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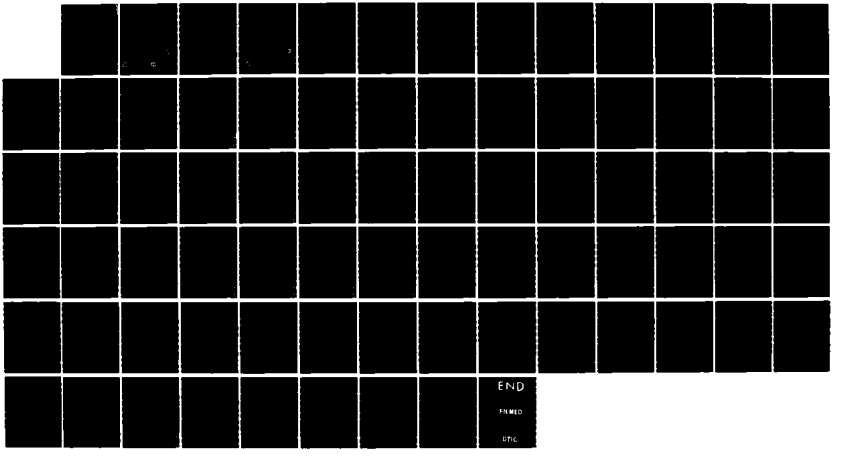

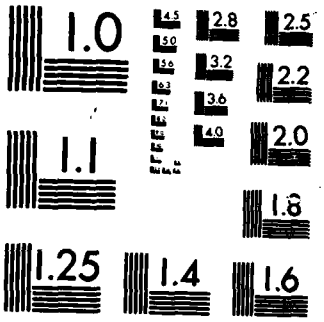

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APPLIED MARINE RESEARCH LABORATORY
OLD DOMINION UNIVERSITY
NORFOLK, VIRGINIA

TOXINS IN THE VICINITY OF THE PROPOSED NORFOLK AND DAM NECK DISPOSAL SITES

By

Raymond W. Alden III, Principal Investigator,
Guy J. Hall, Arthur J. Butt,
and Joseph H. Rule

Final Report
For Period Ending December, 1984

Prepared for the
Department of the Army
Norfolk District, Corps of Engineers
Fort Norfolk, 803 Front Street
Norfolk, Virginia 23510

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For most part toxins are not present at either site except at extremely low levels. Concentrations of toxins higher at DNDS, probably due to influence of Chesapeake Bay plume.

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By

*Raymond W. Alden III, **Guy J. Hall,
***Arthur J. Butt, and ****Joseph H. Rule

INTRODUCTION

Dredging activities are considered essential to the functioning of most ports in maintaining navigational channels. The major question concerning these operations is not whether dredging should be continued, since it is obvious that channels must be maintained and developed. Rather, the question most frequently addressed concerns where to dispose of the dredged material with the least possible ecological impact. Onshore, landfill disposal operations often create a number of socio-economic and ecological problems in the wetlands surrounding ports. In fact, any land available for such activities in a highly urbanized port city is cost prohibitive. Therefore, a great deal of interest is being focused on the feasibility of open ocean disposal of dredged materials as an ecologically sound alternative to onshore disposal (Pequegnat et al., 1978). ov2

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This project represents an overview of a portion of an ongoing multidisciplinary program initiated by the Ocean Dumping Program of the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Army Corps of Engineers (COE). Its purpose is to assess the potential ecological impact of open ocean disposal of materials dredged from Hampton Roads, Virginia, a highly industrialized seaport.

Concern over the transport and concentration of potentially toxic materials in the aquatic ecosystem has led to baseline and trend assessment studies. Many of the organic and inorganic contaminants are not soluble in water and subsequently are deposited in the sediments. The estuary and adjacent coastal waters act as filters to many such materials and may serve as reservoirs for accumulating organic toxins. The potential impact to the biota, including man, cannot be ignored, particularly when toxic substances have been reported in the harbors and channels of a highly industrialized seaport.

Investigators associated with the Applied Marine Research Laboratory at Old Dominion University have conducted extensive analytical testing to assess the chemical, geological and biological patterns at the disposal site under baseline conditions since 1981. The major focus of this paper concerns the overall findings of chemical toxins (heavy metals, chlorinated hydrocarbons, and polynuclear aromatic hydrocarbons) in water, sediment and tissue samples from the Norfolk and Dam Neck Disposal Sites Baseline Monitoring Program.

MATERIALS AND METHODS

STUDY AREAS

Norfolk Disposal Site Study Area

The area designated the Norfolk Disposal Site (NDS) is a potential dredge material disposal site delineated by a circle with a radius of 7.4 km centered at 36°59'N latitude and 75°39'W longitude in the coastal waters off the mouth of the Chesapeake Bay (Fig. 1a). The Site is located beyond the 60 foot (18.3 m) depth contour line, approximately 27 km east of the Cape Henry Channel. Permanent monitoring stations have been established in and around the disposal site. A full description of the NDS study area and the sampling locations have previously been presented (see Alden et al., 1984a,b; Alden and Butt, 1985b).

Dam Neck Disposal Site Study Area

The Dam Neck Disposal Site (DNDS) activated in 1968, is an interim open water site approximately 3 miles east of Dam Neck, Virginia (Fig. 1b). It receives dredged material from Cape Henry Channel and the Thimble Shoal Channel. The area is described as a high energy zone just south of the Chesapeake Bay mouth, and is between the 30 and 50 ft (9.1 to 15.4 m) contour lines.

A strong density stratification is identified in the Dam Neck area. The low salinity surface water is associated with the Chesapeake Bay Plume particularly during the warmer months. This effect is minimized during the winter when vertical mixing is greatest. Wind strength, direction and fetch serve as strong

Figure 1a. Location map of the proposed Norfolk Disposal Site (NDS) off Chesapeake Bay.

