Status of Organic Pollutants in Surface Sediments of Barnegat Bay-Little Egg Harbor Estuary, New Jersey, USA

C.H. Vane*[1], I. Harrison[1], A.W. Kim[1], V. Moss-Hayes[1], B.P. Vickers[1], B. P. Horton[2]

[1]British Geological Survey, Kingsley Dunham Centre, Keyworth, Nottingham, NG12 5GG, UK [2]Department of Earth and Environmental Science, University of Pennsylvania, 240 South 33rd Street, Philadelphia, PA 19104, USA

*Corresponding author. Tel+44 (0)115 936 3017; fax+44 (0)115 936 3460. E-mail address: chv@bgs.ac.uk

Numerous surveys have demonstrated that diffuse pollution from urban-residential run-off and industrial discharges can adversely impact salt marsh and tidal creek sediment quality (Barrett & McBrien, 2006; Fox et al., 2001; Iannuzzi et al., 1995; Long et al., 1995; Sanger et al., 2004; White et al., 2005). The impact of shipping activities, including major discharge of fuel oil onto salt marshes, has also been reported (White et al., 2005). However, few studies have assessed organic pollution accumulating in salt marshes with watersheds that are mainly comprised of forests and wetlands but which have major residential areas located off-shore of the mainland. The salt marshes of Barnegat Bay-Little Egg Harbor Estuary, southeast New Jersey represent one such geographical setting (Fig .1). The shallow (1- 7 m), narrow (3-9 mile) bay is separated from the Atlantic Ocean by a back barrier island complex (Long Beach Island) which is heavily developed and a major area of tourism (Fig. 1). The salt marshes are protected and managed as part of the Edwin B. Forsythe National Wildlife Refuge, this comprises 186 km^2 of wetlands and 145 km^2 of salt marshes and has a mixed pattern of watershed land use such as forestry (45.9 %), wetlands (25.2 %), urban/residential (19.5 %) and agricultural (6.6 %).

The organogenic salt marshes on the East coast of the USA are potentially important sinks for organic contaminants due to preferential adsorption of pollutants to partially decomposed organic matter in the sediments (Fox *et al.*, 2001; Scrimshaw & Lester, 2001). Once sorbed to the sediment, compound groups such as PAHs and PCBs can also accumulate in the leaves and roots of standing-decaying salt marsh plants such as *Spartina alterniflora* which are an important food source for the base of the detrital salt marsh food chain (Mrozek et al., 1983; Wall et al., 2001). Biomagnification of organic pollutants to higher trophic levels (prey to predator) occurs by a combination of lipid-water partitioning and dietary accumulation

processes as well as other food-web specific routes (Connolly & Pedersen, 1988; Kelly et al., 2007). Previous investigations have reported that PCBs in soil can adversely effect the growth of *S. alterniflora* reducing aerial and below ground biomass by 35.7 % and 20.5 % respectively (Mrozek et al., 1983).

The aims of this study were to: 1) determine individual concentrations of parent PAHs and PCBs and total non-volatile hydrocarbons as well as Hg contamination in tidal creek salt marsh sediments in the Little Egg Harbor study area; 2) Identify where possible spatial gradients of contaminants to pin-point sources of pollution; 3) Compare the contaminant concentrations to published benchmarks the soil guide line values (SGV) to evaluate possible impact upon ecological habitat.

Fifteen surface sediments (0-10 cm) were collected from the banks of tidal creeks within the Barnegat Bay-Little Egg Harbor Estuary from June 20th to 29th 2007 using a stainless steel trowel (Fig. 1). Sediments were sealed in polyethylene plastic bags and transported in a cool box at ~4ºC then immediately frozen. In the laboratory an aliquot of each (~500 g) sediment was freeze-dried, sieved through a mesh aperture of 2 mm and the <2 mm fractions ground to a fine powder. Total organic carbon (TOC) content was determined using an Elementar VarioMax C, N analyser after acidification with HCl (50/50 v/v) to remove carbonate. The limits of quantification reported for a typical 300mg sample were 0.18%. For hydrocarbon analysis 2g of ground sediment was extracted with dichloromethane (DCM)/ acetone (1:1 v/v) mixture using a accelerated solvent extraction system (ASE 200, Dionex). A 5 µL aliquot was spotted on to silica rod (Chromarods-S III) using a programmed auto-spotter fitted with a 10 µL syringe. The rods were developed for 21 min using 100 ml n-hexane and then for 8 min with toluene 100 ml. The concentration of saturated and aromatic hydrocarbons was determined using by an Iatroscan Mk6s instrument fitted with a flame ionization detector (FID) and operated using Chrom Star software. The limit of quantification (LOQ) for total non-volatile hydrocarbons was 3 mg/kg.

