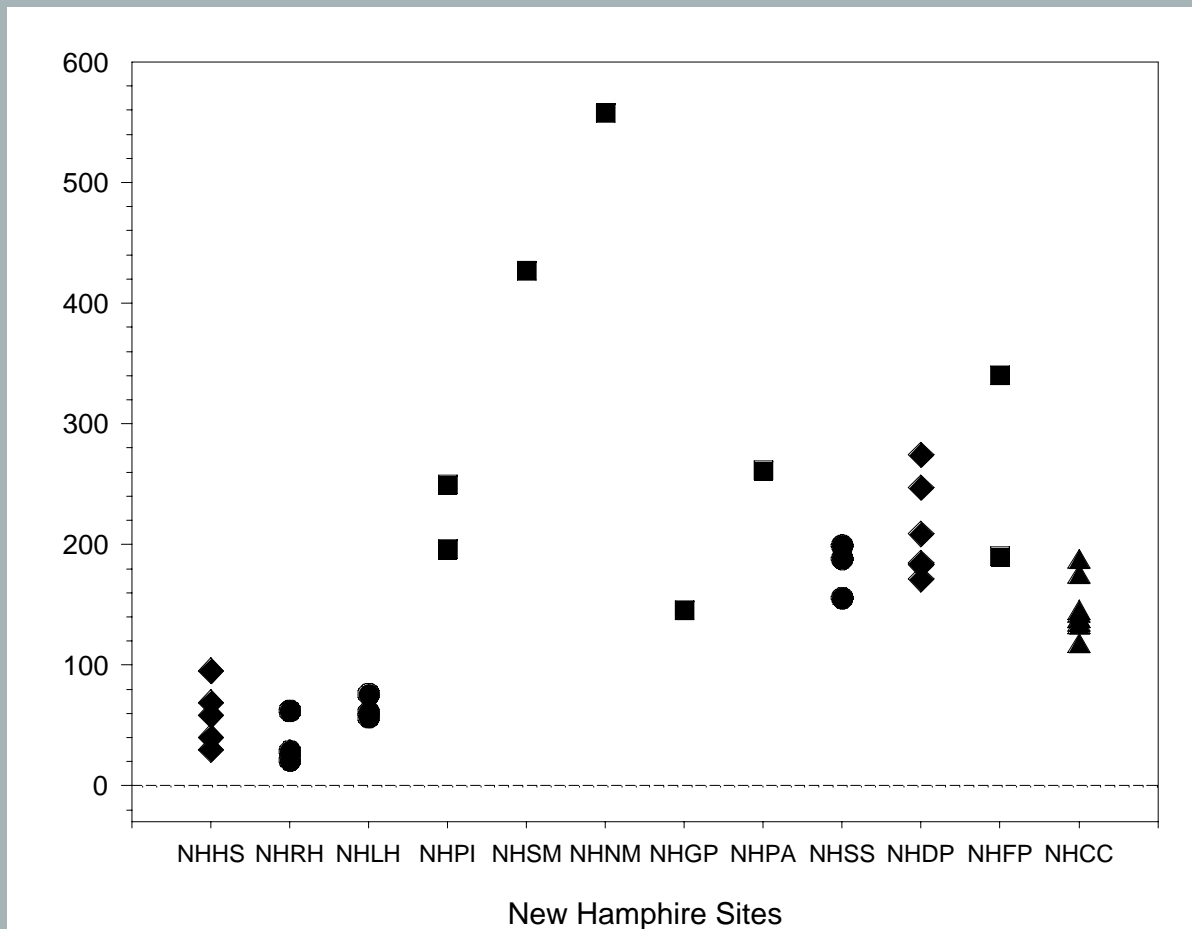
Total PCB concentrations (ppb) in blue mussels at NH sites: Site median values 1993-2001



