DATA REPORT

Sediment Quality Studies in the Gulf of Maine: Casco Bay, Penobscot Bay and Offshore

edited by

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I. Introduction

In September, stations 20 and 29 were sampled as part of a Casco Bay monitoring program which has returned to these two stations eight times since a baseline survey was completed in 1980. In addition, Station 20 and five new stations in Portland Harbor were sampled in August 1983 for PCB, PAH, grain size and organic carbon analyses. The timing and design of the sampling were in response to newspaper reports of PCB spill incidents that had occurred earlier in the year during construction of a drydock.

Baseline surveys were carried out in two new areas: Massachusetts Bay and the basins of the offshore Gulf of Maine. Although heavily utilized for fishing, sewage dumping, oil and other transport, etc. Massachusetts Bay had not been comprehensively sampled as part of a major pollution monitoring study. Nineteen stations in the principal basins of the offshore Gulf of Maine were occupied in June and September during two cruises aboard ships of opportunity. With information from the Casco and Penobscot Bay surveys, analysis of the Massachusetts Bay and Gulf of Maine samples will provide a comprehensive picture of the benthic environment of the Gulf of Maine.

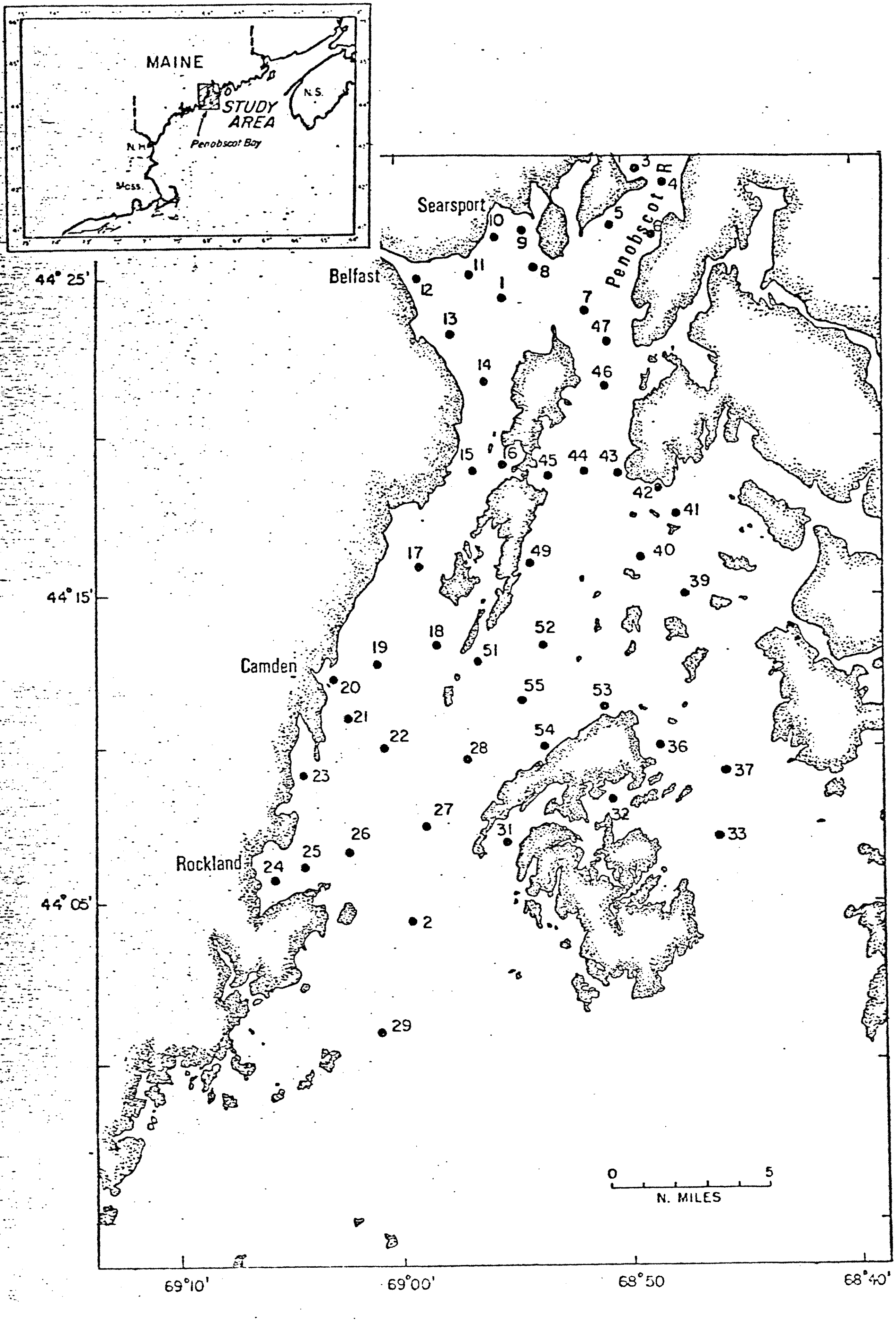
PCB and PAH analysis of sediments from Penobscot Bay, Casco Bay, Portland Harbor and the offshore stations is being carried out by Don Gadbois and Alan Humason of the NMFS Gloucester Lab. Some of the data have been analyzed in relation to possible sources, other sites, and earlier findings.