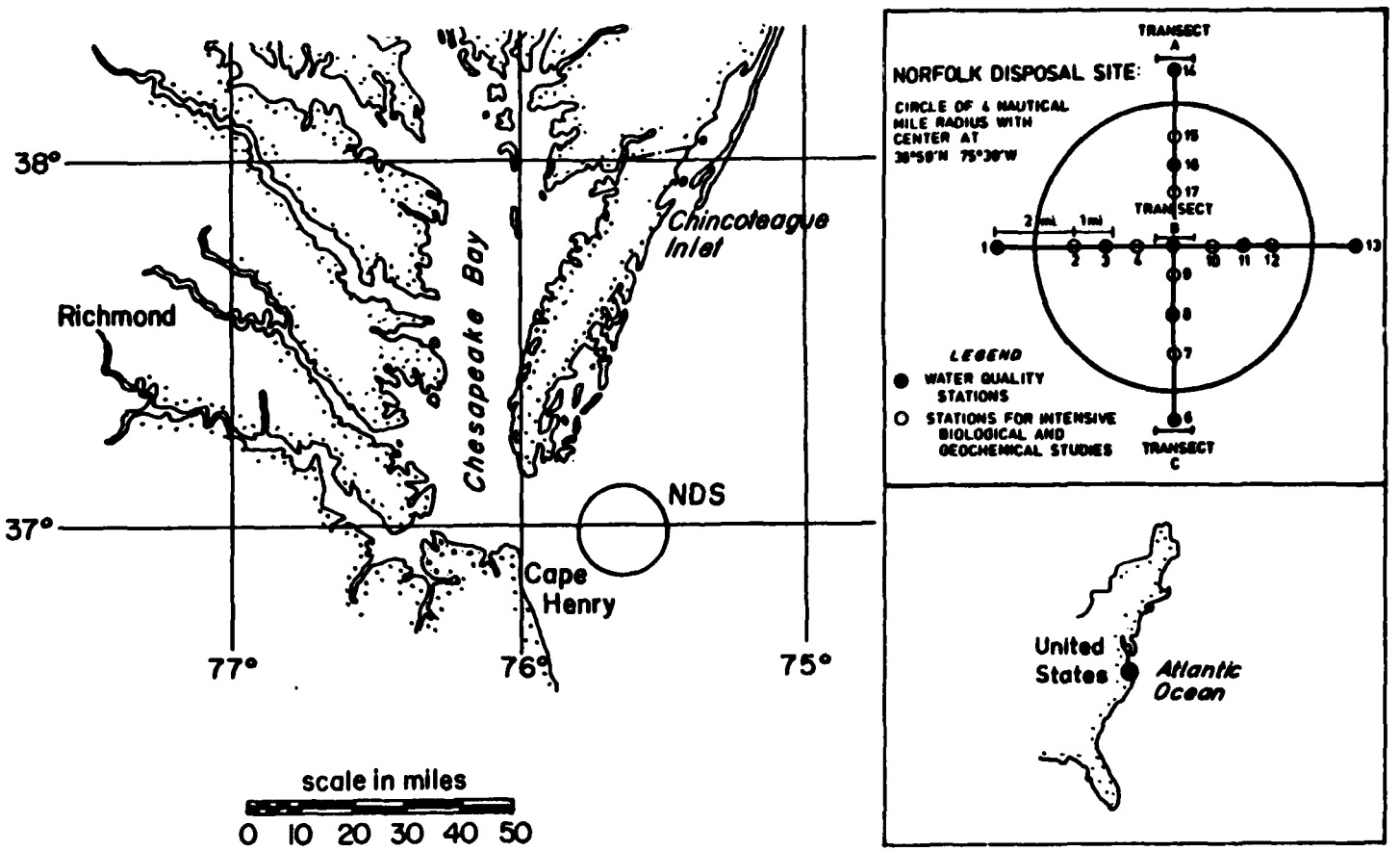
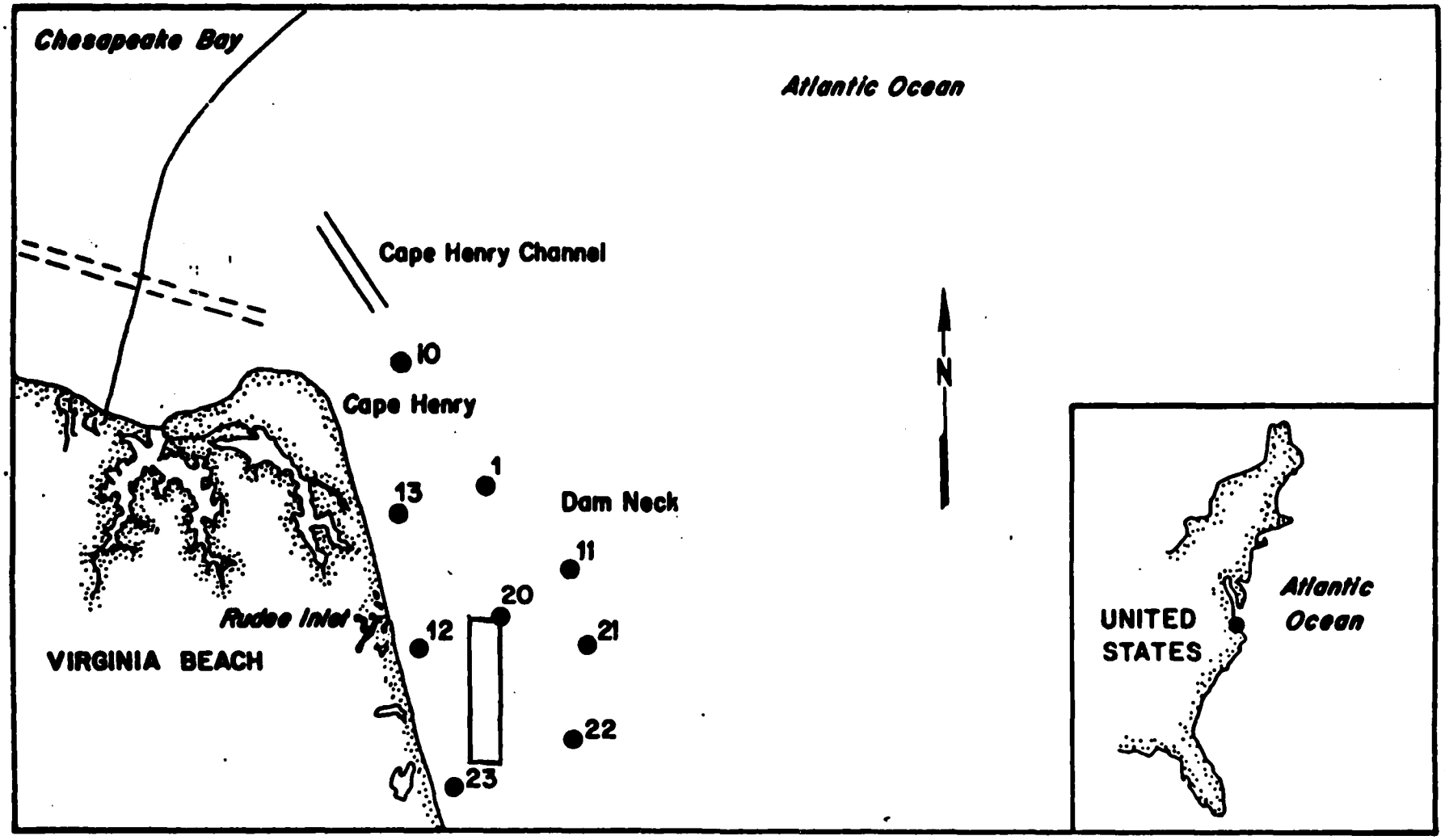


Figure 1b. Location map of the interim Dam Neck Disposal Site (DNDS) off Virginia Beach, Virginia.



influences on water flowing out of the Bay, and along the coast line. The more saline bottom waters show a northward flow inshore, in opposition to the southerly drift of outer shelf water and outflowing freshwater from the Bay.

The inshore zone receives nutrients, suspended solids and organic matter associated with sewage from Chesapeake Bay. A detailed description of the water quality and physical parameters characteristics associated with the Bay Plume and DNDS is presented by Alden and Butt (1985a,b).

Sampling Regime

The toxin monitoring program at NDS and DNDS consisted of comprehensive analytical testing to assess the chemical, geological and biological patterns. Water and representative organisms were collected quarterly from designated sites. Sample collections at NDS were from Stations 5 and 14. Stations at Dam Neck varied depending on the specific analysis. Water and bioaccumulation tests were made from samples taken at Station 10 (DNDS), while sediments were collected inshore and offshore of DNDS at Stations 12 and 32 once during 1984. Analyses were performed for heavy metals, chlorinated hydrocarbons (CHC's), and polynuclear aromatic hydrocarbons (PNAH's).

Water samples were collected 1 m below the surface and 1 m above the bottom. Collections were made in triplicate with teflon lined go-flo bottles.

Biological tissue from fishes and epibenthic macroinvertebrates were also tested for toxins. Zooplankton was collected by oblique bongo (350 micron mesh) tows. Triplicate samples, when available, were obtained for each species. Composite tissue samples were analyzed if sufficient biomass was collected.

Sediment samples were taken in triplicate from two designated stations (12 and 21) at DNDS with a Shipek grab. Standard methods for handling and preservation of samples were rigorously followed (APHA, 1979; EPA, 1980; Grice et al., 1972). Analytical methods for all toxins paralleled those described in detail in previous studies (Alden et al., 1981, 1982, 1984a,c; and Alden, 1984a).

RESULTS

Toxins In Water

Triplicate surface and bottom water samples were analyzed for eight heavy metals (Cd, Cu, Hg, Ni, Pb, Zn, Cr, Mn) for the DNDS studies (Tables B1 and B2, respectively). (Tables B1 and B2 represent the averages of surface and bottom water samples from the collection stations: two at NDS, one at DNDS). A series of MANOVAS indicated no significant patterns for any of the metals (above the detection levels) with respect to depth. The metal concentrations in the water were quite low (low parts-per-billion, ppb levels) throughout the studies. Metal concentrations in the waters of the DNDS were generally higher than those observed at the NDS during the same season. In general, the values were higher at DNDS by a factor of 2 to 3. Elevated concentrations of mercury were observed at both NDS and DNDS during the summer cruise. This trend repeated a pattern observed at NDS during a more intensive study of the region in 1983 (Alden et al., 1984a).

The organics in water analysis indicated that PNAH's and CHC's at NDS and DNDS were generally below the detection limits (Appendix - Tables A1 & A2). In fact, only one of the six monthly replicates taken from DNDS in March contained a toxin (2 ng/l of pyrene), and one sample in September contained 12 ng/l of what appeared to be Heptachlor. None of the samples from NDS contained detectable levels of either PNAH's or CHC's.

Toxins In Sediments

Metal concentrations from DNDS were somewhat higher than levels reported from NDS for Cd, Ni, Pb and Zn (Table C1). The offshore sample (Station 21) showed slightly elevated levels for those metals tested except Zn where no difference was reported. The DNDS levels were generally lower than those found in sediments from the lower Bay, and much lower than levels reported from Hampton Roads (Alden et al., 1982).