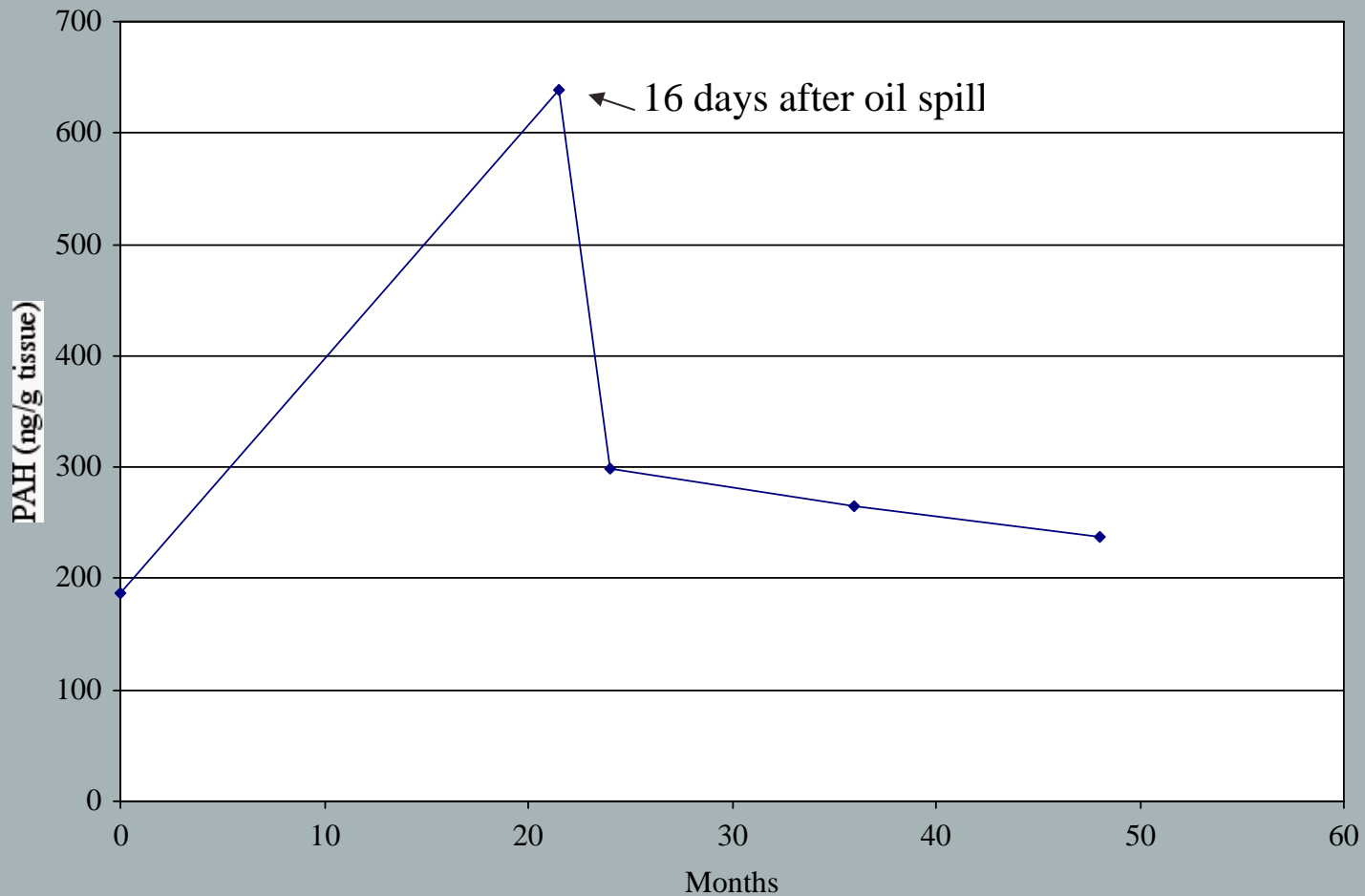
Total PAH concentrations (ppb) in blue mussels at all GOM sites: Site median values 1993-2001