II. Sediment PCB Distribution in the Penobscot Bay Region of the Gulf of Maine

Recent investigations have shown the sediments of the Casco Bay region of the Gulf of Maine to be nearly free of PCB contamination (Larsen, *et al*., 1983a). Trace metal and polynuclear aromatic hydrocarbon samples from the same stations, however, revealed that sediment loads of these pollutants equal or exceed those reported from more highly urbanized embayments to the south (Larsen *et al*., 1983b,c). In an effort to improve upon the environmental data base of the northern Gulf of Maine, and to determine the representativeness of the above results, a systematic survey of the sediments of Penobscot Bay, Maine the largest embayment in northern New England, was undertaken. This communication presents the results of the PCB analyses.

During June and July 1982, 49 stations were sampled in Penobscot Bay (Fig. 1). Precise station locations, depths, salinities, and sediment characteristics can be found in Larsen and Johnson (1983). Sediment subsamples for PCB analysis were taken from the center of a 0.1 m^2 Smith-McIntyre grab and stored frozen until analysis. Laboratory analyses followed procedures developed by the U.S. Environmental Protection Agency for PCB determinations in bottom sediments (US EPA, 1977). Samples were copper treated for sulfur interference.

Low concentrations of PCB's were found at all 49 stations sampled in the 1982 baseline survey of Penobscot Bay. Concentrations at all but two stations were << 0.1 ppm and therefore must be considered trace amounts. Although these values were low, they represent a ubiquitous distribution which is in contrast to the 1980 Casco Bay baseline survey,


MAINE
STUDY AREA
N.S.
N.H.
Mass.
Penobscot Bay
Searsport
Belfast
Penobscot R
Camden
Rockland
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
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18
19
20
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36
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41
42
43
44
45
46
47
49
51
52
53
54
55
44° 25'
44° 15'
44° 05'
69°10'
69°00'
68°50'
68°40'
0
5
N. MILES

where PCB's were not detectable at any of the 32 stations sampled (Larsen _et al_., 1983a). The two Penobscot Bay stations manifesting more than trace amounts of PCB's were station 10 (0.20 ppm) outside Searsport Harbor, and station 24 (0.12 ppm) in Rockland Harbor (Fig. 1). Sample extracts consisted of Aroclor 1254 with residual amounts of 1260.

Based on this baseline survey, it can be concluded that PCB's are not presently a significant contaminant of Penobscot Bay sediments. Their ubiquitous distribution in trace amounts, however, indicates that they are entering the marine environment in this region and therefore are of environmental concern. It is recommended that a monitoring program be instituted to establish temporal trends in sediment PCB accumulations.

II. The Distribution of Polycyclic Aromatic Hydrocarbons in the Surficial Sediments of Penobscot Bay (Maine, U.S.A.) in Relation to Possible Sources and to Other Sites Worldwide

Polycyclic aromatic hydrocarbons (PAHs) are known to occur widely in sedimentary environments. The major source of this contamination is assumed to be anthropogenic, resulting from the incomplete combustion of fossil fuels. Air- and waterborne transport of particulates has been hypothesized as a mechanism for the broad dissemination of these compounds (Hites et al., 1980a). Awareness of the ubiquity and carcinogeneity of at least some PAHs has created growing concern about their effects on species, communities and ecosystems. Correlations have been found between the sediment levels of certain PAHs and the concentrations in resident organisms, indicating that PAH contamination may represent a human health hazard (Dunn, 1980).

PAH contamination of the sediments of Casco Bay, a major Gulf of Maine embayment, has recently been established (Larsen, et al., 1983) and demonstrated the need for additional pollutant surveys in the region. This communication presents the results of a survey undertaken to determine the levels of 16 priority PAHs (U.S. EPA, 1977) in the surficial sediments of Penobscot Bay, the largest embayment in the northern Gulf of Maine. A comparison of PAH levels in Penobscot Bay sediments with other sites in the northeastern United States and worldwide is made to provide perspective on the relative contamination of sediments in these areas. In anticipation of attempts to control PAH contamination, a discussion of potential sources, both distant and local, and of further research needed, is provided.

PENOBSCOT BAY

Located in the northern Gulf of Maine, Penobscot Bay remains largely undeveloped. Its shoreline, islands and wildlife are popularly considered unspoiled and help support an active tourist industry. The bay is 53 km along it north-south axis, and is 34 km at 44°N latitude which may be considered its seaward limit. Rockland, with a population of 8,000, is the largest of several communities bordering the bay. Smaller towns include Belfast, Camden, Castine, and Searsport. The Penobscot River flows into the northern apex of the bay at a rate of 334.7 m^3/sec. and drains an area of over 22196 km^2.

