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FINAL
PRESQUE ISLE BAY SEDIMENT QUALITY EVALUATION REPORT
FOR MAY 1994 STUDY

PRESQUE ISLE BAY SEDIMENT STUDY

EPA Contract No. 68-C2-0134
Work Assignment 1-107

to

Environmental Protection Agency, Region III
Water Quality Planning Section
Philadelphia, PA

September 29, 1994

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THE STATE OF NEW YORK
IN SENATE
JANUARY 1, 1903.

REPORT

OF THE

COMMISSIONERS OF THE LAND OFFICE

IN RESPONSE TO A RESOLUTION
PASSED BY THE SENATE
MAY 1, 1899.

ALBANY: J.B. LEECH, STATE PRINTER.

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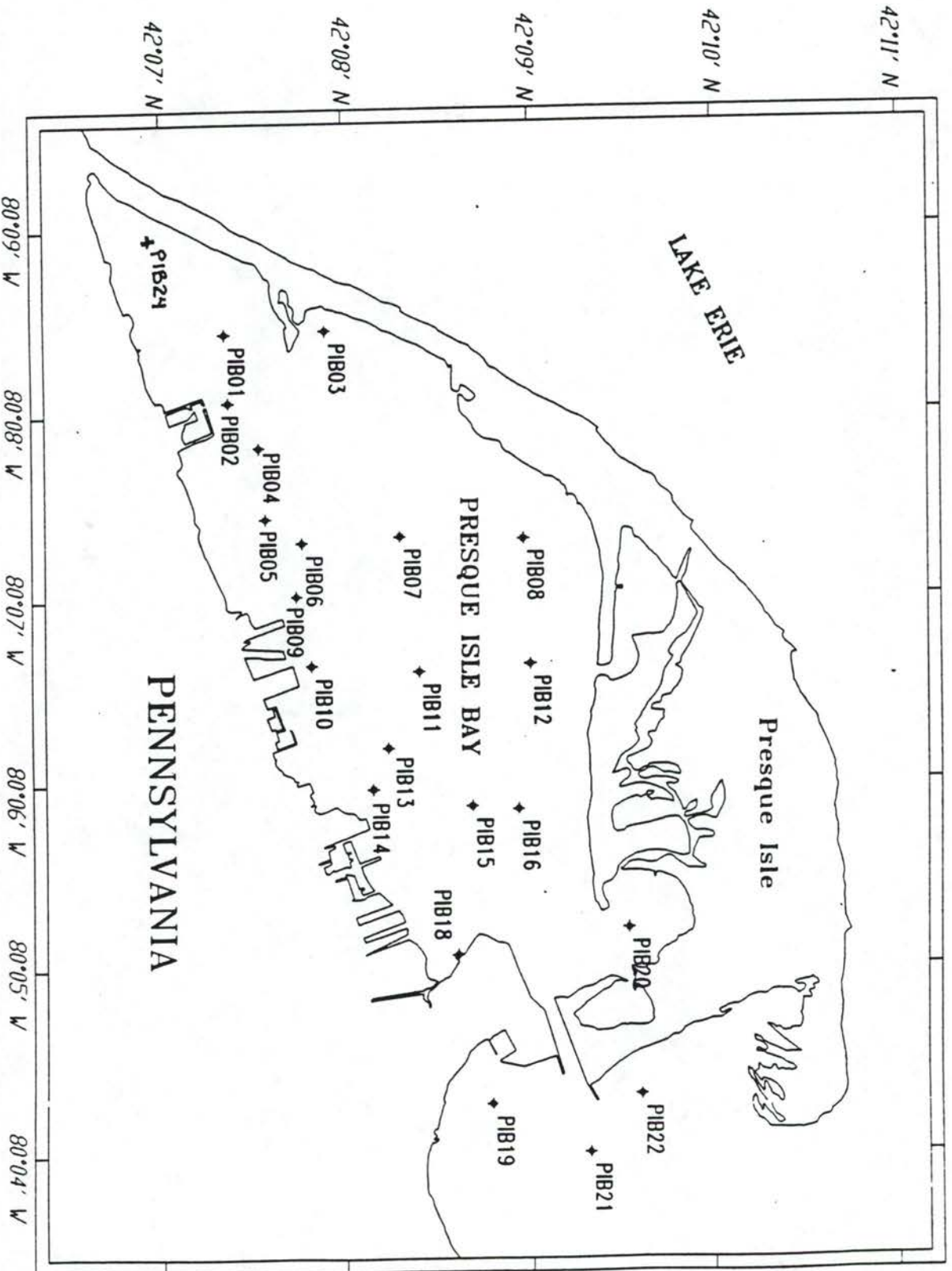


Figure 1-1. Location of Stations Sampled for Presque Isle Bay Study, May 1994.



Table 1-1. Presque Isle Bay Station Locations

Station ID	Latitude*	Longitude*	Water Depth (ft)	Sampling Date	Field Team Comments
PIB01	42°07'21"	80°08'26"	15	16-May-94	Sediment - gray black, fine-silty muck, brown streaking. 5 % free water.
PIB02	42°07'21"	80°08'05"	15	19-May-94	Sediment - fine silty-clay composition. Black-gray in color with brown patches. Thin green organic layer with noticeable black organic material. 2 % free water.
PIB03	42°07'53"	80°08'29"	23	19-May-94	Sediment - Silty-sand texture with pebbles. Black organic materials present. Living organisms (midge). 10 % free water.
PIB04	42°07'33"	80°07'48"	18	19-May-94	Sediment - Dark-gray black clay. Brown sediment throughout; very consistent texture. No free standing water.
PIB05	42°07'34"	80°07'26"	17	20-May-94	Black, gray, and brown silty clay. 2 % free standing water.
PIB06	42°07'46"	80°07'18"	21	20-May-94	Black, gray, and brown silty clay. 2 % free standing water.
PIB07	42°08'18"	80°07'22"	22	18-May-94	Dark-gray to black silty clay like material. Patchy brown material interlayered. Little noticeable organic material. 1 % free standing water.
PIB08	42°08'56"	80°07'19"	18	17-May-94	Gray-black color with areas of brown patches and streaks. Very fine silt material with small amounts of sand. Small amount off noticeable organic material. < 5 % free water.
PIB09	42°07'42"	80°07'00"	16	19-May-94	Silty-clay with some sand. Three distinctive layers of color - brown, gray, gray black. Small amount of organic material.
PIB10	42°07'52"	80°06'37"	16	18-May-94	Black-gray with brown matrix. Speckled with black material. Silty-clay texture. 1 % standing water.
PIB11	42°08'21"	80°06'35"	23	18-May-94	Brownish black with patches of brown and dark black, silty clay. 3 % standing water.

Table 1-1. Presque Isle Bay Station Locations (cont.)

Station ID	Latitude*	Longitude*	Water Depth (ft)	Sampling Date	Field Team Comments
PIB12	42°09'01"	80°06'45"	19	17-May-94	Gray-black color with brown streaks and spots. Very fine silt-muck. Pudding like texture. ~5% free water.
PIB13	42°08'15"	80°06'11"	22	19-May-94	Silty-clay composition. Dark gray, black gray, and brown distinctive colors. Black organic materials present. 2% free water.
PIB14	42°08'08"	80°05'55"	16	18-May-94	Black-gray with bands of brown. Silty clay-like composition. 2% free water. Appears to have more moisture content and is more hydrated than other samples.
PIB15	42°08'44"	80°05'52"	19	19-May-94	Silty-clay. Black gray, dark gray, and brown distinctive colors. 2% standing water.
PIB16	42°08'56"	80°05'50"	20	18-May-94	Mostly dark gray black inter-layered with brown matrix Silty clay texture. Small amount of sand. Organic particles present. 5% free water. Large mussels in sample.
PIB18	42°08'37"	80°04'59"	03	18-May-94	Dark brown sandy-silt with a uniform texture. Mussel shell fragments. Noticeable organic detritus. 60% free water by volume.
PIB19	42°08'51"	80°04'14"	11	16-May-94	Gray, brown, silty muck. Sample contains only 5% free water.
PIB20	42°09'25"	80°05'15"	12	16-May-94	Gray-black very fine silty-muck.
PIB21	42°09'19"	80°03'58"	13	17-May-94	Sandy, silty texture. Dark brown with black organic bands. Uniform texture with few pebbles.
PIB22	42°09'37"	80°04'21"	16	17-May-94	Mostly sand with some silt. Brown in color flecked with black. Few noticeable organic materials. 30% freshwater.

*Station locations determined by Global Positioning System (GPS)

PIB24 42°06'56" 80°08'55" 5' 20 May 94
 Abundant org. material, silty muck to 24". Sand with black bands to depth.

Bulk Chemistry and Toxicity Samples

Sediment chemistry and toxicity samples were collected using a petite Ponar grab sampler. Sampling procedures for operation of the Ponar grab were consistent with APHA *et al.*, (1989) and West and Trulli (1994). In addition to the collection of sediment for the toxicity samples, six liters of overlying lake water were collected for the toxicity test.

Sediment samples for organic chemistry and total organic carbon (TOC) analysis were transferred into solvent- and acid- rinsed glass jars and were shipped to Battelle at -4°C. The organic chemistry analysis was performed at Battelle. A subsample was sent to Global Geochemistry for TOC analysis. Sediment samples for grain-size analysis were transferred to Whirl-pak bags and were shipped at 4°C to Geo/Plan Associates. Sediment samples for toxicity testing were transferred to 4-L polyethylene jars and the overlying water was dispensed into 6-L cubitainers. Both the sediment and water samples were shipped at 4°C to EPA's laboratory in Wheeling, VA.

Macroinfauna

Benthic macroinfauna samples were collected with a petite Ponar grab sampler following procedures described in West and Trulli (1994). Each of the samples were sieved through a 0.5-mm mesh sieve to remove the silt-clay fraction, and then preserved with 10% formalin solution. The samples were transferred to a 70% alcohol solution prior to shipment to Vittor & Associates' laboratory in Mobile, Alabama.

Phytoplankton

For phytoplankton analyses, whole-water samples were collected using a water sampling bottle deployed to three discrete depths (0.5-1 meter below the surface, mid-depth, and 0.5-1 meter above the bottom). Approximately 1-L of collected water was transferred to 1-L sample bottles and preserved in a 1% solution of acidified Lugol's preservative. Phytoplankton samples were delivered to Dr. Mike Campbell, Mercyhurst College, Pennsylvania.

Zooplankton

To quantify zooplankton abundances at each site, vertical net tows were deployed using a 0.5-m diameter #20 (63 μ m mesh) conical plankton net equipped with a cod-end bucket of similar mesh and a flow meter (Kahl Scientific Instrument Corporation, model #005WB138) mounted near the center of the bridle. After lowering the net to an approximate depth of 1-m above the bottom, the net was retrieved to the surface at a rate of 1-2 feet per second. Repeated tows were taken until at least 100 full rotations of the flow meter's propeller were indicated. A horizontal tow was taken at PIB18, where it was too shallow for a vertical tow. The total volume of water sampled at the four stations ranged from 11.0-13.7 m³. After rinsing the net, the sample was transferred to a 1-L sample bottle, narcotized using soda water, and preserved in a 5% buffered formalin solution.

INTRODUCTION

The plankton net efficiency was measured on 28 May 1994 from a concrete pier on the south side of the harbor channel at the entrance to PIB. In repeated trials with and without the net attached, the meter was towed at a constant speed (1-2 feet/sec) horizontally over a known distance. A net efficiency of 85.1% was calculated from the meter readings observed during these trials. This result compares favorably to net efficiencies measured in previous zooplankton studies in Lake Erie which used the same type of plankton net [88% in Krieger and Klarer, 1991 and 83.4% in Makarewicz (1988)]. Zooplankton samples were delivered to Dr. Mike Campbell at Mercyhurst College, Pennsylvania.

1.2 SUMMARY OF SAMPLES COLLECTED

Chemistry Samples. Samples for sediment chemistry analysis, TOC analysis, and grain-size analysis were collected at all of the (21) selected stations. (See Figure 1-1.) Duplicate field samples were collected at Stations PIB02 and PIB03.

Macroinvertebrate Samples. Samples for macroinvertebrate enumeration were collected at eight stations, Stations PIB01, PIB07, PIB08, PIB09, PIB11, PIB18, PIB19, and PIB20.

Plankton Samples. Samples for plankton enumeration were collected at four stations, Stations PIB10, PIB12, PIB18, and PIB20. Samples were collected at three depths (surface, mid-depth, and bottom) in the water column at each of the stations.

Zooplankton Samples. Samples for zooplankton enumeration were collected at four stations, Stations PIB10, PIB12, PIB18, and PIB20.

Toxicity Samples. Samples for sediment toxicity testing were collected at twelve stations, Stations PIB01, PIB04, PIB07, PIB08, PIB09, PIB11, PIB14, PIB16, PIB18, PIB19, PIB20 and PIB22.

Table 1-2 summarizes the types and number of samples collected for this Presque Isle Bay Study.

1.3 REFERENCES

- APHA, AWWA, WPCF. 1989. Standard Methods for the Examination of Water and Wastewater, 16th ed. American Public Health Association, Washington, DC. 1449 pp.
- Krieger, K.A. and D.M. Klarer. 1991. Zooplankton dynamics in a Great Lakes coastal marsh. J. Great Lakes Res. 17:255-269.

Makarewicz, J.C. 1988. Phytoplankton and zooplankton in Lakes Erie, Huron, and Michigan: 1984. U.S. Environmental Protection Agency. Great Lakes National Program Office, Chicago, Illinois. EPA-905/3-88-001.

West, D. and H. Trulli. 1994. Final QAPP for Presque Isle Bay Sediment Study. Prepared under contract No. 68-C2-0134, Work Assignment 1-107 to USEPA. 56 pp.

Table 1-2. Types and Numbers of Samples Collected for Presque Isle Bay Study, May 1994.

Station ID	Chemistry	TOC	Grain Size	Macroinvertebrates	Zooplankton	Phytoplankton	Toxicity
PIB01	1	1	1	1	0	0	1
PIB02	2	2	2	0	0	0	0
PIB03	2	2	2	0	0	0	0
PIB04	1	1	1	0	0	0	1
PIB05	1	1	1	0	0	0	0
PIB06	1	1	1	0	0	0	0
PIB07	1	1	1	1	0	0	1
PIB08	1	1	1	1	0	0	1
PIB09	1	1	1	1	0	0	1
PIB10	1	1	1	0	1	3	0
PIB11	1	1	1	1	0	0	1
PIB12	1	1	1	0	1	3	0
PIB13	1	1	1	0	0	0	0
PIB14	1	1	1	0	0	0	1
PIB15	1	1	1	0	0	0	0
PIB16	1	1	1	0	0	0	1
PIB18	1	1	1	1	1	3	1
PIB19	1	1	1	1	0	0	1
PIB20	1	1	1	1	1	3	1
PIB21	1	1	1	0	0	0	0
PIB22	1	1	1	0	0	0	1
TOTAL	23	23	8	8	4	12	12

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2.0 CHEMICAL CHARACTERIZATION STUDY

The objective of the Chemical Characterization Study was to determine the concentrations and distribution of selected nonpolar organic contaminants in surficial sediments of Presque Isle Bay in relation to sediment grain size and organic carbon concentrations. Organic contaminants of concern include polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), selected organochlorine pesticides, and selected nitrosamines. Concentrations of the organic contaminants in sediments were compared to preliminary sediment quality criteria and threshold values in order to identify those contaminants that may be present at a concentration high enough to cause harm to aquatic communities of Presque Isle Bay. Possible sources of PAHs in the sediments were assessed, based on the composition of the PAH assemblage. This information, combined with information about the structure of the benthic community in the bay and the toxicity of the sediments to aquatic organisms, forms the basis for interpreting the extent and causes of impairment of the beneficial uses of Presque Isle Bay.

Rationale for Grain-size Determinations

The physicochemical makeup of sediments influences their capacity to adsorb and retain chemical contaminants, the rate of sediment resuspension and transport, and the suitability of the sediments to support benthic biological communities. One of the key parameters needed to characterize the properties of sediments is the grain-size distribution, expressed as percent composition of gravel, sand, silt, and clay. Unconsolidated sediments with high silt and clay composition are most susceptible to transport because the sediment particles are small and easily disturbed and moved by modest currents. The species composition of benthic communities is controlled in large part by sediment grain size distribution and its influence on concentrations of oxygen and organic carbon in the sediments.

Sediments with high silt and clay content have relatively high surface areas and are able to adsorb contaminants through simple adsorption reactions. Chemical contaminants often are not uniformly distributed in sediments, but are associated preferentially with a certain grain size fraction. Normalization of contaminant concentrations to a particular grain size fraction of the sediment (usually the silt/clay fraction), decreases variability due to heterogeneous grain size distributions and aids in identifying sources and possible environmental fates of the contaminants.

Rationale for Total Organic Carbon Determinations

Nonpolar organic chemicals and some metals have a high affinity for the organic phase of sediments. In most cases, nearly all the nonpolar organic contaminants in sediments are sorbed (adsorbed and absorbed) to organic coatings on sediment particles (primarily on clay particles) and, to a lesser extent, to dissolved organic matter (humic substances) in the sediment pore water (EPA, 1993a). Therefore, normalization of contaminant concentrations to sediment organic carbon concentration decreases the variability caused by variable amounts of materials not involved in binding of the sediment contaminants. Partitioning theory can be used to estimate the bioavailability and toxicity of nonpolar organic chemicals sorbed to

sediments. This is the basis of EPA's approach to developing sediment quality criteria for nonpolar organic chemicals (EPA, 1993a).

Rationale for Study of Organic Compounds

This chemical characterization study is limited to selected nonpolar organic contaminants of particular concern as determined by earlier evaluations (PADER, 1991; U.S. Army Corps of Engineers, 1992). These contaminants include PAHs, PCBs, organochlorine pesticides, and nitrosamines. These are the chemicals most likely to be the cause of, or important contributors to, the impaired beneficial uses of the bay.

Analysis of sediment samples for an extended PAH list (16 priority pollutant PAHs, a series of alkylated PAHs, and additional environmentally relevant parent PAH compounds) allows for "fingerprinting" of the PAH assemblage. Fingerprinting provides a means for assessing the types of sources of PAHs in the sediments (e.g., fossil fuels, creosote, etc.). For example, the low molecular weight, alkylated PAHs are most abundant in fossil fuels, particularly petroleum products. High molecular weight, five- and six-ring parent PAHs are rare in fossil fuels but are abundant in PAH assemblages from combustion sources. The PAH data can also be used for future ratio analysis of key diagnostic PAHs which reveal the relative contributions of petrogenic and pyrogenic sources to the sediments (Douglas *et al.* 1992).

2.1 METHODS OF PHYSICAL AND CHEMICAL ANALYSES

Sediment Grain-Size. A 200- to 220-g subsample of each sediment sample was analyzed by Geo/Plan Associates (Hingham, Massachusetts) for grain-size distribution. Sediment grain-size distribution was determined by modifications of the standard sieve and pipet methods recommended by the Environmental Protection Agency and United States Army Corps of Engineers (Method 2; Plumb, 1981). Briefly, a deflocculent (sodium hexametaphosphate) was added to the sediment and the mixture was wet-sieved mechanically to separate particles greater than 62 μm in diameter into eight groups. The separated groups were dried and weighed to determine the percent contribution of the size ranges to the total sample mass. The sieved material less than 62 μm in diameter (silts and clays) was further fractionated by pipette analysis. Final results were reported as percent gravel, sand, silt, and clay.

Total Organic Carbon. Sediment subsamples for TOC analysis were removed from the freezer just prior to drying. A dried, finely ground, and homogenized subsample of 175 to 250 mg, weighed to an accuracy of 0.1 mg, was placed in a LECO model 761-100 filtration crucible that had been precombusted for 2 h at 450°C. The sample was treated with 6 N HCl to remove inorganic carbon. Iron and copper chips were added to the sample just prior to analysis to accelerate

combustion. One hour after no further reaction with the acid was observed, the sample was neutralized with deionized water and dried overnight.

The dried samples were analyzed with a LECO model 761-100 carbon analyzer. The analyzer combusts the sediment sample at high temperature, converting the organic carbon to carbon dioxide. The carbon dioxide is then quantified by thermal conductivity detection.