The PNAH's in sediments were extremely low (Table C2). Only phenanthrene, fluorenthene, and pyrene were found above the detection levels (Table A1). However, the values of these PNAH's were extremely low (low ng/g) and there were no significant differences in concentration between the two stations.

The only CHC detectable in the sediments of DNDS was p,p-DDE, the breakdown product of DDT (Table C3). The concentrations of p,p-DDE in the sediments were in the low parts-per-trillion (ppt, pg/g) range. No significant station differences were detected in the concentrations of this CHC.

Toxins In Tissues

The levels of heavy metals in the representative taxonomic groups for the seasonal cruises varied (Appendix, Table D). Sufficient biomass was not available from the December, 1983 NDS cruise for the metals analysis. Higher levels of metals were observed in the fish and zooplankton tissues during the winter cruise, although a considerable amount of inter-sample variability was generally noted (Tables D1 & D2). As in previous studies

(Alden et al., 1984a), the fish tissue samples generally contained lower concentrations of metals than did the epibenthic macroinvertebrates, which, in turn, were lower than the zooplankton samples (Table D3). The metals in biota from DNDS were quite similar to those observed for NDS tissue values during the same season (Tables D4 & D5).

Organic toxins in the representative biotic groups collected at DNDS are presented in Appendix E for PNAH's and CHC's. The PNAH's in biota collected at DNDS were observed in higher concentrations during the spring and, to a lesser degree, winter cruises. Naphthalene, fluorene, phenanthrene, fluoranthene and pyrene were observed in both the fish and invertebrate samples in moderate amounts (mid-ng/g range) during the spring DNDS cruise (Tables E1 & E2, respectively). The CHC levels in the biota were quite low in both the fish and invertebrate samples: α-BHC, heptachlor epoxide, p,p-DDE and heptachlor, all in the parts-per-trillion (ppt) to low parts-per-billion (ppb) range (pg/g to ng/g) (Tables E3 & E4). The DDT breakdown product p,p-DDE was the CHC most frequently observed in the greatest abundance in the biological tissues.

A listing of all species collected during the studies, and the grand mean concentrations of the toxins in the tissues of each are presented in Appendix F.

Minimum Detectable Impacts of Contaminants

In order to determine the levels of toxins which would represent statistically detectable impacts at NDS and DNDS, minimum detectable impact (MDI) values were calculated as

described by Alden (1984b). The MDI's and lowest concentrations required for impact detection are presented in Table 1.

The MDI values ranged from 40% to nearly 600%. The MDI values were generally lower than those observed for NDS for previous years (Alden et al., 1984a). As with the data from previous years, the estimated "impacted" values of metals in seawater for NDS and DNDS were in the low ppb (µg/l) range. The "impacted" values of organics in sediments from DNDS were in the low ppb (ng/g) range for PNAH's and the ppt (pg/g) range for p,p-DDE. Metals in sediment data produced fairly low MDI's and the "impacted" values were in the sub to low ppm (µg/g) range. The mean and "impacted" concentrations of most metals in tissues were similar between the two sites and there was a distinct taxonomic trend in both data sets. The invertebrates tended to have greater MDI's and greater "impacted" values then the fish. This is due to higher mean values and a greater degree of inter-species variability.

For the most part, organic toxins (PNAH's) were only observed in the DNDS biota. The MDI's for these toxins were rather high (170-530%) and the "impacted" values were in the low to mid ppb (ng/g) range for both fish and invertebrates.

TABLE 1. Mean concentrations, MDI's and the lowest calculations required for impact detection.

Matrix	Site	Contaminant	Unit	Concentration	Impacted Cruise Mean Values	Cruise Mean MDI(%)
Water	NDS	Cd	mg/l	0.002	0.012	110
		Cu	"	0.002	0.007	40
		Hg	"	0.0001	0.001	660
		Ni	"	0.003	0.008	110
		Pb	"	0.005	0.011	90
		Zn	"	0.001	0.004	60
		Cr	"	0.001	0.003	170
		Mn	"	0.002	0.008	370
	DNDS	Cd	mg/l	*0.002*	*0.009*	*350*
		Cu	"	0.008	0.019	50
		Hg	"	0.0005	0.001	100
		Ni	"	0.010	0.028	310
		Pb	"	0.008	0.021	80
		Zn	"	0.009	0.024	150
		Cr	"	.0002	0.001	230
		Mn	"	.003	0.014	190
Sediment	DNDS	Ph	ng/g	3	10.98	340
		Fl	"	8	28.8	280
		Pyre	"	10	59.1	520
		p,p-DDE	"	1	0.302	300
		Cd	µg/g	0.286	0.544	90
		Cr	"	*7.996*	*10.395*	*30*
		Cu	"	1.426	2.282	60
		Ni	"	6.188	8.044	30
		Pb	"	5.160	7.740	50
		Zn	"	23.286	27.940	20
Biological Tissues: Fish	NDS	Cu	µg/g	7.856	19.64	150
		Cr	"	0.875	3.412	290
		Ni	"	1.037	4.046	290
		Zn	"	43.962	74.736	70
		Fe	"	24.75	47.025	90
		Mn	"	4.212	10.531	150
	DNDS	*Cu*	*µg/g*	*3.021*	*6.646*	*120*
		Zn	"	46.385	92.417	110
		Fe	"	54.619	142.000	160
		Mn	"	2.347	8.45	260
Epibenthic Macroinvertebrates	NDS	Cu	µg/g	47.988	67.184	40
		Pb	"	0.344	2.342	580
		Zn	"	106.500	244.95	130
		Fe	"	64.111	121.811	90
		Mn	"	3.444	10.333	200
	DNDS	Cu	µg/g	40.511	76.971	90
		Cr	"	0.355	2.417	580
		Ni	"	4.766	26.216	450
		Cd	"	0.266	1.813	580
		Zn	"	165.233	330.466	100
		Fe	"	81.587	252.921	210
		Mn	"	18.733	82.426	340
Zooplankton	NDS	Cu	µg/g	14.970	26.947	80
		Cr	"	15.129	37.823	150
		Ni	"	3.764	17.317	360
		Cd	"	1.505	3.764	150
		Pb	"	36.017	144.070	300
		Zn	"	117.675	200.047	70
		Fe	"	132.631	291.788	120
		Mn	"	24.241	46.058	90
Fish	DNDS	N	ng/g	35.860	136.260	280
		Acn	"	34.810	167.01	380
		F	"	68.490	184.930	170
		Ph	"	76.310	267.090	250
		Fl	"	83.810	343.870	310
		Pyre	"	46.79	229.250	390
Epibenthic Macroinvertebrates		N	ng/g	77.50	364.250	370
		Acy	"	57.350	269.000	310
		Acn	"	53.710	247.000	360
		F	"	58.77	193.95	230
		Ph	"	114.710	458.860	300
		Fl	"	48.000	283.700	490
		Pyre	"	44.710	281.700	530
		B(a)P	"	58.360	367.700	530

DISCUSSION

The waters in the vicinity of NDS and DNDS appear to have very low concentrations of organic toxins. This is not too surprising since the PNAH's and CHC's have a fairly low solubility in seawater and there are no apparent sources of these contaminants in the vicinity. Keizer and Gordon (1973) and Gordon et al. (1974) reported the concentration of total aromatics in coastal waters in the low ppb range. The PNAH's in the water were either below detection limits or, on the one occasion when detectable, in the low ppb (µg/l) range. The CHC's were virtually non-detectable throughout the study.

The metals in water at both sites were moderately low during 1984, although the waters of DNDS tended to exhibit higher metals concentrations than did NDS during any given season. The closer proximity of DNDS to the Chesapeake Bay Plume is probably responsible for the higher metals levels. Alden and Butt (1985a,b) have demonstrated that the water quality of DNDS is impacted by the Bay plume more than is NDS.

Despite these trends, concentrations of metals in water at both sites were generally well within the range of values reported for the Chesapeake Bay and coastal waters (see reviews by Kester and Courant, 1973, and by Bryan, 1984). Mercury levels were elevated at both of the sites, especially during the summer months. Concentrations of Mercury exceeded the reference levels established by the EPA and the Virginia State Water Control Board for marine waters (VSWCB, 1976) on several occasions. The cause

of the elevated mercury levels is unknown, but it appears to be a recurrent phenomenon in the entire region (Alden et al., 1984a).