MATERIAL AND METHODS

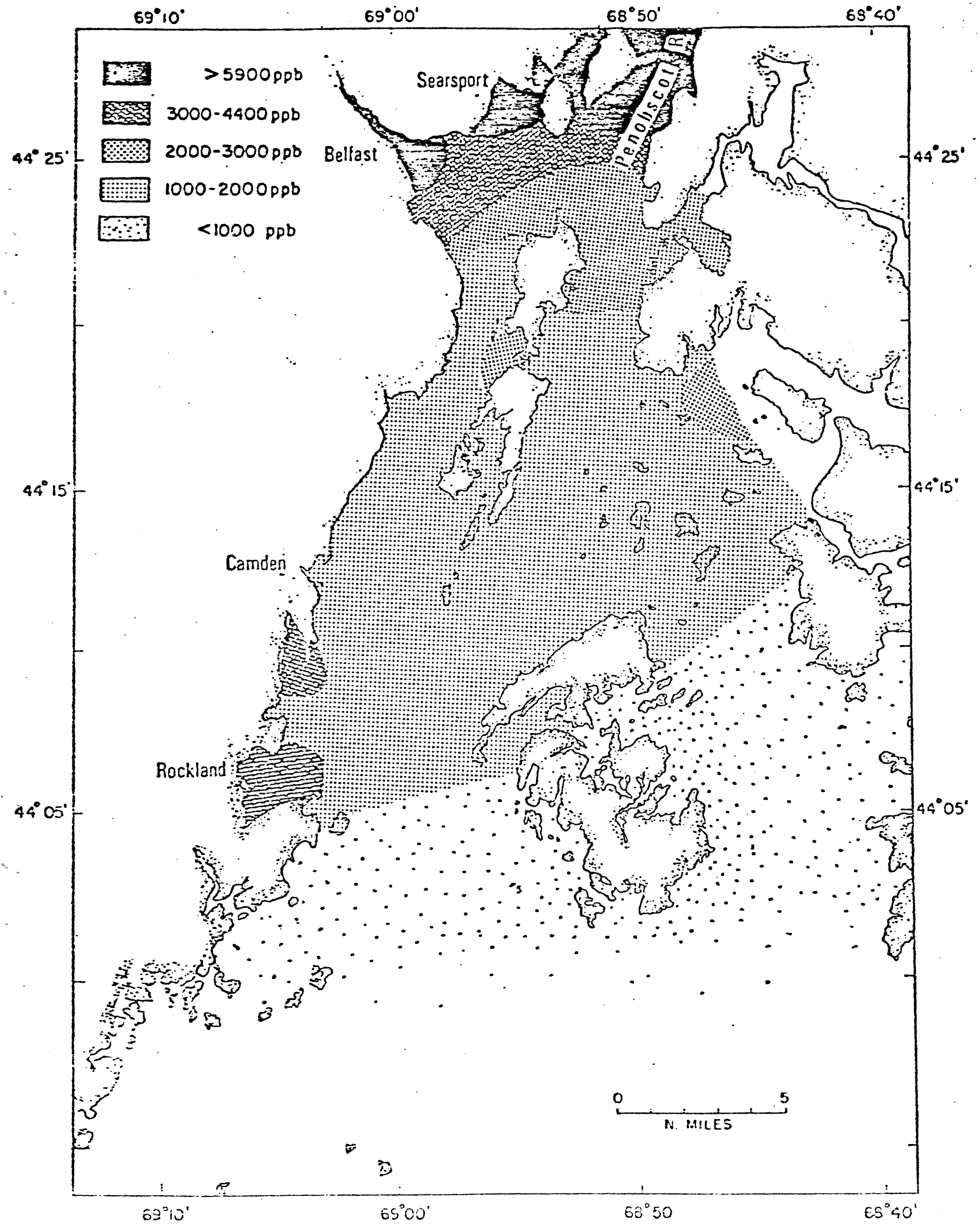
In June and July 1982, 49 stations from throughout Penobscot Bay were sampled using a 0.1 m^2 Smith-McIntyre grab (Fig. 1). Subsamples for hydrocarbon analysis were removed from the center of each grab, using solvent-rinsed scoops and baked glassware, and frozen until analysis. Analytical analyses were performed at the National Marine Fisheries Service Laboratory at Gloucester, Massachusetts following the procedures of Grimmer and Böhnke (1979). Results are in units of ppb dry weight. Selected extracts were combined, concentrated, and analyzed by GC-MS. Subsamples for organic carbon analysis were acidified and stored frozen until ready for analysis. Samples were then dried and ground prior to being run on a Hewlett-Packard 185B CHN analyzer.

RESULTS

Thirteen of the 16 US EPA priority PAHs were encountered in Penobscot Bay sediments (Table 1), while 3, naphthalene, acenaphthylene, and acenaphthene were not detected. The following compounds were confirmed by acquiring their mass spectra: phenanthrene, fluoranthene, pyrene, chrysene, benzo-a-anthracene, benzo-k- fluoranthene and benzo-a-pyrene. In addition to these priority PAHs, benzo-e- pyrene was also indentified by acquiring its mass spectra. Twelve compounds were ubiquitous in Penobscot Bay and 11 occurred at 100% of the stations sampled. Fluorene was encountered at only two stations, 27 and 32, in concentrations of 6 and 4 ppb, respectively. With the exception of anthracene, all of the ubiquitous PAHs exhibited concentrations exceeding 100 ppb at many stations. Only two compounds, however, fluoranthene and benzo-b-fluoranthene, manifested concentrations in the thousand ppb range.

Individual stations in Penobscot Bay were characterized by 12 PAHs. There were only three exceptions to this generalization; station 15 with 11 PAHs due to the absence of anthracene and stations 27 and 32 which exhibited low levels of fluorene (Table 1). Total concentrations of PAH at the 49 stations ranged between 286 and 8,794 ppb (dry wt) with a mean of 2,580 ppb.

The concentration of total PAHs in Penobscot Bay formed a distinct gradient, decreasing from north to south (Fig. 2). Highest total concentrations were found at the entrance to Belfast Harbor (sta. 12), Searsport (sta. 9, 10) and at the mouth of the Penobscot River (sta. 3, 4, 5, 6). Concentrations at these stations all exceeded 5900 ppb. The lowest concentrations were found at the seaward margin of the Bay (sta. 2, 29, 32, 33) where concentrations were all under 1000 ppb. Linear regression of PAH concentration against distance from the mouth of the Bay revealed a relationship significant at the 95% level. Plotting the



69°10'
69°00'
68°50'
68°40'
>5900 ppb
3000-4400 ppb
2000-3000 ppb
1000-2000 ppb
<1000 ppb
Searsport
Belfast
Penobscot R.
44°25'
44°15'
Camden
Rockland
44°05'
0
5
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data indicated that only stations 23, 24, and 25, in the Rockland area, deviated markedly from the regression line.