Extraction of Organic Contaminants from Sediments. Sediment samples were extracted within 14 days of receipt and analyzed within 40 days of extraction (except PIB05 which had to be re-extracted), following methods developed by Battelle in support of NOAA's National Status and Trends Mussel Watch Project (Peven and Uhler, 1993). Approximately, 50 g of sediment was serially extracted three times with a 1:1 mixture of dichloromethane (DCM):acetone containing sodium sulfate. The sample was weighed into a Teflon extraction jar and spiked with the appropriate surrogate internal standards (SIS). Solvent was added and the jar was sealed. The sample was shaken on a shaker table three different times (the first shake was approximately 12 h, the second 4 h, and the third 0.5 h) and centrifuged. The three centrifuged extracts were combined in an Erlenmeyer flask, processed through an alumina column, and concentrated to 900 μ L by sequential Kuderna-Danish/nitrogen evaporation. The concentrated extract was further cleaned by size-exclusion high-performance liquid chromatography (HPLC). This procedure removes common contaminants which interfere with instrumental analysis, including elemental sulfur. The post-HPLC extract was concentrated to approximately 1 mL under nitrogen and the recovery internal standards (RIS) were added to quantify extraction efficiency. The final extract was split for analysis, one half remaining in DCM for PAH and nitrosamine analysis and the other half solvent-exchanged with isooctane for PCB and pesticide analysis.

A 10-g aliquot of the original sediment sample was also taken for dry weight determination. The sediment was dried to constant weight and weighed to the nearest 1.0 mg.

Analysis of Pesticides and PCBs. Pesticides and PCB congeners were analyzed by gas chromatography and quantified by electron capture (GC/ECD). All analytes were determined by the method of internal standards using surrogate internal standards for quantification. Method detection limits for target pesticides and PCBs are summarized in Table 2-1.

Laboratory Quality Control

A rigorous quality control (QC) program was followed to ensure the accuracy, precision, and validity of all analytical data generated for this study.

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Table 2-1. Method Detection Limits (ppm dry weight)

Target Analyte	MDL (mg/kg)	Target Analyte	MDL (mg/kg)
PAHs		Pesticides	
naphthalene	0.0008	A-BHC	0.0007
C1-naphthalenes	0.0008	B-BHC	0.0003
C2-naphthalenes	0.0008	G-BHC	0.0003
C3-naphthalenes	0.0008	D-BHC	0.0003
C4-naphthalenes	0.0008	HEPTACHLOR	0.0009
biphenyl	0.0019	ALDRIN	0.0007
acenaphthylene	0.0022	HEPTACHLOR EPOXIDE	0.0008
acenaphthene	0.0017	G-CHLORDANE	0.0006
dibenzofuran	0.0017	ENDOSULFAN I	0.0003
fluorene	0.0014	A-CHLORDANE	0.0006
C1-fluorenes	0.0014	DIELDRIN	0.0007
C2-fluorenes	0.0014	4,4-DDE	0.0004
C3-fluorenes	0.0014	ENDRIN	0.0019
phenanthrene	0.0023	ENDOSULFAN II	0.0002
anthracene	0.0022	4,4-DDD	0.0010
C1-phenanthrenes/anthracenes	0.0023	ENDRIN ALDEHYDE	0.0006
C2-phenanthrenes/anthracenes	0.0023	ENDOSULFAN SULFATE	0.0007
C3-phenanthrenes/anthracenes	0.0023	4,4-DDT	0.0010
C4-phenanthrenes/anthracenes	0.0023	ENDRIN KETONE	0.0006
dibenzothiophene	0.0044	METHOXYCHLOR	0.0004
C1-dibenzothiophenes	0.0044	TOXAPHENE	0.0085
C2-dibenzothiophenes	0.0044		
C3-dibenzothiophenes	0.0044		
fluoranthene	0.0044		
pyrene	0.0040	PCBs	
C1-fluoranthenes/pyrenes	0.0040	CL2(08)	0.0014
benz[a]anthracene	0.0024	CL3(18)	0.0008
chrysene	0.0030	CL3(28)	0.0004
C1-chrysenes	0.0030	CL4(52)	0.0004
C2-chrysenes	0.0030	CL4(44)	0.0011
C3-chrysenes	0.0030	CL4(66)	0.0007
C4-chrysenes	0.0030	CL5(101)	0.0008
benzo[b]fluoranthene	0.0023	CL4(77)	0.0010
benzo[k]fluoranthene	0.0027	CL5(118)	0.0007
benzo[e]pyrene	0.0025	CL6(153)	0.0013
benzo[a]pyrene	0.0016	CL5(105)	0.0010
perylene	0.0076	CL6(138)	0.0007
indeno[1,2,3-c,d]pyrene	0.0039	CL5(126)	0.0010
dibenz[a,h]anthracene	0.0023	CL7(187)	0.0010
benzo[g,h,i]perylene	0.0042	CL6(128)	0.0006
		CL7(180)	0.0008
		CL7(170)	0.0011

Table 2-1. Method Detection Limits (ppm dry weight) (cont.)

Target Analyte	MDL (mg/kg)	Target Analyte	MDL (mg/kg)
<i>Nitrosoamines</i>		<i>PCBs (cont.)</i>	
N-Nitroso-N-methylethylamine	0.033	CL8(195)	0.0010
N-Nitrosodiethylamine	0.033	CL9(206)	0.0016
N-Nitrosodi-n-propylamine	0.033	CL10(209)	0.0010
N-Nitrosdi-N-butylamine	0.033	AROCLOR 1016/1242	0.0047
N-Nitrosodiphenylamine	0.033	AROCLOR 1221	0.0047
		AROCLOR 1232	0.0047
		AROCLOR 1248	0.0047
		AROCLOR 1254	0.0047
		AROCLOR 1260	0.0047

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- **Procedural Blank.** This QC sample was used to evaluate the degree of contamination, if any, associated with handling, and laboratory extraction/analysis of the sample. The QC goal for this study was to minimize any contamination in the blank so that any target analyte concentrations measured in the samples could be confidently assumed to have been present in the in-place sediment.
- **Standard Reference Material (SRM).** The SRM is a sediment sample that have been well-characterized for organic contaminant content. NIST 1939 was used as the SRM for this study. A SRM sample was processed and analyzed with each batch of sediment samples. Results of the SRM analysis were compared to the certified values. The goal of the SRM analysis was to obtain an accuracy of $\pm 30\%$ of the certified value for each organic contaminant in the SRM sediments.
- **Matrix Spike and Matrix Spike Duplicate.** Duplicate subsamples of one of the samples was fortified with known amounts of the organic contaminants under investigation and the sample was processed and analyzed. These QC samples were used to demonstrate method performance, with a recovery goal of 40 - 120% established for each organic contaminant. The goal for relative percent difference (RPD) for recovery of each compound in the MS/MSD samples was $\leq 30\%$.
- **Sample Replicates.** Aliquots of a sample are processed in duplicate for TOC determination and in triplicate for grain-size determination. The goal for RPD for the duplicate was 5% and for the percent coefficient of variance (%CV) for the triplicate was 20%.

2.2 RESULTS

All twenty-three sediment samples were analyzed in one batch. One procedural blank, one matrix spike, one matrix spike duplicate, and one SRM were analyzed with the samples.

Physical/Chemical Properties of Sediments

Sediment Grain Size. None of the sediments contained more than 1 percent gravel (Table 2-2), allowing construction of a ternary plot describing their relative contributions of sand, silt, and clay in the sediments. The grain-size composition of the surficial sediments from the 21 stations sampled for the Presque Isle Bay Study can be divided into two groups as shown in Figure 2-1. Sediments from four stations (Stations PIB03, PIB18, PIB21, PIB22) contained more than 79 percent sand; sediments from the other 17 stations contained more than 50 percent silt and (PIB19) 4.2 to (PIB14) 31.6 percent clay. Two of the stations, Stations PIB21 and PIB22, which contain sediments with a high percentage of sand are located outside

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Table 2-2. Grain Size and Total Organic Carbon by Percent Weight.

<i>Station ID</i>	<i>Gravel</i>	<i>Sand</i>	<i>Silt</i>	<i>Clay</i>	<i>TOC</i>
PIB01	0.0	25.2	62.4	12.4	3.98
PIB02	0.0	24.0	63.6	12.4	4.12
PIB02-D	0.1	28.9	59.8	11.2	4.39
PIB03	0.0	93.6	4.8	1.6	0.49
PIB03-D	0.1	92.7	4.9	2.4	0.51
PIB04	0.1	30.7	54.7	14.5	4.62
PIB05	0.0	16.7	61.4	21.9	4.62
PIB06	0.0	18.9	52.5	28.6	4.66
PIB07	0.0	18.9	61.9	19.2	4.51
PIB08	0.0	22.8	54.0	23.3	5.02
PIB09	0.0	16.2	67.9	15.8	4.14
PIB10	0.0	37.8	52.0	9.9	4.26
PIB11	0.0	13.1	67.0	19.8	3.93
PIB12	0.0	16.3	78.8	4.9	4.74
PIB13	0.0	10.5	61.2	25.4	3.89
PIB14	0.0	11.6	56.7	31.6	4.45
PIB15	0.0	12.8	60.9	26.3	3.31
PIB16	0.3	24.6	52.5	22.7	3.45
PIB18	0.0	100.0	0.0	0.0	0.06
PIB19	0.0	21.3	74.6	4.2	1.69
PIB20	0.0	41.3	51.0	6.9	6.34
PIB21	0.0	100.0	0.0	0.0	0.01
PIB22	0.2	79.2	18.8	1.8	0.18

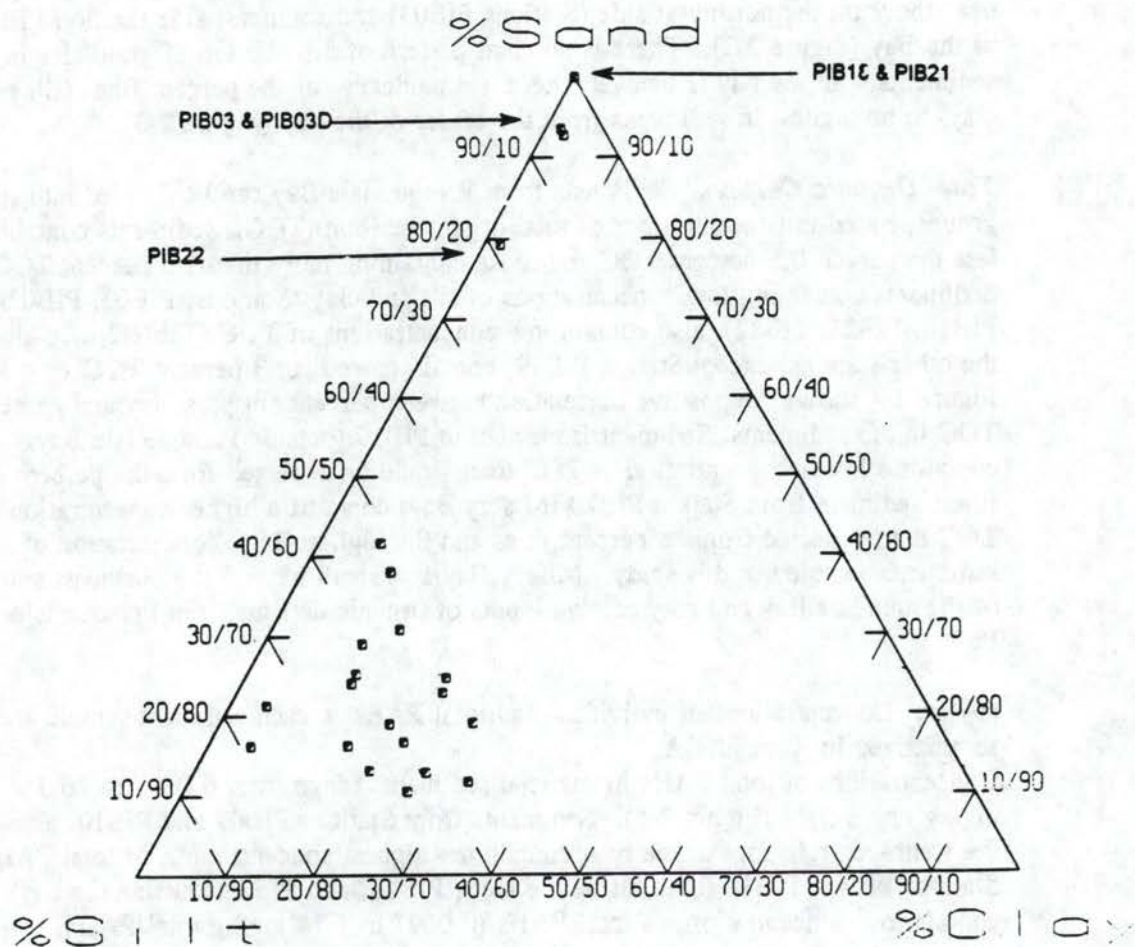


Figure 2-1. Ternary plot of grain-size distribution

of the Bay; the other two stations with predominantly sandy sediments are located near shore on the northwest side (Stations PIB03) and southeast side (Station PIB18) of the Bay (Figure 2-2). There is no clear pattern of distribution of grain size in sediments with the bay. However, there is a tendency for the percent fines (silt plus clay) to be highest in sediments from the center of the bay (Figure 2-3).

Total Organic Carbon. Sediments from Presque Isle Bay can be divided into two groups, based in concentrations of total organic carbon (TOC): sediments containing less than about 0.5 percent TOC and those containing more than 1.5 percent TOC. Sediments containing low concentrations of silt and clay (Stations, PIB03, PIB03-D, PIB18, PIB21, PIB22), also contain low concentrations of TOC (Table 2-2). All the other stations, except Station PIB19, contain more than 3 percent TOC. Figure 2-4 shows the positive correlation between percent silt plus clay and percent TOC in the sediments. Sediment from Station PIB19 (outside Presque Isle Bay) contains a lower concentration of TOC than would be expected from the percent fines; sediment from Station PIB20 (Misery Bay) contains a higher concentration of TOC than expected from its percent fines and the highest TOC concentration of the sediments sampled in this study. Misery Bay is a small bay off the northeast side of Presque Isle Bay and may receive inputs of organic detritus from Presque Isle Park.

PAHs. Concentrations of individual and total PAHs in each sediment sample are summarized in Appendix A.

Concentrations of total PAHs in surficial sediments range from 0.0697 to 26.3 mg/kg dry weight (Figure 2-5). Sediments from Stations PIB09 and PIB10, along the south-central shore of the bay, contain the highest concentrations of total PAHs; Stations PIB03, PIB18 (both inside the bay), PIB21, and PIB22 (outside the bay) contain low concentrations of total PAHs (0.0697 to 1.14 mg/kg total PAHs).

The most abundant PAHs in the heavily contaminated samples are fluoranthene and pyrene, often followed by phenanthrene and one or a few high molecular weight PAHs (especially benzo[b]fluoranthene, benzo[a]pyrene, indeno[1,2,3-c,d]pyrene, and benzo[g,h,i]perylene). Concentrations of perylene (a diagenic PAH) are not unusually high compared to other PAHs, suggesting that the bay sediments are not chronically anoxic.

Nitrosamines. Concentrations of individual and total nitrosamines in each sediment sample are summarized in Appendix A.

Concentrations of nitrosamines in surficial sediments varied more between stations than PAHs (Figures 2-5 and 2-6). However, matrix interferences precluded quantification and allowed for only for tentative estimates of concentrations. Estimated concentrations of total nitrosamines range from below the method detection limit to 0.452 mg/kg. Sediments from Stations PIB11 and PIB05 have the highest total amine concentrations. The dominant amine in sediment from Station

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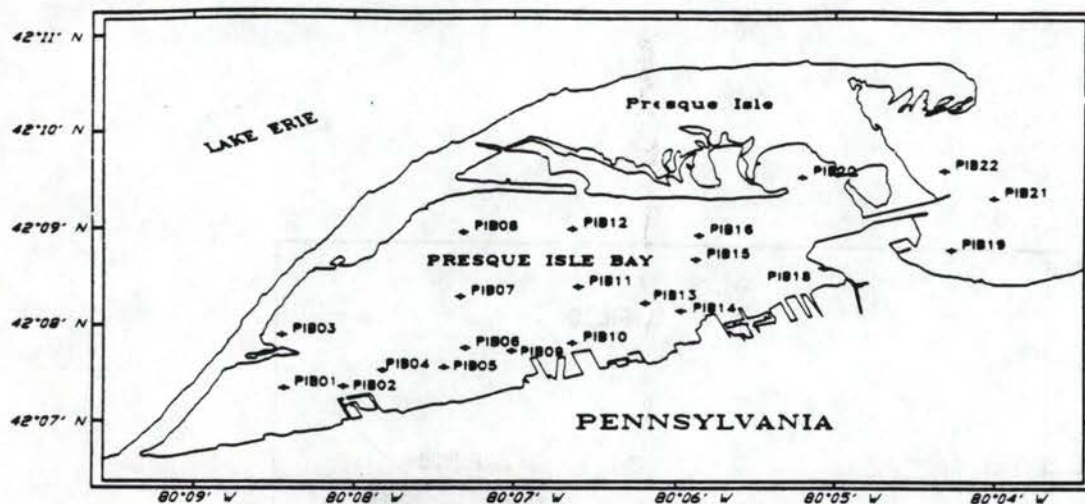


Figure 2-2. Station Locations - Presque Isle Bay Sediment Study May 1994

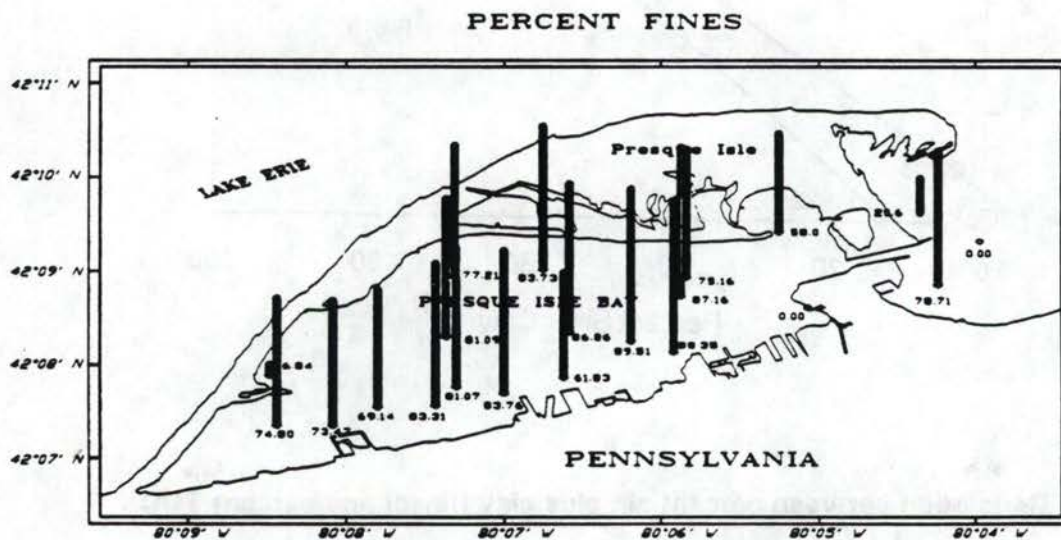


Figure 2-3. Distribution of percent fines (silt plus clay)

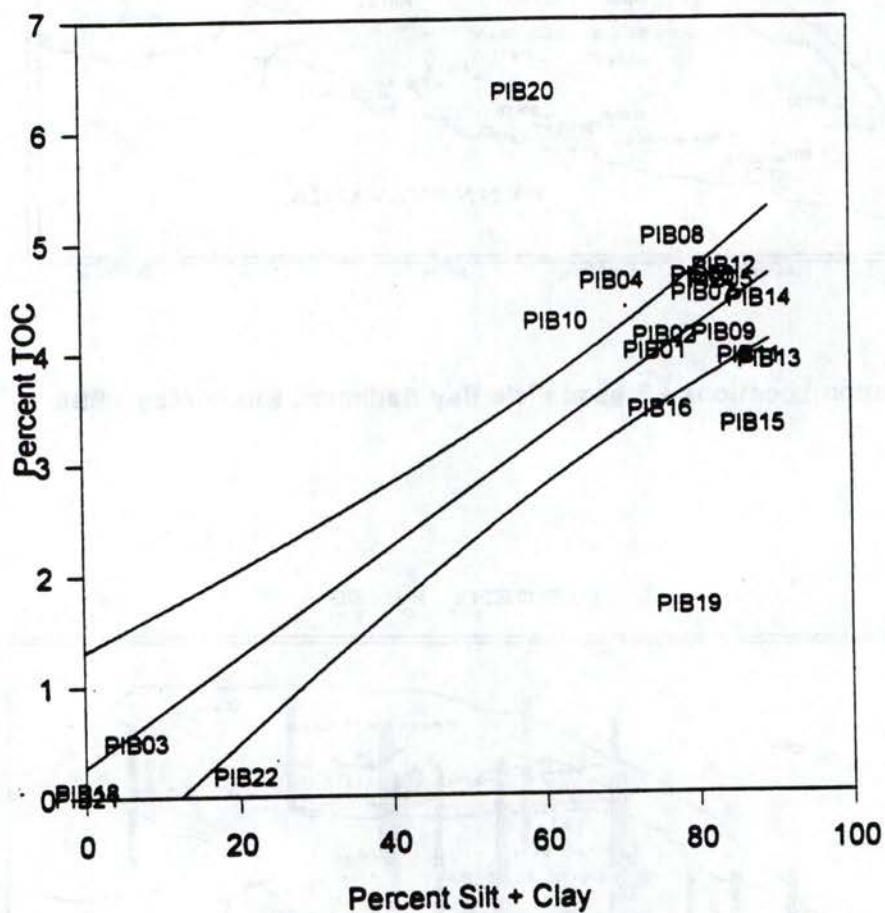
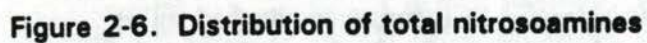
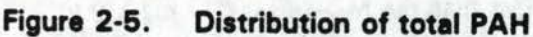


Figure 2-4. Correlation between percent silt plus clay (fines) and percent TOC



PIB11 is N-nitrosodiethylamine; the dominant amine in sediment from Station PIB10 is N-nitrosodiphenylamine.