The metals found in the sediments of DNDS were somewhat higher than those found previously at NDS (Alden et al., 1982), particularly for Cd, Ni, Pb and Zn. On the other hand, the metal concentrations of DNDS sediments were generally lower than those found in the sediments from the lower Bay and much lower than those found in Hampton Roads (Alden et al., 1982). Thus, the metals in sediments levels also appear to reflect the influence of the nearshore location and Bay plume effects on DNDS relative to NDS.

Concentrations of the most commonly found PNAH's (Ph, Fl, Pyre) were detectable at DNDS. However, they were low when compared to concentrations seen elsewhere in Hampton Roads (Alden and Hall, 1984) and in the Bay (Alden, 1984). The levels of PNAH's observed at DNDS are well within the range of fairly pristine marine and coastal ecosystems which have been contaminated by long-range transport from non-point sources (e.g. combustion products introduced by atmospheric deposition) (LaFlamme and Hites, 1978). Recent studies in the lower Chesapeake Bay region have indicated that atmospheric deposition may represent a significant source of PNAH associated with combustion to the Bay and, ultimately, to coastal waters (Webber, 1982). The organic toxins in biota from NDS were almost always below detection levels.

The CHC concentrations in the sediments at DNDS were, for the most part, below detection limit. The metabolities of DDT (e.g. p,p-DDE) accounted for most of the CHC's in the sediment

samples. However, the levels of the p,p-DDE can be considered a trace amount (pg/g). A similar trend was reported by Alden et al. (1984a) at NDS.

The levels of organic toxins in the biota from NDS were extremely low. The PNAH's and CHC's were only rarely found above detection levels, and then only in trace amounts. Dieldrin, DDT breakdown products (p,p-DDE), and heptachlor were the only CHC's found, and virtually all samples containing these compounds were observed during the December cruise. The concentrations of CHC's in the biota taken from both NDS and DNDS were lower than those reported by Stickney et al. (1975). This pattern is not unexpected since the present study was conducted in more offshore waters and many years after most chlorinated pesticides were banned.

The organic toxins in the biota of DNDS were more often observed in detectable levels in comparison to NDS tissue samples. It is interesting to note that PNAH's observed in the highest concentrations (Fl, Pyre, Ph) were those which have been observed to accumulate in biota elsewhere (see Alden et al., 1984d for a discussion of possible mechanisms responsible for these patterns). However, the concentrations of the PNAH's observed in the biota during the present study were orders of magnitude less than those found for organisms exposed to less pristine conditions (Alden et al., 1985).

Maximum concentrations of PNAH's in tissues occurred during the spring. This is a period when the influence of the Bay plume is maximum in this region. Speculations can be made that organic toxins associated with suspended materials originating from the Bay during this period may affect the body burdens in the study

area. This is supported by studies on hydrocarbons in the Bay plume suggesting that "the outwelling of the Chesapeake Bay may provide a chronic input of anthropogenic hydrocarbons to adjacent shelf waters" (Wade and Oertel, 1981).

One of the most obvious patterns with respect to heavy metals in biota taken from both sites is the relatively high degree of variability of concentrations. The most apparent cause for the variability is the fact that samples consisted of many different taxa. It is documented that bioaccumulation patterns of individual species are often very different. However, the magnitude of inter-species variability during 1984 was somewhat less than observed during certain periods of the 1981-1983 NDS toxins study (Alden et al., 1984a). In contrast to PNAH body burdens which were greater at DNDS, the metal concentrations found in biota of the two sites were roughly equivalent.

Regardless of the degree of variability in the data, most of the values observed for the representative biotic groups appeared to fall within the range of values reported previously for similar organisms taken from nearshore waters. Numerous articles have reviewed the topic of bioaccumulation of metals in marine species (e.g. Eisler, 1973; Eisler and Wagner, 1975; Eisler et al., 1978; Phillips and Russo, 1978; Martin, 1979; Dillon, 1984; Bryan, 1984; and Eisler, 1984). Comparison of the overall patterns observed during the present study with those reviewed, indicated that tha biota at NDS and DNDS are not contaminated by metals to an unexpected degree. All metal concentrations in biota were well below those reported by Dillon (1984) as being the lowest levels

shown to cause significant biological effects.

The fish samples contained fairly low levels of most metals (i.e., low ppm; mg/g). All metal concentrations were well within the ranges reported for a variety of fishes in the reviews by Bryan (1984) and Eisler (1984). Cadmium was generally below detection limits. This conforms to a generalization made by Phillips and Russo (1978) "that very little cadmium is accumulated in the edible portions of fishes." The only metals that were observed to occur above 100 ppm were iron and zinc. However, the concentrations of these metals are not considered unusual. These levels were comparable with those reported in fish collected from regions with "no known sources of contamination" (Phillips and Russo, 1978; Bryan, 1984; and Eisler, 1984).

The levels of metals in epibenthic macroinvertebrates were low (low ppm; mg/g). As with the fishes, the metals in the macroinvertebrates were well within the range of values reported in previous studies (Bryan, 1984; and Eisler, 1984). Cadmium, chromium and lead were generally below detection limits. Copper values were higher in the invertebrates than the fishes, as has been reported previously (Phillips and Russo, 1978; Bryan, 1984; and Eisler, 1984). The higher values of copper in many invertebrates are often associated with respiratory pigments. Zinc levels in the macroinvertebrates were higher than in the fishes. These values were within the range of concentrations described by Phillips (1980), as representing the defined levels to which crustaceans regulate zinc body burdens.

The levels of most metals were higher in zooplankton samples than in the other two groups. Although aperiodic contamination by

abiotic debris is a possibility, the metal levels did not appear to be unreasonably high. All these levels fall within the range of metal values reported by Windom (1972) for zooplankton samples taken along the east coast of the United States. The concentrations also fall well within the range of values reported for numerous other studies on single zooplankton species and total collections (Bryan, 1984; and Eisler, 1984). The cadmium concentrations were below the levels reported for a series of zooplankton collections taken off the Pacific coast (Martin and Broenkow, 1975). Martin (1979) reported mixed zooplankton samples often have extremely high concentration factors for heavy metals and that this community may play a significant role in the cycling of metals in the oceans.

Due to a somewhat reduced level of inter-sample variability, the MDI values calculated for toxins in various components of the two ecosystem were reduced below those calculated previously for NDS (Alden et al., 1984a). The MDI's and the estimated mean "impacted" values required for statistical detection appeared reasonable from an ecological point of view. The estimated "impacted" concentrations for the tissue were always below the "highest no effects" levels reported for body burdens (Dillon, 1984). Therefore, the monitoring regime would appear to provide a statistical "early warning system," assuming that conditions do not significantly change (e.g. differences in the species collected, increased non-point sources of toxins to the study area, natural perturbations such as storms, etc.).

SUMMARY AND CONCLUSIONS

A study was conducted from December 1983 to October 1984 to characterize the toxins in water, sediment and biota collected in the vicinity of NDS and DNDS. The levels of organic toxins (PNAH's and CHC's) in the water were usually below detection limits at both sites. The levels of most of the metals were somewhat higher in the waters of DNDS than NDS, possibly indicating a greater influence of the Bay plume. However, the metals in water at both sites were well within the range of concentrations reported for other coastal areas. Mercury values have been observed to be periodically elevated throughout the region, but the source was unknown.

The levels of PNAH's and CHC's in the sediments of DNDS were fairly low. The source of PNAH's appears to be either atmospheric deposition or the transport of combustion products via the suspended solid load of the Bay plume. Trace levels of DDT metabolities were the only CHC's detected in the sediments.

Concentrations of metals in the sediments of DNDS study area were somewhat higher than those observed previously at NDS but below those reported for the lower Chesapeake Bay. The metal content of the sediments of DNDS also appear to reflect the greater influence of the Bay Plume relative to the more offshore NDS.

Likewise, the PNAH's in tissues of biota collected in the vicinity of DNDS were elevated compared to those observed at NDS, which were almost always below the detection levels. However, the body burdens of biota at DNDS were orders of magnitude below the

range of values reported for animals taken from less pristine environments. The CHC's in the biota of the DNDS were found in trace amounts and generally consisted of DDT metabolities.

The concentrations of heavy metals in tissues of biota collected in the vicinity of NDS and DNDS were quite variable from season to season. This variability was due primarily to the varying species composition collected from the representative taxonomic groups. However, the levels of metals in the groups fell well within the ranges of values reported for similar organisms in previous studies. The fish tissues generally exhibited the lowest metals values, the macroinvertebrates had intermediate levels, while the zooplankton contained the highest concentrations. Even samples containing what appeared to be somewhat "elevated" levels of certain metals could be explained in terms of natural species-specific accumulation patterns.