On a smaller scale, similar gradients were also observed in the mouth of the Penobscot River and each of the harbors of Searsport, Belfast, Rockland and Camden. Highest concentrations were noted at the innermost stations and decreased with distance from the harbors and river mouth. This pattern clearly establishes the harbors and river as the origins of major PAH input into Penobscot Bay.

Total PAH concentration was significantly correlated with organic carbon at the 99% level (r = 0.7804). However, calculating the ratio of total PAH to organic carbon (Table 1) demonstrated that 18 stations had elevated ratios relative to the mean, 111.4. These stations occur in the mouth of the Penobscot River, Searsport Harbor, Belfast Harbor and the upper bay connecting these three bodies of water as well as in Rockland, Rockport and Camden harbors. One station (14) on the east side of the bay, south of Cape Rosier, also displayed a high PAH level relative to the organic carbon content of the sediment.

During the analytical procedure, correspondence was noted between chromatographs, i.e. the positions and heights of the peaks were relatively uniform over the entire suite of samples regardless of absolute concentrations. This phenomenon, indicating a common PAH composition, is reflected by Table 1. The average percentage and standard deviation for each compound are also shown in Table 1.

DISCUSSION

Although the 49 stations are spread over a large area, differ in depth by 115 m and in total PAH concentration by an order of magnitude, the percentage composition of individual PAHs in the total samples varied only slightly from station to station. This pattern suggests that the PAH contamination of Penobscot Bay may result from a single or small number of related input vectors. The uniformity of our results, however, may be exaggerated by our analytical method which may have excluded, through evaporation and purification of extracts, some of the substituted and low MW compounds. Changes in the relative amounts of PAH compounds may occur after deposition through such processes as differential solubility, volatilization, particle affinity and photochemical oxidation, as well as the selective effects of macrofauna and microbes on the biodeposition and biodegradation of these compounds (Readman et al., 1982 ; Bjorseth et al., 1979; Lee et al., 1978; Whipple and Hunter, 1981; Gardner et al., 1979, Jones et al., 1983; Swartz and Lee, 1980). A combination of the above factors may be responsible for altering PAH composition, and thereby obscuring sources of these materials.

It is now recognized that the major source of PAHs in the world environment is the incomplete combustion of fossil fuels (Jackim and Lake, 1978; Hites, 1976; Wakeham and Farrington, 1980; Laflamme and Hites, 1978). In some areas pyrolytic PAHs are augmented by PAHs found in petroleum. PAHs formed under low temperatures, such as those found in petroleum, are more highly substituted, while those formed under higher temperatures, such as in the combustion process, are mainly unsubstituted or parent compounds. The ratio of parent to substituted compounds can therefore be used to differentiate between petroleum and combustion derived components (Youngblood and Blumer, 1975; Hites et al., 1980a; Laflamme and Hites, 1978). Extracts from Penobscot Bay the

the sediments had to be combined for GC-MS analysis for substituted compounds. Suspected substituted compounds were determined by selected ion monitoring. The qualitative results indicate that methylpyrenes/fluoranthenes, methylphenanthrenes/anthracenes and methylnaphthalenes, substituted compounds found in petroleum, may occur in trace amounts in Penobscot Bay sediments. Analysis of the alkane fraction, currently underway, will help to differentiate between petroleum and combustion products as sources of PAHs in Penobscot Bay sediments.

Airborne transport of particulate combustion products has been suggested as the mechanism responsible for disseminating PAHs to areas remote from their production. The existence of a world wide background of PAH contamination related to the burning of fossil fuels is supported by the analysis of cores from several regions which show that PAH concentrations have built up in the period since the industrial revolution (Gschwend and Hites, 1981; Farrington _et al_., 1977; Wakeham _et al_., 1980; Platt and Mackie, 1980).

The distribution of PAH in Penobscot Bay indicates that a large proportion of PAHs are most likely introduced to the bay by freshwater runoff. Particulate combustion products transported atmospherically from various distances, settling in the watersheds which drain into the bay, may be the source of this contamination. The Penobscot River drains an area of over 22196 km^2 including the city of Bangor (U.S. Fish & Wildlife Service, 1980). PAH concentration decreases as a function of distance from the mouth of that river. Although total PAH concentration and organic carbon significantly correlated, PAH concentration is not simply a function of the level of organic carbon present. Eighteen of the forty nine stations sampled exhibited elevated ratios of PAHs to organic carbon relative to the mean of 111.4. With the exception of station 20 these stations correspond to areas of total PAH concentration exceeding 2000 ppb.

Local sources undoubtedly contribute to PAH loading in the bay and may be in part responsible for the seaward gradients manifested in the various harbors. Fish processing plants and other industrial activities, wood, oil and coal burning heating systems, and automobile and shipping exhaust all produce combustion products in the vicinity of the bay. The bay also receives treated domestic sewage which has been implicated as a source of PAHs (Grimmer, 1979). The Penobscot River serves as a shipping channel for the city of Bangor and drains a large watershed. Belfast has 4 food processing plants, a shoe factory, a 1.9 x 10^6 ℓ/day sewage treatment facility and is fed by the Passagassawakeag River, with a small drainage basin. The harbor at Searsport with no river emptying into it and no proximate urban areas, has shipping generated by its loading docks, fuel storage facility and chemical plant, and may be a trap for organic matter supplied to the bay from the Penobscot River. Camden, Rockland and Rockport receive little freshwater drainage; landward waterborne inputs of PAHs are, therefore, limited to localized runoff. Rockland supports 5 fish processing plants involving the largest fishing fleet in the State, and a 10.6 x 10^6 ℓ/day sewage treatment facility. Camden is the center, in the summer months, for an active yachting community and concomitant tourist trade, and has a 4.6 x 10^6 ℓ/day sewage treatment facility.

