NS&T Program

National Status and Trends Program
for Marine Environmental Quality

CARIBBEAN

El Morro, San Juan, Puerto Rico (NOAA Photo Archive)

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National Ocean Service
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Center for Coastal Monitoring and Assessment

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Status and Trends of Contaminant Levels in Biota and Sediments of the CARIBBEAN

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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 regarding concentrations of contaminants in the Florida Keys and Puerto Rico. The NS&T results were compared with those obtained in the Caribbean by the International Mussel Watch Program.

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 the 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 population growth in these areas continues to increase steadily. In response to these contaminant problems, an evolving national effort is underway to determine the extent and impact of contaminants on coastal and estuarine areas and to develop management strategies.

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.

CCMA manages NOAA's NS&T Program, which 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 (PCBs) congeners, several pesticides, butyltins, and selected trace elements in sediment and mollusk samples from the coastal waters of the U.S. (Table 1). Data are used to determine the extent 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. 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. Mussel Watch sites 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 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.

In the laboratory, molluscan samples are composited to include about 20 or 30 individuals for 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. The Project sediment data are combined with those of the Mussel Watch Project data in this report.

The NS&T Mussel Watch sites in Puerto Rico are shown in Figure 1. The site names, acronyms, latitudes and longitudes, years of data available and population within 20 km of the site are listed in Table 2.

The average concentrations of major and trace elements and of categories of organic compounds are shown graphically in the Appendices.

RESULTS AND DISCUSSION

Status

Oysters

Oysters were collected at three sites in Puerto Rico and one site in the Florida Keys.

The sampling site at Boqueron Bay (Bahia de Boqueron) (PRBB) is located within a small bay system on the south side of the larger Bay and is only accessible by small boat. Small

TABLE 1

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

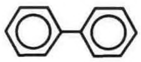
(Number below chemical structure is the Chemical Abstracts Service registry number.)

Polycyclic aromatic hydrocarbons

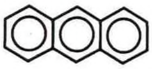
Low molecular weight PAHs
(2- and 3-ring structures)

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

Naphthalene
91-20-3

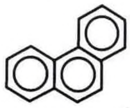


Biphenyl
92-52-4



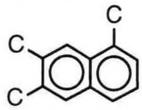
Anthracene
120-12-7

Acenaphthene
83-32-9

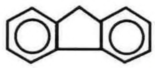


Phenanthrene
85-01-8

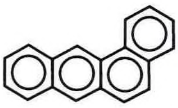
Acenaphthylene
208-96-8



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

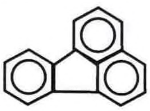


Fluorene
86-73-7

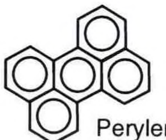


Benz[*a*]anthracene
56-55-3

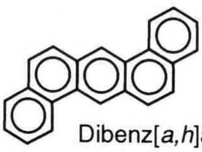
Benzo[*e*]pyrene
192-97-2



Fluoranthene
206-44-0



Perylene
198-55-0



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

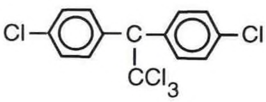
Benzo[*ghi*]perylene
191-24-2

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

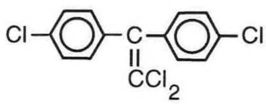
Benz[*a*]anthracene
Benzo[*a*]pyrene
Benzo[*b*]fluoranthene
Benzo[*e*]pyrene
Benzo[*ghi*]perylene
Benzo[*k*]fluoranthene
Chrysene
Dibenz[*a,h*]anthracene
Fluoranthene
Indeno[1,2,3-*cd*]pyrene
Perylene
Pyrene

Chlorinated pesticides

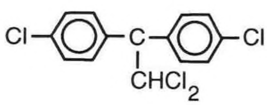
2,4'-DDD
4,4'-DDD
2,4'-DDE
4,4'-DDE
2,4'-DDT
4,4'-DDT



4,4'-DDT
50-29-3



4,4'-DDE
72-55-9



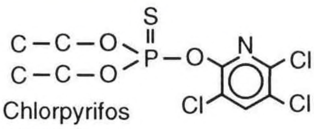
4,4'-DDD
72-54-8

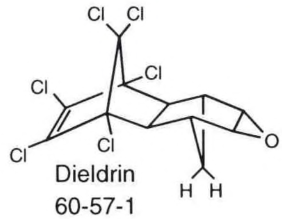
TABLE 1 (cont.)

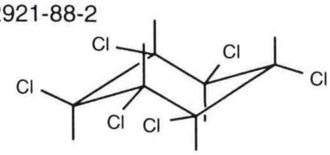
Organic contaminants, and major and trace elements determined as part of the NS&T Program.

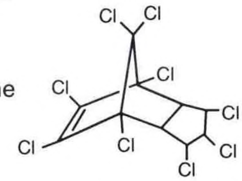
(Number below chemical structure is the Chemical Abstracts Service registry number.)

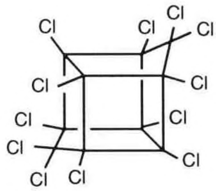
Aldrin
Chlorpyrifos
cis-Chlordane
Dieldrin
Endosulfan-II
delta-Hexachlorocyclohexane
gamma-Hexachlorocyclohexane (Lindane)
Heptachlor
Heptachlor epoxide
Hexachlorobenzene
alpha-Hexachlorocyclohexane
beta-Hexachlorocyclohexane
Mirex
cis-Nonachlor
trans-Nonachlor
Oxychlordane

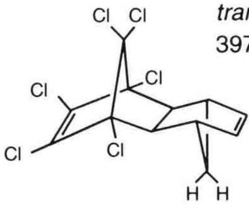

Chlorpyrifos
2921-88-2


Dieldrin
60-57-1


gamma-Hexachlorocyclohexane
58-89-9

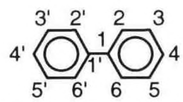

trans-Nonachlor
39765-80-5


Mirex
2385-85-5


Aldrin
309-00-2

Polychlorinated biphenyl congeners (IUPAC numbering system)

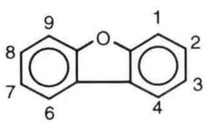
PCB 8, PCB 18, PCB 28, PCB 44, PCB 52, PCB 66, PCB 101, PCB 105, PCB 118, PCB 128, PCB 138, PCB 153, PCB 170, PCB 180, PCB 187, PCB 195, PCB 206, PCB 209


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
Oct achlorodibenzo-*p*-dioxin

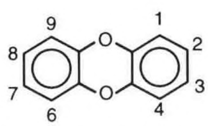

Dibenzo-*p*-dioxin parent structure

TABLE 1 (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

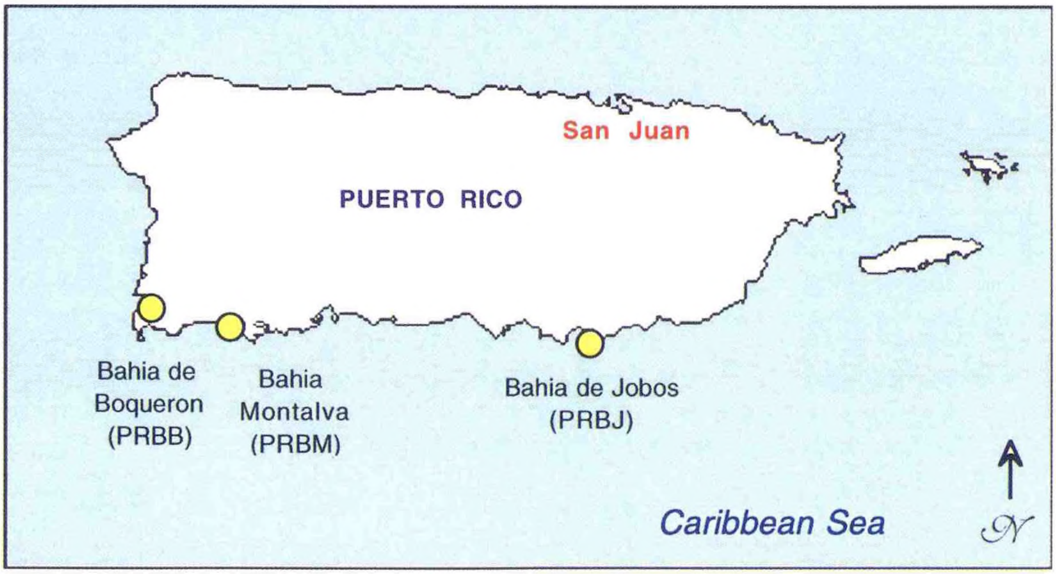


Figure 1. NS&T Mussel Watch sampling sites in Puerto Rico.

TABLE 2

NS&T sampling sites in Puerto Rico and the Florida Keys.

Site	Location	Site code	Latitude (N)	Longitude (W)	Years of tissue data*	Population^Δ (20 km of site)
Mussel Watch Project						
(*Crassostrea rhizophorae* collected in Puerto Rico, and *Chama sinuosa* collected in Bahia Honda)						
Bahia de Boqueron	Puerto Rico	PRBB	18° 00.47'	67° 10.51'	4	121,554
Bahia Montalva	Puerto Rico	PRBM	17° 58.26'	66° 59.37'	3	149,520
Bahia de Jobos	Puerto Rico	PRBJ	17° 56.35'	66° 10.88'	4	122,972
Bahia Honda	Florida Keys	BHKF	24° 39.67'	81° 16.38'	4	10,137

* Years of tissue data available through 1997.

Δ 1990 Census.

specimens of *C. rhizophorae* were found growing on the roots of the red mangroves. A possible source of contamination was fresh water runoff from a nearby garbage dump at the Marine Police Station.

The oysters collected at Montalva Bay (Bahia Montalva) (PRBM) were all attached to the roots of red mangroves, rubble and wooden pilings along the shoreline. By 1996, this site was devoid of live oysters. There were no obvious point sources of contamination, as the area is very rural with no industry nearby.

The site at Jobos Bay (Bahia de Jobos) (PRBJ) is located at the east end of the bay in Laguna de las Mareas. Oysters were found growing on the roots of red mangrove trees. Turtle and manatee grass was abundant throughout the bay, starting near the edge of the mangrove roots. Potential contamination is possible from the opposite end of the bay from the electrical power plant.

The Caribbean oyster population at the NS&T sampling sites in Puerto Rico is declining or depleted due to the heavy demands made by the tourist industry for fresh oysters.

The sampling site at Bahia Honda in the Florida Keys is located in the Bahia Honda State Park and no obvious sources of contamination were observed.

Oysters and mussels are not equal in their ability to concentrate trace elements (O'Connor, 1993). The trace elements Ag, Cu, and Zn are accumulated to a greater extent in the oyster *C. virginica* in comparison to the mussel *M. edulis.* While under similar conditions mussels accumulate Cr and Pb to concentrations more than three times of those in oysters (NOAA, 1989). Therefore, only the NS&T nationwide oyster data were used to compare to the Ag, Cu and Zn South Florida oyster data. The differences in bioaccumulation between oysters and mussels for the other elements and the organic analytes are not sufficiently great as to prevent the combination of the data from the two bivalves .

The Puerto Rico and Bahia Honda data were compared to the nationwide NS&T median and 85th percentile values. Concentrations above the 85th percentiles are the highest 15% of the data set and are used as a measure of "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.

The average annual concentrations of the measured contaminants were below the NS&T 85th percentile at all the Puerto Rico and Florida Keys sites except for Cr at Bahia de Boqueron and Bahia Montalva, ΣBTs at Bahia de Boqueron, and As and Ni at Bahia Honda. The high levels of ΣBTs may be the result of boating activities. No obvious sources of contamination by trace metals were observed near the Puerto Rico and Bahia Honda sampling sites. The high levels of As at Bahia Honda may be the result of species differences and/or chemical speciation of As in coastal marine waters. Contaminant trends will be discussed below.