PCBs. Concentrations of PCB are reported as individual congeners and total Aroclor formulations. The data are summarized in Appendix A.

The only identifiable Aroclor detected in the sediment samples was Aroclor 1254. The concentration of total Aroclor 1254 in sediments range from <0.0046 to 0.304 mg/kg dry weight (Figure 2-7). Sediment from Station PIB08 has the highest PCB concentration; sediment from Station PIB21 (outside the bay) has no detectable PCBs.

Pesticides. Concentrations of chlorinated pesticides in each sediment sample are summarized in Appendix A.

As expected, concentrations of the different pesticides in sediments vary. For example: endrin was not detected in any of the samples; concentrations of dieldrin range from less than the MDL (0.00065 mg/kg) to 0.01 mg/kg dry weight; concentrations of total DDT range from less than the MDL (0.00042 mg/kg) to 0.031 mg/kg dry weight (Figure 2-8); and concentrations of γ -chlordane range from 0.00064 to 0.0135 mg/kg dry weight. Sediments from Stations PIB06, PIB08, and PIB10, near the south-central shore of the bay, contain the highest concentrations of individual and total pesticides. One representative example of the distribution of pesticides represented by DDT, is shown in Figure 2-7. The spatial distribution of total DDT is shown in Figure 2-8.

Quality Control

A procedural blank was analyzed with each batch of samples. None of the organic compounds of interest were detected above the method detection limits (MDL).

The matrix spike recoveries for the PAH compounds averaged 116%, and ranged from 110% to 150%. These recoveries were slightly higher than the data quality indicator goals of 40 - 120%, but should not impact the data quality significantly.

The amounts of the spikes added to the samples were much lower than the actual pesticide and PCB concentrations in the matrix samples for several of the chlorinated pesticides and PCB congeners. An accurate matrix spike recovery calculation could not be made for these analytes due to underspiking. However, a blank spike (not part of the scope of work) was analyzed with the samples and all of the recoveries for individual chlorinated pesticides and PCB congeners were within the range of 65 to 117 percent. The matrix spike and matrix spike duplicate recoveries for the chlorinated pesticides and PCB congeners that had spikes sufficient to be distinguished from the background ranged from 68 to 117 percent, within the data quality indicator goals.

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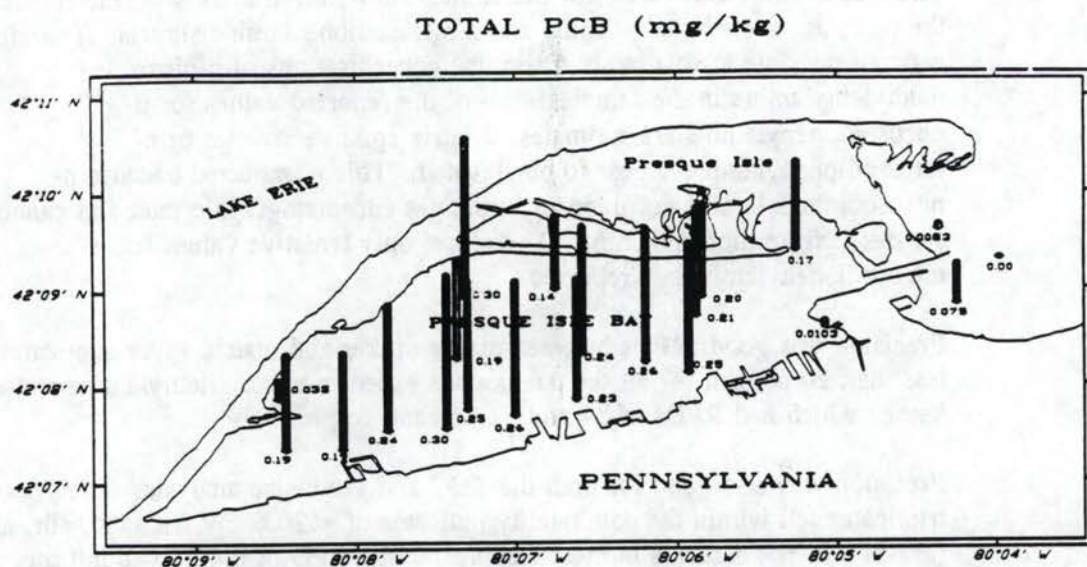


Figure 2-7. Distribution of total PCB (the most predominant aroclor)

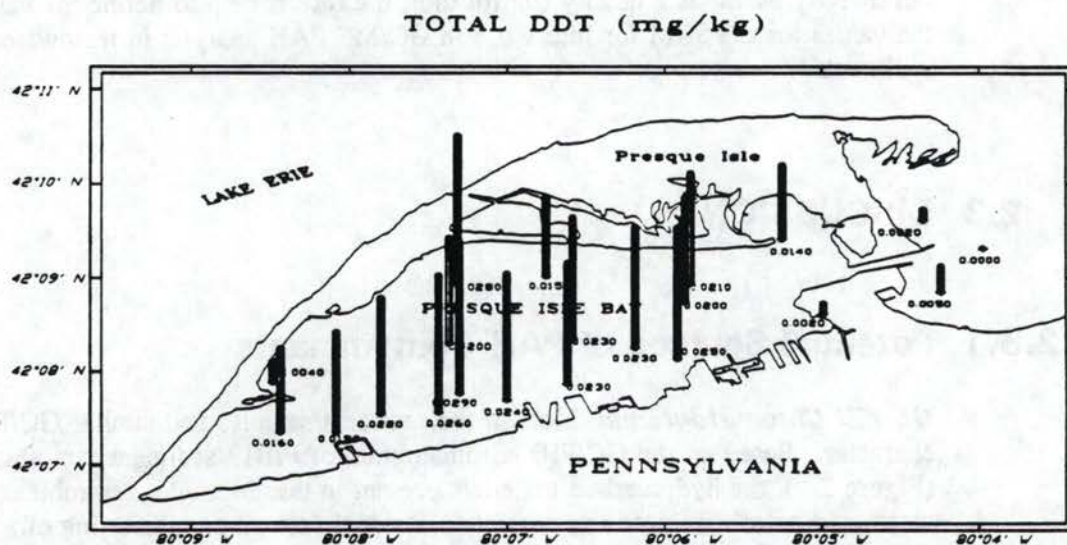


Figure 2-8. Distribution of total DDT

The matrix spike recoveries for the amines showed that there was interference with the n-nitroso-n-methylethylamine and n-nitrosodiphenylamine signals. Therefore, it was not possible to accurately determine concentrations of n-nitroso-n-methylethylamine in the samples. All of the reported values for n-nitrosodiphenylamine are estimates. Matrix spike recoveries of n-nitrosodiphenylamine appear to be elevated. This is expected because n-nitrosodiphenylamine decomposes in the gas chromatographic inlet and cannot be separated from diphenylamine. Therefore, only tentative values for n-nitrosodiphenylamine are reported.

Precision was good; RPDs between matrix spikes and matrix spike duplicates were less than 20 percent for all the compounds except n-nitrosodiethylamine and endrin ketone which had RPDs of 34 and 52 percent, respectively.

Precision was also good for both the TOC and grain-size analysis. The grain-size triplicates fell within the data quality indicator of <20% CV for sand, silt, and clay (gravel was not detected in these samples). The RPD of the TOC duplicates ranged from 2 - 6 percent, not significantly different from the data quality indicator of <5 percent.

The SRM analyzed with the samples, NIST 1939, has consensus values for five PAHs. Concentrations of these analytes were 30 to 302 percent different than the consensus values. Consensus values are based on various analytical techniques while not directly useful as a quality control tool, the results help to define the values for the values for the SRM for future use in GC/MS PAH analysis in freshwater sediments.

2.3 DISCUSSION

2.3.1 Potential Sources of PAH Contaminants

GC/FID Chromatograms. Most of the sediment samples had similar GC/FID character. Based on the GC/FID chromatogram of PIB13 sediment samples (Figure 2-9), the hydrocarbon materials present in these samples resemble a weathered petroleum product, possibly a residual fuel oil or lubricating oil. The relative absence of the lower molecular weight hydrocarbons in the *n*-C₈ through *n*-C₁₅ range, coupled with a large, late eluting unresolved complex mixture (UCM or "hump"), indicates either a heavy lubricating oil type product, or a moderately degraded petroleum product.

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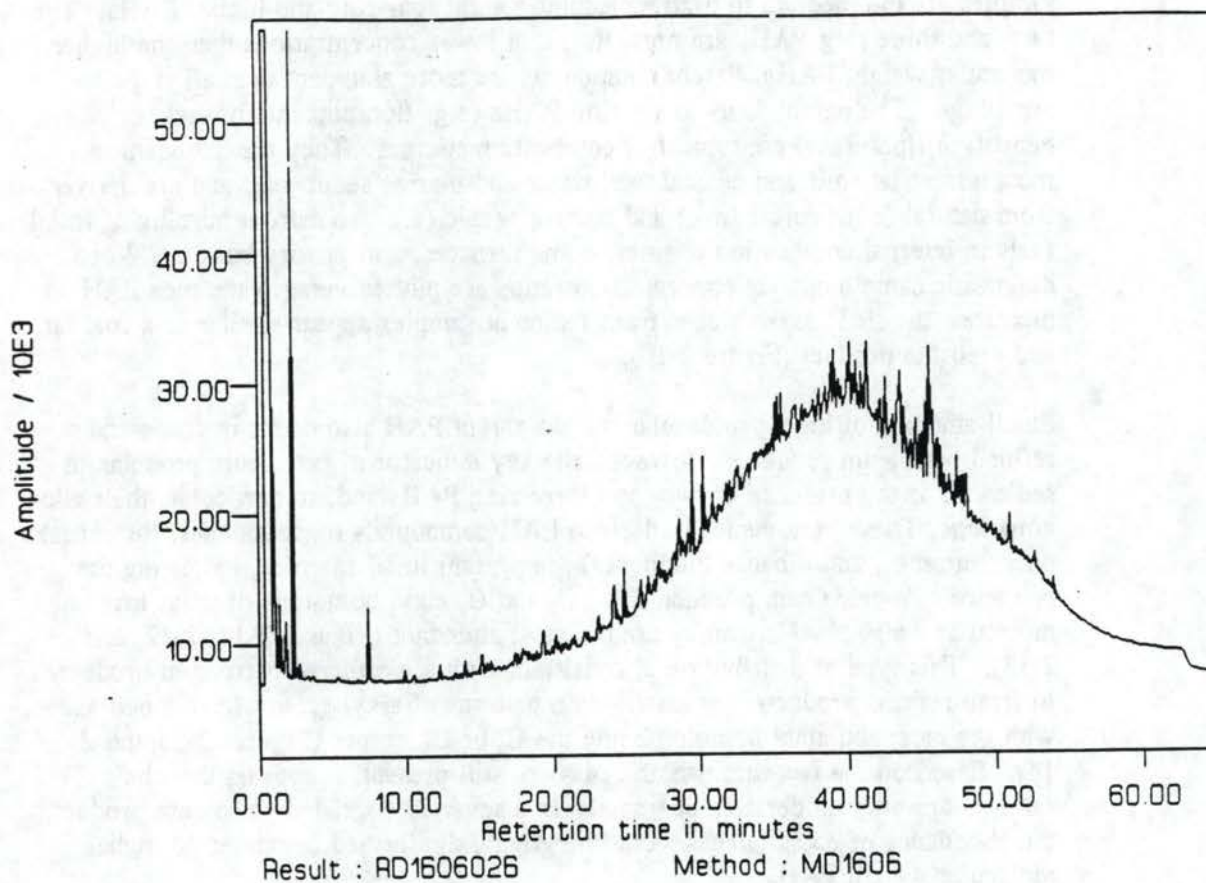


Figure 2-9. GC/FID chromatogram of sediment from Station PIB13

Polycyclic Aromatic Hydrocarbon Data. The dominant PAHs in most sediment samples are the medium to high molecular weight four-ring and higher PAHs. The two- and three-ring PAHs are present, but at lower concentrations than the higher molecular weight PAHs. Parent compounds are more abundant than alkyl homologs. The parent four- to six-ring PAHs (e.g. fluoranthene through benzo[*g,h,i*]perylene) are typical of combustion sources. They are abundant in most terrestrial soils and coastal freshwater and marine sediments, and are derived from natural (e.g., forest fires) and anthropogenic (e.g., soot from burning of fossil fuels in internal combustion engines, home furnaces, and factory boilers). When diagnostic sample analyte concentration ratios are plotted versus reference PAH mixtures, the PAH assemblages from sediment samples appear similar to a coal tar and creosote product (Figure 2-10).

Small amounts of higher molecular weight parent PAH also occur in crude and refined petroleum products. However, the key indicator of petroleum products in sediments is the presence of two- and three-ring PAHs and, in particular, their alkyl homologs. These petrogenically derived PAH compounds (naphthalenes, fluorenes, phenanthrenes, and dibenzothiophenes) are present in all samples, indicating the presence of a petroleum product. The C₃ and C₄ alkyl homologs of these low molecular weight PAHs usually are the most abundant (Figures 2-11, 2-12, and 2-13). This type of distribution is consistent with a weathered petroleum product. In fresh refined products, the distribution patterns of alkyl groups have a bell shape, with the most abundant homolog being the C₂ or C₃ isomer (Figures 2-13 and 2-14). Based on the fact that naphthalenes are still present, it appears that the samples are only moderately degraded. In a severely degraded petroleum product, the abundance of naphthalenes would be greatly diminished compared to higher molecular weight PAHs.

Figure 2-10 shows the diagnostic ratios for the sample set plotted versus those for selected standard oil products from Battelle's hydrocarbon fingerprinting library. This plot shows that the samples appear to be most similar to coal tar and creosote type products, based solely on the PAH data. These groupings can be attributed to weathering (losses of low molecular weight PAHs), and a pyrogenic, parent PAH input.

Based on the GC/FID fingerprint, PAH data for the sample set, and the diagnostic ratio plots, it appears that the samples may contain a petroleum product in the heavy fuel oil range (e.g., fuel oil #6), with major influences of coal tar and creosote, with pyrogenic influences possibly attributable to inputs from road runoff from an urban area (Erie, PA). The major source of pyrogenic PAHs in most urban estuaries is soot and carbon black from engine exhaust and tire wear in runoff from roadways.

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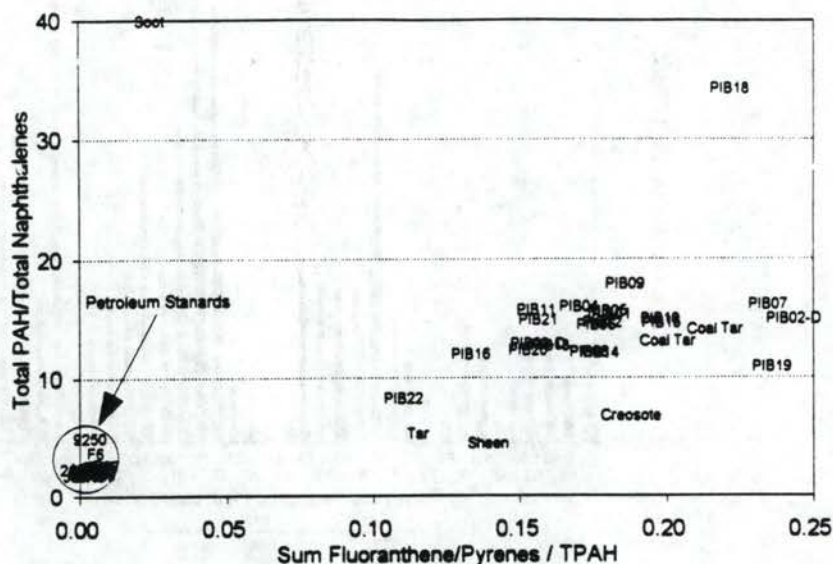


Figure 2-10 Diagnostic sample analyte concentration ratios (total naphthalenes/total PAH versus sum fluoranthene/pyrenes/total PAH) plotted with reference PAH mixtures (petroleum standards [fuel oils, jet fuels, lube oils] sheen, coal tar, tar, creosote)

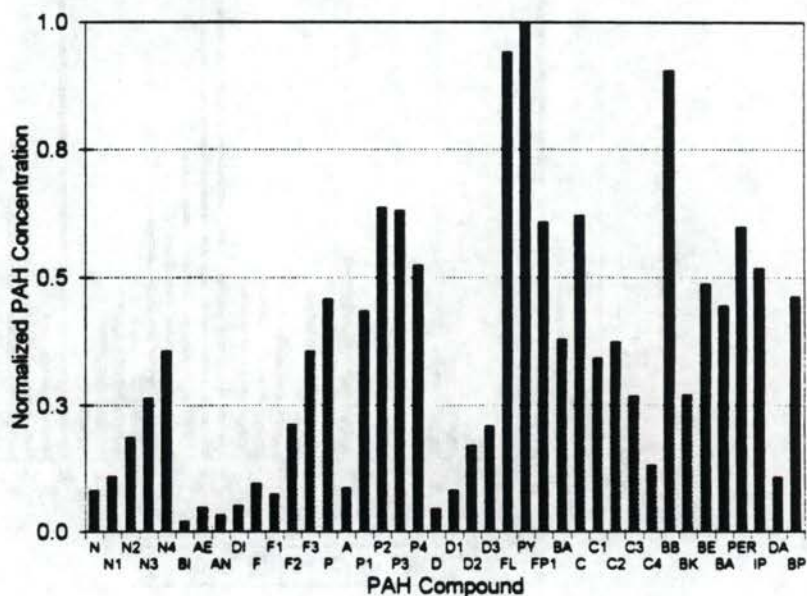


Figure 2-11. Distribution of alkyl homologs for Station PIB03

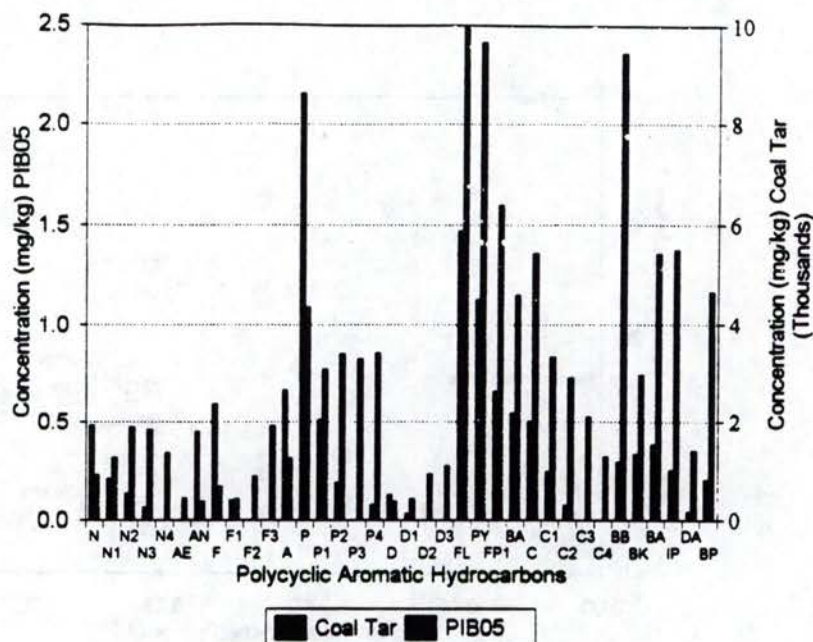


Figure 2-12. Distribution of alkyl homologs for Station PIB05 and coal tar

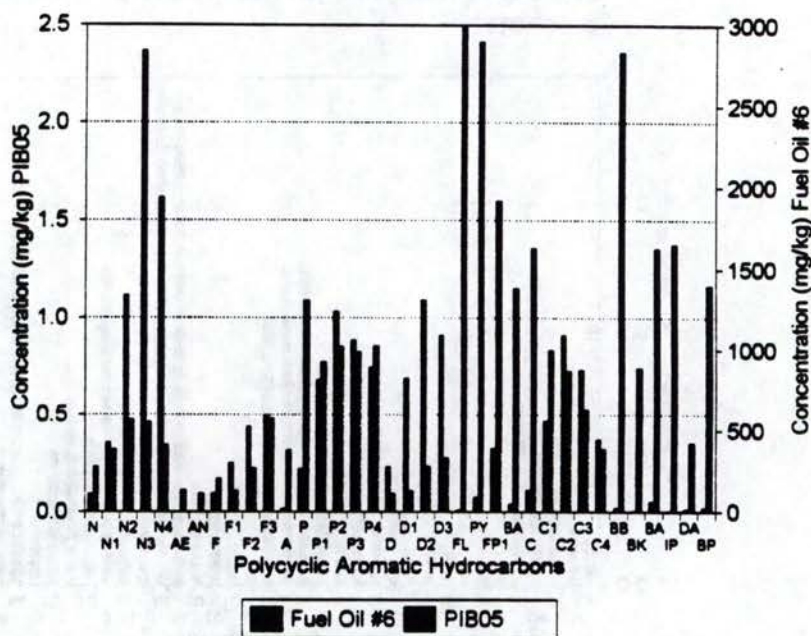


Figure 2-13. Distribution of alkyl homologs for Station PIB05 and fuel oil #6

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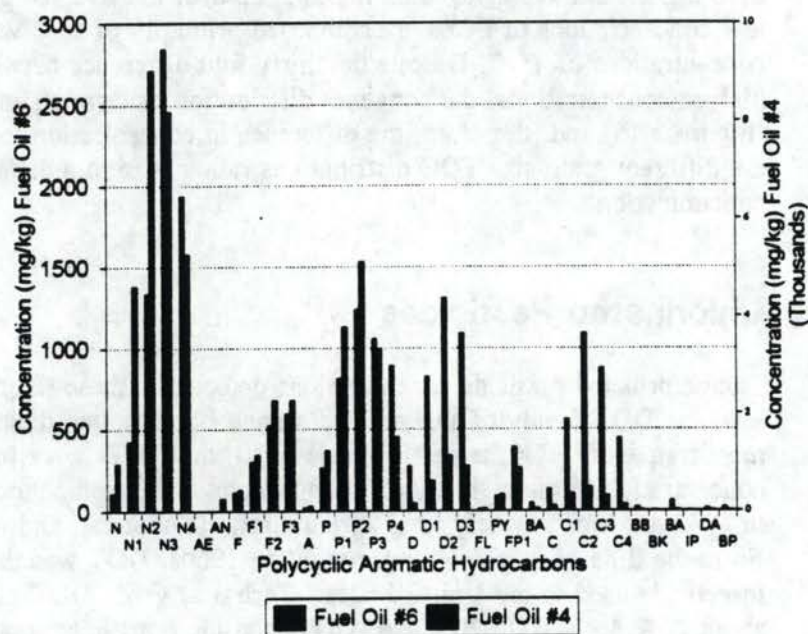