Resolution limits in the analytical procedure and modification of PAHs during and after deposition make it difficult to pinpoint sources, and may account for the discrepancy between the uniform composition observed and the apparent lack of a uniform source. Collection of larger samples for quantitative analysis of substituted PAHs and seasonal measurements of PAH levels in air, freshwater and water column samples would help in determining the origin of these potentially harmful compounds.

PAH values for surficial sediments from northeastern United States, European and other sites are listed in Table 2. Care must be exercised in comparing results from different studies as methodologies of PAH analysis differ from one investigator to another. Hilpert et al. (1978) observed an interlaboratory precision of ± 25% in a study of petroleum hydrocarbon analysis at eight different laboratories. Intercalibration in sampling procedure and PAH analysis is urgently needed. It is possible, however, to draw some general conclusions from Table 2. The lowest levels reported are from the abyssal plain off the northeast United States coast (5 ppb) and in the intertidal zone of an undeveloped area of Alaska (18 ppb). The highest value of 1.79×10^6 ppb was recorded in Southampton Water (U.K.) near a large oil refinery outfall. Sediments near heavily developed or industrialized areas in the Mediterranean, the Charles River, MA, Norway, The Neckar, Rhine and Danube Rivers, The Severn Estuary, and Casco Bay, ME, exhibited PAH values in the range of 198-232,000 ppb. After applying a conversion factor of 0.5 to Penobscot Bay PAH values and other dry weight basis values for comparison with wet weight results, Penobscot Bay sediment PAH levels fall in the range of 50-5,830 ppb which includes sediments from the Cariaco Trench, the Baltic Sea, the New York Bight, Buzzards Bay and Massachusetts Bay. Most of these areas are affected by anthropogenic activities. Penobscot Bay values are significantly higher than would be expected for an area previously considered to be uncontaminated.

In conclusion, PAH levels in Penobscot Bay sediments compare with those of industrialized regions. Contamination is probably the result of several anthropogenic inputs: predominantly atmospherically transported particulates collected in watersheds, but also locally produced industrial, heating and vehicular combustion products, exhaust gases from ships, and treated domestic sewage. If the sources of PAHs are anthropogenic and recent, as hypothesized, then the coastal environment is subject to highly elevated levels of PAHs relative to preindustrial times as well as offshore sediments. As these known carcinogens and mutagens are passed up the food chain the impact on man could be significant and should be evaluated.

Table 1. The concentrations of individual PAHs (ppb, dry wt.) found at the 49 Penobscot Bay stations. ND indicates not detected.

Station	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo-a-anthracene	Chrysene	Benzo-b-fluoranthene	Benzo-k-fluoranthene	Benzo-a-pyrene	Dibenzo-a,h-anthracene	Benzo-g,h,i-perylene	Indeno-1,2,3-c,d-pyrene	Total	Organic Carbon (mg/g)	PAH/organic carbon
1	107	11	2080	204	110	135	143	182	232	37	354	124	3719	24.9	149.4
2	17	2	212	21	18	14	17	17	16	3	23	9	369	7.8	47.3
3	252	49	3700	502	512	276	601	402	376	37	610	198	7515	38.8	193.7
4	192	36	2680	441	465	246	499	431	413	47	641	228	6319	41.4	152.6
5	211	33	3240	430	445	253	388	384	537	68	637	186	6812	34.3	198.6
6	207	28	2700	426	374	248	656	404	540	76	328	180	6167	47.0	131.2
7	86	18	1220	178	184	108	264	147	222	27	294	96	2844	25.2	112.9
8	121	16	2040	285	306	237	310	263	218	23	384	185	4388	27.5	159.6
9	232	35	3110	539	370	205	206	275	346	43	486	126	5973	27.7	215.6
10	223	43	2580	525	517	285	485	515	408	44	652	145	6422	132.7	48.4
11	130	15	1960	296	279	174	490	302	327	58	252	120	4403	27.4	160.7
12	217	32	3530	515	540	578	1000	696	497	120	856	213	8794	29.3	300.1
13	102	11	1390	205	235	161	110	173	305	27	311	104	3134	24.7	126.9
14	60	7	857	112	93	58	82	102	140	18	181	52	1762	16.2	108.8
15	43	ND	644	92	81	52	95	72	88	19	150	53	1389	16.4	84.7
16	59	6	868	138	158	104	122	135	124	21	207	99	2041	26.2	77.9
17	41	4	514	83	80	54	142	104	94	18	176	54	1364	17.5	77.9
18	51	5	745	96	100	67	137	112	117	24	104	45	1603	18.0	89.1