The overall picture of toxins at the two sites indicate that both are fairly pristine. However, the somewhat higher levels of metals in water and sediments, and organic toxins in the biota of DNDS tend to indicate that, of the two, this site is more greatly influenced by anthropogenic sources of contamination via the Bay Plume. The fact that body burdens of biota collected at DNDS increased following a period of maximum outwelling of the Bay may also be indicative of the subtle plume effects in the region. Nevertheless, the potential effects of the Plume on toxins in the vicinity of DNDS appear to have not reached a level that would provoke environmental concern.

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APPENDIX A. DETECTION LIMITS

TABLE A1

Detection Limits for
PNAH Analyses
ACOE Project Dam Neck and Norfolk Disposal Sites

Compound	Detection Limits		
	Water (µg/l)	Tissue (ng/g)	Sediment (ng/g)
Naphthalene (N)	2	4	4
Acenaphthylene (Acy)	2	4	4
Acenaphthalene (Acn)	2	4	4
Fluorene (F)	1	1	1
Dibenzothiopene (DBT)	-	-	-
Phenanthrene (Ph)	1	2	1
Anthracene (A)	1	2	1
Fluoranthene (Fl)	1	2	2
Pyrene (Pyre)	1	2	2
Benzo(a)anthracene (B(a)A)	1	3	3
Chrysene (Ch)	1	3	3
Dibenzo(a,h)anthracene (DiB(a,h)A)	1	2	2
1,12-Benzoperylene (B(ghi)P)	1	1	1
Benzo(a)pyrene (B(a)P)	1	5	5
Benzo(b)fluoranthene (B(b)Fl)	1	5	5
Benzo(k)fluoranthene (B(k)Fl)	1	5	5
Indeno(1,2,3-cd)pyrene (IP)	1	1	1

TABLE A2

Detection Limits for Chlorinated Hydrocarbons Analyses ACOE Project Dam Neck and Norfolk Disposal Sites

Compound	Detection Limits		
	Water (µg/l)	Tissue (ng/g)	Sediment (ng/g)
α-BHC	0.003	0.002	0.002
Lindane	0.004	0.001	0.001
Aldrin	0.004	0.001	0.001
Hepox-Epox	0.083	0.001	0.001
p,p-DDE	0.004	0.003	0.003
Kepone	0.095	0.017	0.017
o,p-DDT	0.023	0.010	0.010
p,p-DDD	0.011	0.003	0.003
p,p-DDT	0.023	0.010	0.010
Heptachlor	0.009	0.009	0.009
Endrin	0.011	0.011	0.011

TABLE A3

Detection Limits for
Trace Metals Determinations
ACOE Project Dam Neck and Norfolk Disposal Sites
Project Year 1983-1984

Element	Detection Limits	
	Water (µg/l)	Tissue (µg/g)
Cu	2.0	0.9
Cr	20.0	3.0
Ni	2.0	3.0
Cd	1.0	1.3
Pb	9.0	2.0
Zn	1.0	0.8
Fe	N/A	5.0
Mn	8.0	4.8
Hg	0.4	N/A
V	100.0	N/A

N/A = no analysis performed.

APPENDIX B. METALS IN WATER

TABLE B1. Metals in water samples collected at NDS. For each month, the first row values are the means, the second row are the standard errors, and the third row are the number of samples.

Month	Metal Concentrations (mg/l)							
	Cd	Cu	Hg	Ni	Pb	Zn	Cr	Mn
2 (1984)	0.0098	0.001	0.0006	0.0099	0.0065	0.0006	0.0018	0.0088
	0.0039	0.0001	0.0002	0.0003	0.0009	0.0004	0.0012	0.0012
	12	12	12	12	12	12	12	12
5 (1984)	0.0004	0.001	0	0.0009	0.0024	0.0031	0.0016	0.0003
	0	0.0002	0	0	0.0005	0.0004	0.0001	0.0001
	12	12	12	12	12	12	12	12
7 (1984)	0	0.0084	0.001	0	0	0	0	0.0026
	0	0.0002	0.0001	0	0	0	0	0.001
	12	12	12	12	12	12	12	12
12 (1984)	0.0015	0.0004	99.99	0.0025	0.0118	0.0038	0	0
	0.0006	0.0002	99.99	0.0009	0.0012	0.0009	0	0
	12	11	99.99	11	11	10	11	11

TABLE B2. Metals in water samples collected at DNDS. For each month, the first row values are the means, the second row are the standard errors, and the third row are the number of samples.

	Metal Concentrations (mg/l)							
Month	Cd	Cu	Hg	Ni	Pb	Zn	Cr	Mn
2 (1984)	0.0062	0.006	0.0001	0.0227	0.014	0.014	0	0
	0.003	0.0004	0	0.002	0	0.0007	0	0
	6	6	6	6	6	6	6	6
5 (1984)	0	0.0015	0.0007	0.0009	0.0036	0.0028	0.0016	0
	0	0.0001	0.0002	0.0001	0.0009	0.0002	0.0001	0
	6	6	6	6	6	6	6	6
8 (1984)	0	0.0178	0.001	0	0	0.0012	0	0.0137
	0	0.001	0	0	0	0.0012	0	0.002
	6	6	6	6	6	6	6	6
12 (1984)	0.0032	0.0075	99.99	0.0168	0.017	0.0197	0	0
	0.0002	0.0006	99.99	0.0007	0.0013	0.0029	0	0
	6	6	99.99	6	6	6	6	6

APPENDIX C. TOXINS IN SEDIMENTS

Table C1. Concentration of metals in sediments (ng/g) from DNDS. For each site, the first row values are the means, the second row are the standard errors, and the third row are the number of samples.

	Metals in Sediments (ng/g)					
Site	Cd	Cr	Cu	Ni	Pb	Zn
12	0.2133	7.36	1.18	5.75	4.44	23.7867
	0.0433	0.3487	0.07	0	0	0.928
	3	3	3	3	3	3
21	0.36	8.6333	1.6733	6.6267	5.88	22.7867
	0	0.0767	0.0667	0.1233	0	0.441
	3	3	3	3	3	3

TABLE C2. Concentrations of PNAH's in sediment (ng/g) from DNDS. For each site, the first row values are the means, the second row are the standard errors, and the third row are the number of samples.

	PNAH's in Sediment (ng/g)							
Site	N	Acy	Acn	F	DBT	Ph	A	Fl
12	0	0	0	0	0	1.0633	0	6.3267
	0	0	0	0	0	1.0633	0	3.9475
	3	3	3	3	3	3	3	3
21	0	0	0	0	0	3.9267	0	8.8433
	0	0	0	0	0	2.2575	0	5.63[illegible]7
	3	3	3	3	3	3	3	3

TABLE C2. (Continued)

Site	PNAH's in Sediment (ng/g)								
	Pyre	B(a)A	Ch	DiB(a,h)A	B(ghi)P	B(a)P	B(b)F	B(k)F	IP
12	0	0	0	0	0	0	0	0	1.1767
	0	0	0	0	0	0	0	0	1.1767
	3	3	3	3	3	3	3	3	3
21	0	0	0	0	0	0	0	0	17.8833
	0	0	0	0	0	0	0	0	14.5018
	3	3	3	3	3	3	3	3	3

Table C3. Concentrations of CHC's in sediment (ng/g) from DNDS. For each site, the first row values are the means, the second row are the standard errors, and the third row are the number of samples.

	CHC's in Sediment (ng/g)											
Site	α-BHC	Lindane	Aldrin	Hep Epox	Kepone	o,p-DDT	p,p-DDD	p,p-DDT	p,p-DDE	β-BHC	Dieldrin	Heptachlor
12	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	3	3	3	3	3	3	3	3	3	3	3	3
21	0	0	0	0	0	p	0	0	0.1513	0	0	0
	0	0	0	0	0	p	0	0	0.0049	0	0	0
	3	3	3	3	3	3	3	3	3	3	3	3

APPENDIX D. METALS IN TISSUES

TABLE D1. Concentrations of metals (µg/g) in fish tissues at NDS. For each month, the first row values are the means, the second row are the standard errors, and the third row are the number of samples

	Metals (µg/g)							
Month	Cu	Cr	Ni	Cd	Pb	Zn	Fe	Mn
2 (1984)	13.9875	1.75	2.075	0	0	63.475	35.6375	8.425
	2.8993	0.8656	1.0513	0	0	3.4322	4.764	0.7404
	8	8	8	8	8	8	8	8
5 (1984)	0.8333	0	0	0	0	21.2333	11.3667	0
	0.8333	0	0	0	0	0.8413	2.2747	0
	3	3	3	3	3	3	3	3
8 (1984)	2.26	0	0	0	0	26.38	15.36	0
	0.5715	0	0	0	0	3.872	4.128	0
	5	5	5	5	5	5	5	5

TABLE D2. Concentrations of metals (g/g) in tissues of zooplankton from NDS. For each month, the first row values are the means, the second row are the standard errors, and the third row are the number of samples.

