NS&T Program

National Status and Trends Program
for Marine Environmental Quality

WATERS OF THE CAROLINAS

Charleston Harbor, South Carolina, 1998, M. Beaver (NOAA Photo Collection, NOAA Central Library)

National Oceanic and Atmospheric Administration
National Ocean Service
National Centers for Coastal Ocean Science
Center for Coastal Monitoring and Assessment

2002
Regional Reports Series 7

For further information on the NS&T Program please call 301 713 3028 or write:

National Status and Trends Program
N/SCI 1, SSMC-IV, Rm. 9110
1305 East West Hwy.
Silver Spring, MD 20910

Disclaimer

Status and Trends of Contaminant Levels in Biota and Sediments of the WATERS OF THE CAROLINAS

A. Y. Cantillo and G. G. Lauenstein
Center for Coastal Monitoring and Assessment
National Centers for Coastal Ocean Science
NOAA/National Ocean Service
1305 East West Hwy.
Silver Spring, MD 20910

INTRODUCTION

As part of its continuing mission to bring important results into the public arena, the NOAA National Status and Trends (NS&T) Program has prepared this summary of its findings in the waters off the Carolinas. Results of this effort have been partially described in Lauenstein and Cantillo (2002).

AREA DESCRIPTION

The estuaries of North and South Carolina along the southeastern U.S coast on the Atlantic Ocean are an important natural resource supporting commercial fisheries and recreational activities. The watershed includes farmlands, woodlands, and heavily impacted industrial and metropolitan areas, though the most heavily populated area of the tidally-influenced Carolinas is limited to the vicinity of Charleston, South Carolina.

There is a large intercoastal area in North Carolina bounded to the east by the barrier Outer Islands. Roanoke Sound is the northernmost sound and the sampling site in the Sound is a the mouth of John Creek (RSJC) (Figure 1, Table 1). Further south is Pamlico Sound. There are three sampling sites in this Sound. The sites at Wysocking Bay (PSWB), Pungo River (PSPR) and Neuse River (PSNR) are on the mainland side of the Sound. The Cape Hatteras (PSCH) site is on the Outer Banks. Oysters in some of these areas are few in number. To the southwest is the site in Pivers Island (BIPI) in the Beaufort Inlet, near the NOAA research laboratory.

To the southwest, a series of sampling sites was established in small inlets These are Battery Island (CFBI) at Cape Fear, Lower Bay (WBLB) at Winyah Bay, North Bay on the Santee River (SRNB), and Fort Johnson (CHFJ) and Shutes Folly Island (CHSF) in Charleston Harbor. The stations around Charleston, South Carolina, CHSF and CHFJ, have the highest human population density of this section of the coast (Figure 2).

NATIONAL STATUS AND TRENDS PROGRAM

Our Nation's estuaries and coastal waters receive chemical wastes from industrial, municipal, and agricultural sources. In recent decades, as industrialization has grown and diversified, complex mixtures of synthetic organic compounds, trace elements, and nutrients have been discharged into US coastal waters.

In addition to coming from industrial sources, contaminants are released to the environment in the course of our daily lives. For generations, chemicals from such non-point sources as agricultural runoff, urban runoff and non-agricultural insect and plant control programs have added significantly to the total burden of coastal contaminants. Airborne transport is another significant source of contaminants to coastal ecosystems. In recent years, coastal contamination has become more of a concern as

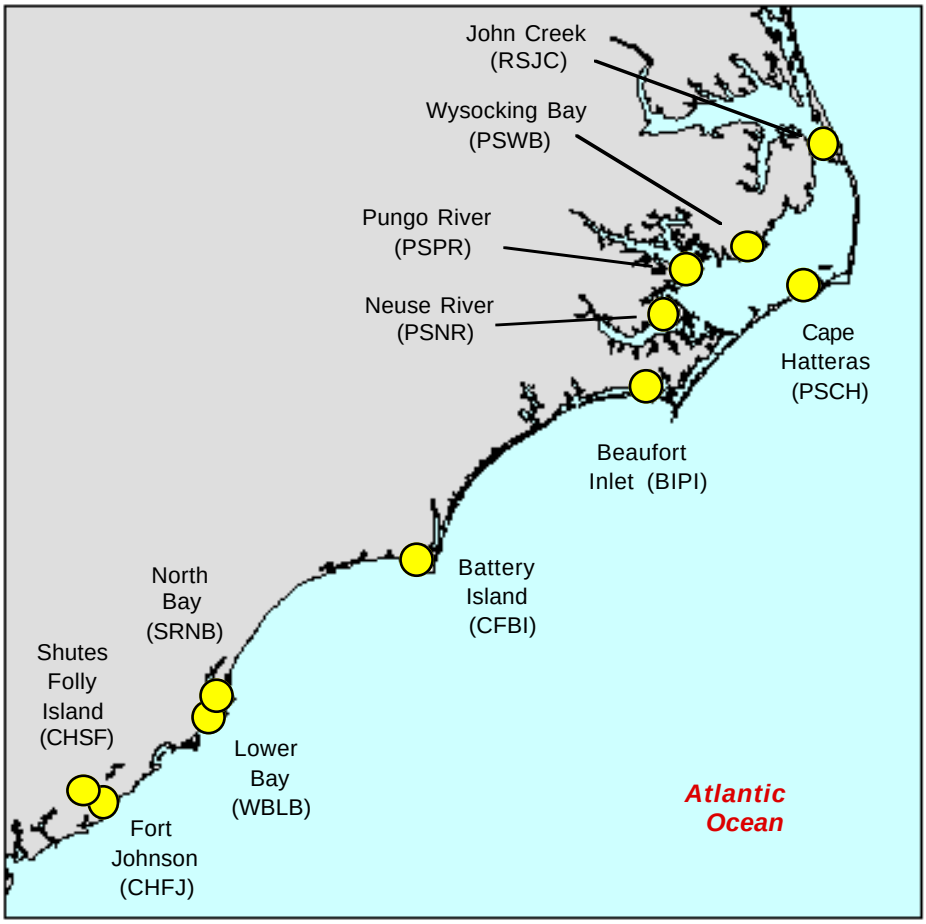


Figure 1. NS&T Mussel Watch Project sampling sites in the waters off the Carolinas

TABLE 1
NS&T sampling sites in the Carolinas

Site	Site code	Latitude (N)	Longitude (W)	Years of tissue data*	Population$^{\Delta}$ (20 km of site)
Mussel Watch Project					
American oyster (*Crassostrea virginica*)					
John Creek	RSJC	35° 53.39'	75° 38.02'	10	14646
Cape Hatteras	PSCH	35° 12.17'	75° 42.97'	6	2584
Wysocking Bay	PSWB	35° 24.74'	76° 02.38'	10	2217
Pungo River	PSPR	35° 17.76'	76° 26.35'	6	2581
Neuse River	PSNR	35° 05.38'	76° 31.74'	7	4027
Pivers Island	BIPI	34° 43.10'	76° 40.53'	6	34789
Battery Island	CFBI	33° 54.95'	78° 00.21'	11	18059
Lower Bay	WBLB	33° 14.60'	79° 11.83'	7	12945
North Bay	SRNB	33° 10.10'	79° 14.50'	7	4365
Fort Johnson	CHFJ	32° 45.03'	79° 54.02'	10	212391
Shutes Folly Island	CHSF	32° 46.41'	79° 54.73'	9	251094

$^{\Delta}$ 1990 Census.

* Years of tissue data available through 1997.

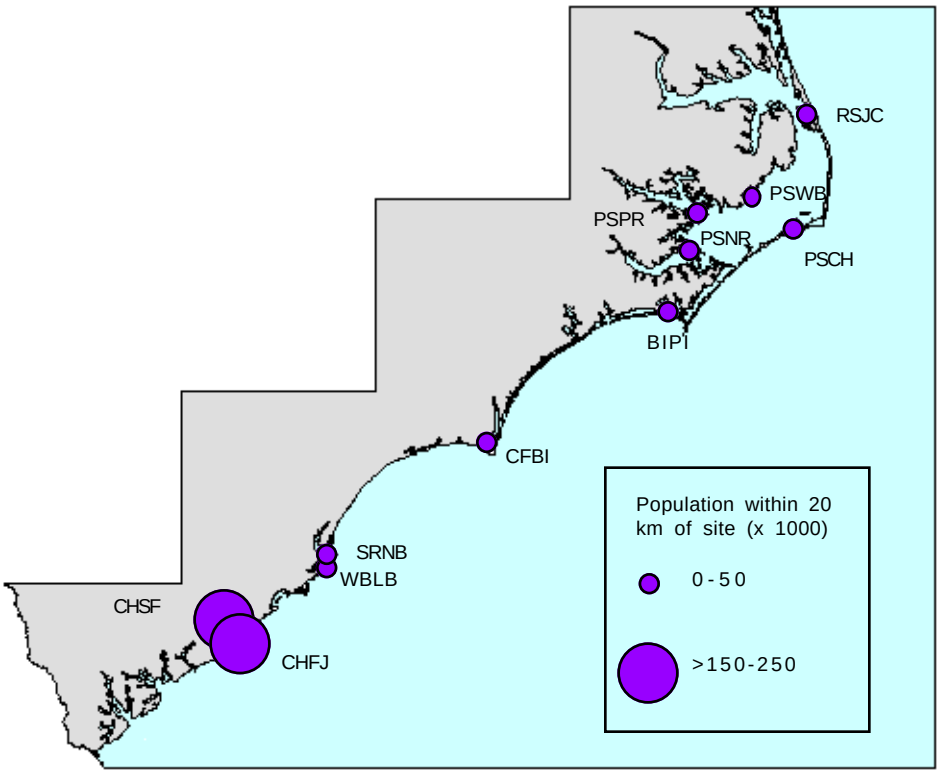


Figure 2. Population within 20 km of the Mussel Watch sampling sites in the Carolinas.

Outer Banks, North Carolina, 1973, M. Hollinger, NOAA/NODC (NOAA Photo Collection, NOAA Central Library)

population growth in these areas has continued to increase steadily. In response, an evolving national effort is underway to determine the extent and impact of contaminants on coastal and estuarine areas and to develop management strategies (National Research Council, 1990).

The Center for Coastal Monitoring and Assessment (CCMA), in the National Centers for Coastal Ocean Science (NCCOS) of NOAA's National Ocean Service, conducts a variety of environmental monitoring and assessment studies that are pertinent to NOAA's Environmental Stewardship mission, as outlined in its Strategic Plan: "A Vision for 2005". These studies focus on three long-term goals:

- Assess the status and trends of environmental quality in relation to levels and effects of contaminants and other sources of environmental degradation in US marine, estuarine, and Great Lakes environments;

- Develop diagnostic and predictive capabilities to determine effects of contaminants and other sources of environmental degradation on coastal and marine resources and human uses of these resources;

- Develop and disseminate scientifically sound data, information, and services to support effective coastal management and decision making.

NOAA's NS&T Program, managed by CCMA, was initiated in 1984 to determine the status of, and to detect changes in, the environmental quality of the nation's coastal waters. This program monitors contaminant levels through the **Mussel Watch Project,** which determines concentrations of polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyl (PCB) congeners, several pesticides, butyltins, and selected trace elements in sediment and mollusk samples from U.S. coastal waters (Table 2). Data are used to determine the level and temporal trends of chemical contamination on a nationwide basis and to identify which coastal areas are at greater risk in terms of threats to environmental quality and resources. The Mussel Watch network consists of more than 280 sites. The **Quality Assurance Project** is designed to document sampling protocols, analytical procedures, and laboratory performances of the Mussel Watch Project and is an integral part of the NS&T Program.

SURVEY METHODS

Mussel Watch Project sites are sampled at regular intervals (biennially in winter for mollusks, less frequently for sediments). The sites are designed to describe national and regional distributions of contamination. They are selected to represent large coastal areas and to avoid small-scale patches of contamination, or "hot spots." Sites selected for monitoring are generally 10 to 100 km apart. Where possible, sites were selected to coincide with historical monitoring sites such as the US Environmental Protection Agency's Mussel Watch sites sampled during the 1970s, and to complement sites sampled through state programs such as the California Mussel Watch Program (Lauenstein, 1996).

Mollusks (mussels or oysters) and sediments are collected at each Mussel Watch Project site. Several species of mollusks are collected: blue mussels (*Mytilus edulis*) from the US North Atlantic; blue mussels (*Mytilus* species) and California mussels (*M. californianus*) from the Pacific coast; eastern oysters (*Crassostrea virginica*) from the South Atlantic and the Gulf of Mexico; smooth-edge jewelbox (*Chama sinuosa*) from the Florida Keys; Caribbean oyster (*C. rhizophorae*) from Puerto Rico; Hawaiian oysters (*Ostrea sandvicensis*) from Hawaii; and zebra mussels (*Dreissena polymorpha* and *D. bugensis*) from the Great Lakes. Coastal and estuarine mollusks are collected by hand or dredged from intertidal to shallow subtidal zones, brushed clean, packed in dry ice, and shipped to the analytical laboratory. Sediments are collected using a grab sampler and the top two centimeters are removed for analysis. The mollusk and sediment samples are usually shipped to the laboratory within a day of collection.

TABLE 2

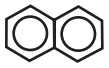
Organic contaminants and major and trace elements determined as part of the NS&T Program.

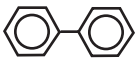
(Number below chemical structure is the Chemical Abstracts Service registry number.)

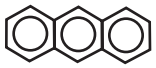
Polycyclic aromatic hydrocarbons

Low molecular weight PAHs
(2- and 3-ring structures)

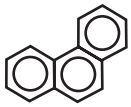
1-Methylnaphthalene
1-Methylphenanthrene
2-Methylnaphthalene
2,6-Dimethylnaphthalene
1,6,7-Trimethylnaphthalene
Acenaphthene
Acenaphthylene
Anthracene
Biphenyl
Fluorene
Naphthalene
Phenanthrene


Naphthalene
91-20-3

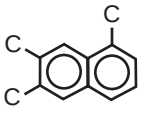

Biphenyl
92-52-4

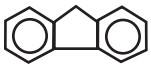

Anthracene
120-12-7

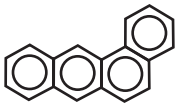

Acenaphthene
83-32-9

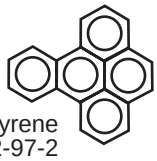

Phenanthrene
85-01-8

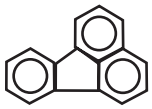

Acenaphthylene
208-96-8


1,6,7-Trimethylnaphthalene
2245-38-7

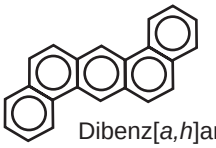

Fluorene
86-73-7


Benz[*a*]anthracene
56-55-3


Benzo[*e*]pyrene
192-97-2


Fluoranthene
206-44-0


Perylene
198-55-0


Dibenz[*a,h*]anthracene
53-70-3

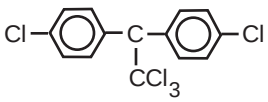

Benzo[*ghi*]perylene
191-24-2

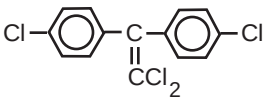
High molecular weight PAHs
(4-, 5-, and 6-rings)

Benz[*a*]anthracene
Benzo[*a*]pyrene
Benzo[*b*]fluoranthene
Benzo[*e*]pyrene
Benzo[*ghi*]perylene
Benzo[*k*]fluoranthene
Chrysene
Dibenz[*a,h*]anthracene
Fluoranthene
Indeno[1,2,3-*cd*]pyrene
Perylene
Pyrene

Chlorinated pesticides

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


4,4'-DDT
50-29-3


4,4'-DDE
72-55-9

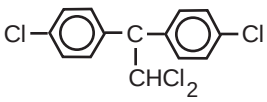
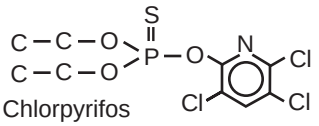

4,4'-DDD
72-54-8

TABLE 2 (cont.)

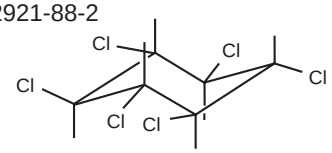
Organic contaminants, and major and trace elements determined as part of the NS&T Program.

(Number below chemical structure is the Chemical Abstracts Service registry number.)

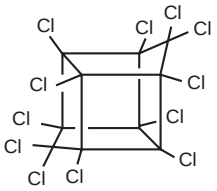
Aldrin
Chlorpyrifos
cis-Chlordane
Dieldrin
Endosulfan-II
delta-Hexachlorocyclohexane
gamma-Hexachlorocyclohexane
(Lindane)
Heptachlor
Heptachlor epoxide
Hexachlorobenzene
alpha-Hexachlorocyclohexane
beta-Hexachlorocyclohexane
Mirex
cis-Nonachlor
trans-Nonachlor
Oxychlordane



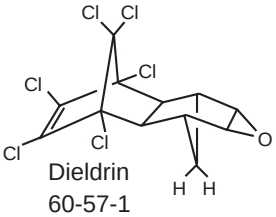
Chlorpyrifos
2921-88-2



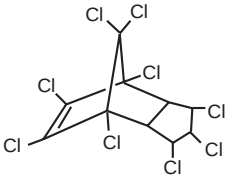
gamma-Hexachlorocyclohexane
58-89-9



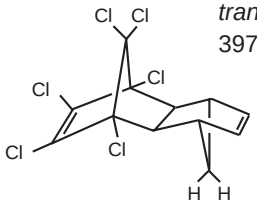
Mirex
2385-85-5



Dieldrin
60-57-1



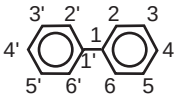
trans-Nonachlor
39765-80-5



Aldrin
309-00-2

Polychlorinated biphenyl congeners (IUPAC numbering system)

PCB 8, PCB 18, PCB 28, PCB 44, PCB 52, PCB 66, PCB 101, PCB 105, PCB 118, PCB 128, PCB 138, PCB 153, PCB 170, PCB 180, PCB 187, PCB 195, PCB 206, PCB 209

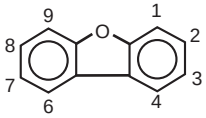


PCB parent structure

Planar PCBs (PCB 77, PCB 126, PCB 169)

Chlorinated dibenzofurans

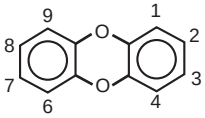
2,3,7,8-Tetrachlorodibenzofuran
1,2,3,7,8-Pentachlorodibenzofuran
2,3,4,7,8-Pentachlorodibenzofuran
1,2,3,4,7,8-Hexachlorodibenzofuran
1,2,3,6,7,8-Hexachlorodibenzofuran
2,3,4,6,7,8-Hexachlorodibenzofuran
1,2,3,7,8,9-Hexachlorodibenzofuran
1,2,3,4,6,7,8-Heptachlorodibenzofuran
1,2,3,4,7,8,9-Heptachlorodibenzofuran
Octachlorodibenzofuran



Dibenzofuran parent structure

Chlorinated dibenzodioxins

2,3,7,8-Tetrachlorodibenzo-*p*-dioxin
1,2,3,7,8-Pentachlorodibenzo-*p*-dioxin
1,2,3,4,7,8-Hexachlorodibenzo-*p*-dioxin
1,2,3,6,7,8-Hexachlorodibenzo-*p*-dioxin
1,2,3,7,8,9-Hexachlorodibenzo-*p*-dioxin
1,2,3,4,6,7,8-Heptachlorodibenzo-*p*-dioxin
Octachlorodibenzo-*p*-dioxin



Dibenzo-*p*-dioxin parent structure

TABLE 2 (cont.)

Organic contaminants, and major and trace elements determined as part of the NS&T Program.

(Number below chemical structure is the Chemical Abstracts Service registry number.)

Major and trace elements

Al	-	aluminum	Cu	-	copper	Ag	-	silver
Si	-	silicon	Zn	-	zinc	Cd	-	cadmium
Cr	-	chromium	As	-	arsenic	Hg	-	mercury
Mn	-	manganese	Se	-	selenium	Tl	-	thallium
Fe	-	iron	Sn	-	tin	Pb	-	lead
Ni	-	nickel	Sb	-	antimony			

Organotins

Monobutyltin^{3+}, dibutyltin^{2+}, tributyltin^{+}, tetrabutyltin

Bodie Island Lighthouse at sunset, North Carolina, W. Folsom, NOAA/NMFS (NOAA Photo Collection, NOAA Central Library)

In the laboratory, molluscan samples are composited to include about 20 or 30 individuals of oysters and mussels, respectively. The molluscan composite samples and sediment samples are analyzed for organic and metal contaminants. The sampling and analytical protocols are described in detail in Lauenstein and Cantillo (1993, 1998). Data are also available from the NS&T **Benthic Surveillance Project** that analyzed contaminant levels and effects in sediment and fish from over 100 sites in 1984 through 1992.

From 1986 to 1994 all the samples from the Carolinas were collected and analyzed by Battelle Ocean Sciences in Duxbury, MA. From 1995 – 1999 the Geochemical and Environmental Research Group (GERG) of Texas A&M University performed the characterization of organic contaminants while the Department of Oceanography Trace Element Research Laboratory at Texas A&M University performed the trace element analyses. Both Texas laboratories are located in College Station, TX. From 1995 – 1999 mollusks and sediments along the shores of the Carolinas were collected by both GERG and NOAA.

The NS&T Mussel Watch sites in coastal waters of the Carolinas are shown in Figure 1. The site names, acronyms, latitudes and longitudes, years of data available and human populations within 20 km of the sites are listed in Table 1. The average concentrations of major and trace elements and of categories of organic compounds in sediment are shown graphically in Appendix I. Appendix II provides graphical representations of trace element and organic concentrations in oysters through time.

RESULTS AND DISCUSSION

Status

Sediment

The average concentrations of several NS&T analytes in sediments collected over several years are shown in Appendix I. Data from the Carolinas were compared to the nationwide NS&T median and 85th percentile values. Concentrations above the 85th percentile are in the highest 15% of the data set and are used to indicate "high" concentrations. Percentiles are robust with regard to both outliers and concentrations below the detection limit. The NS&T medians and 85th percentiles are listed in Table 3.

In general, the concentrations of NS&T contaminants in the sediments collected at the Mussel Watch sites in the Carolinas were below NS&T "high" levels except for a few isolated instances. Manganese was above the NS&T "high" at Lower Bay; tin at Neuse River; total chlordane pesticides at Pivers Island; hexachlorobenzene at the Neuse and Pongo River sites; and mirex at Wysocking Bay and Cape Hatteras. There were several sites with "high" arsenic and selenium concentrations. High levels of these elements are also reflected in the tissue of oysters collected from these sites.

Oysters

Oysters and mussels are not equal in their ability to concentrate trace elements (O'Connor, 1993). The trace elements Ag, Cu, and Zn are concentrated more than ten fold in the oyster *C. virginica* relative to the mussel *M. edulis.* Therefore, only the NS&T nationwide oyster data were used to compare to the Ag, Cu, and Zn in Carolinian oysters. The differences in bioaccumulation between oysters and mussels for Ni, As, Se, Cd, Hg, Pb and the organic analytes are not sufficiently great as to prevent the combination of the data from the two bivalve genera.

Using the 85th percentile as the basis for comparison, oysters from the estuaries of the Carolinas do not rank as having unusually elevated concentrations for any chemical except As. The majority of the trace elements reported for the Carolinas were at the national median or at least below the national 85th percentile (Table 3). Arsenic exhibited consistently high concentrations from Beaufort, NC to the Florida panhandle (Valette-Silver *et al*., 1999). Arsenic concentrations in bivalves at these sites were among the highest of any of the NS&T sites in the nation. Valette-Silver *et al*. (1999) hypothesized that the main sources of arsenic are phosphate deposits and soil

TABLE 3

NS&T Mussel Watch Data medians and 85th percentile values (1986 - 1997)

(Medians and percentiles were determined using the average at each site across all sampled years. Element data in µg/g dry wt. unless noted, and organic data in ng/g dry wt.).

Oyster data only

	Cu	Zn	Ag	Pb
n	128	128	128	128
Median	140	2200	2.3	0.51
85th percentile	290	4600	5.0	0.82

Mussel and oyster data

	Ni	As	Se	Cd	Hg
n	281	281	281	281	280
Median	1.9	9.2	2.8	2.8	0.10
85th percentile	2.1	16	3.9	5.9	0.21

	∑DDTs	∑PCBs	∑PAHs	∑Cdane	∑Dieldrin
n	280	280	268	280	280
Median	33	100	300	10	5.1
85th percentile	140	450	1200	32	15

	Mirex	Hexachloro-benzene	Lindane	Endrin	∑BTs
n	280	280	280	45	250
Median	0.24	0.23	1.2	0.38	54
85th percentile	1.2	1.1	2.8	2.3	200

Sediment data (Calculated using Mussel Watch Project sediment data only.)

	Al (%)	Si (%)	Cr	Mn	Fe (%)
n	223	178	222	199	223
Median	2.4	3.0	54	370	2.1
85th percentile	4.8	36	120	740	3.7

	Ni	Cu	Zn	As	Se
n	223	223	223	223	207
Median	17	14	67	6.9	0.38
85th percentile	36	47	130	12	0.74

	Ag	Cd	Sn	Sb	Hg
n	223	223	223	178	223
Median	0.11	0.19	1.3	0.47	0.057
85th percentile	0.59	0.56	3.1	1.8	0.22

TABLE 3 (cont.)

NS&T Mussel Watch Data medians and 85th percentile values (1986 - 1997)
(Medians and percentiles were determined using the average at each site across all sampled years. Element data in µg/g dry wt. unless noted, and organic data in ng/g dry wt.).

