

FINAL REPORT

on

**ORGANIC POLLUTANT BIOGEOCHEMISTRY
STUDIES IN THE NORTHEAST U.S. MARINE
ENVIRONMENT**

PART 1:

**THE STATE OF ORGANIC POLLUTANT (PCB,
PAH, COPROSTANOL) CONTAMINATION OF THE
BOSTON HARBOR - MASSACHUSETTS BAY -
CAPE COD BAY SYSTEM:
SEDIMENTS AND BIOTA**

PART 2:

**ORGANIC GEOCHEMICAL STUDIES IN THE
HUDSON CANYON AND GULF OF MAINE AREAS**

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to

**NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION
National Marine Fisheries Service**

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EXECUTIVE SUMMARY

A comprehensive survey of toxic organic pollutant contaminant distributions in sediments and selected biota was conducted in Boston Harbor, Massachusetts Bay, and Cape Cod Bay. Our goal was to establish a monitoring network including a selection of sampling stations and a proper selection of parameters with sufficient statistical rigor to allow "change" to be rigorously assessed. This study was part of a larger program that included heavy metal determinations and a biological survey of the sea bed.

Both the concentrations of pollutants and generic sources of these pollutants were assessed. Our data indicate that Boston Harbor is a very heavily polluted area with contributions from sewage discharges and storm water runoff, the dominant sources. Of great importance was the finding that Massachusetts Bay, from The Stellwagen Bank area landward, contains significantly elevated levels of toxic PCBs and polycyclic aromatic hydrocarbons levels which may be increasing with time. The total mass of these pollutants far exceed those in the New York Bight Apex, an area acknowledged to be a heavily impacted coastal area. The loading of PCB per square kilometer in Massachusetts Bay is a factor of 2-3 higher than the New York Bight. Levels of PCB in the offshore sediments are quite similar to those found in Buzzards Bay. Cape Cod Bay appears widely impacted as well. The sewage tracer, coprostanol, is widely distributed in the Massachusetts and Cape Cod Bay indicating that sewage discharges are contributors to the pollutant loading offshore.

The Gulf of Maine depositional basins also reflect significant inputs of PCB, PAH and coprostanol from land-based sources, as do stations examined in the Hudson Canyon.

These results indicate that the "health" of the offshore areas of Massachusetts Bay and the medium-range transport of pollutants must be factored into management decisions made by federal and state agencies concerning the location of sewage discharges, the impacts of dredged natural disposal and other areas of the coastal and offshore zones. The fragmented, narrow approach to managing pollution inputs to the Massachusetts Bay-Cape Cod Bay area on a site by site basis should give way to a more holistic approach, examining the effects of combined pollutant inputs to the region as has been the case in other coastal areas.

PART I:

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CAPE COD BAY SYSTEM: SEDIMENTS AND BIOTA**

I. INTRODUCTION

I.1 General

The Boston Harbor, Massachusetts Bay, Cape Cod Bay region (Figure 1) is the site of considerable pollutant input originating from multiple uses of the coastal zone and nearshore environment. Direct sources of pollutant inputs include direct stormwater runoff, municipal wastewater and sewage sludge discharge inputs to the Boston Harbor, riverine (Charles River) discharges to the Harbor, and chronic inputs from port and harbor activities. In addition to pollutant sources centered in the Boston Harbor area, numerous sewage outfalls discharge directly to the coastal waters of Massachusetts Bay, and harbor dredged material is disposed at several offshore sites near Stellwagen Bank and in Cape Cod Bay.

Strategies of waste disposal in the region, which presently include direct discharge of municipal wastewater, several sewage sludge discharges, and disposal of contaminated harbor and channel sediments at several designated disposal sites, may be altered during the next 2-5 years including changing strategies of sludge disposal, the possible ocean dumping of sewage sludge and increased disposal of dredged materials. Additionally, the locations of the major sludge outfalls in outer Boston Harbor has been proposed to be relocated several miles outside the harbor, Metcalf and Eddy (1979). The ability to assess the resultant impacts of changing waste disposal strategies and uses of the coastal zone on the marine environment is of great importance. Specifically, a knowledge of regional pollutant transport and fates and concomitant biological perturbations will be essential to best guide scientifically sound ocean waste management decisions in the future.

Such information is and will continue to be needed by municipal, state, and federal agencies in order to (1) better designate appropriate sites for waste disposal operations, (2) better determine and predict the transport and fate of materials dumped or discharged offshore, (3) better assess the causal mechanisms for perturbations in the biota ranging from those altering community structure, to those affecting the harvestability of

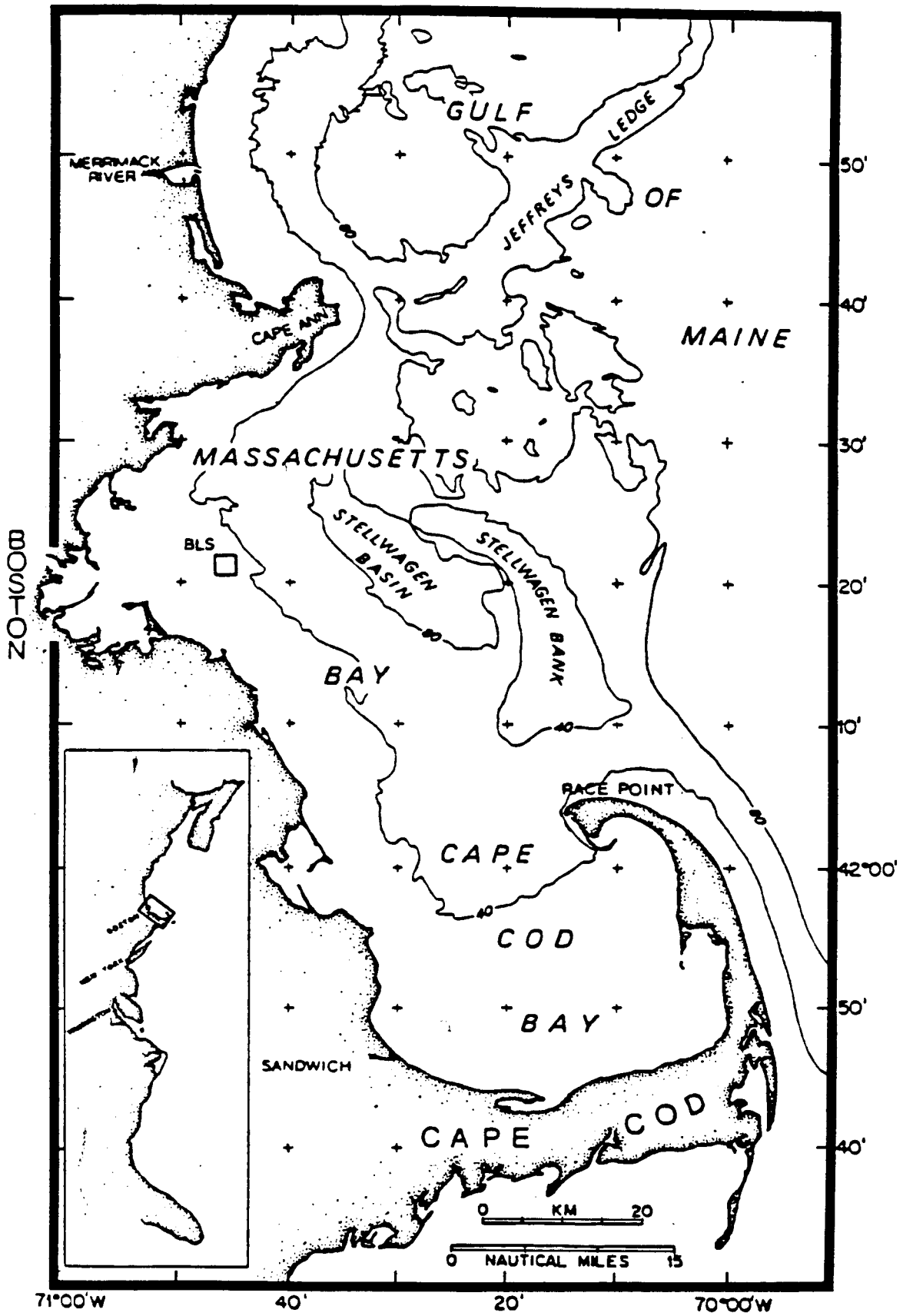


Figure 1. Location of Study Area.

fish and shellfish, (4) better manage the coastal resources by providing a scientifically rigorous monitoring methodology for assessing ecological changes and impacts.

1.2 Background Information

Tidal fluctuations in the northern (President Roads, Dorchester Bay, and Inner Harbor) and southern (Quincy Bay, Hingham Bay, and Hull Bay) sections of Boston Harbor are approximately 9.5 ft. Maximum current velocity in the main channel is approximately two knots and occurs near Deer Island Light 3 hours after the beginning of flood tide. Residence time in open portions of the harbor is slightly less than two tidal cycles. Flow from tributaries (primarily Malden, Mystic, Neponset, and Charles Rivers) ranges from 20 cfs to 1,800 cfs with a summer average of 350 cfs. The daily inflow of salt water is approximately 320,000 cfs for a six-hour period (FWPCA, 1968). Salinity in the open harbor is about 25 ‰.

Sediments in Boston Harbor are primarily silts and clays containing high levels of organic carbon and nitrogen. Levels in the harbor range from 2.1-5.5% TOC and 0.06-0.37% TON, respectively. Directly seaward of Deer Island, sediments are coarser and levels of TOC and TON are lower, 0.4% and 0.04%, respectively.

The harbor opens into Massachusetts Bay which is bounded on three sides by the Massachusetts coast and opens to the Gulf of Maine between Cape Ann and Race Point on Cape Cod. This opening is partially blocked by Stellwagen Bank, an important submarine feature, which rises to within 20 m of the surface. Most of the Bay is about 80m deep, although maximum depth in Stellwagen Basin, located in the center of the bay, is over 100 m.

Massachusetts and Cape Cod Bays are delineated by Cape Ann to the north and Cape Cod to the south. Cape Cod Bay joins with Buzzards Bay to the south through the Cape Cod Canal. Massachusetts and Cape Cod Bays are characterized by moderate rainfall, an absence of large rivers, and seawater of uniformly high salinity (30-32‰) throughout the year. Recent studies on circulation in Massachusetts Bay (Butman, 1975) demonstrated that current speeds in the Bay are controlled primarily by semi-diurnal rotary tides and that seasonal changes occur in forcing factors with currents dominated by wind stress in winter and the density distributions established by runoff in the spring, primarily from the Merrimack River. At the southern mouth of the bay near Cape Cod, tidal currents are strong and wind generated currents and waves become important. In the deep basin and on shallow borders of the bay, tidal currents are weaker. Current

stresses are low enough to allow deposition of fine material for a large fraction of the time on the shallow borders of the bay and in the deep basin, but on Stellwagen Bank and in the southern channel leading to the Gulf of Maine, large tidal currents prevent deposition during much of the time (Butman, 1975).

The substrate composition in Massachusetts Bay is dominated by mixed coarse sediments of glacial deposition in shallow waters grading into fine muds with a high clay content below about 40 m (Willett, 1972; Setlow, 1973). Sediments in the central basin of Cape Cod Bay consist of fine sand or muds, however, along the western edge, from Plymouth to Cape Cod Canal, the sandy beaches are interspersed with regions of gravel, stones, rocks, and boulders down to 10 m or more (Ryther, 1968).

The bottom sediment distribution can be grouped in four categories by location and sediment type (Schlee et al., 1973). Nearshore, adjacent to the rocky coast from Cape Ann to Plymouth, the rough bottom is a patchwork of gravel, sand, mud, and bedrock, while adjacent to constructional features (outwash and moraines) from Plymouth around Cape Cod, the generally smooth bottom is well-sorted sand mixed with gravel. Offshore, the shallow bank is well-sorted sand, or sand and gravel. Finest grained sediment of clay, silt, and sand is found in the deep basin and in the channels entering the bay.

The single most important source of contaminants to the offshore system is Boston Harbor with its extensive industrialization, sewage discharges, and heavy ship traffic. Additionally, five major sewage systems on the northern side of Massachusetts Bay release approximately 25×10^9 gallons of sludge and effluent per year (Gilbert et al., 1976; Metcalf and Eddy, Inc., 1979). These discharges represent significant sources of polychlorinated biphenyls (PCBs) and other toxic organics - e.g., polycyclic aromatic hydrocarbons (PAHs), as well as heavy metals to the offshore areas (Gilbert et al., 1976). Dumping of dredged material, industrial, and military waste in the Massachusetts Bay Foul Area, located outside of Boston Harbor, has been and continues to be another major source of contaminants to the Bay (Chase, 1976; Gilbert, 1975; Riser, 1974, Subsea Surveyors, 1973). The "Foul Area", a one nautical mile radius area located at $42^{\circ}27.5'N$. Lat. and $70^{\circ}345.0'W$. Long. and approximately 100 m depth, was an active industrial and military waste dump site between 1946 and 1974. The site reportedly contains munitions, low-level radioactive waste, industrial chemical waste, and construction debris as well as dredge spoils. During 1946 to 1962, 4,000 low-level radioactive containers are believed to have been deposited near the site. Pollutant distributions in Boston Harbor and Massachusetts Bay have been the subject of three other studies (Gilbert et al., 1976; Fitzgerald, 1980; Whelon, et al., 1983).

Cape Cod Bay, the nearly circular embayment of a maximum depth of 55m is not directly influenced by the heavy industrialization centered around the Boston Harbor and Massachusetts Bay area. In addition to possible transport of pollutants from the more heavily impacted areas to the north, Cape Cod Bay receives inputs of pollutants from dredged material disposal and possible inputs from power plants and from shipping traffic through the Cape Cod Canal.

1.3 Objectives of the Present Study

Much of the previous data generated on organic pollutant inputs to the study area was not sufficiently rigorous, either in statistical design or analytical scope to give an accurate picture of the pollution biogeochemistry of the region. Our research was aimed at:

- a) selecting a sampling grid based on present waste disposal activities and potential transport and deposition of these materials, as well as on present informational needs and future waste disposal strategies;
- b) applying a successful chemical monitoring strategy (i.e., Bpehm, 1983b) to a set of sediment and benthic macrobiota samples taken from the study area. This strategy is designed to facilitate the differentiation between different sources of pollution.
- c) conducting a statistically sound sediment sampling program (i.e., multiple replicate samples taken at each station) which also reflects recent deposition (i.e., top 2 cm) at each station.
- d) obtaining a parallel set of macrobital species in close association with the sediments being monitored, to assess the bioaccumulation of sediment-associated pollutants.

2. METHODS AND MATERIALS

2.1 Sampling

A series of twenty-five (25) sampling stations was selected to represent 1) areas of sediment deposition, 2) proximity to existing and potential future waste disposal sites, 3) proximity to possible pollutant sources. The station grid is shown in Figure 2 and 3 and locations detailed in Table 1. Five sediment sample replicates were obtained at each station by subsampling the 0-2 cm section of a modified Van Veen Grab sampler (0.1m²). All samples were transferred to clean, solvent-rinsed glass and were refrigerated on board and frozen at -20°C after shipment to the laboratory.

Benthic organisms were obtained using an otter trawl. Animals were carefully sorted on board with strict attention paid to avoiding contamination. Samples of finfish (dab, winter flounder, yellowtail flounder), shellfish (mussels), and crustacea (lobsters and cancer crabs) were obtained for possible analyses. American dab, (Hippoglossoides plattessoides), winter flounder, (Pseudopleuronectes americanus) and crabs (Cancer borealis) were selected as target species for this study as they represented different feeding types which were obtained at several stations for comparative assessment.

2.2 Analytical Methods

Solvents and Reagents

All chemicals and reagents used in this study were either of high purity when purchased or were processed in the laboratory to yield negligible blank levels for all analyte classes.

Reference PAH compounds of defined identity and of at least 98% purity were obtained from Aldrich Chemical, Inc. or Sigma Chemical, Inc. Reference PCB compounds were obtained from Ultra Scientific, Inc. Reference pesticide and sterol standards were obtained from Supelco, Inc. or Analabs, Inc.

The extracting and processing solvents, Hexane, methanol, and methylene chloride, were Burdick and Jackson pesticide analysis quality and were used directly after confirmation of purity. KOH, HCl, and Na₂SO₄ were Fisher, Ar-ACS grade. Water was purified using a Millipore Milli-Q system followed by solvent extraction. A 5N KOH stock solution was prepared and exhaustively extracted with methylene chlorolide until no

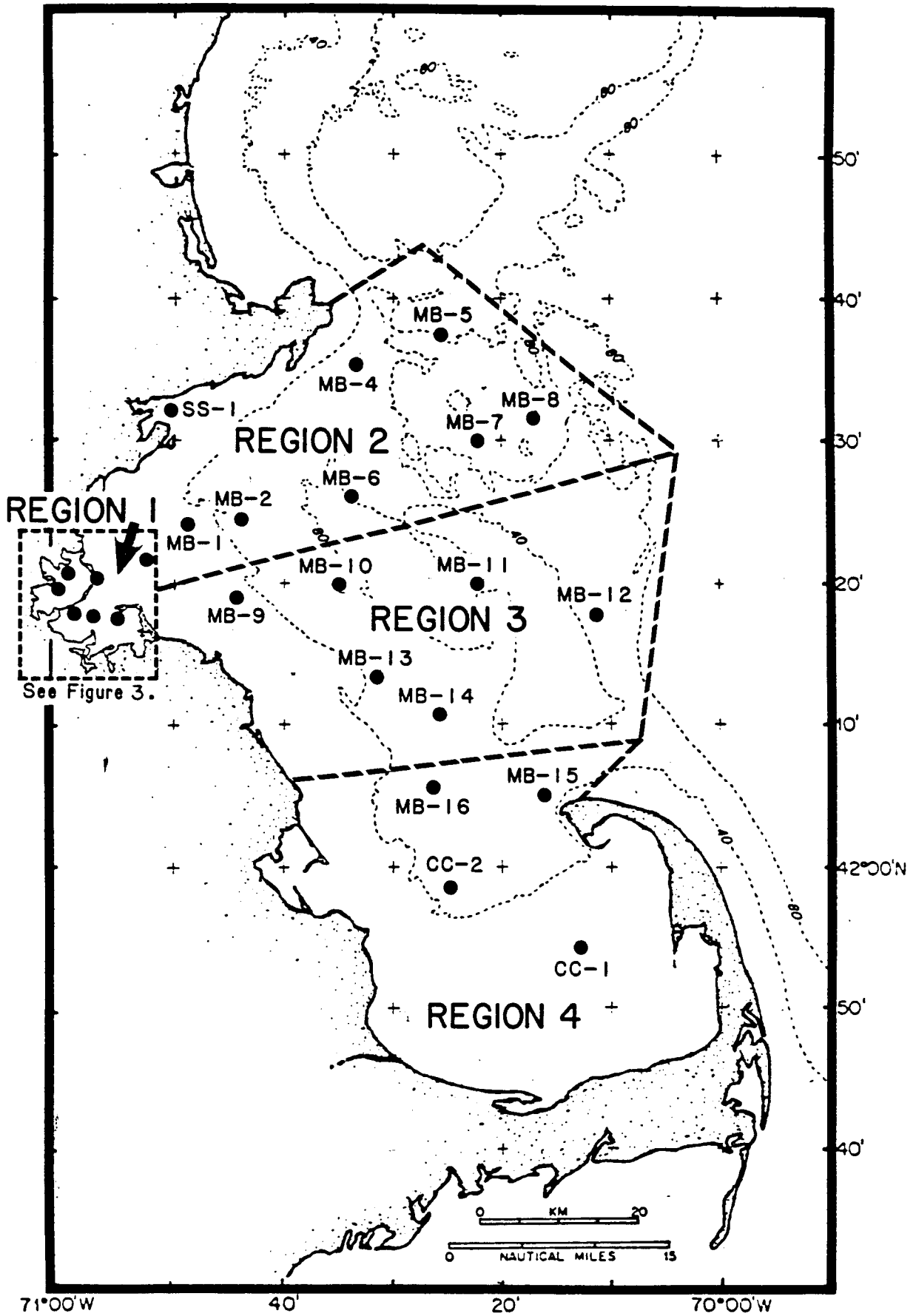


Figure 2. Locations of Sampling Stations in Massachusetts Bay (MB) and Cape Cod (CC): R/V Mya 27 June- 6 July 1983.