For each Hg preparation 0.5 g sediment was treated with 5 ml deionised water and 5 ml of aqua regia for 15 h then heated at boiling point for 2 h. Once cooled, 50 ml of deionised water was added and shaken. After settling a 5 ml aliquot was transferred and diluted with deionised water to give a 2% solution. The samples were analysed using PSA atomic fluorescence spectrometer system comprising a XYZ Autosampler and a Millennium Merlin operated with an Ar flow rate of 30-50 psi and detector set at 253.7 nm. The limit of quantification (LOQ) for Hg was 0.02 mg/kg.

The method used to extract and determine PAH concentrations was based on that described by Vane et al., (2007a). Briefly, 5 g of sieved sediment was extracted by sonication with 20 ml 50/50 v/v acetonitrile and tetrahydrofuran (THF) at 50°C. Filtered (0.2 µm) sample extracts (including those of the QCs and the procedural blanks) were analysed by an HPLC system that incorporated a fluorescence detector –

(details of the HPLC system are included in Table 3). Separation of 18 PAHs was achieved within 45 mins by gradient programming the eluent. Quality control was achieved by subjecting a well-characterised, PAH proficiency testing sediment (see Table 2) to the above procedure (except that a weighed 0.1g was extracted into 100 ml acetonitrile/THF). A procedural blank prepared from 15g white quartz sand (Sigma Aldrich, UK) – a material devoid of PAH - was treated in a similar fashion. A total of four QC runs were conducted at intervals throughout the analysis of the samples (Table 2). Limits of quantification are presented in Table 3 and for each PAH comprise the peak area, occurring at the retention time of that PAH, in the procedural blanks to which has been added three times the standard deviation of the areas.

The method used to extract and determine PCB concentrations, has been described by Vane et al., (2007). In summary, sediments were spiked with authentic standards, mixed with an equal amount of anhydrous sodium sulphate and extracted with hexane/acetone (1:1v/v) in an ASE 200 (Dionex). Extracts were eluted through a Pasteur pipette containing anhydrous sodium sulphate (1g) and Florisil with 10 ml of n-hexane. The eluant was extracted with dimethylsulphoxide (DMSO, 2 × 12 ml) and diluted with 18 MΩ de-ionised water (25 ml) prior to extraction with n-hexane (50 ml). The n-hexane extracts were reduced to 5 ml, passed through anhydrous sodium sulphate (1g) and reduced to 100 μl. Combined gas chromatography-mass spectrometry (GC-MS) was performed on a Carlo Erba Mega 500 series gas chromatograph (GC) directly coupled to a Varian 1200L triple quadropole mass spectrometer operating in full scan mode (ionization energy 70 eV, mass range 39-550 amu). Sample application (1 μl) was by split/splitless injection; the GC was fitted with a fused silica ZB-5 column (60 m length x 0.32 mm i.d. x 0.25 μm film thickness). The GC oven was temperature-programmed from 100°C (1 min. isothermal) to 200°C (at 5°C / min.) to 280°C (at 2.4°C / min.) to 320°C (at 20°C / min.) and held isothermally at 320°C for 5 min and helium was used as carrier gas at 16 p.s.i. The LOD based on the minimum concentrations that gave clearly defined peaks was between 0.1-0.20 μg/kg. Quality control was achieved by subjecting a PCB certified reference material (EC-4) to the above procedure and analysing it by the same method as for the samples. A procedural blank prepared from white quartz sand (Sigma Aldrich, UK) – a material devoid of PCBs - was treated in a similar fashion.

Total hydrocarbon concentrations for surface sediments of Barnegat-Bay-Little Egg Harbor Estuary ranged from 47 mg/kg at Turtle Cove (site 3), to 1003 mg/kg at Parker Run (site 7), the mean total hydrocarbon concentration for the sediments was 231 mg/kg. Overall, the salt marsh creek sediments were dominated by saturate as compared to aromatic hydrocarbons (Table 1). No clear systematic downstream or upstream concentration gradients for Scotts Landing, Parker Run, Cedar Run or Mill Creek were observed suggesting that the pollution was not derived from the urbanized off-shore centre at Long Beach Island. In pristine estuarine and intertidal sediments total hydrocarbon concentrations range from about 0.5 to 10 mg/kg and can be as high as 30 mg/kg, where there is significant input from *n*-alkanes sourced