Figure 2-14. Distribution of alkyl homologs for fuel oil #6 and fuel oil #4

2.3.2 PCBs

The PCB concentrations (both Aroclor formulations and congeners) in these sediment samples can be divided into two distinct groups. A majority of these samples are similar, containing Aroclor concentrations ranging from 0.18 to 0.3 mg/kg. Five samples have markedly lower concentrations ranging from 0.01 to 0.08 mg/kg and averaging 0.03 mg/kg. Four of the five sediments containing very low concentrations of PCBs are composed primarily of sand with low concentrations of TOC. Despite the thirty fold difference between the lowest and highest concentrations, the congener distribution pattern is similar among all samples (Figure 2-15) and, therefore, the difference in concentration is most likely related to the different grain-size/TOC distributions rather than to a difference in source of the contamination.

2.3.3 Chlorinated Pesticides

The chlorinated pesticide concentrations detected in these samples are relatively low; the DDT family of analytes, chlordane isomers, and dieldrin were detected most frequently. Of the pesticides detected, the DDTs were found in highest concentration in the majority of these samples. The compound DDT was patented in 1942 and was a widely used agricultural, commercial, and residential pesticide. From the time of its patenting through the 1960s, DDT was the dominant insecticide used in the United States. Technical grade DDT normally consists of about 70% 4,4'-DDT, 20% 2,4'-DDT, and the remainder small amounts of 4,4'-DDE, 2,4'-DDE, 4,4'-DDD, and 2,4'-DDD. Although its use was banned in the United States and Canada in 1972, DDT and its breakdown products are still present in the environment. In natural soils and sediments, 4,4'-DDT is degraded abiotically or by microorganisms to 4,4'-DDE and 4,4'-DDD. Because of its degradation kinetics, at least 50% of total DDT (sum of isomers) should be in the form of DDD and/or DDE if the pesticide was introduced into the environment prior to the ban in 1972 (Rapaport *et al.* 1985). In these sediment samples, the 4,4'-DDT congener constitutes between 0 and 30% of the total DDT concentration indicating that the parent compound has been degraded or converted into its metabolites (Figure 2-16). This indicates that the input of "new" DDT is small, and that most of the DDT has been resident in sediments of Presque Isle Bay for a long time or entered the bay from long-term repositories on land in runoff.

Chlordane, a pesticide containing 45 or more different isomers and congeners, is a home and agricultural pesticide. It was used extensively for termite control until it was phased out in the United States beginning in 1975. Chemically it is similar to dieldrin, both belonging to the structural group of chlorohydrocarbons known as the cyclodiene insecticides (Stetter, 1983). Its wide dispersal in the environment stems primarily from its use in treating soils around homes for termite control.

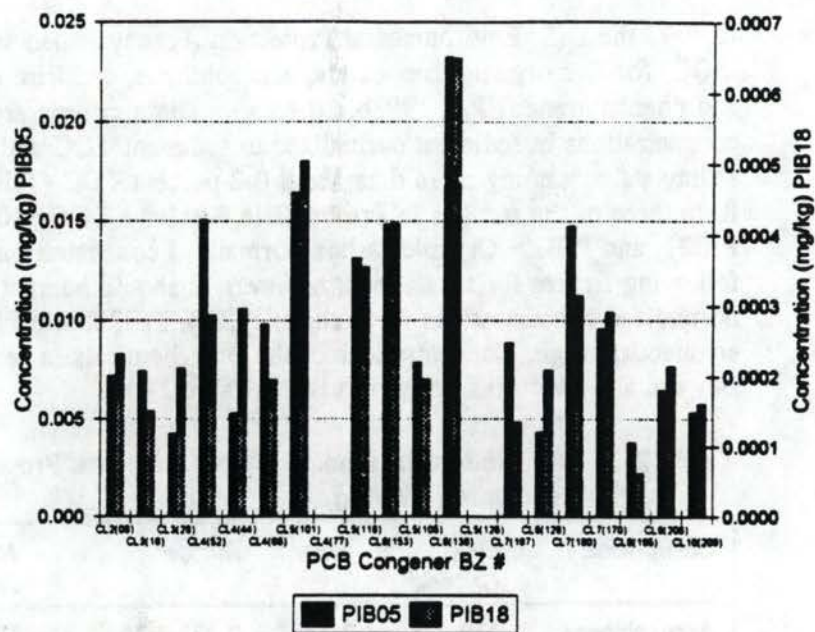


Figure 2-15. PCB congener distributions for Stations PIB05 and PIB18

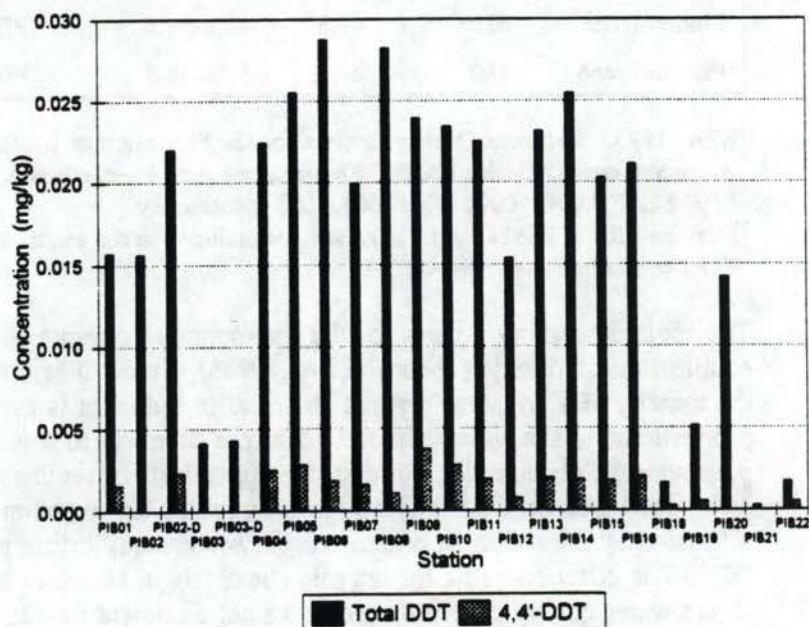


Figure 2-16. Concentrations of total DDT and 4,4'-DDT in the sediments in Presque Isle Bay

2.3.4 Sediment Quality Criteria

In 1993 the U.S. Environmental Protection Agency issued sediment quality criteria (SQC) for five organic compounds, acenaphthene, dieldrin, endrin, fluoranthene, and phenanthrene (EPA, 1993b,c,d,e,f,g). These criteria are based upon concentrations in sediment normalized to sediment TOC and are applicable to sediments containing more than about 0.2 percent TOC (Table 2-2). Sediments from three of the stations in Presque Isle Bay have TOC < 0.2 percent, PIB18, PIB21, and PIB22. Organic carbon normalized concentrations are presented in the following figures for all stations; however, it should be kept in mind that the normalized concentrations for Stations PIB18, PIB21, and PIB22 are probably erroneously high. Concentrations of the five chemicals in sediments of Presque Isle Bay are all lower than criterion values (Table 2-3).

Table 2-3. EPA Sediment Quality Criteria for the Protection of Benthic Organisms (mg/kg_{OC})

<i>Compound</i>	<i>EPA Criteria^a</i>	<i>Mean^b</i>	<i>Range^b</i>	<i>Highest Station</i>	<i>2nd Highest Station</i>
Acenaphthene	130	2.13	0.433-4.36	PIB09	PIB10
Dieldrin	11	0.0817	0.0817-0.236	PIB10	PIB09
Endrin	4.2	Endrin was not detected in any of the samples.			
Fluoranthene	620	47.5	10.6-88.6	PIB09	PIB10
Phenanthrene	180	24.1	5.28-58.6	PIB19	PIB10

^aEPA. 1993. Sediment Quality Criteria for the Protection of Benthic Organisms: Acenaphthene, Dieldrin, Endrin, Fluoranthene, and Phenanthrene. Fact sheets EPA-822-F-006, -007, -005, -004, -003 respectively.

^bStations PIB18, PIB21, and PIB22 are not included in the mean and range as their TOC concentrations were < 0.2%.

The sediment quality criteria for the five nonpolar organic chemicals are based on equilibrium partitioning theory (EPA, 1993a). In equilibrium partitioning theory, the toxicity of a nonpolar organic chemical in sediment is assumed to be proportional to the concentration of the free chemical in solution in the sediment pore water. Concentrations of dissolved chemicals in sediment pore water are estimated based on their tendency to bind reversibly to sediment organic carbon, estimated by the sediment organic carbon/water equilibrium partition coefficient (K_{oc}). The criterion value for organic chemicals in sediment pore water is the same as the water quality criterion chronic value. Sediment quality criteria are expressed as the concentration of the chemical normalized to the concentration of TOC in the bulk sediment (mg/kg_{OC}).

Acenaphthene. Acenaphthene occurs in coal, is found in low concentrations in most crude oils, and is released during the high temperature carbonization or coking

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of coal. Acenaphthere is also used as a dye intermediate in the manufacture of plastics, insecticides, and fungicides, and has been detected in cigarette smoke and gasoline condensates (EPA, 1993b).

Concentrations of acenaphthere normalized to TOC in sediments for each station are presented in Figure 2-17. All stations have concentrations less than the SQC of 130 mg/kg_{oc}. Concentrations range between 0.433 mg/kg_{oc} and 9.87 mg/kg_{oc}, one to two orders of magnitude less than the SQC. Sediment from Station PIB18 has the highest normalized concentration of acenaphthere, 9.87 mg/kg_{oc}, but also has a %TOC of 0.06 which may erroneously elevate the normalized concentration. Sediment from Station PIB21 appears to have the second highest normalized concentration; however the estimated dry weight concentration is less than the MDL of 0.00172 mg/kg. The stations with sediments containing the next highest normalized concentrations are PIB09 and PIB10, 4.36 mg/kg_{oc} and 3.76 mg/kg_{oc} respectively.

Dieldrin. Dieldrin was one of the most widely used chlorinated hydrocarbon pesticides prior to its cancellation in 1974. Aldrin, which quickly transforms to dieldrin, was used in even greater quantity than dieldrin until its cancellation, also in 1974. Both chemicals were used primarily to control insect pests, originally on corn and later on citrus fruits (EPA, 1993c).

Concentrations of dieldrin in sediments normalized TOC for each of the stations are presented in Figure 2-18. Sediments from all stations have concentrations less than the SQC of 11 mg/kg_{oc}. Concentrations range between 0.0086 mg/kg_{oc} and 1.43 mg/kg_{oc}, one to three orders of magnitude less than the SQC. The stations with sediments containing the highest normalized concentration of dieldrin are Stations PIB21, PIB22, and PIB18. All three of these stations have estimated dry weight concentrations of dieldrin less than or just above the method detection limit of 0.00065 mg/kg dry wt and also have extremely low TOC concentrations, $\leq 0.2\%$. The low TOC concentrations may erroneously elevate the organic carbon-normalized dieldrin concentration for these sediments. The stations with sediments containing the highest concentrations dieldrin and TOC $> 0.2\%$ are Stations PIB10 and PIB09 with 0.236 mg/kg_{oc} and 0.176 mg/kg_{oc} respectively. Both of these concentrations are approximately 50 times less than the SQC.

Endrin. Endrin is a chlorinated hydrocarbon insecticide closely related to aldrin and dieldrin. Prior to its cancellation (1986) it was used in the agricultural chemical industry for the control of pests on fruits and vegetation (EPA, 1993d).

Endrin was not detected above the MDL of 0.00187 mg/kg dry wt in sediments from any of the stations in Presque Isle Bay. The EPA SQC for endrin is 4.2 mg/kg_{oc}.

Fluoranthene. Fluoranthene is a high temperature combustion product produced by the pyrolysis of petrogenic materials such as coal and petroleum. It is also

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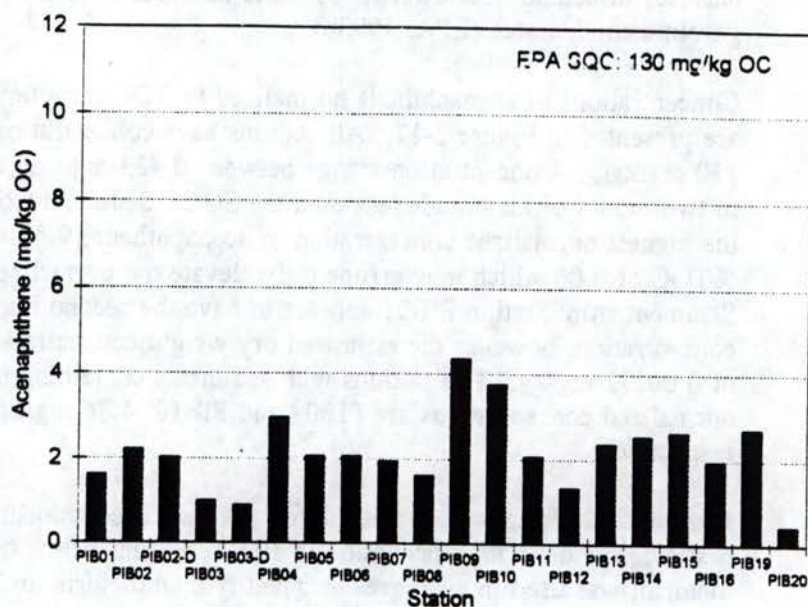


Figure 2-17. Concentrations of acenaphthene normalized to total organic carbon in the sediments in Presque Isle Bay

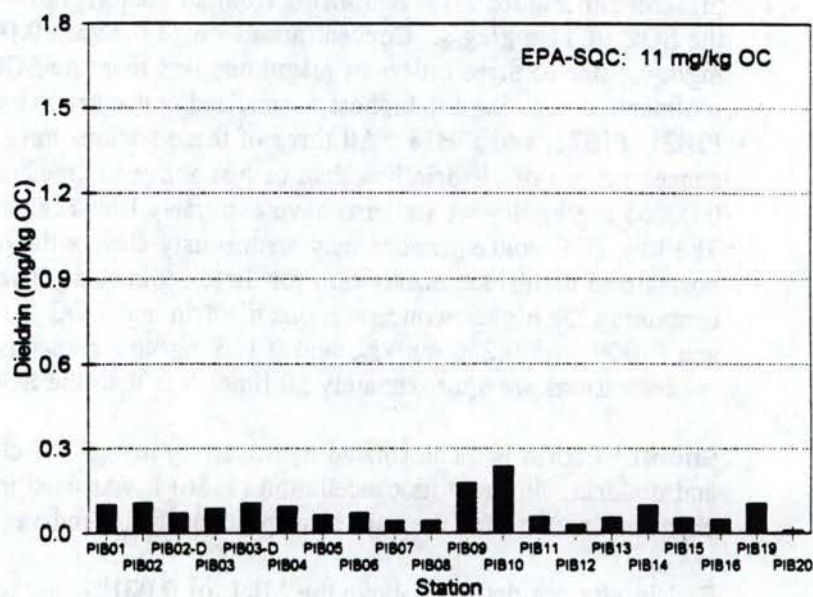


Figure 2-18. Concentrations of dieldrin normalized to total organic carbon in the sediments in Presque Isle Bay

present at low concentrations in crude oil, middle distillate products, and residual oils. It is ubiquitous in the environment (EPA, 1993e).

Concentrations of fluoranthene normalized to TOC in sediments from each of the stations are presented in Figure 2-19. Sediments from all stations have concentrations less than the SQC of 620 mg/kg_{oc}. Concentrations range between 10.6 mg/kg_{oc} and 285 mg/kg_{oc}, two times to fifty times less than the SQC. Sediment from Station PIB18 has the highest normalized concentration of fluoranthene, 285 mg/kg_{oc}, but also has a TOC of 0.06 percent which may erroneously elevate the normalized concentration. Sediment from Station PIB21 appears to have the second highest normalized concentration; however, the estimated dry weight concentration is less than the MDL of 0.00172 mg/kg and the TOC content is <0.2 percent. The stations with the next highest normalized concentrations are PIB09 and PIB10, 88.6 mg/kg_{oc} and 86.4 mg/kg_{oc} respectively, approximately seven times less than the SQC.

Phenanthrene. Phenanthrene is naturally present in coal and petroleum, and has some industrial uses. It is also formed as a high temperature combustion product (EPA, 1993a).

Concentrations of phenanthrene normalized to TOC in sediments from each of the stations are presented in Figure 2-20. Sediments from all stations have concentrations less than the SQC of 180 mg/kg_{oc}. Concentrations range between 5.28 mg/kg_{oc} and 131 mg/kg_{oc}, just less than to thirty times less than the SQC. Sediment from Station PIB18 has the highest normalized concentration of phenanthrene, 131 mg/kg_{oc}, but also has a TOC of 0.06 percent which may erroneously elevate the normalized concentration. The stations with the highest normalized concentrations of phenanthrene and TOC content >0.2 percent in sediments are PIB19 and PIB10, with 58.6 mg/kg_{oc} and 47.5 mg/kg_{oc} respectively, approximately three times less than the SQC.

Even though there were no exceedances of EPA SQC for any of the five compounds with criteria, it should be kept in mind that these comparisons are done on an individual compound basis and do not take into account combined effects of the various contaminants. The PAHs acenaphthene, fluoranthene, and phenanthrene are not usually present independently of other PAH compounds and always indicate the presence of other PAH compounds. Currently, there is no EPA SQC for total PAH.