Station	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo-a-anthracene	Chrysene	Benzo-b-fluoranthene	Benzo-k-fluoranthene	Benzo-a-pyrene	Dibenzo-a,h-anthracene	Benzo-g,h,i-perylene	Indeno-1,2,3-c,d-pyrene	Total	Organic Carbon (mg/g)	PAH/organic carbon
19	45	5	768	98	97	57	145	105	86	10	168	65	1649	17.8	92.6
20	52	7	694	116	136	76	213	120	103	12	148	56	1733	10.7	162.0
21	42	6	698	103	114	62	190	115	106	14	184	59	1693	17.6	96.2
22	50	6	650	98	92	51	156	104	86	17	162	58	1530	20.1	76.1
23	109	16	1640	241	224	127	154	201	188	26	346	101	3373	22.6	149.2
24	122	21	1540	244	246	188	203	186	193	34	220	53	3250	12.3	264.2
25	111	29	1550	202	186	92	290	177	242	23	260	73	3235	10.3	314.1
26	41	4	583	84	77	47	139	105	14	14	170	50	1328	18.8	70.6
27	34	4	484	61	51	33	52	58	52	9	113	49	1006	16.5	61.0
28	28	3	418	67	62	34	114	79	69	12	141	45	1072	17.8	60.2
29	11	1	156	16	14	9	19	14	10	2	23	11	286	4.7	60.9
31	40	2	588	80	70	42	81	75	63	10	127	43	1221	23.0	53.1
32	27	3	331	47	40	25	70	38	32	4	56	26	703	14.1	49.9
33	38	4	449	70	59	36	56	58	51	10	101	57	989	19.0	52.1
36	47	6	691	97	82	51	67	70	72	20	141	75	1419	25.5	55.6
37	25	3	410	56	57	44	57	60	50	10	98	37	907	15.0	60.5
39	51	5	629	101	86	49	134	95	91	19	172	56	1488	19.3	77.1
40	56	5	624	99	85	64	170	129	210	26	216	56	1740	19.1	91.1
41	78	11	1240	164	154	84	272	171	162	18	293	107	2764	18.3	151.0
42	41	5	716	100	105	60	138	107	99	12	181	62	1626	21.3	76.3
43	53	4	777	107	103	61	83	108	102	16	198	60	1672	19.0	88.0
44	53	5	788	106	99	43	84	101	94	24	185	54	1636	20.9	78.3
45	47	7	642	99	96	54	119	89	19	17	172	80	1441	21.4	113.5
46	64	8	924	136	120	83	430	214	260	13	210	70	2532	18.6	136.1

Station	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo-a-anthracene	Chrysene	Benzo-b-fluoranthene	Benzo-k-fluoranthene	Benzo-a-pyrene	Dibenzo-a,h-anthracene	Benzo-g,h,i-perylene	Indeno-1,2,3-c,d-pyrene	Total	Organic Carbon (mg/g)	PAH/organic carbon
47	71	9	1100	153	162	90	208	160	135	15	240	85	2428	21.4	113.5
49	62	9	792	121	136	84	225	152	178	25	124	81	1989	18.3	108.7
51	38	5	435	77	70	49	72	63	64	9	111	54	1047	17.2	60.9
52	48	7	765	79	91	75	72	83	104	21	70	46	1461	21.2	68.9
53	45	4	636	90	75	43	48	81	130	15	159	54	1380	21.8	63.3
54	44	6	555	83	83	63	253	128	134	25	178	43	1595	16.8	94.9
55	38	3	540	76	70	39	55	114	58	21	148	54	1216	17.8	68.3
Range	17-252	ND-49	156-3700	16-539	14-540	9-578	17-1000	14-696	10-540	2-120	23-641	9-228	286-8794		
Percentage of total PAH															
Mean	3.2	0.4	45.1	6.4	6.0	3.9	7.9	6.4	6.3	1.0	9.7	3.5			
Standard Deviation	0.4	0.1	4.8	0.7	1.2	0.8	3.1	1.0	2.0	0.3	2.0	0.9			
Range	2.5-4.6	0.2-0.9	34.8-57.4	5.2-9.0	3.0-8.1	2.6-15.9	3.4-8.0	4.6-8.0	1.1-12.1	0.5-1.7	4.8-13.2	1.6-5.8			

Table 2. Comparison of total PAH concentrations in marine and freshwater (FW) surficial sediments.

Location	Reference	Total PAH µg/g wet wt.	Number of Stations	Depth (m)
North America				
Gulf of Maine				
Penobscot Bay	this study	0.286-8.794*	49	9.2-126.3
Casco Bay	Larsen et al., 1983	0.215-14.425	32	2-43
Gulf of Maine	Laflamme & Hites, 1978	0.543	1	-
Murray Basin	Windsor & Hites, 1979	0.540	1	282
Jordan Basin	Windsor & Hites, 1979	0.500	1	265
Wilkinson Basin	Windsor & Hites, 1979	0.540-0.870	1	215
Franklin Basin	Windsor & Hites, 1979	0.200	1	225
North Atlantic				
continental rise	Windsor & Hites, 1979	0.160	1	4150
continental slope	Windsor & Hites, 1979	0.120	1	1830
abyssal plain	Windsor & Hites, 1979	0.018-.097	2	5250,5465
abyssal plain	Laflamme & Hites, 1978	0.055	1	-
Charles River, MA	Laflamme & Hites, 1978	87.0	1	-
Charles River	Windsor & Hites, 1979	120.0	1	-
Massachusetts Bay	Windsor & Hites, 1979	0.160-3.400	3	90,130,155
Boston Harbor, MA	Windsor & Hites, 1979	8.500	1	6
Buzzards Bay, MA	Hites et al., 1977	0.8	1	17
Buzzards Bay	Youngblood & Blumer, 1975	4-5	3	-
Buzzards Bay	Laflamme & Hites, 1978	0.803	1	17
Falmouth Marsh, MA	Youngblood & Blumer, 1975	8	1	intertidal
New Bedford Harbor, MA	Youngblood & Blumer, 1975	63	1	-
Pettaquamscutt River, RI	Hites et al., 1980b	10.0	1	-
New York Bight	Laflamme & Hites, 1978	5.83	1	28
Pennsylvania Creek (FW)	Herbes, 1981 7.2-58	.1	4	.3
Lake Erie (FW)	Eadie et al., 1982	0.53-3.75	7	-
Adirondack Lakes (FW)	Heit et al., 1981	4.070-12.807*	2	-
Alaska	Laflamme & Hites, 1978	0.005-0.113	2	intertidal
Mono Lake, California (FW)	Laflamme & Hites, 1978	0.157-0.399	2	5-10