from for example plant waxes. Sediments containing total hydrocarbons at concentrations >100 mg/kg are generally considered to have received some petroleum pollution and sediments with values >500 mg/kg are indicative of significant petroleum inputs (Bharati et al., 1997; Readman et al., 2002; Volkman et al., 1992; Volkman & Nichols, 1991). Using these criteria, ten of the fifteen sites had total hydrocarbon values that suggested minimal levels of petroleum contamination and one site (7) had received significant hydrocarbon pollution. The low hydrocarbon values at sites 3, 10, 13, 14 and 15 probably represent background hydrocarbons derived from biological sources such as the dominant salt marsh plants, namely cord grasses (*Spartina patens* and *S. alterniflora*) and possibly other sources such as animals as well as micro and macroalgae (Volkman et al., 1992). Overall, the range of hydrocarbon concentrations encountered in the Little Egg Harbor Estuary, are consistent with biologically derived hydrocarbon source augmented by low levels anthropogenic hydrocarbon contamination. The values are broadly comparable to that from a study of sediment cores from Newark Bay Estuary, New Jersey, where mean total petroleum hydrocarbon (TPH) in sediments from the 1970's to 1990 ranged from 240 mg/kg in Passaic River to 280 mg/kg in Newark Bay Estuary (Huntley et al., 1995). In contrast, the same study also showed a high input, accumulation and preservation of TPH during the 1960's with mean TPH values of 2,300 to 3,100 mg/kg for Passaic River sediments and 1,000 to 1,300 within Newark Bay Estuary sediments. The higher values were attributed in part to catastrophic oil spill events as well as diffuse pollution sources (Huntley et al., 1995). Similarly, downcore TPH profiles tracking an oil spill event in 1969 at salt marsh in Wild Harbor, West Falmouth, MA, showed TPH values as high as 9000 mg/kg (White et al., 2005).

Mercury concentrations ranged from <0.02 to 2.61 mg/kg, the mean of the study area was 0.31 mg/kg (Table 1). The Hg concentrations confirmed a low Hg content indicative of natural background for 14 of the 15 sites. The highest concentration of Hg (2.61mg/kg) was found at site 11, situated in the upper non-tidal reaches of Cedar Run (Fig. 1). Mercury in sediments may either be of geogenic (natural background) origin or be of anthropogenic origin or be a mix of both. The precise source of the Hg at site 11 was difficult to ascertain given that inspection of the area showed no industry and a lack of similarly elevated levels downstream at sites 12 and 13 or an associated decreasing Hg gradient (Table 1; Fig. 1). One plausible explanation for the elevated Hg content at site 11 is that the pollution represents a single discharge event of material containing elevated Hg from the nearby road bridge. The Hg concentration at site 11 exceed Hg effects range median (ERM) limit of 0.71 mg/kg for marine and estuarine ecosystems, indicating that Hg may have a possible adverse effect on aquatic organisms (Long et al., 1995). Nevertheless, these concentrations remain low relative to industrialised New Jersey waterways such as Passaic River (Armstrong et al., 2005). Overall, the Hg concentrations observed in this current study are similar to those previously reported for surface sediments collected from the nearby Mullica River (see Fig. 1) which varied from 0.24-0.46 mg/kg with the

exception of one location which lies in close proximity to a small road bridge (Armstrong et al., 2005).

Total PAH (Σ 18 PAHs) concentrations (see Table 3) ranged from 37 $\mu g/kg$ at Mill Creek (site 14) to 1696 $\mu g/kg$ at Tuckerton Creek (site 5) with a mean for the study area of 671 $\mu g/kg$. These data are comparable with those reported for contaminants in surface sediments taken from the mudflats of the Mullica River (Iannuzzi et al., 2005), where total PAH (Σ 25 PAHs) concentrations varied between 436 $\mu g/kg$ and 1380 $\mu g/kg$ with a mean of 786 $\mu g/kg$. In their report, Iannuzzi et al. have contrasted the contamination of the Mullica River, a region they note to be held as "one of the least disturbed estuarine rivers in the urban corridor of the N.E. United States", with that of the lower Passaic River mudflats. In the Passaic River study area, they reported total PAH (Σ 25 PAHs) concentrations in the range 13,600 $\mu g/kg$ to 131,000 $\mu g/kg$ with a mean of 30,493 $\mu g/kg$. In our study no appreciable correspondence between TOC and total PAH concentration was found to exist (Fig. 2) and the correlation was weaker ($r^2 = 0.22$) than for the PCBs ($r^2 = 0.48$) (Fig. 4). It was observed that the sediments exhibiting the lowest total hydrocarbons concentrations were also those with the lowest total PAH concentrations (*i.e.* from sites 3, 10, 13, 14 and 15) supporting the assertion that these sediments are comparatively uncontaminated. To aid in identifying the sources of PAH, isomeric ratio cross plots (Fig. 3) were constructed based on the relative concentrations of isomeric pairs of PAHs whose ratios have been identified as diagnostic of PAH origin (Yunker et al., 2002). The resulting three cross plots revealed that petrogenic inputs of PAH did not predominate in any of the samples. The only points that plot outside the purely combustion zones of the cross plots occur for samples from sites 3, 10 and 14. Whilst there is the possibility that this could signify some petrogenic contribution to the overall PAH distribution in these instances, it needs to be borne in mind that diagnostic ratios are merely indicative, not rigorous means of unequivocally assigning PAH origin. Accordingly, it is probably prudent to observe only that all the samples display a dominance of the pyrolitic PAHs. The likely sources of these will be a combination of local point source anthropogenic inputs and the ubiquitous pyrolitic PAH deposition that results from global aeolian transport (Jaward et al., 2004). The latter will be present in greater proportion in the samples with low, compared to those with higher, total PAH concentrations