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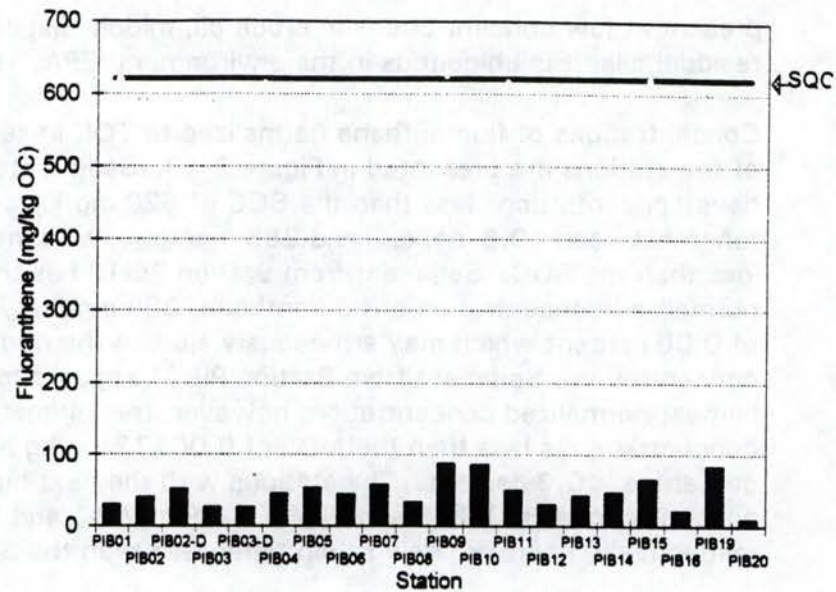


Figure 2-19. Concentrations of fluoranthene normalized to total organic carbon in the sediments in Presque Isle Bay

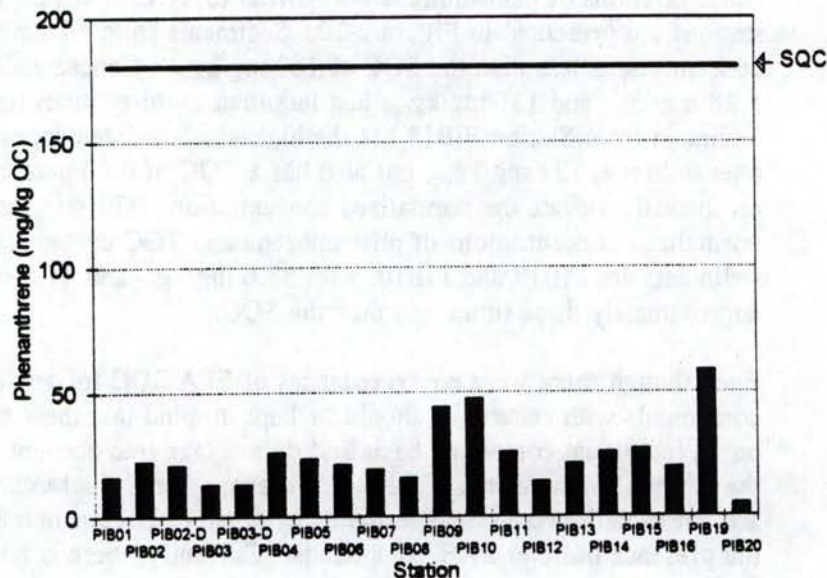


Figure 2-20. Concentrations of phenanthrene normalized to total organic carbon in the sediments in Presque Isle Bay

2.3.5 Sediment Quality Threshold Concentrations

Long and Morgan (1990) proposed threshold concentrations of chemicals in sediments not expected to cause adverse biological effects. They evaluated over 150 studies of the toxicity of contaminants to benthic organisms to identify the lowest concentrations associated with adverse biological effects. Their approach was to tabulate and sort the studies based on sediment chemistry data and observed toxicity to benthic animals. The observed biological effects were sorted according to biological end-point measured, e.g., mortality or a suite of chronic effects, and the consensus ranges in values associated with adverse effects. The major objective was to identify concentrations of contaminants above which adverse effects might first be observed, and the concentrations above which adverse effects always or almost always are observed. Using these data, two levels of concern were established:

ER-L: the concentration of contaminant at the low end of the range in which effects might be observed. ER-L values are concentrations equivalent to the lower 10th percentile of the compiled effects data, and indicate the low end of the range of concentrations at which effects have been observed. ER-L's are levels above which adverse effects might begin for sensitive life stages and/or species.

ER-M: the median concentration in the range of reported values associated with biological effects. ER-M values are concentrations of contaminant equivalent to the 50th percentile of the compiled effects data, and represent the concentration above which effects frequently would be observed or predicted among most species.

The ER-L and ER-M values for the contaminants of interest in this study as compiled by Long and Morgan are found in the table below.

PCBs. Eighteen of the 22 sediment samples from Presque Isle Bay contain concentrations of total PCBs, as Aroclor 1254, greater than the ER-L value (Table 2-4). None of the sediments contain more than the ER-M concentration.

Thus, concentrations of PCBs may be high enough in sediments from most locations in the bay that they could elicit a response to sensitive species of aquatic organisms. However, concentrations are low enough that many species of benthic organisms will not be affected.

Table 2-4. Summary of exceedances of ER-L and ER-M sediment quality threshold values of Long and Morgan (1990). L, exceeds ER-L value; M, exceeds ER-M values; P, concentration below reporting limit and uncertain.

Compound	FIB01	FIB02/02B	FIB03/03B	FIB04	FIB05	FIB06	FIB07	FIB08	FIB09	FIB10	FIB11	FIB12	FIB13	FIB14	FIB15	FIB16	FIB18	FIB19	FIB20	FIB21	FIB22
PCB	L	L		L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	
Total DDT	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	
Chlordane	L	L	L	M	M	M	M	M	M	M	L	L	M	M	L	L	L	L	L	L	
Dieldrin	L	L	L	L	L	L	L	L	L	M	L	L	L	L	L	L	L	L	L	L	L
Endrin	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Acenaphthene									L												
Benzo(a)anthracene	L	L		L	L	L	L	L	M	M	L	L	L	L	L	L	L	L	L	L	
Benzo(a)pyrene	L	L		L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	
Chrysene	L	L		L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	
Fluoranthene	L	L		L	L	L	L	L	M	M	L	L	L	L	L	L	L	L	L	L	
Fluorene	L	L		L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	
Naphthalene													L					L			
Phenanthrene	L	L		L	L	L	L	L	M	M	L	L	L	L	L	L	L	L	L	L	
Pyrene	L	L		L	L	L	M	L	L	L	M	L	L	L	L	L	L	L	L	L	
Total PAH	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	

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Contaminant	ER-L (mg/kg)	ER-M (mg/kg)
PCB	0.05	0.40
Total DDT	0.003	0.35
Chlordane	0.0005	0.006
Dieldrin	0.00002	0.008
Endrin	0.00002	0.045
Acenaphthene	0.15	0.65
Benz(a)anthracene	0.23	1.6
Benzo[a]pyrene	0.40	2.5
Chrysene	0.40	2.8
Fluoranthene	0.60	3.6
Fluorene	0.035	0.64
Naphthalene	0.34	2.1
Phenanthrene	0.225	1.38
Pyrene	0.35	2.2
Total PAH	4.0	35

Total DDT. There is a two-order-of-magnitude difference between the ER-L and ER-M for total DDT, possibly reflecting the wide range of sensitivity of aquatic organisms to this pesticide and its degradation products. Concentrations of total DDT (sum of DDT, DDD, and DDE) in sediments from Presque Isle Bay range from 0.0003 to 0.029 mg/kg. Sediments from three stations contain concentrations of total DDT less than the ER-L value: PIB18 (southeast bay adjacent to inner harbor docks); PIB21 and PIB22 (outside the entrance to Presque Isle Bay) (Table 2-4). Sediments from all other stations contain total DDT concentrations in excess of the ER-L value. The highest concentration, nearly 10 times the ER-L value, is for sediment from Station PIB06. None of the sediments contain concentrations of total DDT in excess of the ER-M.

The ER-L and ER-M values for DDT are 0.001 and 0.007, respectively. Concentrations of DDT in sediments from nine stations are lower than the ER-L value: Stations PIB02, PIB03, PIB03D, PIB12, PIB18, PIB19, PIB20, PIB21, and PIB22. No sediments have a DDT concentration in excess of the ER-M value.

The ER-L and ER-M values for DDD are 0.002 and 0.020 mg/kg, respectively. Sediments from five stations contain DDD concentrations lower than the ER-L value:

Stations PIB03, PIB03D, PIB18, PIB21, and PIB22. None of the sediments contain DDD concentrations in excess of the ER-M value.

The ER-L and ER-M values for DDE are 0.002 and 0.015 mg/kg, respectively. Sediments from only three stations contain DDE at concentrations lower than the ER-L value: Stations PIB18, PIB21, and PIB22. These are the same stations where concentrations of total DDT in sediments were less than the ER-L value for total DDT. None of the sediments contain DDE concentrations in excess of the ER-M value. However, sediment from one station (Station PIB-08, just off the north shore of the bay) contains 0.014 mg/kg DDE, just under the ER-M value.

Chlordane. Chlordane, like DDT, occurs in the environment as the parent compound and several isomers. In this investigation, α -chlordane and γ -chlordane were measured in sediment samples. The sum of these two isomers will be used as an indication of the concentration of total chlordane in sediments from Presque Isle Bay. The ER-L and ER-M values for chlordane are 0.0005 and 0.006, respectively. Sediments from three stations contain concentrations of chlordane lower than the ER-L value: Stations PIB18, PIB21, and PIB22 (Table 2-4). These are the same stations where concentrations of total DDT are lower than the ER-L value for DDT. Sediments from eight stations contain concentrations of chlordane in excess of the ER-M value: Stations PIB04, PIB05, PIB06, PIB07, PIB09, PIB10, PIB13, and PIB14. With the exception of Station PIB07, which is near the center of the bay, all of these stations are located off the south shore of Presque Isle Bay adjacent to the city of Erie, PA. Sediments from these stations are likely to be elicit a response by benthic organisms.

Dieldrin. Dieldrin and endrin have the lowest ER-L value of any of the organic chemicals measured in this study: 0.00002 mg/kg (20 parts per trillion). This is below the reporting limit for dieldrin with the analytical chemical methods used in this study, which is 0.00065 mg/kg and about 32 times higher than the ER-L value. Concentrations of dieldrin in sediments from Presque Isle Bay range from 0.0001 (a semiquantitative estimate) to 0.010 mg/kg. Thus, concentrations of dieldrin in sediments from all stations probably exceed the ER-L value (Table 2-4). Sediments from Stations PIB18, PIB21, and PIB22 contain the lowest concentrations of dieldrin. Sediments from only one station (Station PIB10 at the Cascade Docks) contain dieldrin at a concentration in excess of the ER-M value. Therefore, dieldrin may be affecting benthic organisms throughout the bay, but particularly off the Cascade Docks.

Endrin. Endrin, like dieldrin has an ER-L value of 0.00002 mg/kg, below the reporting limit of the analytical method. However, endrin was not detected in any sediments from Presque Isle Bay at a concentration greater than the detection limit of about 0.0001 mg/kg. Therefore, it is uncertain if any sediments contain endrin at a concentration in excess of the ER-L value. None of the sediments contain endrin at a concentration in excess of the ER-M value of 0.045 mg/kg.

Polycyclic Aromatic Hydrocarbons. The ER-L and ER-M values for total PAHs (4.0 and 35 mg/kg, respectively, representing the sum of the 16 priority pollutant PAHs) are higher than the corresponding values for any individual PAHs for which threshold values are available. Concentrations of total PAHs are high in sediments from many areas of Presque Isle Bay. Sediments from all but three stations (Stations PIB18, PIB21, and PIB22) contain concentrations of total PAHs between the ER-L and ER-M values (Table 2-4). The highest concentration of total PAHs is 26.3 mg/kg in sediments from Station PIB09. Sediments from the area of Station PIB10 contain 25.3 mg/kg total PAHs.

The distribution of individual PAHs in sediments is similar to that for total PAHs, with a few exceptions. Sediments from only two stations (Stations PIB09 and PIB10) exceed the ER-L concentration for acenaphthene (Table 2-4). The concentration of naphthalene exceeds the ER-L value in sediments from only two stations, Stations PIB14 and PIB19.

Concentrations of benz[a]anthracene, fluoranthene, and phenanthrene exceed the ER-M value in sediments from Stations PIB09 and PIB10 (Table 2-4). Pyrene exceeds ER-M in PIB07 and PIB11. There are no other exceedances of the ER-M values for either individual or total PAH. Sediments from Stations PIB3, PIB3D, PIB18, PIB21, and PIB22 consistently contain concentrations of individual PAHs below the ER-L values. Sediments from Station PIB20 (Misery Bay) contained acenaphthene, benzo[a]pyrene, and naphthalene at concentrations below the ER-L values.

Conclusions

Generally, the concentrations of contaminants of concern are below available sediment quality criteria although some stations exhibit concentrations for some compounds that exceed ER-L and ER-M values. Stations PIB09 and PIB10 consistently showed the highest levels of organic contaminants for the various compounds analyzed. Both stations contained concentrations of dieldrin, fluoranthene, and phenanthrene less than the sediment quality criteria but higher than Long and Morgan's ER-M value. In addition, these two stations also contain elevated concentrations (above ER-M values) of chlordane and benz[a]anthracene. Sediment toxicity tests at Station PIB09 using *Hyaella azteca* (amphipod) did not show significant mortality (88% survival rate) which was not significantly different from control sediments. Sediment from Station PIB10 was not tested in the toxicity study. The sediments from stations with the highest *Hyaella azteca* mortality (Stations PIB20 and PIB08), tended to have lower concentrations of organic contaminants than the stations that had higher survival rates. Thus, sediment toxicity tests could demonstrate no clear relationships between toxicity and organic contaminant concentrations of the compounds analyzed. The available data also indicate that station and benthic species community structure did not correspond to PAH concentration levels. Rather, the benthic community appears to be distributed more in relation to sediment texture than sediment quality. Further, the Presque Isle Bay benthic community is characterized primarily by pollutant tolerant

taxa, chironomid larvae and oligochaets, with pollution sensitive species such as trichopterans and amphipods present. This suggests that the concentrations of organic contaminants measured in the sediments of Presque Isle Bay, although elevated at locations, are not the major factor influencing the benthic community structure nor toxicity to the amphipod *Hyaella azteca*.

The relatively strong relationship between sediment texture (percent fines) and organic contaminant concentrations and lack of correspondence between contaminants, toxicity, and benthic community suggests that there are no "hot spots" in the Bay. Moreover, *Hyaella azteca*, the test animal used in the sediment toxicity testing, was not found at Station PIB18 even though the sandy substrate at this site is suitable for this species and the survival rate of this organism in the toxicity tests suggested that this sediment is an acceptable habitat for *Hyaella azteca*. The data suggest that other factors influence the distribution of this and probably other species in the system. Additional evaluations are warranted to describe the status of the system and to fully understand the toxic responses measured at the other stations.

Finally, the phytoplankton data did not identify any unusual patterns or species relative to previous data. The available data suggest, however, that the Bay is likely experiencing eutrophication and its resultant effects. These effects may be greater than in other parts of Lake Erie. However, further studies to verify this suggestion are needed.

2.4 REFERENCES

- Douglas, G.S., K.J. McCarthy, D.T. Dahlen, J.A. Seavey, and W.G. Steinhauer. 1992. The Use of Hydrocarbon analyses for Environmental Assessment and Remediation. *J. Soil Contamination* 1(3):197-216.
- EPA. 1993a. Technical Basis for Deriving Sediment Quality Criteria for Nonionic Organic Contaminants for the Protection of Benthic Organisms by Using Equilibrium Partitioning. U.S. Environmental Protection Agency, Office of Water, Washington, DC. EPA-822-R-93-011.
- EPA. 1993b. Sediment Quality Criteria for the Protection of Benthic Organisms: Acenaphthene. U.S. Environmental Protection Agency, Office of Science and Technology, Washington, DC. EPA-822-R-93-013.
- EPA. 1993c. Sediment Quality Criteria for the Protection of Benthic Organisms: Dieldrin. U.S. Environmental Protection Agency, Office of Science and Technology, Washington, DC. EPA-822-R-93-015.
- EPA. 1993d. Sediment Quality Criteria for the Protection of Benthic Organisms: Endrin. U.S. Environmental Protection Agency, Office of Science and Technology, Washington, DC. EPA-822-R-93-016.
- EPA. 1993e. Sediment Quality Criteria for the Protection of Benthic Organisms: Fluoranthene. U.S. Environmental Protection Agency, Office of Science and Technology, Washington, DC. EPA-822-R-93-012.
- EPA. 1993f. Sediment Quality Criteria for the Protection of Benthic Organisms: Phenanthrene. U.S. Environmental Protection Agency, Office of Science and Technology, Washington, DC. EPA-822-R-93-014.
- Long, E.R. and L.G. Morgan. 1990. *The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program*. National Oceanic and Atmospheric Administration Technical Memorandum NOS OMA 52. NOAA, Rockville, MD, USA.
- PADER. 1991. Presque Isle Bay Ecosystem Study. Background Report, June 1991. Report from Potomac-Hudson Engineering, Inc., Bethesda, MD. to the Pennsylvania Dept. of Environment Resources, Meadville, PA.

Peven, C.S. and A.D. Uhler. 1993. Analytical procedures for trace and major element analysis. In Sampling and Analytical Methods of the National Status and Trends Program National Benthic Surveillance and Mussel Watch Project. Volume III. NOAA Technical Memorandum NOS ORCA 71. National Oceanic and Atmospheric Administration, Silver Spring, MD.

Plumb, R.H. 1981. Procedures for handling and chemical analysis of sediment and water samples. Tech. Rep. EPA/CE-81-1. Prepared for the Environmental Protection Agency/United States Army Corps of Engineers Technical Committee on Criteria for Dredged and Fill Material. Published by the U.S. Army Engineer Waterways Experimental Station, CE, Vicksburg, MS. Great Lakes Laboratory, State University College at Buffalo, Buffalo, NY.

Rapaport, R.A., N.R. Urban, P.D. Capel, J.E. Baker, B.B. Looney, S.J. Eisenreich, and E. Gorham. 1985. "New" DDT inputs to North America: atmospheric deposition. *Chemosphere* 14(9):1167-1173.

Stetter, J. 1983. Insecticidal chlorohydrocarbons. Pp. 24-28 in K.H. Buchel (Ed.), *Chemistry of Pesticides*. John Wiley & Sons Inc., New York, NY.

U.S. Army Corps of Engineers. 1992. Chemical, Physical, and Bioassay Analysis of Sediment Samples, Erie Harbor, Erie, Pennsylvania. U.S. Army Corps of Engineers, Buffalo District.

3.0 BENTHIC MACROINFAUNA

3.1 INTRODUCTION

Presque Isle Bay is located on the southern shore of Lake Erie and receives runoff from a generally urban and industrialized watershed. The long flushing time (2.5 years) of the bay results in the deposition and accumulation of wastes in sediments, with the potential to affect the health and diversity of the biota exposed to these wastes. The distribution and abundance of benthic macroinfauna is a well recognized method for studying the diverse affects of contaminated sediment on the benthic community.

This study sampled eight of the 21 sampling stations for benthic macroinfauna and sediments, to identify potential trends in distribution or abundance of bottom-dwelling macroinvertebrates. Battelle Ocean Sciences contracted Barry A. Vittor & Associates, Inc. to analyze sediment samples for benthic infauna and to interpret the results of their findings. This section summarizes these results.

Sample processing procedures included staining, sorting, identification, and enumeration of all macroinvertebrates retained by a 0.5-mm-mesh screen. Wet-weight biomass was measured for major taxonomic groups (i.e., Annelida, Mollusca, non-insect Arthropoda, and Insecta).

3.2 ANALYTICAL PROCEDURES

Various types of numerical indices were chosen for analysis and interpretation of the macroinfaunal database. Selection was based primarily on the ability of the indices to provide a meaningful summary of data, as well as on their usefulness in the characterization of benthic communities. All taxa censused were included in estimates of species diversity and other community parameters. This approach may have over-estimated diversity in some cases, where certain taxa (e.g., some LPIL designations) were redundant and represented taxa that could be identified to genus or species levels. These indices were not re-calculated by deleting potentially redundant taxa, because of the equal possibility that these unidentifiable organisms actually did represent taxa not otherwise present in a sample. Moreover, the potential error that could be introduced by inclusion of redundant taxa was considered here to be small, and no greater than that represented by calculation of community indices for single samples.

Infaunal abundance, often related to the productivity of the benthos, was reported as the total number of individuals per station and as the number of individuals per square meter. Species richness was reported as both the total number of taxa represented in a given sample and by Margalef's Index D (Margalef, 1958). This is estimated as

$D = (S-1)/\ln N$, where S is the number of taxa and N is the number of individuals in the sample.

Species diversity, which is often related to the ecological stability and environmental "quality" of the benthos, was estimated by Pielou's diversity index (Pielou, 1956). The following formula was applied:

$$H' = - \sum_{i=1}^S p_i (\ln p_i)$$

where S is the number of species in the sample, i is the i 'th species in the sample, and p_i is the number of individuals of the i 'th species divided by the total number of individuals of all species in the sample.