Total PAH concentrations (ppb) in blue mussels at NH sites: Site median values 1993-2001



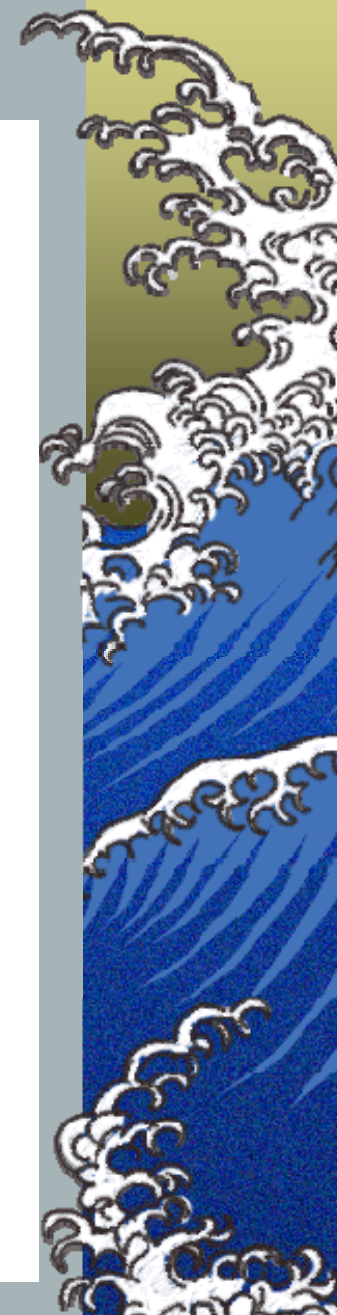
Total PAH concentrations in mussels from Dover Point, NH before and after an oil spill (7/96).



Regional-National Comparison:

Frequency of site concentrations (1993-99)
that exceed 1991 NS&T MD+1SD

Contaminant	Gulfwatch 93-99		NS&T (1991)		Sites > NS&T MD+1SD 93-99 %
	MD	+1SD	MD	+1SD	
Ag	0.07	0.24	0.08	0.48	7
Al	229	341	280	653	5
Cd	1.6	2.2	2.3	5.4	0
Cr	1.7	2.7	1.4	2.7	16
Cu	6.9	8.6	8.8	12	5
Fe	389	570	400	790	5
Hg	***	***	0.11	0.24	**
Ni	1.4	2.1	2.1	3.6	2
Pb	2.6	5.2	0.77	3.6	26
Zn	96	131	130	200	1
ΣPAH	96	321	227	937	3
ΣPEST	9.6	29	30	116	1
ΣPCB	44*	171*	26	145	4



CONCLUSIONS

- *No sites showed extremely high levels of any target contaminant;*
- *Contamination levels varied from obvious hot spots to relatively pristine areas;*
- *Spatial trends were different for the various contaminants;*
- *All temporal trends were decreasing;*
- *Ecosystem-wide, the more populated and industrialized southwestern Gulf typically had higher tissue concentrations;*
- *No contaminant at any site, except Pb at several sites, exceeded USFDA guidelines for seafood.*



Significance of the Program

- ▶ *Decadal monitoring programs are essential for understanding the input and fate of chemical contaminants into marine ecosystems.*
- ▶ *Most significant spatial trends and gradients indicate that elevated levels of contaminants are associated with urbanization.*
- ▶ *Knowledge of land-based activities is necessary for understanding trends and elevated levels.*
- ▶ *Declining temporal trends indicate effectiveness of pollution control e.g. Pb, Cr.*



LIMITATIONS

- ▶ *Results tell little about chemical effects on biota;*
- ▶ *Site selection criteria, ecosystem conditions and imbalanced degree of support result in spatial biases in design;*
- ▶ *Have not included expanded array of emerging contaminants of concern;*
- ▶ *Cannot make direct linkages to other organisms or environmental media.*