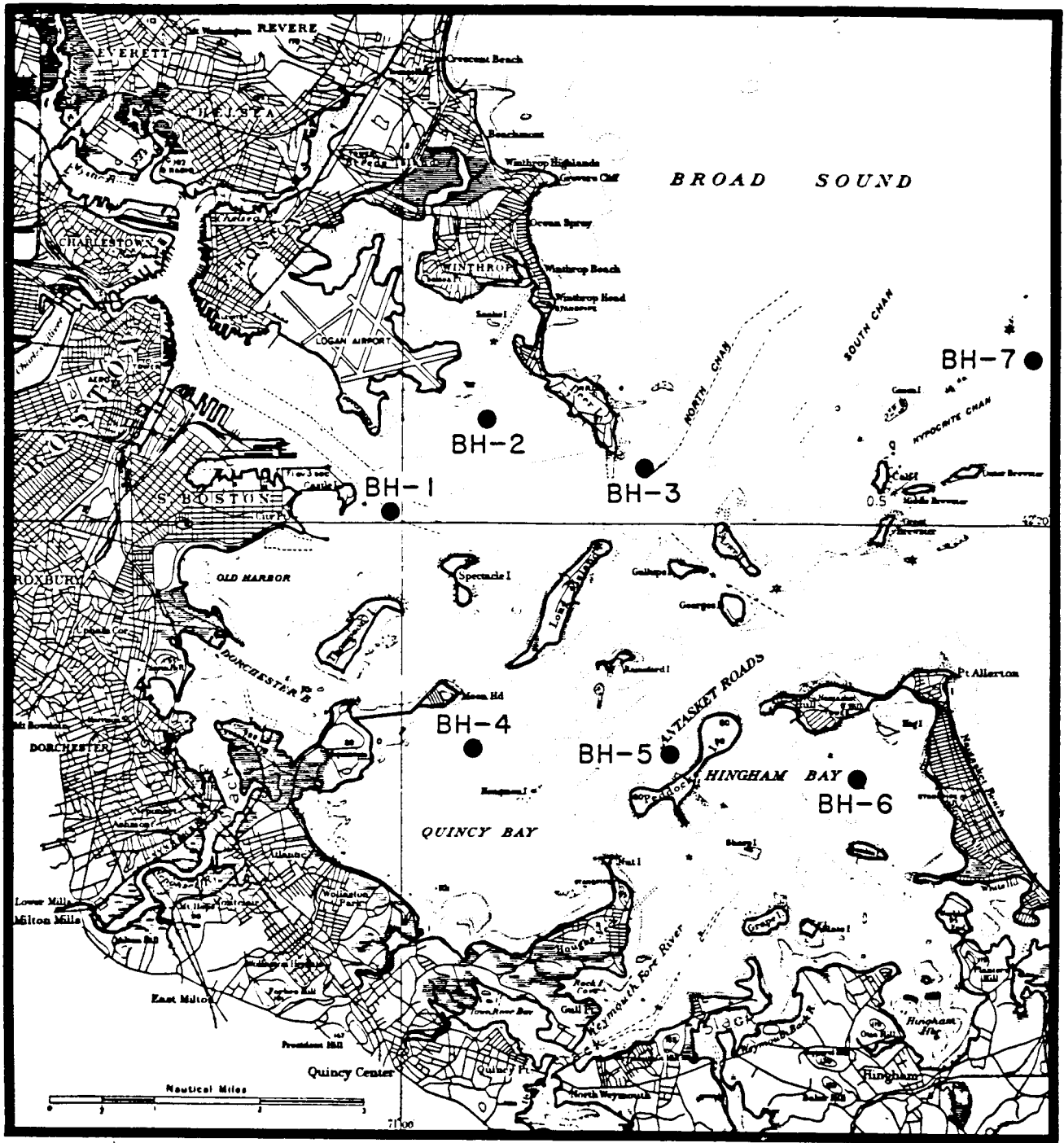


Figure 3. Locations of Boston Harbor (BH) Sampling Stations.

TABLE 1. DESCRIPTION OF BENTHIC STATIONS

STATION	SEDIMENT DESCRIPTION	STATION DEPTH (M)	LORAN LINES	LATITUDE	LONGITUDE
CC-1	Soft mud bottom	35	13872.76	70°13.4'	41°54.5'
CC-2	Soft mud bottom	47	13918.70	70°23.9'	41°58.4'
MB-16	Soft mud bottom	60	13900.27	70°26.5'	42°05.4'
MB-15	Soft mud bottom	56	13844.43	70°16.9'	42°04.8'
MB-12	Rocky bottom	-	13746.30	70°11.1'	42°17.7'
MB-11	Soft mud bottom	100	13806.40	70°22.8'	42°19.9'
MB-8	Soft mud w/pebble, stones	104	13709.21	70°16.8'	42°31.6'
MB-7	Soft mud bottom	150	13151.00	70°22.4'	42°30.2'
MB-5	Soft mud bottom	134	13736.64	70°26.0'	42°37.1'
MB-4	Soft grey mud	70	13790.06	70°32.8'	42°35.1'
MB-6	Soft mud bottom	96	13842.40	70°33.3'	42°25.8'
SS-1	Black mud w/stones	12	13914.93	70°50.3'	42°32.0'
MB-3	Rocky bottom	64	13864.13	70°40.5'	42°30.3'
BH-1	Black mud w/shells	5.7	14044.27	71°00.48'	42°19.77'
BH-2	Soft black mud	8	14029.64	70°58.84'	42°20.68'
BH-3	Sand/stones	28	14015.83	70°56.50'	42°20.38'
BH-6	Soft grey ooze	6	14015.81	70°54.33'	42°17.46'
BH-4	Black ooze/mud/shells	6	14047.85	70°59.19'	42°17.53'
BH-5	Soft brown mud	8	14031.47	70°56.83'	42°17.66'
BH-7	Fine sand/stones	28	13977.64	70°51.4'	42°21.7'
MB-1	Soft mud	36	13953.06	70°49.2'	42°23.7'
MB-2	Rocky bottom	58	13911.69	70°43.2'	42°24.4'
MB-9	Sand/stones	40	13944.14	70°44.2'	42°18.6'
MB-10	Soft grey clayey mud	83	13880.18	70°35.0'	42°20.1'
MB-13	Soft grey mud	64	13889.82	70°31.5'	42°13.7'
MB-14	Soft grey mud	67	13854.65	70°24.2'	42°11.8'

residues were detected by GC-ECD. Na_2SO_4 was prepared by ignition at 450°C . No cleanup of HCl was necessary. Silica, grade 923, and alumina, Brockmann I grade were obtained from the Aldrich Chemical Co.

Sample Extractions and Cleanup

The extraction of sediments for analysts of PAH, PCB, pesticides coprostanol was performed using the method of ambient temperature shaking (Brown et al., 1980; Boehm et al., 1981). Sediment was thawed, homogenized and 150g introduced into a screw-top Teflon jar (250ml). Methanol was first added to dry the sediment. The sediment-solvent mixture was shaken for 1/2 hr., the methanol-water solution decanted, and the process repeated. The methanol was then replaced with an azeotropic solution of methylene chloride and methanol (9:1). Internal standards (androstane, o-terphenyl) were added at this point. Extraction via vigorous shaking continued for an additional 12 hours with solvent changes at 4 and 8 hours. The extracts were combined in a separatory funnel. HCl (0.25N) was added and a small aliquot of hexane introduced and the organic (methylene chloride-hexane) phase isolated. This phase was subsequently dried over sodium sulfate, concentrated, and the remaining methylene chloride displaced with hexane.

The subsamples for TOC analysis (5g) were thawed, acidified with HCl, freeze-dried, and finally ground in a ball mill in preparation for analysis. Analysis by high temperature combustion was performed on an HP-185 CHN analyzer.

Frozen biota samples were received in the laboratory. The samples were thawed and dissections performed as follows. The flatfish, dab and flounder, were filleted with clean stainless steel utensils. A minimum of three individuals were pooled for analysis. The entire soft tissue parts of the crabs were withdrawn for analysis. Individual organisms were first sorted according to size, the desired tissue composited (flounder fillets or crab soft tissue), and sample homogenized using a Polytron blender. An aliquot of homogenized tissue was removed for dry weight determination and the homogeneous sample was then placed into a screw-top Teflon jar (250ml), KOH and internal reference standards added, and the jar sealed after flushing with nitrogen. The sample was heated to 80°C and digested overnight (16 hrs.). Upon completion of the digestion the sample was diluted with Milli-Q water and repeatedly extracted (six times) with hexane. The organic (hexane) phase was dried over Na_2SO_4 , reduced in volume using a rotary evaporator, and total extractable lipid weight determined. Most biogenic lipid materials

which interfere with the analysis were removed at this point using an alumina column cleanup procedure (Boehm, et al., 1982).

Fractionation and Analysis

Sediment and organism extracts were charged to 100% activated silica gel/5% deactivated alumina/activated copper (11 g, 1 g, 2 g) chromatography column (1 cm i.d.) that was wet-packed in dichloromethane and prepared by eluting with 30 ml each of dichloromethane and hexane. The sample of no more than 50 mg extract weight in 0.5 ml hexane was charged to the column. The column was eluted with 18 ml of hexane followed by 21 ml of hexane:dichloromethane (1:1) to isolate the saturated hydrocarbons (f_1) and unsaturated (including PAH and pesticide and PCB) compounds (f_2) respectively. Polar compounds including the sterols (f_3) were subsequently eluted with methanol. PAH (f_2 fractions) from two to five rings were analyzed directly by fused silica glass capillary gas chromatographic mass spectrometry (GC/MS). A 30m DB-5 column (0.25mm I.D., J&W Scientific) was used in all GC/MS and subsequent GC/ECD (capillary chromatography with electron capture detections) analyses. Parent ion (M^+) total ion currents from GC/MS were computer-integrated, and amounts of PAH were computed using relative response factors generated from GC/MS analysis of quantitative standard mixtures. Quantification of aromatic hydrocarbons by GC/MS agreed with that obtained by GC/FID to within 20% as determined through a NOAA intercalibration exercise (Battelle, unpublished data).

The f_2 fractions were also analyzed by GC/ECD for PCB and pesticide determinations. PCB was quantified both as commercial Aroclor formulations and by chlorine content (Boehm, 1983a; Boehm, et al., 1984); (Ballschmiter and Zell, 1980). For the latter analysis a mixed Aroclor standard was analyzed by GC/MS to determine the number of chlorine substitutions of individual resolved components. Subsequently, the retention times of these compounds were compared with those of each eluting sample peak, definitive PCB isomeric family (pseudo-component) identifications were made (C_{12} to C_{17}), and the areas of each unique member of that family were summed and quantified relative to an internal standard (3,4,5, -tribromomobiphenyl). Relative response factors were determined for at least two reference compounds of each PCB isomeric family and averaged to arrive at a single factor for each pseudo-component family. PCB as Aroclor 1242, 1254, or 1260 was also quantified by the internal standard method using standard solutions of individual Aroclor formulations to identify at least six unique resolved components of each formulation and to calculate average response factors.

Certain f_2 fractions were also analyzed by GC/ECD for pesticide content. PCB interference was partially removed by silica chromatography of the f_2 fraction (Ribick, et al., 1981) and individual components identified by analysis of pesticide reference standards. Further confirmation of the DDT family was obtained by saponification of the extract (Risebrough, et al., 1968) and reanalysis.

The f_3 fractions were analyzed for coprostanol and other sterol components using the method of Hatcher and McGillivray (1979). The fractions were dried under nitrogen, dissolved in pyridine, and reacted with N,O-bis (trimethylsilyl) acetamide to form trimethyl silyl (TMS) ethers of the sterol compounds. The TMS ethers were then analyzed by GC/FID and quantified relative to an external standard (cholestane) spiked into the solution prior to analysis. The identities and response factors of TMS ethers were determined by silylating solutions of sterol standards and analyzing under identical analytical conditions.

Quality Control/Quality Assurance

QC/QA procedures covered a range of activities including daily calibration of all instruments, the analysis of standard compound to verify column performance, and the verification of the purity of all solvents and reagents. Procedural blanks were analyzed with each batch of samples. Other QC/QA checks included, 1) the analyses of triplicate tissue and sediment samples to determine analytical precision, 2) the analysis of reference materials including a certified Canadian reference sediment sample (PCB) and the NOAA/ICES/Woods Hole mussel homogenate (PAH). Results of the triplicate analyses are presented in the Data Appendix, Table A.1 and in Table 9.

The certified Canadian sediment sample (NRC SRM HS-2) contains 112ng total PCB/g. Our analysis yielded a value of 111.9 ng/g. Blanks were clean of all PCB and sterol compounds and contained only traces of PAH. The recovery of a PCB Aroclor spike achieved a 91% recovery. Reextraction of a sediment sample yielded only 10% more PCB material indicating that our actual sediment recovery and that of the spiked PCB were identical. Triplicate analyses of a mixed PCB spike yielded a precision of 26.4 ± 5.2 ng/g indicating that our combined analytical precision was $\pm 20\%$. (Field precision which represents a combination of analytical plus sampling precision is extensively addressed through replicate analysis in the Results Section).

3. RESULTS

3.1 Surface Sediments

Summaries of the concentrations of PAH, PCB, Coprostanol, and TOC concentrations in surface sediments from the study area are presented in Tables 2-5. The study area has been subdivided into five areas corresponding to the Boston Harbor (Region 1), the transitional area (Region 1A) near the entrance to the harbor, Northern Massachusetts Bay (Region 2), Southern Massachusetts Bay (Region 3), and Cape Cod Bay (Region 4) for ease of data presentation (see Figure 2). Along with the presentation on absolute concentrations of these compound classes, several source parameter ratios are presented in Tables 2-5 as well. These include:

- a) The Fossil Fuel Pollution Index (Boehm 1983a,b)

$$FFPI = \frac{\Sigma N + 1/2(C_0P + C_1P) + \Sigma P + \Sigma F + \Sigma DBT}{\Sigma PAH} \times 100$$

where

C_0P = Phenanthrene
 C_1P = Methyl Phenanthrenes
 ΣN = C_0, C_1, C_2, C_3, C_N (naphthalenes)
 ΣP = C_2, C_3, C_4P (phenanthrenes)
 ΣF = C_0, C_1, C_2, C_3F (fluorenes)
 ΣDBT = C_0, C_1, C_2, C_3DBT (dibenzothiophenes)
 ΣPAH = Numerator + Fluoranthene, Pyrene, Benzanthracene, Chrysene, Benzopyrenes.

This ratio varies from approximately 100 for fossil fuels to near zero for combustion related PAH.

- b) PAH/TOC and PCB/TOC which are ratios of total PAH (2-5 rings) and total PCB (dichlorobiphenyls to heptachloro biphenyls) to total organic carbon (Boehm & Farrington 1984; Boehm, 1983b).
- c) Coprostanol/Total Steroids - This is the ratio of the sewage tracer steroid coprostanol to five major steroids not unique to sewage. Sewage sludge itself exhibits a ratio of 0.5-0.8, while a purely biogenic source would exhibit a ratio of near zero. This ratio may be high even through the absolute coprostanol content is low. (Hatcher and McGillivray 1979; Boehm, 1982).

A comparison of values by Region is presented in Table 6.