	Tl	Pb	TOC (%)	∑DDTs	∑PCBs
n	145	223	220	224	224
Median	0.073	18	1.0	2.9	15
85th percentile	0.56	40	2.4	18	80

	∑PAHs	∑Cdane	∑Dieldrin	Mirex
n	224	224	224	224
Median	380	0.51	0.30	0.002
85th percentile	2300	3.1	1.9	0.36

	Hexachloro-benzene	Lindane
n	223	224
Median	0.14	0.04
85th percentile	0.92	0.47

∑DDTs: The sum of concentrations of DDTs and its metabolites, DDEs and DDDs.
∑PCBs: The sum of the concentrations of homologs, which is approximately twice the sum of the 18 congeners.
∑PAHs: The sum of concentrations of the 18 PAH compounds.
∑Cdane: The sum of *cis*-chlordane, *trans*-nonachlor, heptachlor and heptachlorepoxide.
∑Dieldrin: The sum of dieldrin and aldrin.
∑BTs: The sum of the concentrations of tributyltin and its breakdown products dibutyltin and monobutyltin (as ng Sn/g dry wt.).
n: Number of data points (roughly equivalent to the number of sampling sites).

pesticide residues, with the enrichment mechanism being the transport of As by a mixture of atmospheric deposition, river and aquifer inputs, and ocean upwelling. No decreasing trend was exhibited for As with the exception of the Pungo River site in Pamlico Sound.

High total-butyltin concentrations were found at the two Charleston Harbor sites, which is not unexpected because this is the most urban area along the coast of the Carolinas and because the harbor has considerable maritime traffic and recreational boating. High total-butyltin concentrations were also noted at the Beaufort, NC site. The area around Beaufort is heavily used for recreational boating.

Total-chlordane, a pesticide banned in the 1980s in the US, is lower than the 85th percentile at all but one site and usually the concentration of this contaminant is near or below the national median of Mussel Watch sites. DDT, a pesticide banned in the 1970's, is at or below the national median at all sites. Dieldrin and aldrin are also at or below the national median concentrations at most Carolina sites.

Concentrations of total polycyclic aromatic hydrocarbons (∑PAHs), like most other organic contaminants, are correlated with population in estuarine and coastal areas. Thus it is not unexpected that two sites with relatively high concentrations of PAHs are in Charleston Harbor. The site at Beaufort Inlet-Pivers Island exhibits the highest PAH concentrations but these high concentrations are in part due to the

TABLE 4

Temporal trends in chemical concentrations measured nationally at 186 Mussel Watch Project sites and at eleven sites in the Carolinas for which data exist for the years 1986-1997.

	Trend				Trend		
Aggregated chemicals*	I	D	NT	Element	I	D	NT
∑Cdane	1	81 (2)	104	As	11	11 (1)	164
∑DDTs	1	38 (1)	147	Cd	3	28 (1)	155
∑Dield	1	32 (1)	154	Cu	7 (2)	14 (1)	165
∑PCBs	1	37 (1)	148	Hg	7	9	170
∑PAHs	3	3 (3)	180	Ni	6	8	172
∑BTs	0	18	168	Pb	14	9	163
				Se	8	9	169
				Zn	7	9	170

I - Increasing, D - Decreasing, NT - No trend. Increasing and decreasing trends for Metropolitan New York are given in parentheses.
* Individual organic compound concentrations have been aggregated into these groups:
∑DDTs: The sum of concentrations of DDTs and its metabolites, DDEs and DDDs.
∑Cdane: The sum of *cis*-chlordane, *trans*-nonachlor, heptachlor and heptachlorepoxide.
∑PCBs: The sum of the concentrations of di-, tri-, tetra-, penta-, hexa-, hepta-, octa-, and nonachlorobiphenyls.
∑PAHs: The sum of concentrations of the 18 PAH compounds.
∑BTs: The sum of the concentrations of tributyltin and its breakdown products dibutyltin and monobutyltin (as tBT/g dry wt.).

Wind-swept dunes near the abandoned Coast Guard Station, Nags Head, North Carolina, E. J. Pastula, NOAA/NMFS (NOAA Photo Collection, NOAA Central Library)

fact that the sampling site is immediately adjacent to a bridge while other Mussel Watch Project sites are removed from point sources of contamination and as a result give a better indication of the overall contaminant burden of the area in which they are located.

Trends

Contamination trends at the NS&T sites around the US from 1986 through 1995 have been identified by comparing annually measured concentrations in mollusk samples from each of 186 sites that were sampled for at least six years (Table 4). The non-parametric Kendall-tau test was used to determine statistically significant correlations between contaminant concentration and year. A total of 186 sites nationally was examined for each chemical, which if the probability level is ≤0.05 would result in about 10 trends per chemical being reported nationally due to random variations alone.

The most common observation for the national data was that no trend was evident, but, when trends were noted, decreases greatly outnumbered increases. Contamination is decreasing for chemicals whose U.S. use has been banned, such as chlordane, DDT, and dieldrin, or severely curtailed, such as tributyltin and Cd. For other chemicals there is no evidence, on a national scale, for either increasing or decreasing trends (O'Connor, 1996). Table 4 shows the numbers of sites with Increasing (I), Decreasing (D), or No Trends (NT) in concentrations of each chemical with trends specific to the Carolinas shown in parenthesis. For most sites, a decreasing trend was observed.

CONCLUSIONS

Most trace elements and organic contaminants measured by NOAA's Mussel Watch Project in the Carolinas are at national median concentrations or lower. Total butyltin concentrations are high at the two sites within Charleston Harbor, which is not unexpected because of the maritime and recreational boating traffic in the horbor. The highest concentrations of As quantified in oysters and mussels, nationally, are found in the sites of the Carolinas. There is no apparent association between human population and these elevated As concentrations. Rather, these elevated As concentrations may be associated with large phosphate deposits found in the US Southeast. Few decreasing or increasing trace element or organic contaminant trends were seen in the Carolinas.

ACKNOWLEDMENTS

The authors wish to thank the staff at NOAA's National Marine Fisheries Service, Texas A&M University (TAMU/GERG), and Battelle Ocean Sciences for field operations and analytical support.

REFERENCES

Lauenstein G. G., A. Y. Cantillo, S. Kokkinakis, S. Frew, H. J. Jobling, and R. R. Fay (1997) Mussel Watch Project site descriptions through 1997. Tech. Memo. NOS ORCA 112, NOAA/NOS/ORCA, Silver Spring, MD, 354 pp.

Lauenstein G. G., and A. Y. Cantillo (1998) Sampling and analytical methods of the National Status and Trends Program Mussel Watch Project: 1993-1996 update. NOAA tech. memo. NOS ORCA 130, 233 pp.

Lauenstein G. G., and A. Y. Cantillo (2002) The status and trends of trace element and organic contaminants in oysters, *Crossostrea virginica*, in the waters of the Carolinas, USA. Sci. Total Environ., 285:79-87.

Lauenstein G. G., and A. Y. Cantillo (eds.) (1993). Sampling and Analytical Methods of the NOAA National Status and Trends Program National Benthic Surveillance and Mussel Watch Projects 1984-1992: Vol. I - IV. NOAA Tech. memo. NOS ORCA 71. NOAA/NOS/ORCA, Silver Spring, MD.

Lauenstein, G. G. (1996) Temporal Trends of Trace Element and Organic Contaminants in the Conterminous Coastal and Estuarine United

States, 1986-1993. Ph. D. Dissertation George Mason University, Fairfax, VA. 184 pp.

National Research Council, Washington, DC. Committee on a Systems Assessment of Marine Environmental Monitoring. 1990. Managing Troubled Waters: The Role of Marine Environmental Monitoring. National Academy Press, Washington, DC. 125 pp.

O'Connor, T. P. (1993) The NOAA National Status and Trends Mussel Watch Program: National monitoring of chemical contamination in the coastal United States. In: Environmental Statistics, Assessment and Forecasting. C. R. Cothern and N. P. Ross (eds). Lewis Publ., Boca Raton, FL.

O'Connor, T. P. (1996) Trends in chemical concentrations in mussels and oysters collected along the US coast from 1986 to 1993. Mar. Environ. Res., 41:183-200.

Valette-Silver, N. J., G. F. Riedel, E. A. Crecelius, H. Windom, R. G. Smith, and S. S. Dolvin (1999) Elevated arsenic concentrations in bivalves from the Southeast coasts of the USA. Mar. Environ. Res. 48: 311-333.

NS&T DATA AND INFORMATION PRODUCTS

Data and information resulting from CCMA activities are made available to users and the scientific community at large in different formats and media.

NOAA Technical Memoranda provide detailed accounts of methods, data summaries, and results of various NS&T Program projects and related activities, such as sediment toxicity surveys, analytical methods, and sediment quality assessments.

Digitized data and program information about the NS&T program are available at our website. Presently, data from the Mussel Watch Project (1984-1994) and the Benthic Surveillance Project (1984-1992) can be retrieved by downloading from the NCCOS Information Service which can be accessed at (http://ccmaserver.nos.noaa.gov). New data sets are added to the Service as they are digitized and checked for accuracy. The data sets can also be requested from CCMA.

Scientific publications containing the results of CCMA projects are published as research papers in journals, books, and proceedings of professional conferences. The publications are authored by CCMA staff, contractors, and collaborators. A cumulative list of these publications is issued periodically.

Mussel Watch sampling site in Cape Hatteras, Pamlico Sound (PSCH) (TAMU/GERG).

For further information on the NS&T Program or to obtain a list of available publications, write:

Mussels (TAMU/GERG)

Dr. Adriana Cantillo
National Status and Trends Program
NOAA/NOS/NCCOS/CCMA
1305 East/West Highway
Silver Spring, MD 20910

Phone: 301 713 3028
Fax: 301 713 4388

APPENDICES

Appendix I

Sediment data

Appendix II

Trace element and organic trends in mussels

Appendix I

Sediment data

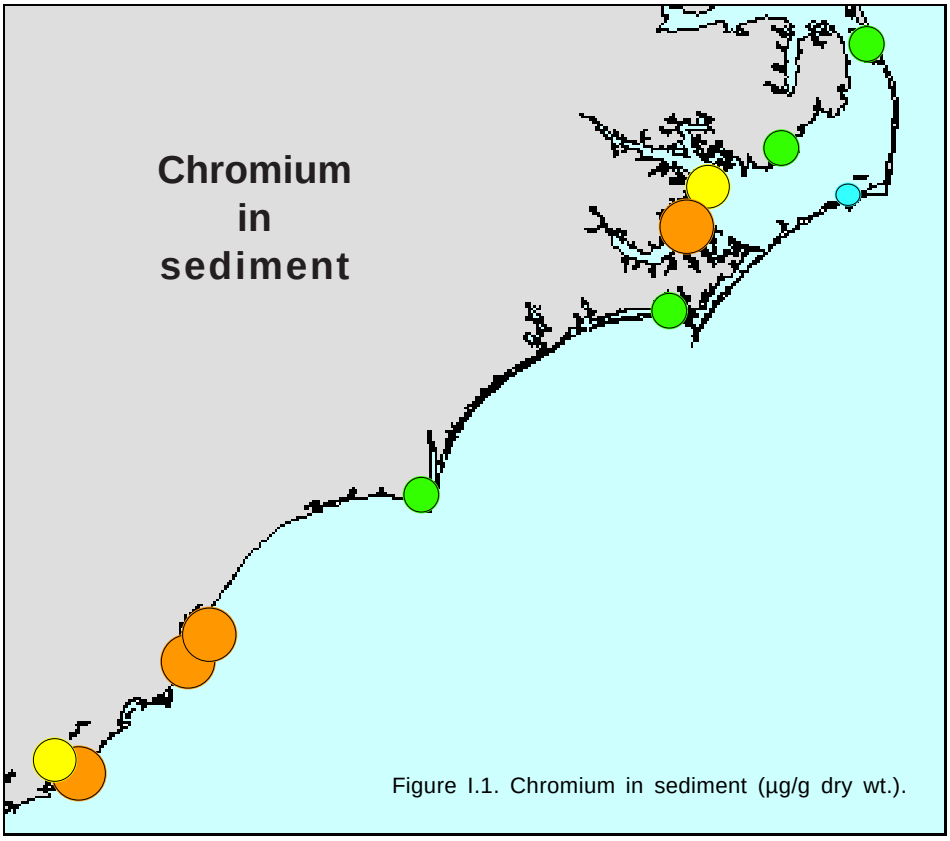


Figure I.1. Chromium in sediment (µg/g dry wt.).

Mussel Watch sampling site in John Creek, Roanoke Sound (RSJC) (TAMU/GERG).

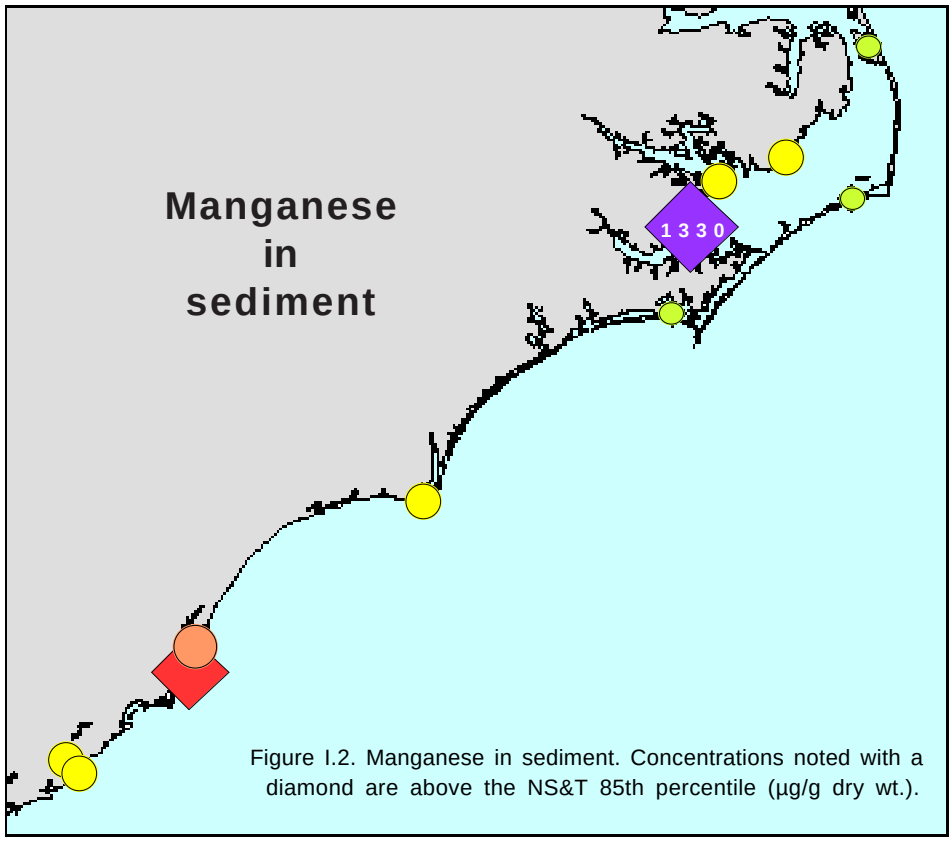


Figure I.2. Manganese in sediment. Concentrations noted with a diamond are above the NS&T 85th percentile (µg/g dry wt.).

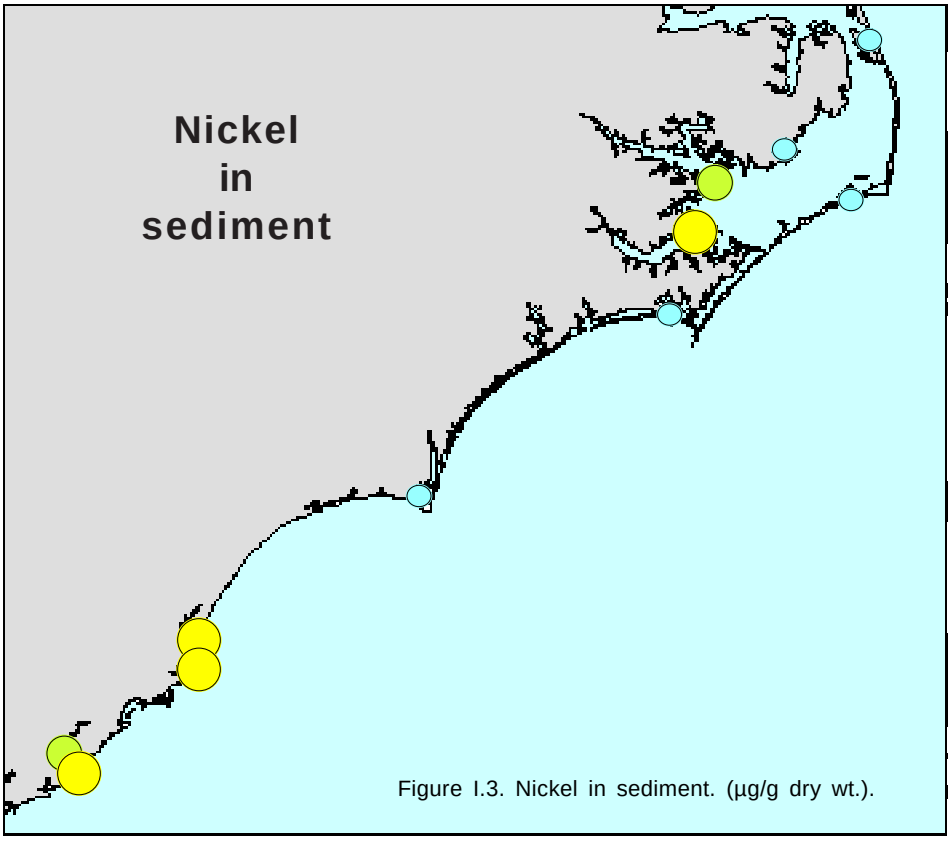


Figure I.3. Nickel in sediment. (µg/g dry wt.).

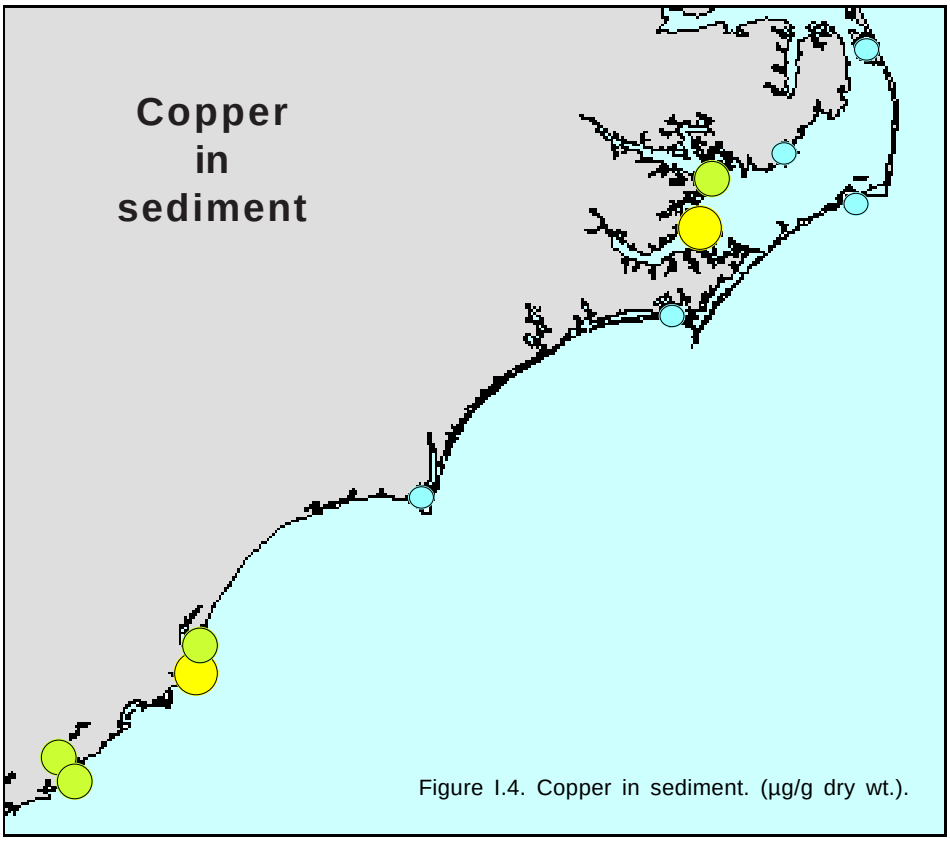


Figure I.4. Copper in sediment. (µg/g dry wt.).

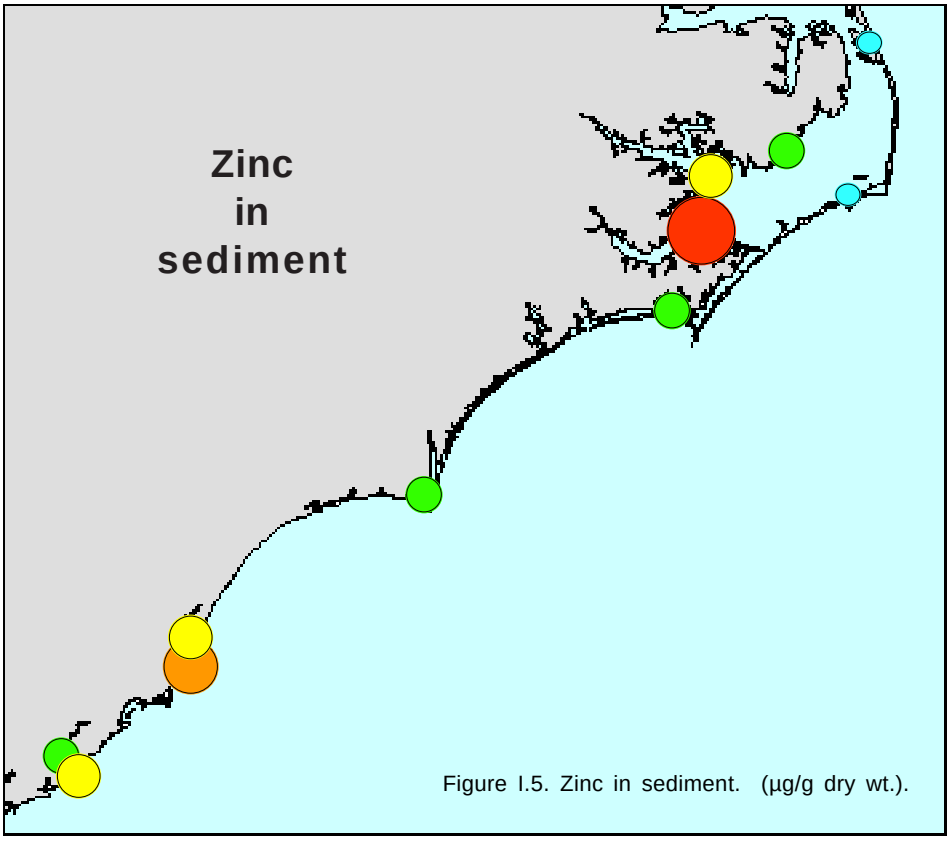


Figure I.5. Zinc in sediment. (µg/g dry wt.).

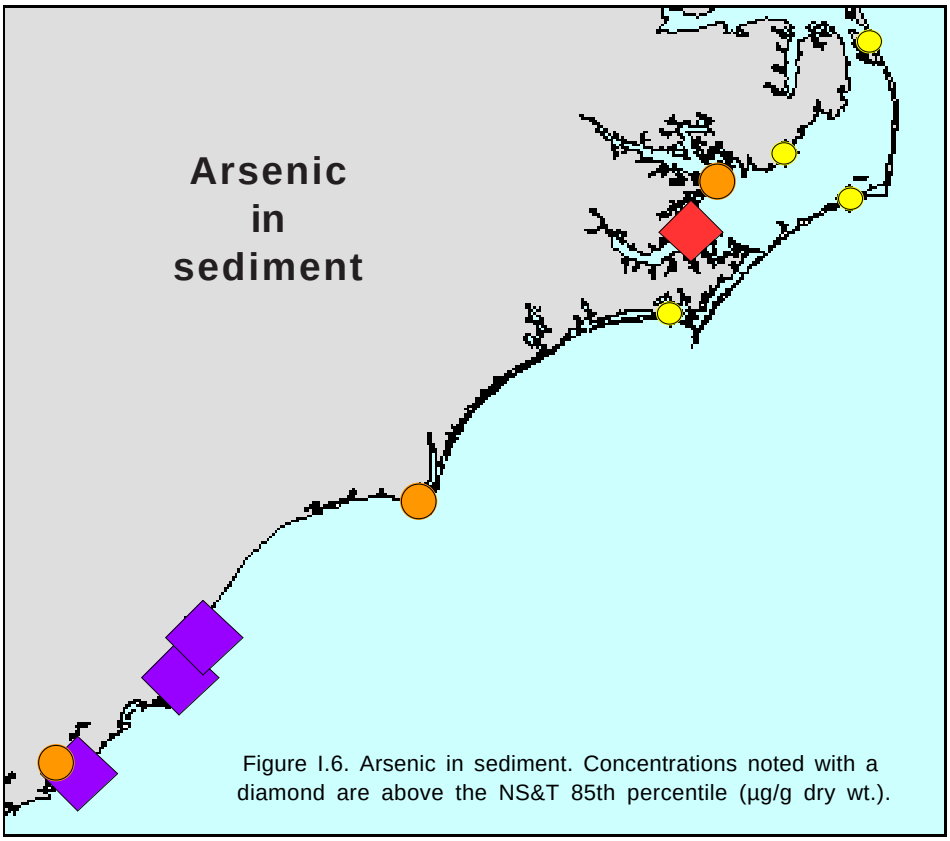


Figure I.6. Arsenic in sediment. Concentrations noted with a diamond are above the NS&T 85th percentile (µg/g dry wt.).

