Bull. Environ. Contam. Toxicol. 30, 530–535 (1983)

Distribution of Polycyclic Aromatic Hydrocarbons in the Surficial Sediments of Casco Bay, Maine*

Peter F. Larsen,[1] Donald F. Gadbois,[2] Anne C. Johnson,[1] and Lee F. Doggett[1]

[1]*Bigelow Laboratory for Ocean Sciences, W. Boothbay Harbor, ME 04575, and* [2]*National Marine Fisheries Service, Gloucester, MA 01930*

Polycyclic aromatic hydrocarbons (PAH) have received increasing attention in recent years because of their carcinogenic and mutagenic properties combined with their nearly ubiquitous distribution in depositional environments (YOUNGBLOOD & BLUMER 1975). There are several routes of entry of PAH's into the nearshore marine sediments including petroleum pollution, fallout from air pollution, effluents from industries and sewage treatment plants, storm drain runoff, and creosote wharfs and pilings (DUNN and FEE 1979). A wide variety of marine organisms, especially commercially harvested shellfish, are known to become contaminated by PAH's (ibid) and a strong correlation exists between sediment levels of certain PAH's and organism concentrations (DUNN 1980).

In spite of the public health implications of PAH's, there are few reports of their areal distribution in coastal sediments. In this communication we present levels of 16 priority PAH's (U.S. ENVIRONMENTAL PROTECTION AGENCY 1977) from the surficial sediments of Casco Bay, Maine. Casco Bay is a 400 sq. km. embayment in the Gulf of Maine which includes Portland Harbor, a major oil port and the principal fishing port in Maine. Recent data are presently available on the distribution of trace metals, PCB's and benthic fauna in Casco Bay (LARSEN et al. 1982, 1983a, b).

METHODS

In April 1980, 30 stations (Fig. 1) were sampled in Casco Bay using a 0.1 m^2 Smith-McIntyre grab. Subsamples for hydrocarbon analysis were removed from the center of each grab, using solvent-rinsed scoops and glassware, and frozen until analysis. Analytical analyses were performed at the National Marine Fisheries Service laboratory at Gloucester, Massachusetts following the procedures of DUNN & ARMOUR (1980); see also HUMASON and GADBOIS (1982).

RESULTS AND DISCUSSION

Results of the sediment PAH analyses are presented in Table 1. Each of the 16 PAH's occurred in Casco Bay at between 1 and 30 stations. Eight compounds, pyrene, benzo-a-anthracene, chrysene, benzo-b-fluoranthene, benzo-a-pyrene, dibenzo-a,h-anthracene,

---

*Cont. No. 83003 of the Bigelow Laboratory for Ocean Sciences

Table 1. The concentrations of individual PAH's (ppb, wet weight) found at the 30 Casco Bay stations. Blank space indicates compound not detected.

Station Number	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo-a-anthracene
2								57	110
4				18	15				71
8			140	22	36			64	92
9	113			18	55	34	136	67	56
10			34					72	191
11								136	188
15				41				32	60
16			58					52	59
17				29				36	41
19			1150		670			685	670
21				23			218	208	417
26				40				113	162
29				94				120	254
32								54	54
34			84					55	48
36		1870							211
37					810			635	530
41		165		17				51	65
42				22				38	62
43				65				30	46
46				302				242	287
47									59
48								870	565
50				226	2000	755	1420	1680	1325
52				108				44	226
53									294
54								64	32
55				16				189	152
56				28				137	129
57				18				35	68
Occurrences	1	2	4	18	6	2	3	26	30
Range	ND-113	ND-1870	ND-1150	ND-302	ND-2000	ND-755	ND-1420	ND-1680	32-1325

ND = Not detected

Table 1 (continued)

Station Number	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	PAH's per station	{PAH}total
2	86	99		26	87	39	33	8	637
4	80	205		32	36	22	26	9	505
8	98	340		34	46		28	10	900
9	46	136		10	37	16	21	13	745
10	163	346		103	125	82	52	9	1168
11	154	335		168	137	46	67	8	1231
15	66	132		29	26	22	24	9	432
16	43	147		20	62	34	30	9	505
17	618	169		20	48	40	32	9	1033
19	545	1860		398	720	328	269	10	7295
21	241	488		98	210	106	82	10	2091
26	216	497		114	178	78	74	9	1472
29	204	434		98	158	94	60	9	1516
32	72	124	48	17	48	25	31	9	473
34	72	184		25	72	44	30	9	614
36	800							3	2881
37	775	4550		312	396	152	150	9	8310
41	66	151	43		39	28	25	10	650
42	55			14			24	6	215
43	41		21	11	30		18	8	262
46	363	1380		163		72	89	8	2897
47	52	248			31		12	5	402
48	650	2850		420	635	305	272	8	6567
50	1450	2845		805	920	494	505	12	14425
52	236	376		86	127		48	8	1251
53	448	1415		82	256			5	2495
54	81	286		50			30	6	543
55	198	440	84	58	140	87	70	10	1434
56	129	454	193	56	198	75	79	10	1478
57	71	165		40	54	23	25	9	499
	30	27	5	27	26	22	28		
	ND-1450	ND-4550	ND-193	ND-805	ND-920	ND-494	ND-505		