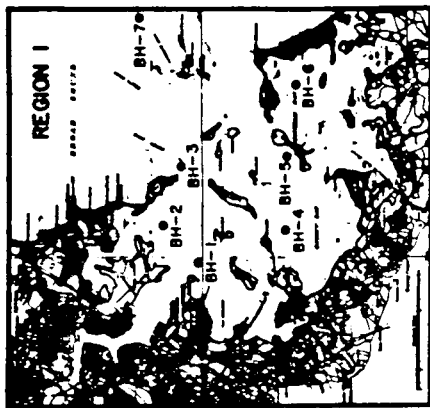


TABLE 2 SUMMARY OF ORGANIC POLLUTANT DATA-REGION 1 AND 1A

PARAMETERS	STATIONS						
	BH-1	BH-2	BH-4	BH-5	BH-6	BH-7	MB-1
<u>Polycyclic Aromatic Hydrocarbons (PAH)</u>							
Total Concentration (ug/g) ^a	2.7±1.8	880±4.7	6.5±2.0	6.0±1.3	2.4±0.6	0.8±0.8	14.3±10.8
PAH/TOC (x10 ³)	.24±.08	31.6±6.8	.16±.03	.31±.12	.18±.03	.25±.15	1.1±.52
FFPI ^b	35±17	52±2.1	23±6.2	46±5.3	18±2.0	14±3.5	31±3.8
<u>Polychlorinated Biphenyls (PCB)</u>							
Total concentration (ng/g)	70.4±27.7	139±15.0	330±119	100±23.7	60.6±5.0	14.5±7.6	39.3±23.9
PCB/TOC (x10 ⁶)	7.3±1.5	5.0±.68	7.8±1.8	4.3±.90	4.6±.43	3.8±.58	4.6±1.2
<u>Coprostanol</u>							
Concentration (ug/g)	2.4±.96	15.9±6.5	1.2±.20	6.2±1.5	2.5±.52	.60±.30	.18±.17
Coprostanol/Steroids ^c	.30±.03	.42±.03	.21±.04	.25±.04	.24±.01	.15±.05	.02±.01
Coprostanol/PCB	35±9.4	120±51	4.3±2.7	63±13	43±11	40±4.0	4.0±1.7
<u>Total Organic Carbon (mg/g)</u>	10.2±5.1	27.1±1.8	41.5±11.9	23.5±4.7	13.3±1.4	3.7±1.5	8.7±4.7

a PAH include 2-5 ring compounds

b FFPI = fossil fuel pollution index (see text)

c steroids = sum of: cholesterol, 5 β-cholestanol (=coprostanol), 5α cholesterol, β-sitosterol, stigmasterol

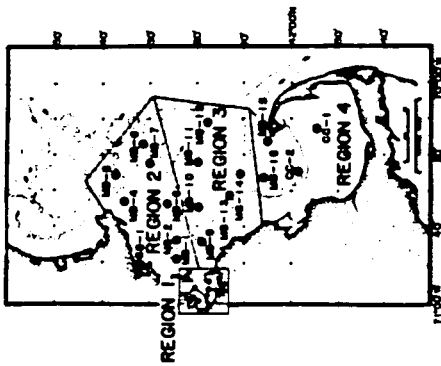


TABLE 3 SUMMARY OF ORGANIC POLLUTANT DATA - REGION 2

Parameter	STATION				
	MB-4	MB-5	MB-6	MB-7	MB-8
<u>Polycyclic Aromatic Hydrocarbons (PAH)</u>					
Total Concentration (ug/g) ^a	2.3±1.1	0.6±0.2	3.5±1.0	1.3±0.3	0.3±0.2
PAH/TOC (x10 ³)	.15±.04	.05±.01	.14±.04	.06±.02	.01±.006
FFPI ^b	20±1.5	16±1.9	38±7.8	32±6.2	8.7±5.4
<u>Polychlorinated Biphenyls (PCB)</u>					
Total Concentration (ng/g)	21.0±7.9	4.6±1.2	82.9±16.0	24.7±11.2	23.4±4.4
PCB/TOC (x10 ⁶)	1.4±.42	.40±.07	3.3±.51	1.2±.58	.97±.18
<u>Coprostanol</u>					
Concentration (ug/g)	.14±.05	.03±.02	.34±.10	.06±.05	.45±.07
Coprostanol/Steroids ^c	.03±.01	.02±.008	.04±.01	.02±.02	.08±.01
Coprostanol/PCB	7.1±2.2	6.0±3.0	4.1±1.9	2.4±2.1	19.8±4.3
Total Organic Carbon (mg/g)	15.1±3.6	11.7±2.1	25.1±1.3	20.4±0.7	24.0±0.9

a PAH include 2-5 ring compounds

b FFPI = fossil fuel pollution index (see text)

c steroids = sum of: cholesterol, 5 β cholesterol (=coprostanol), 5α-cholestanol, β-sitosterol, stigmasterol

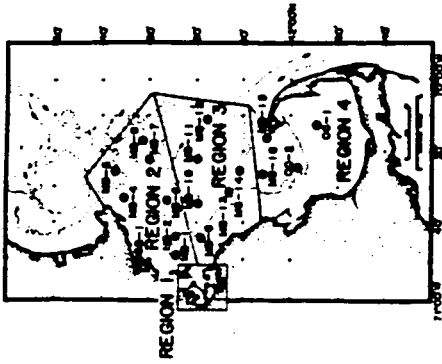


TABLE 4: SUMMARY OF ORGANIC POLLUTANT DATA-REGION 3

PARAMETER	MB-9	MB-10	STATION MB-11	MB-13	MB-14
<u>Polycyclic Aromatic Hydrocarbons (PAH)</u>					
Total Concentration (ug/g) ^a	0.2±0.1	1.5±0.1	1.9±0.1	0.5±0.1	0.7±0.1
PAH/TOC (x10 ³)	.09±.10	.09±.007	.20±.03	.07±.02	.08±.02
FFPI ^b	16±6.6	26±5.0	18±1.4	14±5.0	16±1.4
<u>Polychlorinated Biphenyls (PCB)</u>					
Total Concentration (ng/g)	2.3±0.7	25.3±3.6	7.0±2.1	6.7±.78	10.3±1.0
PCB/TOC (x10 ⁶)	1.1±.92	1.5±.26	.72±.14	1.0±.20	1.1±.05
<u>Coprostanol</u>					
Concentration (ug/g)	.05±.02	.11±.05	.12±.05	.13±.02	.19±.05
Coprostanol/Steroids ^c	.02±.007	.02±.02	.04±.02	.02±.006	.02±.003
Coprostanol/PCB	19.9±4.7	4.1±1.6	23.7±14.5	19.4±14.5	18.4±3.9
<u>Total Organic Carbon (mg/g)</u>	3.1±1.7	17.0±1.2	9.6±1.3	6.5±0.6	9.3±0.8

a PAH include 2-5 ring compounds

b FFPI=fossil fuel pollution index (see text)

c steroids=sum of: cholesterol, 5 β-cholestanol (=coprostanol), 5α-cholestanol, β-sitosterol, stigmaterol

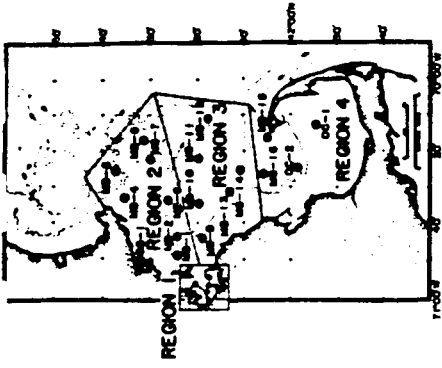


TABLE 5 SUMMARY OF ORGANIC POLLUTANT DATA-REGION 4

PARAMETER	MB-16	STATION CC-1	CC-2
<u>Polycyclic Aromatic Hydrocarbons (PAH)</u>			
Total Concentration (ug/g) ^a	0.6±0.1	1.0±0.4	1.4±0.1
PAH/TOC (x10 ³)	.06±.01	.05±.01	.17±.18
FFPI ^b	18±0.6	37±5.4	48±9.7
<u>Polychlorinated Biphenyls (PCB)</u>			
Total Concentration (ng/g)	5.1±3.7	31.3±4.0	26.9±4.0
PCB/TOC (x10 ⁶)	.48±.36	1.6±.61	1.7±.26
<u>Coprostanol</u>			
Concentration (ug/g)	.07±.02	.08±0.5	.10±.05
Coprostanol/Steroids ^c	.03±.006	.01±.001	.02±.009
Coprostanol/PCB	16.9±15.2	2.6±1.2	3.9±2.3
<u>Total Organic Carbon (mg/g)</u>	10.6±1.8	21.5±6.7	15.6±.80

a PAH include 2-5 ring compounds

b FFPI=fossil fuel pollution index (see text)

c steroids=sum of: cholesterol, 5 β-cholastanol (=coprostanol), 5α cholastanol, β-sitosterol, stigmasterol

TABLE 6 SUMMARY OF ORGANIC POLLUTANT DATA REGIONAL COMPARISONS

PARAMETER	1	REGION 2	3	4
Polycyclic Aromatic Hydrocarbons (PAHs)				
Total Concentration (ug/g)-mean (range)	180 ^d (2.4-880)	1.6 (.3-3.5)	.96 (.2-1.9)	1.0 (.6-1.4)
PAH/TOC (x10 ³)-mean (range)	6.5 ^e (.16-32)	.08 (.01-.15)	.11 (.07-2.0)	.09 (.06-1.7)
FFPI ^b -mean (range)	32 ^f (18-52)	23 (9-38)	18 (14-26)	34 (18-48)
Polychlorinated Biphenyls (PCB)				
Total Concentration (ng/g)-mean (range)	140 (70-330)	31.3 (4.6-83)	10.3 (2.3-25.3)	21.1 (5.1-31.3)
PCB/TOC (x10 ⁶)-mean (range)	5.8 (4.3-7.8)	1.5 (.4-3.3)	1.1 (.7-1.5)	1.3 (.48-1.7)
Coprostanol				
Concentration (ug/g)-mean (range)	5.6 (1.2-15.9)	.20 (.03-.45)	.12 (.05-.19)	.08 (.07-1.0)
Coprostanol/Steroids ^c -mean (range)	.28 (.21-.42)	.04 (.02-0.8)	.02 (.02-.04)	.02 (.01-.03)
Coprostanol/ PCB-mean (range)	41.2 (4.3-117)	7.9 (2.4-19.8)	17.1 (4.1-23.7)	7.8 (2.6-16.9)
Total Organic Carbon (mg/g)-mean (range)	23.2 (10.2-41.5)	19.2 (11.7-25.1)	9.1 (3.1-17.0)	15.9 (10.6-21.5)

a PAH include 2-5 ring compounds

b FFPI=fossil fuel pollution index (see text)

c Steroids-sum of: cholesterol, 5 β cholestanol
(=coprostanol), 5αcholestanol, β-sitosterol, stigmasterol

d arithmetic mean; geometric mean = 12 (ug/g)

e arithmetic mean; geometric mean = .22

f arithmetic mean; geometric mean = 34.8

TABLE 7 VARIABILITY OF ORGANIC POLLUTANTS IN SEDIMENT - 20 STATIONS

PARAMETER	σ/\bar{x} (MEAN)	σ/\bar{x} (RANGE)
PCB	.25	.08-.45 (one value higher, .73)
Total PAH	.36	.05-.7 (one value higher, 1.0)
Individual PAH	(See Table A-2)	
FFPI	.21	.03-.49 (one value higher, .62)
Coprostanol	.41	.15-.90

3.1.1 Chlorinated Hydrocarbons

3.1.1.1. Polychlorinated Biphenyl (PCB) Concentrations. PCB values presented in Tables 2-5 indicate that, not surprisingly, levels are highest in Region 1 (Table 2). Values in Boston Harbor stations ranged from 70-330 ng/g. The highest PCB concentration was found at Station BH-4 in Quincy Bay (330 ng/g), the station with the highest organic carbon loading (~4%). In general, these PCB values are in the range of polluted harbor sediments elsewhere (see discussion), although much lower than areas such as the Arthur Kill and Newark Bay areas in New York or the New Bedford Harbor. The overall Boston Harbor area mean PCB concentration (Table 6) was found to be 140 ng/g.

Replicate analyses from each of the Region 1 stations indicated that σ/\bar{X} values (i.e. coefficient of variation) ranged from .08 to .39. (Data for individual replicates is presented in Table A-1 for PCB, Coprostanol and TOC parameters and for all 20 stations). Ratios of PCB/TOC in Region 1 averaged 5.8. The range of PCB/TOC values is quite limited (4.3 to 7.8). These ratios are typical of highly impacted areas. For example, the sediments from the sewage dumpsite in New York Bight exhibited PCB/TOC values of 6.1 and 11.4 and central Buzzards Bay was seen to have a value of 6.1 (Boehm, 1983c).

PCB concentrations near the entrance to Boston Harbor (Region 1A), at Stations BH-7 and MB-1 averaged 14.5 and 39.3 ng/g respectively with PCB/TOC values of 3.8 and 4.6. These sites apparently are also strongly influenced by fluxes of material from the harbor and the elevated PCB levels along with higher TOC and PAH levels attest to the depositional nature of MB-1.

PCB concentrations in Regions 2, the northern Massachusetts Bay area, were on the average lower than those in Boston Harbor by a factor of 4 (Tables 3 and 6). However, the values in this region ranged from 4.6 to 83 ng/g. Highest mean values were found at MB-6 (82.9 ng/g), MB-7 (24.7 ng/g), and MB-8 (23.4 ng/g) all considerable distances from shore. The elevated values found at MB-6 may be ascribed to the proximity of the Massachusetts Bay "foul area" a disposal site for dredged material. MB-7 and MB-8 further offshore, lie in a depositional basin and apparently are focal sites of medium-to long-range transport of contaminated sediment.

Replicate PCB analyses of samples in Region 2 exhibited σ/\bar{X} values ranging from .19 to .45 (See Table A.1). An overall summary of replicate variability for each parameter examined is presented in Table 7.

The PCB/TOC ratio from samples from Region 2 (Table 6) averaged 1.5 (range .4-3.3) much lower than those values in Regions 1 and 1A. The PCB/TOC values at MB-6 (mean = 3.3) were similar to those at nearshore impacted areas probably due to the direct input of contaminated material via dredge spoil disposal in the "foul" area. Other stations exhibited PCB/TOC values from 0.4 to 1.2. The lower PCB/TOC values in Region 2 compared to those from Region 1 are either due to the dilution of Boston Harbor sediment input by localized marine biogenic inputs of TOC, or are related to loss of PCB from particulates during transit offshore. PCBs strongly associate with particles. These strong PCB-particle affinities and low degradation rates of PCB, favor the former "dilution" hypothesis to explain the lower PCB/TOC ratios offshore.

Region 3 PCB values were lower on the average by a factor of 3 than the Region 2 values. PCB concentrations (Tables 4 and 6) averaged 10.3 ng/g with a range of 2.3 to 25.3. Highest values were found in the Stellwagen Basin area. Note the MB-10 (PCB = 25.3 ng/g) had been sampled previously (Boehm, 1983b; Station 35) at which time PCB values were found to be ~ 6.0 ng/g. Concentrations have appeared to increase by a factor of four at this station.

Replicate PCB analysis of Region 3 sediments illustrated that σ/\bar{X} values ranged from .10 to .30.

PCB/TOC ratios in Region 3 were quite similar to those from Region 2. Mean PCB/TOC values in Region 3 were 1.1 (range .7-1.5) compared to 1.0 at Region 2 (if the MB-6 "foul area" result is omitted). It is interesting to note that although PCB levels apparently increased by a factor of 4 at M-10 over previous determinations (Boehm 1983b), the PCB/TOC ratio at this station was consistently ~ 1.5 indicating that the PCB increase is related to the increased accumulation of PCB-bearing fine particles at this site or to small scale patchiness at the station.

The Cape Cod Bay area, Region 4, including stations MB-16, CC-1 and CC-2 exhibited higher PCB values than Region 3 (Table 5 and 6). Region 4 values (mean 21 ng/g) are similar to those from the Region 2 area, if again the "foul area" anomaly is omitted. Cape Cod Bay has been a region of dredged material disposal in the past. This apparent finding of possible elevated PCB levels should be carefully evaluated due to the existence of only two monitoring stations in Cape Cod Bay in this study.

Replicate analyses in Region 4 yielded σ/\bar{X} values from .13 to .74, the higher variation being associated with the lowest absolute value.

PCB/TOC values in Region 4 (mean 1.3, range .48-1.7) again were quite similar to those from both Regions 2 and 3. Thus, it appears that outside of Boston Harbor proper and nearby adjacent areas, sediments in the offshore study area are characterized by PCB/TOC ratios of $1.3 \pm .7$.

3.1.1.2 PCB Compositional Data. Analysis of PCB by capillary gas chromatography facilitates the determinations of individual PCB isomer concentrations and those of the isomeric families (i.e., dichlorobiphenyls, trichlorobiphenyls... heptachlorobiphenyls). One replicate from each station was quantified according to these groupings to detail the PCB compositional profiles. These data are presented in Figures 4 through 8.

Sediments from Regions 1 and 1A area are for the most part characterized by a bimodal distribution (Figures 4 and 5) with maxima at C₁₃ and C₁₅ or C₁₆. Sediments from other sewage-impacted sites in The New York area exhibit this identical bimodal distribution (Boehm, 1983a). Note also that the composition of the MB-6 "foul area" and MB-4 (Figure 6) also exhibit this profile, thus linking them with harbor sediments or other sewage sources (e.g., discharges along the northern Massachusetts Bay shore). Similarly the results from station CC-1, in another dredged material disposal site in Cape Cod Bay is linked to harbor-type sediments. Apparently, these C₁₃ compounds are lost due to dissolution as suspended sediments are transported offshore, as most of the other sediments exhibit no such C₁₃ maximum. Instead the offshore PCB profiles (Figures 5, 6 and 7) consist of a single maximum at C₁₆ or C₁₅. Occasionally a dichlorobiphenyl maxima is also observed (MB-9, MB-11, MB-5).

3.1.1.3 Other Chlorinated Organics Data. Samples from four Boston Harbor and three Massachusetts Bay samples were scrutinized for the presence of several other chlorinated hydrocarbons. Only the DDT family was detected in the sediments at concentrations ranging from 1-11 ng/g, the highest value being found in Boston Harbor (BH-4) (Table 8).

3.1.2 Polycyclic Aromatic Hydrocarbons (PAH)

Analytical data for sediment PAH levels are summarized in Tables 2-6 and are detailed by replicate and by PAH compound in Table A-1 (detailed information is available but not presented here for each individual PAH compound in each replicable). Total PAH concentrations are greatest in Boston Harbor (Table 2 and 6) where values range from 2.4 to 880 ug/g with an arithmetic mean of 180ug/g. The geometric mean, which accounts for the fact that PAH levels determined are not normally distributed statistically, is 12 ug/g which probably better reflects a true mean. However, the northern part of Boston Harbor, as represented by the single BH-2 "hot spot" contains some of the highest levels of PAH ever reported. Obviously the Boston Harbor system is patchy with regards to PAH and more detailed sampling is needed.