Pivers Island, Beaufort Inlet (BIPI) (TAMU/GERG)

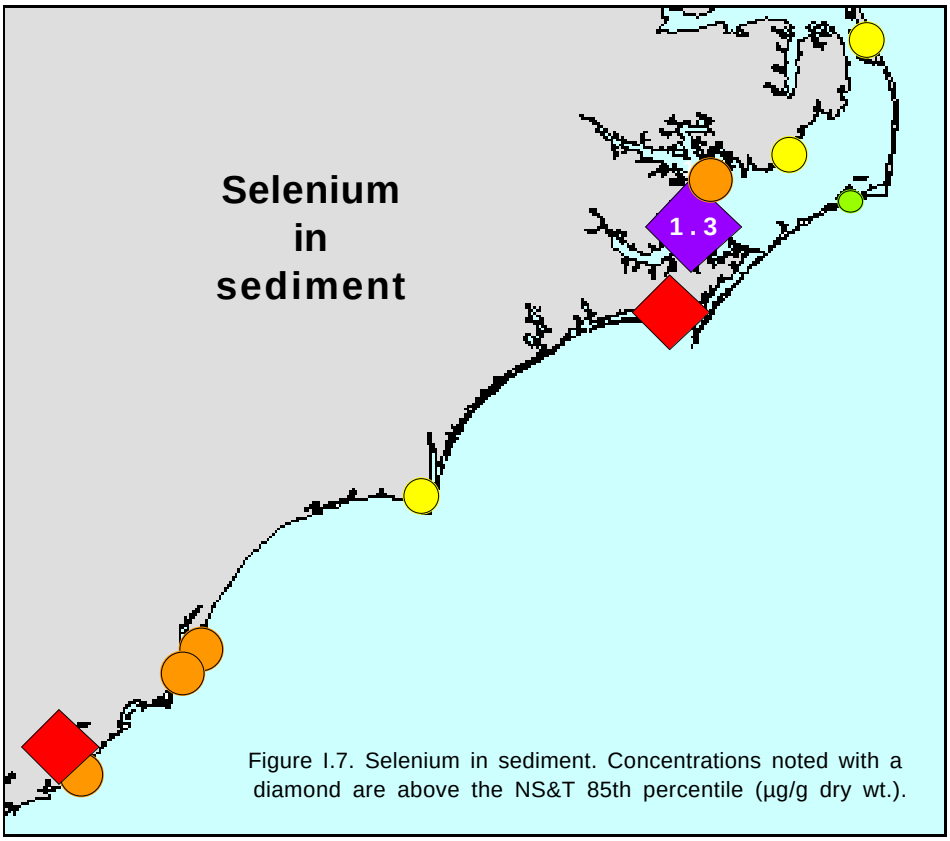


Figure I.7. Selenium in sediment. Concentrations noted with a diamond are above the NS&T 85th percentile (µg/g dry wt.).

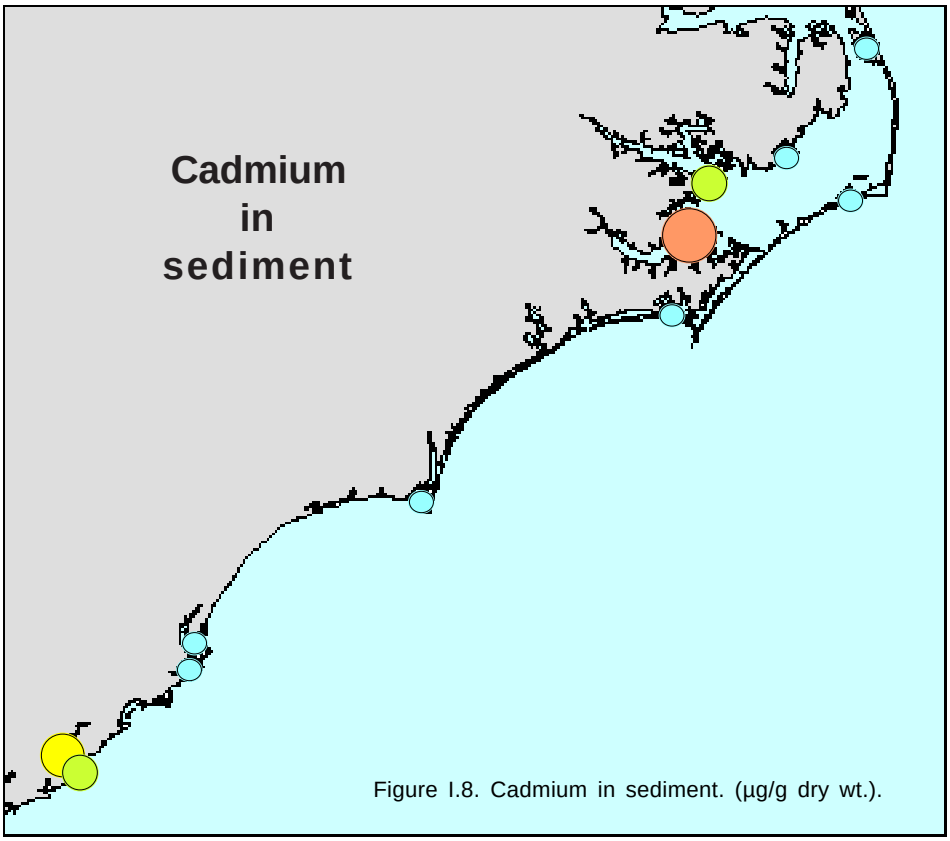


Figure I.8. Cadmium in sediment. (µg/g dry wt.).

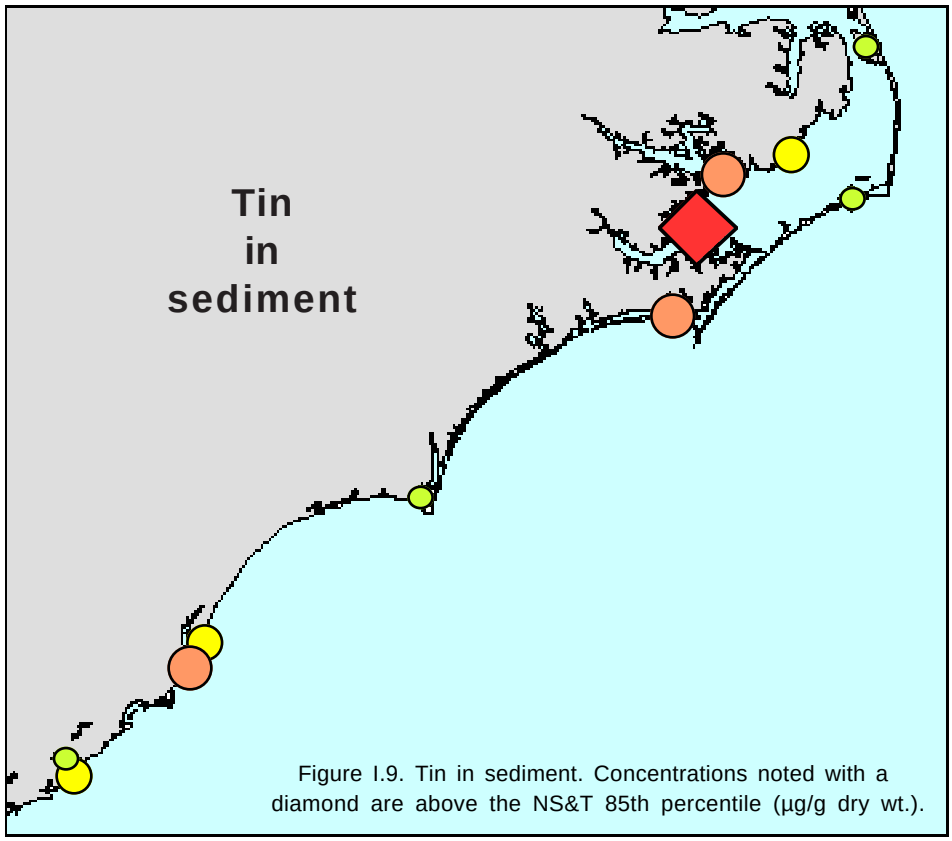


Figure I.9. Tin in sediment. Concentrations noted with a diamond are above the NS&T 85th percentile (µg/g dry wt.).

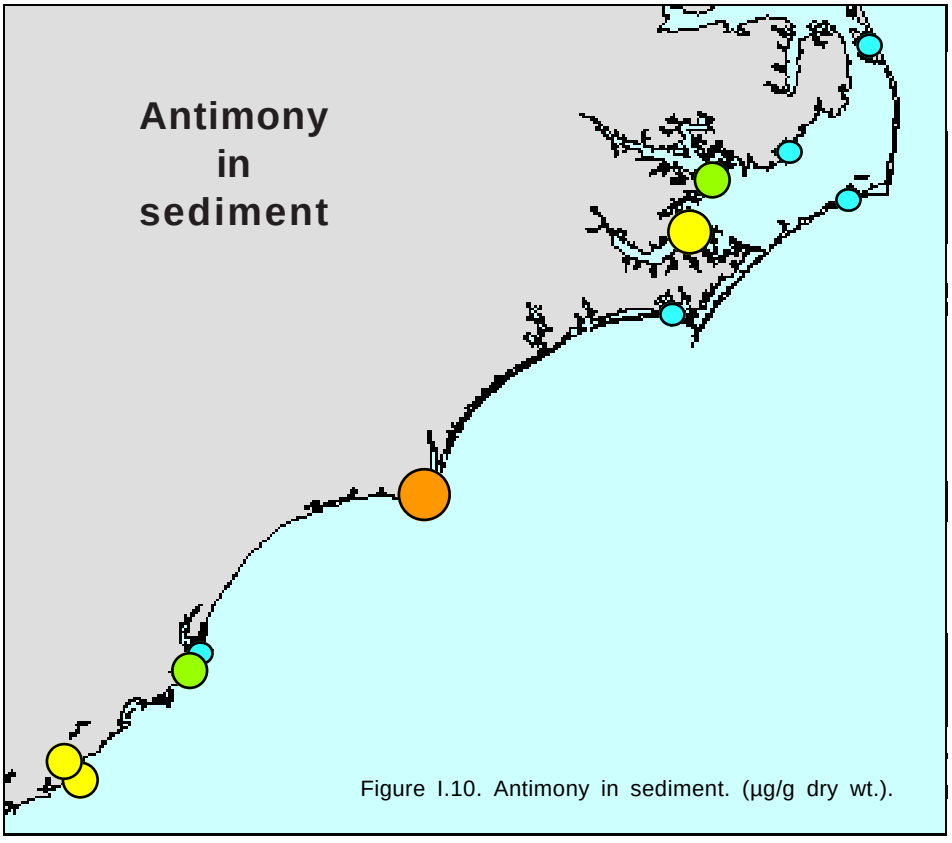


Figure I.10. Antimony in sediment. (µg/g dry wt.).

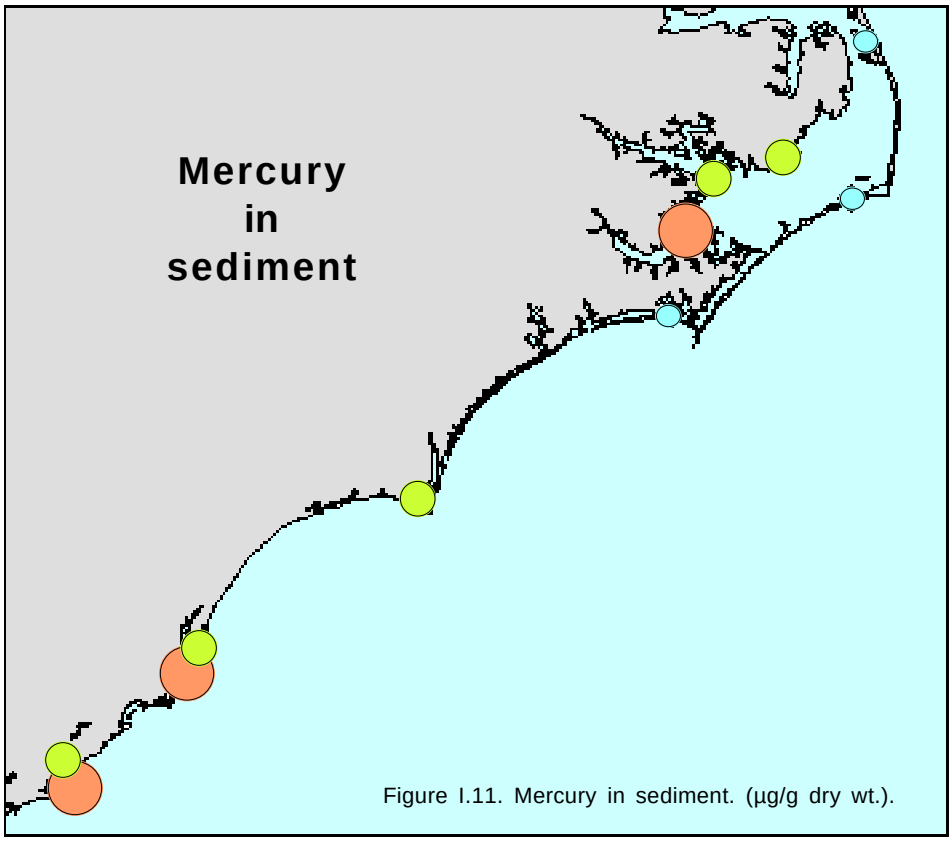


Figure I.11. Mercury in sediment. (µg/g dry wt.).

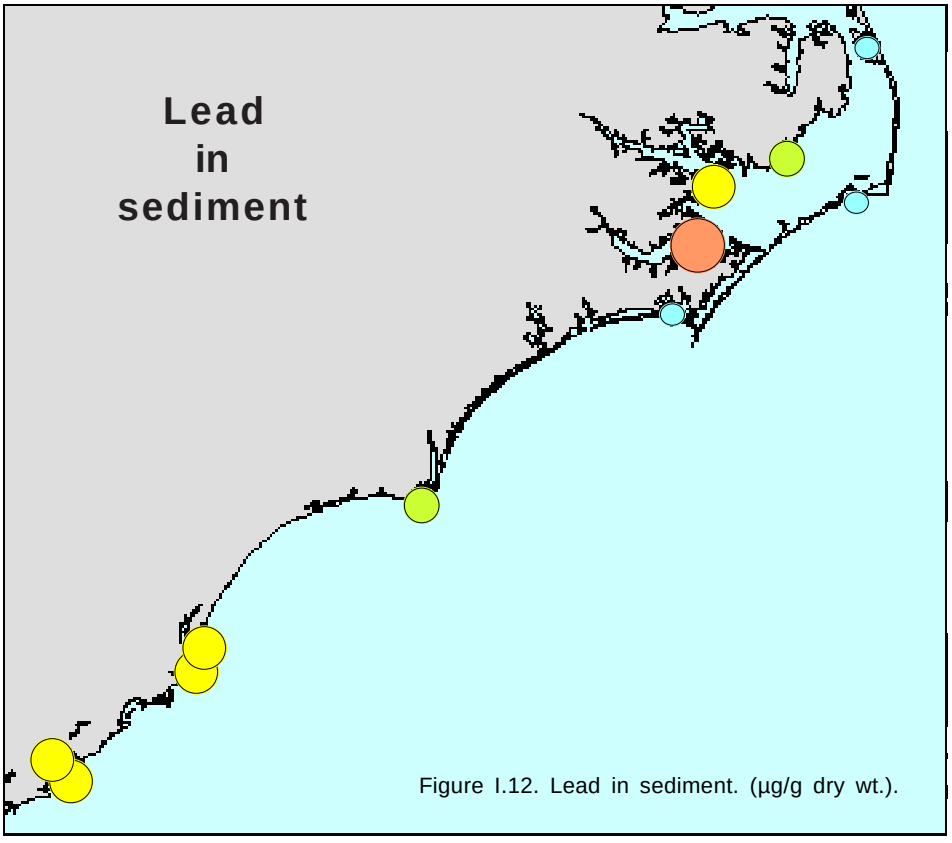


Figure I.12. Lead in sediment. (µg/g dry wt.).

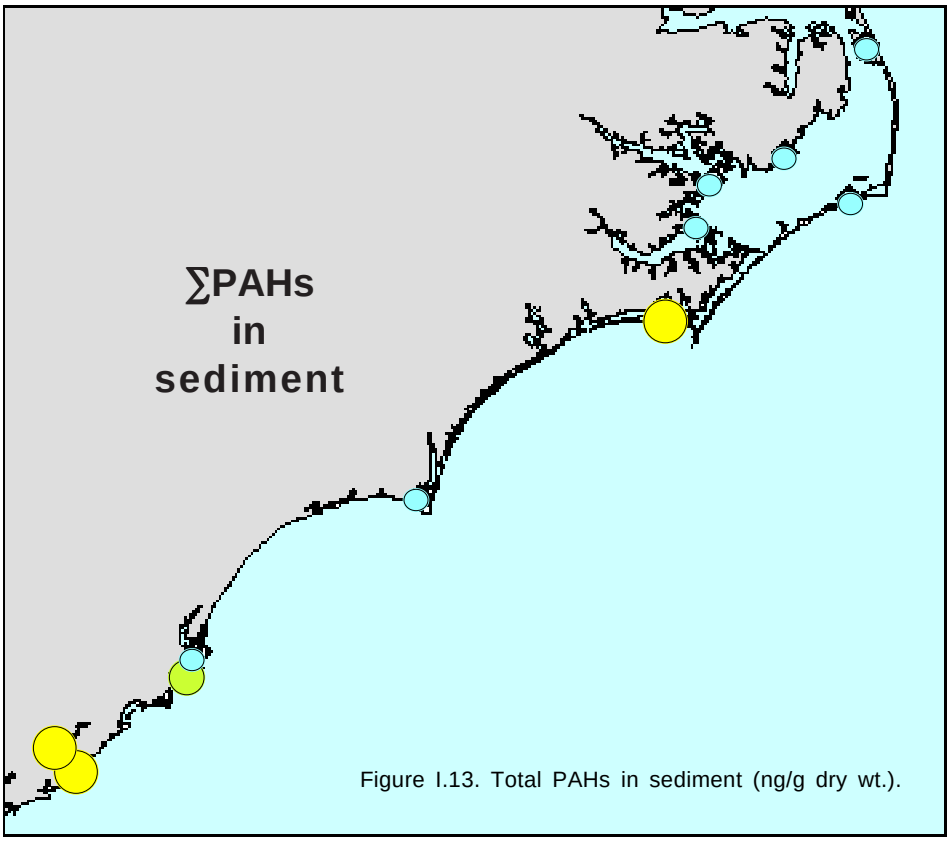


Figure I.13. Total PAHs in sediment (ng/g dry wt.).

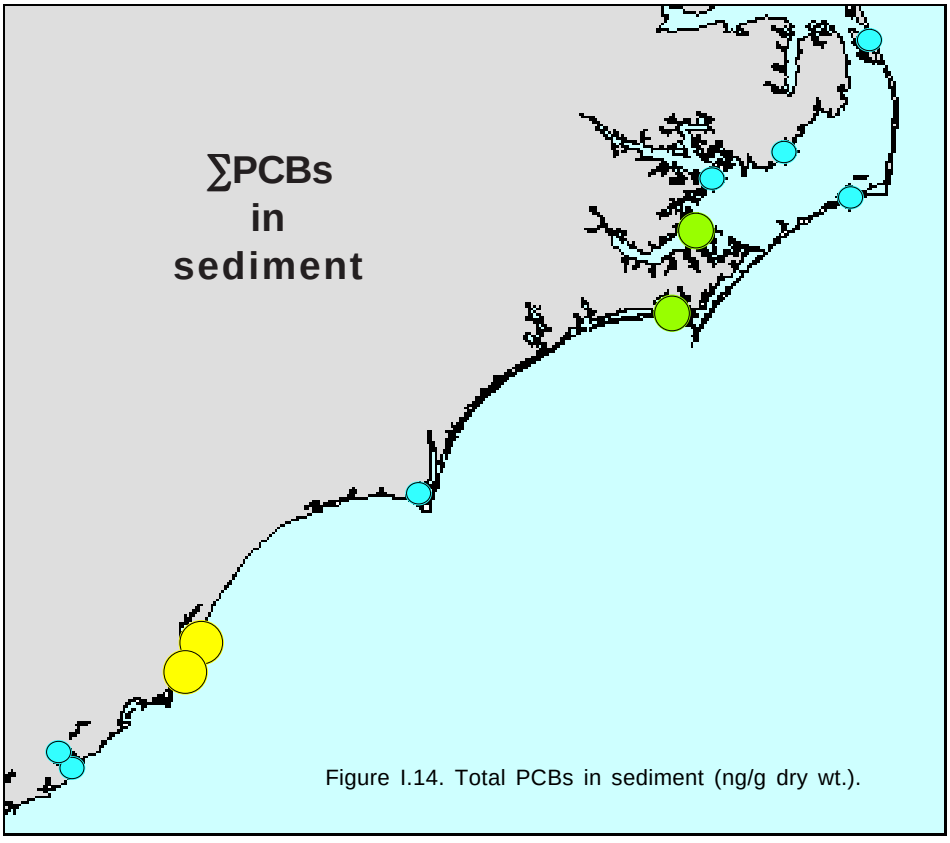


Figure I.14. Total PCBs in sediment (ng/g dry wt.).

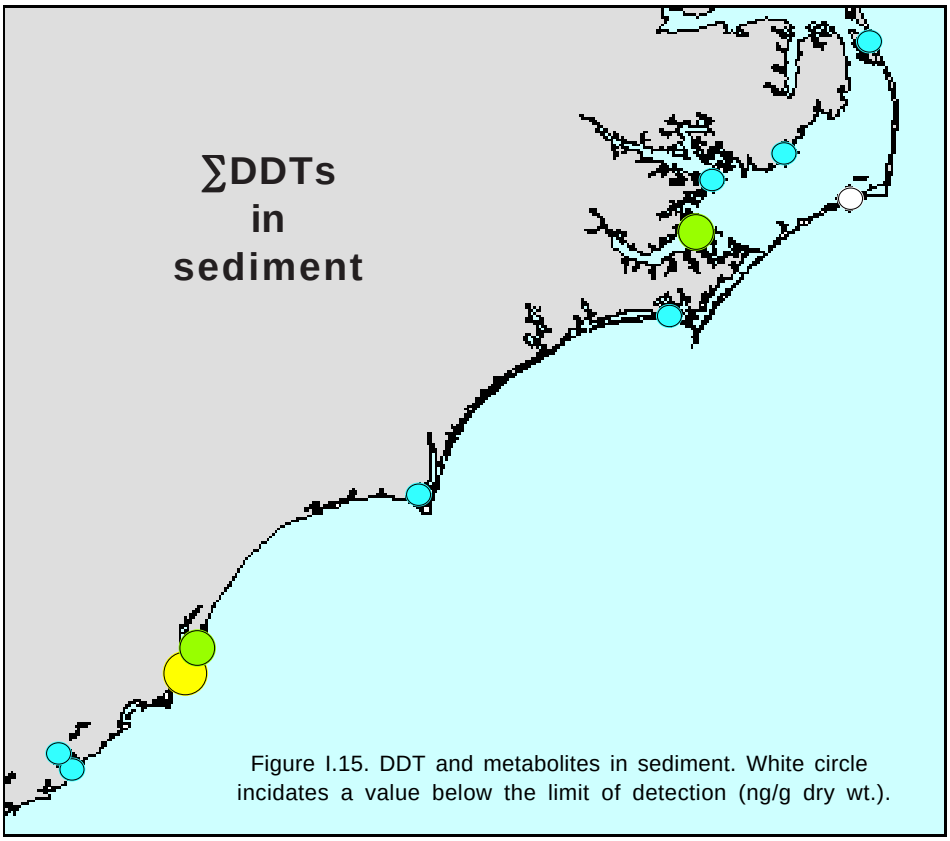


Figure I.15. DDT and metabolites in sediment. White circle incidates a value below the limit of detection (ng/g dry wt.).

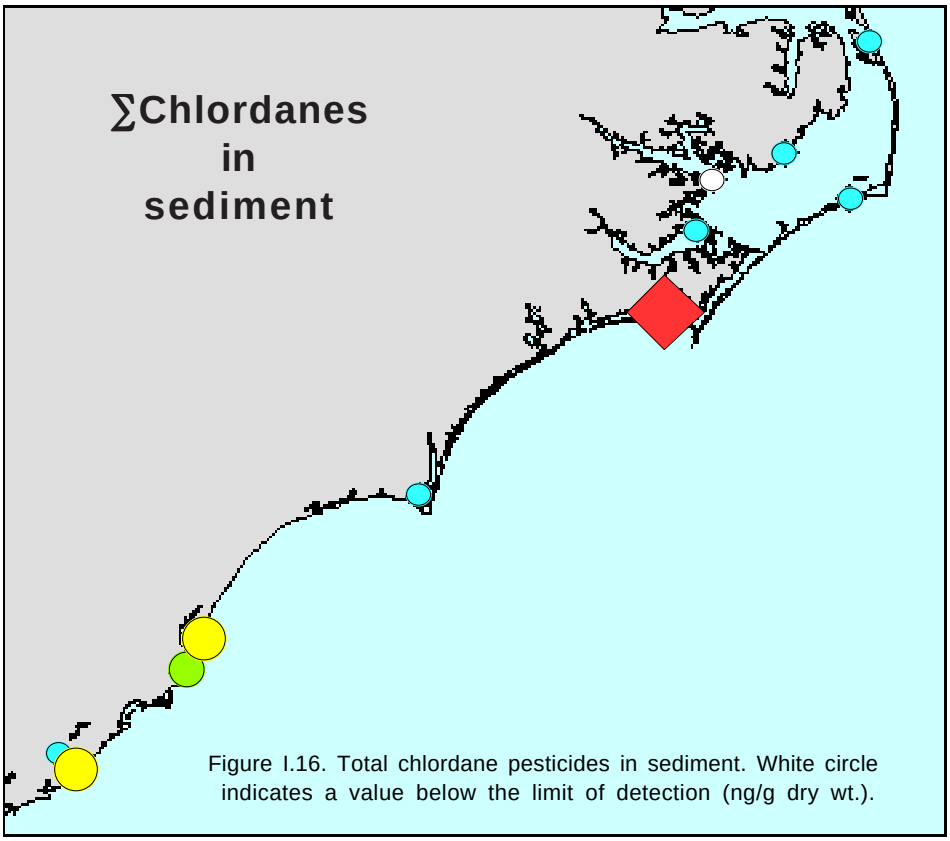


Figure I.16. Total chlordane pesticides in sediment. White circle indicates a value below the limit of detection (ng/g dry wt.).