benzo-g,h,i-perylene and indeno-1,2,3-c,d-pyrene occurred at over 73% of the stations. All 16 individual PAH's exhibited concentrations in the hundred ppb range at specific stations and eight exceeded 1,000 ppb wet weight at least at one station. The highest individual concentration was that of benzo-b-fluroanthene at station 37 which was measured at 4,550 ppb.

Individual stations manifested between 3 and 13 PAH compounds with a mean of 8.57. Total concentrations of PAH at the 30 stations ranged between 215 and 14,425 ppb (wet weight) with a mean of 2,164 ppb. There was no significant correlation between the number of PAH's at a station and the total concentration at that station ($p>.10$) which suggests a multiplicity of inputs of these pollutants.

There was a strong geographic element to the distribution of PAH concentrations in Casco Bay (Fig. 1). With only one exception (sta. 17), stations in the upper and mid sections of the Bay were characterized by values of 900 ppb and below. Concentrations above 2,000 ppb were limited to stations in the Portland vicinity including the principal shipping channel into Casco Bay and the mouth of the Presumpscot River(stations 19, 21, 36, 37, 46, 48, 50 and 53). Intermediate values, between 1,033 and 1,516 ppb, were found at lower Bay stations (10, 11, 26, 29, 52, 55 and 56). High environmental levels of PAH's in this area were hardly unexpected as each of the potential sources mentioned in the introduction exist in the region. What is somewhat surprising is the marked concentration of highly contaminated stations in the Portland area. This is strongly suggestive of localized, anthropogenic inputs. LARSEN et al. (1982) encountered similar pollutant distributions with the implication of anthropogenic inputs from within Portland Harbor in their survey of Casco Bay sediment trace metals.

The PAH benzo-a-pyrene has received considerable attention in the literature because of its well-established carcinogeneity. This compound was encountered at 90% of the stations sampled and had a mean concentration of 109.6 ppb. This concentration should be considered conservative since HUMASON & GADBOIS (1982) experienced only a 40% recovery of benzo-a-pyrene using the same methods and equipment as in the present study.

The persistence of PAH's in estuarine sediments seems to be related to their molecular weights (MW) (READMAN et al. 1982). Low MW compounds tend to be volatile and subject to rapid microbial degradation, hence they have short residence times. High MW PAH's have a high particulate affinity and low microbial degradation rate and hence tend to accumulate in sediments. The present results support these conclusions as the low MW compounds such as naphthalene, phenanthrene and anthracene were found at few stations whereas, with the exceptions of fluoranthene and benzo-k-fluoranthene, the high MW compounds were found at a majority of the stations.

It would seem that a definite possibility exists for the contamination of the living marine resources of this commercially important area. We therefore are in the process of evaluating PAH levels in tissues of commercially harvested shellfish and examining sediments from other regions of the Gulf of Maine to determine the scale of the potential threat to environmental quality.