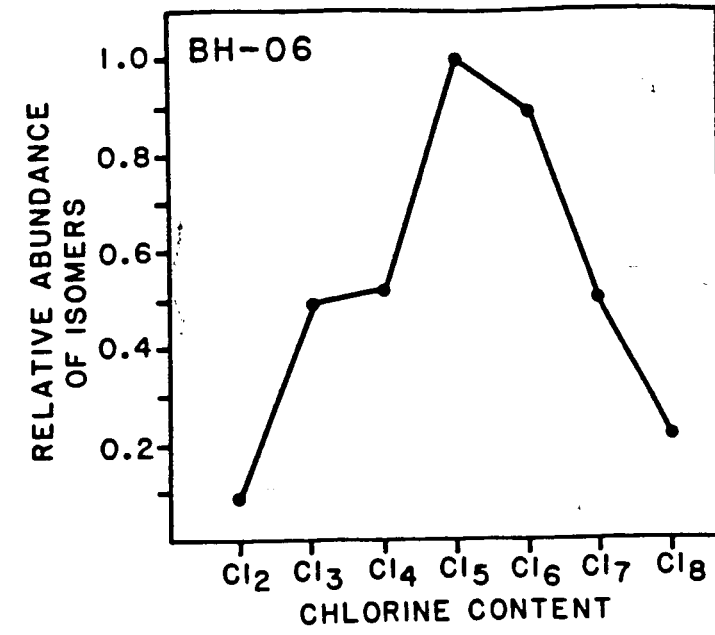
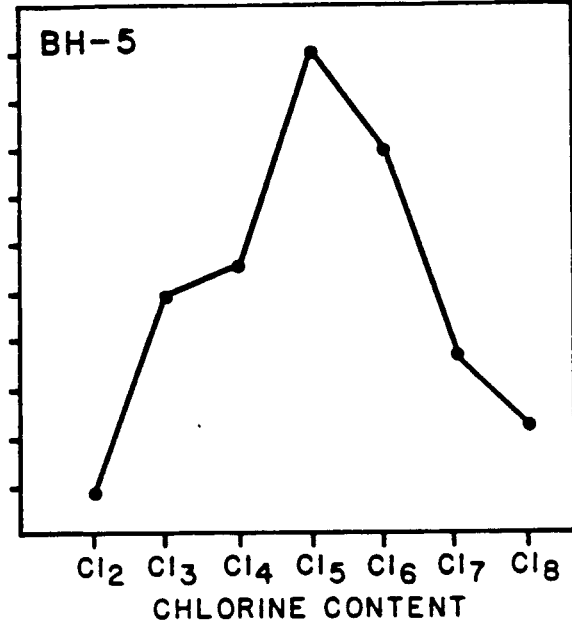
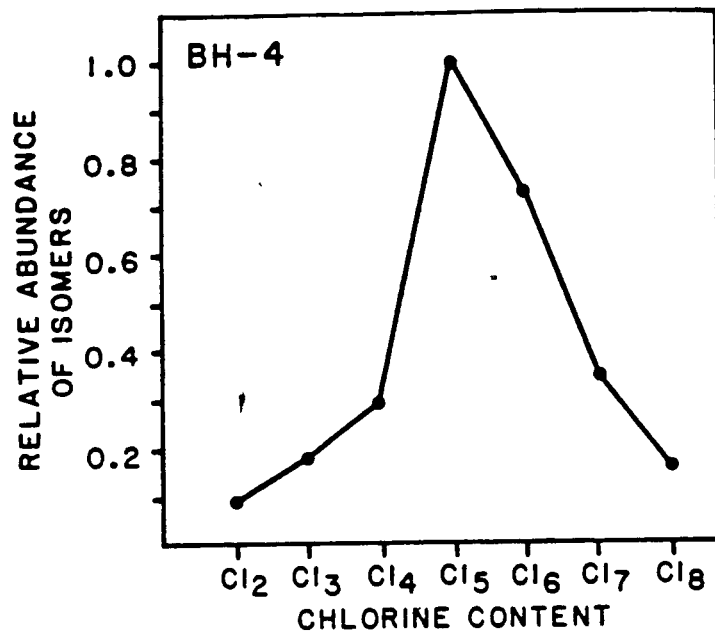
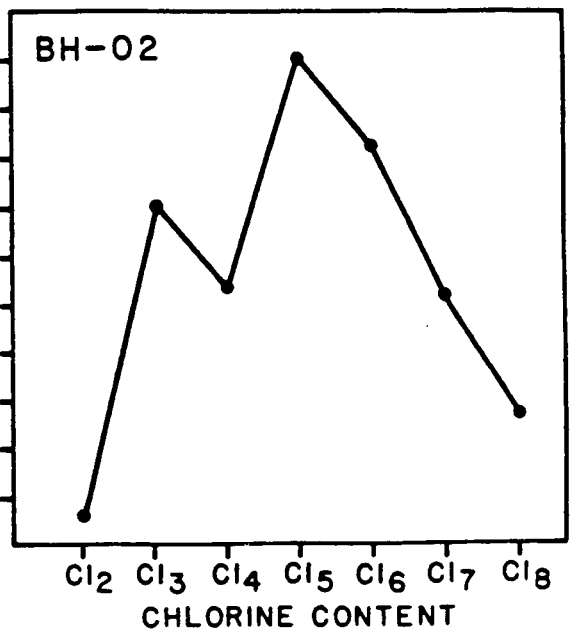
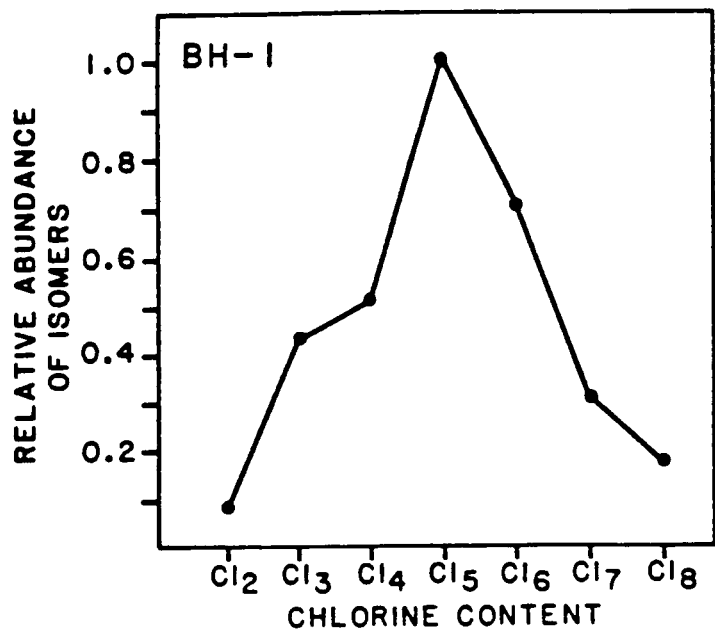


Figure 4. PCB Isomer Distributions for Region 1 Sediments.

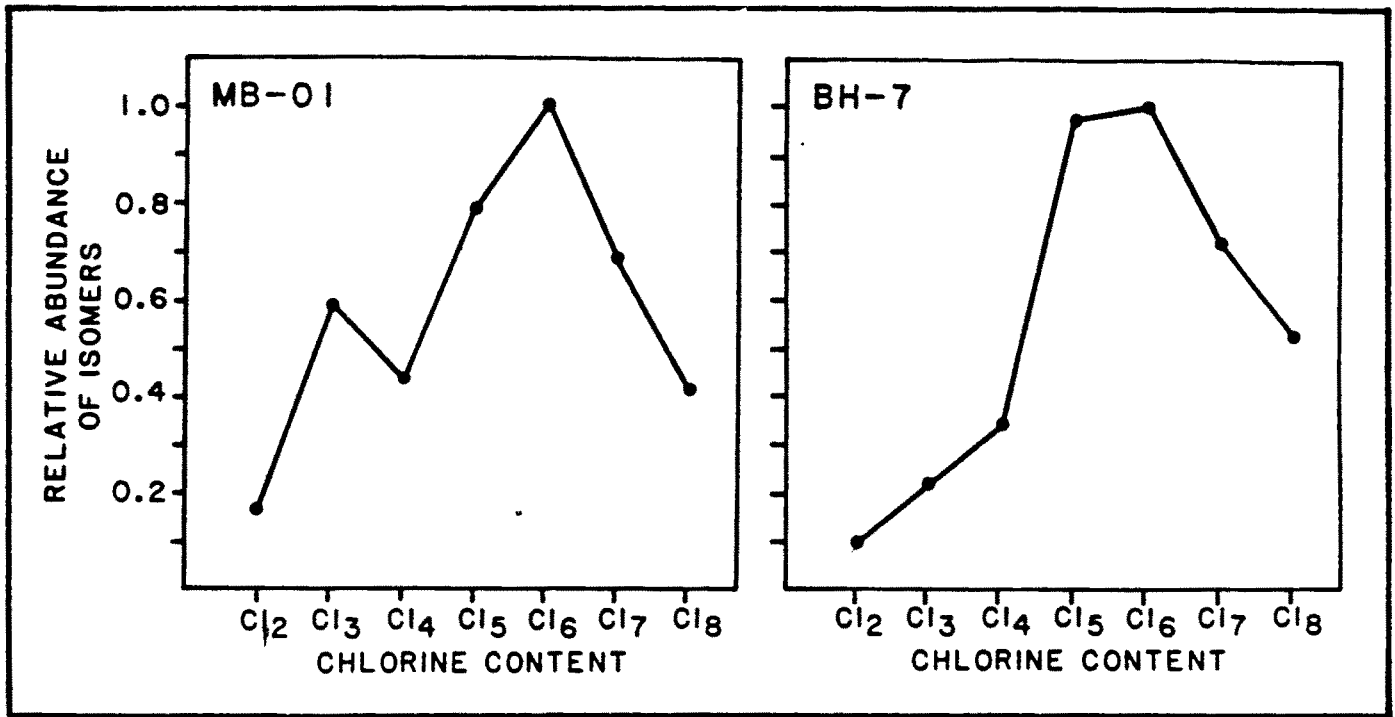


Figure 5. PCB Isomer Distributions for Region 1A Sediments.

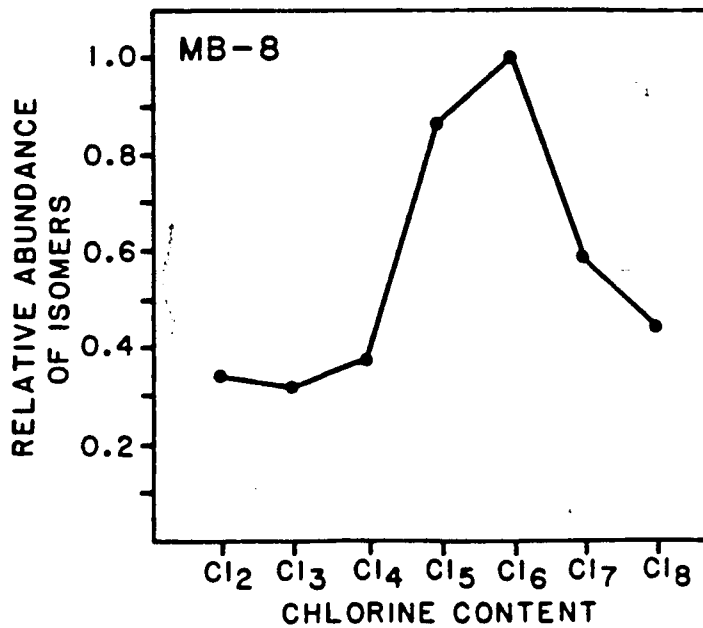
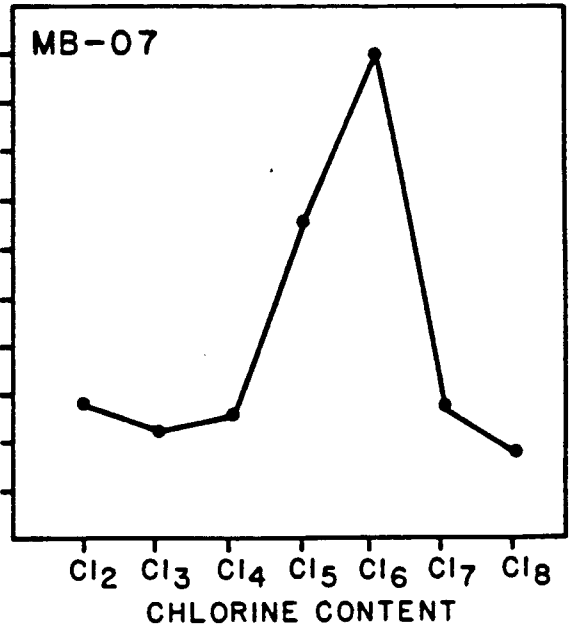
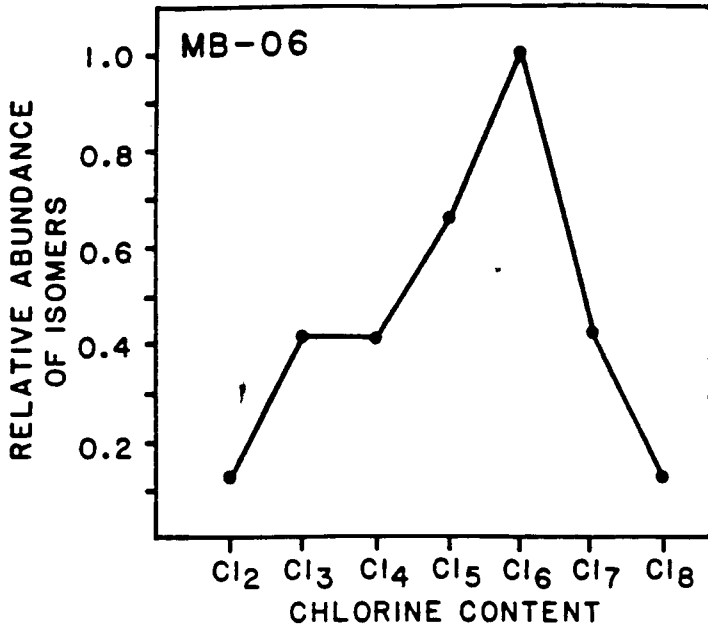
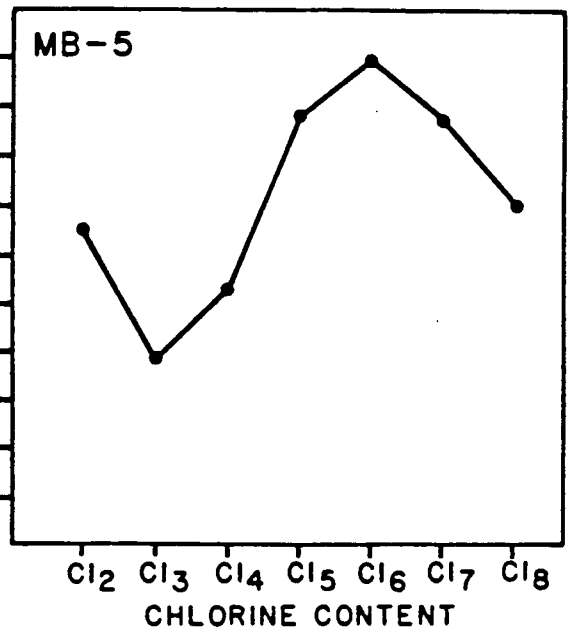
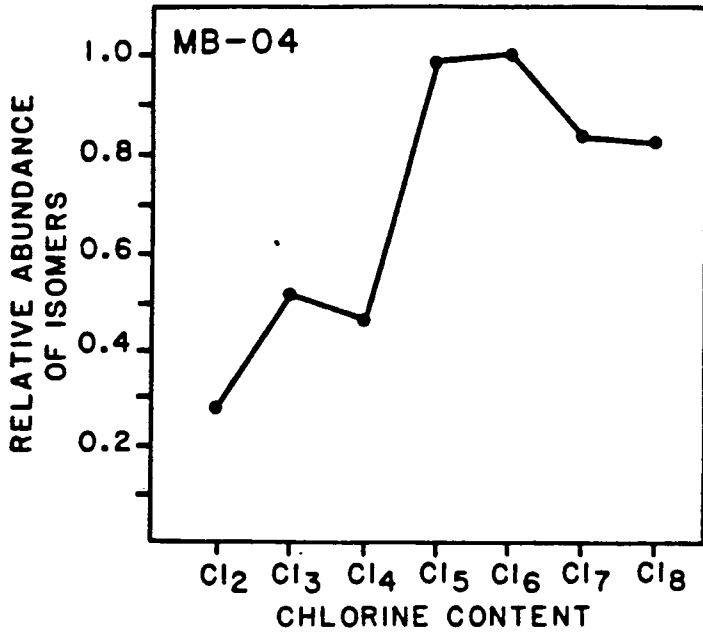


Figure 6. PCB Isomer Distributions for Region 2 Sediments.

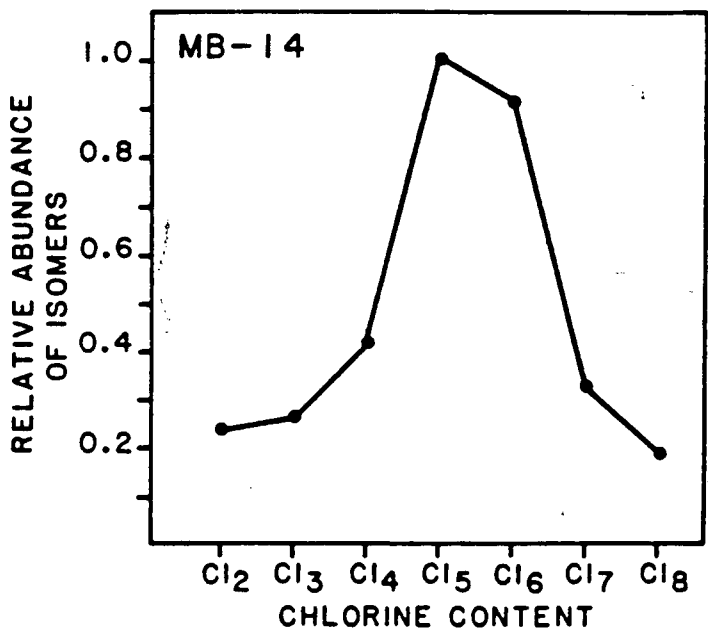
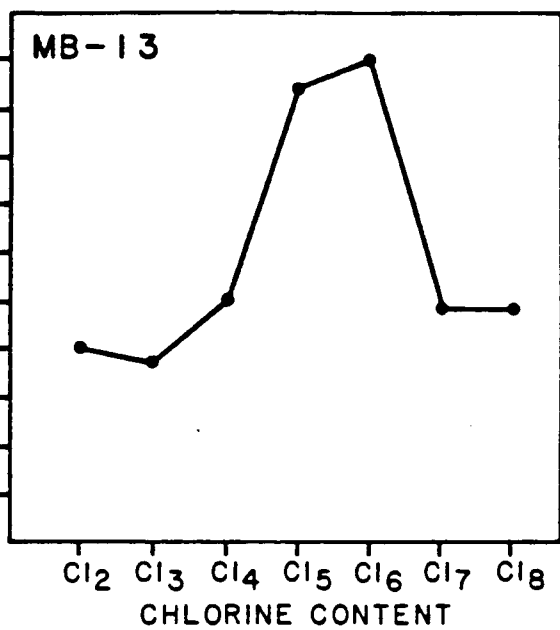
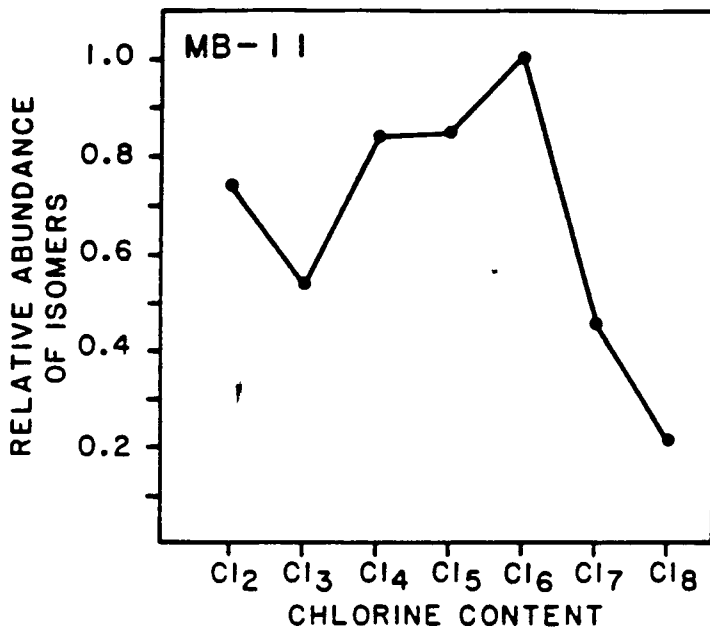
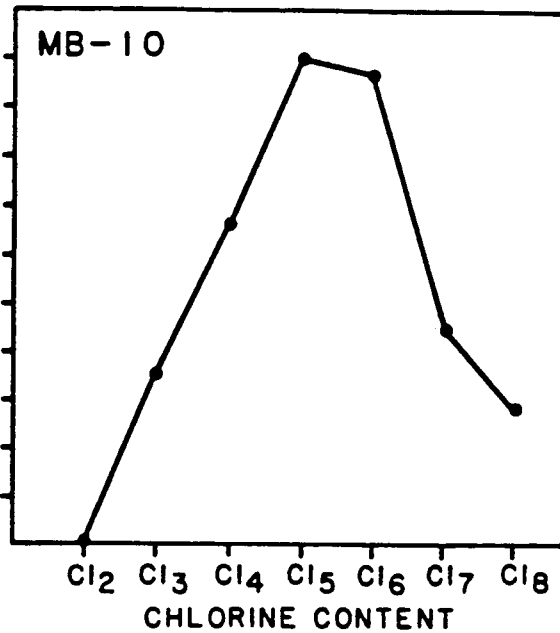
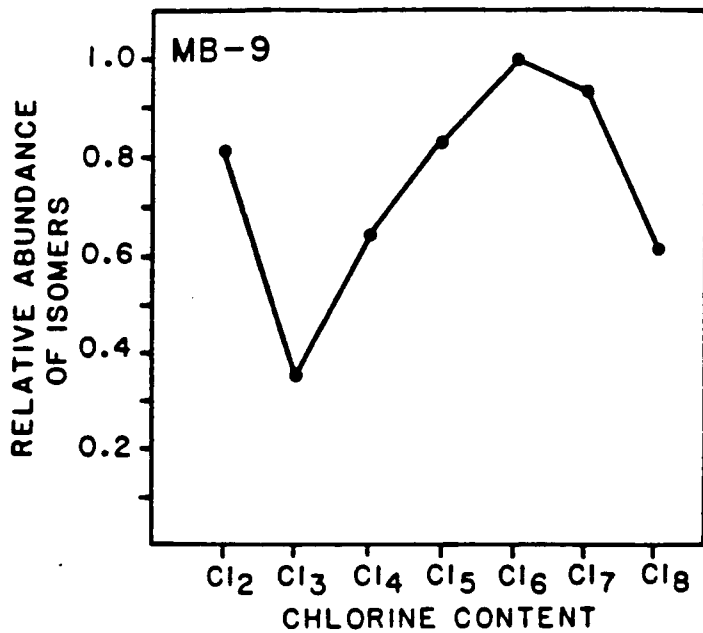


Figure 7. PCB Isomer Distributions for Region 3 Sediments.