Month	Metals (µg/g)							
	Cu	Cr	Ni	Cd	Pb	Zn	Fe	Mn
2 (1984)	16.56	38.54	12.02	3.24	57.06	1037.76	469.5	7.26
	6.049	5.8347	8.1892	0.9543	57.06	845.708	317.2114	0.551
	5	5	5	5	5	5	5	5
5 (1984)	15.7125	6.9	0	0.975	0	115.7	40.025	36.8125
	2.6078	3.0618	0	0.3736	0	15.8007	11.8273	5.6642
	8	8	8	8	8	8	8	8
8 (1984)	11.5	2.325	0.975	0.4	81.75	47.2	294.525	20.325
	1.4983	1.4361	0.975	0.4	45.8967	9.5313	21.3084	0.278
	4	4	4	4	4	4	4	4

TABLE D3. Concentrations of metals (µg/g) in epibenthic macroinvertebrates at NDS. For each month, the first row values are the means, the second row are the standard errors, and the third row are the number of samples

Month	Metals (µg/g)							
	Cu	Cr	Ni	Cd	Pb	Zn	Fe	Mn
2 (1984)	51.5143	0	0	0	0.4429	72.9143	64.3571	4.4286
	2.4978	0	0	0	0.4429	5.8882	11.3729	1.2353
	7	7	7	7	7	7	7	7
5 (1984)	32.2	0	0	0	0	207.8	61	0
	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1
8 (1984)	39.1	0	0	0	0	240.3	45.5	0
	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1

TABLE D4. Concentrations of metals (µg/g) in fishes at DNDS. For each month, the first row values are the means, the second row are the standard errors, and the third row are the number of samples.

Month	Metal Concentration (µg/g)							
	Cu	Cr	Ni	Cd	Pb	Zn	Fe	Mn
1 (1984)	4.3571	0	0	0	0	55.3571	87.4714	2.3143
	1.7308	0	0	0	0	19.3321	41.2695	1.4953
	7	7	7	7	7	7	7	7
6 (1984)	2.55	0	0	0	0	98.4	80.85	14.2
	0.25	0	0	0	0	59.8	47.85	3.5
	2	2	2	2	2	2	2	2
9 (1984)	2.7333	0	0	0	2.5	27.9667	33.2	0
	0.7311	0	0	0	2.5	0.0333	1.5631	0
	3	3	3	3	3	3	3	3
10 (1984)	1.9429	0	0	0	0	30.4571	23.4429	0
	0.2852	0	0	0	0	1.7584	2.6802	0
	7	7	7	7	7	7	7	7

TABLE D5. Concentrations of metals (µg/g) in epibenthic macroinvertebrates from DNDS. For each month, the first row values are the means, the second row are the standard errors, and the third row are the number of samples.

	Metal Concentration (µg/g)							
Month	Cu	Cr	Ni	Cd	Pb	Zn	Fe	Mn
1 (1984)	48.1333	0	0	0.8	0	84.5	108.2333	7.0333
	10.0194	0	0	0.8	0	50.4488	59.0096	3.8585
	3	3	3	3	3	3	3	3
6 (1984)	67.3	0	10.1	0	0	296.3	216.1	94.1
	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1
9 (1984)	28.7667	1.0667	10.9333	0	0	182.8333	634.2667	17.8
	7.1564	1.0667	10.9333	0	0	11.2993	603.1783	17.8
	3	3	3	3	3	3	3	3
10 (1984)	33.3	0	0	0	0	194.4	24.85	0
	1.7	0	0	0	0	4.4	0.25	0
	2	2	2	2	2	2	2	2

APPENDIX E. ORGANICS IN TISSUES FROM DNDS

TABLE E1. Concentrations of PNAH's (ng/g) in tissues of fishes from DNDS. For each month, the first row values are the means, the second row are the standard errors, and the third row are the number of samples.

	PNAH's (ng/g)								
Month	N	Acy	Acn	F	DBT	Ph	A	Fl	Pyre
1 (1984)	60.5571	0	109.4	135.2571	0	18.4143	0	30.0429	40.0429
	30.8152	0	76.0456	31.5147	0	18.4143	0	30.0429	40.0429
	7	7	7	7	7	7	7	7	7
6 (1984)	121.6667	0	0	186.6667	0	479.3333	0	901.3333	249.6667
	121.6667	0	0	93.9758	0	58.4076	0	141.8736	249.6667
	3	3	3	3	3	3	3	3	3
9 (1984)	0	0	0	0	0	37.3233	0	0	0
	0	0	0	0	0	37.3233	0	0	0
	3	3	3	3	3	3	3	3	3
10(1984)	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	9	9	9	9	9	9	9	9	9

TABLE E1. (Continued)

Month	PNAH's (ng/g)							
	B(a)A	Ch	DiB(a,h)A	B(ghi)P	B(a)P	B(b)F	B(k)F	IP
1 (1984)	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	7	7	7	7	7	7	7	7
6 (1984)	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	3	3	3	3	3	3	3	3
9 (1984)	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	3	3	3	3	3	3	3	3
10 (1984)	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	9	9	9	9	9	9	9	9

TABLE E2. Concentrations of PNAH's (ng/g) in tissues of epibenthic macroinvertebrates from DNDS. For each month, the first row values are the means, the second row are the standard errors, and the third row are the number of samples.

	PNAH's (ng/g)								
Month	N	Acy	Acn	F	DBT	Ph	A	Fd	Pyre
1 (1984)	0	267.1	0	123.6	0	0	0	0	0
	0	143.3339	0	39.7408	0	0	0	0	0
	3	3	3	3	3	3	3	3	3
6 (1984)	361.6667	0	250.6667	150.6667	0	535.3333	0	1202	208.6667
	194.172	0	125.7171	76.4947	0	94.7793	0	353.3077	208.6667
	3	3	3	3	3	3	3	3	3
9 (1984)	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	2	2	2	2	2	2	2	2	2
10 (1984)	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	6	6	6	6	6	6	5	6	6

TABLE E2. (Continued)

Month	PNAH's (ng/g)							
	B(a)A	Ch	DiB(a,h)A	B(ghi)P	B(a)P	B(b)F	B(k)F	IP
1 (1984)	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	3	3	3	3	3	3	3	3
6 (1984)	0	0	0	0	272.3333	0	0	0
	0	0	0	0	272.3333	0	0	0
	3	3	3	3	3	3	3	3
9 (1984)	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	2	2	2	2	2	2	2	2
10 (1984)	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	6	6	6	6	6	6	6	6

TABLE E3. Concentrations of CHC's (ng/g) in tissues of fishes from DNDS. For each month, the first row values are the means, the second row are the standard errors, and the third row are the number of samples.

	CHC's (ng/g)								
Month	α-BHC	Lindane	Aldrin	Hep Epox	Kepone	o,p-DDT	p,p-DDD	p,p-DDT	p,p-DDE
1 (1984)	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	6	6	6	6	6	6	6	6	6
6 (1984)	4.6	0	0	4.4	0	0	0	0	0
	4.6	0	0	4.4	0	0	0	0	0
	3	3	3	3	3	3	3	3	3
9 (1984)	1.71	0	0	0	0	0	0	0	21.1967
	1.71	0	0	0	0	0	0	0	7.7817
	3	3	3	3	3	3	3	3	3
10 (1984)	0.3186	0	0	0	0	0	0	0	3.6143
	0.3166	0	0	0	0	0	0	0	2.296
	7	7	7	7	7	7	7	7	7

TABLE E3. (Continued)

Month	CHC's (ng/g) β-BHC	Dieldrin	Heptachlor
1 (1984)	0	0	0
	0	0	0
	6	6	6
6 (1984)	0	0	0
	0	0	0
	3	3	3
9 (1984)	0	0	0
	0	0	0
	3	3	3
10 (1984)	0	0	1.2771
	0	0	1.2771
	7	7	7

TABLE E4. Concentrations of CHC's (ng/g) in epibenthic macroinvertebrates from DNDS. For each month, the first row values are the means, the second row are the standard errors, and the third row are the number of samples.