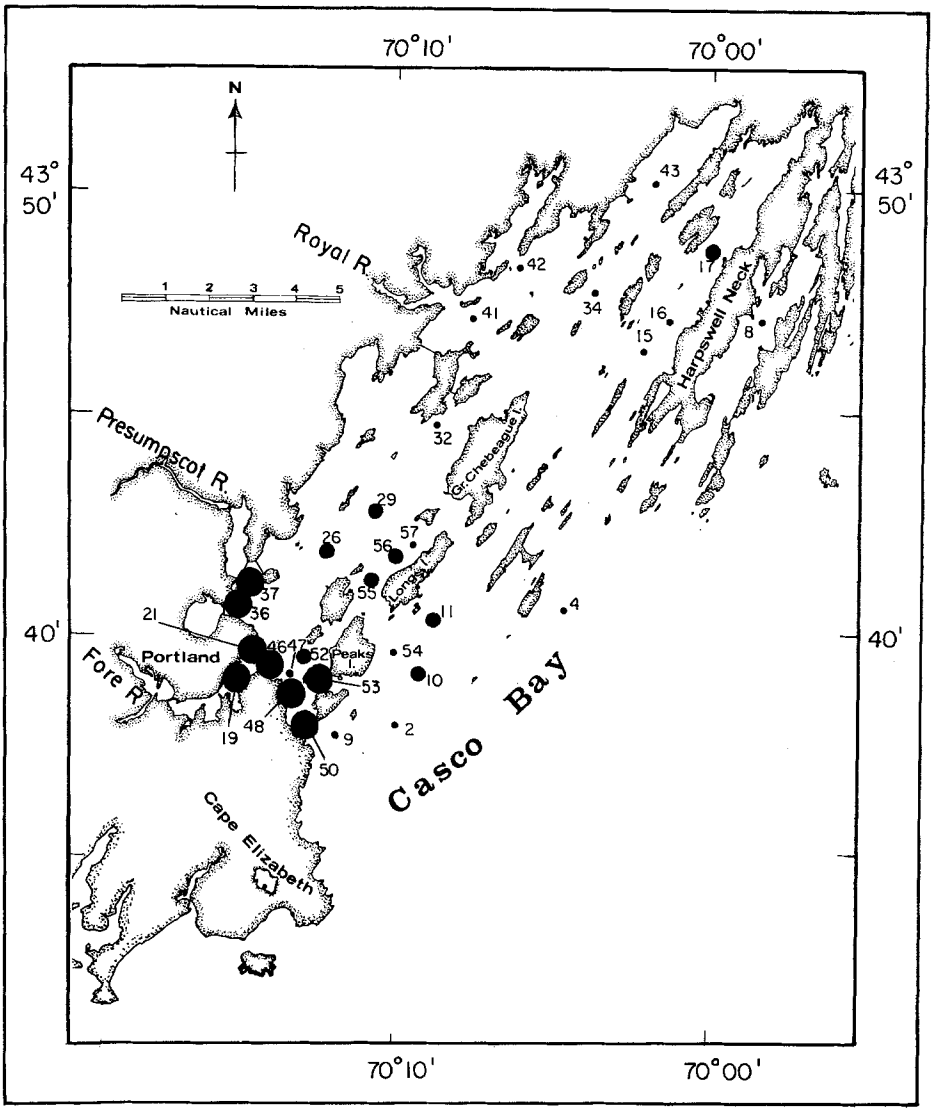

Fig. 1. Location of stations sampled for PAH's. Small filled circles indicate concentrations < 1,000 ppb, intermediate circles 1,000-2,000 ppb and large circles > 2,000 ppb.

ACKNOWLEDGEMENTS

The authors acknowledge the contributions of P. DeRocher and M. Dunton of the Maine Department of Marine Resources (DMR), and of A. Humason (NMFS). This work was supported by the Ocean Pulse program under NOAA-NMFS contract NA-80-FA-C-0008 and by the DMR contract 2-81 with funds provided by the Office of Coastal Zone Management.

REFERENCES

DUNN, B.P.: Polycyclic aromatic hydrocarbons in marine sediments, bivalves, and seaweeds: Analysis by high-pressure liquid chromatography. In: Polynuclear Aromatic Hydrocarbons: Chemistry and Biological Effects. Batelle Press, Columbus, Ohio, 367, (1980).

DUNN, B.P. and R.J. ARMOUR: Anal. Chem. 52, 2077 (1980).

DUNN, B.P. and J. FEE: J. Fish. Res. Bd. Can. 36, 1469 (1979)

HUMASON, A.W. and D.F. GADBOIS: Bull. Environ. Contam. Toxicol. 29, 645 (1982).

LARSEN, P.F., V. ZDANOWICZ, A.C. JOHNSON and L.F. DOGGETT: Chem. in Ecol. 1, (1982)

LARSEN, P.F., D.F. GADBOIS, A.C. JOHNSON and L.F. DOGGETT: Mar. Poll. Bull. In press (1983a)

LARSEN, P.F., A.C. JOHNSON and L.F. DOGGETT: Environmental Benchmark Studies in Casco Bay - Portland Harbor, Maine, April 1980. NOAA Tech. Memo. NMFS-F/NEC Series, In press (1983b).

READMAN, J.W., R.F.C. MANTOURA, M.M. RHEAD and L. BROWN: Est. Coast. Shelf. Sci. 14, 369 (1982)

U.S. ENVIRONMENTAL PROTECTION AGENCY: Sampling and analysis procedures for screening of industrial effluencts for priority pollutants. U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio, 34, (1977).

YOUNGBLOOD, W.W. and M. BLUMER: Geochim. Cosmochim. Acta 39, 1303 (1975)

Accepted February 20, 1983