Species diversity within a given community is dependent on both the number of taxa present (species richness) and the distribution of all individuals among those species (equitability or evenness). To quantify and compare the equitability in the fauna to the species diversity for a given area, Pielou's evenness Index J' (Pielou, 1966) was calculated as $J' = H' / \ln S$, where H' is Pielou's Index of Diversity (as calculated above) and S is the number of taxa in the sample.

Numerical classification analysis (Boesch, 1977) was performed on the faunal data to examine between-station differences at the site and to compare faunal composition at each station within the site. Classification analysis by both station (normal analysis) and species (inverse analysis) was performed by using the Czekanowski quantitative index of faunal similarity (Field and MacFarlane, 1968). This index considers both the number of species in common and the difference in number of individuals among stations. Although it is weighted toward the occurrence of dominant (*i.e.*, abundant) species, preliminary selection of species based on their percent abundance by station and percent frequency of occurrence for the study area can reduce the weighted bias.

The value of the similarity index is 1.0 when the two samples are identical and 0 when no species are in common. Hierarchical clustering of similarity values is achieved by using the group-average sorting strategy (Lance and Williams, 1967), displayed in the form of dendrograms (cluster graphs).

Both similarity classification and cluster analyses were performed with the aid of a "Package of Computer Programs for Benthic Community Analysis" (Bloom *et al.*, 1977) as modified for use in Barry Vittor and Associates (BVA) benthic data management program. Species selected for these analyses were those that comprised at least 0.1% of all individuals collected during the survey. Total densities for each of the selected species at a given station collection were log-transformed [$x = \ln(x+1)$] for the analysis.

3.3 RESULTS AND DISCUSSION

3.3.1 Station Characteristics

Water depths and sediment texture are summarized in Table 3-1. Depth ranged from 3 ft. at Station PIB18 to 23 ft. at Station PIB11. Highest percent sand (100.0%) was observed at Station PIB18; the next-highest percent sand (41.3%) was observed at Station PIB20. Lowest percent sand (13.1%) was found at Station PIB11. Highest percent clay (23.2%) was measured at Station PIB08; while highest percent silt (74.5%) was observed at Station PIB19.

Except for the sand substrate at Station PIB18, sediments were classified as either sandy clayey silt or clayey sandy silt, and represented depositional environments. Low percent clay was observed at Stations PIB19 (in Lake Erie) and PIB20, which is located due north of Station PIB18.

Two sediment hydrocarbons that appeared to be representative of constituents in study are samples - biphenyl and naphthalene - were tabulated with sediment texture data to summarize sediment quality at benthic sample stations.

PAH concentrations were relatively low at Station PIB18 and were high at deeper-water stations characterized by high percent silt/clay (*e.g.*, Stations PIB08 and PIB09). Concentrations of selected PAH constituents are summarized in Table 3-1. The highest concentration of biphenyl was measured at PIB08 and both biphenyl and naphthalene concentration were very low at PIB18. PAH data reflected moderate hydrocarbon levels at all stations except PIB18, which contained no silt or clay sediment.

Table 3-1. Water depth, sediment texture, and selected PAH components at benthic macroinfauna stations; May 16, 1994

Station	Depth (ft.)	% Gravel	% Sand	% Silt	% Clay	Biphenyl mg/kg	Naphthalene mg/kg
PIB01	15	0.0	26.2	62.4	12.4	0.02800	0.12430
PIB07	22	0.0	18.9	61.9	19.2	0.03945	0.21803
PIB08	18	0.0	22.8	54.0	23.2	0.06703	0.21863
PIB09	16	0.0	16.2	67.9	15.8	0.06081	0.28229
PIB11	23	0.0	13.1	67.0	19.8	0.04715	0.22789
PIB18	3	0.0	100.0	0.0	0.0	0.00086	0.00307
PIB19	11	0.0	21.3	74.5	4.2	0.02538	0.34194
PIB20	12	0.7	41.3	57.0	6.9	0.02242	0.12785

3.3.2 Community Composition

A total of 1,782 individuals was consused from the eight macroinfaunal samples — Stations PIB01, PIB07, PIB08, PIB09, PIB11, PIB18, PIB19, PIB20 (see Table 3-2). Annelids comprised 980 (55.0%) of these organisms; most annelids were oligochaetes, which accounted for 943 individuals. Arthropods were next most-abundant, with 468 individuals (26.3%), of which 397 were insects and 62 were crustaceans. Molluscs were represented by 334 individuals (18.7%).

Fifty-eight (58) taxa were identified from the eight samples, including possibly redundant taxa (e.g., Chironomidae LPIL). Insects accounted for 22 of these taxa, or 37.9% of the total number. Chironomids were the most diverse insect group, and were represented by 17 taxa. Annelids (primarily oligochaetes) comprised 15 taxa, or 25.9% of the species encountered. Molluscs accounted for 9 taxa (15.5%), and crustaceans accounted for 6 taxa (10.3%). Arthropods (crustaceans, insects, and arachnids combined) comprised 34 taxa, or nearly 60% of all taxa collected.

Tubificidae (LPIL) was by far the most abundant taxon, with 824 individuals, or 46.2% of the total. This oligochaete taxon was comprised of juvenile or otherwise unidentifiable individuals. The chironomid *Procladius* (LPIL) was second most-abundant, with 164 individuals (9.2%), followed by the bivalves *Pisidium punctatum* (106 individuals), and *Dreissena polymorpha* (84 individuals). Four of the ten most-abundant taxa were molluscs, and three of the six most-abundant taxa occurred at seven of the eight stations sampled.

3.3.3 Basic Community Statistics

Species abundance ranged from only 6 at Station PIB18 to 33 at PIB08 (Table 3-3). The average number of taxa was 20.6 per station. Five of the six taxa at PIB18 were oligochaetes; no arthropods were found at this location. While five oligochaete taxa were also found at PIB08, there was also a high number of non-chironomid taxa, such as Trichoptera and Amphipoda. This combination of taxa was unexpected, since crustaceans are generally viewed as indicators of low sediment contamination, and this station contained elevated PAH levels.

Individual abundances ranged from 1,120/m² (Station PIB18) to 12,080/m² (PIB19). Lowest abundances occurred at stations where lower numbers of taxa were observed. At three of the four lowest stations, infaunal densities were lower than expected for temperate lake habitats; infaunal density at the shallowest, sandy station (PIB18) was unusually low. Very high densities at PIB08 and PIB19 appeared to reflect the presence of high organic content, and were produced by very high abundances of tubificid oligochaetes. These stations were also characterized by high PAH concentrations.

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Table 3-2. Taxonomic listing and abundance of phyla taxa from Presque Isle Bay survey, May 1994

Phylum	No. Individuals	% Total	No. Taxa	% Total
Annelida	980	55.0	15	25.9
Mollusca	334	18.7	9	15.5
Crustacea	62	3.5	6	10.3
Insecta	397	22.3	22	37.9
Arachnida	9	0.5	6	10.3
Totals	1782		58	

Species		No. Individuals	% Total	Cumulative %*	Station Occurrence	% Station Occurrence
Tubificidae (LPIL)	(O)	824	46.7	46.7	8	100.0
Procladius (LPIL)	(I)	164	9.3	56.0	7	87.5
Pisidium punctatum	(M)	106	6.0	62.0	7	87.5
Dreissena polymorpha	(M)	84	4.8	66.8	6	75.0
Tanytarsus (LPIL)	(I)	68	3.9	70.7	5	62.5
Pisidium compressum	(M)	51	2.9	73.6	7	87.5
Limnodrilus hoffmeisteri	(O)	47	2.7	76.3	6	75.0
Mytilopsis leucophaeata	(M)	43	2.4	78.7	5	62.5
Manayunkia speciosa	(P)	34	1.9	80.6	3	37.5
Candona (LPIL)	(C)	32	1.8	82.4	5	62.5
Coelotanypus (LPIL)	(I)	31	1.8	84.2	6	75.0
Chironomus (LPIL)	(I)	25	1.4	85.6	7	87.5
Cryptochironomus (LPIL)	(I)	23	1.3	85.5	5	62.5
Gammarus fasciatus	(C)	22	1.2	86.7	4	50.0
Ceratopogonidae (LPIL)	(I)	22	1.2	87.9	6	75.0
Sphaerium patella	(M)	19	1.1	89.0	5	62.5
Sphaerium partumeium	(M)	19	1.1	90.1	5	62.5
Quistadrilus multisetosus	(O)	17	1.0	91.1	3	37.5
Limnodrilus cervix	(O)	15	0.8	91.9	2	25.0
Polypedilum (LPIL)	(I)	13	0.7	92.6	4	50.0
Chironomidae (LPIL)	(I)	13	0.7	94.0	5	62.5
Oecetis inconspicua	(I)	12	0.7	95.4	4	50.0
Amnicola limosa	(M)	10	0.6	96.0	4	50.0
Limnodrilus maumeensis	(O)	9	0.5	96.5	2	25.0
Cladopelma (LPIL)	(I)	7	0.4	96.9	4	50.0
Aulodrilus pigueti	(O)	6	0.3	97.2	2	25.0
Dicrotendipes (LPIL)	(I)	6	0.3	97.5	1	12.5
Branchiura sowerbyi	(O)	6	0.3	97.8	2	25.0
Limnodrilus (LPIL)	(O)	5	0.3	98.1	1	12.5
Limnodrilus clapedianus	(O)	5	0.3	98.4	1	12.5
Dero (LPIL)	(O)	4	0.2	98.6	1	12.5
Gammarus (LPIL)	(C)	3	0.2	98.8	2	25.0

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Table 3-2. Taxonomic listing and abundance of phyla and numerically dominant taxa from Presque Isle Bay survey, May 1994 (cont.)

Species		No. Individuals	% Total	Cumulative %*	Station Occurrence	% Station Occurrence
Glossiphoniidae (LPIL)	(H)	3	0.2	99.0	1	12.5
Orthotrichia (LPIL)	(I)	3	0.2	99.2	2	25.0
<i>Hyalella azteca</i>	(C)	2	0.1	99.3	1	12.5
<i>Sperchon</i> (LPIL)	(A)	2	0.1	99.4	1	12.5
Oligochaeta (LPIL)	(O)	2	0.1	99.5	1	12.5
Hyalellidae (LPIL)	(C)	2	0.1	99.6	1	12.5
Naididae (LPIL)	(O)	2	0.1	99.7	2	25.0
<i>Hydracarina</i> (LPIL)	(A)	2	0.1	99.8	2	25.0
<i>Unionicola</i> (LPIL)	(A)	2	0.1	99.9	2	25.0
<i>Tribelos</i> (LPIL)	(I)	1	0.05	99.95	1	12.5
<i>Dero flabelliger</i>	(O)	1	0.05	99.95	1	12.5
<i>Hygrobates</i> (LPIL)	(A)	1	0.05	99.95	1	12.5
<i>Koenikea</i> (LPIL)	(A)	1	0.05	99.95	1	12.5
<i>Neumania</i> (LPIL)	(A)	1	0.05	99.95	1	12.5
<i>Caecidotea</i> (LPIL)	(C)	1	0.05	99.95	1	12.5
<i>Ablabesmyia rhamphe</i> group	(I)	1	0.05	99.95	1	12.5
<i>Endochironomus subtendens</i>	(I)	1	0.05	99.95	1	12.5
<i>Glyptotendipes</i> (LPIL)	(I)	1	0.05	99.95	1	12.5
<i>Harnishia</i> (LPIL)	(I)	1	0.05	99.95	1	12.5
<i>Labrundinia</i> (LPIL)	(I)	1	0.05	99.95	1	12.5
<i>Enallagma</i> (LPIL)	(I)	1	0.05	99.95	1	12.5
Trichoptera (LPIL)	(I)	1	0.05	99.95	1	12.5
<i>Hydroptila</i> (LPIL)	(I)	1	0.05	99.95	1	12.5
<i>Leptocerus americanus</i>	(I)	1	0.05	99.95	1	12.5
<i>Valvata tricarinata</i>	(M)	1	0.05	99.95	1	12.5
Sphaeriidae (LPIL)	(M)	1	0.05	99.95	1	12.5

(A): Arachnida, (C): Crustacea, (H): Hirudinea, (I): Insecta, (M): Mollusca,
(O): Oligochaeta, (P): Polychaeta

* Note: Cumulative % may exceed 100% due to rounding of decimal fraction.

Species diversity (H') was very low at PIB18 (0.98), where lowest species abundance occurred, but was also low at PIB19, where Tubificidae (LPIL) was extremely abundant compared to other taxa. Very high numerical dominance at both stations was also reflected in very low species evenness (J'). Highest species diversity (2.57) was observed at PIB11, which had a moderate number of taxa, and a moderate number of individuals. Oligochaetes were not numerically dominant at PIB11.

Species richness (D) corresponded closely to number of taxa, and ranged from 1.24 (PIB18) to 5.51 (PIB20).

Wet-weight biomass was extremely low at Station PIB18 (0.007 g/0.05m²), where most individuals were small oligochaetes (Table 3-4). High biomass was measured at PIB08 (1.072 g/0.05m²) and PIB20 (1.047 g/0.05m²). Molluscs were relatively abundant at both stations, but insects comprised the greatest proportion of biomass at PIB20.

Table 3-3. Summary statistics for benthic macroinfauna samples collected May 16, 1994 at Presque Isle Bay (Lake Erie). Sample size is 0.05m².

Station	Number of Taxa	Number of Individuals	Density (#/m ²)	H'	J'	D
PIB01	15	83	1660	1.84	0.68	3.17
PIB07	16	92	1840	2.37	0.85	3.32
PIB08	33	509	10180	2.37	0.68	5.13
PIB09	17	79	1580	2.40	0.85	3.66
PIB11	25	166	3320	2.57	0.80	4.69
PIB18	6	56	1120	0.98	0.55	1.24
PIB19	23	604	12080	1.30	0.41	3.44
PIB20	30	193	3860	2.41	0.71	5.51

H' : Pielou's Species Diversity

J' : Pielou's Evenness

D : Margalef's Species Richness

(Note: Each index calculated using log base e)

3.3.4 Community Classification Analysis

Although this survey involved only limited spatial sampling within the study area, both normal (station) and inverse (species) classification analyses were performed on the May 1994 data set, and are displayed as dendrograms (Figures 3-1 and 3-2). Forty-two taxa were selected for analysis, including 14 annelids, 13 insects, 8 crustaceans/arachnids, and 7 molluscs. These taxa represented 99% of the organisms collected. Data were also arranged in a two-way table, to show the correspondence between station and species groups (Table 3-5).

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Table 3-4. Wet weight biomass of major taxa at Presque Isle Bay stations sampled in May 1994; expressed as g/0.05²

Station	Taxon	Biomass
PIB01	Annelida	0.001
	Crustacea/Arachnida	0.002
	Insecta	0.005
	Mollusca	0.015
	Total	0.023
PIB07	Annelida	0.001
	Crustacea/Arachnida	0.012
	Insecta	0.006
	Mollusca	0.126
	Total	0.145
PIB08	Annelida	0.040
	Crustacea/Arachnida	0.085
	Insecta	0.049
	Mollusca	0.898
	Total	1.072
PIB09	Annelida	0.002
	Crustacea/Arachnida	0.011
	Insecta	0.239
	Mollusca	0.006
	Total	0.246
PIB11	Annelida	0.005
	Crustacea/Arachnida	0.003
	Insecta	0.017
	Mollusca	0.375
	Total	0.395
PIB18	Annelida	0.006
	Mollusca	0.001
	Total	0.007
PIB19	Annelida	0.355
	Crustacea/Arachnida	0.005
	Insecta	0.092
	Mollusca	0.022
	Total	0.474
PIB20	Annelida	0.010
	Crustacea/Arachnida	0.023
	Insecta	0.563
	Mollusca	0.451
	Total	1.047

Table 3-5. Data matrix of station and species groups compiled from classification analysis dendrograms, Presque Isle Bay, May 1994

	Group C		Group B					Group A
	PIB20	PIB19	PIB11	PIB09	PIB07	PIB01	PIB08	PIB18
<i>Dero</i> (LPIL)	0	0	0	0	0	0	0	4
<i>Oligochaeta</i> (LPIL)	0	0	0	0	0	0	0	2
<i>Unionicola</i> (LPIL)	0	0	0	1	0	1	0	0
<i>Candona</i> (LPIL)	0	9	15	0	4	3	1	0
<i>Tubificidae</i> (LPIL)	82	442	25	17	13	3	201	41
<i>Procladius</i> (LPIL)	16	25	30	17	18	31	27	0
<i>Pisidium punctatum</i>	5	11	23	6	13	27	21	0
<i>Pisidium compressum</i>	2	15	5	4	9	2	14	0
<i>Tanytarsus</i> (LPIL)	4	0	2	0	8	1	53	0
<i>Dreissena polymorpha</i>	6	0	8	5	9	2	54	0
<i>Coelotanypus</i> (LPIL)	6	0	4	7	6	2	6	0
<i>Mytilopsis leucophaea</i>	11	3	2	2	0	0	25	0
<i>Ceratopogonidae</i> (LPIL)	1	3	1	5	0	2	10	0
<i>Quistadrilus multisetosus</i>	1	8	0	0	0	0	8	0
<i>Sphaerium partumeium</i>	0	4	4	1	4	0	6	0
<i>Polypedium</i> (LPIL)	0	4	2	0	0	1	6	0
<i>Cryptochironomus</i> (LPIL)	6	3	7	0	0	3	4	0
<i>Chironomidae</i> (LPIL)	7	1	0	0	1	2	2	0
<i>Gammarus fasciatus</i>	3	1	0	0	1	0	17	0
<i>Oecetis inconspicua</i>	4	0	1	0	2	0	5	0
<i>Chironomos</i> (LPIL)	0	0	0	4	1	2	6	0
<i>Manayunkia speciosa</i>	0	0	20	3	0	0	11	0
<i>Amnicola limosa</i>	0	0	5	2	1	0	2	0
<i>Cladopelma</i> (LPIL)	1	0	1	2	0	0	3	0
<i>Orthotrichia</i> (LPIL)	0	0	0	0	1	0	2	0
<i>Hydracarina</i> (LPIL)	0	0	0	0	1	0	1	0
<i>Aulodrilus pigueti</i>	0	0	3	0	0	0	3	0
<i>Gammarus</i> (LPIL)	0	0	1	0	0	0	2	0
<i>Glossiphoniidae</i> (LPIL)	0	0	0	0	0	0	3	0
<i>Sperchon</i> (LPIL)	0	0	0	0	0	0	2	0
<i>Limnodrilus hoffmeisteri</i>	7	30	1	1	0	0	4	4
<i>Branchiura sowerbyi</i>	1	5	0	0	0	0	0	0
<i>Dicrotendipes</i> (LPIL)	6	0	0	0	0	0	0	0
<i>Hyaella azteca</i>	2	0	0	0	0	0	0	0
<i>Hyalellidae</i> (LPIL)	2	0	0	0	0	0	0	0
<i>Naididae</i> (LPIL)	1	0	0	0	0	0	1	0

Numerical classification of the eight stations was interpreted at a 3-group level (Figure 3-1). Group A was distinguished at a 17% level of similarity, indicating that this group (Station PIB18) contained an infaunal assemblage that was very different from the other stations. Groups B and C were delineated at a 48% level of similarity, indicating that these groups were comprised of relatively similar infaunal assemblages. Group C (PIB19 and PIB20) was distinguished from Group B stations mainly by shallower water depth and location. Stations PIB19 and PIB20 were located near the entrance channel on the east, while Group B stations were located in the central and western area of the Bay.

Numerical classification of the 42 taxa delineated 4 groups, at a 20% or lower level of similarity (Figure 3-2), indicating presence of a relatively heterogeneous grouping of taxa. Group 1 contained 3 oligochaete taxa, while Group 2 contained only the water mite *Unionicola* (LPIL). Group 3 was very diverse and included 29 of the 42 taxa. Species Group 4 contained 9 taxa, in 2 subgroups. The first sub-group consisted of 4 oligochaetes and 1 chironomid, while the second sub-group contained 2 amphipod crustaceans, 1 oligochaete, and 1 chironomid.

3.3.5 Infaunal-Habitat Relationships

Aquatic habitats regarded as being relatively clean generally contain reduced numbers of chironomid dipterans and oligochaetes (Cairns, *et al.*, 1973). Elevated diversities in such systems result from low numerical dominance and moderate numbers of species/individuals of crustaceans, molluscs, and beetles, as well as numerous other groups. Some species of chironomids contain hemoglobin, which provides adaptation to oxygen-poor conditions typical of areas affected by organic pollution (Gauvin, 1973). Non-organic pollution indicators are varied; some dipterans (*e.g.*, *Chironomus*) and tubificid oligochaetes are intolerant of elevated copper concentrations, but are not greatly affected by elevated lead or zinc concentrations.