Sediment

Contaminant levels higher than the NS&T 85th percentile were found for Cr, Mn, Ni, Cu, Zn, As, Se, and Hg at some or all of the Puerto Rico sites. The trace organic contaminants were present in very low concentrations. No major potential sources of contamination were found near the sampling sites. Differences in trace metal levels partly reflect differences in local mineralogy.

Trends

Only three or four years of data are available for the Puerto Rico and Bahia Honda sites, so statistically significant trends cannot be determined. The levels of most of the contaminants are very low and in many cases below the limit of detection.

INTERNATIONAL MUSSEL WATCH

The International Oceanographic Commission, in collaboration with the United Nations Environment Programme (UNEP) and NOAA, supported the creation of the International Mussel Watch (IMW) Project, and carried out the initial monitoring phase in Latin America, including the Caribbean Basin, in 1991 - 1992. The primary goal of the IMW Project was to assess the levels of chlorinated hydrocarbon pesticides and PCBs in bivalves collected in coastal marine waters. A description of the effort and results for Latin America are reported in International Mussel Watch Secretariat (1995) and Sericano *et al.* (1995). The sites and bivalve species sampled in the Caribbean Basin are listed in Table 5 and shown in Figure 2. The results of the analyses of specimen collected in the Caribbean as part of the IMW and NS&T Mussel Watch Projects are shown in Appendix III. Only NS&T data for samples collected in 1992 were used, in order to reduce temporal variations between the NS&T and IMW data sets.

With some exceptions, the levels of contaminants measured by the IMW and NS&T Mussel Watch Projects at sites in the Caribbean are low, and in many cases below the limit of detection. Most of the higher values found were below the NS&T 85th percentile. Exceptions were found at sites in Mexico and Aruba. The sampling site in Laguna Madre is near the local lighthouse. The site at Tampico receives industrial and domestic effluents from the city of Tampico through discharge into the Panuco River. The site in Aruba is located in the main port of the island and there are petroleum tanks nearby.

CONCLUSIONS

Most of the concentrations of the contaminants in bivalves measured as part of the NS&T Program in Puerto Rico and Bahia Honda were very low. Exceptions were found for Cr at Bahia de Boqueron and Bahia Montalva, ΣBTs at Bahia de Boqueron, and As and Ni at Bahia Honda. Sediment concentrations of these contaminants were high at the Puerto Rico sites. No obvious sources of contamination were noted at the sampling sites so the observed levels may be indicative of local mineralogy.

With some exceptions, the levels of contaminants measured by the IMW and NS&T Mussel Watch Projects in sites in the Caribbean are low relative to US mainland sites, and in many cases below the limit of detection.

ACKNOWLEDGMENTS

The authors wish to thank J. Sericano for providing information, M. Bello (NOAA Miami Regional Library) for assistance with the site location in Cuba, and A. E. Theberge (NOAA Central Library) for graphics support.

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

	ΣDDTs	ΣPCBs	ΣPAHs	ΣCdane	ΣDieldrin
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	ΣBTs
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 Program 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 (%)	ΣDDTs	ΣPCBs
n	145	223	220	224	224
Median	0.073	18	1.0	2.9	15
85th percentile	0.56	40	2.4	18	80

	ΣPAHs	ΣCdane	ΣDieldrin	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

ΣDDTs: The sum of concentrations of DDTs and its metabolites, DDEs and DDDs.
ΣPCBs: The sum of the concentrations of homologs, which is approximately twice the sum of the 18 congeners.
ΣPAHs: The sum of concentrations of the 18 PAH compounds.
ΣCdane: The sum of *cis*-chlordane, *trans*-nonachlor, heptachlor and heptachlor epoxide.
ΣDieldrin: The sum of dieldrin and aldrin.
ΣBTs: 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).

Mangroves, 1996, R. B. Mieremet, NOAA OSDIA (NOAA Photo Archive, NOAA Central Library)

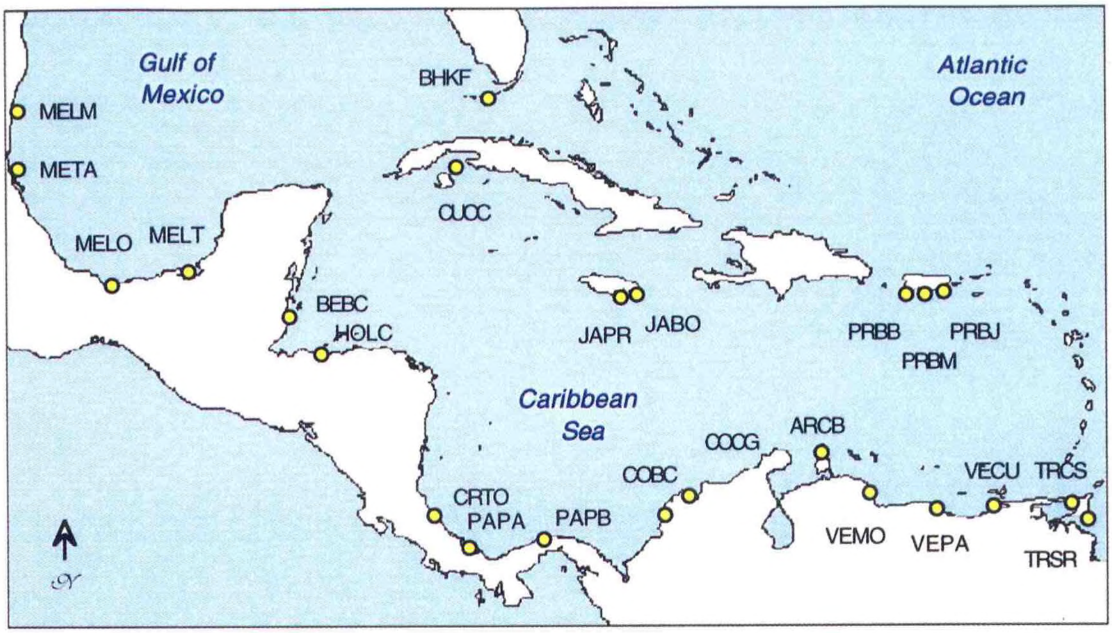


Figure 2. NS&T Mussel Watch and International Mussel Watch sampling sites in the Caribbean Basin and the Florida Keys.

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TABLE 4

International Mussel Watch sampling sites in the Caribbean Basin.

Site	Country, territory or state	Site code	Species sampled
IMW sites			
Laguna Madre	Mexico	MELM	*Crassostrea virginica*
Tampico	Mexico	META	*Crassostrea virginica*
Laguna de Ostion	Mexico	MELO	*Crassostrea virginica*
Laguna de Terminos	Mexico	MELT	*Crassostrea virginica*
Belize City	Belize	BEBC	*Crassostrea rhizophorae*
La Ceiba	Honduras	HOLC	*Donax denticulatus*
Tortuguero	Costa Rica	CRTO	*Protothaca grata*
Puerto Almirante	Panama	PAPA	*Ctenoides scabra*
Portobelo	Panama	PAPB	*Isognomon alatus*
Bahia de Cartagena	Colombia	COBC	*Crassostrea rhizophorae*
Cienaga Grande	Colombia	COCG	*Crassostrea virginica*
Bowden	Jamaica	JABO	*Isognomon alatus*
Port Royal	Jamaica	JAPR	*Isognomon alatus*
Cayo Culebra	Cuba	CUCC	*Isognomon alatus*
Commander's Bay	Aruba	ARCB	*Ctenoides scabra*
Morrocoy	Venezuela	VEMO	*Isognomon alatus*
Paparo	Venezuela	VEPA	*Tivela mactroides*
Cumana	Venezuela	VECU	*Trachycardium isocardia*
Caroni Swamp	Trinidad and Tobago	TRCS	*Mytella guayanensis*
Southern Range	Trinidad and Tobago	TRSR	*Donax denticulatus*
NS&T sites			
Bahia de Boqueron	Puerto Rico	PRBB	*Crassostrea rhizophorae*
Bahia Montalva	Puerto Rico	PRBM	*Crassostrea rhizophorae*
Bahia de Jobos	Puerto Rico	PRBJ	*Crassostrea rhizophorae*
Bahia Honda	Florida	BHKF	*Chama sinuosa*

Red mangroves, 1997, R. B. Mieremet, NOAA OSDIA (NOAA Photo Archive, NOAA Central Library)

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 via electronic mail. 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://seaserver.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 the CCMA office.

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 in different agencies. A cumulative list of these publications is issued periodically.

Mangrove roots, NOAA/OAR/National Undersea Research Program Photo Collection (NOAA Photo Archive, NOAA Central Library)

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

Oyster shells. (TAMU/GERG)

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APPENDICES

Appendix I
Sediment data for Puerto Rico

Appendix II
NS&T oyster trend data for Puerto Rico and the Florida Keys

Puerto Rico

Bahia Honda

Appendix III

NS&T and International Mussel Watch bivalve data for the Caribbean

Appendix I

NS&T sediment data for Puerto Rico

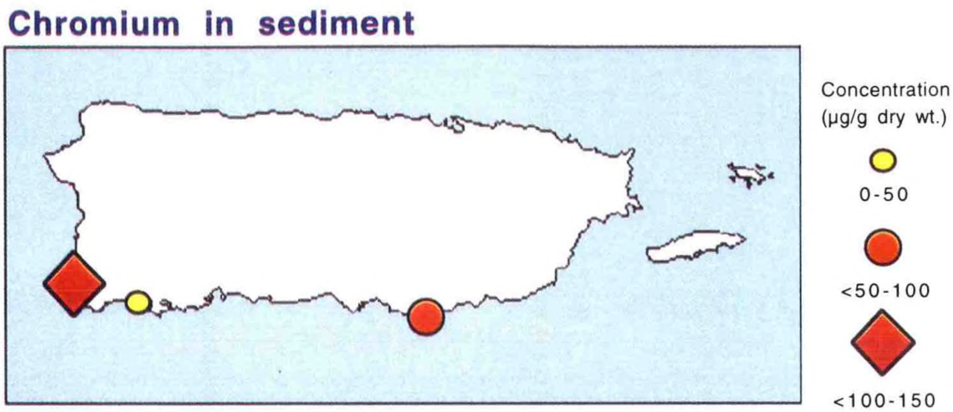


Figure I.1. Chromium in sediment. Average of data from 1986 to 1995. Concentrations noted with a diamond are above the NS&T nationwide 85th percentile (µg/g dry wt.).

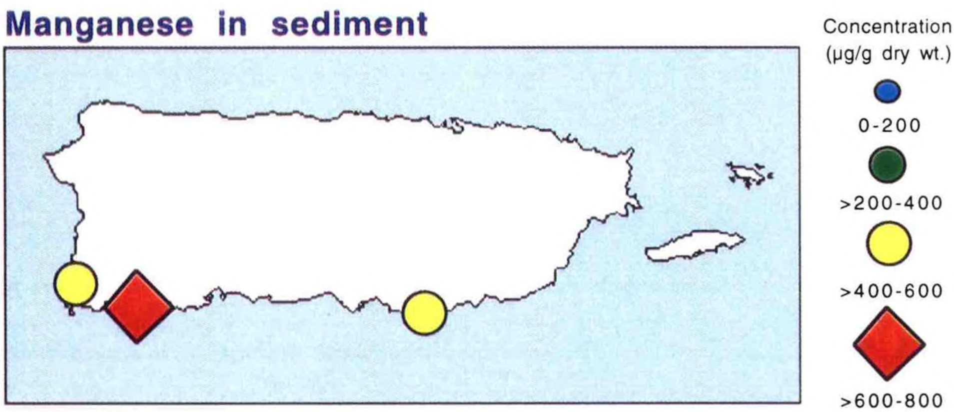


Figure I.2. Manganese in sediment. Average of data from 1986 to 1995. Concentrations noted with a diamond are above the NS&T nationwide 85th percentile (µg/g dry wt.).