Table 2 - Continued

Europe				
Tamar Estuary (FW)	Readman et al., 1982	4.9	8	-
Southampton Water Estuary	Knap et al., 1982	91-1791	19	-
Severn Estuary drainage system	John et al., 1979	1.6-25.7*	9	intertidal
Mediterranean	Mille et al., 1981	0.198-0.372	2	6
Cote Bleue	Mille et al., 1982	1.2-232	3	3-10
Les Embiez	Mille et al., 1982	13-15	2	3-10
Monaco	Mille et al., 1982	5.2-12.1	2	3-10
Baltic Sea	Poutanen et al., 1981	0.258*	1	164
S. Baltic Sea	Law & Andrulewicz, 1983	0.05-2.55*	7	-
Gulf of Finland	Poutanen et al., 1981	0.437*	1	60
W. Norway	Bjorseth et al., 1979	0.284-99.452*	6	-
Neckar, Rhine & Danube Rivers (FW)	Haugenmaier & Kaut, 1981	0.6-44.56*	73	-
Other				
Walvis Bay, Africa	Laflamme & Hites, 1978	0.068	1	-
Cariaco Trench	Laflamme & Hites, 1978	1.756	1	-
Amazon River System(FW)	Laflamme & Hites, 1978	N.D.-0.544	4	-
South Georgia Is.	Platt & Mackie, 1979	0.100	1	18

*µg/g dry wt.

IV. On the Occurrence of PCBs in the Surficial Sediments of Casco Bay, Maine.

In a recent communication, Larsen *et al*., 1983a reported that the surficial sediments of the Casco Bay region of the Gulf of Maine (Fig. 1) appeared to be relatively free of PCB contamination. This conclusion was based on an April 1980 baseline survey of 32 stations in the Bay in which no PCBs were detected. Monitoring of six stations through 1980 confirmed the above conclusions. In April 1981, however, trace amounts of Arochlors 1242 and 1254 were detected in replicate samples from station 20, a trace metal impacted station in Portland Harbor (Larsen *et al*., 1983c).

Monitoring of the benthic community and several chemical pollutants has continued in Casco Bay as a component of the National Oceanic and Atmospheric Administration's Northeast Monitoring Program. In this report we update the status of Casco Bay in regard to sediment PCB levels.

METHODS

Monitoring of selected Casco Bay stations has been continued on a summer-winter basis from 1981 to the present, in particular, during July 1981, February, July and December 1982 and August-September 1983. Sampling was initially limited to two stations, station 20 in Portland Harbor and station 29, a "control" station in lower Casco Bay proper (Fig. 3). Based on preliminary indications of PCB contamination at the Portland Harbor station, five additional stations were occupied in the harbor area in August 1983 in order to assess spatial distributions (Fig. 3). Single sediment subsamples for PCB analyses were removed from