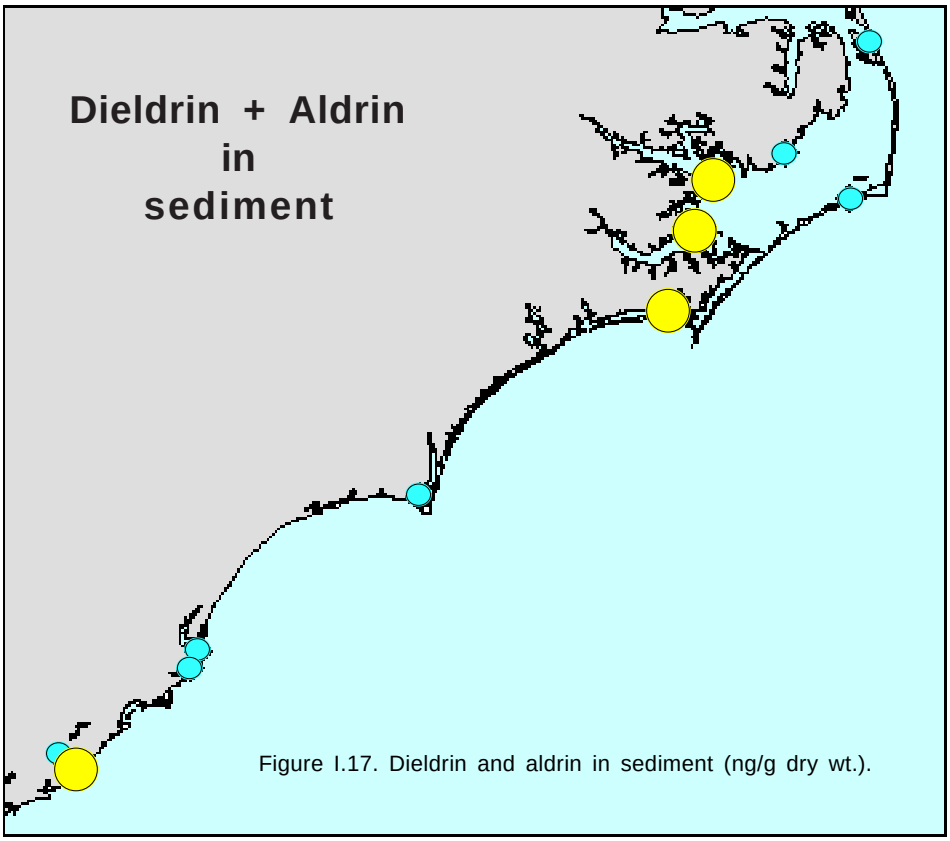


Figure I.17. Dieldrin and aldrin in sediment (ng/g dry wt.).

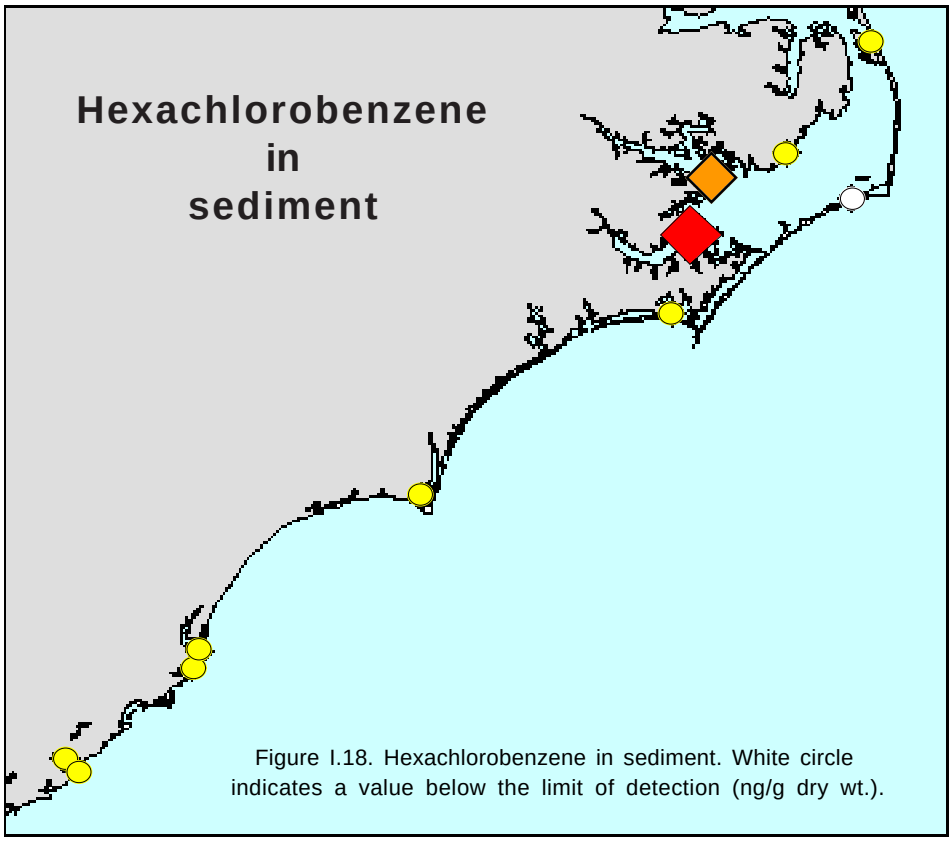


Figure I.18. Hexachlorobenzene in sediment. White circle indicates a value below the limit of detection (ng/g dry wt.).

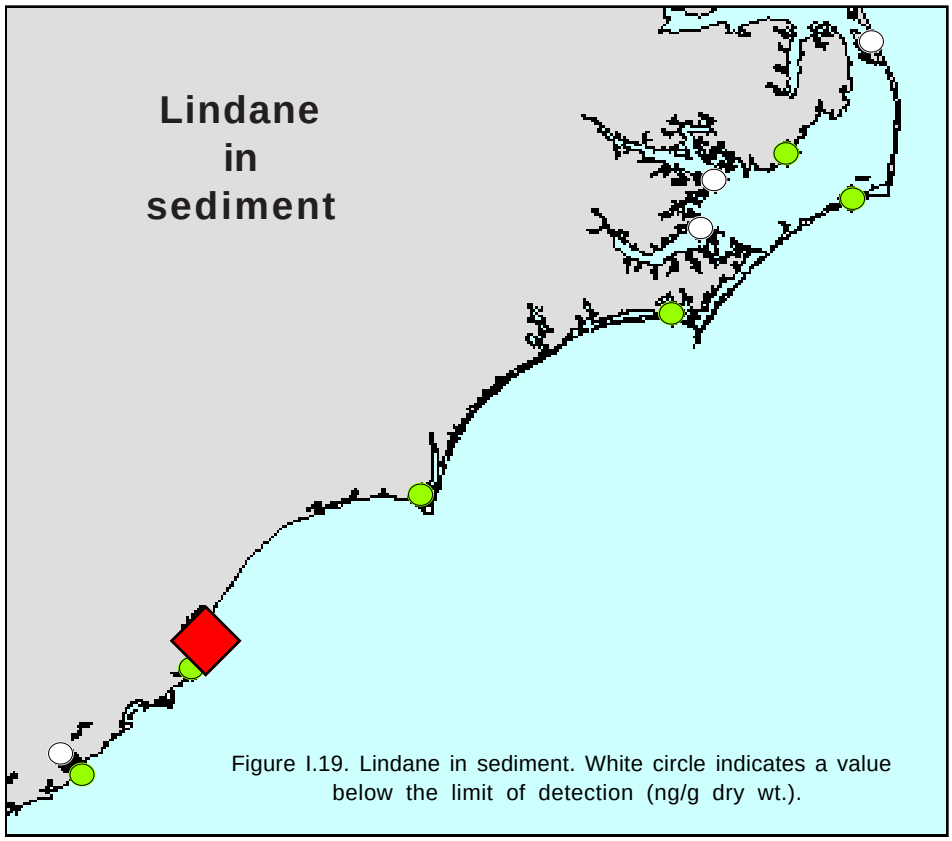


Figure I.19. Lindane in sediment. White circle indicates a value below the limit of detection (ng/g dry wt.).

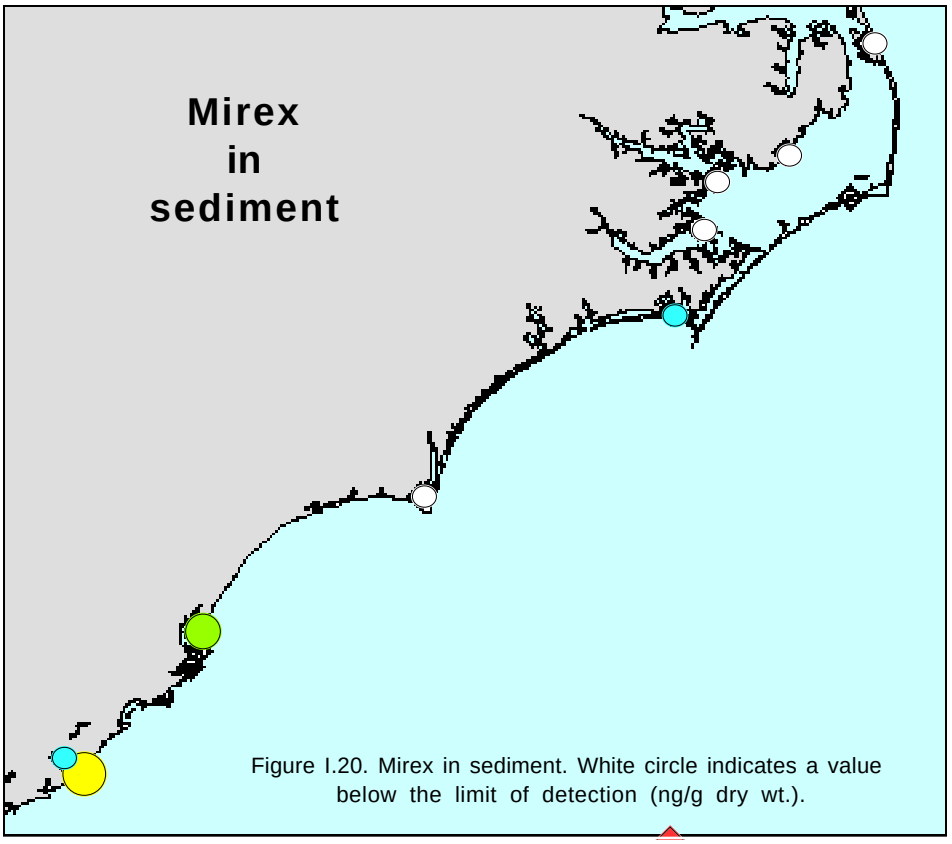
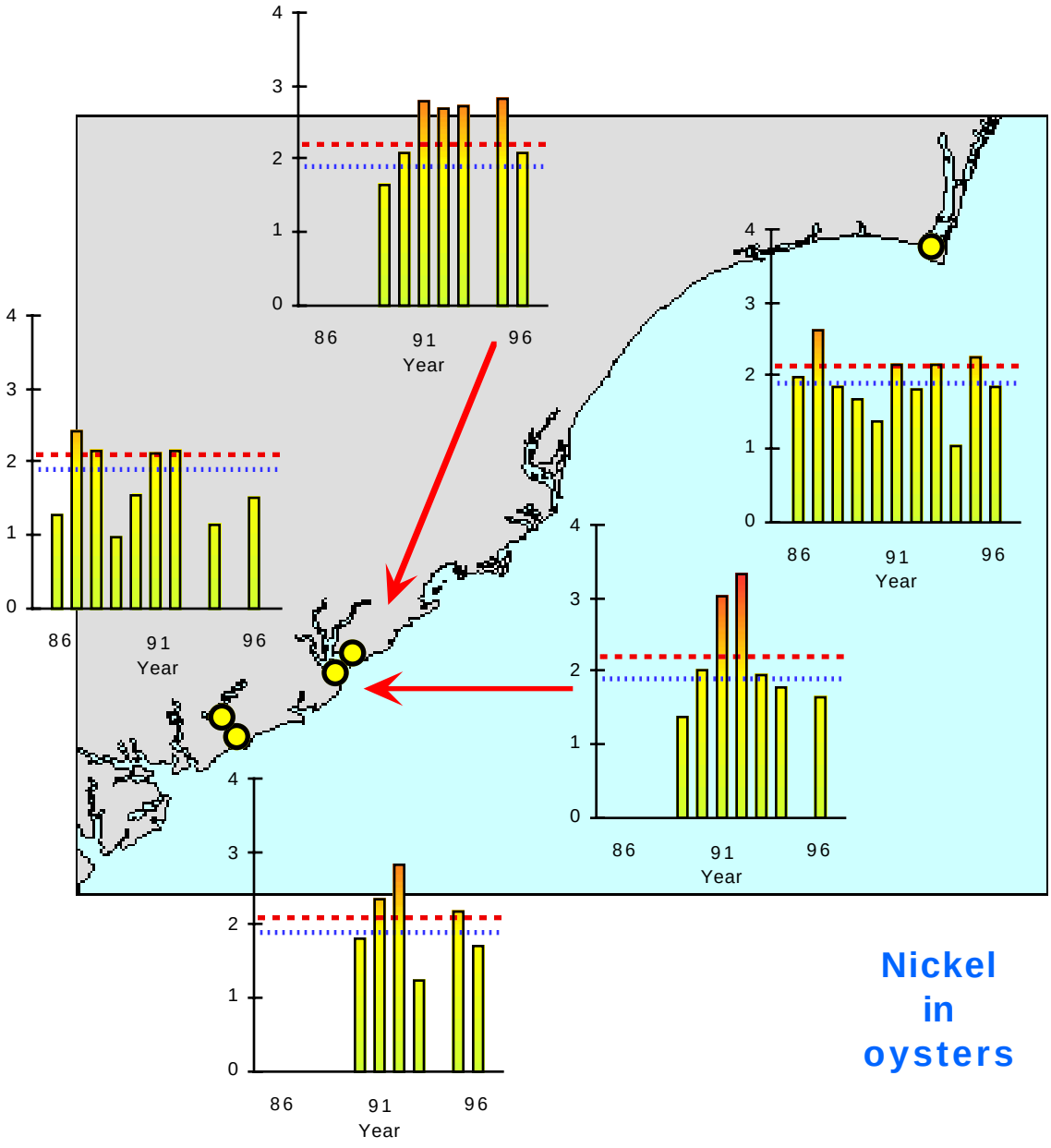


Figure I.20. Mirex in sediment. White circle indicates a value below the limit of detection (ng/g dry wt.).

Appendix II - Trace element and organic trends in oysters



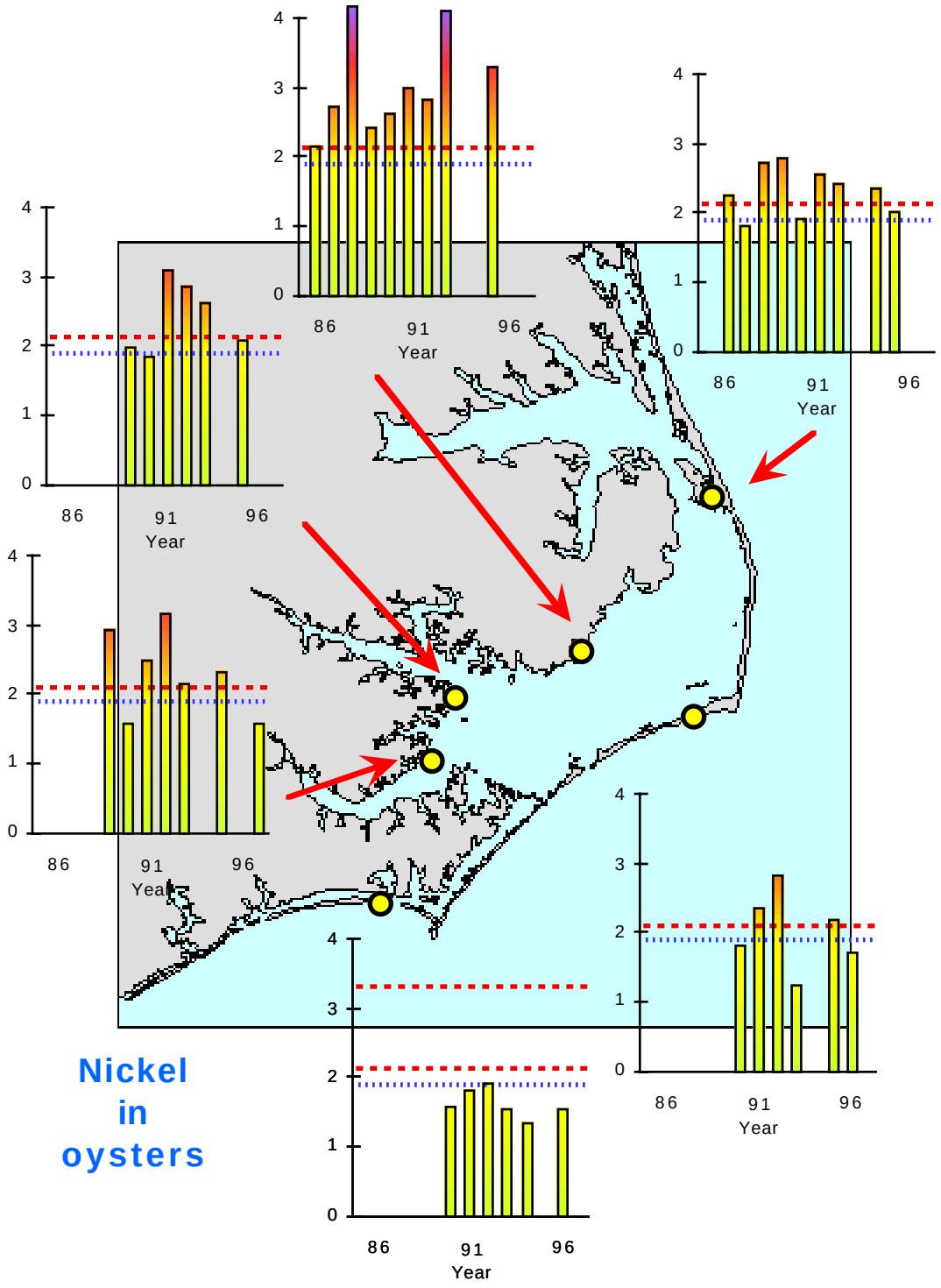
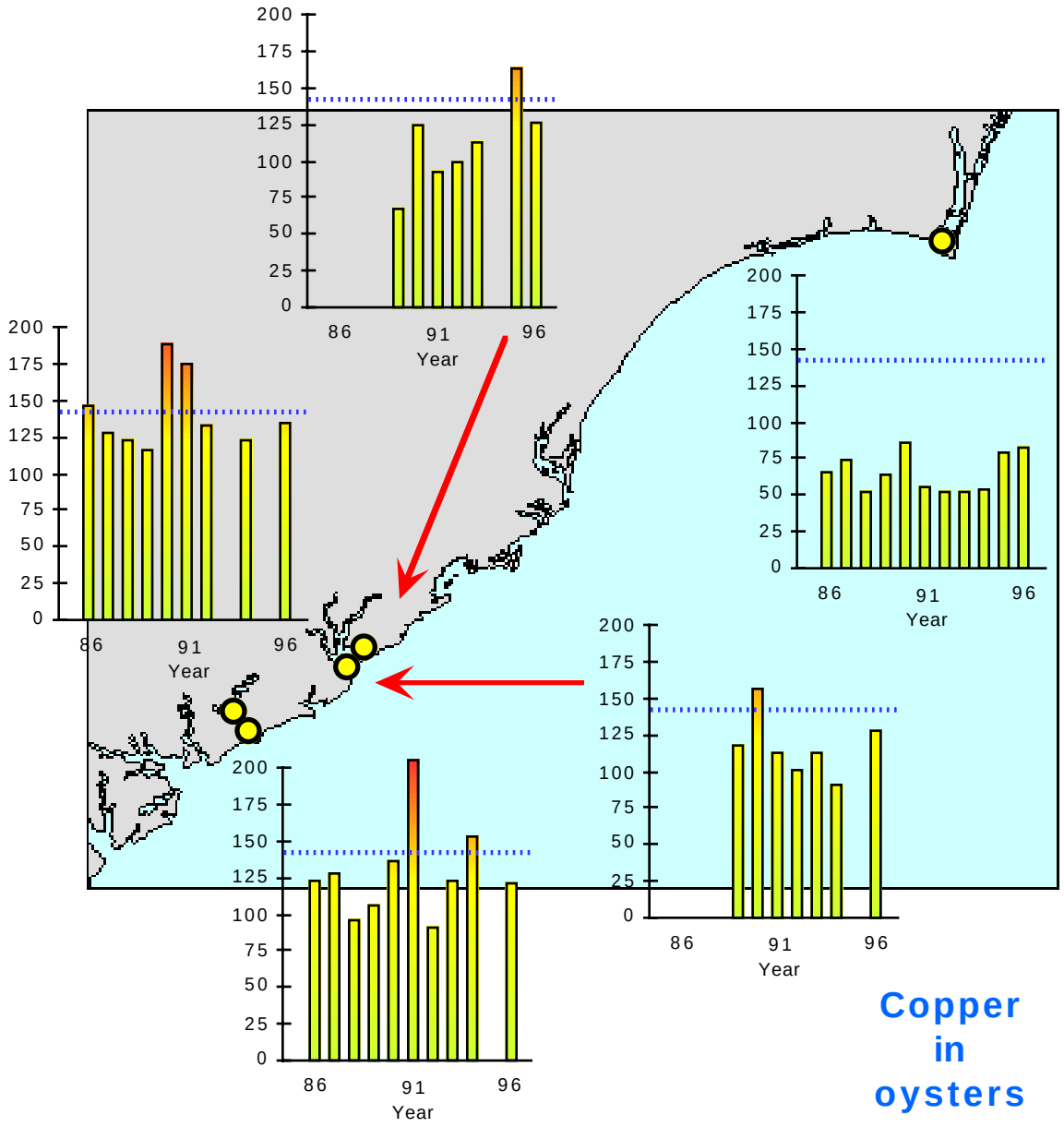


Figure II.1. Nickel trends in oysters. Dotted blue line is NS&T median and dashed red line is NS&T nationwide 85th percentile. (µg/g dry wt.).