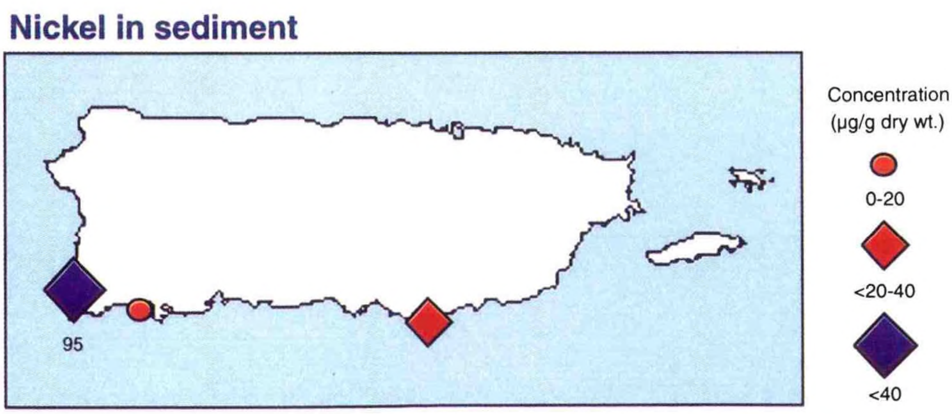


Figure I.3. Nickel in sediment. Average of data from 1986 to 1995. Concentrations were above the NS&T nationwide 85th percentile (µg/g dry wt.).

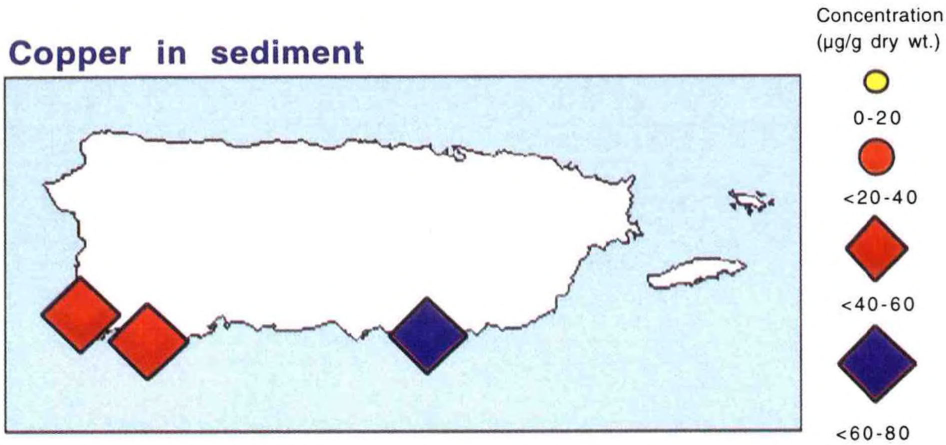


Figure I.4. Copper in sediment. Average of data from 1986 to 1995. Concentrations noted with a diamond are above the NS&T nationwide 85th percentile (µg/g dry wt.).

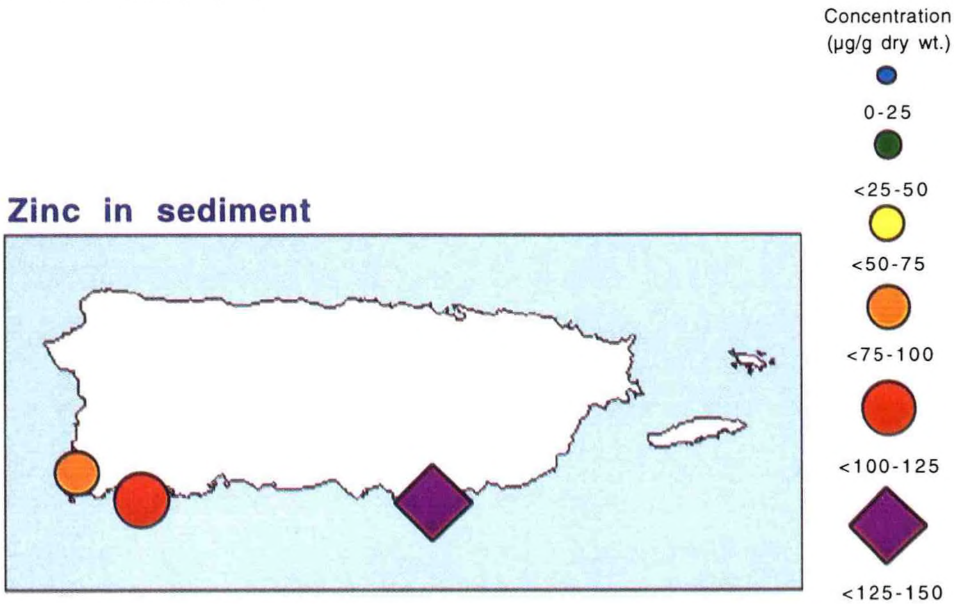


Figure I.5. Zinc in sediment. Average of data from 1986 to 1995. Concentrations were above the NS&T nationwide 85th percentile (µg/g dry wt.).

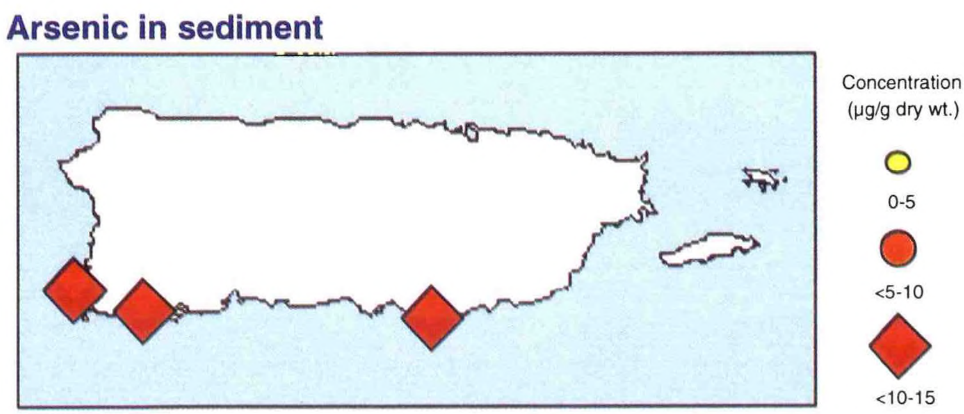


Figure I.6. Arsenic in sediment. Average of data from 1986 to 1995. Concentrations noted with a diamond are above the NS&T nationwide 85th percentile (µg/g dry wt.).

Selenium in sediment

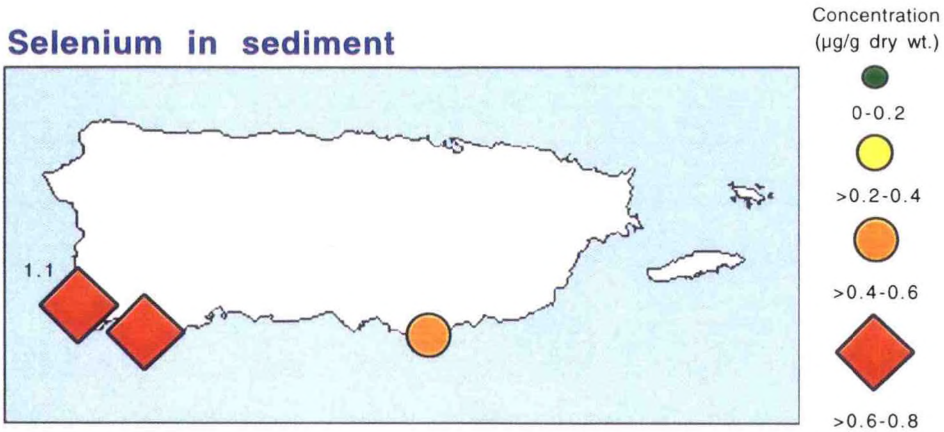


Figure I.7. Selenium in sediment. Average of data from 1986 to 1995. Concentrations noted with a diamond are above the NS&T nationwide 85th percentile (µg/g dry wt.).

Silver in sediment

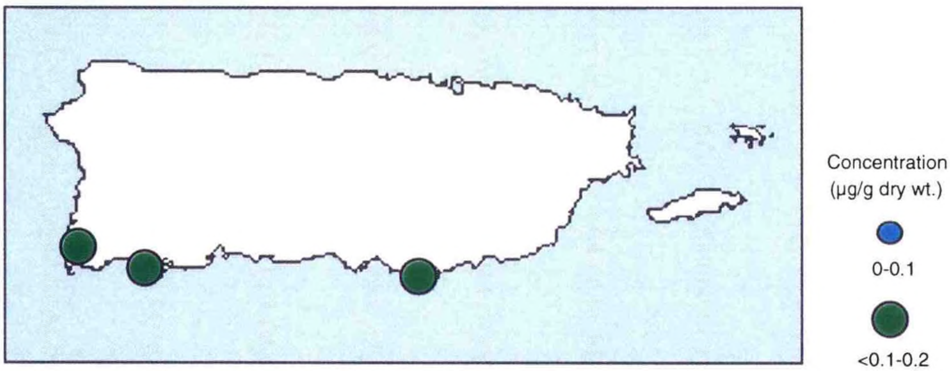


Figure I.8. Silver in sediment. Average of data from 1986 to 1995. Concentrations noted with a diamond are above the NS&T nationwide 85th percentile (µg/g dry wt.).

Cadmium in sediment

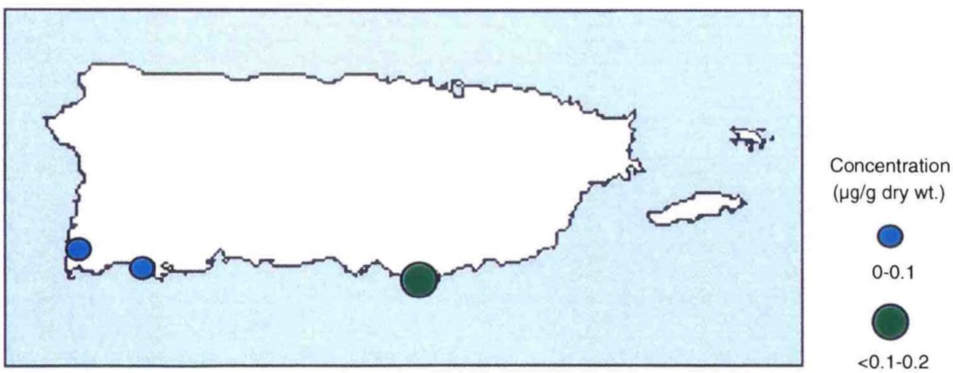


Figure I.9. Cadmium in sediment. Average of data from 1986 to 1995. Concentrations noted with a diamond are above the NS&T nationwide 85th percentile (µg/g dry wt.).

Tin in sediment

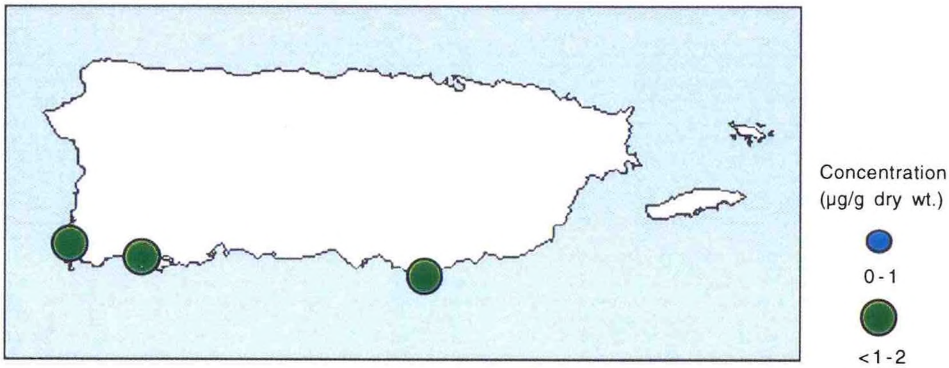


Figure I.10. Tin in sediment. Average of data from 1986 to 1995. Concentrations were below the NS&T nationwide 85th percentile (µg/g dry wt.).