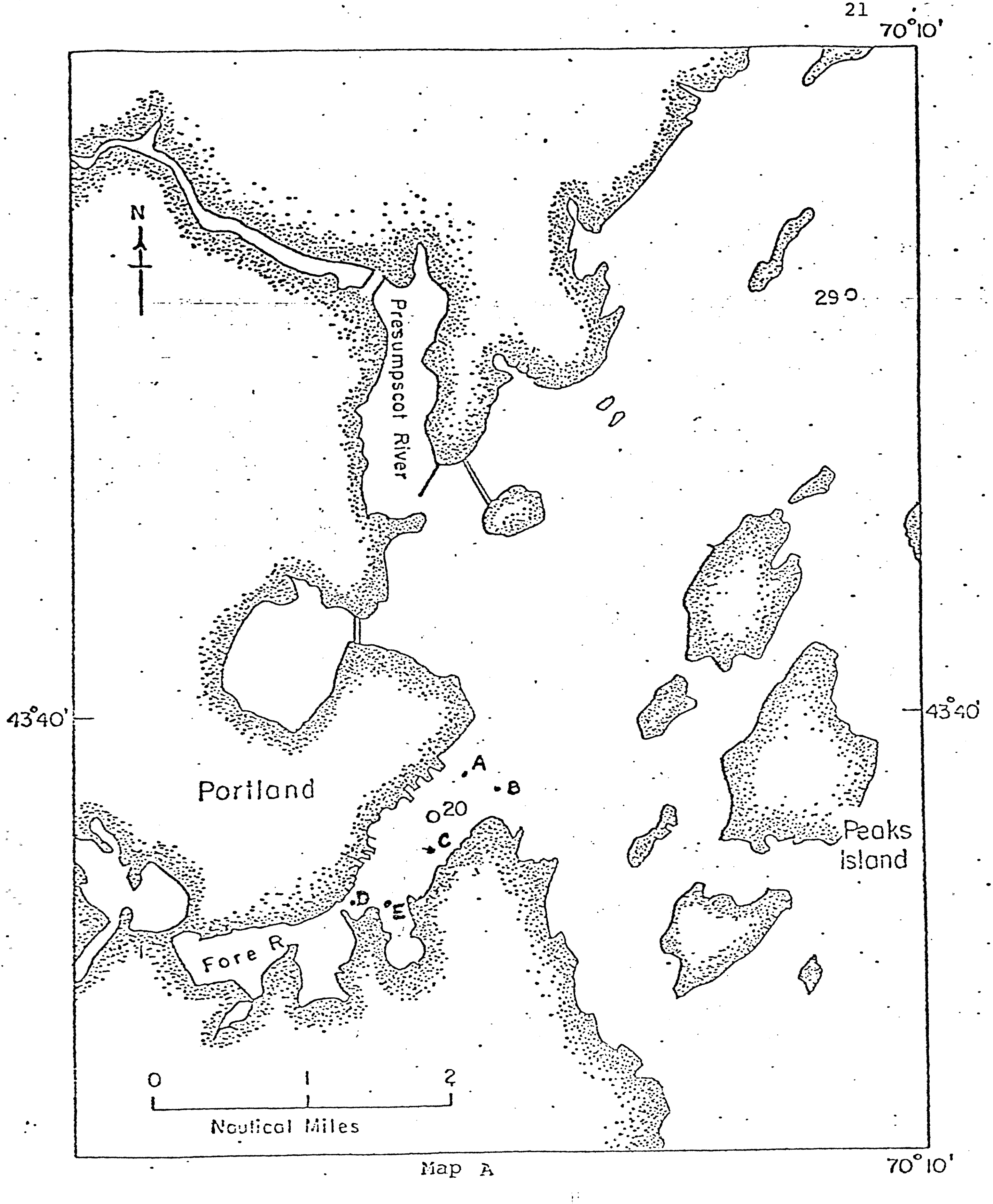

Fig. 3. Location of stations sampled for PCBs in Casco Bay.

the center of a 0.1 m^2 Smith-McIntyre grab at each station, with the exception of stations 20 and 29 in December 1982 and at station 20 in August 1983 when duplicate subsamples were taken. In September 1983, six replicate grab samples were taken at stations 20 and 29 and a single subsample for PCB analysis was removed from each.

Sediment subsamples for PCB analyses were frozen immediately and stored frozen until analysis. Laboratory procedures were consistent throughout the course of the monitoring and followed methods developed by the US Environmental Protection Agency for PCB determinations in bottom sediments (US EPA, 1977). Samples were copper treated for sulfur interference.

Organic carbon content of the sediments was determined on a Hewlett-Packard Model 185B CHN analyzer. Grain size distributions were analyzed by standard sieve and pipette techniques (Ingram, 1971; Galehouse, 1971).

RESULTS AND DISCUSSION

The results of this monitoring effort stand in sharp contrast to those of the initial baseline survey and previously reported monitoring (Larsen et al., 1983a). In the present study, PCBs were encountered at every station (Table 3). At station 29, PCB sediment levels ranged between 0.04 and 0.10 ppm with a mean of 0.06 ppm. In Portland Harbor, concentrations ranged from 0.08 to 0.34 ppm. Within given sampling periods station 20 values were 2 to almost 7 times higher than those observed at station 29. The intersample variability encountered at station 20, for example July and December 1982, is believed to be due to slight errors in station relocation.

The five stations spaced throughout Portland Harbor and sampled in August 1983 manifested sediment PCB concentrations between 0.11 and 0.32 ppm. Whereas this sampling density is not sufficient to draw definitive conclusions as to the absolute distribution of total PCBs in Portland Harbor sediments, the data are suggestive. The highest concentrations are found at those stations closest to the Portland waterfront, i.e.,

Table 3. Concentrations of total PCBs (ppm. dry wt.) in surficial sediments of Casco Bay

			Date			
Station	7/81	2/82	7/82	12/82	8/83	9/83
20	0.21	0.25	0.34	0.08*	0.21*	0.08
				0.11*	0.23*	0.14
						0.10
						0.20
						0.17
						0.09
29	0.05	0.10	0.05	0.04*	-	0.04
				0.05*	-	0.06
						0.05
						0.04
						0.06
						0.10
A					0.32	
B					0.11	
C					0.20	
D					0.23	
E					0.14	

*Duplicate subsamples taken from single grabs stations 20 and A, while the lowest values are found further removed from the waterfront, i.e. B and E.

For purposes of comparison, a recent survey of PCBs in the sediments of the New York Bight found maximum concentrations of about 0.150 ppm (Reid *et al*., 1982).

Linear correlations were computed between PCB levels, total organic carbon (TOC) and the fine sediment fraction (percent sediment <63 μm) for all samples taken in 1983. Correlation coefficients (r) were as follows: TOC x <63 μm = 0.840; PCB x TOC = 0.184; and PCB x <63 μm = −0.190. To be significant r must exceed 0.456 for the 95% confidence level and 0.575 for the 99% confidence level. In other words, TOC was highly significantly correlated with the sediment fine fraction. The correlation between PCB concentration and both TOC and sediment fine fraction, however, was not significantly different from zero. The lack of a relationship between TOC and PCB concentration is considered indicative of PCBs entering Portland Harbor, directly, i.e. not associated with sewage organic carbon.

SUMMARY AND CONCLUSIONS

Environmental monitoring of Portland Harbor and Casco Bay established that PCBs are present in the surficial sediments. Levels were consistently and substantially higher in the Portland Harbor area (stations 20, A, B, C, D and E) than in lower Casco Bay proper (station 20). These levels are comparable or above levels recently reported in the New York Bight and no correlation between PCB concentration and either grain size or organic carbon content existed. We make no speculations as to potential source(s) of the PCBs.

The results demonstrate the value of well-devised monitoring programs.

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