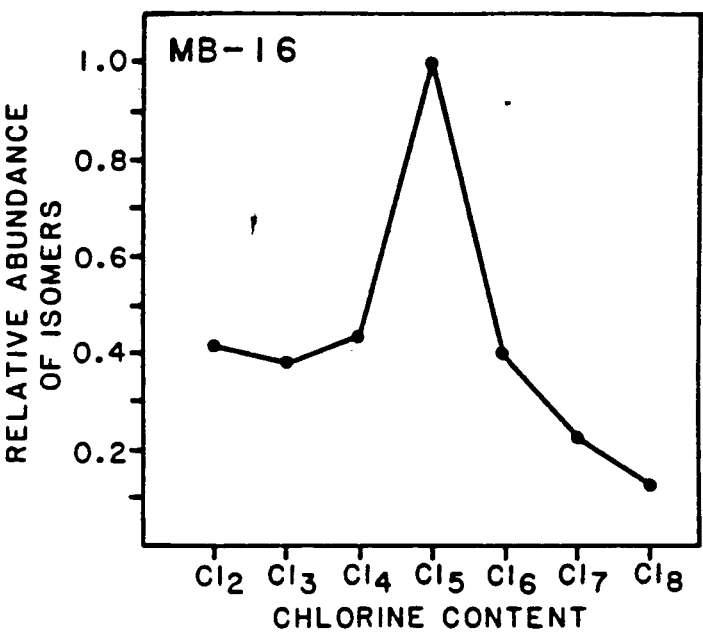
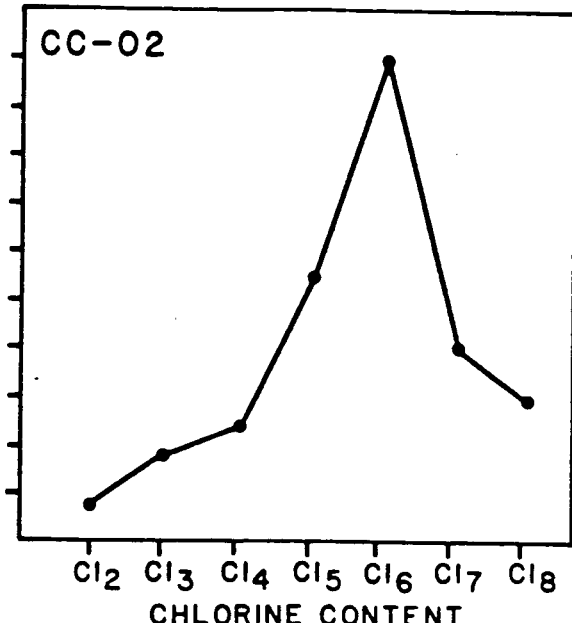
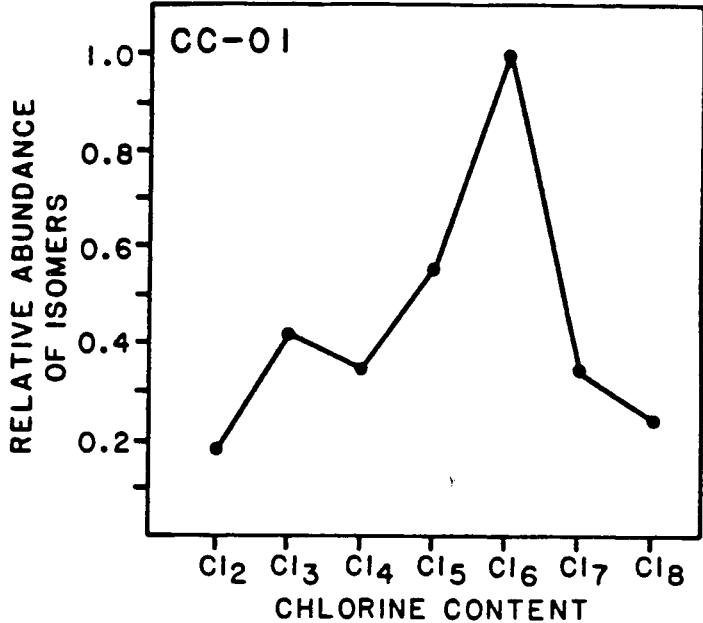


Figure 8. PCB Isomer Distributions for Region 4 Sediments.

TABLE 8. OTHER CHLORINATED HYDROCARBONS^a IN AREA SEDIMENTS

Sample Station:Replicate No.	DDT* (ng/g)
MBO7: Rep. 5	1.1
MB06: Rep. 4	1.0
BH02: Rep. 1	2.2
BH06: Rep. 4	1.8
BH04: Rep. 1	11.7
BH05: Rep. 3	2.5
MB01: Rep. 3	1.1

^aOther Compounds Searched for:

α BHC, β BHC, γ BHC(lindane), δ BHC, heptachlor, heptachlor epoxide, adrin, endosulfan I, dieldrin, endrin, endosulfan II, endosulfan sulfate (no corresponding peaks found for those samples).

* = KOH/MeOH saponification

The concentrations of total PAH outside of the harbor at station MB-1 are very high, 14.3 ug/g, thus supporting the PCB evidence that this is a true depositional site that receives harbor related pollutant inputs at high levels.

PAH values in Regions 2,3, and 4 are roughly the same with mean values 1.6, .96 and 1.0 ug/g respectively. Ranges of levels within each area vary similarly. Station MB-6 in Region 2 contains higher PAH levels, 3.5 ± 1.0 ug/g, probably owing to its proximity to the "foul area". In general, these PAH values are considerably higher (factor of 2.5) than levels encountered in known perturbed areas such as The Christiaennsen Basin in The New York Bight Apex where PAH values range from .07 to .7 ug/g (Boehm 1982; O'Connor et al 1982).

PAH/TOC ratios have been computed for each sample. The ratios are highest in Boston Harbor (Tables 2 and 6) and decrease offshore where the regional means of PAH/TOC (Table 6) are all approximately 0.1. Dilution of PAH, sourced in nearshore areas, by biogenic TOC is probably the cause of the lowering of this ratio as was the case for PCB/TOC values.

Of considerable value are the computed FFPI values. While detailed PAH data are presented in the data appendix, (Table A-2), the FFPI as developed by Boehm (1983a,b) summarizes the compositional data to yield an index which reflects the related input of fossil PAH (petroleum, coal combustion PAH (products of fossil fuel combustion; urban air particulates)). These distinctions are very important as petroleum PAH compounds are thought to be more readily available to marine organisms than higher molecular weight, combustion-related PAH. These compositional ratios vary at a given station less than do the absolute PAH values. (See Tables 2-6).

Spatial compositional variations are seen in Boston Harbor (Table 2) where FFPI values at BH-4 and BH-6 indicate primarily combustion PAH (FFPI=23 and 18) while the BH-2 and BH-5 compositions (FFPI=52 and 46) are equally split between the two basic types of PAH inputs.

In Region 2 we see primarily combustion PAH present (FFPI \approx 20) with the exception again being MB-6 and also MB-7 which contain 40% fossil PAH (FFPI=40).

The PAH composition in Region 3 is largely combustion-related (FFPI=20). However, the MB-10 station, in the Stellwagen Basin, is slightly enriched in fossil PAH. The Cape Cod Bay area, Region 4, needs further study due to enhanced PCB and fossil PAH levels (See Tables 5 and 6). In spite of similar total PAH values found at stations MB-16, CC-1, and CC-2 it is clear that fossil PAH (two and three ring compounds) are 6 times as important at CC-1 and CC-2 than they are at MB-16. The FFPI values at MB-16

are approximately 5 while values at the CC-1 and CC-2 stations are 30. Thus it is clear that a complete appraisal of PAH levels includes both a consideration of the total PAH and the FFPI (i.e., PAH composition).

3.1.3 Coprostanol

Concentrations of the sewage tracer, coprostanol, and of the Coprostanol/Total steroids and Coprostanol/PCB ratios are presented in Tables 2-6. Coprostanol levels in Boston Harbor are high 1-16ug/g. These levels are similar to those encountered in the 12 mile sewage sludge disposal site in New York Bight and to those in New Haven Harbor (Boehm, unpublished date). Coprostanol values are highest (15.9 ± 6.5 ug/g), at BH-2 the site of the extraordinarily high PAH levels.

Concentrations of coprostanol outside of the harbor decrease rapidly. Levels in Region 2 are highest at MB-6 and MB-8 (.34 and .45 ug/g respectively), but average 0.2 ug/g for the region. Levels are moderate, .05-.2ug/g, in the other regions, which compare with those in Buzzards Bay (Boehm, 1983c) and outside of the zone of dumping impact in the New York Bight Apex (Boehm, 1982).

The coprostanol/total steroid ratio, which indicates when the sterol composition of the sample approaches that for pure sewage sludge, is high in the Boston Harbor. Sewage sludge elsewhere (New York) has a ratio of 0.5-0.7 (not analyzed from the Boston Harbor sources) and it is quite reasonable to assume that the ratio would be similar in the study area. Values at BH-1 through BH-6 range from .21 to .42 indicating a large sewage-related impact. Values decrease offshore, (BH-7=0.15, MB-1=0.02) and remain low (.02 to .08 elsewhere) (and independent of absolute coprostanol values). Dilution of sewage related material by marine steroidal lipid inputs probably accounts for this change.

The Coprostanol/PCB ratio is an interesting and useful parameter in that it relates the presence of PCB to sewage-related material. The values will range from zero (no sewage) to approximately 200 (Boehm, 1982). Ratio values in the New York Bight sewage dumping area are routinely 100-200. The highest Coprostanol/PCB value is found in the study area at BH-2 (117), confirms the strong influence of sewage inputs at this station. Intermediate values of 30-60 are found elsewhere in the harbor. Note the BH-4 value is low (4.3). We see an interesting distribution of these values offshore. Intermediate values are found at MB-8, MB-9, MB-11, MB-14, MB-16 (~20) indicating significant sewage-related PCB transport far offshore!

3.2 Marine Animals

Three species of marine animals, an invertebrate Cancer borealis (Cancer crab), and two flatfish Pseudopleuronectes americanus (winter flounder), and Hippoglossoides plattesoides (American dab) were selected for analysis. Winter flounder and crabs were obtained nearshore while the dabs were obtained offshore.

3.2.1 PCB Concentrations and Compositions

PCB concentrations in these species at those stations where animals were obtained, are presented in Table 9 on wet weight (PCB-W) dry weight (PCB-D) and lipid weight (PCB-L) bases. Levels of PCB in the crabs are greater than those in winter flounder which are in turn higher than the dabs. On a wet weight basis, PCB-W levels in crabs ranged from .065 to .279 ppm. The FDA action limit of PCB-W concentrations is 2 ppm. Concentrations in crabs from Boston Harbor are approximately four times higher than those obtained in Massachusetts Bay and approximately twice those found in Cape Cod Bay. However, PCB-L values in Boston Harbor are only twice what they are in Cape Cod Bay, and similar to those found in Massachusetts Bay (Station MB-1).

The winter flounder PCB-W concentrations ranged from .065 to .135 ug/g, roughly half the crab levels. All of the samples examined came from the Boston Harbor area. The PCB concentration found further offshore at station MB-1 is lower than any of the Boston Harbor values. On a lipid weight basis, PCB-L concentrations were 5 to 10 times lower than those found in the crab samples. These PCB-L values are remarkably constant within the flounder set for all stations other than BH-1 which was twice as high.

PCB-W concentrations in the offshore dab were lowest of all the animals, ranging from .01 to .03 ug/g, with PCB-L values from 2.1 to 6.6 ug/g. These lipid weight values are 2.5 times lower than those found for the winter flounder.

PCB compositions, in terms of Aroclor matches (no individual isomedeterminations were performed on animals) are quite similar for the invertebrate and two fish species examined, with most of the PCB compounds in the tetrachlorobiphenyl (C14) to heptachlorobiphenyl (C17) range. This distribution of PCB isomers is distinctly "heavier" (i.e., more chlorine items) than distributions found in sediments.

TABLE 9 SUMMARY OF PCB DATA ON ANIMAL TISSUES

Species	Station	Total PCB Concentration			% Aroclor 1242	%Aroclor 1254	% Aroclor 1260
		Wet Weight basis (ug/g)	Dry Weight basis (ug/g)	Lipid Weight basis (ug/g)			
Cancer Crab (soft parts)	BH-2	.242	.982	200	16.8	57.7	25.5
	BH-5	.279	1.25	238	12.3	60.1	27.6
	BH-6	.235	.876	256	11.2	54.0	34.8
	MB-1	.065	.278	178	4.6	41.7	53.6
	CC-1	.143	.461	92	12.3	53.5	34.2
	CC-2	.140	.650	110	7.7	50.5	41.8
Winter Flounder (edible flesh)	BH-1	.135	.613	37	15.3	53.1	31.6
	BH-2 ^a	.0941+.009	.385+.035	18+1.6	17.9	53.9	28.2
	BH-5	.093	.377	17	15.4	55.0	29.3
	BH-6	.090	.353	15	15.5	56.0	28.5
	MB-1	.065	.116	14	15.0	54.0	27.5
Dab (edible flesh)	MB-3	.020	.098	5.8	6.1	64.8	29.1
	MB-4	.010	.045	2.1	15.8	47.4	36.8
	MB-6	.034	.131	6.6	9.2	58.8	31.9
	MB-10	.028	.116	5.6	9.5	54.2	36.3
	MB-13	.028	.134	6.2	15.9	56.3	27.8
	MB-14	.024	.116	5.8	10.0	58.3	31.7
	CC-2	.019	.084	3.6	13.9	61.1	25.0

^aTriplicate analyses performed

3.2.2 PAH Concentrations

Results of GC/MS analyses for PAH in animal tissues are presented in Tables 10, 11 and 12.

Significant PAH levels were found only in the cancer crabs. PAH concentrations in this species ranged from 7 to 460 ng/g dry weight. (To convert to wet weight or lipid weight bases, multiply by PCB factors shown in Table 9). PAH levels in Boston Harbor crabs are clearly much higher than those found outside of the harbor. Crabs from the MB-1 depositional area contain higher PAH levels (as well as higher PCB levels) than elsewhere offshore. Samples from Cape Cod Bay are nearly PAH-free with small quantities of the naphthalene compounds the major inputs. This contrasts with moderate PCB levels in the same samples.

Quantities of higher molecular weight PAH (i.e., 4 and 5 rings) are very low, compared with the relatively abundant naphthalene and phenanthrene homologues. Thus sediment and biotal PAH compositions are quite different.

PAH levels in winter flounder (Table 11) in Boston Harbor and elsewhere are very low, generally less than 10 ng/g at all stations.

The dab sample set also contain very low PAH levels with only trace ($\frac{1}{10}$ ng/g) amounts of PAH found in any of the dab samples (Table 12).