Mercury in sediment

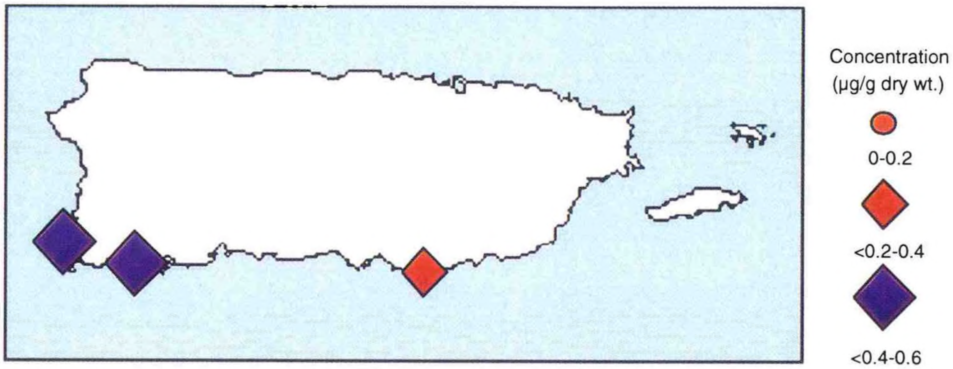


Figure I.11. Mercury in sediment. Average of data from 1986 to 1995. Concentrations were below the NS&T nationwide 85th percentile (µg/g dry wt.).

Lead in sediment

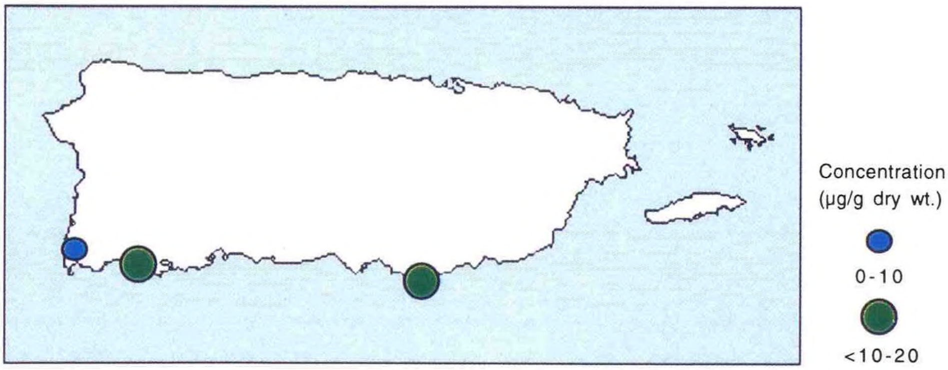


Figure I.12. Lead in sediment. Average of data from 1986 to 1995. Concentrations were below the NS&T nationwide 85th percentile (µg/g dry wt.).

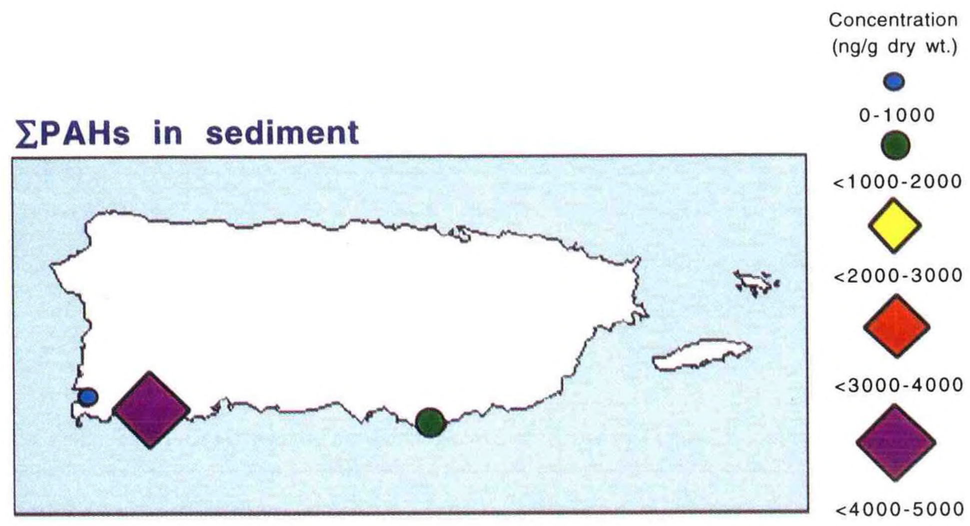


Figure I.13. ΣPAHs in sediment. Average of data from 1986 to 1995. Concentrations were below the NS&T nationwide 85th percentile (ng/g dry wt.).

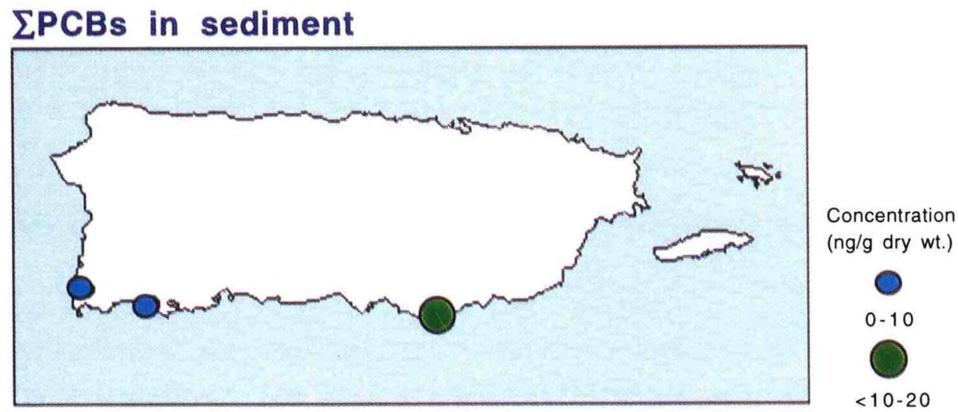


Figure I.14. ΣPCBs in sediment. Average of data from 1986 to 1995. Concentrations were below the NS&T nationwide 85th percentile (ng/g dry wt.).

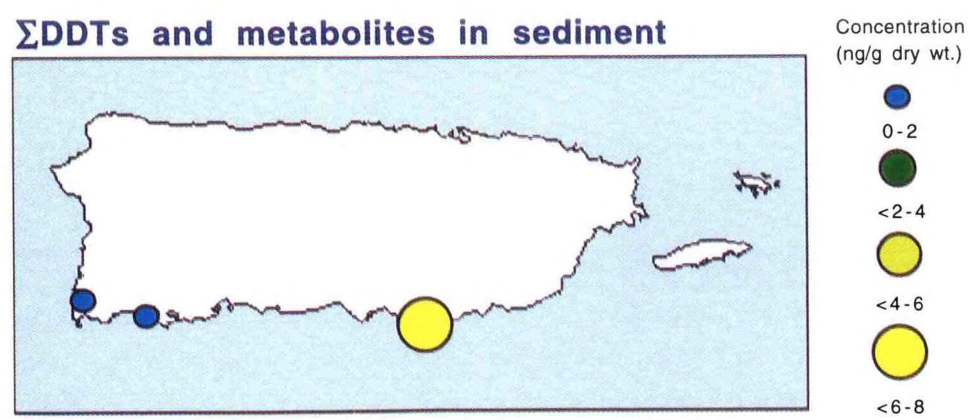


Figure I.15. ΣDDTs and metabolites in sediment. Average of data from 1986 to 1995. Concentrations were below the NS&T nationwide 85th percentile (ng/g dry wt.).

ΣCdane in sediment

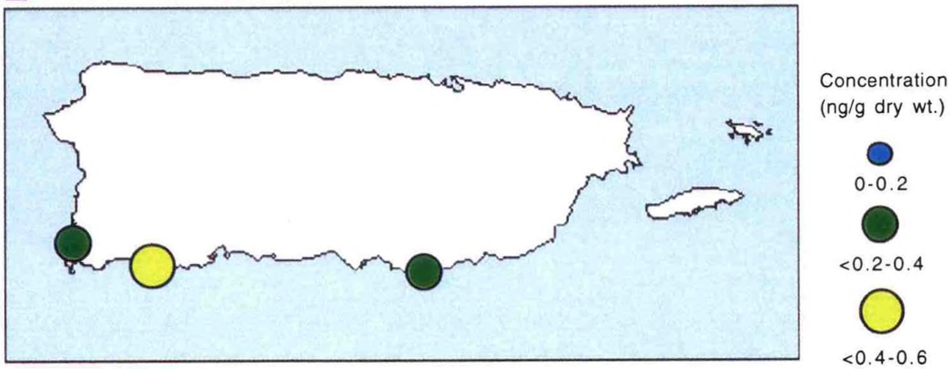


Figure I.16. Total chlordane pesticides in sediment. Average of data from 1986 to 1995. Concentrations were below the NS&T nationwide 85th percentile (ng/g dry wt.).

Dieldrin + aldrin in sediment

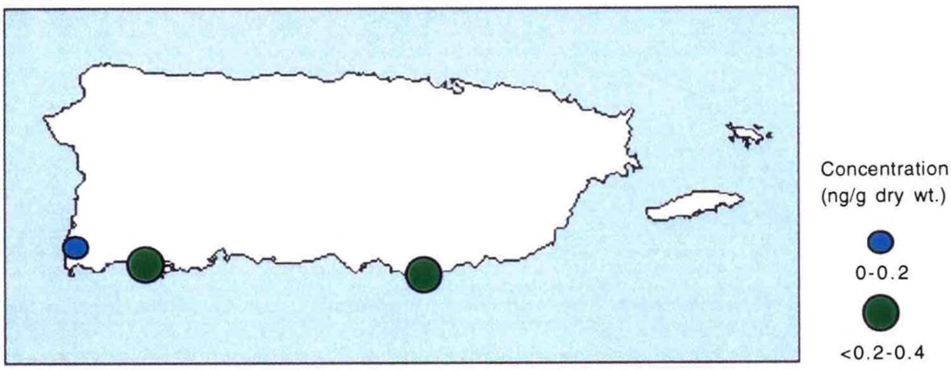


Figure I.17. Dieldrin and aldrin in sediment. Average of data from 1986 to 1995. Concentrations were below the NS&T nationwide 85th percentile (ng/g dry wt.).

Lindane in sediment

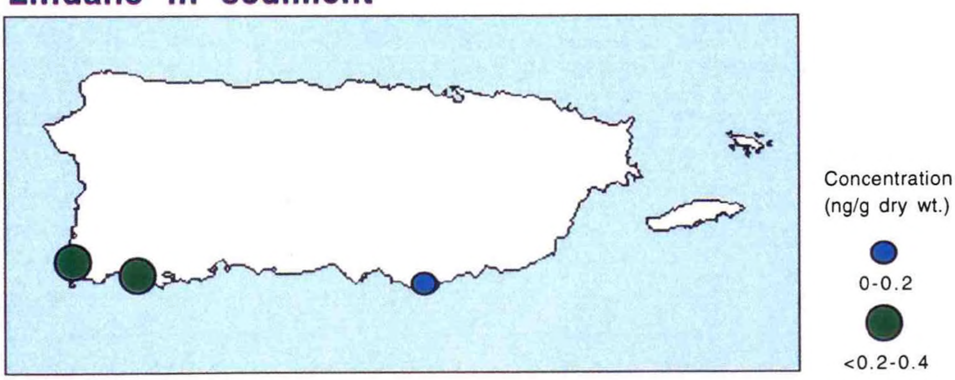


Figure I.18. Lindane in sediment. Average of data from 1986 to 1995. Concentrations were below the NS&T nationwide 85th percentile (ng/g dry wt.).