200
175
150
125
100
75
50
25
0
86
91
96
Year
Copper
in
oysters

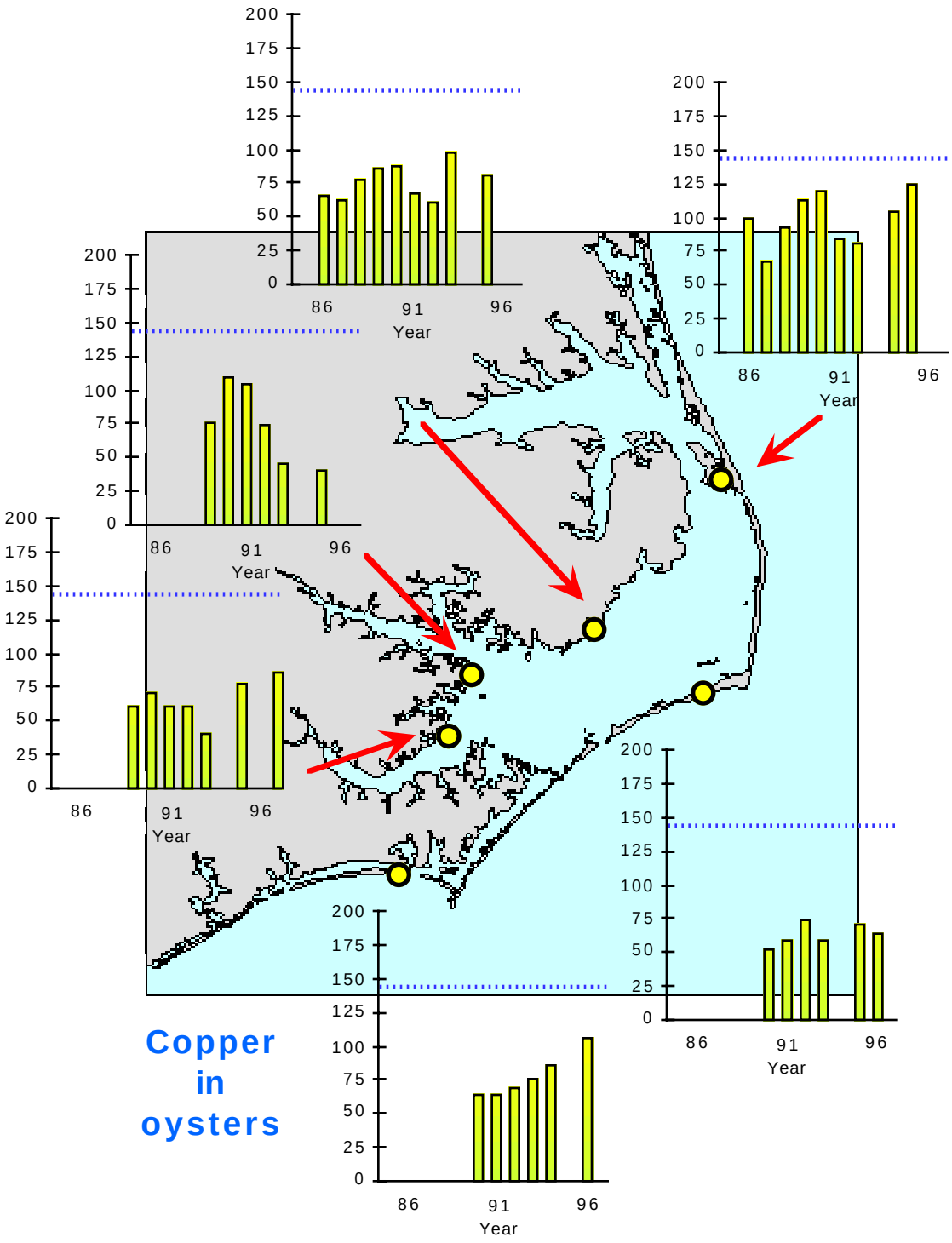
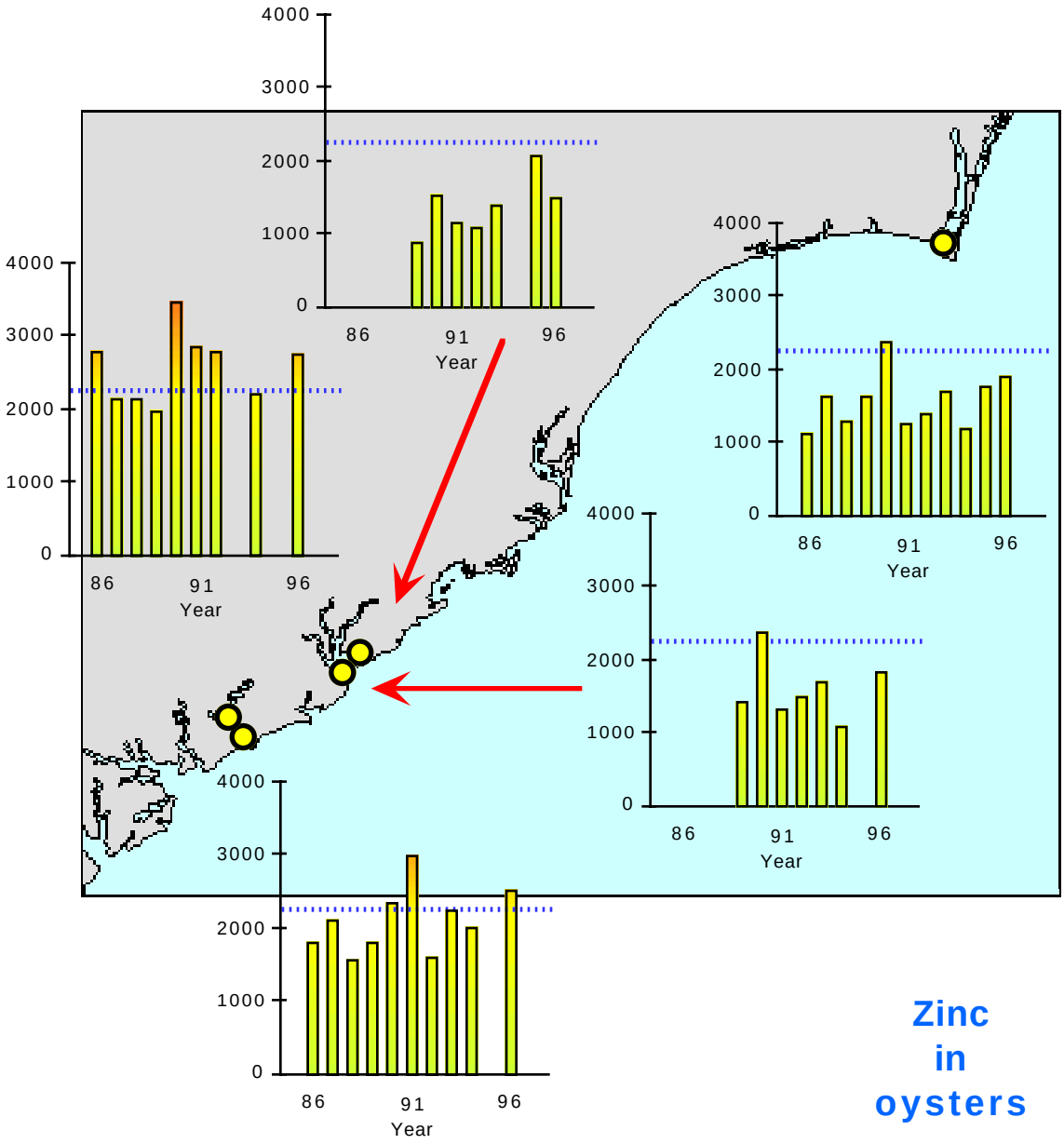


Figure II.2. Copper trends in oysters. Dotted blue line is NS&T median. (µg/g dry wt.).


4000
3000
2000
1000
0
86
91
96
Year
Zinc
in
oysters

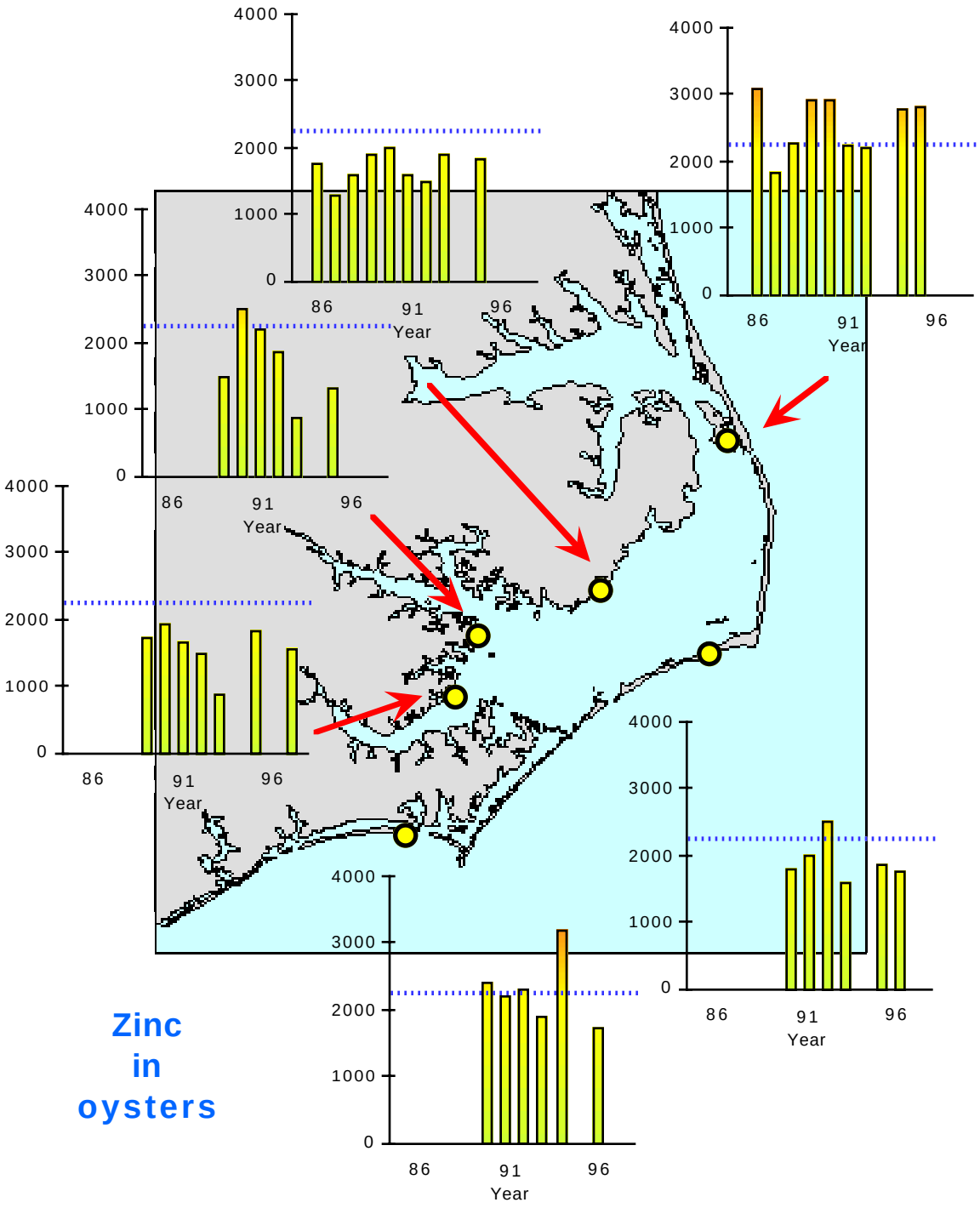
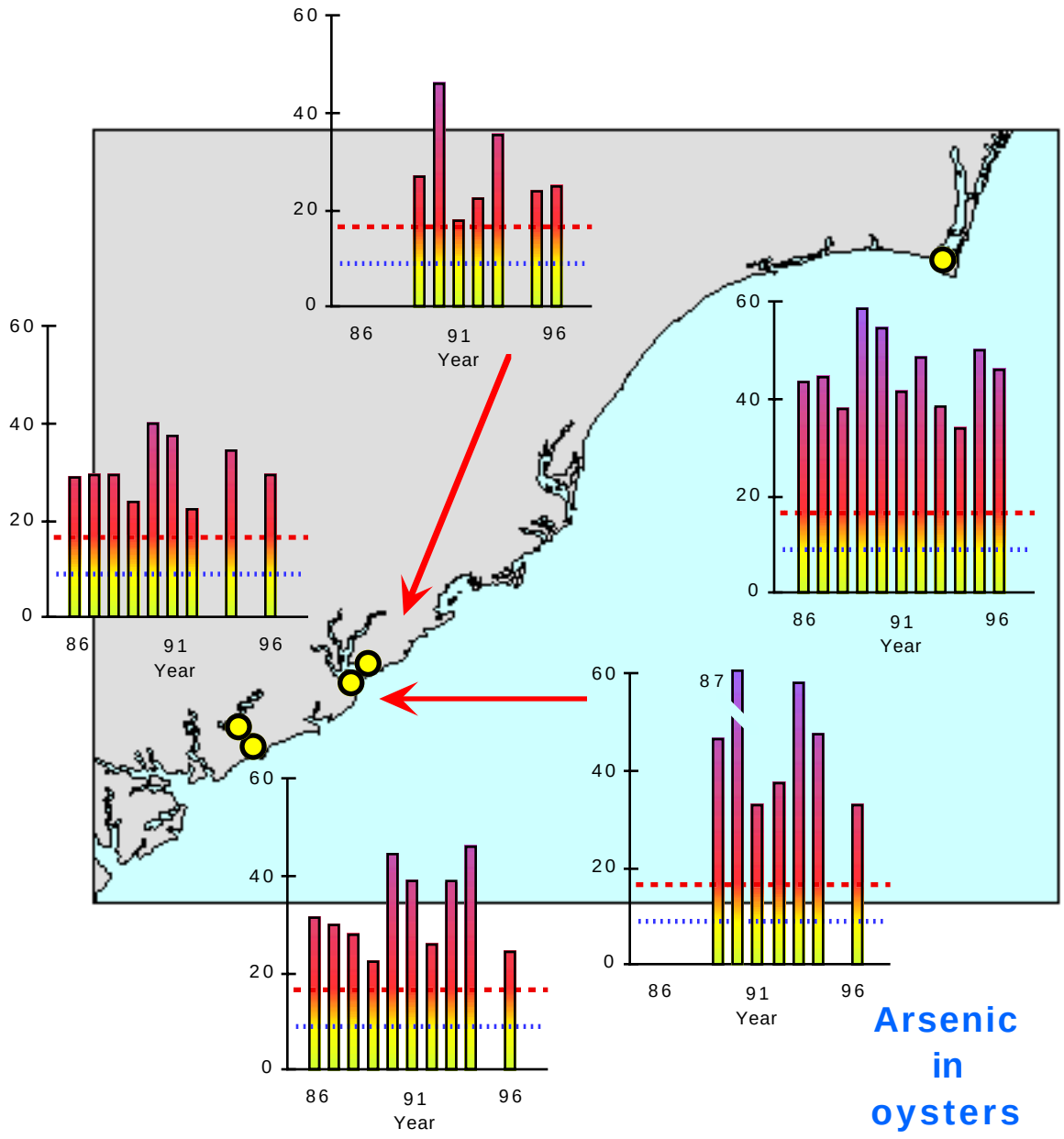


Figure II.3. Zinc trends in oysters. Dotted blue line is NS&T median. (µg/g dry wt.).


60
40
20
0
86
91
96
Year
87
Arsenic in oysters

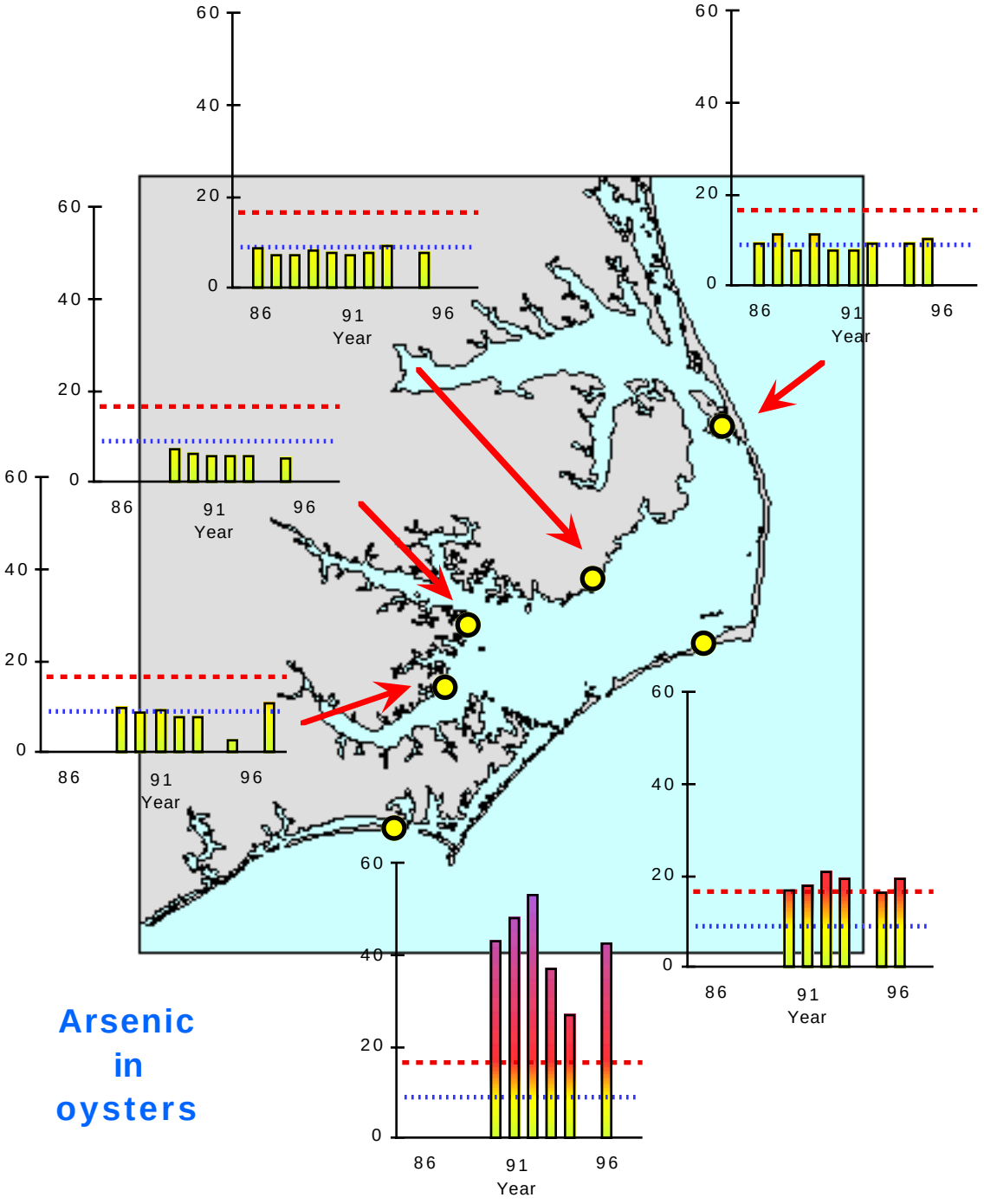
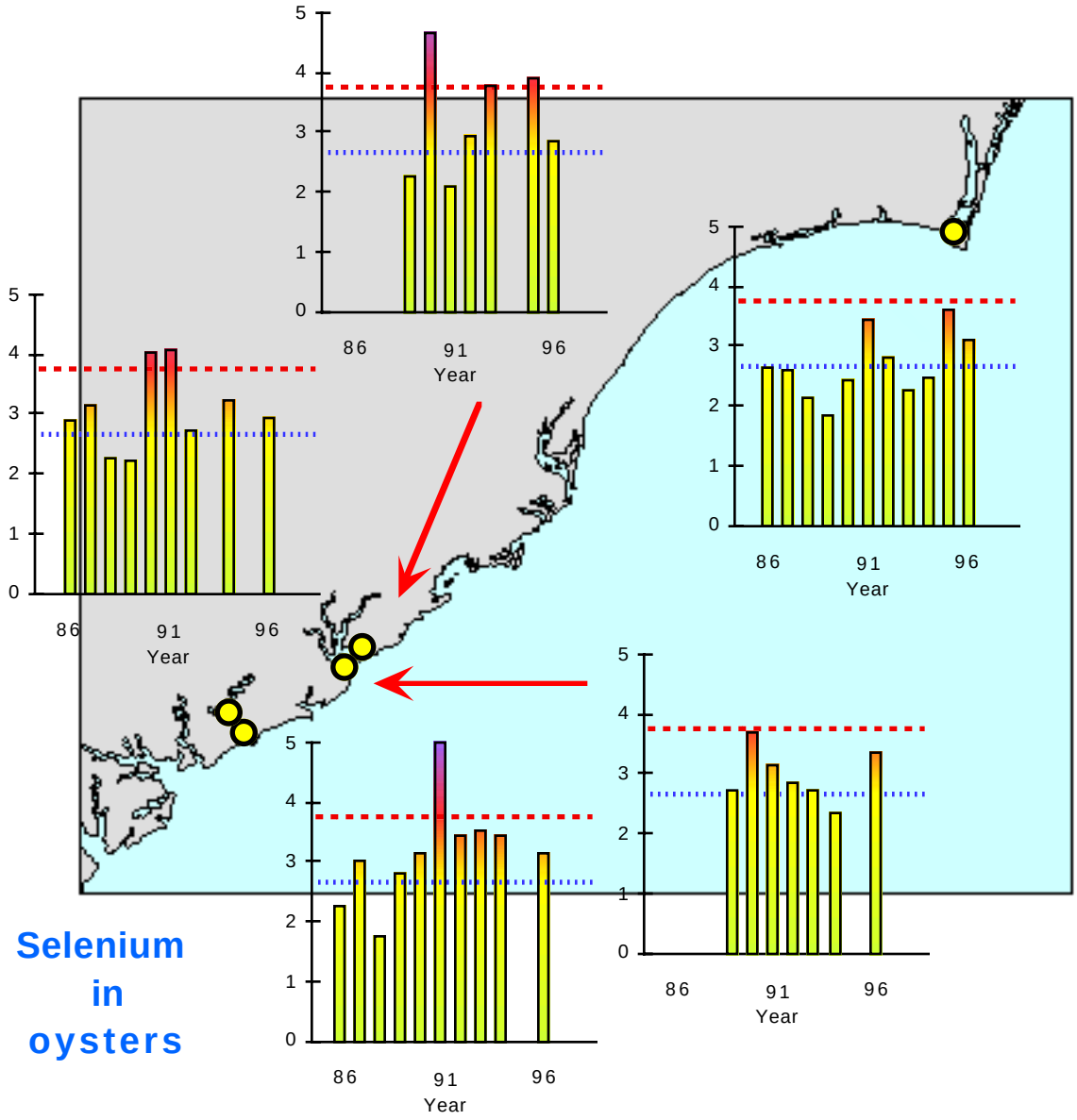


Figure II.4. Arsenic trends in oysters. Dotted blue line is NS&T median and dashed red line is NS&T nationwide 85th percentile. (µg/g dry wt.).



Selenium in oysters

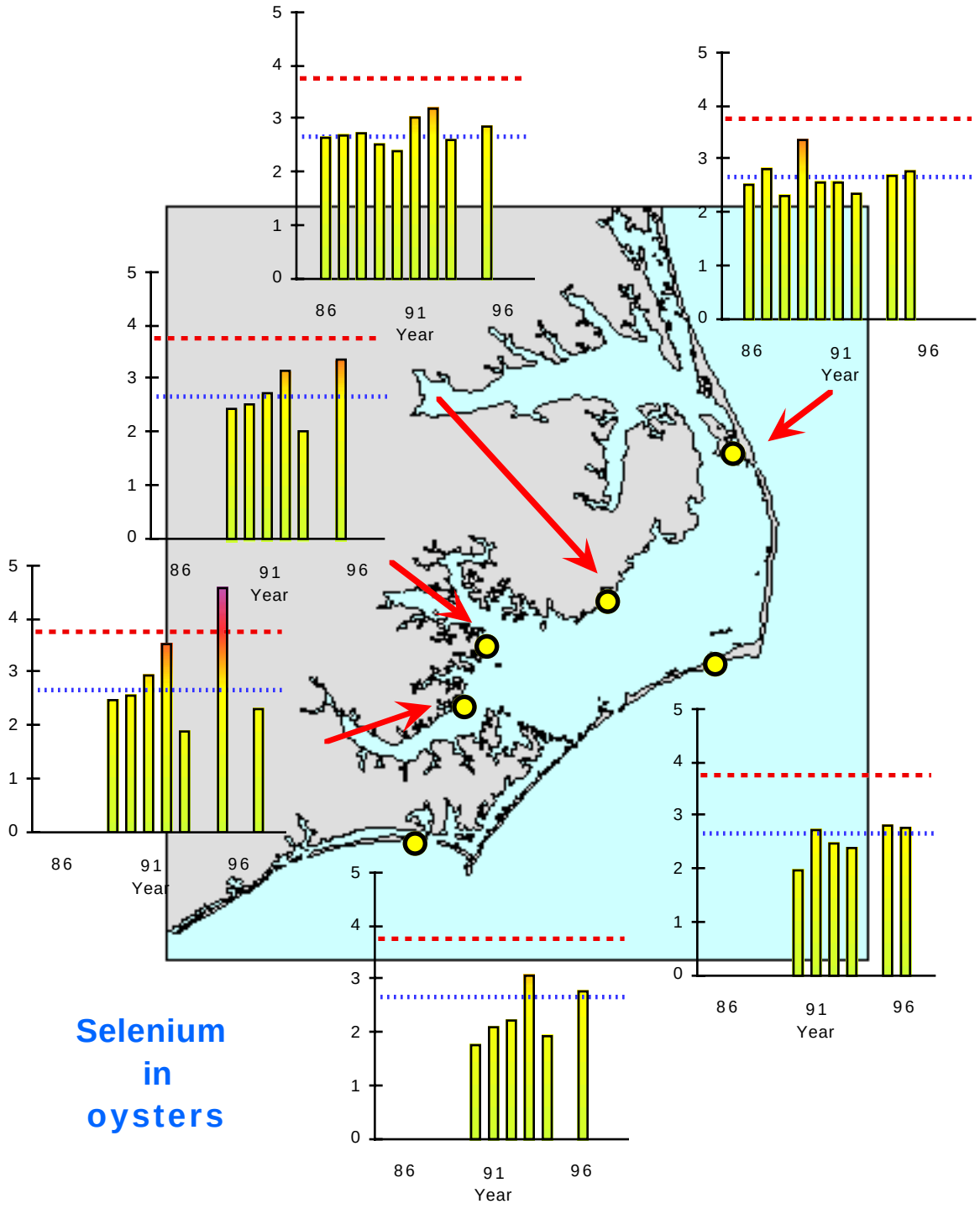
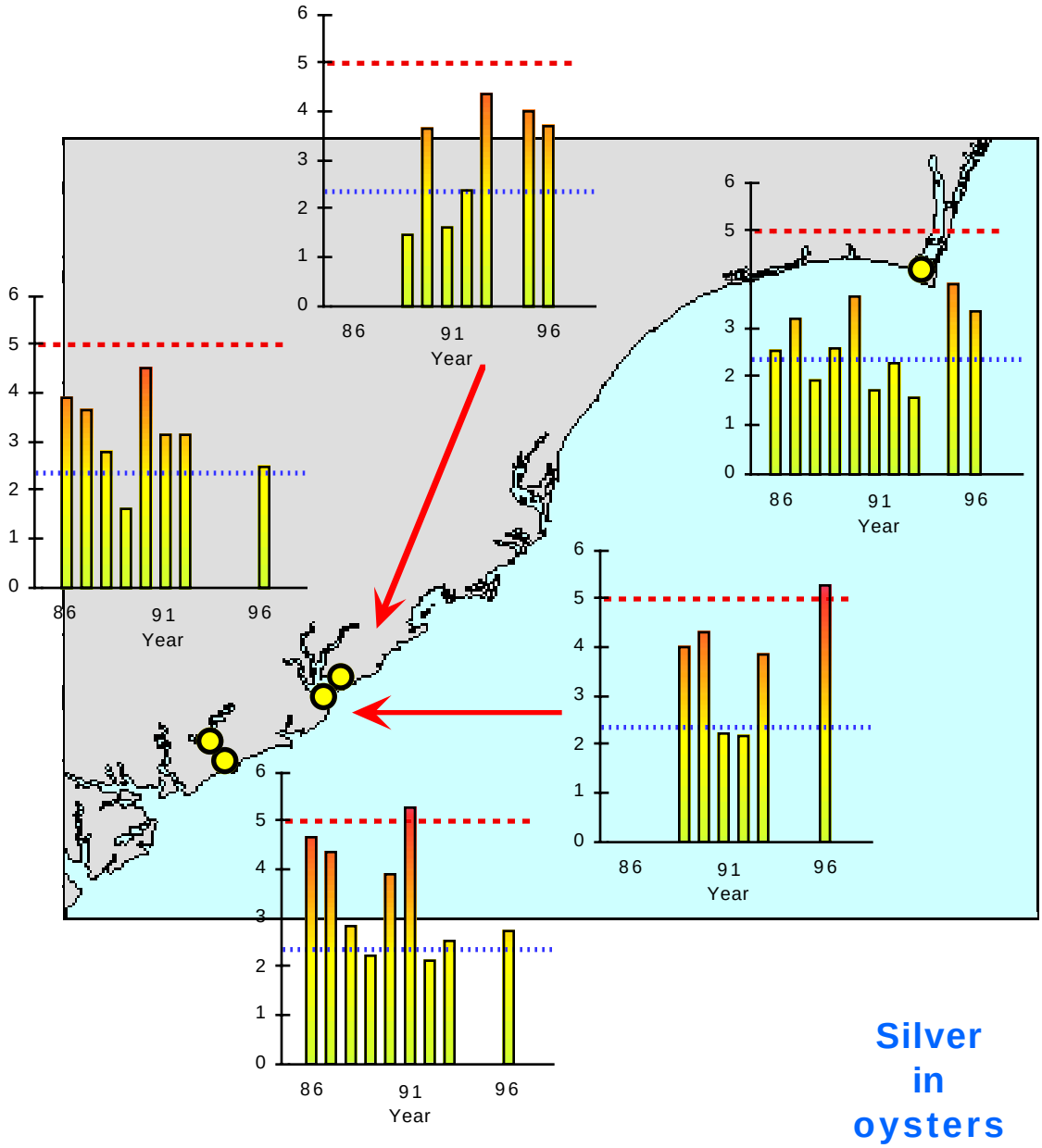


Figure II.5. Selenium trends in oysters. Dotted blue line is NS&T median and dashed red line is NS&T nationwide 85th percentile. (µg/g dry wt.).