The concentrations of individual congeners (ICES 7 group) and total PCBs as well as summed tri-, tetra-, penta-, hexa-, hepta-chlorinated congeners are shown in Table 4. The mean concentration of 15 tidal creek sites was 21 $\mu g/kg$ and all sites showed some degree of PCB contamination, although this was low (Table 4). The highest concentrations were along Parker Run at sites 9 (50 $\mu g/kg$) and 7 (48 $\mu g/kg$) and the lowest at site 3, Turtle Cove (4 $\mu g/kg$). Comparison of TOC with PCB content revealed a weak but nevertheless positive correlation ($r^2 = 0.48$) (Fig 4), the most likely explanation being the sorption of PCB congeners to clay particles and or natural organic matter in the sediment. No clear spatial trend in PCB values were

observed from coast to upper reaches of the creeks suggesting diffuse and atmospheric pollution as compared to single point sources. This is perhaps not surprising given that the onshore area lacks major industries and is not heavily urbanized. A previous survey of PCBs in surface sediments of the Mullica River conducted in 1999 and 2000 revealed total PCBs in the range 25 to 46 µg/kg, with a mean of 36 µg/kg (Iannuzzi et al., 2005). This range is broadly consistent with the PCB values found in this current study and supports the notion that the sediments in Little Egg Harbor Estuary are not receiving significant inputs of PCB pollution (Table 4). The homologue distributions were centered at the tetra-, penta-, and hexa-chlorinated congeners with lower relative amounts of tri- and hepta-chlorinated counterparts (Table 4). Although the homologue distributions encountered here are broadly similar to that of the industrial formulation Aroclor 1254 (the most widely sold mixture in the USA) the proportions of tri-chlorinated were higher than would be expected if this was the sole source. The most plausible explanation being that the low concentrations of PCBs in the Barnegat Bay-Little Egg Harbor Estuary are derived from a mix Aroclors such as 1254, 1260, 1242 and 1016 (Frame et al., 1996). Other factors such as dechlorination, volatilization and partitioning from air to water to sediment have probably also modified the congener profiles and homologue distributions to such an extent that source apportionment is beyond the scope of this study (Frame et al., 1996; Gouin et al., 2004; Melanchev et al., 2004; Tyler & Millward, 1996).

Another approach to assessing PCB contamination is to compare sediment concentrations with benchmark values (sediment Quality Criteria), demonstrated to be correlated with deleterious effect on sediment dwelling organisms. Four consensus-based sediment effect concentration ranges for PCBs in marine and estuarine sediments have been identified as <TEC 40 µg/kg (12.5 % incidence of toxicity) to TEC-moderate effect concentration (MEC) 40-400 µg/kg (30.3 % incidence of toxicity), to MEC-extreme effect concentration (EEC) 400-1700 µg/kg (48.7 % incidence of toxicity) and EEC >1700 µg/kg (83.8 % incidence of toxicity) (MacDonald *et al.*, 2000). On this basis the PCB values in 13 of the 15 sites are below those judged to be harmful to sensitive biota and the concentrations at sites (7 and 9) are unlikely to have an adverse effect on biota living in the surface sediments. Past studies examining the effect of total PCB concentrations in sediments on the growth of *S. alterniflora* have given disparate results. Response matching of *S. alterniflora* to PCB contamination levels at a polluted superfund site (5.5-156 µg/kg PCB) located in Georgia, USA showed no measurable change in plant health as compared to a reference site (Wall et al., 2001). In contrast lower levels of PCBs in soils have been suggested to adversely impact upon *S. alterniflora* growth and biomass production (Mrozek et al., 1983).