Appendix II

NS&T oyster trend data for Puerto Rico

Nickel and copper in oysters

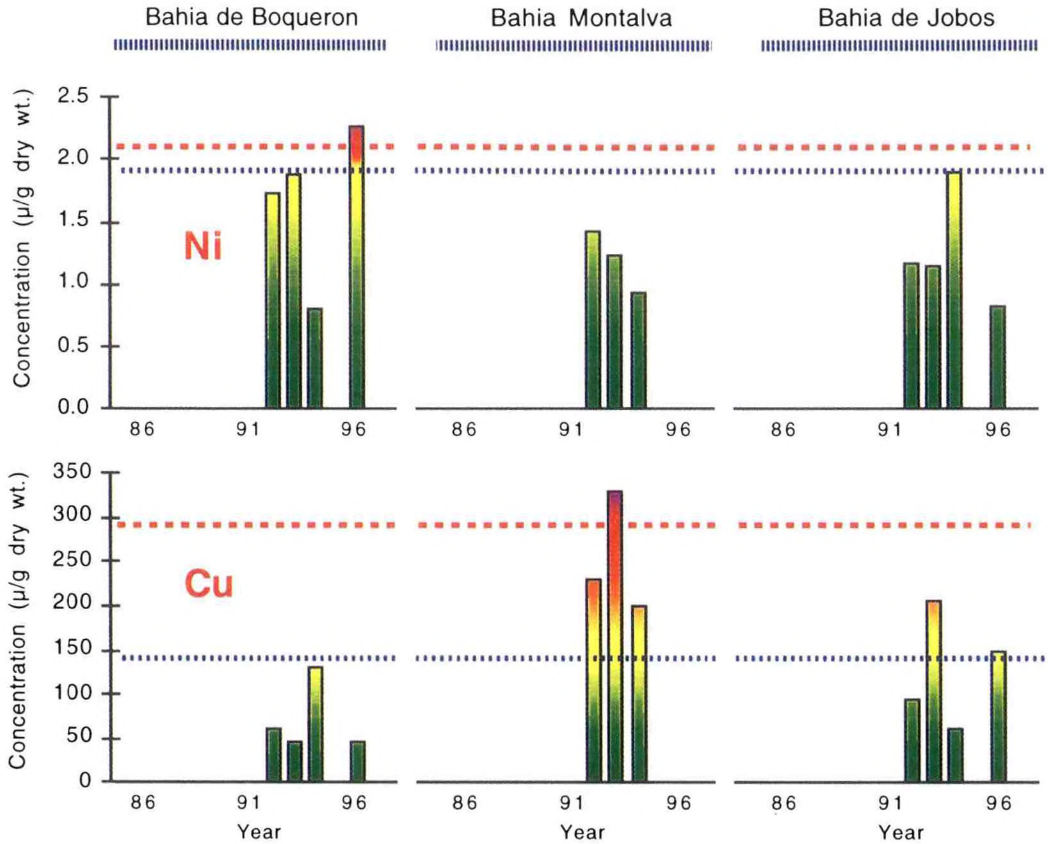


Figure II.1. Nickel, copper, zinc, arsenic, selenium, silver and cadmium trends in oysters. Dotted blue line is NS&T median and dashed red line is NS&T nationwide 85th percentile (µg/g dry wt.).

Zinc, arsenic and selenium trends in oysters

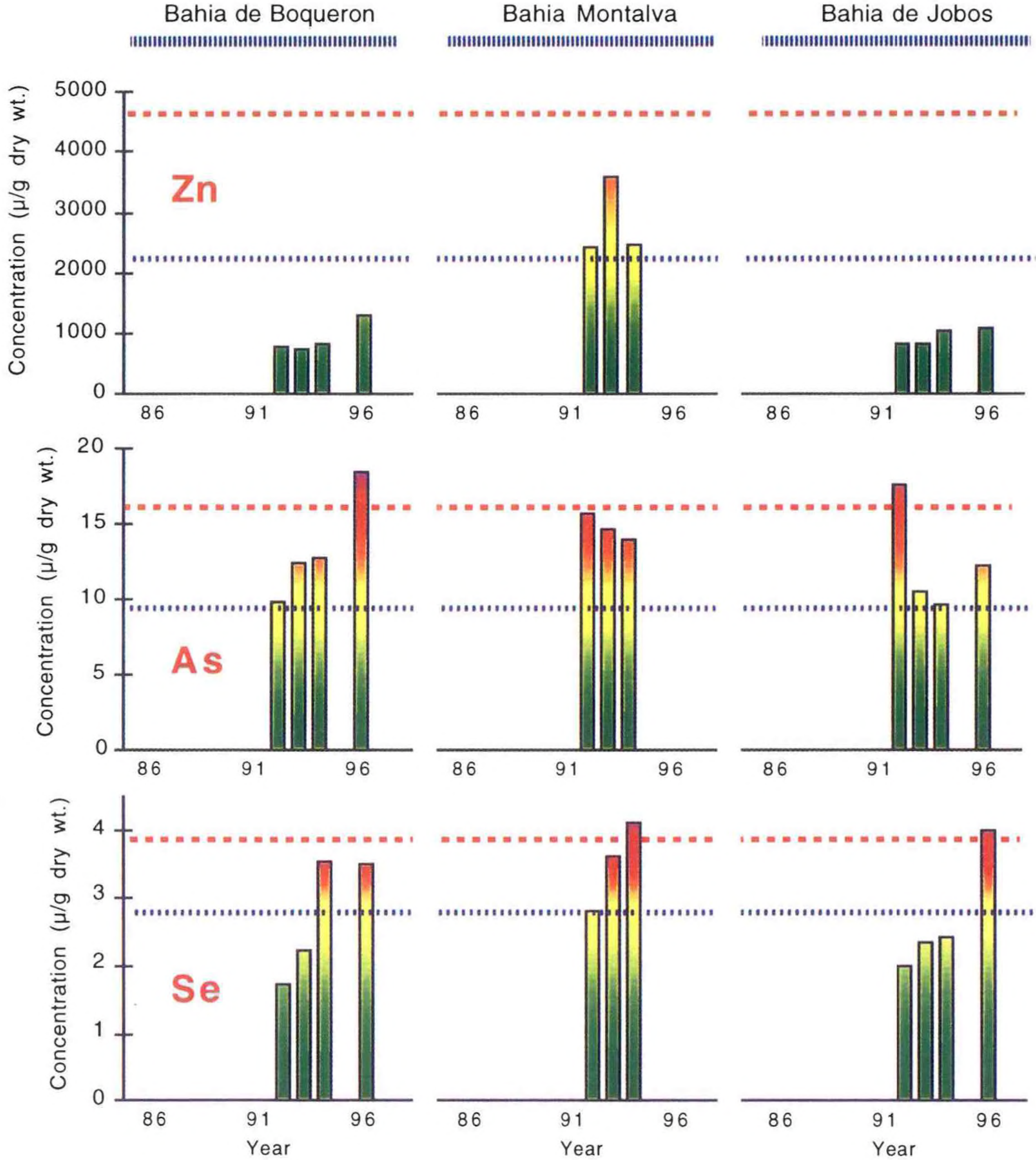
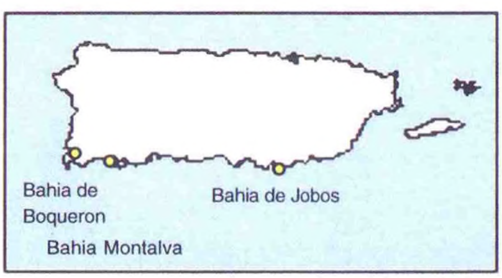


Figure II.2. Zinc, arsenic and selenium trends in oysters. Dotted blue line is NS&T median and dashed red line is NS&T nationwide 85th percentile (µg/g dry wt.).



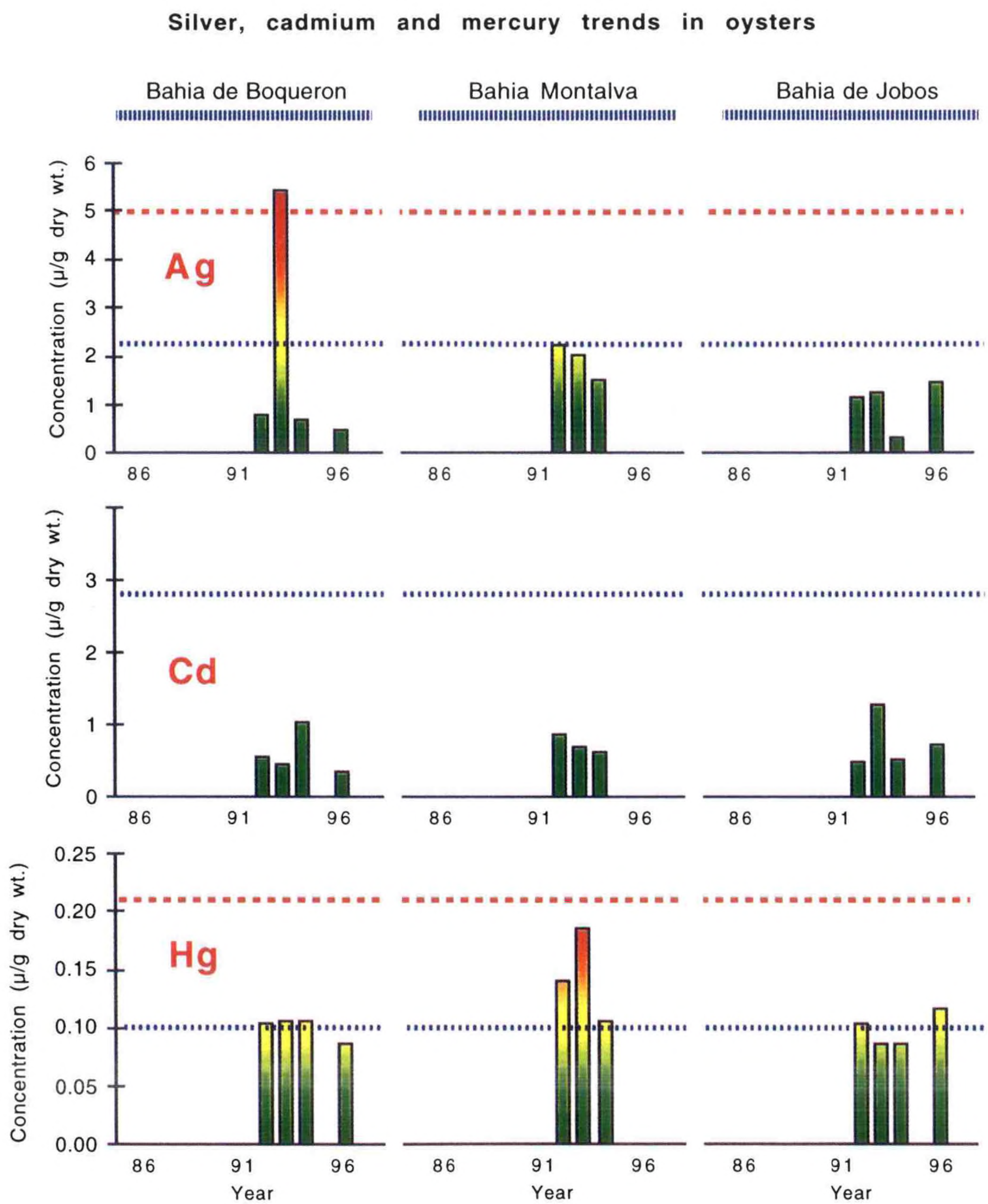


Figure II.3. Silver, cadmium and mercury trends in oysters. Dotted blue line is NS&T median and dashed red line is NS&T nationwide 85th percentile (µg/g dry wt.).