4. DISCUSSION

The organic contaminant data presented for surface sediments from the Massachusetts Bay area indicate that, on the basis of PCB and PAH concentrations, the area can be classified as at least as impacted as is the New York Bight Apex. This comparison is useful in that the Bight Apex has been studied extensively and has been shown (Mayer 1983) to be a degraded system. The comparison is summarized in Tables 13 and 14. Direct comparisons are difficult due to the differing natures of the two offshore areas: New York Bight is dominated by ocean dumping inputs plus fluxes from the estuary, while Massachusetts Bay is dominated by fluxes from the nearshore area. Also the data for New York Bight is quite variable due to heterogenous sediment types. However, it is clear from the comparisons shown in Tables 13 and 14 indicate that:

TABLE 10 PAH CONCENTRATIONS IN ANIMALS - CRABS (ng/g dry weight)

PAH Compounds	STATION					
	BH-2	BH-5	BH-6	MB-1	CC-1	CC-2
Naphthalene (N)	16	10	12	11	4	7
C ₁ N	2	44	7	3	nd	1
C ₂ N	31	28	9	15	1	1
C ₃ N	nd	nd	3	nd	nd	nd
C ₄ N	nd	nd	1	nd	nd	nd
Biphenyl	7	4	3	4	1	3
Fluorene (F)	nd	1	1	nd	nd	nd
C ₁ F	nd	8	nd	nd	nd	nd
C ₂ F	nd	13	nd	nd	nd	nd
C ₃ F	nd	4	nd	nd	nd	nd
Phenanthrene (P)	5	25	30	3	1	4
C ₁ P	1	9	17	nd	nd	nd
C ₂ P	nd	5	9	nd	nd	nd
C ₃ P	83	280	nd	nd	nd	nd
C ₄ P	nd	nd	nd	nd	nd	nd
DBT (Dibenzothiophene)	nd	<1	1	nd	nd	nd
C ₁ DBT	nd	6	1	nd	nd	nd
C ₂ DBT	nd	4	nd	nd	nd	nd
C ₃ DBT	nd	3	nd	nd	nd	nd
Flouranthrene	nd	2	6	nd	nd	nd
Pyrene	nd	11	11	nd	nd	nd
Benzanthraocene	nd	nd	nd	2	nd	nd
Chrysene	nd	nd	nd	<1	nd	nd
Benzofluoranthene	nd	11	11	nd	nd	nd
Benzo(e)pyrene	nd	nd	nd	1	nd	nd
Benzo(a)pyrene	nd	nd	nd	22	nd	nd
Total PAH:	145	457	111	61	7	16

nd = less than 1ng/g

TABLE 11 PAH CONCENTRATIONS IN ANIMALS - WINTER FLOUNDER (ng/g dry weight)

PAH Compounds	STATION					
	BH-1	BH-2	BH-3	BH-5	BH-6	MB-1
Naphthalene (N)	3	1	nd	nd	nd	nd
C ₁ N	nd	nd	nd	nd	nd	nd
C ₂ N	nd	nd	nd	nd	nd	nd
C ₃ N	nd	nd	nd	nd	nd	nd
C ₄ N	nd	nd	nd	nd	nd	nd
Biphenyl	nd	2	nd	nd	1	2
Fluorene (F)	nd	nd	nd	nd	nd	nd
C ₁ F	nd	nd	nd	nd	nd	nd
C ₂ F	nd	nd	nd	nd	nd	nd
C ₃ F	nd	nd	nd	nd	nd	nd
Phenanthrene (P)	1	1	1	nd	1	8
C ₁ P	nd	nd	nd	nd	nd	nd
C ₂ P	nd	nd	nd	nd	nd	nd
C ₃ P	nd	nd	nd	nd	nd	nd
C ₄ P	nd	nd	nd	nd	nd	nd
DBT (Dibenzothiophene)	nd	nd	nd	nd	nd	8
C ₁ DBT	nd	nd	nd	nd	nd	nd
C ₂ DBT	nd	nd	nd	nd	nd	nd
C ₃ DBT	nd	nd	nd	nd	nd	nd
Flouranthrene	1	nd	nd	nd	nd	8
Pyrene	nd	nd	nd	nd	nd	nd
Benzanthraocene	nd	nd	nd	nd	nd	8
Chrysene	nd	nd	nd	nd	nd	nd
Benzo(a)fluoranthene	nd	nd	nd	nd	nd	8
Benzo(e)pyrene	nd	nd	nd	nd	nd	nd
Benzo(a)pyrene	nd	nd	nd	nd	nd	nd
Total PAH	5	4	1	nd	2	10

nd = less than 1ng/g

TABLE 12 PAH CONCENTRATIONS IN ANIMALS - DABS (ng/g dry weight)

PAH Compounds	STATION					
	MB-3	MB-4	MB-6	MB-10	MB-13	MB-14
Naphthalene (N)	3	nd	nd	2	nd	5
C ₁ N	nd	nd	nd	nd	nd	nd
C ₂ N	nd	nd	nd	nd	nd	nd
C ₃ N	nd	nd	nd	nd	nd	nd
C ₄ N	nd	nd	nd	nd	nd	nd
Biphenyl	1	nd	nd	nd	nd	1
Fluorene (F)	nd	nd	nd	nd	nd	nd
C ₁ F	nd	nd	nd	nd	nd	nd
C ₂ F	nd	nd	nd	nd	nd	nd
C ₃ F	nd	nd	nd	nd	nd	nd
Phenanthrene (P)	6	nd	nd	nd	1	nd
C ₁ P	2	nd	nd	nd	nd	nd
C ₂ P	nd	nd	nd	nd	nd	nd
C ₃ P	nd	nd	nd	nd	nd	nd
C ₄ P	nd	nd	nd	nd	nd	nd
DBT (Dibenzothiophene)	nd	nd	nd	nd	nd	nd
C ₁ DBT	nd	nd	nd	nd	nd	nd
C ₂ DBT	nd	nd	nd	nd	nd	nd
C ₃ DBT	nd	nd	nd	nd	nd	nd
Flouranthrene	nd	nd	nd	nd	nd	nd
Pyrene	nd	nd	nd	nd	nd	nd
Benzanthracene	nd	nd	nd	nd	1	nd
Chrysene	nd	nd	nd	nd	nd	nd
Benzofluoranthene	nd	nd	nd	nd	nd	nd
Benzo(e)pyrene	nd	nd	nd	nd	nd	nd
Benzo(a)pyrene	nd	nd	nd	nd	nd	nd
Total PAH	12	nd	nd	2	1	6

nd = less than 1ng/g

- 1) Although the absolute concentrations of PCB and PAH are greater in the dumpsites and adjacent depositional areas in the New York Bight, the total mass of PCB and PAH is far greater in Massachusetts Bay, perhaps by a factor of 5, than in New York Bight, with elevated PCB and PAH concentrations found over a much greater area than in the New York Bight.
- 2) On an equivalent area basis the PAH concentrations (per km²) in both areas are similar, while the PCBs are apparently much greater in Massachusetts Bay.

Other comparative summaries are presented in Tables 15 and 16.

Sewage related sources constitute the major input of PAH and PCB to the sediments of the study area. While the pollutant levels in the Boston Harbor proper are for the most part "typical" of heavily polluted harbors elsewhere, the offshore area contains a greater mass of organic pollutants than in other studied areas on the east coast.

The implication of these elevated levels is not clear. Levels of PCB and PAH in finfish in the area are quite low. However, levels in cancer crabs are much higher, but still an order of magnitude lower than FDA action levels.

The important impacts may be found in examining benthic community structure and health. Indeed preliminary results of a composition benthic ecology study (Larsen, personal communication) suggest that community structures in several offshore areas suggest a highly degraded benthic habitat. In any event the magnitude of the chemical impact illustrated by the data presented here may indicate that the Massachusetts Bay benthic ecosystem is being exposed to high levels of toxic organics.

The wide area extent of organic pollutant contamination is striking and strongly argues for continued, statistically designed, monitoring at selected stations in the area and the study of transport of these materials further offshore. The latter concern is addressed in Part 2 of this study.

TABLE 13 COMPARATIVE PCB BUDGETS - MASSACHUSETTS BAY vs. NEW YORK BIGHT APEX

	ng/g dry weight	ng/cm ³	ng/cm ² ^b	g/km ²	Areas (km ²)	kg PCB
<u>New York Bight Apex^a</u>						
Dredged Material Dumpsite	200	400	800	8000	6	48
Sewage Sludge Dumpsite	200	400	800	8000	16	128
Christianensen Basin	30	60	120	1200	130	156
Outer Bight Apex	1.0	2.0	4.0	40	850	34
Total PCB (kg) =						366
kgPCB /km² =						.37
<u>Massachusetts Bay^c</u>						
Region 2	31	62	124	1240	2310	2864
Region 3	10	20	40	400	1810	724
Total PCB (kg) =						3588
kgPCB /km² =						.87

a-Data Sources = Boehm, 1982; Boehm, et al., 1984; MacLeod et al., 1981; O'Connor et al., 1982; Part 2 of this study

b-2cm thick

c-See Table 6

TABLE 14 COMPARATIVE PAH BUDGETS: MASSACHUSETTS BAY vs. NEW YORK BIGHT APEX

	ng/g	ng/cm ³	ng/cm ²	g/km ²	km ²	kg PAH
<u>New York Bight Apex^a</u>						
Dredged Material Dumpsite	5000	10000	20000	200,000	6	1200
Sewage Sludge Dumpsite	3000	6000	12000	120,000	16	1920
Christianensen Basin	10000	20000	40000	400,000	130	52,000
Outer Bight	100	200	400	4000	850	3,400
				Total PAH (kg)=		58520
				kg PAH/km ² =		58.5
<u>Massachusetts Bay^c</u>						
Region 2	1600	3200	6400	6400	2310	148,000
Region 3	960	1920	3840	38400	1810	69,500
				Total PAH (kg)=		217500
				kg PAH/km ² =		52.8

a-Data source Boehm 1982; Boehm et al., 1984; MacLeod et al., 1981; O'Connor et al., 1982; Part 2 of this study

b-2cm thick

c-See Table 6

TABLE 15 REPORTED PCB CONCENTRATIONS IN OTHER U.S. NEARSHORE AND MARINE SEDIMENTS

LOCATION	CONCENTRATION (ppm)	REFERENCE
New Bedford Harbor		
Upper Acushnet River	up to 1,000	Farrington (unpublished)
Inner Harbor	3-100	Mass. DEQE (1980, unpublished) Farrington (unpublished)
Outer Harbor	0.3-78	US EPA (1980, unpublished) Farrington, (unpublished)
Buzzards Bay	.01-0.54	SMU (1980, unpublished) Boehm (1983b,c)
Boston Harbor		
Sewage Solids (MDC) Region 1 Sediments	20-30 0.14	Gilbert et al., (1976) (This study)
Massachusetts Bay		
Nearshore	.015-.030	Gilbert et al., (1976)
Offshore Region 2 Region 3	.001-.020 .031 .010	Gilbert et al., (1976) (This study) (This study)
Chesapeake Bay	.004-0.4	Sayler et al., (1978)
Gulf of Mexico	.0002-.035	US EPA, (1976)
Escambia Bay (Fla.)	ND-8	US EPA, (1976)
Coastal California (depending on distance from Los Angeles discharges)	.5-7	Young et al., (1977)
Offshore Continental Shelf (east coast)	.3-8	Boehm (1983b)

**TABLE 16 REPORTED PCB CONCENTRATIONS IN NEW YORK BIGHT REGION
SEDIMENTS**

LOCATION	CONCENTRATION (ppm)	REFERENCE
Hudson River	0.5-140	Bopp et al., 1981
Upper Bay	0.13 0.40	MacLeod et al., 1981 Boehm, 1981
Lower Bay	0.7	MacLeod et al., 1981
Newark Bay	1.6	Boehm 1981b
Arthur Kill Region	2-3 0.32 (dredged area) -1.1	MacLeod et al., 1981 Boehm 1981
Raritan Bay	0.4-0.5 0.27	MacLeod et al., 1981 Boehm 1981
Christiaensen Basis	1.3-1.5 0.05-0.15 0.1-0.3	MacLeod et al., 1981 Boehm, 1982 West and Hatcher, 1980
New York Bight (non-dumpsite)	ND-.01 0.002-0.01	Boehm, 1982 West and Hatcher, 1981
Dredge Spoils (Metropolitan N.Y.)	0.4-3.5 3.7-6.9	MacLeod et al., 1981 Boehm and Fiest, 1983
Sewage Sludge (Metropolitan N.Y.)	3.5 6.4	Bopp et al., 1981 West and Hatcher, 1980
Sewage Sludge Deposit (New York Bight)	0.4 0.06-0.2 1.5-2.2	Boehm, 1982 " " West and Hatcher, 1980
Dredge Spoil Deposit (New York Bight)	0.003-.28 0.003 0.4	Boehm, 1982 " " West and Hatcher, 1980

ND = None Detected.

PART II:
**ORGANIC GEOCHEMICAL STUDIES IN THE HUDSON CANYON
AND GULF OF MAINE AREAS**

1. INTRODUCTION

As part of our continuing series of investigations on organic pollutant biogeochemistry of offshore benthic habitats, a study of pollutant levels in deeper offshore areas off the northeastern U.S. coast were undertaken.

The Hudson Valley and Canyon area geographically link the degraded benthic environment of the New York Bight Apex with the deep sea. In order to investigate organic pollutant gradients between the Bight and the deeper shelf-slope area, a detailed study was undertaken involving sampling and analysis of sediments from the area. Although data on sedimentary organic pollutants is abundant from the N.Y. Bight proper, there is little data addressing potential transport of pollutants further offshore.

Work by Farrington and Tripp (1977) on hydrocarbon levels represent the only published work addressing these deeper sediments.

Similarly, the transport of organic pollutants to the depositional basins of the Gulf of Maine has been investigated by Laflamme and Hites (1978) and Windsor and Hites (1979). These authors reported PAH values from three stations in the Wilkinson Basin region, one from the Franklin Basin and one from the Jordan Basin from samples collected from 1975-1977. Levels of total PAH (3-6 rings) ranged from 200 to 900 ng/g (dry weight).

This phase of our work is essentially an update of Gulf of Marine PAH levels, four to six years later and represents the first reported values of PAH, PCB and coprostanol from the Hudson Canyon and first reported PCB and coprostanol values from the Gulf of Maine.

2. METHODS AND MATERIALS

Twenty-three (23) stations in the New York Bight, Hudson Valley, Hudson Canyon region were occupied in August, 1981, or September, 1983. Surface sediment samples (0-30cm) were obtained using a modified Van Veen grab sampler. Ten (10) stations were occupied in December, 1981, in the Gulf of Maine. Station locations are presented in Figures 1 and 2 and are detailed in Table 1.

TABLE 1 STATION LOCATIONS

SITE	STATION NO.	STATION COORDINATES		DEPTH (m)
		LATITUDE	LONGITUDE	
New York Bight	NY6	40°25.0'	73°46.0'	49
	NY7	40°25.0'	73°46.0'	24
	NY40	40°24.9'	73°49.9'	29
	A71	40°13.4'	73°45.9'	64
	A82	40°08.0'	73°37.7'	73
	NY14	39°49.3'	73°01.5'	75
	NY30	40°14.8'	73°25.1'	37
Hudson Valley and Canyon	150	39°45.2'	72°39.5'	70
	153	39°47.2'	72°49.0'	70
	144	39°42.0'	72°31.2'	82
	122	39°23.6'	72°14.1'	338
	123	39°24.0'	72°19.0'	150
	126	39°28.5'	72°15.3'	897
	120	39°29.2'	72°08.5'	357
	129	39°32.4'	72°11.5'	152
	131	39°30.5'	72°19.7'	670
	136	39°35.6'	72°24.5'	278
	138	39°40.5'	72°21.2'	110
	141	39°39.6'	72°27.5'	212
	175	39°40.4'	72°28.3'	190
	174	39°55.0'	73°09.0'	70
143	39°40.7'	72°29.3'	130	
Gulf of Maine	568	42°57'	69°54'	232
	585	42°45'	69°51'	228
	503	42°25'	70°00'	192
	505	42°25'	69°45'	276
	OP79	42°46'	69°19'	71
	509	42°25'	69°18'	258
	511	42°25'	69°03'	205
	521	42°25'	67°54'	196
	529	42°25'	67°06'	368
	579	42°04'	60°39'	220

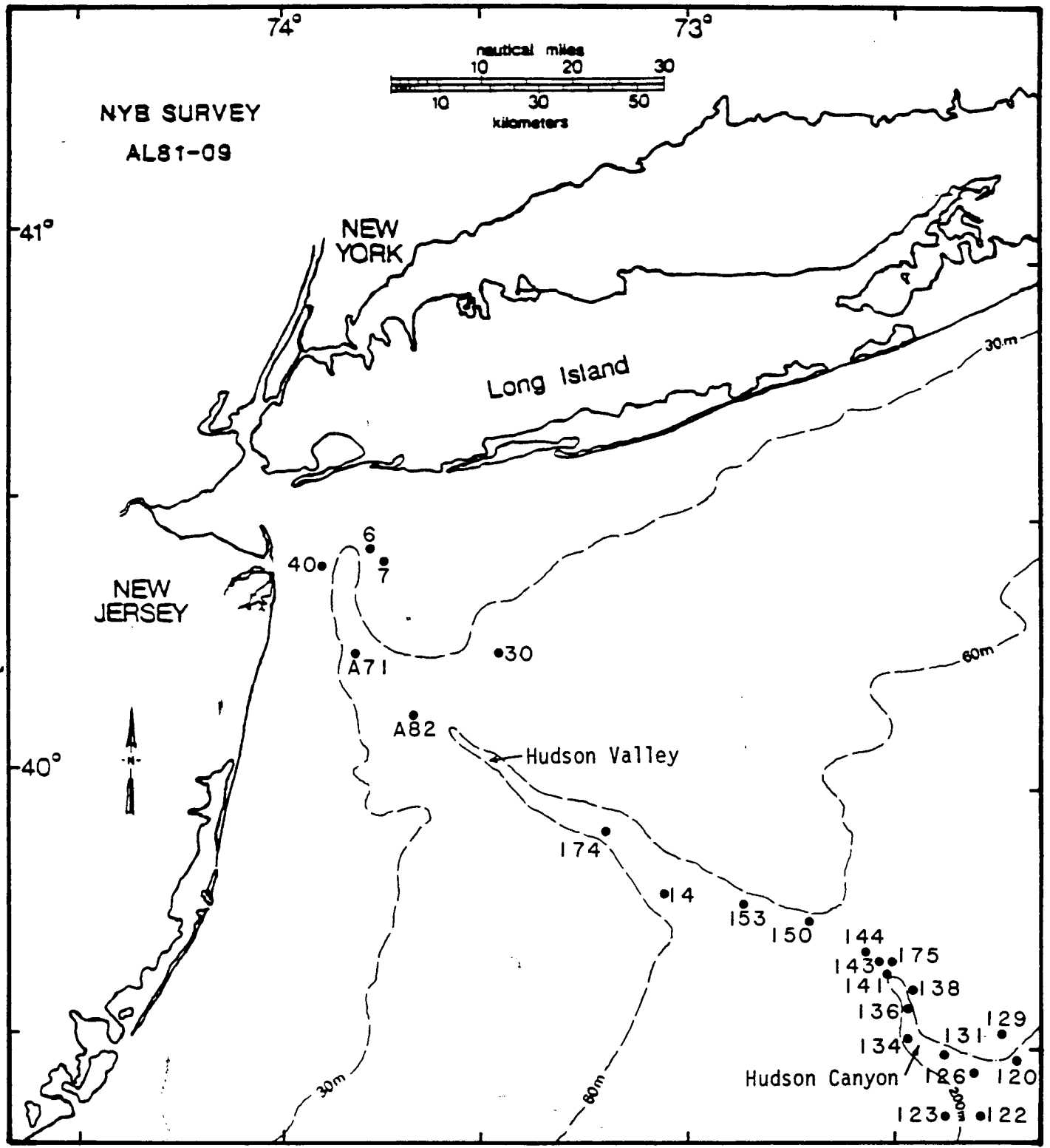


Figure 1. Sampling Stations in the New York Bight, Hudson Valley, and Hudson Canyon Area.