Acknowledgements

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List of Tables

Table 1. Total hydrocarbon and total Hg concentrations (mg/kg dry wt) in surface sediment of Barnegat Bay-Little Egg Harbor Estuary.

Site	Location	TOC % wt	Saturate HCs (mg/kg)	Aromatic HCs (mg/kg)	Σ Hydrocarbons (mg/kg)	Total Hg (mg/kg)
	Scots Landing	5.5	120	21	141	0.22
2	Scots Landing	4.6	122	19	141	0.20
3	Turtle Cove	0.6	47	<3	47	0.03
4	Scots Landing	7.3	180	<3	180	0.29
5	Tuckerton Creek	8.9	316	40	356	0.14
6	Parker Run	2.6	185	164	349	0.12
7	Parker Run	9.8	760	242	1003	0.09
8	Parker Run	5.7	111	<3	111	0.16
9	Parker Run	6.6	203	39	241	0.25
10	Parker Cove	4.0	63	27	90	0.02
11	Cedar Run	2.7	199	68	267	2.61
12	Cedar Run	3.8	240	67	307	0.10
13	Cedar Run	7.2	66	7	73	0.05
14	Mill Creek	0.5	49	24	73	<0.02
15	Mill Creek	3.9	60	26	86	0.02

HCs= Hydrocarbons; Σ Hydrocarbons=(sum of aromatic and saturate hydrocarbons).

Table 2. Quality Control Reference Material PAH concentrations (µg/kg dry wt) and fluorescence programming.

QC Data LGC Contest 58.3c	Naph	Ace	Fluor	Phen	Anth	Fanth	Pyr	B[a]A	Chrys	B[b]F
Assigned Value (mg/kg)	3.09	1.08	7.70	34.00	5.91	31.74	23.50	11.48	9.94	9.02
Uncertainty (mg/kg)	1.23	0.43	3.08	13.60	2.36	12.70	9.40	4.59	3.98	3.61
Permissible Max. (mg/kg)	4.32	1.51	10.78	47.60	8.27	44.44	32.90	16.07	13.92	12.63
Permissible Min. (mg/kg)	1.85	0.65	4.62	20.40	3.55	19.04	14.10	6.89	5.96	5.41
QC Run 1 (mg/kg)	3.49	1.10	7.27	34.10	4.58	38.99	25.18	9.47	7.68	7.22
QC Run 2 (mg/kg)	2.90	0.96	7.21	33.03	4.51	38.75	23.70	9.41	7.65	6.93
QC Run 3 (mg/kg)	3.29	0.92	7.08	34.38	4.39	38.10	22.45	10.33	9.15	7.07
QC Run 4 (mg/kg)	3.09	0.87	6.72	32.30	4.19	29.32	20.75	8.53	8.81	6.94

PAH Abbreviations :
in Figures & Tables

Naph: naphthalene, 1-MN: 1-methylnaphthalene, 2-MN: 2-methylnaphthalene Ace: acenaphthene
Anth: anthracene, Fanth: fluoranthene, Pyr: pyrene, B[a]A: benz[a]anthracene, Chrys: chrysene
B[k]F: benzo[k]fluoranthene, B[a]P: benz[a]pyrene, DBA: dibenz[a,h]anthracene, B[ghi]P: benz
IP: Indeno[1,2,3-c,d]pyrene

Table 3. PAH concentrations (µg/kg dry wt) for surface sediments in Barnegat Bay
Little Egg Harbor Estuary.