Lead, ΣPAHs and ΣPCBs trends in oysters

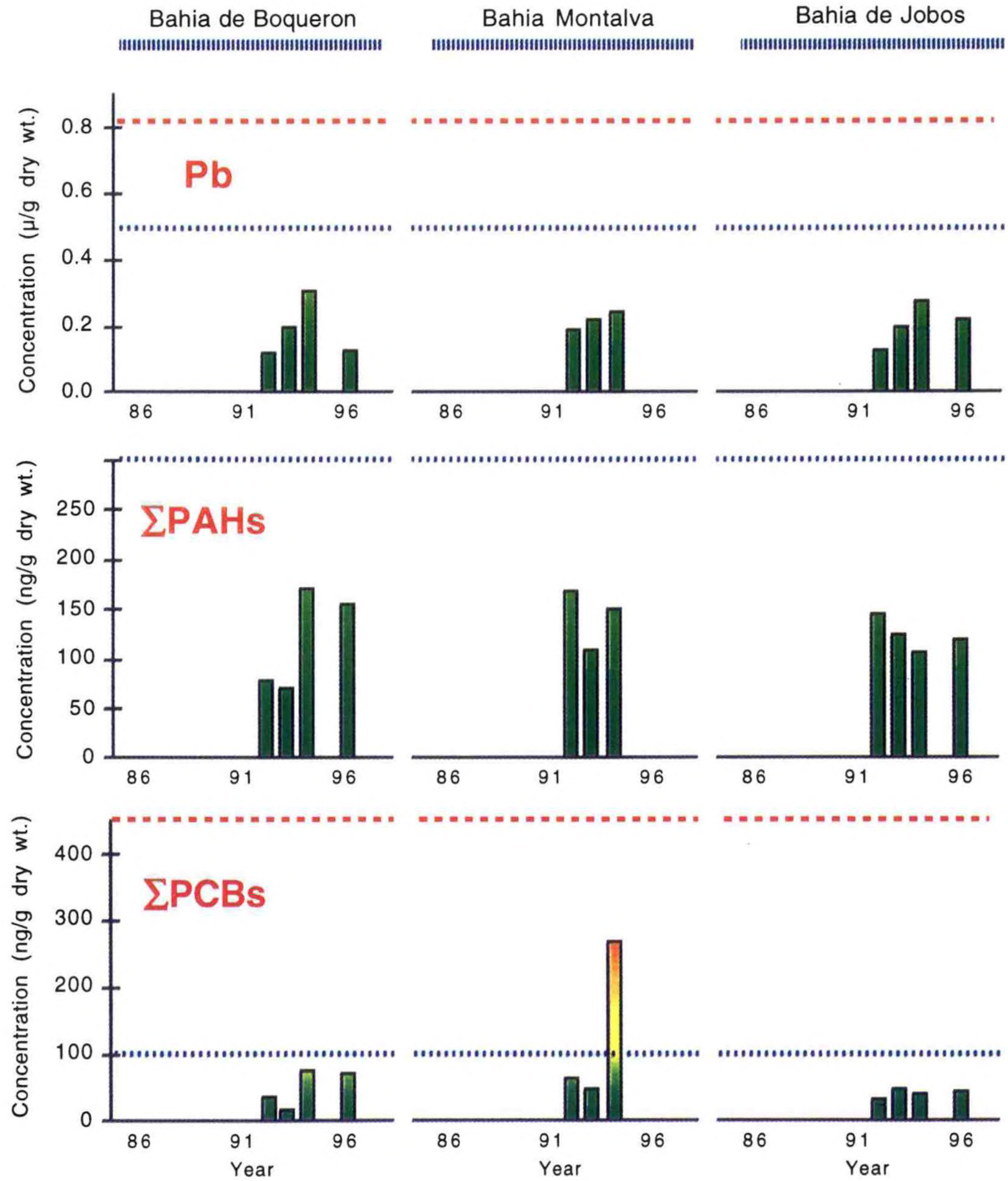


Figure II.4. Lead (µg/g dry wt.), ΣPAHs (ng/g dry wt.) and ΣPCBs (ng/g dry wt.) trends in oysters. Dotted blue line is NS&T median and dashed red line is NS&T nationwide 85th percentile. A "<" indicates a value below the limit of detection.

ΣDDT and metabolites, dieldrin and aldrin, and lindane trends in oysters

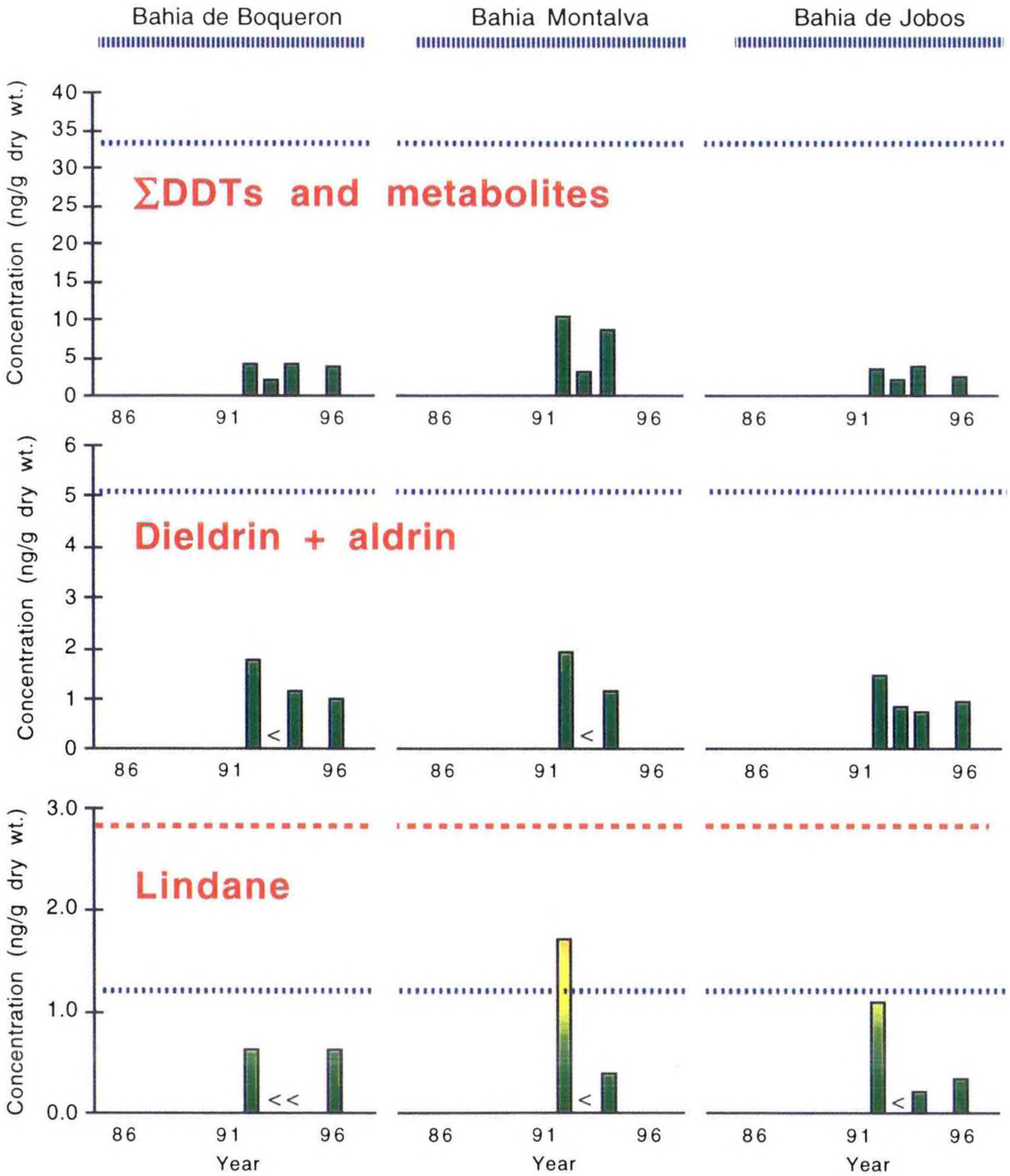
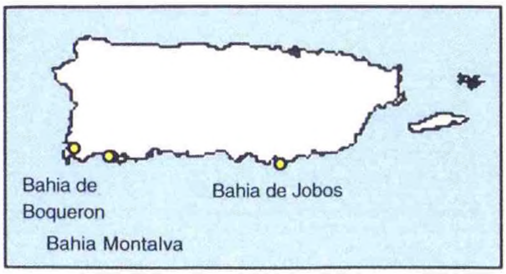


Figure II.5. ΣDDT and metabolites, dieldrin and aldrin, and lindane trends in oysters. Dotted blue line is NS&T median and dashed red line is NS&T nationwide 85th percentile. A "<" indicates a value below the limit of detection (ng/g dry wt.).



NS&T smooth-edged jewel box trend data for Bahia Honda

Nickel, copper, zinc, arsenic, selenium, silver and cadmium in the smooth-edged jewel box