Previous studies of Presque Isle Bay were reviewed by Gannet (1993) and have indicated that levels of sediment contaminants may vary with distance from the shoreline, extent of filtering wetlands along the shoreline, proximity to stormwater input to the Bay, and water depth/depositional patterns. Areas of coarser sediments (sand) were generally cleaner than areas with predominantly silt/clay sediments, although five sediment areas that are not in the path of stormwater discharge plumes are also relatively non-polluted.

Benthic communities in the Bay were summarized by PADER (1991) and were shown to be dominated by pollution tolerant species such as oligochaetes, chironomids, and some pelecypods. Pollution-sensitive species such as amphipods and trichopterans were found to be much less abundant due to decreased habitat suitability (*i.e.*, few areas of coarse substrate). Physical alteration of habitats, rather than chemical contaminant loading, has been suggested as the principal factor in the distribution of benthic infaunal species composition and abundance (PADER, 1991).

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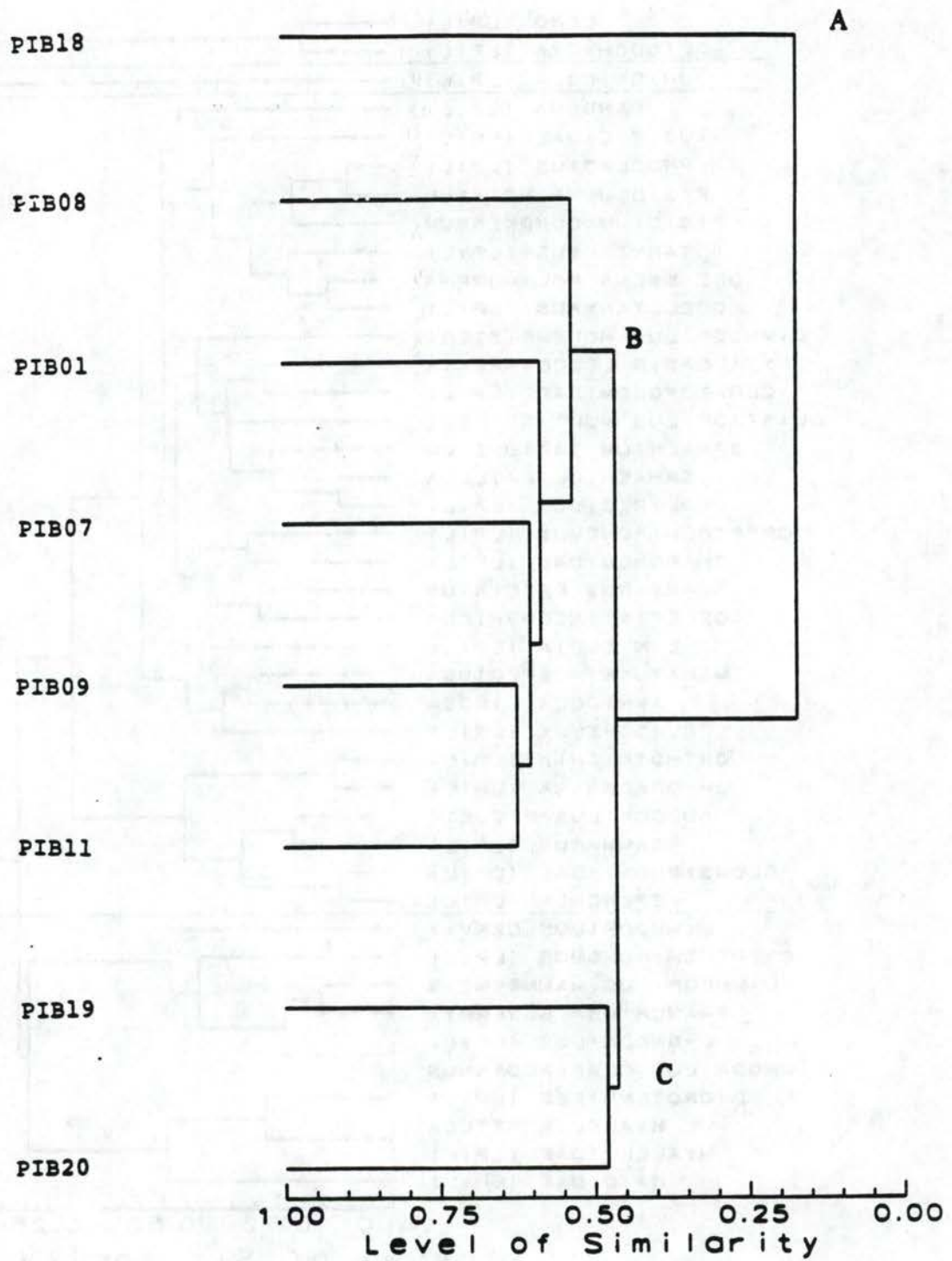


Figure 3-1. Normal (station) numerical classification dendrogram for benthic infauna sampled at Presque Isle Bay in May 1994.

BENTHIC MACROINFAUNA

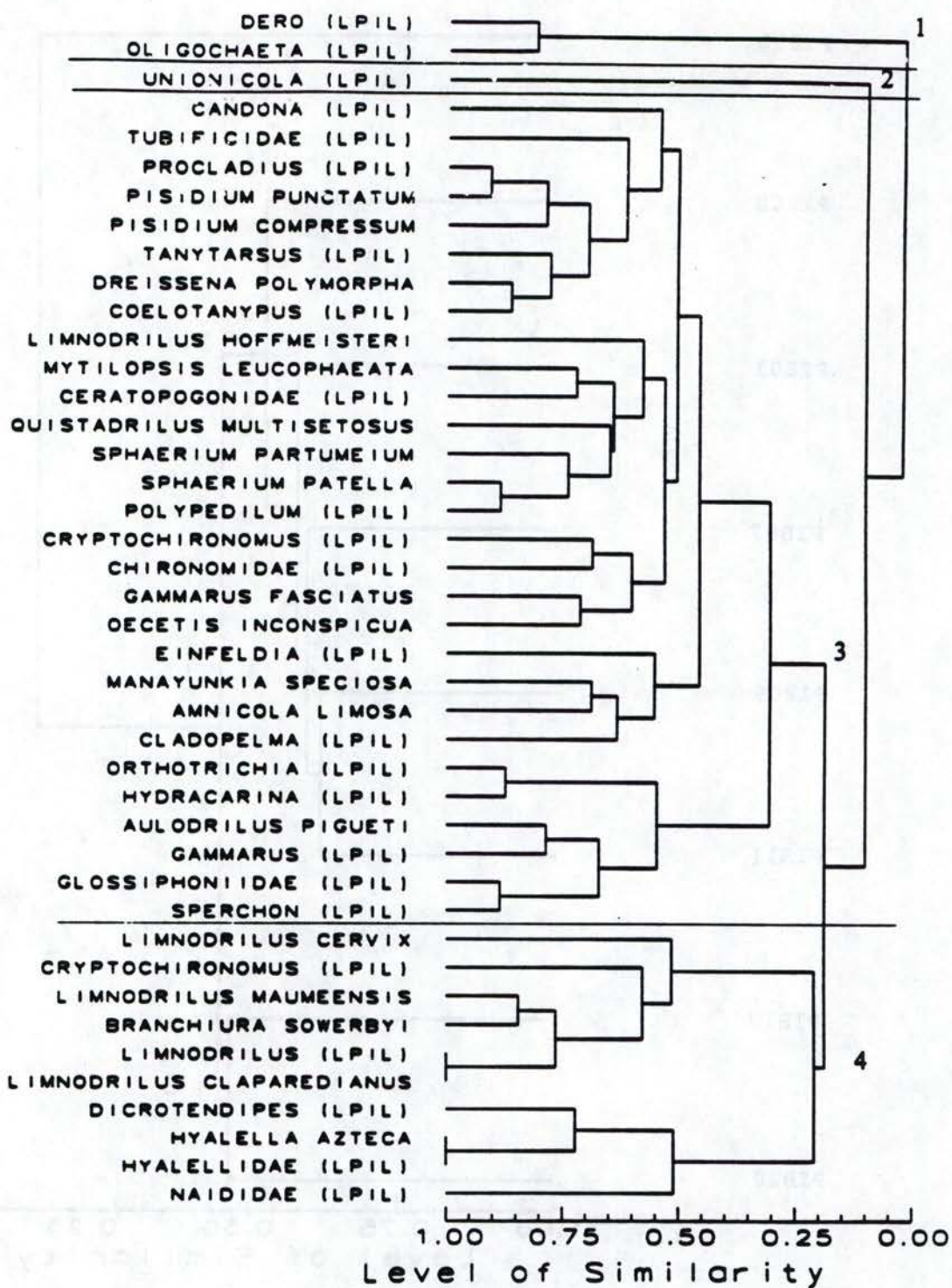


Figure 3-2. Inverse (species) numerical classification dendrogram for benthic infauna sampled at Presque Isle Bay in May 1994

The May 1994 survey results suggest that the macroinfauna distribution in relation to sediment texture. However, the limited scope of this project precludes rigorous statistical comparisons of benthic community statistics and sediment characteristics. Evaluation of habitats using sediment chemistry (PAH) data suggested that the sediment quality was not a significant factor in abundance or diversity of the benthos. Presque Isle Bay benthos were characterized primarily by pollution tolerant taxa; chironomid (midge) larvae were the most speciose group, and oligochaetes were numerically dominant, overall. However, this trend was less pronounced at Station PIB08, PIB11, and PIB20, where oligochaetes occurred in reduced numbers and pollution sensitive species such as trichopterans and amphipods were present. These stations were characterized by sediments generally similar to those at stations dominated by oligochaetes and chironomids, except for Station PIB20, where percent clay was very low. Relatively depauperate benthos at Station PIB18 did not appear to be produced by sediment contamination, since these sediments were relatively coarse and contained very low PAH levels. Although the sandy substrate at this site should have been suitable for species such as *Hyalalea* (amphipod) and various Trichoptera, these taxa were absent from PIB18.

3.3.6 CONCLUSIONS

The results of this investigation are summarized below:

1. Sedimentary habitats were characterized mainly as sandy clayey silt, although the shallowest station sampled contained sand only.
2. Benthic macroinfaunal communities were dominated by oligochaetes and chironomids, reflecting the relatively fine, organic sediments present at most of the 8 stations.
3. Species and individual abundances were variable but were generally lowest nearest the southern shoreline of the Bay.
4. Species diversities and evenness were also variable, but exhibited no spatial trends or correspondence to PAH concentrations.
5. Station and species groups indicated the presence of two principal station-species associations. These represented one group of 2 stations near the Bay entrance and one group of 5 stations in the Bay, away from the entrance. Although different assemblages of low-abundance taxa occurred at these station groups, they both included taxa such as oligochaetes, crustaceans (amphipods), and chironomids. Neither station nor species groupings appeared to correspond to sediment texture or PAH levels.

3.4 REFERENCES

- Bloom, S.A., S.L. Santos, and J.G. Field. 1977. A package of computer programs for benthic community analysis. *Bull. Mar. Sci.* 27:577-580.
- Boesch, D.F. 1977. Application of numerical classification in ecological investigations of water pollution. EPA Rep. 600/3-77-033. U.S. Environmental Protection Agency, Corvallis, OR. 115 pp.
- Cairns, J., Jr., K.D. Dickson, and G. Lanzo. 1973. Rapid biological monitoring systems for determining aquatic community structure in receiving systems. Pp. 148-163, *In: Biological Methods for the Assessment of Water Quality*. ASTM STP 528.
- Field, J.G. and G. MacFarlane. 1968. Numerical methods in marine ecology. I.A. quantitative "similarity" analysis of rocky shore samples in False Bay, South Africa. *Zool. Afr.* 3:119-137.
- Gauvin, A.R. 1973. Use of aquatic invertebrates in the assessment of water quality. Pp. 95-116, *In: Biological Methods for the Assessment of Water Quality*. ASTM STP 528.
- Gannet Fleming, Inc. 1993. Special Study: Presque Isle Bay Sediment Quality Evaluation. Report to US EPA, Region III. Lance, G.N., and W.T. Williams. 1967. A general theory of classificatory sorting strategies. I. Hierarchical systems. *Comput. J.* 9:373-380.
- Margalef, R. 1958. Information theory in ecology. *Gen. Sys.* 3:35-71.
- PADER. 1991. Presque Isle Bay Ecosystem Study, Background Report. Prepared by Potomac-Hudson Engineering, Inc.
- Pielou, E.C. 1966. The measurement of diversity in different types of biological collections. *J. Theoret. Biol.* 13:131-144.

4.0 PLANKTON CHARACTERIZATION STUDY

On 16-18 May 1994, plankton communities were sampled at the same four locations in Presque Isle Bay where plankton samples had been collected during October 1992 (EPA Region III, 1993). Depths at sampling stations, PIB10, PIB12, PIB18 and PIB20 were 7.0, 6.0, 1.0 and 3.7 m respectively.

Evaluation of this data was based on the assumption that the sites were representative of the entire PIB ecosystem, including sites remote from and near potential sources of pollution. For example PIB10 and PIB18 were expected to indicate impacts from Cascade Creek and Mill Creek, respectively. PIB12 was expected to indicate the general status of the bay distant from the mouths of creeks and harbor activities. PIB20, in Misery Bay, was expected to indicate the status of this major habitat connected to PIB.

4.1 METHODS

Sampling procedures for plankton basically conformed to APHA *et al.* (1985) and West and Trulli (1994). Zooplankton samples were collected using a 63 mm mesh plankton net (bottom to surface vertical tows). Whole water was collected at three discrete depths (surface, mid-, bottom depth) in the water column at each of the four stations.

4.1.1 Laboratory Processing

Phytoplankton

In the laboratory, exactly 1L of each whole-water phytoplankton sample was placed in a 1-liter graduated cylinder, covered, and stored in the dark for one week, allowing at least 4 hours/cm of chamber height for the phytoplankton to settle. The top portion of the sample column was then siphoned-off, concentrating the sample to approximately 50 mL. Three 0.1-mL subsamples from each concentrated sample were examined microscopically in a Palmer-Maloney cell. Using a Whipple grid, phytoplankton were identified and enumerated at 675 $\times$ magnification in perpendicular strips that crossed at the center of the counting cell. The entire contents of the cell were examined at 150X to enumerate the larger rare forms of phytoplankton. At least 200 phytoplankters were counted in each subsample. After three subsamples were counted for each sample, the relative standard deviation (RSD) of the counts for each of the dominant species was calculated following the protocol of Makarewicz (1993b). If the RSD for any dominant taxon exceeded 50%, then the count data for the subsample most different from the average count was discarded, and an additional subsample was taken and enumerated.

Phytoplankton were identified to the lowest practicable taxon, using taxonomic keys in APHA *et al.* (1985), Patrick and Reimer (1966), Prescott (1962 and 1978) and Whitford and Schumacher (1984). Annotated line drawings of the phytoplankton

PLANKTON CHARACTERIZATION STUDY

taxa (and smaller zooplankton) prepared for the October 1992 (Gannett Flemming, Inc., 1993) study were updated to validate additional species identified during the present study. Phytoplankton concentrates were stored in 50-mL glass vials to provide a source of voucher specimens.

Zooplankton

The volume of each zooplankton sample was adjusted so that it contained at least 200 zooplankters per milliliter. After thoroughly mixing each sample, a subsample was taken using a 1-mL Henson-Stempel pipette and placed in a Sedgewick-Rafter counting chamber for microscopic examination. The entire contents of the chamber were enumerated. After three subsamples were counted for each sample, the RSD of the counts for each of the dominant species was calculated. If the RSD for any dominant taxon exceeded 50%, then all count data for the subsample most different from the average was discarded, and an additional subsample was enumerated. Large rare forms of zooplankton were counted in the entire sample and fractions thereof (1/10 to 1/50), following the method of Lind (1979).

Zooplankton were identified to species using taxonomic keys in Balcer *et al.* (1984), Brooks (1957), Dodson and Frey (1991), Hann (1982), Megard (1967), Stemberger (1979), Pennak (1978), and Ward and Whipple (1959). During routine processing of the vertical tow samples, larger specimens of zooplankton were separated into individual vials to provide voucher specimens.

4.1.2 Data Analysis

Using appropriate measurements of lake water sampled, concentrate volume, subsample volume and portion of subsample enumerated, the density of organisms estimated by each subsample was calculated on a hand-held calculator and recorded on data sheets. Zooplankton density was reported in units of organisms per cubic meter. Phytoplankton density was reported in units of organisms per milliliter.

Density estimates for each taxon and subsample were entered into a spreadsheet (Lotus) file. Lotus was then used to calculate average density and standard deviation from the sample mean (SD) for each taxon and sample, the overall average per station, and the percentage abundance of each taxon.

The statistical significance of variations among stations in densities of phytoplankton were tested with a single-factor Analysis of Variance (ANOVA), using Abstat software. The average density estimates obtained for each of the three depths sampled per station were used as replicate observations. The fact that these were not random samples should not invalidate the statistical analysis in this case, because density estimates from different depths would be expected to overestimate the error (within station) variance component. Density estimates were log-transformed prior to ANOVA in order to homogenize the sample variances. Scheffe's test was performed following ANOVA to determine the significance of

differences between paired station means. The 0.05 probability-level was used to judge significance for all statistical tests.

4.2 RESULTS

4.2.1 Phytoplankton

Appendices 1-4 contain original data for individual subsamples of the three whole water samples collected at each station, including the sample mean and SD of the density estimates for each taxon of phytoplankton. The SD expressed as a percentage of the sample mean of density estimates for subsamples was usually less than 15% for the dominant taxa of phytoplankton and exceeded 30% in only two cases (Table 4-1). Table 4-2 lists the overall average of the three samples per station and the percent abundance of the total based upon the overall averages.

Table 4-1. Subsampling variability for dominant plankton organisms in whole water (phytoplankton) and vertical net tow (zooplankton) samples from Presque Isle Bay, May 16-18, 1994. Data represent frequency occurrence of calculations of standard deviation (SD) expressed as a percentage of the sample mean of triplicate subsamples. Phytoplankton and zooplankton species with average density estimates exceeding 150/mL and 750/m³, respectively, were considered dominant.

Standard Deviation (% Avg Density)	Frequency Occurrence		
	Phytoplankton	Zooplankton	Total
0 to 5%	8	3	11
5.1% to 10%	16	7	23
10.1% to 15%	9	7	16
15.1% to 20%	5	3	8
20.1% to 25%	3	2	5
25.1% to 30%	5	0	5
30.1% to 40%	2	1	3
> 40%	0	0	0

4.2.1.1 Abundance of Major Groups of Phytoplankton

Summary statistics for major groups of phytoplankton enumerated in concentrates of whole water samples from Presque Isle Bay (Table 4-3) indicate that Cryptophyta and Chlorophyta were the dominant groups, together comprising 90-98% of the total number of organisms at all four stations. All of the numerically important forms in both groups were small (4-15 μm) flagellates. Diatoms (Chrysophyta: Bacillariophyceae) comprised 1-2% of the total at all of the stations except PIB18, where they made up 9% of the total. Non-flagellate Chlorophyta accounted for 1.9-3.5% of the total at the four stations. Chrysophyceans made up only 0.1-0.5% of the total number of phytoplankton. Cyanobacteria, Pyrrophyta and Euglenophyta each comprised less than 0.1% of the total at all four stations.

4.2.1.2 Specific Comparison Among Stations

A total of 59 taxa of phytoplankton were identified in the 12 samples (Table 4-2), with diatoms and green algae (Chlorophyta) represented by the most different kinds (24 and 23 species respectively). A total of 40, 38, 46 and 50 different kinds of phytoplankton were found in samples from Stations PIB10, PIB12, PIB18 and PIB20, respectively. Although statistical analysis indicated no significant differences among stations in the average total number of different phytoplankton taxa per sample (Table 4-4), the average number of chlorophyte species per sample at PIB20 was four-fold to be significantly higher than at PIB10, and the average number of diatom taxa per sample at PIB18 was higher than at PIB12 and PIB20.

The same four taxa were numerically dominant at all four stations: *Rhodomonas minuta nannoplanktonica* (Cryptophyta) and three additional small flagellate species tentatively identified as *Chlamydomonas* spp. (Chlorophyta). *R. minuta* was the most abundant of these taxa at Stations PIB10, PIB12 and PIB18 with average densities (in replicates) ranging from 868-1,447/mL and comprising 40-52% of total count. It was abundant also at Station 20 (1,420-2,055/mL and comprised 20% of the total) but was second in numerical importance to the coccoid-form *Chlamydomonas* (3,499-5,848/mL and 55% of the total). The densities of each of the three *Chlamydomonas* spp. (i.e., ovoid, coccoid, and small flagellates) in individual samples from Stations PIB10, PIB12 and PIB18 ranged from 167-751/mL and accounted for 10-23% of the total number of phytoplankton.