Site	Naph µg/kg	1-MN µg/kg	2-MN µg/kg	Ace µg/kg	Fluor µg/kg	Phen µg/kg	Anth µg/kg	Fanth µg/kg	Pyr µg/kg	B[a]A µg/kg	Chrys µg/kg	B[b]F µg/kg	Pery µg/kg	B[µg
1	11.7	24.8	15.6	4.40	15.3	110	49.0	270	205	119	125	138	99.6	9
2	12.4	22.4	13.9	5.02	9.64	73.7	17.2	117	125	60.5	61.8	79.0	69.6	4
3	0.62	4.02	1.99	<LOQ	0.71	9.14	0.49	7.97	8.64	2.93	5.46	6.85	5.43	4.
4	13.7	53.7	17.9	3.20	7.71	54.2	16.7	105	92.0	52.6	67.2	80.9	72.6	4
5	10.1	49.4	15.9	3.91	7.96	88.1	9.97	305	187	67.5	208	228	61.7	1
6	4.62	21.9	6.46	2.48	4.77	28.6	5.60	74.2	47.8	22.7	31.1	44.5	32.3	2
7	23.9	44.3	25.9	3.57	13.7	52.0	19.9	90.1	79.6	38.7	30.2	38.0	74.3	2
8	6.38	35.2	11.2	2.70	6.33	35.1	6.76	52.7	37.9	20.4	28.8	41.1	45.8	2
9	8.78	37.3	12.8	5.38	10.1	57.5	14.7	141	111	50.4	80.3	93.1	67.4	4
10	3.90	14.2	5.74	0.90	2.85	42.4	1.07	5.91	2.16	5.14	5.70	4.47	30.7	2.
11	27.3	8.29	40.1	9.89	21.5	73.3	17.3	285	197	81.5	85.5	92.1	54.9	4
12	3.18	8.25	5.11	3.31	14. 6	55.2	26.2	147	103	67.3	160	77.8	32.4	4
13	6.08	35.7	7.76	3.09	5.50	36.5	2.71	24.8	15.6	6.59	13.0	16.3	35.3	9.
14	0.99	6.06	1.52	<LOQ	0.61	2.86	0.83	5.13	1.88	1.48	1.92	1.65	9.03	1.
15	2.45	25.7	4.40	1.18	2.01	23.3	1.91	36.6	22.0	3.72	8.98	4.65	7.52	2.
LOQ	0.35	1.30	0.36	0.66	0.05	0.18	0.20	1.79	1.66	0.32	0.15	0.31	0.69	0.

HPLC Detection Data (Waters 474 Fluorescence Scanning Detector):

Ex (nm)	275	275	275	275	275	253	240	240	240	254	254	350	350	3
Em (nm)	325	325	325	325	325	373	425	425	425	395	395	440	440	4
RT (mins)	9.6	13.2	14.2	15.4	16.6	19.4	21.2	22.4	23.3	25.5	26.3	28.8	29.2	3

HPLC Conditions:

Columns	Hypersil Green PAH Analytical (250 x 4.0) & Hypersil Green PAH Guard (10 x 4.0)
Columns Temperature	25°C (Grace-Vydac 7995R Column Heater/Cooler)
Pump System	Waters 600E with flowrate set to 0.7 ml/min
Mobile Phase	A = 80% Acetonitrile/20% Methanol B = Water
Pump Gradient Programming	Initially 65% A : 35% B to 100% A at 14 mins. (Waters Curve 9) and held to end of run
Sample Loop & Volume	Rheodyne 5 µl

LOQ : Limit of Quantification (i.e. Average Area of Procedural Blank + 3 x Std. Deviation), Ex: Excitation Wavelength,   Em

Table 4. Surface sediment PCB concentrations (μg/kg dry wt) in Barnegat Bay-Little Egg Harbor Estuary and quality control PCB concentrations for National Water Research Institute reference material (EC-4).

Site	Site Name	PCB 28	PCB 52	PCB 101	PCB 118	PCB 153	PCB 138	PCB 180	Σ7 PCBs	Tri-Cl
1	Scots Landing	1.6	0.7	0.9	1.2	1.2	1.3	0.4	7.3	4
2	Scots Landing	1.2	0.4	0.6	0.9	1.0	1.0	0.3	5.4	3
3	Turtle Cove	0.2	0.1	0.1	0.0	0.2	0.0	0.0	0.6	1
4	Scots Landing	1.5	0.6	1.1	1.8	2.2	2.0	0.9	10.1	4
5	Tuckerton Creek	1.4	0.5	1.6	2.5	2.7	3.7	1.3	13.7	4
6	Parker Run	0.8	0.6	1.5	1.5	2.1	1.9	0.9	9.2	2
7	Parker Run	0.0	0.4	0.2	0.0	0.3	0.0	0.0	0.8	9
8	Parker Run	0.8	0.3	0.4	0.7	0.5	0.6	0.2	3.4	2
9	Parker Run	1.1	1.0	2.2	2.5	4.1	5.3	1.5	17.7	3
10	Parker Cove	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2	1
11	Cedar Run	0.0	0.1	0.3	0.0	0.4	0.0	0.4	1.2	2
12	Cedar Run	0.5	0.8	1.0	0.9	0.7	0.9	0.3	4.9	0
13	Cedar Run	0.3	0.1	0.2	0.0	0.2	0.0	0.1	0.9	1
14	Mill Creek	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0
15	Mill Creek	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0
	PCB Quality Control									
	Certified values EC4, PCBs in Harbour Sediment	6.8 (±1.8)	12.5 (±5.7)	22.4 (±9.5)	17.8 (±7.7)	27.3 (±7.5)	28.7 (±9.7)	26.1 (±11.0)	None Given	
	BGS values EC4 (n=10)	6.9	12.7	22.4	18.1	27.6	28.7	26.4		
	BGS Std. Dev	0.6	2.0	1.1	1.3	1.8	4.4	1.3		