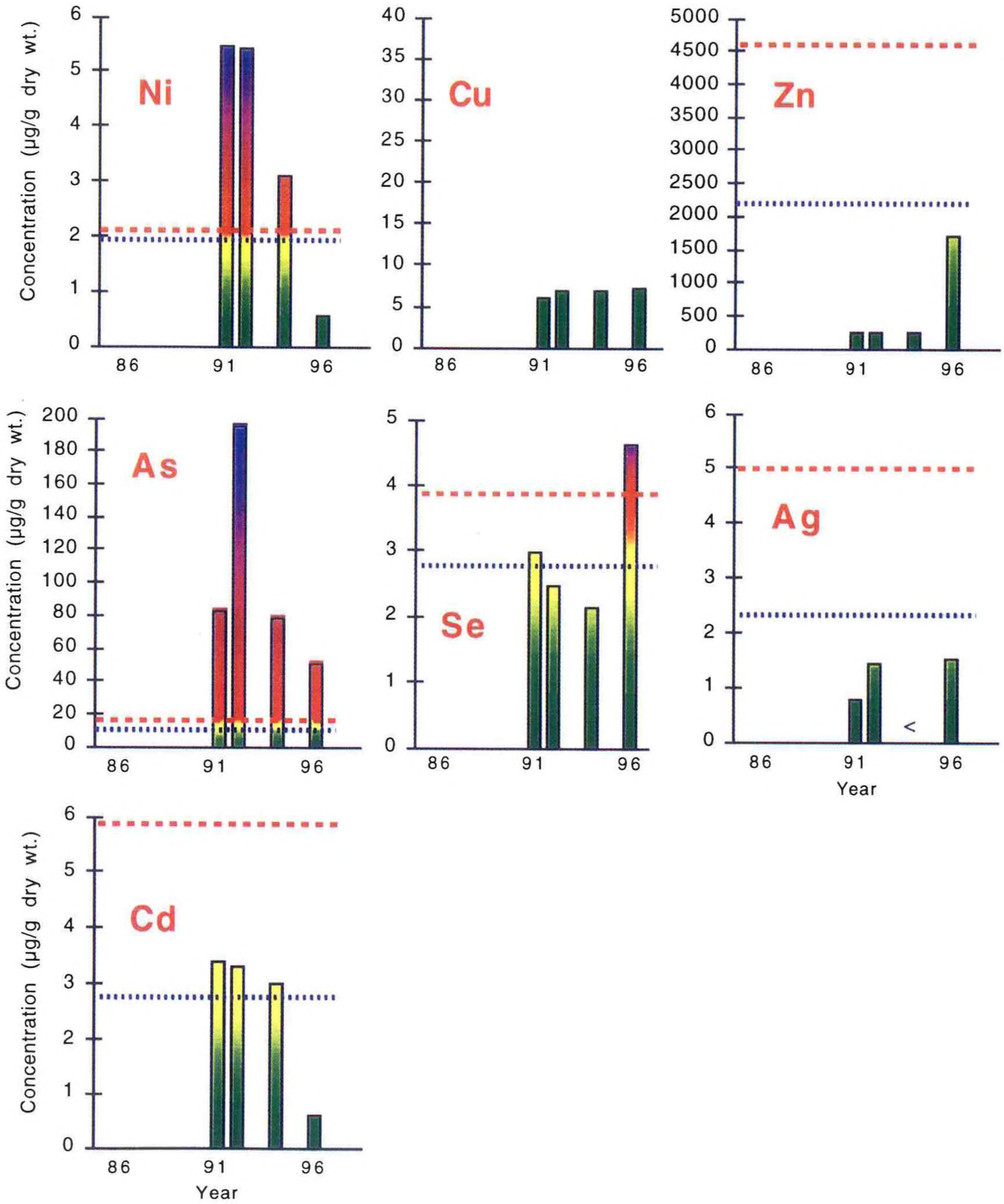


Figure II.6. Nickel, copper, zinc, arsenic, selenium, silver and cadmium in the smooth-edged jewel box. Dotted blue line is NS&T median and dashed red line is NS&T nationwide 85th percentile. A "<" indicates a value below the limit of detection (µg/g dry wt. unless noted).

Mercury, lead, ΣPAHs, lindane and ΣBTs in the smooth-edged jewel box

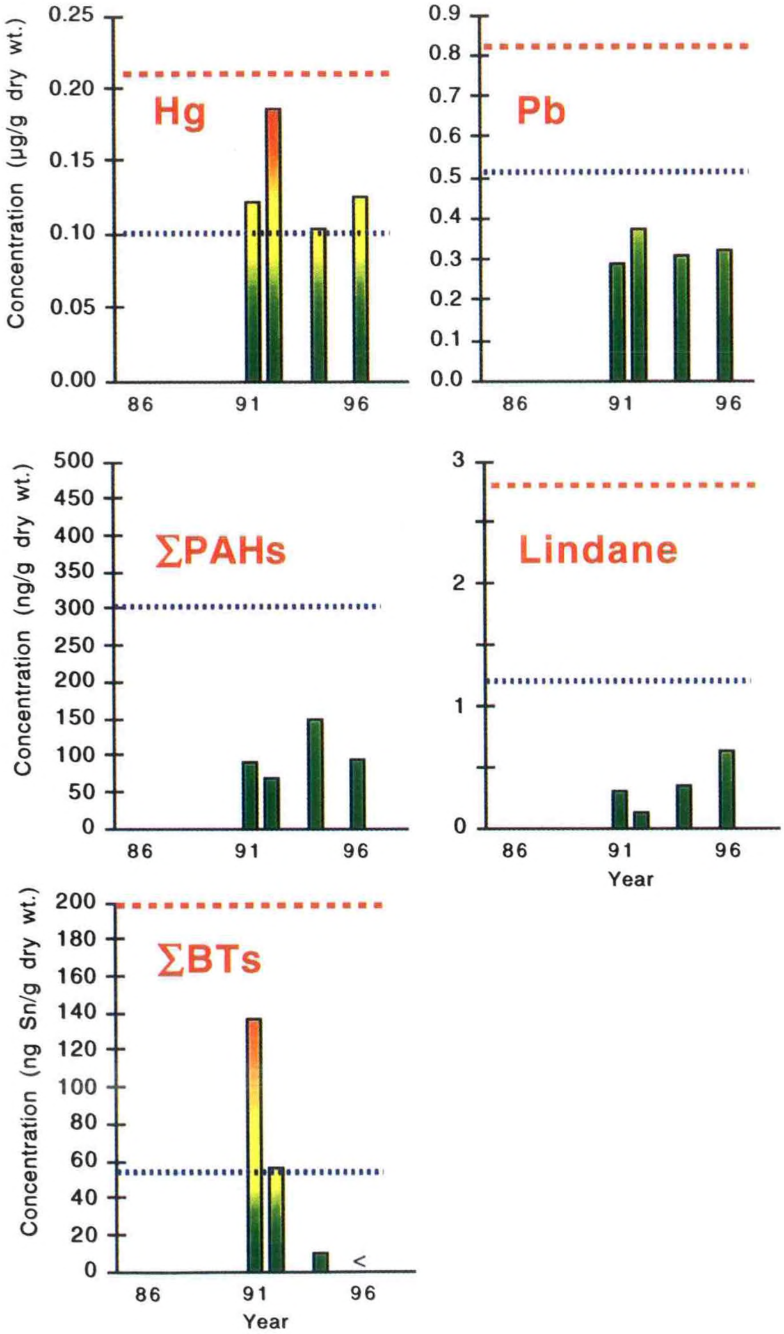


Figure II.7. Mercury, lead, ΣPAHs, lindane and ΣBTs in the smooth-edged jewel box. Dotted blue line is NS&T median and dashed red line is NS&T nationwide 85th percentile. A "<" indicates a value below the limit of detection (µg/g dry wt. unless noted).

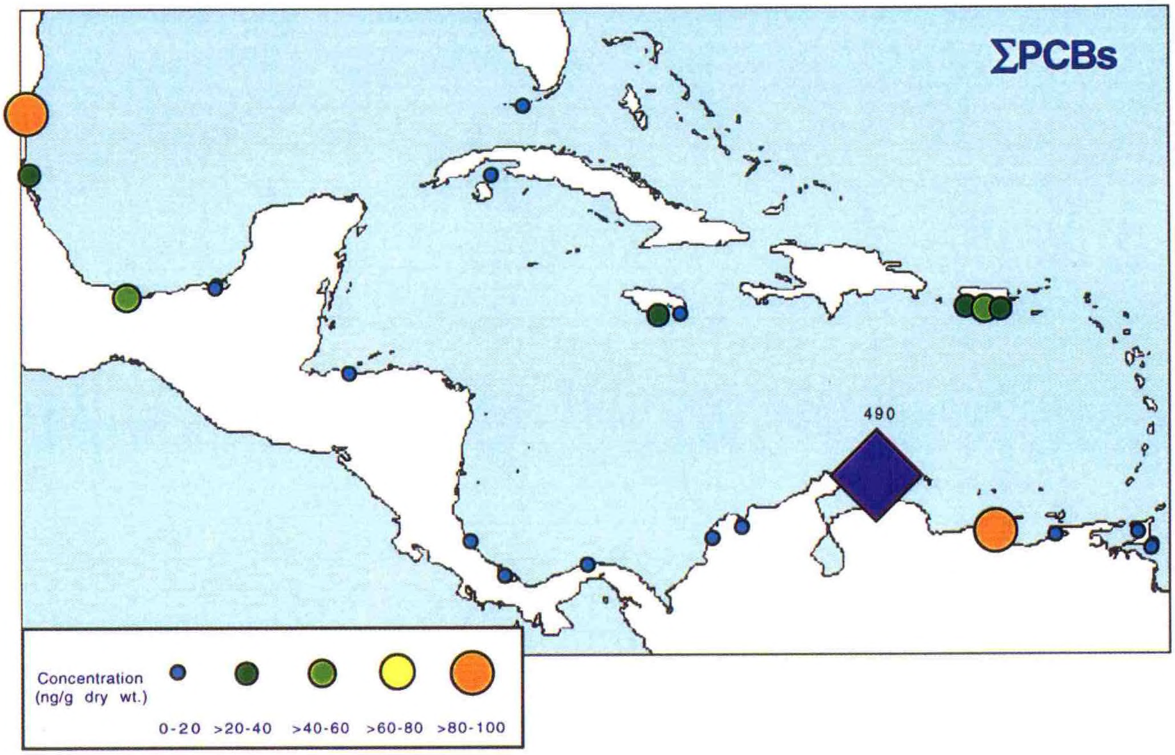
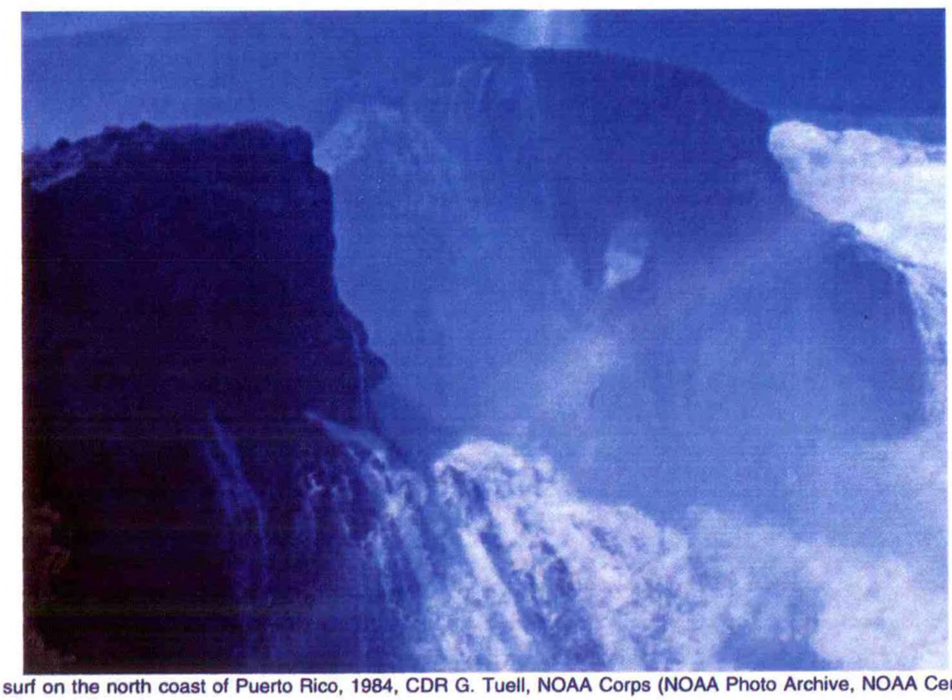


Figure III.1. ΣPCB congeners in bivalves in the Caribbean. Only 1992 NS&T data used. Concentrations noted with a diamond are above the NS&T 85th percentile (ng/g dry wt.).