Silver in oysters

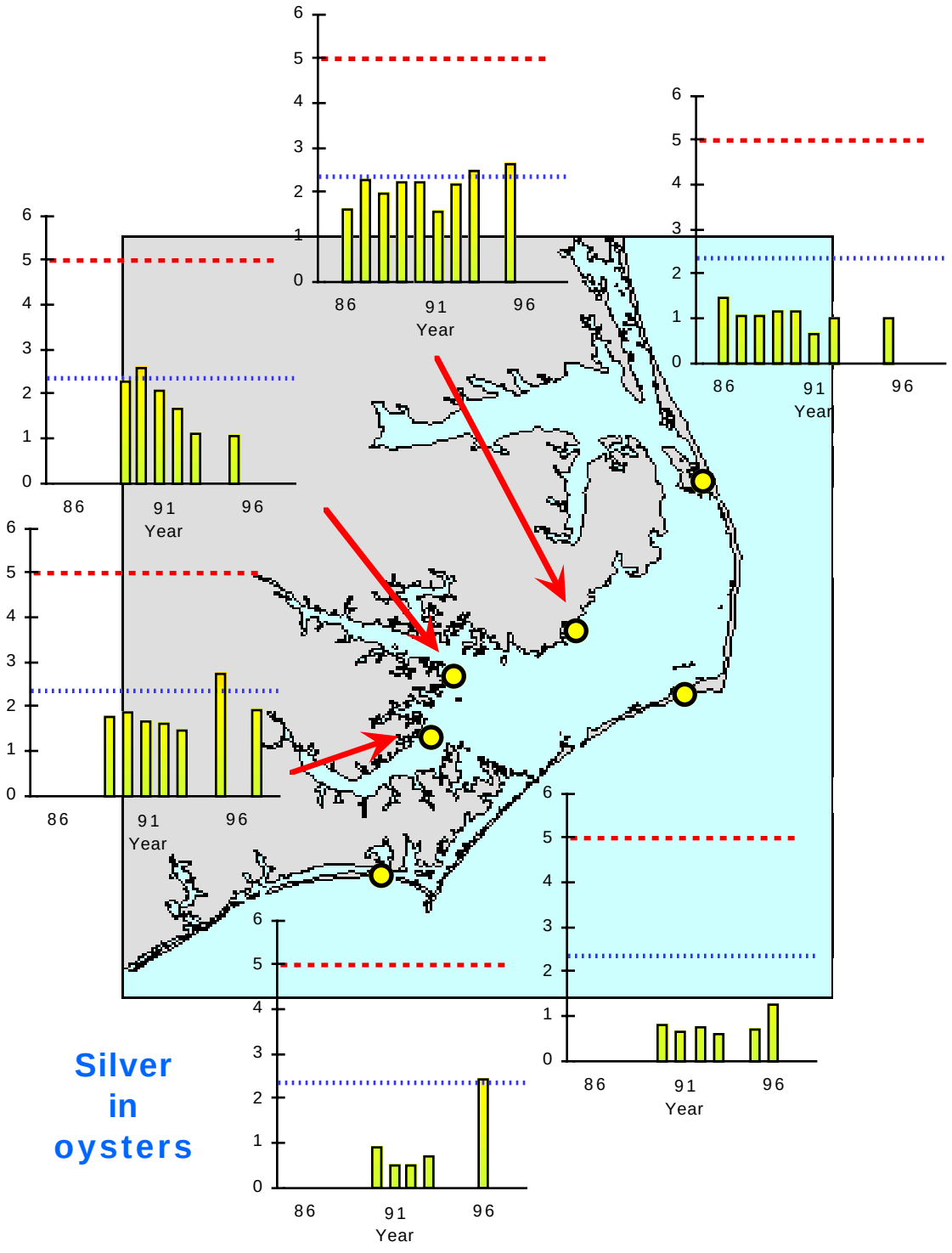
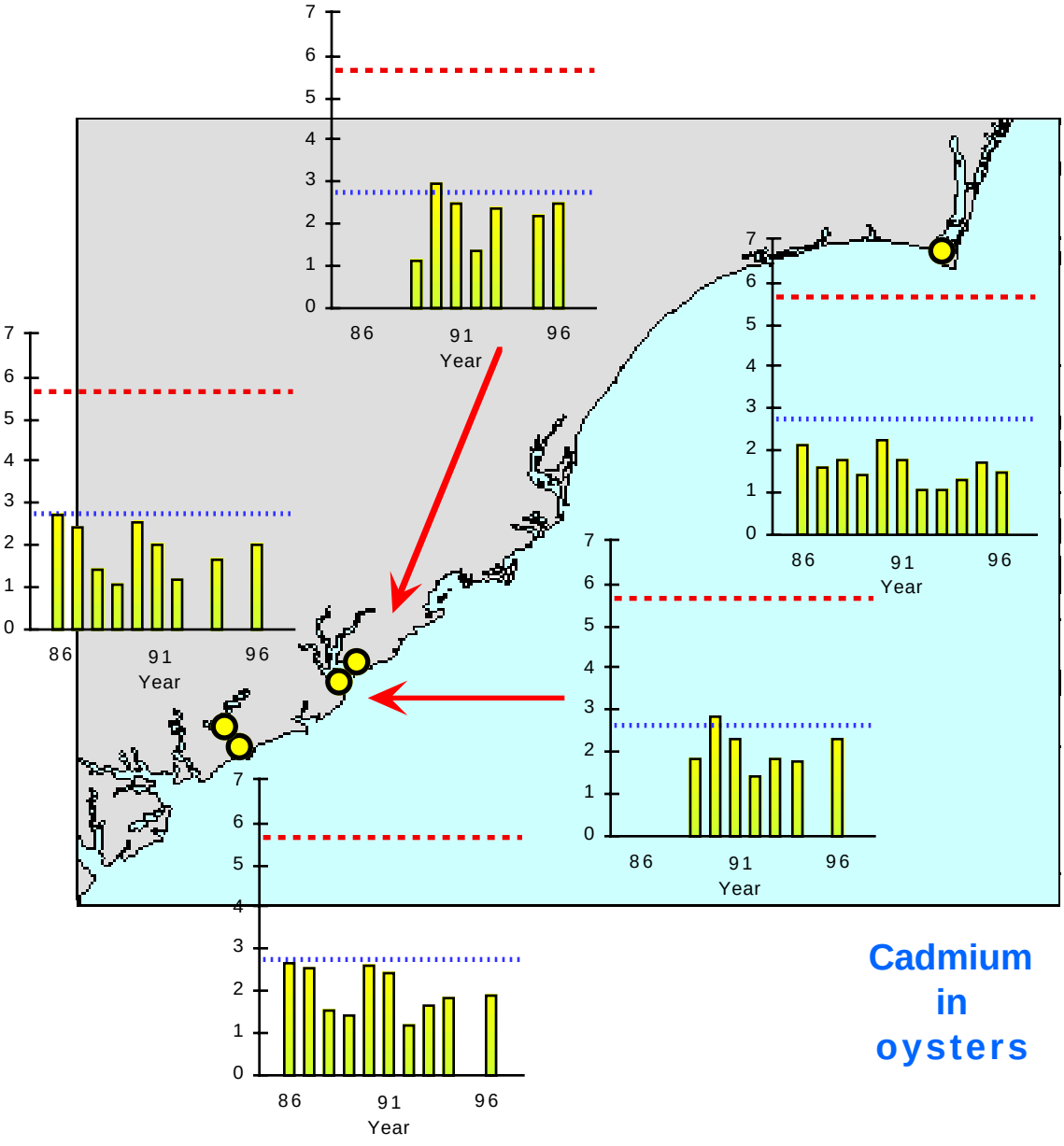


Figure II.6. Silver trends in oysters. Dotted blue line is NS&T median and dashed red line is NS&T nationwide 85th percentile. (µg/g dry wt.).



Cadmium in oysters

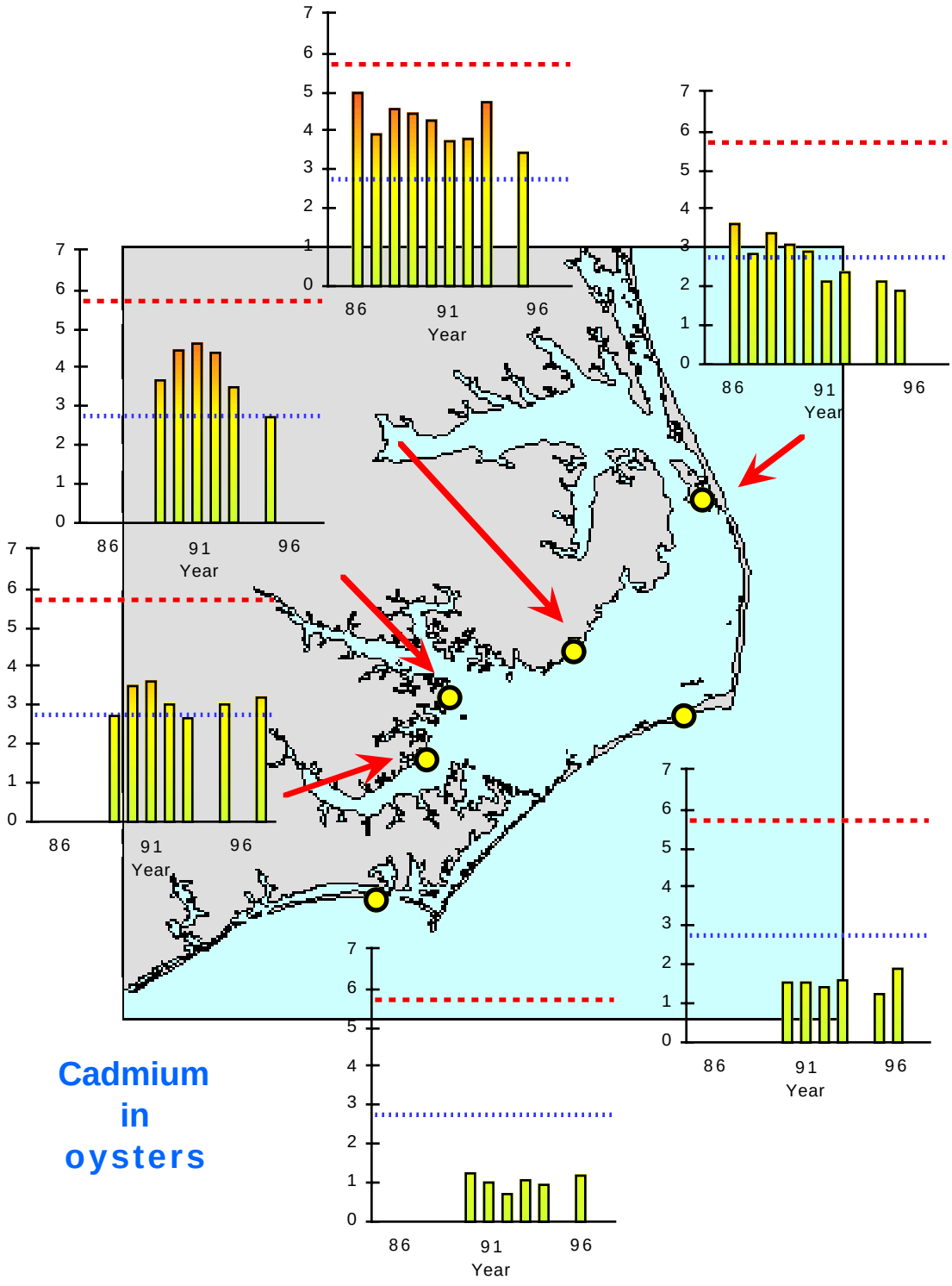
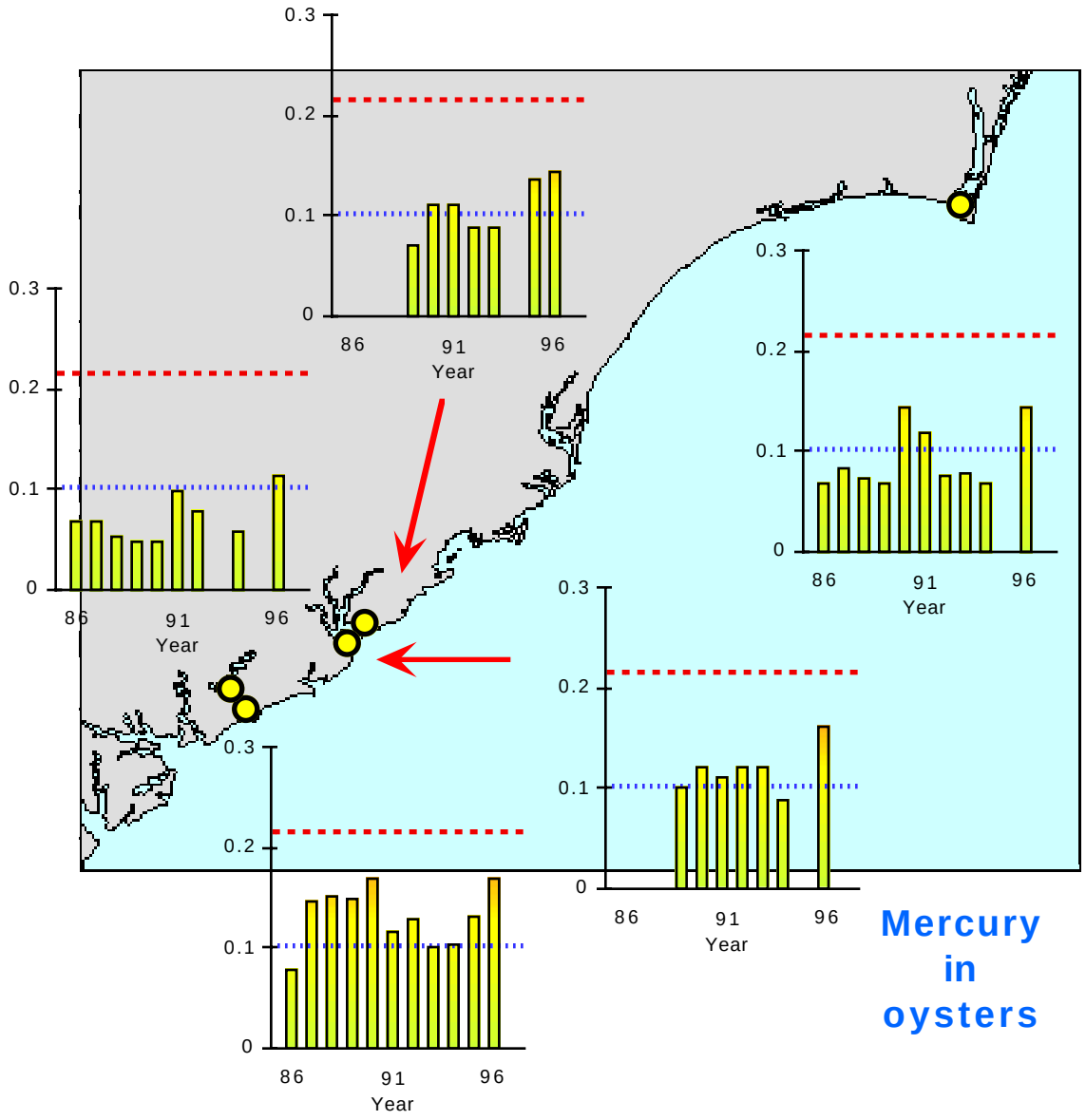


Figure II.7. Cadmium trends in oysters. Dotted blue line is NS&T median and dashed red line is NS&T nationwide 85th percentile. (µg/g dry wt.).


0.3
0.2
0.1
0
86
91
96
Year
Mercury in oysters

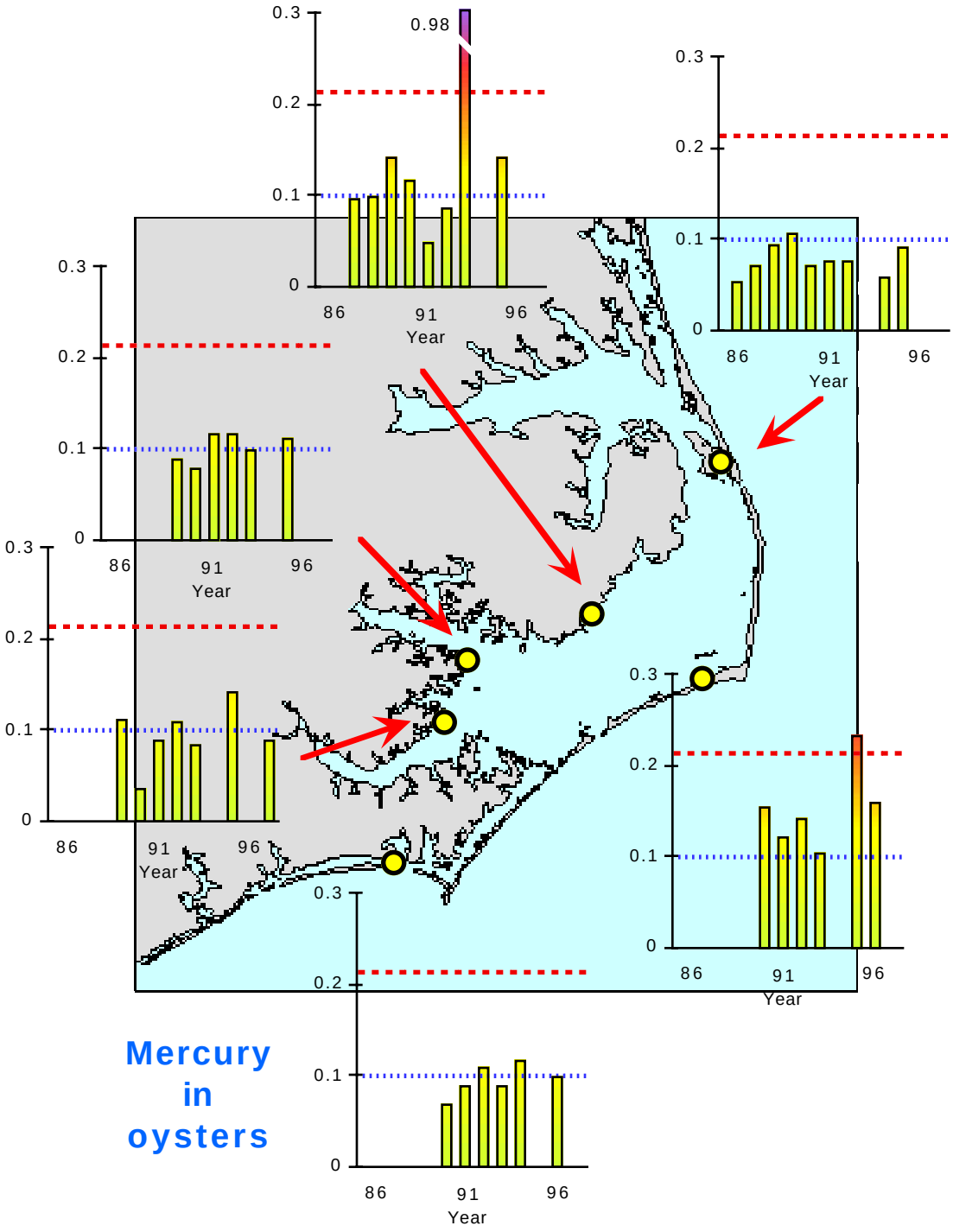
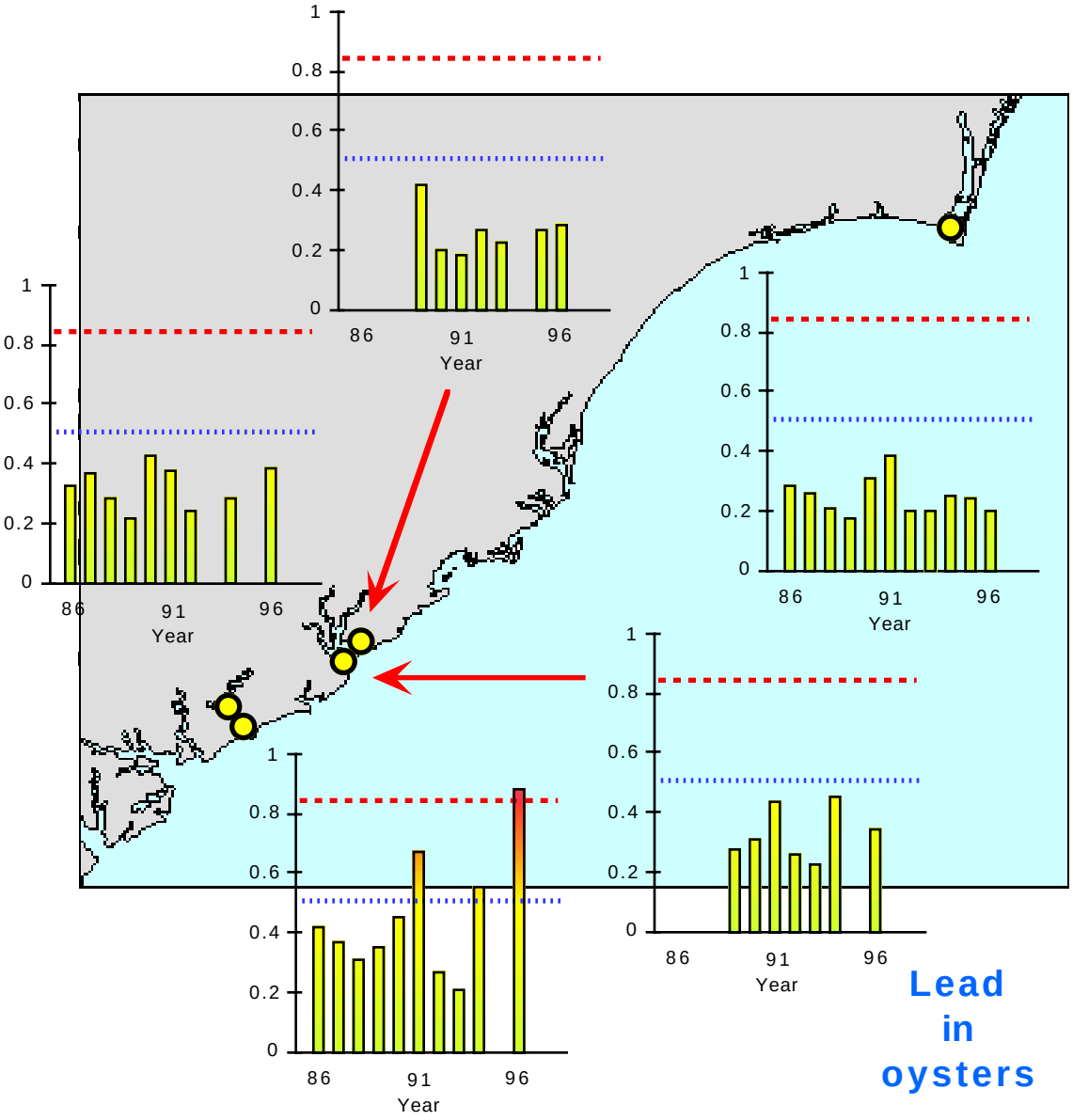


Figure II.8. Mercury trends in oysters. Dotted blue line is NS&T median and dashed red line is NS&T nationwide 85th percentile. (µg/g dry wt.).