Gulfwatch Accomplishments

- ▶ *11 annual data reports*
- ▶ *Synthesis of results from 1993-2001 & 2002-2004*
- ▶ *Synthesis of results & program review for 1991-95*
- ▶ *scientific peer-reviewed articles (3)*
- ▶ *Use of results by managers, scientists, industry, public*
- ▶ *Series of workshops and scientific peer review to guide continuation and expansion of program*
- ▶ *Developed new long-term plan and establishing linkages with related programs*



Future Activities

- ▶ *Implement an expanded environmental quality monitoring program*
 - ▶ *Continue Gulfwatch (blue mussels), using different timing and sites*
 - ▶ *Add/delete analytes;*
 - ▶ *Linkages mussel <--> sediment*
 - ▶ *Mussel sub-lethal effects*
 - ▶ *Relate mussel data to other species*
 - ▶ *Science partnerships to enhance Gulfwatch program*
 - ▶ *Gulfwatch 'tissue bank' archive*
 - ▶ *Contaminant sources and loading rates*



Further Information

*Interactive map and data on GoMOOS web site:

<http://www.gomoos.org/chameleon/gulfwatch/>

*Gulfwatch program description on GOM Council site

<http://www.gulfofmaine.org/gulfwatch/>

*NH Estuaries Project report: monitoring NH shellfish tissue

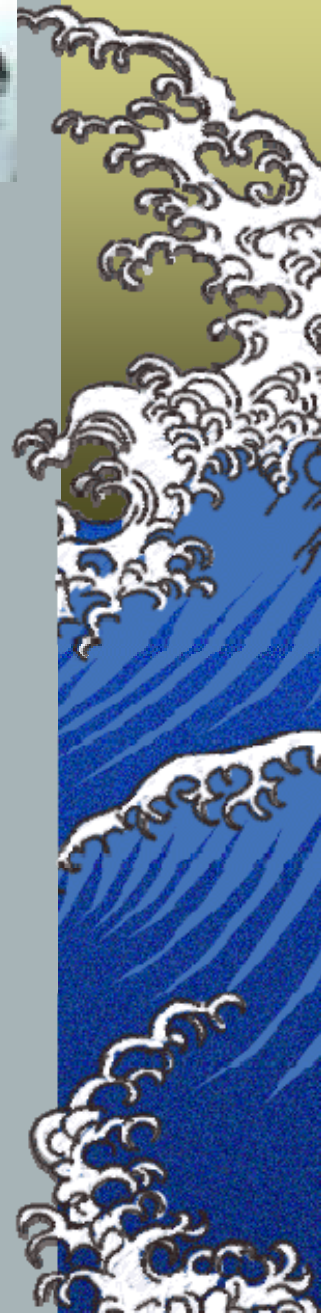
<http://www.nhep.unh.edu/resources/publications.htm>

*NOAA National Status and Trends Mussel Watch Program

http://www8.nos.noaa.gov/cit/nsandt/download/mw_monitoring.aspx



Spatial Trends



- ▶ *Significant spatial trends were analyzed using the Mann-Kendall non-parametric trends test.*
- ▶ *The test is usually used for temporal trends, but was modified so that median concentrations for each site were entered in geographic order.*
- ▶ *Recommended by the EPA (2000, Data Quality Assessment Guide) for cases where there are a high number of non-detects in the data.*

Temporal Trends

Test for significant temporal trends: **Mann-Kendall non-parametric test**

- requires a minimum of 6 years of temporal data to detect a significant trend.
- requires at least 10 years of data before it can estimate the slope of a trend.

Benchmark Sites Sampled 8 – 9 years

- Sandwich MA
- Clark's Cove ME (NH benchmark)
- Kennebec River ME
- Hospital Island NB
- Digby NS

Multi-year Sites Sampled 6 years

- Niger River NB