Hurricane surf on the north coast of Puerto Rico, 1984, CDR G. Tuell, NOAA Corps (NOAA Photo Archive, NOAA Central Library)

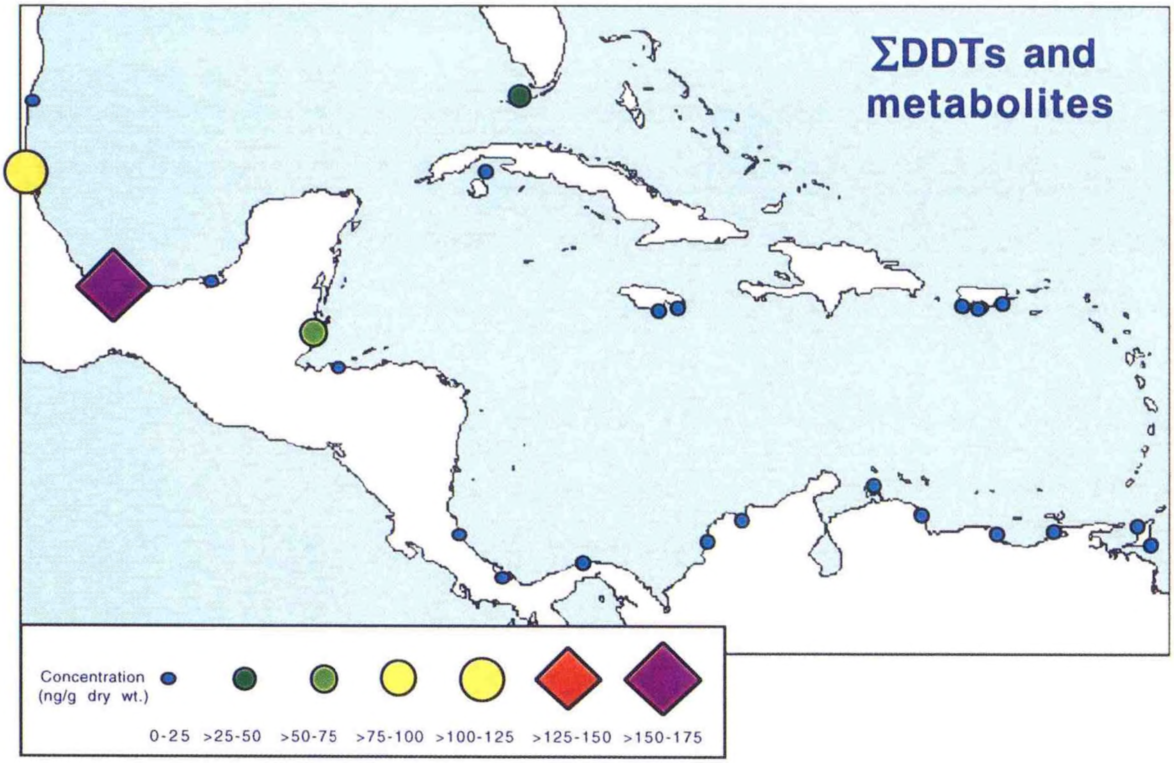


Figure III.2. ΣDDT and metabolites in bivalves in the Caribbean. Only 1992 NS&T data used. Concentrations noted with a diamond are above the NS&T 85th percentile (ng/g dry wt.).

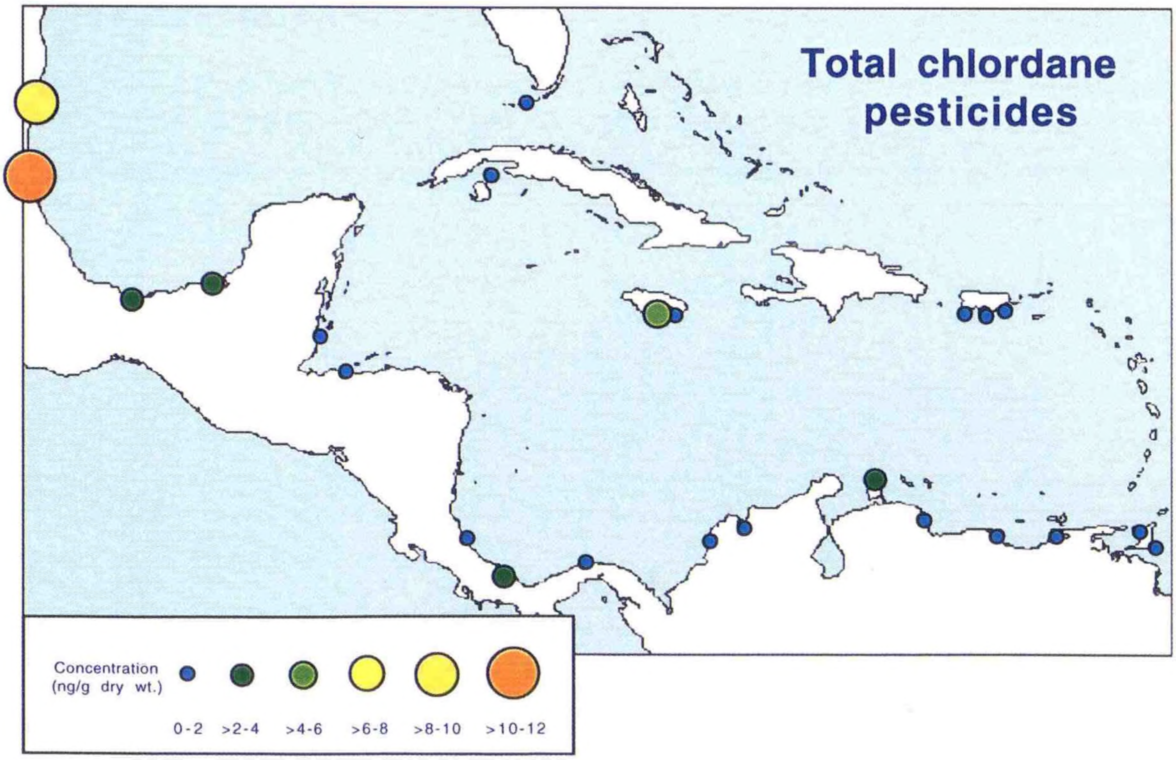


Figure III.3. Total chlordane pesticides in bivalves in the Caribbean. Only 1992 NS&T data used (ng/g dry wt.).

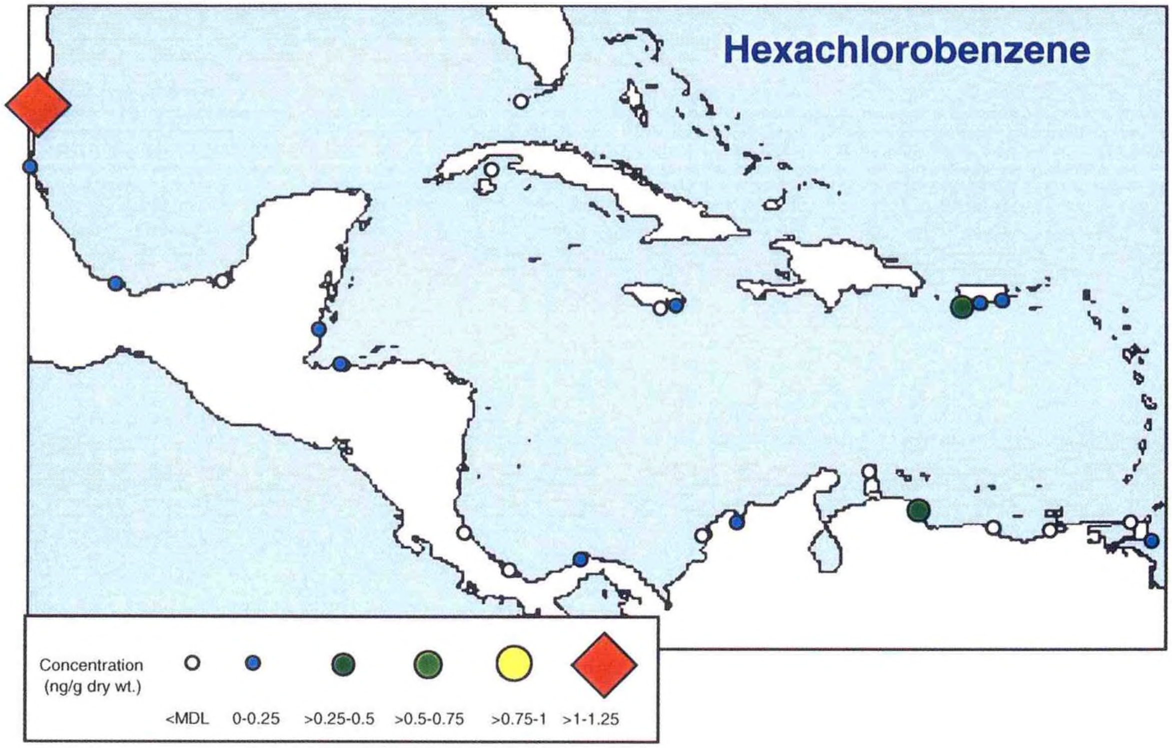


Figure III.4. Hexachlorobenzene in bivalves in the Caribbean. Only 1992 NS&T data used. Concentrations noted with a diamond are above the NS&T 85th percentile. White circles denote concentrations below the limit of detection (ng/g dry wt.).

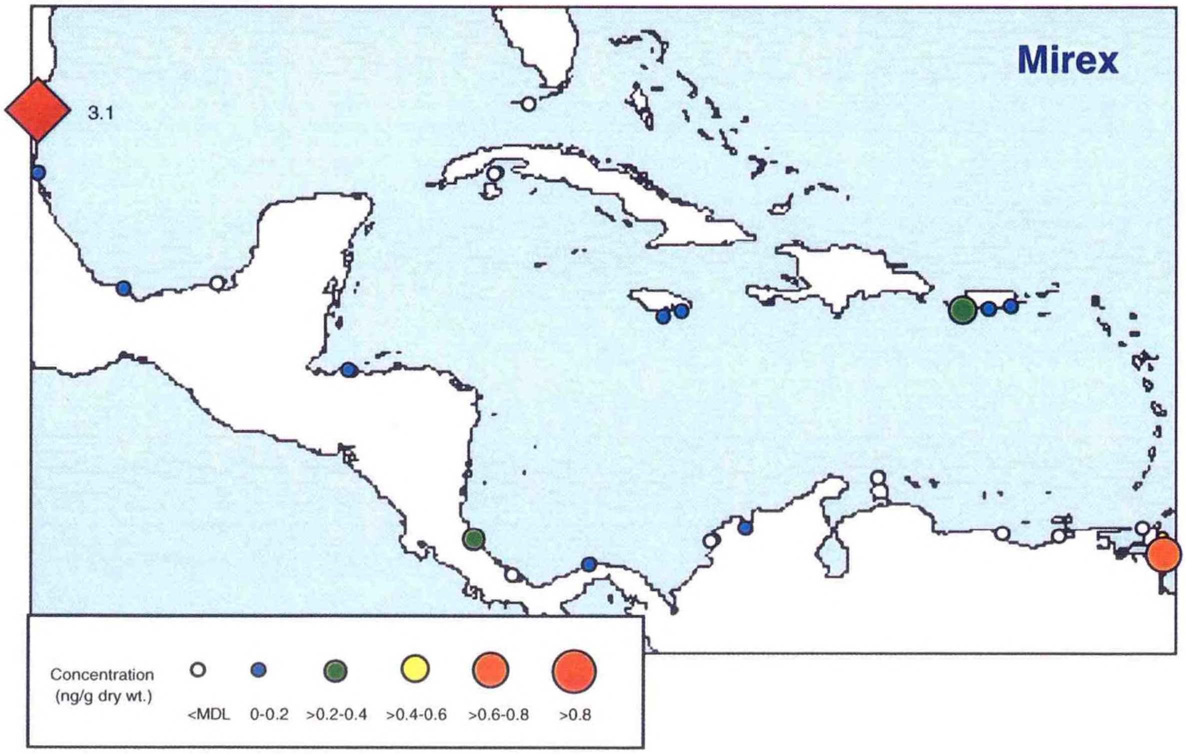


Figure III.5. Mirex in bivalves in the Caribbean. Only 1992 NS&T data used. Concentrations noted with a diamond are above the NS&T 85th percentile. White circles denote concentrations below the limit of detection (ng/g dry wt.).

U.S. Secretary of Commerce
William M. Daley

Under Secretary of Commerce for Oceans and Atmosphere, and Administrator
National Oceanic and Atmospheric Administration
D. James Baker, Ph.D.

Assistant Secretary of Commerce for Oceans and Atmosphere,
and Deputy Administrator
Terry D. Garcia

Assistant Administrator for Ocean Services and Coastal Zone Management
National Ocean Service
Nancy Foster, Ph.D.