1
0.8
0.6
0.4
0.2
0
86
91
96
Year
Lead
in
oysters

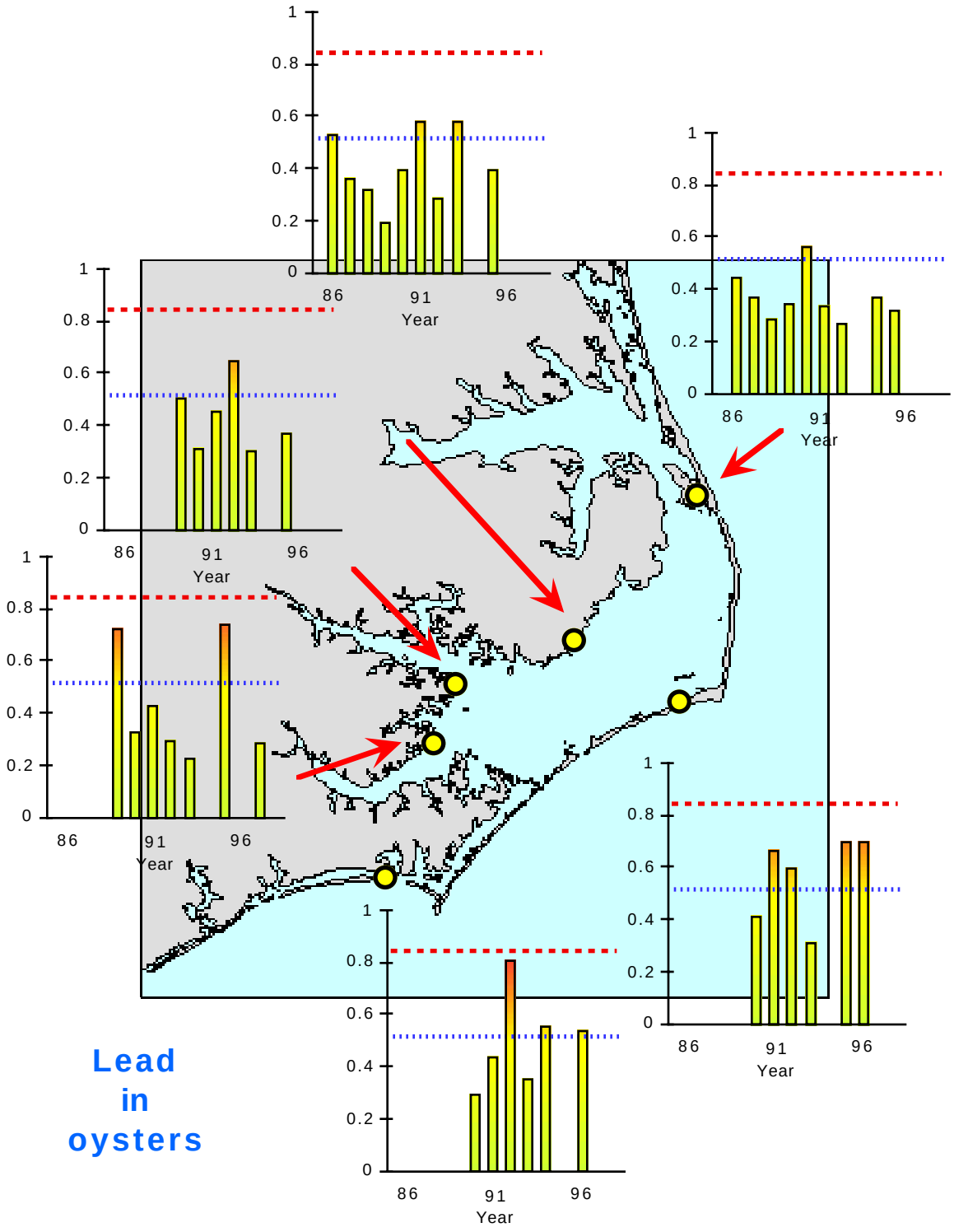
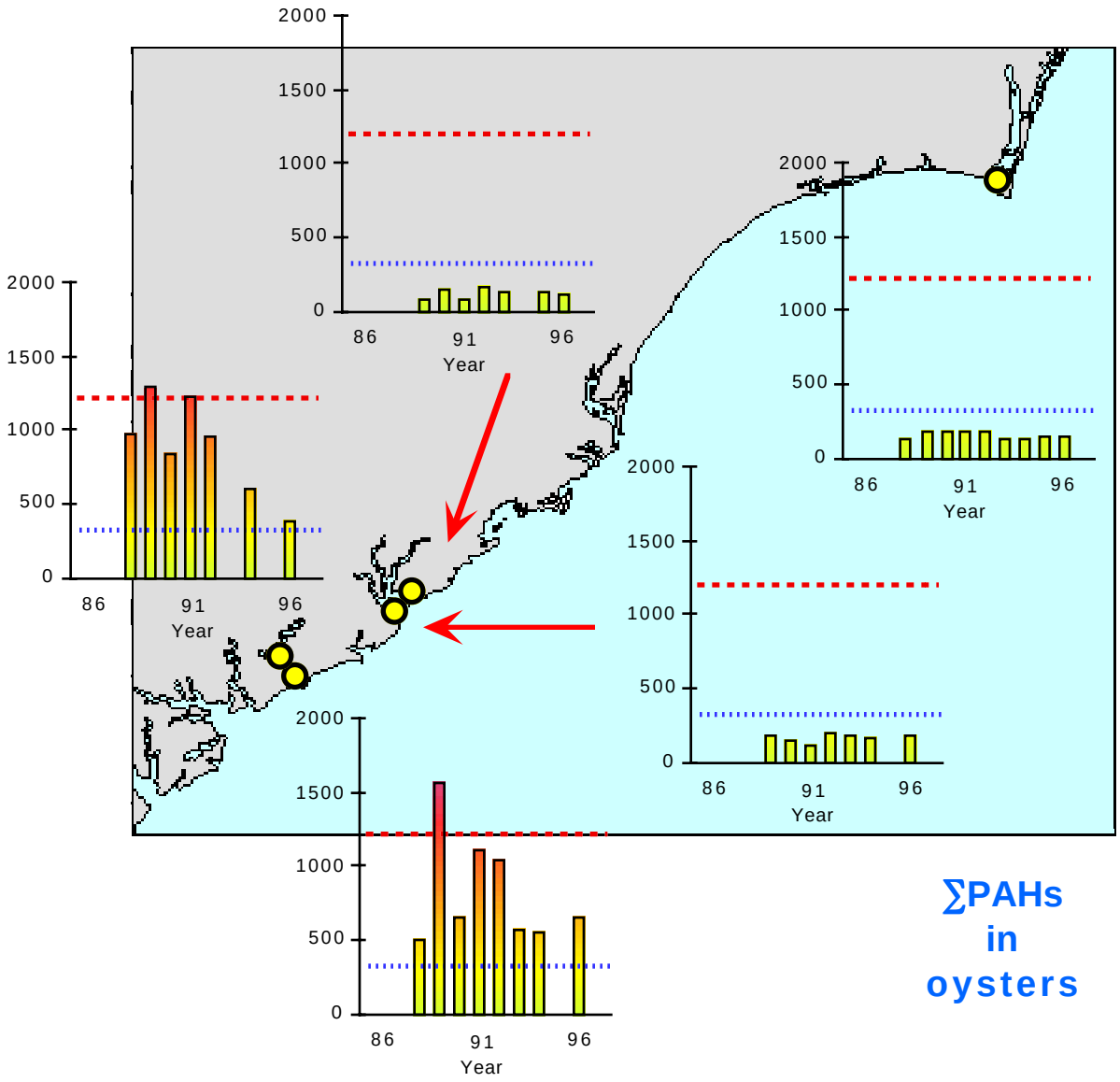


Figure II.9. Lead trends in oysters. Dotted blue line is NS&T median and dashed red line is NS&T nationwide 85th percentile. (µg/g dry wt.).


2000
1500
1000
500
0
86
91
96
Year
∑PAHs
in
oysters

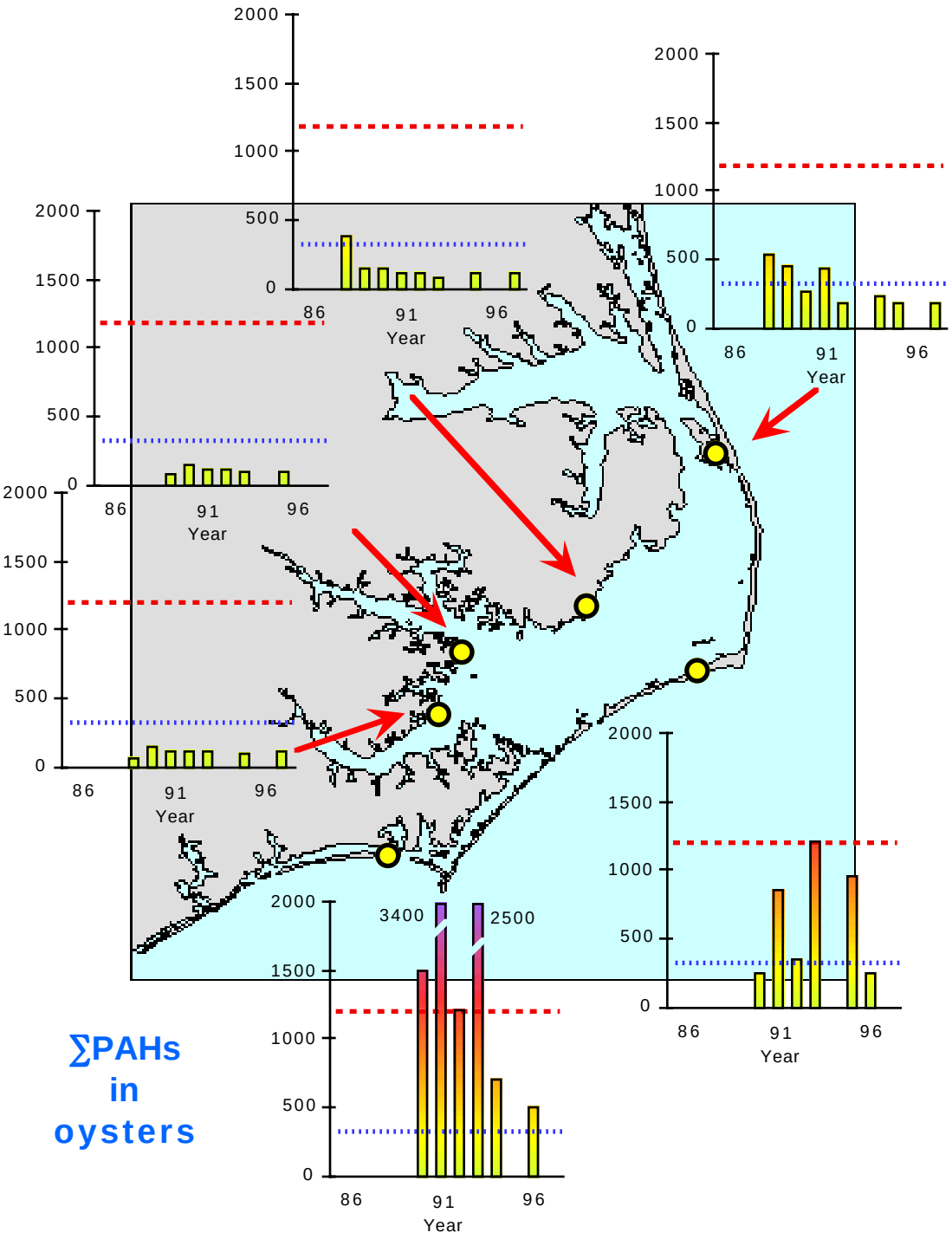
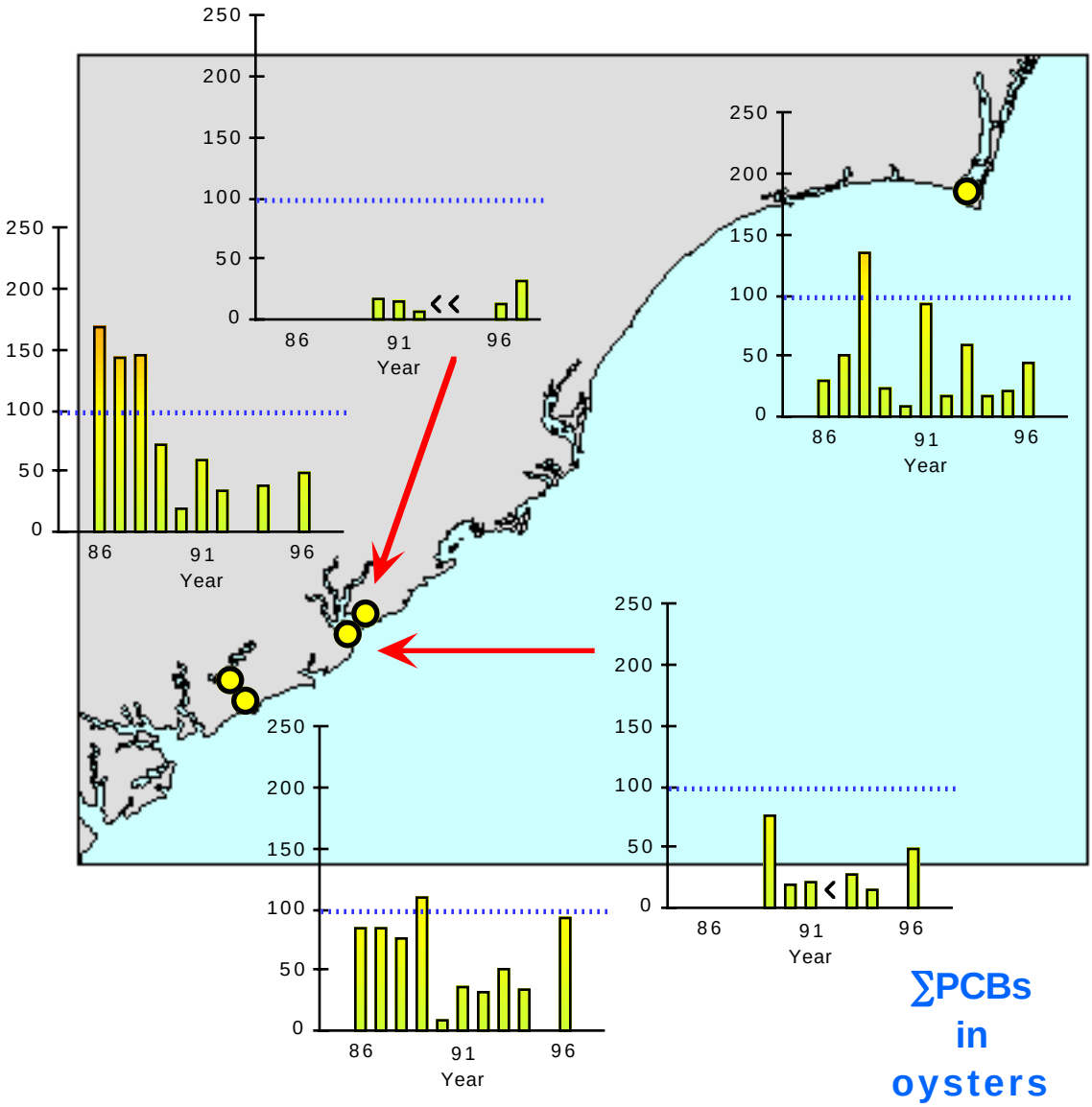


Figure II.10. Total PAHs trends in oysters. Dotted blue line is NS&T median and dashed red line is NS&T nationwide 85th percentile. (ng/g dry wt.).


250
200
150
100
50
0
86
91
96
Year
∑PCBs
in
oysters

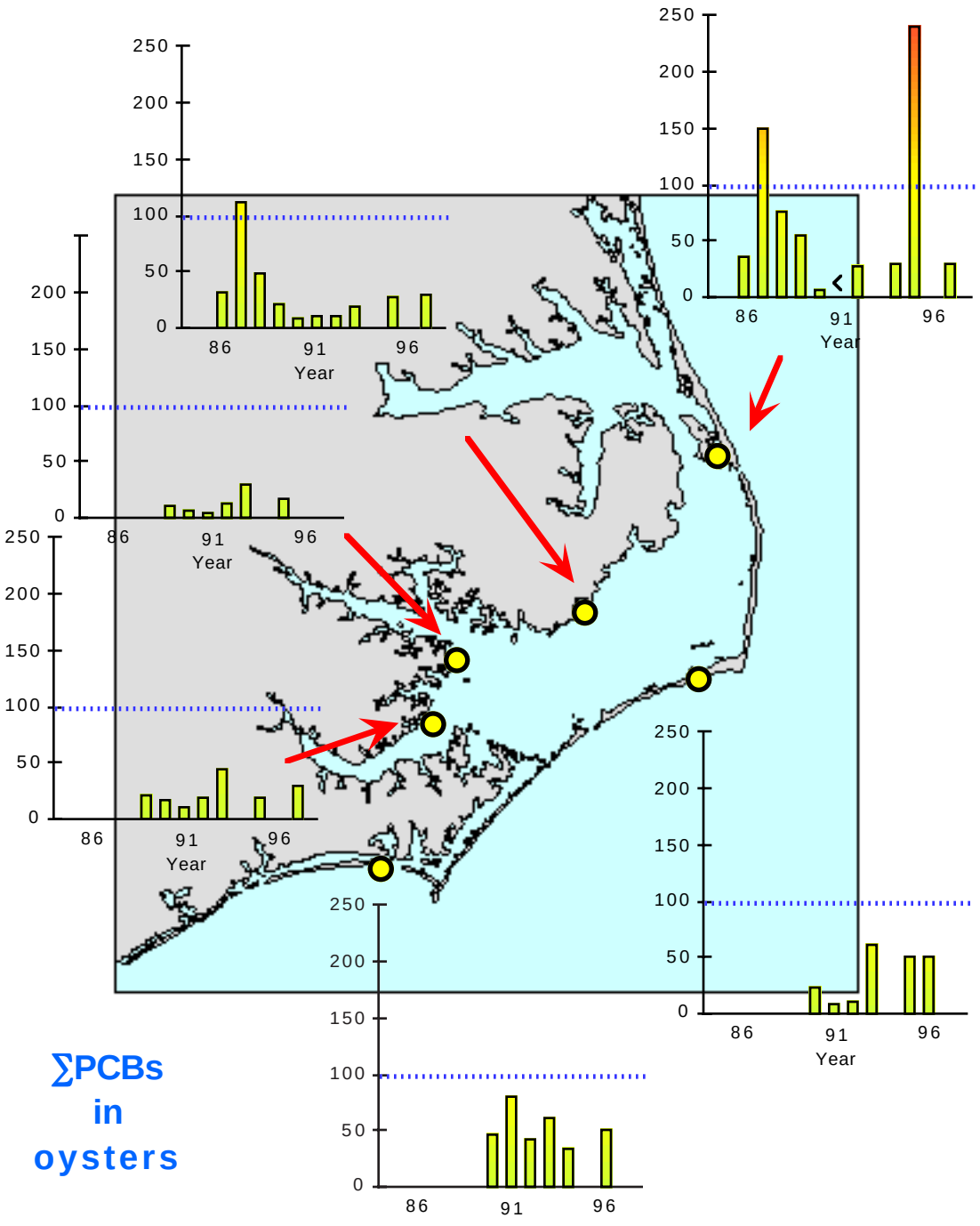
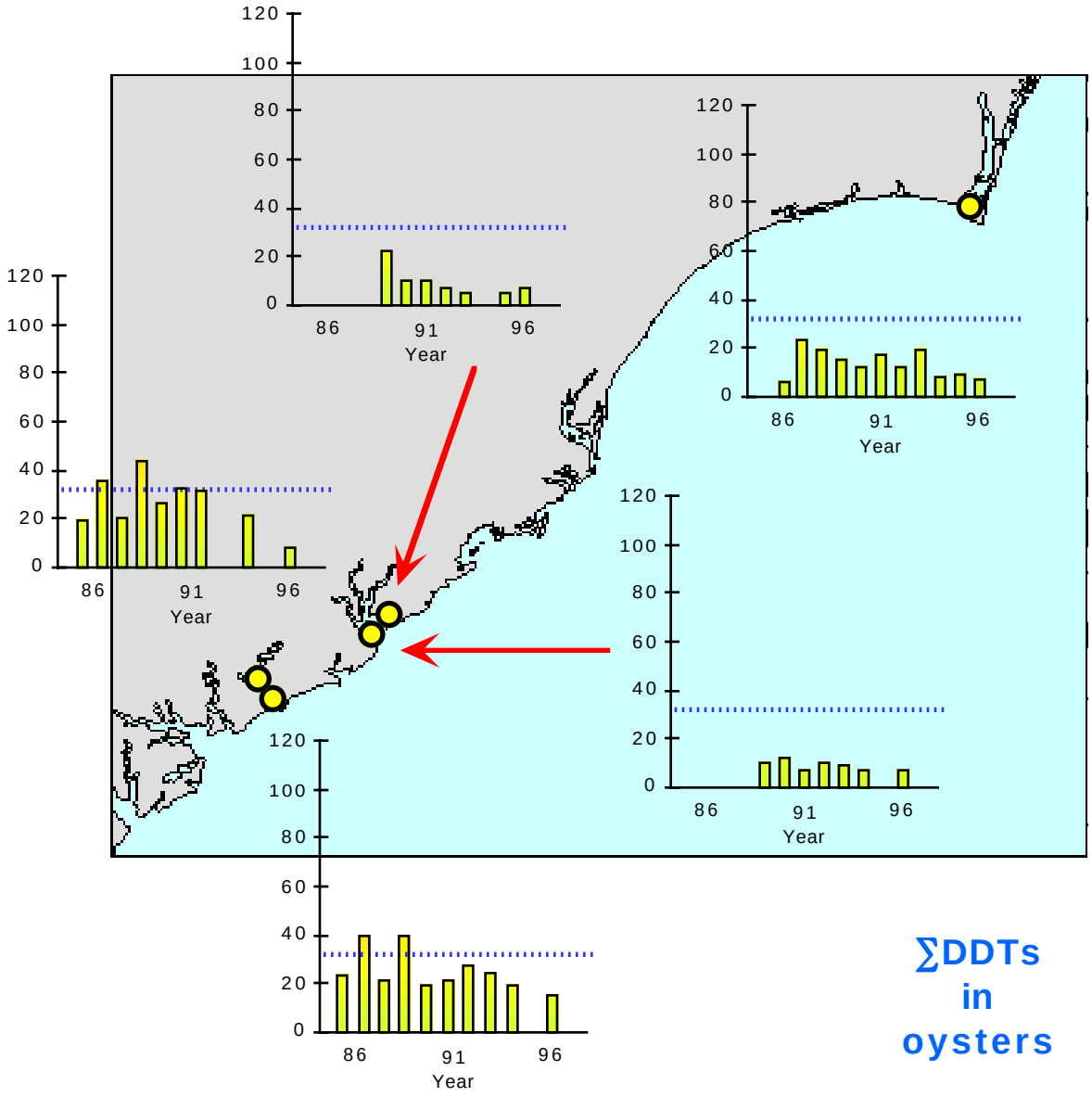


Figure II.11. Total PCBs trends in oysters. Dotted blue line is NS&T median. A "<" used to indicate values below the limit of detection. No values were below the NS&T nationwide 85th percentile. (ng/g dry wt.).