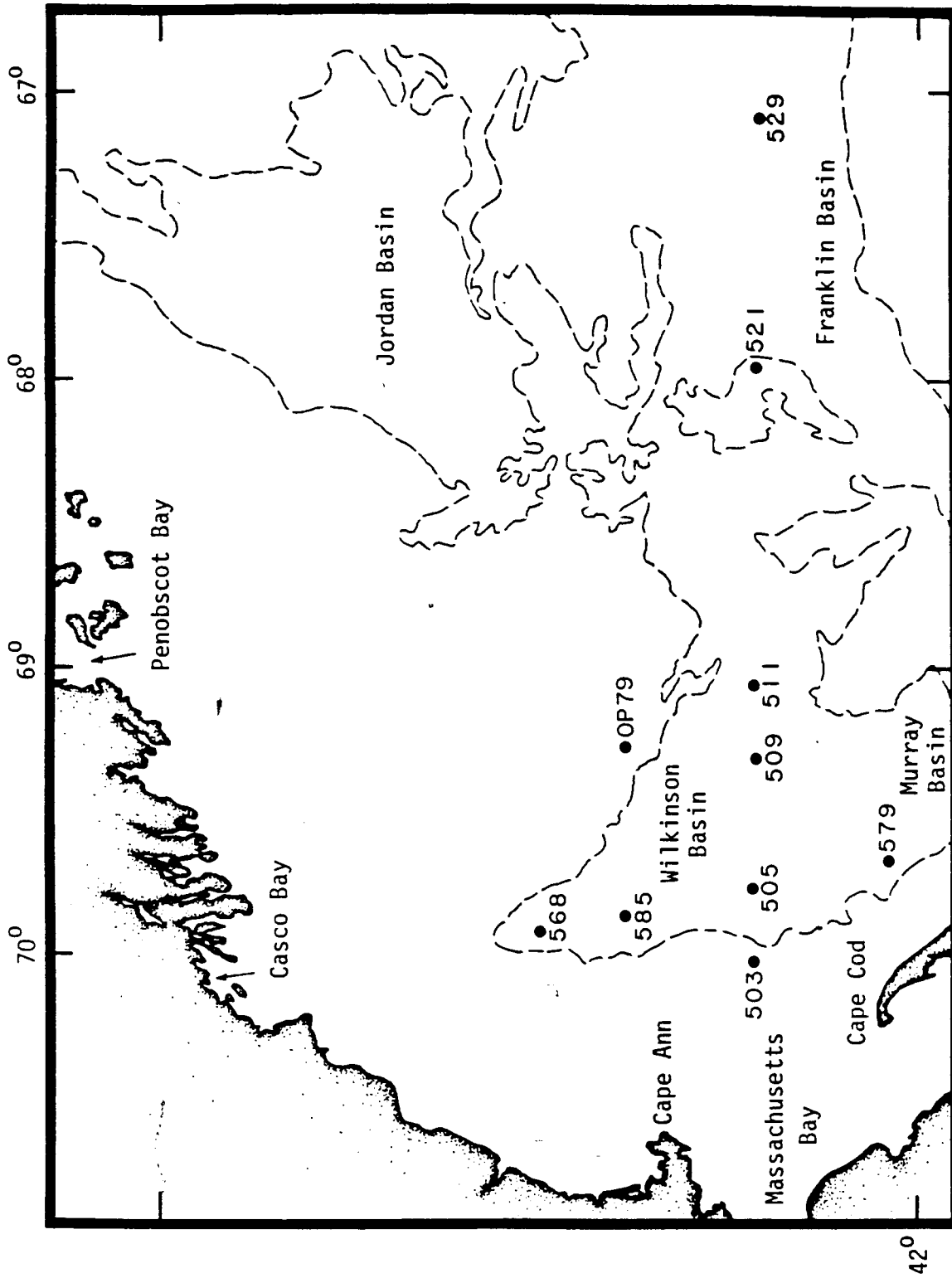


Figure 2. Sampling Stations in the Gulf of Maine.

Sample handling and analytical procedures for PAH, PCB and coprostanol were identical to those presented in Part 1 of this report.

3. RESULTS

Concentrations of PCB, PAH and coprostanol in sediments from the New York Bight/Hudson Canyon transect and Gulf of Maine area are presented in Tables 2 and 3 respectively.

In the New York Bight/Hudson Canyon sample set a general decrease in pollutant concentrations with distance offshore is revealed (Table 2). However, beginning at station 175, at about 200m depth and continuing through station 123, higher than expected PAH and PCB levels are encountered. Station 131 appears to lie at the center of an area exhibiting higher PAH, PCB and total sterol values. PAH values reach 900 ng/g at station 131 which are similar values to those encountered at station A82, approximately 70 nautical miles closer to the pollutant sources.

The FFPI values indicate that petrogenic PAH sources have contributed to these elevated PAH levels. After decreasing to FFPI values <10, indicating a predominantly combustion PAH assemblage, stations 138, 134, and 122 exhibit a significant increase in FFPI values.

Coprostanol levels in heavily sewage sludge-impacted areas (stations NY6 and NY7) are very high ranging from 25-60 ppm. The distinction between the sewage-impacted areas and the dredged material-impacted area, NY40, is clearly revealed by the coprostanol values. At NY40, despite very high PAH values equivalent to those at NY7, and despite PCB values within a factor of two of the NY7 values, the low coprostanol values (1.5ppm) indicate that the PAH and PCB compound concentration at NY40 are due to mixed contaminated harbor dredgings, not sewage sludge.

Although total sterol values are seen to increase markedly at the depositional area at about 200m (i.e., stations 138 to 131). Coprostanol values do not covary with this and remain low. The ratio of coprostanol to total sterols, an indicator of sewage contribution to the total sterols is high at stations NY6 and NY7, (.4-.5) but remains very low down the valley-canyon transect, indicating that the deposition of material at 200m is largely due to non-sewage related sources.

Data from sediments of the Gulf of Maine (Table 3) show that PCB concentrations range narrowly from 4-11 ng/g. The one exception is at station OP79, a topographical high (see Table 1). These PCB values are similar to those found at stations

TABLE 2 ANALYTICAL RESULTS FROM THE NEW YORK BIGHT-HUDSON VALLEY HUDSON CANYON AREA

STATION	TOTAL PCB (ng/g)	TOTAL PAH (ng/g)	FFPI	COPROSTANOL (ug/g)	TOTAL STEROLS (ug/g)	COP/TOTAL STEROIDS	COPROSTANOL PCB
NY 6	110	3100	59	25.7	59.7	.43	230
NY 7	150	42000	71	66.3	140	.46	440
NY 40	77.2	46000	27	1.5	8.8	.18	19
A 71	98.6	1920	19	.80	8.2	.10	8
A82	57±1.0	1310±84	23±7.9	.93±.09	14.6±1.3	.06	16
NY30	3.0	<10	-	<.01	.54	-	-
174	7.7	95	12	.049	2.9	.02	6
NY14	3.8	45	7	.023	1.8	.01	9
153	4.0	53	18	.037	3.8	.01	9
150	3.8	80	8	.029	2.1	.01	8
144	1.4	21	7	.038	2.4	.02	27
143	1.9	15	7	.01	0.5	.02	0.5
175	5.2	150	9	<.01	2.9	-	-
141	2.8	34	9	.03	2.4	.01	11
138	14.	280	14	.07	6.7	.01	5
136	6.1	160	10	.05	6.9	.01	8
134	9.3	480	15	.15	16	.01	16
131	13	900	22	.10	7.0	.01	8
123	5.1	120	11	.059	3.0	.02	12
126	4.4	53	9	<.01	2.0	-	-
122	3.3	59	10	.010	1.5	.01	3
120	2.9	52	11	.025	1.6	.02	9
129	1.8	15	17	<.01	0.5	-	-

TABLE 3 ANALYTICAL RESULTS FROM THE GULF OF MAINE

STATION	TOTAL PCB (ng/g)	TOTAL PAH (ng/g)	FFPI	COPROSTANOL (ug/g)	TOTAL STEROLS (ug/g)	COP/TOTAL STEROLS	COP/PCB
568	5.1	240	7	.09	1.7	.05	18
585	4.4	140	9	.04	3.9	.01	9
503	8.4	360	10	.24	7.0	.03	29
505	11.0	240	11	.09	3.4	.03	8
OP79	1.4	<10	-	<.01	0.3	-	-
509	7.1	270	11	<.01	2.0	-	-
511	4.9	44	14	.03	3.8	.01	6
521	4.3	110	5	<.01	1.1	-	-
529	6.7	84	25	.06	2.8	.02	9
579	7.1	240	12	.10	2.7	.04	14

MB-9, MB-11 and MB-13 (see Part 1 of this report) in Massachusetts Bay. The highest PCB value was found at station 505 in the Wilkinson Basin.

Levels of total PAH compounds ranged from 40 to 360 ng/g the sole exception being station OP79 (PAH < 10ng/g). The mean PAH value in the Gulf of Maine was 190 ± 103 ng/g excluding station OP79. These values are somewhat lower than those PAH values reported by Windsor and Hiles (1979). (440 ± 330 for four stations).

However, Winsor and Hites found that two of their four stations contained 200ng/g of PAH, similar to the above values. No statistical comparisons are possible as no replication was performed on our or their data sets.

PAH compositional data, summarized via the FFPI value in Table 3 indicate that the Gulf of Maine PAH compounds are almost solely of a combustion origin. The FFPI value of 25 for station 529 indicates a minor petrogenic imprint on the overall PAH assemblage.

Coprostanol and coprostanol/total sterol values indicate that sewage-related material has been transported to these depositional basins. Station 503, the closest to the Massachusetts Bay area contains the highest (.24 ug/g) value, similar to those in depositional areas in Massachusetts Bay. That station 503 is indeed depositional is reflected also by the elevated total sterol value (Table 3).

The higher coprostanol/PCB values (14-29) found at stations 579, 568 and 503 signify that the PCB at those stations, although in low concentrations, may be sourced in sewage related particulates transported offshore. Such values for this ratio, greater than 10 are typical for contaminated Boston Harbor sediments and those in other depositional sites in the nearshore region.

4. DISCUSSION

The analytical results presented above indicate that the pollutant organic compounds introduced in the coastal regions of Massachusetts Bay and the New York Bight are transported considerable distances offshore. Contaminants reside in deeper depositional areas represented by the Hudson Canyon depositional area beyond the shelf break near 200m and the Wilkinson Basin the the Gulf of Maine. Transport mechanisms to these deeper regions are uncertain, but may involve gross slumping of sediment material from further up the Hudson Valley or quiescent net deposition at this site. Stanley and Freeland (1978) noted that a "mud line" signifying the seperation of energy zones in the Canyon occurred, below 130m depth. This mud line recorded a depth below which the

threshold current velocities needed to erode fine sediment decreased in intensity and frequency. Thus the elevated PAH and PCB concentrations reflect this net deposition of land-sourced pollutants in the Canyon. The slightly elevated coprostanol levels suggest a weak sewage component to this deposited material, but for the most part other inputs (i.e., dredged material transport) appear as likely especially when one views the PAH/Coprostanol ratio. This ratio is apparently 0.1-1.0 in sewage-impacted areas in the Bight Apex, but is approximately 30 where dredged material dominates. At the shelf break depositional site the ratio is 5-10.

Sewage-related inputs to deeper areas seem more important in the Gulf of Maine where PAH/Coprostanol ratio in the Wilkinson Basin area (station 503 and 505) is about 1-3 and where coprostanol/PCB equals 29. However, the low coprostanol/total steroid ratio suggests that higher PAH and PCB in the Wilkinson Basin may be merely due to the fact that more high organic material accululates at this site along with associated pollutants. Thus the source for the elevated PCB and PAH is the basins in not clear. Windsor and Hites (1979) have suggested that urban air particulates deposit on the ocean's surface and eventually reside in these basins.

It is clear, however, that long range transport of organic pollutants is occurring in these deeper offshore areas. As coastal pollutant inputs change the impacts on these offshore depositional areas needs to be monitored. It appears that PAH levels have been relatively stable in the Gulf of Maine over the period of 1975-1981. However, temporal changes in PCB loadings are unknown. Further periodic assessment of the state of pollutant contamination of these offshore depositional areas should be undertaken.

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DATA APPENDICES

TABLE A-1 DATA ON INDIVIDUAL SEDIMENT REPLICATES FOR PCB, TOTAL PAH AND TOC

Station	Replicate No.	PAH($\mu\text{g/g}$)	PAH($\mu\text{g/g}$) $\bar{X} \pm S$	FFPI	FFPI $\bar{X} \pm S$	PCB(ng/g)	PCB $\bar{X} \pm S$	Coprostanol ($\mu\text{g/g}$)	Coprostanol $\bar{X} \pm S$	TOC(mg/g)
CC-1	1	1.2	1.0 ± 0.4	37.0	37.0 ± 5.4	28.0	31.3 ± 4.0	.06	$.08 \pm .05$	2.13
	2	1.5		30.0		37.7		.17		2.87
	3	0.6		36.0		28.1		.08		1.05
	4	1.2		45.0		30.9		.06		2.34
	5	0.6		39.0		31.8		.05		2.37
CC-2	1	8.6	1.4 ± 0.1	87.0	48 ± 9.7	31.6	26.9 ± 4.0	.09	$.10 \pm .05$	1.68
	2	1.4		61.0		30.7		.08		1.48
	3	1.3		40.0		24.6		.19		1.50
	4	1.5		49.0		22.6		.10		1.60
	5	1.4		41.0		24.9		.05		1.56
MB-1	1	7.8	14.3 ± 10.8	31.2	31.3 ± 3.8	42.9	39.3 ± 23.9	.13	$.18 \pm .17$	0.86
	2	10.8		29.7		27.9		.05		0.67
	3	7.2		35.2		79.4		.48		1.62
	4	33.3		35.0		20.6		.08		0.33
	5	12.2		25.2		25.8		.14		0.89
MB-4	1	4.0	2.3 ± 1.1	21.5	20.1 ± 1.5	32.1	21.0 ± 7.9	.22	$.14 \pm .05$	2.02
	2	2.4		21.7		21.0		.15		-
	3	1.3		18.7		24.6		.09		1.33
	4	1.6		18.8		12.2		.12		1.21
	5	2.3		19.5		15.3		.12		1.48
MB-5	1	0.5	0.6 ± 0.2	16.6	16.4 ± 1.9	5.9	4.6 ± 1.2	.04	$.03 \pm .02$	1.37
	2	1.0		16.3		5.3		.05		1.35
	3	0.7		14.0		4.0		.04		1.19
	4	0.6		15.9		5.0		.04		1.02
	5	0.4		19.4		2.9		.01		0.90
MB-6	1	2.0	3.5 ± 1.0	25.3	37.7 ± 7.9	64.5	82.9 ± 16.0	.21	$.34 \pm .10$	2.38
	2	3.7		41.7		84.2		.31		2.64
	3	3.2		34.6		75.4		.47		2.48
	4	4.7		43.6		108.		.40		2.65
	5	3.8		43.4		82.4		.31		2.40
MB-7	1	1.1	1.3 ± 0.3	41.7	3.2 ± 6.2	23.3	24.7 ± 11.2	.03	$.06 \pm .05$	2.02
	2	0.8		30.0		23.8		.14		2.13
	3	1.3		25.0		8.1		.01		2.08
	4	1.6		31.0		27.8		.07		2.03
	5	1.6		30.4		39.4		.04		1.95
MB-8	1	0.2	0.3 ± 0.2	8.4	8.7 ± 5.4	27.4	23.4 ± 4.4	.48	$.45 \pm .07$	2.53
	2	0.3		10.3		16.7		.42		2.47
	3	0.2		-		21.4		.40		2.35
	4	0.3		9.6		26.9		.39		2.37
	5	0.6		15.0		24.4		.24		2.30

TABLE A-1 DATA ON INDIVIDUAL SEDIMENT REPLICATES FOR PCB, TOTAL PAH AND TOC (continued)

Station	Replicate No.	PAH($\mu\text{g/g}$)	PAH($\mu\text{g/g}$) $\bar{X} \pm S$	FFPI	FFPI $\bar{X} \pm S$	PCB(ng/g)	PCB $\bar{X} \pm S$	Coprostanol ($\mu\text{g/g}$)	Coprostanol $\bar{X} \pm S$	TOC(mg/g)
MB-9	1	0.3	0.2 ± 0.1	21.2	15.9 ± 6.6	3.1	2.3 ± 0.7	.05	$.045 \pm .016$	0.12
	2	0.1		14.3		1.5		.02		0.53
	3	0.3		24.3		3.0		.07		0.39
	4	0.1		9.3		1.9		.05		0.35
	5	0.1		10.6		1.9		.04		0.18
MB-10	1	1.4	$1.5 \pm .1$	28.0	25.6 ± 5.0	22.7	26.5 ± 5.6	.11	$.11 \pm .05$	1.79
	2	1.4		30.3		20.8		.10		1.75
	3	1.7		29.0		27.7		.16		1.82
	4	1.4		22.0		25.4		.04		1.52
	5A	1.5		13.5		36.4		.11		1.64
	5B	1.3		19.2		22.0		.25		-
	5C	1.4		23.0		30.7		.06		-
MB-11	1	1.7	1.9 ± 0.1	15.8	17.8 ± 1.4	4.2	7.0 ± 2.1	.08	$.12 \pm .05$	0.77
	2	1.8		17.8		7.8		.12		1.10
	3	2.1		19.5		6.8		.08		0.93
	4	1.9		18.9		6.3		.20		0.92
	5	1.8		17.4		9.9		.14		1.06
MB-13	1	0.4	0.5 ± 0.1	15.6	14.1 ± 5.0	6.3	$6.7 \pm .78$	0.10	$.13 \pm .02$	0.62
	2	0.3		5.8		5.9		.13		0.65
	3	0.6		16.7		7.9		.13		0.58
	4	0.6		18.8		6.3		.13		0.74
	5	0.5		13.5		6.8		.15		0.65
MB-14	1	1.0	0.7 ± 0.2	17.8	15.8 ± 1.4	11.7	10.3 ± 1.0	.26	$.19 \pm .05$	1.01
	2	0.6		14.7		10.8		.16		1.02
	3	0.7		14.1		10.3		.19		.88
	4	0.7		16.3		9.4		.21		.87
	5	0.6		15.9		9.1		.13		.85
MB-16	1	0.7	0.6 ± 0.1	23.7	$18. \pm 0.6$	7.5	5.2 ± 3.7	.06	$.07 \pm .02$	1.29
	2	-		-		2.0		.08		1.17
	3	0.7		17.3		8.8		.10		0.98
	4	0.1		64.9		7.1		.06		1.02
	5	0.4		12.0		0.3		.05		0.83
BH-1	1	0.6	2.7 ± 1.8	12.0	35 ± 17	38.2	70.4 ± 27.7	1.3	$2.4 \pm .96$	0.52
	2	4.5		41.0		80.8		3.5		1.67
	3	4.6		52.5		107.		2.1		1.43
	4	1.9		24.0		78.3		3.3		0.88
	5	1.6		45.2		47.5		1.7		0.62
BH-2	1	1070	880 ± 469	50.0	52 ± 2.1	155.	$139 \pm 15.$	35.4	15.9 ± 6.5	3.00
	2	813		55.		117.		16.7		2.84
	3	552		54.		152.		17.1		2.53
	4	1050		52.		134.		17.8		2.65
	5	914		51.		135.		24.3		2.84
BH-4	1	8.1	6.5 ± 2.0	33.0	22.9 ± 6.2	450.	327 ± 119	1.0	$1.2 \pm .2$	4.31
	2	7.8		23.3		308.		1.1		5.23
	3	3.5		16.2		146.		1.3		2.24
	4	7.6		20.4		314.		1.4		3.95
	5	5.5		21.3		421		1.0		5.04