	CHC's (ng/g)								
Month	α-BHC	Lindane	Aldrin	Hep Epox	Kepone	o,p-DDT	p,p-DDD	p,p-DDT	p,p-DDE
1 (1984)	0	0.6367	0	0	0	0	0	0	0.7933
	0	0.6367	0	0	0	0	0	0	0.7933
	3	3	3	3	3	3	3	3	3
6 (1984)	29.0667	0	0	0.8667	0	0	0	0	0
	1.8853	0	0	0.8667	0	0	0	0	0
	3	3	3	3	3	3	3	3	3
9 (1984)	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	3	3	3	3	3	3	3	3	3
10	0	0	0	0	0	0	0	0	8.58
	0	0	0	0	0	0	0	0	5.445
	6	6	6	6	6	6	6	6	6

TABLE E4. (Continued)

Month	CHC's (ng/g)		
	β-BHC	Dieldrin	Heptachlor
1 (1984)	0	0	0
	0	0	0
	3	3	3
6 (1984)	0	0	0
	0	0	0
	3	3	3
9 (1984)	0	0	1.5633
	0	0	1.5633
	3	3	3
10 (1984)	0	0	0
	0	0	0
	6	6	6

APPENDIX F. SPECIES LIST FOR TOXINS IN TISSUES

TABLE F1

SPECIES CODES FOR TISSUE PNA'S AND PESTICIDES

FIRST NUMBER:
- 1 = Fish
- 2 = Other
- 3 = Plankton

LAST NUMBER:
- 0 = Not specified (whole body)
- 1 = Liver
- 2 = Muscle
- 3 = Internal organs
- 5 = 2 + 3

MIDDLE TWO NUMBERS:

- 1 = ANCHOVY (Anchoa mitchilli)
- 2 = SAND DAB (Hippoglossoides sp.)
- 3 = SMALLMOUTH FLOUNDER (Etropus microstomus)
- 4 = PINFISH (Lagodon rhomboides)
- 5 = SPOT (Leiostomas xanthurus)
- 6 = ATLANTIC SILVERSIDES (Menidia menidia)
- 7 = SILVER HAKE (Merluccius bilinearis)
- 8 = PLANEHEAD FILEFISH (Monocanthus hispidus)
- 9 = BUTTERFISH (Pomatomus triacanthus)
- 10 = BLUEFISH (Pomatomus saltatrix)
- 11 = SEA ROBIN (Prionotus sp.)
- 12 = STRIPED CUSK-EEL (Rissola marginata)
- 13 = WINDOWPANE FLOUNDER (Scophthalmus aquosus)
- 14 = SCUP (Stenotomus chyrsops)
- 15 = LIZARD FISH (Synodus foetens)
- 16 = SEA ROBIN (Prionotus sp.)
- 17 = RED HAKE (Urophycis chuss)
- 18 = SPOTTED HAKE (Urophycis regius)
- 19 = EEL (Anguilla sp.)
- 20 = FLOUNDER
- 21 = HAKE - Species unknown
- 22 = SILVER HAKE (Merluccius bilinearis)
- 23 = RED HAKE (Urophycis chuss)
- 24 = SPOTTED FLUKE (Scophthalmus aquosus)
- 25 = BLUE CRAB (Callinectes sapidus)
- 26 = CANCER CRAB (Cancer irroratus)
- 27 = SPIDER CRAB (Libinia emarginata)
- 28 = LADY CRAB (Ovalipes ocellatus)
- 29 = CRAB
- 30 = SHRIMP (Crangom septemspinosa)
- 31 = KNOBBED WHELK (Busycon k.)
- 32 = CHANNEL WHELK (Busycon c.)
- 33 = PLANKTON
- 34 = RED HAKE (Urophycis chuss)
- 35 = ROCK CRAB (Cancer irroratus)
- 36 = MISCELLANEOUS SMALL FISH
- 37 = HAKE - Species unknown
- 38 = MENHADEN (Brevoortia tyrannus)
- 39 = MULLET (Mugil sp.)
- 41 = CROAKER (Micropogonius undulatus)
- 42 = COD (Gadus morhua)
- 43 = SEA BASS (Centropristis striata)
- 44 = MUSSEL (Mytilus edulis)

TABLE F2. Concentrations of metals (μg/g) in tissues from NDS. For each species, the first row values are the means, the second row are the standard errors, and the third row are the number of samples.

Species Code*	Metals in Tissues by Species (μg/g)							
	Cu	Cr	Ni	Cd	Pb	Zn	Fe	Mn
1062	9.6	0	0	0	0	66.2	30.9	5.7
	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1
1200	12.175	2.525	1.075	0	0	63.025	36.725	7.575
	5.6781	1.4648	1.075	0	0	7.1417	4.6524	0.3816
	4	4	4	4	4	4	4	4
1202	8.1714	0.5571	1.7571	0	0	39.6857	21.1714	4.4857
	3.4642	0.5571	1.1571	0	0	8.3758	7.1151	2.1488
	7	7	7	7	7	7	7	7
1422	2.9333	0	0	0	0	28.9667	13.4667	0
	0.7172	0	0	0	0	6.3357	3.0002	0
	3	3	3	3	3	3	3	3

* See Species Code key for species/tissue identification.

TABLE F2. (Continued)

Species Code*	Metals in Tissues by Species (µg/g)							
	Cu	Cr	Ni	Cd	Pb	Zn	Fe	Mn
1432	1.4	0	0	0	0	20.4	29.6	0
	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1
2262	39.1	0	0	0	0	240.3	45.5	0
	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1
2300	51.5143	0	0	0	0.4429	72.9143	64.3571	4.4286
	2.4978	0	0	0	0.4429	5.8882	11.3729	1.2353
	7	7	7	7	7	7	7	7
2352	32.2	0	0	0	0	207.8	81	0
	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1
3330	14.9706	15.1294	3.7647	1.5059	36.0176	370.7765	226.2235	24.2412
	2.1046	4.3591	2.5994	0.4293	20.2333	253.5278	98.1011	4.0995
	17	17	17	17	17	17	17	17

* See Species Code key for species/tissue identification.

TABLE F3. Concentrations of metals (µg/g) in tissues from DNDS. For each species, the first row values are the means, the second row are the standard errors, and the third row are the number of samples

	Metals in Tissues by Species (µg/g)							
Species Code*	Cu	Cr	Ni	Cd	Pb	Zn	Fe	Mn
1010	3	0	0	0	.0	157.4	193.1	8.4
	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1
1052	2.5571	0	0	0	1.0714	29.3143	30.3286	0
	0.3258	0	0	0	1.0714	0.8562	1.8583	0
	7	7	7	7	7	7	7	7
1060	2.8	0	0	0	0	158.2	128.7	10.7
	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1
1150	2.1	0	0	0	0	26.9	10.6	0
	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1
1202	1.4	0	0	0	0	30.825	23.075	0
	0.1354	0	0	0	0	2.9139	3.6107	0
	4	4	4	4	4	4	4	4

* See Species Code key for species/tissue identification.

TABLE F3. (Continued)

Species Code*	Metals in Tissues by Species (µg/g)							
	Cu	Cr	Ni	Cd	Pb	Zn	Fe	Mn
1382	7.9	0	0	0	0	54.4	50.2	7.8
	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1
1392	1.1	0	0	0	0	17.4	12.2	0
	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1
1412	1.4	0	0	0	0	15.3	16.6	0
	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1
1413	13.3	0	0	0	0	84.7	288.7	0
	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1
1422	2.3	0	0	0	0	38.6	33	17.7
	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1

* See Species Code key for species/tissue identification.

TABLE F3. (Continued)

Species Code*	Metals in Tissues by Species (µg/g)							
	Cu	Cr	Ni	Cd	Pb	Zn	Fe	Mn
2250	34.2333	0	0	0	0	186.2	28.9333	1
	2.6333	0	0	0	0	12.6	4.3333	0
	3	3	3	3	3	3	3	0
2270	67.3	0	10.1	0	0	296.3	216.1	3
	1	1	1	1	1	1	1	94.1
	1	1	1	1	1	1	1	1
2300	35.4	0	0	0	0	79	203.1	1
	1	1	1	1	1	1	1	7.8
	1	1	1	1	1	1	1	1

* See Species Code key for species/tissue identification.