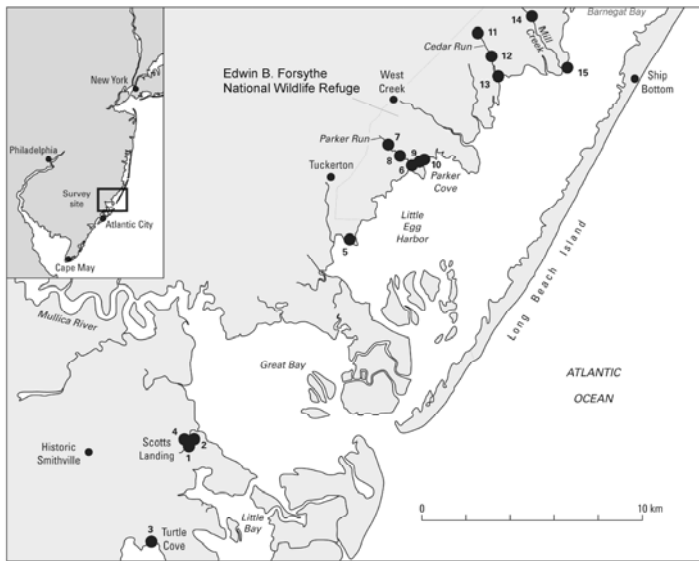Fig. 1. Map showing locations of tidal creeks sampled in Barnegat Bay-Little Egg Harbor Estuary, New Jersey, USA.