∑DDTs in oysters

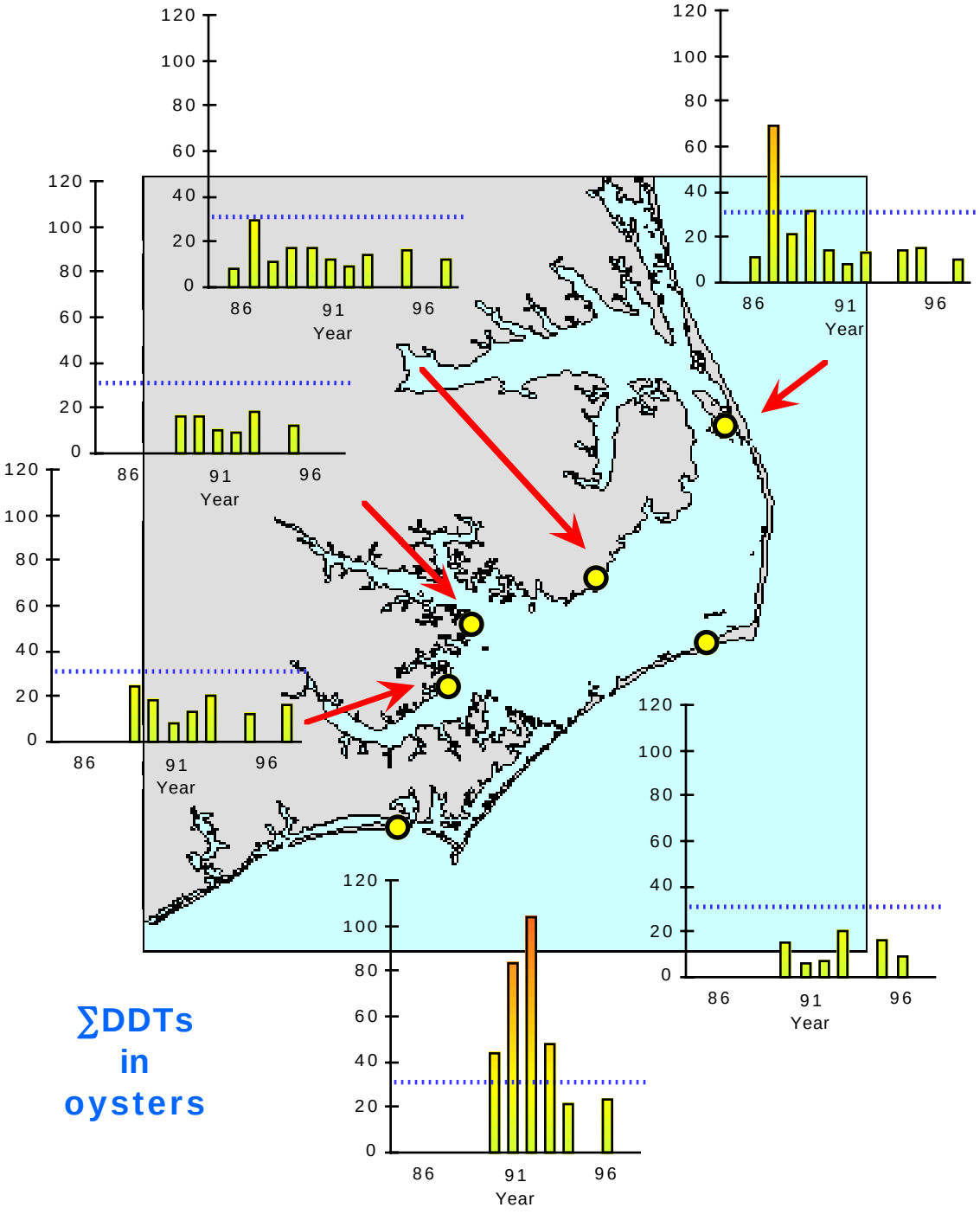
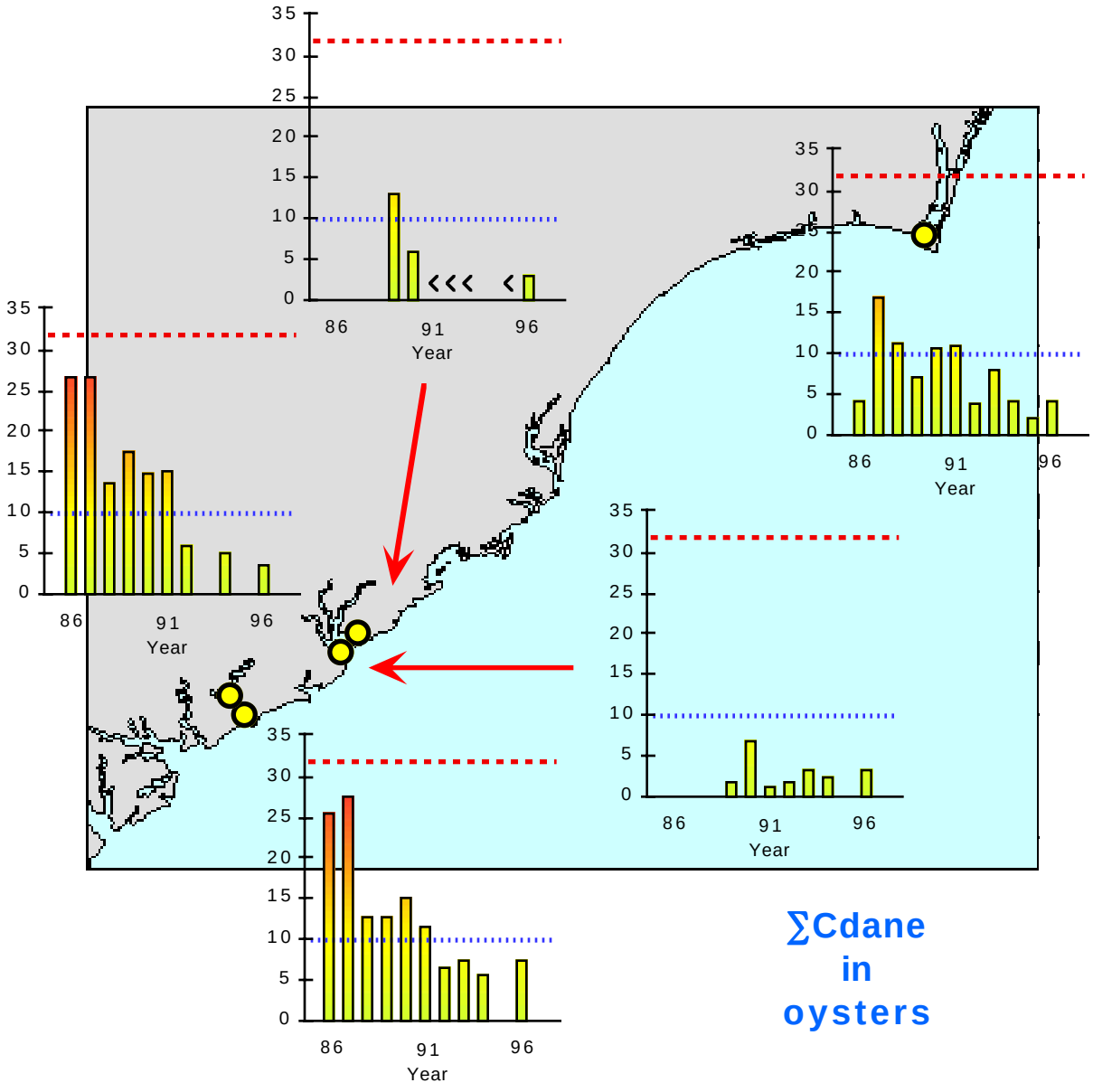


Figure II.12. Total DDTs and metabolites trends in oysters. Dotted blue line is NS&T median. (ng/g dry wt.).


35
30
25
20
15
10
5
0
86
91
96
Year
∑Cdane
in
oysters

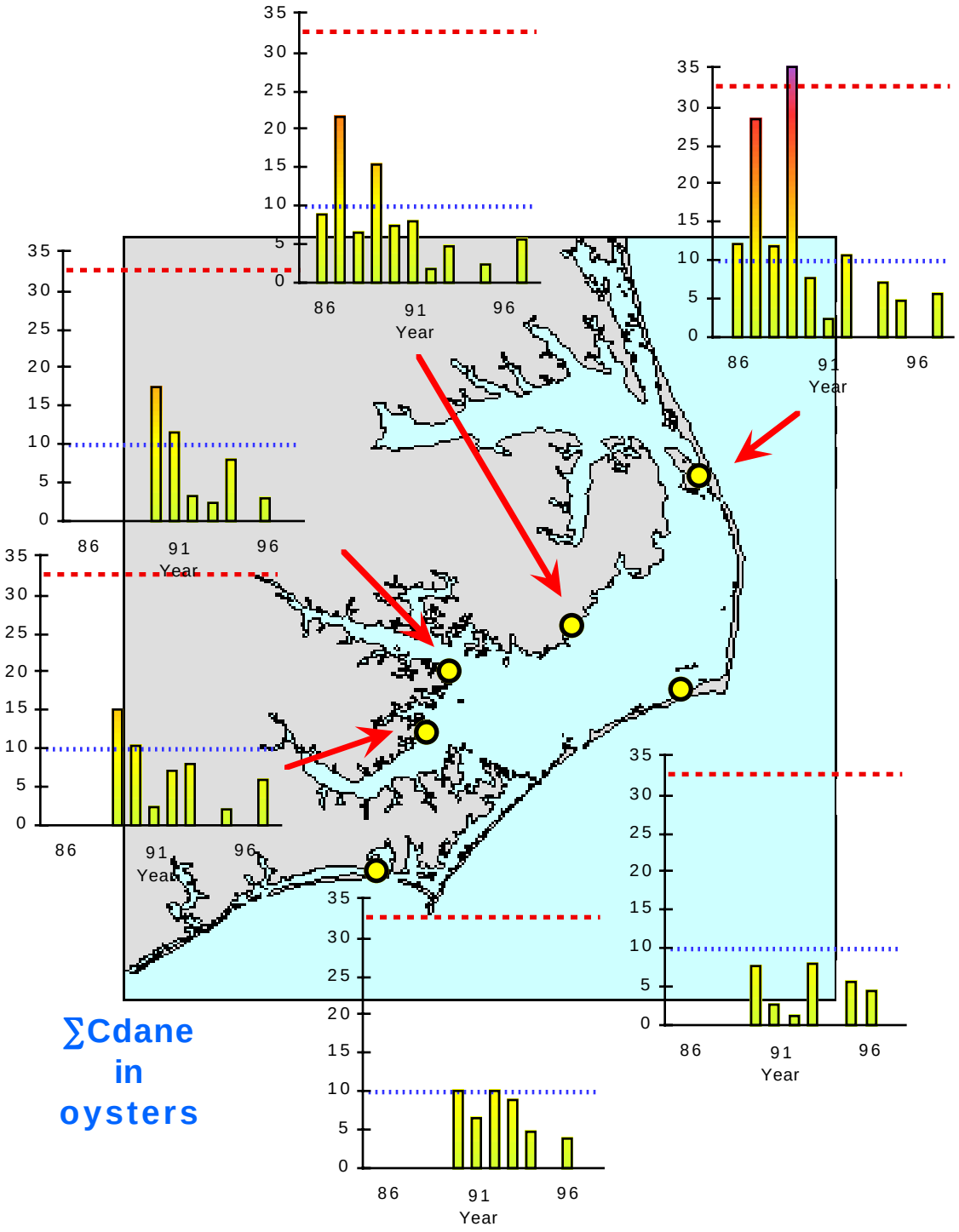
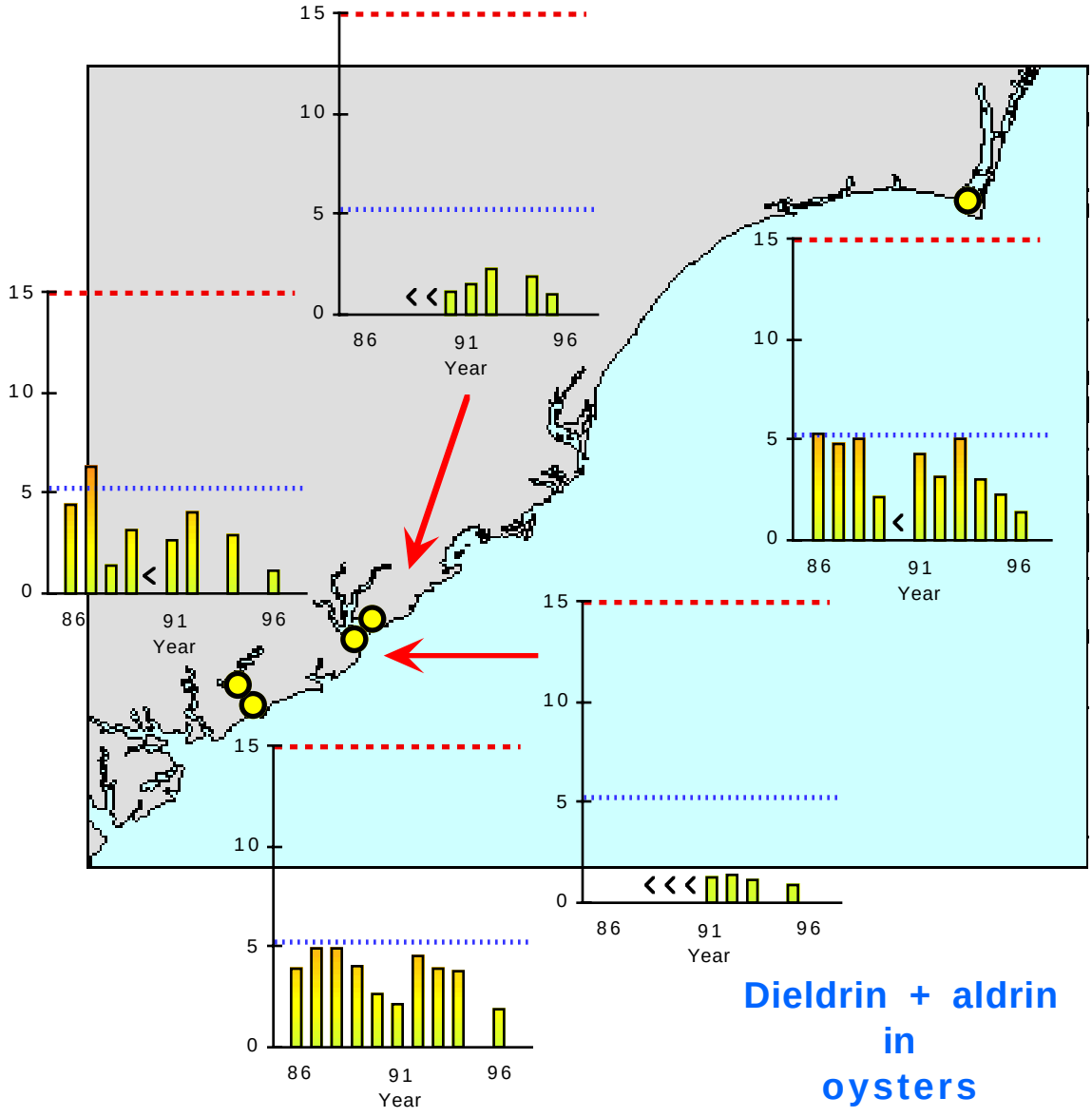


Figure II.13. Total chlordane pesticides trends in oysters. Dotted blue line is NS&T median and dashed red line is NS&T nationwide 85th percentile. (ng/g dry wt.).



Dieldrin + aldrin in oysters

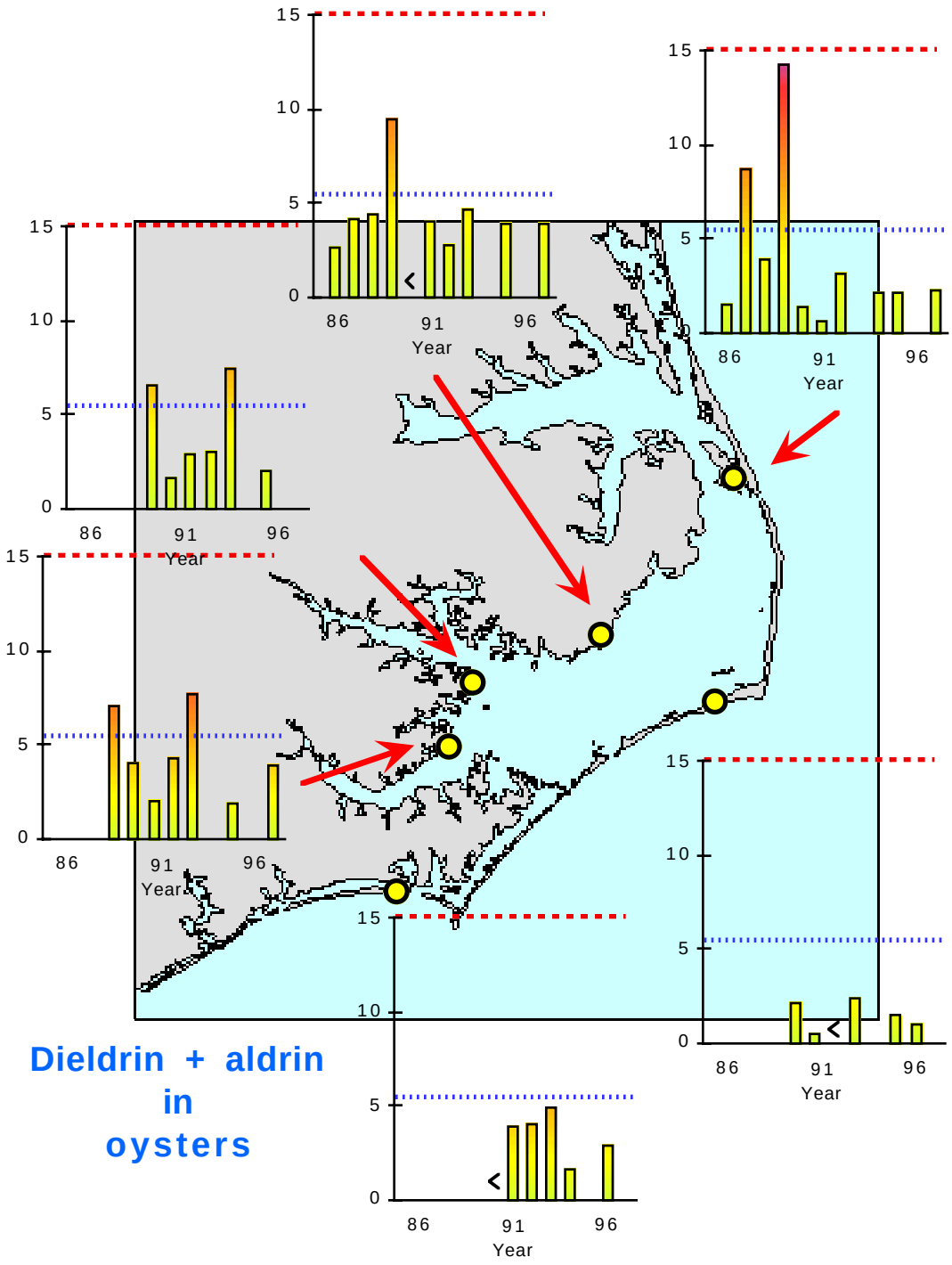
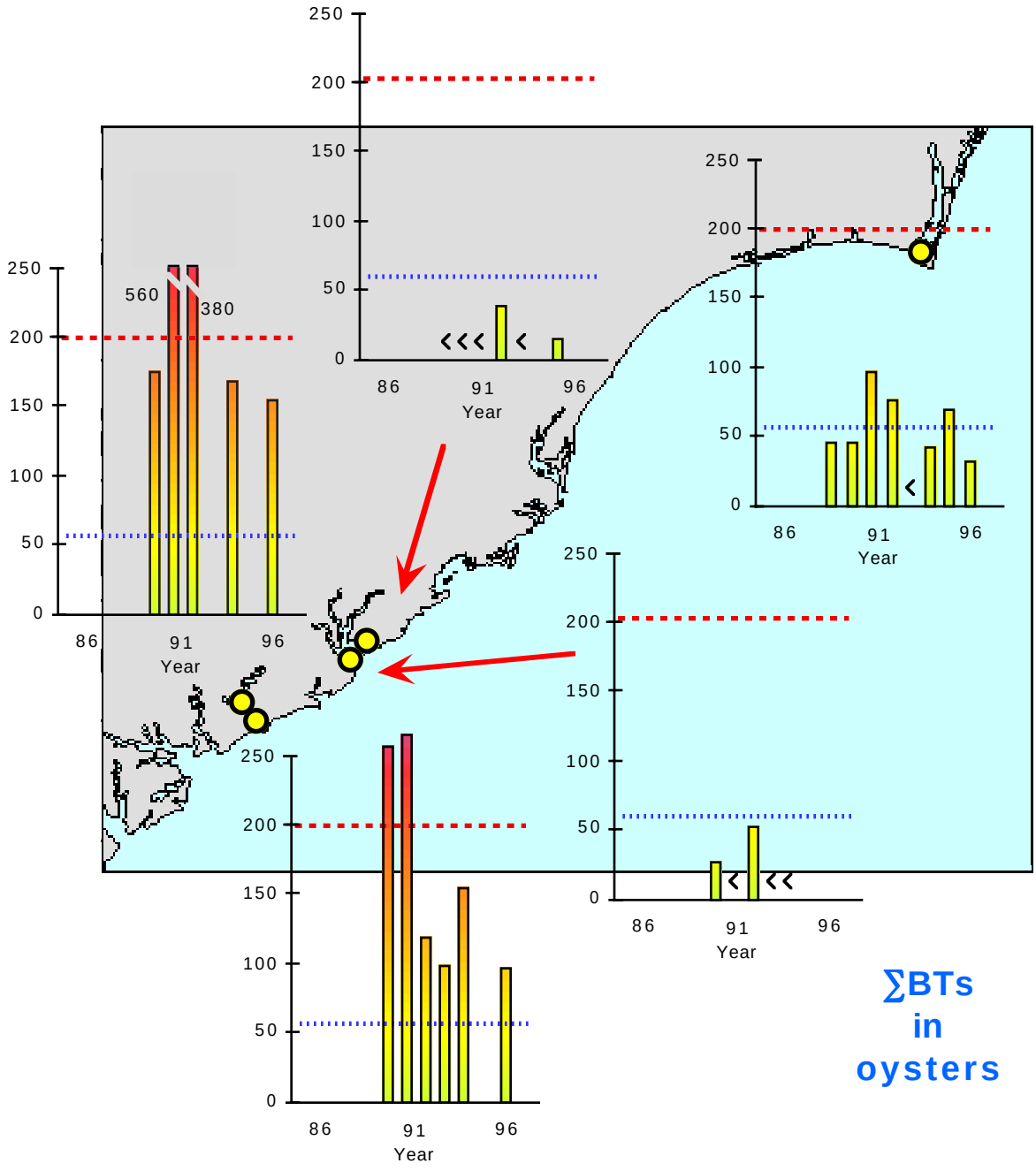


Figure II.14. Total dieldrin and aldrin trends in oysters. A "<" used to indicate values below the limit of detection. Dotted blue line is NS&T median and dashed red line is NS&T nationwide 85th percentile. (ng/g dry wt.).


250
200
150
100
50
0
560
380
86
91
96
Year
∑BTs
in
oysters

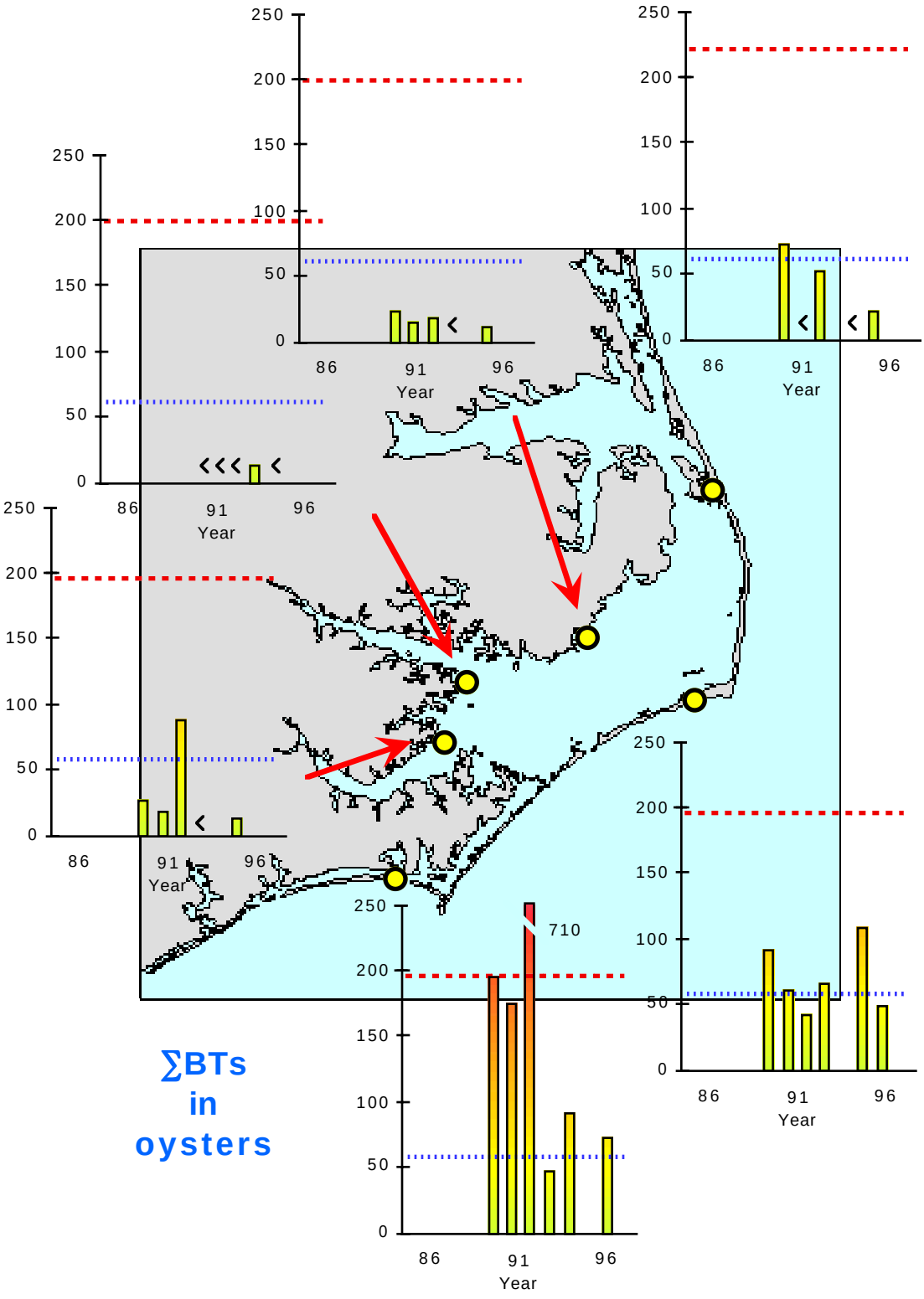


Figure II.15. Total tributyltins trends in oysters. A "<" used to indicate values below the limit of detection. Dotted blue line is NS&T median and dashed red line is NS&T nationwide 85th percentile. (ng Sn/g dry wt.).

Secretary
U.S. Department of Commerce
Donald L. Evans

Administrator
National Oceanic and Atmospheric Administration
Conrad C. Lautenbacher, Jr.

Acting Assistant Administrator
National Ocean Service
Margaret Davidson