TABLE F3. (Continued)

Species Code*	Metals in Tissue by Species (µg/g)							
	Cu	Cr	Ni	Cd	Pb	Zn	Fe	Mn
2350	38.05	0	0	0	0	182.25	73.35	0
	3.05	0	0	0	0	7.75	48.25	0
	2	2	2	2	2	2	2	2
2353	67.9	0	0	2.4	0	0	0	13.3
	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1
2440	15.2	3.2	32.8	0	0	188.7	1840.6	53.4
	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1
3330	28.25	3.5	0	2.25	7.25	76.4	1417.55	90.5
	2.75	0.5	0	0.65	1.15	11.6	54.35	11.9
	2	2	2	2	2	2	2	2

* See Species Code key for species/tissue identification.

TABLE F4. Concentrations of PNAH's (ng/g) in tissues from DNDS. For each species, the first row values are the means, the second row are the standard errors, and the third row are the number of samples.

	PNAH's in Tissue by Species (ng/g)								
Species Code*	N	Acy	Acn	F	DBT	Ph	A	Fl	Pyre
1010	0	0	382.9	122	0	0	0	0	0
	0	0	129.3	11.3	0	0	0	0	0
	2	2	2	2	2	2	2	2	2
1052	0	0	0	21.7143	0	15.9957	0	0	0
	0	0	0	21.7143	0	15.9957	0	0	0
	7	7	7	7	7	7	7	7	7
1152	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	3	3	3	3	3	3	3	3	3
1202	25	0	0	35.475	0	0	0	0	0
	25	0	0	35.475	0	0	0	0	0
	4	4	4	4	4	4	4	4	4
1382	0	0	0	0	0	0	0	0	0
	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1

* See Species Code key for species/tissue identification.

TABLE F4. (Continued)

Species Code*	PNAH's in Tissue by Species (ng/g)								
	N	Acy	Acn	F	DBT	Ph	A	Fl	Pyre
1392	201.3	0	0	284.8	0	128.9	0	280.3	210.3
	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1
1412	122.6	0	0	124.1	0	0	0	0	0
	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1
1420	121.6667	0	0	186.6667	0	479.3333	0	249.6667	901.3333
	121.6667	0	0	93.9758	0	58.4076	0	249.6667	141.8736
	3	3	3	3	3	3	3	3	3
2250	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	3	3	3	3	3	3	3	3	3
2252	0	0	0	0	0	0	0	0	0
	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1

* See Species Code key for species/tissue identification.

TABLE F4. (Continued)

	PNAH's in Tissue by Species (ng/g)								
Species Code*	N	Acy	Acn	F	DBT	Ph	A	Fl	Pyre
2275	361.6667	0	250.6667	150.6667	0	535.3333	0	1202	208.6667
	194.172	0	125.7171	76.4947	0	94.7793	0	353.3077	208.6667
	3	3	3	3	3	3	3	3	3
2300	0	267.1	0	55.9667	0	0	0	0	0
	0	143.3339	0	28.1118	0	0	0	0	0
	3	3	3	3	3	3	3	3	3
2350	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	3	3	3	3	3	3	3	3	3
2352	0	0	0	202.9	0	0	0	0	0
	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1

*See Species Code key for species/tissue identification.

TABLE F4. (Continued)

	PNAH's in Tissue by Species (ng/g)							
Species Code*	B(a)A	Ch	DiB(a,h)A	B(ghi)P	B(a)P	B(b)F	B(k)F	IP
1010	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	2	2	2	2	2	2	2	2
1052	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	7	7	7	7	7	7	7	7
1152	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	3	3	3	3	3	3	3	3
1202	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	4	4	4	4	4	4	4	4
1382	0	0	0	0	0	0	0	0
	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1

*See Species Code key for species/tissue identification.

TABLE F4. (Continued)

Species Code*	PNAH's in Tissue Species (ng/g)							
	B(a)A	Ch	DiB(a,h)A	B(ghi)P	B(a)P	B(b)F	B(k)F	IP
1392	0	0	0	0	0	0	0	0
	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1
1412	0	0	0	0	0	0	0	0
	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1
1420	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	3	3	3	3	3	3	3	3
2250	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	3	3	3	3	3	3	3	3
2252	0	0	0	0	0	0	0	0
	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1

** See Species Code key for species/tissue identification.*

TABLE F4. (Continued)

	PNAH's in Tissue by Species (ng/g)							
Species Code*	B(a)A	Ch	DiB(a,h)A	B(ghi)P	B(a)P	B(b)F	B(k)F	IP
2275	0	0	0	0	0	272.3333	0	0
	0	0	0	0	0	272.3333	0	0
	3	3	3	3	3	3	3	3
2300	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	3	3	3	3	3	3	3	3
2350	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	3	3	3	3	3	3	3	3
2352	0	0	0	0	0	0	0	0
	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1

* See Species Code key for species/tissue identification.

TISSUE F5. Concentrations of CHC's (ng/g) in tissues by species from DNDS. For each species, the first row values are the means, the second row are the standard errors and the third row are the number of samples.

	CHC's in Tissue by Species (ng/g)								
Species Code*	α-BHC	Lindane	Aldrin	Hep Epox	Kepone	o,p-DDT	p,p-DDD	p,p-DDT	p,p-DDE
1010	0	0	0	0	0	0	0	0	0
	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1
1052	1.472	0	0	0	0	0	0	0	15.146
	1.0113	0	0	0	0	0	0	0	5.9649
	5	5	5	5	5	5	5	5	5
1152	0	0	0	0	0	0	0	0	4.2867
	0	0	0	0	0	0	0	0	4.2867
	3	3	3	3	3	3	3	3	3
1202	0	0	0	0	0	0	0	0	0.075
	0	0	0	0	0	0	0	0	0.075
	4	4	4	4	4	4	4	4	4
1382	0	0	0	0	0	0	0	0	0
	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1

*See Species Code key for species/tissue identification.

TABLE F5. (Continued)

	CHC's in Tissue by Species (ng/g)								
Species Code*	α-BHC	Lindane	Aldrin	Hep Epox	Kepone	o,p-DDT	p,p-DDD	p,p-DDT	p,p-DDE
1412	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	2	2	2	2	2	2	2	2	2
1420	4.6	0	0	4.4	0	0	0	0	0
	4.6	0	0	4.4	0	0	0	0	0
	3	3	3	3	3	3	3	3	3
2250	0	0	0	0	0	0	0	0	0
	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1
2252	0	0	0	0	0	0	0	0	9.16
	0	0	0	0	0	0	0	0	9.16
	3	3	3	3	3	3	3	3	3

* See Species Code key for species/tissue identification.

TABLE F5. (Continued)

	CHC's in Tissue by Species (ng/g)								
Species Code*	α-BHC	Lindane	Aldrin	Hep Epox	Kepone	o,p-DDT	p,p-DDD	p,p-DDT	p,p-DDE
2275	29.0667	0	0	0.8667	0	0	0	0	0
	1.8853	0	0	0.8667	0	0	0	0	0
	3	3	3	3	3	3	3	3	3
2300	0	0.955	0	0	0	0	0	0	1.19
	0	0.955	0	0	0	0	0	0	1.19
	2	2	2	2	2	2	2	2	2
2302	0	0	0	0	0	0	0	0	0
	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1
2352	0	0	0	0	0	0	0	0	6
	0	0	0	0	0	0	0	0	6
	4	4	4	4	4	4	4	4	4
2440	0	0	0	0	0	0	0	0	0
	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1

*See Species Code key for species/tissue identification.

TABLE F5. (Continued)

Species Code*	CHC's in Tissue by Species (ng/g) β-BHC	Dieldrin	Heptachlor
1010	0	0	0
	1	1	1
	1	1	1
1052	0	0	1.788
	0	0	1.788
	5	5	5
1152	0	0	0
	0	0	0
	3	3	3
1202	0	0	0
	0	0	0
	4	4	4
1382	0	0	0
	1	1	1
	1	1	1
1412	0	0	0
	0	0	0
	2	2	2
1420	0	0	0
	0	0	0
	3	3	3

*See Species Code key for species/tissue identification.

TABLE F5. (Continued)

Species Code*	CHC's in Tissue by Species (ng/g) β-BHC	Dieldrin	Heptachlor
2250	0	0	0
	1	1	1
	1	1	1
2252	0	0	0
	0	0	0
	3	3	3
2275	0	0	0
	0	0	0
	3	3	3
2300	0	0	0
	0	0	0
	2	2	2
2302	0	0	4.69
	1	1	1
	1	1	1
2352	0	0	0
	0	0	0
	4	4	4
2440	0	0	0
	1	1	1
	1	1	1

* See Species Code key for species/tissue identification.

END

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