Fig. 2. Total PAH concentration (µg/kg dry wt) *versus* total organic carbon, TOC (% wt/wt).
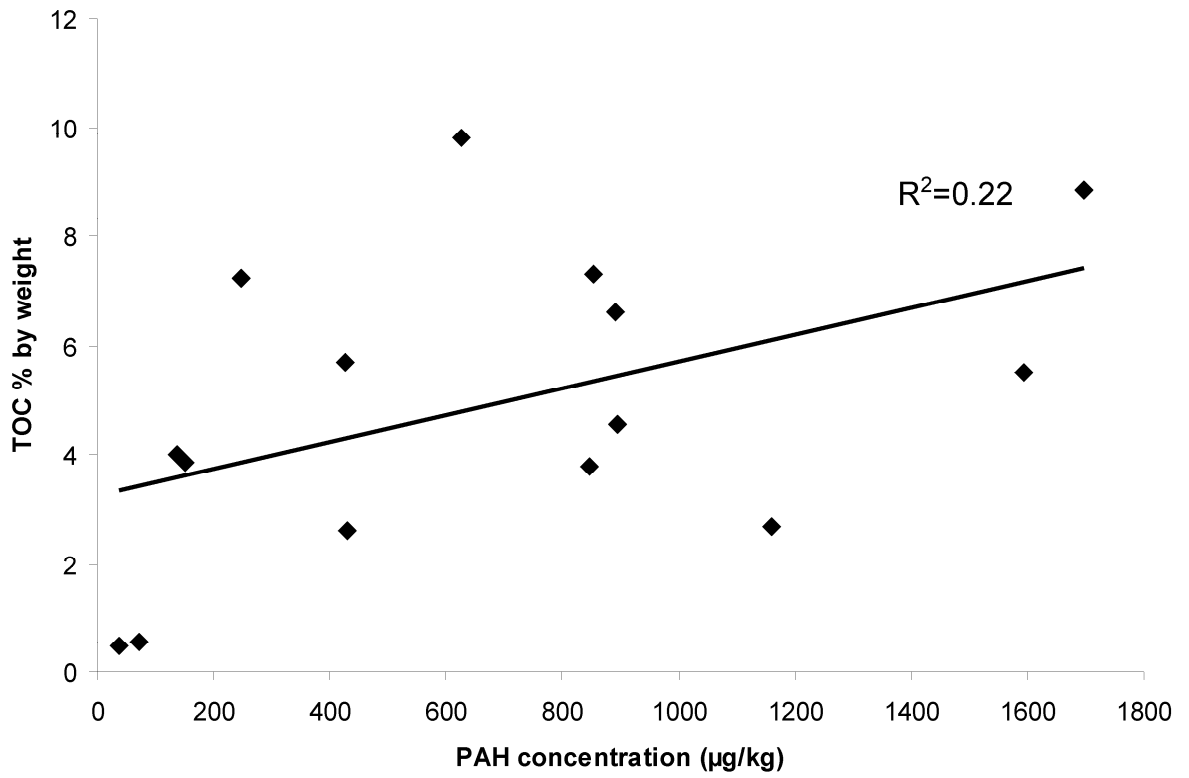
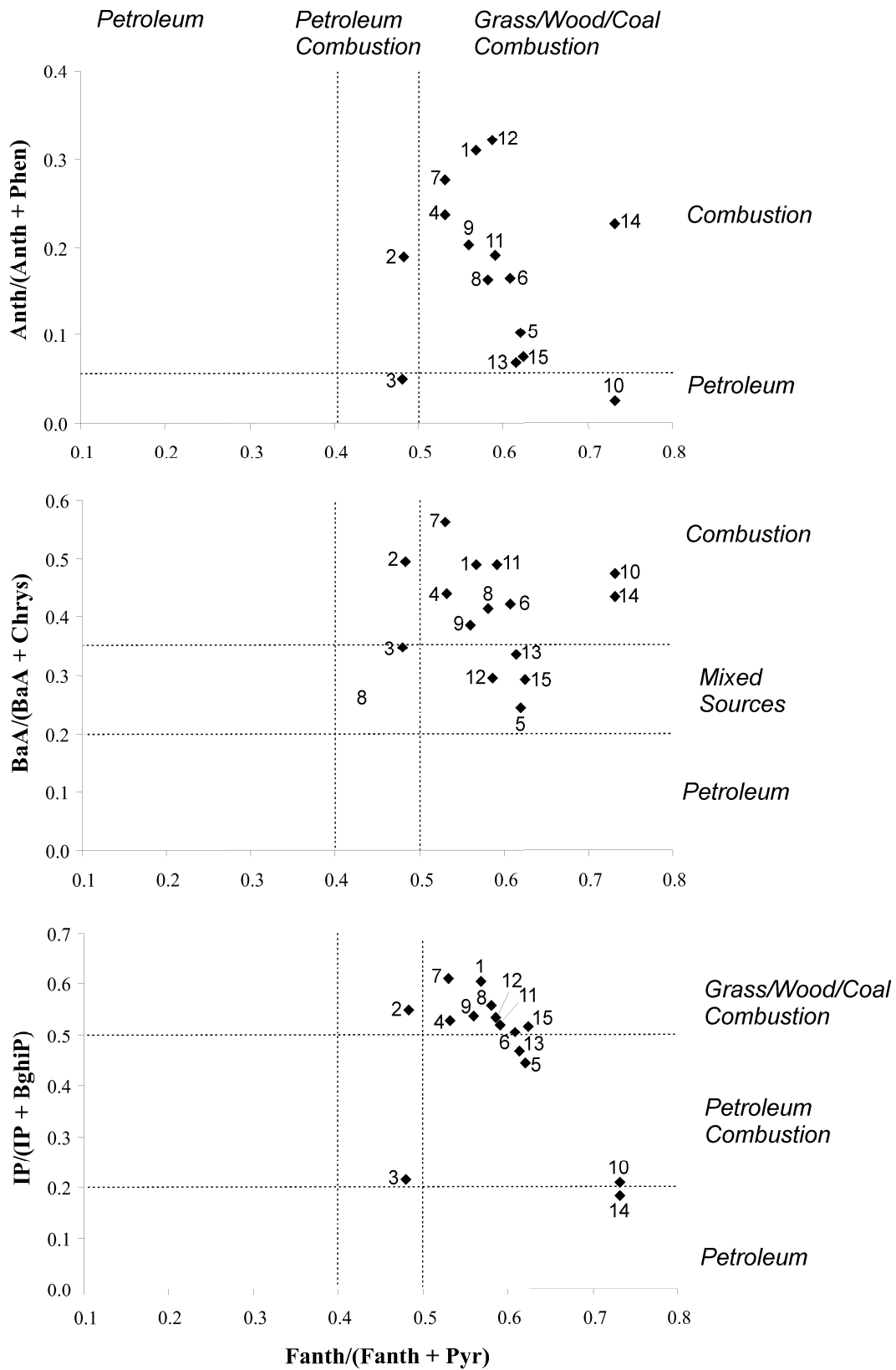Fig. 3. PAH isomeric plot for tidal creek surface sediments from Barnegat Bay-Little Egg Harbor Estuary.

Fig. 4. TOC (% wt/wt) compared with total PCB concentration (µg/kg dry wt) (a)
and; (b) Aromatic hydrocarbons compared with total PCB concentration.