TABLE A-1 DATA ON INDIVIDUAL SEDIMENT REPLICATES FOR PCB, TOTAL PAH AND TOC (continued)

Station	Replicate No.	PAH($\mu\text{g/g}$)	PAH($\mu\text{g/g}$) $\bar{X} \pm S$	FFPI	FFPI $\bar{X} \pm S$	PCB(ng/g)	PCB $\bar{X} \pm S$	Coprostanol ($\mu\text{g/g}$)	Coprostanol $\bar{X} \pm S$	TOC(mg/g)
BH-4	1	8.1	6.5 ± 2.0	33.0	22.9 ± 6.2	450.	327 ± 119	1.0	$1.2 \pm .2$	4.31
	2	7.8		23.3		308.		1.1		5.23
	3	3.5		16.2		146.		1.3		2.24
	4	7.6		20.4		314.		1.4		3.95
	5	5.5		21.3		421		1.0		5.04
BH-5	1	6.2	6.0 ± 1.3	41.	$46. \pm 5.3$	73.0	100 ± 23.7	5.7	6.2 ± 1.5	2.63
	2	9.4		46.		86.6		6.3		1.89
	3	5.9		40.		127.		8.6		2.91
	4	5.2		48.		90.6		4.5		1.84
	5	8.2		53.		123.		6.1		2.49
BH-6	1	2.2	2.4 ± 0.6	17.3	18.1 ± 2.0	57.1	60.6 ± 5.0	3.0	2.5 ± 0.5	1.27
	2	3.2		20.1		65.2		2.8		1.41
	3	1.8		18.7		55.5		2.6		1.12
	4	1.9		15.1		66.7		1.7		1.36
	5	2.7		19.5		58.4		2.7		1.50
BH-7	1	1.0	0.8 ± 0.8	15.0	13.5 ± 3.5	22.3	14.4 ± 7.6	.80	$.60 \pm .3$	0.51
	2	0.9		15.8		7.1		.30		0.22
	3	0.5		9.5		13.9		.60		0.38

TABLE A-2 DETAILED PAH DATA ($\mu\text{g/g}$)

PAH Compounds (m/z)	STATION				
	BH-1	BH-2	BH-4	BH-5	BH-6
N (128)	.009 ± .009	5.4 ± 1.4	.040 ± .021	.10 ± .08	.003 ± .002
C ₁ N (142)	.033 ± .028	13 ± 4.3	.062 ± .019	.24 ± .12	.007 ± .004
C ₂ N (156)	.091 ± .070	25 ± 6.3	.085 ± .0303	.40 ± .16	.018 ± .006
C ₃ N (170)	.122 ± .097	46 ± 9.8	.056 ± .036	.32 ± .11	.017 ± .009
C ₄ N (184)	.061 ± .080	44 ± 8.9	.009 ± .014	.10 ± .06	.002 ± .001
B (154)	-	2.5 ± .62	.012 ± .005	.035 ± .02	-
F (166)	.027 ± .026	5.0 ± 1.4	.037 ± .011	.052 ± .017	.016 ± .005
C ₁ F (180)	.032 ± .024	7.7 ± 1.8	.017 ± .015	.050 ± .016	.005 ± .003
C ₂ F (194)	.062 ± .047	19 ± 3.7	.023 ± .029	.070 ± .034	.003 ± .003
C ₃ F (208)	.046 ± .044	27 ± 4.3	.030 ± .051	.064 ± .050	-
P (178)	.18 ± .17	34 ± 9.2	.39 ± .08	.43 ± .12	.23 ± .048
C ₁ P (192)	.21 ± .16	48 ± 11	.23 ± .09	.34 ± .082	.19 ± .037
C ₂ P (206)	.22 ± .13	67 ± 15	.28 ± .12	.26 ± .064	.11 ± .037
C ₃ P (220)	.13 ± .09	53 ± 12	.71 ± .14	.16 ± .078	.035 ± .019
C ₄ P (234)	.04 ± .05	16 ± 5.5	.11 ± .095	.073 ± .061	.005 ± .005
DBT (184)	.013 ± .010	3.0 ± .76	.027 ± .009	.034 ± .0101	.008 ± .003
C ₁ DBT (198)	.028 ± .021	9.7 ± 2.6	.036 ± .027	.062 ± .019	.006 ± .003
C ₂ DBT (212)	.041 ± .036	24 ± 5.8	.076 ± .054	.077 ± .033	.002 ± .002
C ₃ DBT (226)	.020 ± .022	24 ± 6.3	.11 ± .092	.064 ± .038	.002 ± .001
FL (202)	.28 ± .02	64 ± 35	.80 ± .20	.63 ± .15	.36 ± .073
PY (202)	.31 ± .18	72 ± 19	.89 ± .23	.57 ± .12	.33 ± .063
BA (228)	.13 ± .08	45 ± 11	.38 ± .11	.27 ± .061	.14 ± .044
CH (228)	.16 ± .01	51 ± 16	.47 ± .12	.33 ± .068	.21 ± .045
BF (252)	.33 ± .17	100 ± 27	1.1 ± .32	.76 ± .15	.36 ± .095
BEP (252)	.03 ± .02	8.7 ± 2.6	.42 ± .13	.062 ± .021	.12 ± .036
BAP (252)	.16 ± .08	45 ± 13	.40 ± .12	.30 ± .079	.15 ± .045
PER (252)	.04 ± .03	11 ± 2.6	.10 ± .037	.09 ± .028	.039 ± .015

N=naphthalene
 C₁, C₂, C₃, C₄ N = alkylated naphthalenes
 B=biphenyl
 F=fluorene
 C₁, C₂, C₃ F = alkylated fluorenes
 P=phenanthrene
 C₁, C₂, C₃, C₄ P = alkylated phenanthrenes
 DBT=dibenzothiophene
 C₁, C₂, C₃ DBT = alkylated benzothiophenes
 FL,PY=fluoranthene, pyrene
 BA,CH=benzanthracene, chrysene
 BF,BEP,BAP,PER = benzo(a)fluoranthenes, benzo(a)pyrene, perylene

TABLE A-2 DETAILED SEDIMENT PAH DATA
(continued)

PAH Compounds (m/z)	STATION				
	BH-7	MB-1	MB-4	MB-5	MB-6
N (128)	.002 ± .001	.028 ± .010	.006 ± .004	<.001	.058 ± .027
C ₁ N (142)	.002 ± .001	.049 ± .014	.010 ± .006	<.001	.042 ± .019
C ₂ N (156)	.003 ± .001	.11 ± .04	.015 ± .009	.003 ± .002	.074 ± .037
C ₃ N (170)	.003 ± .001	.13 ± .051	.011 ± .008	.003 ± .002	.090 ± .039
C ₄ N (184)	<.001	.031 ± .025	<.001	.002 ± .001	.044 ± .041
B (154)	<.001	.015 ± .009	.004 ± .002	<.001	.014 ± .012
F (166)	.005 ± .002	.17 ± .079 (1.3) ^a	.012 ± .007	.003 ± .001	.028 ± .015
C ₁ F (180)	.003 ± .001	.089 ± .14 (.62) ^a	.006 ± .003	.002 ± .001	.037 ± .025
C ₂ F (194)	<.001	.056 ± .026 (.27) ^a	.003 ± .002	<.001	.058 ± .046
C ₃ F (208)	<.001	.032 ± .035 (.27) ^a	<.001	<.001	.074 ± .038
P (178)	.064 ± .023	.032 ± .035 (2.1) ^a	.16 ± .065	.044 ± .007	.21 ± .063
C ₁ P (192)	.050 ± .025	.069 ± .16 (2.9) ^a	.18 ± .091	.038 ± .007	.24 ± .041
C ₂ P (200)	.027 ± .017	.038 ± .029 (1.0) ^a	.15 ± .076	.030 ± .007	.21 ± .048
C ₃ P (220)	.006 ± .004	.19 ± .11	.046 ± .11	.007 ± .006	.12 ± .060
C ₄ P (239)	<.001	.053 ± .041	.044 ± .032	<.001	.038 ± .031
DBT (184)	.002 ± .001	.078 ± .030 (.41) ^a	.006 ± .004	.002 ± .001	.017 ± .005
C ₁ DBT (198)	.002 ± .001	.048 ± .012 (.28) ^a	.014 ± .006	.004 ± .002	.036 ± .017
C ₂ DBT (212)	<.001	.030 ± .021 (.12) ^a	.014 ± .008	.002 ± .001	.069 ± .034
C ₃ DBT (226)	<.001	.010 ± .007	.003 ± .002	<.001	.058 ± .042
FL (202)	.13 ± .045	1.4 ± .37 (5.4) ^a	.30 ± .11	.082 ± .013	.37 ± .053
PY (202)	.12 ± .044	1.2 ± .26 (4.2) ^a	.31 ± .11	.076 ± .012	.37 ± .052
BA (228)	† .061 ± .024	.69 ± .24 (1.9) ^a	.15 ± .064	.032 ± .010	.16 ± .045
CH (228)	.055 ± .020	.67 ± .17 (2.0) ^a	.18 ± .083	.034 ± .021	.26 ± .046
BF (252)	.12 ± .04	1.5 ± .67	.37 ± .80	.14 ± .081	.54 ± .13
BEP (252)	.04 ± .016	.21 ± .12	.14 ± .081	.049 ± .029	.041 ± .017
BAP (252)	.056 ± .021	.82 ± .42	.18 ± .085	.040 ± .024	.20 ± .050
PER (252)	.012 ± .005	.21 ± .11	.044 ± .023	.018 ± .011	.062 ± .016

^aSingle high outlier

N=naphthalene

C₁, C₂, C₃, C₄ N = alkylated naphthalenes

B=biphenyl

F=fluorene

C₁, C₂, C₃ F = alkylated fluorenes

P=phenanthrene

C₁, C₂, C₃, C₄ P = alkylated phenanthrenes

DBT=dibenzothiophene

C₁, C₂, C₃ DBT = alkylated benzothiophenes

FL,PY=fluoranthene, pyrene

BA,CH=benzanthracene, chrysene

BF,BEP,BAP,PER = benzo(a)fluoranthene, benzo(a)pyrene, perylene

TABLE A-2 DETAILED SEDIMENT PAH DATA
(continued)

PAH Compounds (m/z)	STATION				
	MB-7	MB-8	MB-9	MB-10	MB-11
N (128)	0.006 ± 0.001	<0.001	<0.001 ±	0.009 ± 0.005	0.004 ± 0.005
C ₁ N (142)	0.009 ± 0.002	<0.001	0.001 ±	0.011 ± 0.004	0.007 ± 0.005
C ₂ N (156)	0.017 ± 0.005	<0.001	0.002 ± 0.001	0.021 ± 0.008	0.014 ± 0.004
C ₃ N (170)	0.019 ± 0.008	0.001	0.002 ± 0.001	0.013 ± 0.005	0.012 ± 0.004
C ₄ N (184)	0.003 ± 0.002	<0.001 ±	0.001 ±	0.002 ± 0.001	<0.001
B (154)	0.004 ± 0.001	<0.001	<0.001 ± 0	0.006 ± 0.002	0.004 ± 0.002
F (166)	0.11 ± 0.003	<0.001	0.002 ± 0.001	0.011 ± 0.003	0.012 ± 0.001
C ₁ F (180)	0.009 ± 0.003	0.001	0.002 ± 0.001	0.005 ± 0.002	0.006 ± 0.002
C ₂ F (194)	0.009 ± 0.005	<0.001	0.001 ± 0.001	0.004 ± 0.002	0.004 ± 0.002
C ₃ F (208)	0.005 ± 0.006	<0.001	<0.001	0.002 ± 0.001	<.001
P (178)	0.11 ± 0.022	0.020 ± 0.013	0.019 ± 0.014	0.12 ± 0.008	0.014 ± 0.006
C ₁ P (192)	0.10 ± 0.030	0.015 ± 0.013	0.011 ± 0.009	0.096 ± 0.008	0.11 ± 0.011
C ₂ P (200)	0.080 ± 0.020	0.009 ± 0.011	0.007 ± 0.008	0.067 ± 0.012	0.086 ± 0.013
C ₃ P (220)	0.031 ± 0.014	0.002 ± 0.002	0.002 ± 0.002	0.023 ± 0.013	0.030 ± 0.010
C ₄ P (234)	0.005 ± 0.004	<0.001	<0.001	0.004 ± 0.002	0.003 ± 0.002
DBT (184)	0.007 ± 0.001	<0.001	<.001	0.007 ± 0.004	0.008 ± 0.001
C ₁ DBT (198)	0.011 ± 0.003	0.001	0.002 ± 0.002	.011 ± 0.004	0.013 ± 0.002
C ₂ DBT (212)	0.011 ± 0.007	0.001 ±	<.001	0.008 ± 0.006	0.008 ± 0.003
C ₃ DBT (220)	0.005 ± 0.004	<0.001	<0.001	0.004 ± 0.004	0.002 ± 0.001
FL (202)	0.19 ± 0.038	0.051 ± 0.022	0.025 ± 0.018	0.21 ± 0.017	0.26 ± 0.011
PY (202)	0.18 ± 0.035	0.043 ± 0.018	0.024 ± 0.016	0.19 ± 0.013	0.23 ± 0.011
BA (228)	0.058 ± 0.019	0.019 ± 0.012	0.12 ± 0.009	0.10 ± 0.015	0.10 ± 0.010
CH (228)	0.093 ± 0.034	0.028 ± 0.015	0.015 ± 0.010	0.11 ± 0.008	0.15 ± 0.009
BF (252)	0.20 ± 0.090	0.095 ± 0.046	0.030 ± 0.020	0.25 ± 0.030	0.35 ± 0.027
BEP (252)	0.009 ± 0.006	0.004 ± 0.005	0.011 ± 0.008	0.031 ± 0.035	0.13 ± 0.012
BAP (252)	0.050 ± 0.022	0.029 ± 0.018	0.012 ± 0.009	0.093 ± 0.009	0.12 ± 0.006
PER (252)	0.025 ± 0.015	0.011 ± 0.007	0.004 ± 0.003	0.030 ± 0.003	0.065 ± 0.015

^aSingle high outlier-parenthesis

N=naphthalene

C₁, C₂, C₃, C₄ N = alkylated naphthalenes

B=biphenyl

F=fluorene

C₁, C₂, C₃ F = alkylated fluorenes

P=phenanthrene

C₁, C₂, C₃, C₄ P = alkylated phenanthrenes

DBT=dibenzothiophene

C₁, C₂, C₃ DBT = alkylated benzothiophenes

FL,PY=fluoranthene, pyrene

BA,CH=benzanthracene, chrysene

BF, BEP, BAP, PER = benzofluoranthenes, benzo(e)pyrene, benzo(a)pyrene, perylene

TABLE A-2 DETAILED SEDIMENT PAH DATA
(continued)

PAH Compounds (m/z)	STATION			
	MB-13	MB-14	MB-16	CC-2
N (128)	.002 ± .001	.002 ± .001	<.002	.075 ± .14
C ₁ N (142)	.001 ± .0005	.003 ± .002	<.002	.081 ± .15
C ₂ N (156)	.002 ± .001	.005 ± .002	<.003	.17 ± .32
C ₃ N (170)	.002 ± .001	.003 ± .002	<.003	.19 ± .34
C ₄ N (184)	<.001	<.001	<.001	.05 ± .06
B (154)		.002 ± .001	<.001	.018 ± .030
F (166)	.002 ± .001	.004 ± .001	.002 ± .001	.018 ± .009
C ₁ F (180)	<.001	.002 ± .001	.002 ± .001	.028 ± .025
C ₂ F (194)	<.001	<.001	.002 ± .001	.045 ± .047
C ₃ F (208)	<.001	<.001	<.001	.087 ± .102
P (178)	.034 ± .008	.055 ± .008	.053 ± .004 (.95) ^a	.19 ± .17
C ₁ P (192)	.031 ± .014	.040 ± .008	.034 ± .018 (1.9) ^a	.29 ± .38
C ₂ P (206)	.023 ± .012	.030 ± .011	.022 ± .015 (3.0) ^a	.41 ± .66
C ₃ P (220)	.005 ± .004	.008 ± .006	.008 ± .002 (.07) ^a	.23 ± .34
C ₄ P (239)	<.001	<.001	<.001	.04 ± .03
DBT (184)	.001 ± .001	.003 ± .001	.002 ± 0 (0.2) ^a	.024 ± .032
C ₁ DBT (198)	.003 ± .002	.005 ± .002	.004 ± .001 (.21) ^a	.047 ± .063
C ₂ DBT (212)	.002 ± .001	.002 ± .002	.003 ± 0 (.47) ^a	.073 ± .11
C ₃ DBT (226)	<.001	<.001	.001 ± 0 (.21) ^a	.025 ± .018
FL (202)	.066 ± .011	.095 ± .015	.10 ± .012 (.37) ^a	.192 ± .058
PY (202)	.066 ± .010	.087 ± .014	.092 ± .007 (2.0) ^a	.270 ± .270
BA (228)	.030 ± .008	.040 ± .010	.034 ± .010	.072 ± .047
CH (228)	.043 ± .008	.053 ± .012	.045 ± .014	.058 ± .033
BF (252)	.10 ± .019	.16 ± .039	.11 ± .036	.079 ± .061
BEP (252)	.036 ± .010	.054 ± .016	.006 ± .002	.010 ± .008
BAP (252)	.041 ± .008	.056 ± .017	.039 ± .020	.044 ± .031
PER (252)	.010 ± .004	.016 ± .007	.016 ± .002	.015 ± .013

^aSingle high outlier-parenthesis

N=naphthalene

C₁, C₂, C₃, C₄ N = alkylated naphthalenes

B=biphenyl

F=fluorene

C₁, C₂, C₃ F = alkylated fluorenes

P=phenanthrene

C₁, C₂, C₃, C₄ P = alkylated phenanthrenes

DBT=dibenzothiophene

C₁, C₂, C₃ DBT = alkylated benzothiophenes

FL,PY=fluoranthene, pyrene

BA,CH=benzanthracene, chrysene

BF, BEP, BAP, PER = benzo(f)fluoranthene, benzo(e)pyrene, benzo(a)pyrene, perylene