Although considerably less abundant than the flagellates, several taxa of diatoms occurred consistently in the 12 samples. Average total density of diatoms per station was greater at Stations PIB18 and PIB20 than at Stations PIB10 and PIB12 (Table 4-4). This difference was mainly due to higher counts of *Achnanthes* at Stations PIB18 and PIB20 (43-122/mL). *Asterionella formosa*, *Cocconeis*, *Cyclotella*, *Navicula*, *Synedra*, and *Tabellaria fenestrata* each usually occurred at average densities ranging from 1-15/mL among all four stations. The relative abundance of individual diatom taxa never exceeded 1% at any of the stations.

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Table 4-2. Average nanoplankton densities (number/mL) at sampling stations in Presque Isle Bay and percentage of total.

Taxon	PIB10-PW		PIB12-PW		PIB18-PW		PIB20-PW	
	Stn.Avg.	Percent	Stn.Avg.	Percent	Stn.Avg.	Percent	Stn.Avg.	Percent
Cyanobacteria								
<i>Anabaena</i> sp.	0	0.0000	0	0.0000	0	0.0000	0.122222	0.0014
<i>Anacystis aeruginosa</i>	0	0.0000	0.177778	0.0070	0.066667	0.0035	0.122222	0.0014
<i>Anacystis</i> sp. (small cells)	0.233333	0.0081	0.588889	0.0232	0.055556	0.0029	0.177778	0.0021
<i>Anacystis</i> sp. 2 (<i>Chroococcus</i>)	0.577778	0.0202	0.822222	0.0323	0.244444	0.0128	0.855556	0.0101
<i>Oscillatoria</i>	0.122222	0.0043	0.222222	0.0087	0.544444	0.0286	0.666667	0.0078
Subtotal	0.933333	0.0326	1.811111	0.0712	0.911111	0.0478	1.944444	0.0229
Phylum Chrysophyta								
Bacillariophyceae								
<i>Achnanthes</i>	8.177778	0.2853	14.43333	0.5677	93.02222	4.8821	80.5	0.9467
<i>Asterionella formosa</i>	3.4	0.1186	4.311111	0.1696	4.377778	0.2298	2.266667	0.0267
<i>Cocconeis</i>	1.2	0.0419	1.233333	0.0485	1.122222	0.0589	6.777778	0.0797
<i>Cyclotella</i>	9.4	0.3279	14.23333	0.5598	13.8	0.7243	11.25556	0.1324
<i>Cymatopleura solea</i>	0	0.0000	0	0.0000	0.055556	0.0029	0	0.0000
<i>Cymbella</i>	0.066667	0.0023	0.3	0.0118	0.533333	0.0280	1.533333	0.0180
<i>Diploneis</i>	0	0.0000	0	0.0000	0.055556	0.0029	0.2	0.0024
<i>Esmotia</i>	0.244444	0.0085	0	0.0000	0.111111	0.0058	0	0.0000
<i>Fragilaria crotonensis</i>	0.433333	0.0151	0.6	0.0236	0.055556	0.0029	0	0.0000
<i>Fragilaria</i> sp. 2 (cf <i>F. capucina</i>)	0.588889	0.0205	0.533333	0.0210	0.533333	0.0280	6.677778	0.0785
<i>Gomphonema</i>	0	0.0000	0	0.0000	4.288889	0.2251	0.422222	0.0050
<i>Gyrodinium</i>	0.066667	0.0023	0	0.0000	0	0.0000	0	0.0000

PLANKTON CHARACTERIZATION STUDY

Table 4-2. Average nanoplankton densities (number/mL) at sampling stations in Presque Isle Bay and percentage of total. (cont.)

Taxon	PIB10-PW		PIB12-PW		PIB18-PW		PIB20-PW	
	Stn.Avg.	Percent	Stn.Avg.	Percent	Stn.Avg.	Percent	Stn.Avg.	Percent
<i>Melosira islandica</i>	0.633333	0.0221	0.411111	0.0162	0.355556	0.0187	0.666667	0.0078
<i>Meridion circulare</i>	0	0.0000	0	0.0000	0.944444	0.0496	0	0.0000
<i>Navicula</i>	1.455556	0.0508	0.911111	0.0358	31.27778	1.6416	1.266667	0.0149
<i>Nitzschia</i>	0.066667	0.0023	0.122222	0.0048	0.4	0.0210	0	0.0000
<i>Pinnularia</i>	0.055556	0.0019	0.055556	0.0022	0	0.0000	0.066667	0.0008
<i>Rhoicosphenia</i>	0.066667	0.0023	0	0.0000	1.188889	0.0624	0.066667	0.0008
<i>Stauroneis</i>	0	0.0000	0	0.0000	1.855556	0.0974	0	0.0000
<i>Stephanodiscus</i>	0.766667	0.0267	1.177778	0.0463	0.6	0.0315	0.788889	0.0093
<i>Surirella</i>	0.055556	0.0019	0	0.0000	0.122222	0.0064	0.066667	0.0008
<i>Synedra</i>	4.244444	0.1481	5.411111	0.2128	9.944444	0.5219	51.47778	0.6054
<i>Tabellaria fenestrata</i>	0.7	0.0244	1.822222	0.0717	1.455556	0.0764	3.044444	0.0358
unidentified diatom	0	0.0000	0.166667	0.0066	0.822222	0.0432	0.055556	0.0007
Subtotal	31.62222	1.1031	45.72222	1.7983	166.9222	8.7606	167.1333	1.9655
Chrysophyceae								
<i>Dinobryon divergens</i>	6.788889	0.2368	13.18889	0.5187	5.422222	0.2846	11.13333	0.1309
<i>Mallomonas</i>	0.544444	0.0190	0.122222	0.0048	0.422222	0.0222	0.166667	0.0020
Subtotal	7.333333	0.2558	13.31111	0.5235	5.844444	0.3067	11.3	0.1329
Phylum Pyrrophyta								
<i>Glenodinium</i>	0.244444	0.0085	0.244444	0.0096	0	0.0000	0.233333	0.0027
Phylum Cryptophyta								
<i>Cryptomonas</i>	9.188889	0.3206	5.088889	0.2002	2.5	0.1312	12.08889	0.1422

PLANKTON CHARACTERIZATION STUDY

Table 4-2. Average nanoplankton densities (number/mL) at sampling stations in Presque Isle Bay and percentage of total. (cont.)

Taxon	PIB10-PW		PIB12-PW		PIB18-PW		PIB20-PW	
	Stn.Avg.	Percent	Stn.Avg.	Percent	Stn.Avg.	Percent	Stn.Avg.	Percent
<i>Rhodomonas minuta</i> <i>nannoplanktonica</i>	1157.033	40.3626	1023.733	40.2652	994.9111	52.2160	1732.311	20.3723
(<i>Chroomonas</i>)								
Subtotal	1166.222	40.6831	1028.822	40.4654	997.4111	52.3472	1744.4	20.5144
Phylum Euglenophyta								
<i>Euglena</i>	0.055556	0.0019	0	0.0000	0.188889	0.0099	0.122222	0.0014
<i>Trachelomonas</i>	0.066667	0.0023	0.055556	0.0022	0	0.0000	0.233333	0.0027
Subtotal	0.122222	0.0043	0.055556	0.0022	0.188889	0.0099	0.355556	0.0042
Phylum Chlorophyta								
<i>Ankistrodesmus falcatus</i>	0.922222	0.0322	0.388889	0.0153	0.466666	0.0245	9.111111	0.1071
<i>Cosmarium</i>	0.055556	0.0019	0	0.0000	0	0.0000	0.066667	0.0008
<i>Closterium</i>	0	0.0000	0	0.0000	0	0.0000	0.066667	0.0008
Ovoid flagellate (<i>Chlamydomonas</i>)	466.6778	16.2798	354.7889	13.9545	228.7222	12.0040	620.4222	7.2963
Coccoid flagellate (<i>Chlamydomonas</i>)	645.3111	22.5114	545.0556	21.4380	196.2333	10.2989	4657.533	54.7733
Small flagellate (<i>Chlamydomonas</i>)	449.8889	15.6942	471.6556	18.5510	237.9111	12.4863	1129.133	13.2788
Large green flagellate	3.688889	0.1287	0.577778	0.0227	0.055556	0.0029	0.311111	0.0037
Coccoid non-flag. (<i>Chlorella</i>)	50.68889	1.7683	43.32222	1.7039	57.68889	3.0277	129.5889	1.5240
<i>Coelastrum</i>	37.55556	1.3101	31.22222	1.2280	7.666667	0.4024	11.17778	0.1315
<i>Elakatothrix viridis</i>	0	0.0000	0	0.0000	0	0.0000	0.688889	0.0081
<i>Gloeocystis</i>	0	0.0000	0	0.0000	0.166667	0.0087	2.022222	0.0238

PLANKTON CHARACTERIZATION STUDY

Table 4-2. Average nanoplankton densities (number/mL) at sampling stations in Presque Isle Bay and percentage of total. (cont.)

Taxon	PIB10-PW		PIB12-PW		PIB18-PW		PIB20-PW	
	Stn.Avg.	Percent	Stn.Avg.	Percent	Stn.Avg.	Percent	Stn.Avg.	Percent
<i>Lagerheimia</i>	0	0.0000	0	0.0000	0	0.0000	0.122222	0.0014
<i>Pediastrum duplex</i>	0.388889	0.0136	0.3	0.0118	0.166667	0.0087	0.866667	0.0102
<i>Pediastrum simplex</i>	0.311111	0.0109	0.244444	0.0096	0.177778	0.0093	0.366667	0.0043
<i>Scenedesmus acuminatus</i>	0	0.0000	0	0.0000	0	0.0000	0.122222	0.0014
<i>Scenedesmus denticulatus</i>	0	0.0000	0	0.0000	0	0.0000	0.411111	0.0048
<i>Scenedesmus quadricauda</i>	1.333333	0.0465	1.166667	0.0459	0.655556	0.0344	4.177778	0.0491
<i>Scenedesmus bijuga</i>	0.122222	0.0043	0.233333	0.0092	0.055556	0.0029	0.177778	0.0021
<i>Spirogyra</i>	0	0.0000	0.122222	0.0048	0.122222	0.0064	0.522222	0.0061
<i>Staurastrum</i>	0	0.0000	0	0.0000	0	0.0000	0.366667	0.0043
<i>Tetraedron lunula</i>	0	0.0000	0	0.0000	0.311111	0.0163	0	0.0000
<i>Tetraedron trigonum</i>	0	0.0000	0	0.0000	0	0.0000	0.055556	0.0007
<i>Tetrastrum</i>	0	0.0000	0.055556	0.0022	0.111111	0.0058	0	0.0000
Subtotal	1656.944	57.8017	1449.133	56.9969	730.5111	38.3395	6567.311	77.2326
Other Unidentified								
Unidentified non-flagellates	91.37778	3.1877	77.05556	3.0307	67.58889	3.5473	159.9111	1.8806
Unidentified flagellates	1565.567	54.6141	1372.078	53.9662	662.9222	34.7922	6407.4	75.3520
Ciliated protozoa	3.177778	0.1109	3.377778	0.1329	3.588889	0.1884	10.61111	0.1248
TOTAL	2866.6	100.0000	2542.478	100.0000	1905.378	100.0000	8503.289	100.0000

PLANKTON CHARACTERIZATION STUDY

Table 4-3. Summary statistics [arithmetic mean ($\bar{x}$), range in density (No./mL, percent relative abundance (%)] for major groups of phytoplankton at sampling stations on Presque Isle Bay, May 16-18, 1994, based upon counts in concentrates of whole water samples.

Taxon	Mean ($\bar{x}$) (No./mL) Range (No./mL) Percent Relative Abundance (%)	Station			
		PIB10	PIB12	PIB18	PIB20
Cyanobacteria	$\bar{x}$ Range %	0.9 0.4 - 1.2 0.03	1.8 1.0 - 2.3 0.07	0.9 0.5 - 1.5 0.05	1.9 0.7 - 2.8 0.03
Chrysophyta Bacillariophyceae	$\bar{x}$ Range %	31.6 24 - 37 1.1	45.7 30 - 70 1.8	166.9 136 - 219 8.8	167.1 130 - 206 2.0
Chrysophyta Chrysophyceae	$\bar{x}$ Range %	7.3 6.8 - 8.1 0.26	13.3 8 - 18 0.52	5.8 5.2 - 6.8 0.31	11.3 8 - 13 0.13
Pyrrophyta	$\bar{x}$ Range %	0.24 0.2 - .3 0.01	0.24 0.2 - .3 0.01	0 0 0.0	0.23 0.2 - 0.3 0.003
Cryptophyta	$\bar{x}$ Range %	1166.2 982 - 1458 40.7	1028.8 870 - 1261 40.5	997.4 978 - 1051 52.3	1744.4 1431 - 2067 20.5
Euglenophyta	$\bar{x}$ Range %	0.1 0 - 0.2 0.004	0.05 0 - 0.2 0.002	0.19 0 - 0.4 0.01	0.36 0.3 - 0.4 0.004
Chlorophyta flagellates	$\bar{x}$ Range %	1565.6 1406 - 1650 54.6	1372.1 1045 - 1805 54.0	662.9 547 - 746 34.8	6407.4 5590 - 7415 75.4
Chlorophyta nonflagellates	$\bar{x}$ Range %	91.4 62 - 116 3.2	77.1 49 - 123 3.0	67.6 64 - 71 3.5	159.9 96 - 230 1.9
Ciliates	$\bar{x}$ Range %	3.2 2.3 - 4.0 0.11	3.4 1.4 - 5.6 0.13	3.6 2.6 - 4.7 0.19	10.6 10 - 12 0.12
Total	$\bar{x}$ Range %	2866.6 2548 - 3254 100	2542.5 2025 - 3285 100	1905.4 1813 - 1954 100	8503.3 7746 - 9865 100

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Table 4-4. Results of ANOVA tests comparing phytoplankton density and species richness among sampling stations in Presque Isle Bay. Results of Scheffe's test indicate differences among sample means that were significant at = 0.05 probability level. Numbers for sampling stations are arranged in lowest to highest value order from left to right. Stations numbers underscored by a common line do not differ significantly from each other.

Variable	F-Ratio	Probability	Results of Scheffe's Test
Total Phytoplankton	52.821	0.0000	<u>18 12 10</u> 20
Total Number of Taxa	2.281	0.1562	<u>12 10 18</u> 20
Total Cyanobacteria	2.338	0.1499	<u>18 10 12</u> 20
Number of Cyanobacteria Taxa	1.595	0.2653	<u>10 18 12</u> 20
Total Diatoms	25.206	0.0002	<u>10 12 18</u> 20
Number of Diatom Taxa	6.204	0.0175	<u>20 12 10</u> 18
<i>Achnanthes</i>	25.955	0.0002	<u>10 12 18</u> 20
<i>Asterionella formosa</i>	14.201	0.0014	<u>18 12 10</u> 20
<i>Cocconeis</i>	14.2011	0.0014	<u>18 12 10</u> 20
<i>Fragilaria capucina</i>	2.235	0.1616	<u>12 18 10</u> 20
<i>Navicula</i>	58.927	0.0000	<u>12 20 10</u> 18
<i>Synedra</i>	48.605	0.0000	<u>10 12 18</u> 20
<i>Tabellaria fenestrata</i>	4.411	0.0414	<u>10 18 12</u> 20
<i>Dinobryon divergens</i>	6.282	0.0169	<u>18 10 20</u> 12
Total Cryptophyta	6.673	0.0144	<u>18 12 10</u> 20
<i>Cryptomonas</i>	7.844	0.0091	<u>18 12 10</u> 20
<i>Rhodomonas minuta</i> <i>nannoplanktonica</i>	6.620	0.0147	<u>18 12 10</u> 20
Total Chlorophyta	81.570	0.0000	18 <u>12 10</u> 20
Number of Chlorophyta Taxa	5.400	0.0252	<u>10 18 12</u> 20
Total green flagellates	82.169	0.0000	18 <u>12 10</u> 20
ovoid flagellate	18.470	0.0006	<u>18 12 10</u> 20
coccoid flagellate	90.983	0.0000	18 <u>12 10</u> 20
small flagellate	23.945	0.0002	18 <u>12 10</u> 20
Total green non-flagellates	3.012	0.0944	<u>18 12 10</u> 20
<i>Ankistrodesmus</i>	46.961	0.0000	<u>12 18 10</u> 20
<i>Scenedesmus quadricauda</i>	9.817	0.0047	<u>18 12 10</u> 20
Total Ciliates	8.765	0.0066	<u>12 10 18</u> 20

except PIB18, where *Achnanthes* and *Navicula* comprised 4.9 and 1.6% of the average total count, respectively.

Moderately low average densities of the chrysophycean *Dinobryon divergens* and cryptophyte *Cryptomonas* occurred at all four stations (2.5-13/mL and 0.13-0.52% of the total). Small non-flagellate chlorophytes, including *Coelastrum* and a coccoid (*Chlorella*-like) form occurred at average densities ranging from 8-130/mL (0.1-3% of total). The average density per station for *Ankistrodesmus falcatus* and *Scenedesmus quadricauda* ranged from 0.4-1.3/mL (both were <0.05% of total) at PIB10, PIB12 and PIB18. These chlorophytes were significantly more abundant at PIB20 (Table 4-4) where their average densities were 9.1 and 4.2/mL, respectively.

Densities of several plankton taxa appeared to vary with depth, although it was not possible to test this statistically since only one sample was collected per depth at each station. At the three deeper stations (PIB10, PIB12 and PIB20) the highest densities of, *Rhodomonas minuta*, coccoid-form *Chlamydomonas*, total diatoms, *Fragilaria capucina*, and ciliated protozoa occurred in the sample collected nearest the bottom (Appendix B). At Station PIB18 where all three samples were collected within one meter (Appendix B), negligible variation with depth was observed for *R. minuta* and the coccoid *Chlamydomonas*. However, remarkably higher densities of diatoms *Achnanthes* and *Navicula* occurred in the near-bottom sample at PIB18. It is likely that these were benthic diatoms that had become suspended in the lowest part of the water column by disturbance or wave action.

4.2.1.3 Comparison with Previous Studies of Presque Isle Bay

The total densities of phytoplankton observed in these samples (1,905-8,503/mL) were lower than the densities found in samples collected by EPA in October 1992 at the same four stations (9,865-11,989/mL) which were enumerated by the same subcontractor. Specifically, the present study found much lower densities of the cryptophyceans *Cryptomonas* and *R. minuta* (identified as *Chroomonas* in the 1992 study). Densities of Cyanobacteria, the chrysophycean *Mallomonas* and colonial diatom *Asterionella formosa* were also notably higher in the fall 1992 collections than in the present study. These differences probably reflect normal seasonal variations in phyto-plankton abundance. *Chlamydomonas*-type flagellates occurred in the same general range of densities in the present study as in October 1992.

Total phytoplankton densities observed in the present study are much higher than the numbers reported by Zagorski and O'Toole (1970) for early June samples collected at roughly the same locations in Presque Isle Bay (0.7-6.8/mL). However, their counts probably greatly underestimated phytoplankton abundance since they filtered their water samples through a 10 μ m mesh net. The filtration would result in the loss of small flagellates (including most of the *R. minuta* and three *Chlamydomonas*-type flagellates) that dominated the samples collected in recent studies.

For a similar reason, phytoplankton results obtained in the present study cannot be compared to those of Bardarik *et al.* (1973). Water collected for phytoplankton analyses in that study was filtered through a number 20 silk bolting cloth to concentrate the algae for enumeration, which resulted in undersampling in $< 1 \mu\text{m}$ size species.

4.2.1.4 Comparison with Recent Studies of Lake Erie

Makarewicz (1993a) summarized the results of phytoplankton analyses of spring and summer samples collected at offshore sites in the central and eastern basins of Lake Erie from 1983-1987. The average and maximum densities reported by Makarewicz (1993a) for *R. minuta* and what he called "unidentified flagellates-ovoid and spherical" (probably includes ovoid and coccoid *Chlamydomonas* in the present study) were in the same general range as the densities found for those taxa in the present study.

The average densities reported at offshore sites for diatom species, Pyrrophyta and Cyanobacteria are higher than the densities found in the present study. However, Makarewicz's data is based upon samples collected during 33 separate cruises, and probably included one or more sampling dates when these groups were at or near their seasonal maxima.

4.2.2 Zooplankton

Appendices 5 and 6 contain original data for individual subsamples of the vertical tow samples collected at each station, including the sample mean and SD of the density estimates for each taxon. The SD expressed as a percentage of the sample mean was usually less than 15% for the dominant taxa of zooplankton and exceeded 25% in only one case (Table 4-1). Table 4-5 contains an overall summary of the zooplankton data, including the density estimates based upon counts of rare taxa in entire samples.

4.2.2.1 Abundance of Major Groups of Zooplankton

Copepod nauplii were the most abundant taxon at most stations (Table 4-5), with densities ranging from $5,378/\text{m}^3$ at PIB18 to $12,365/\text{m}^3$ at PIB12, and percent abundance ranging from 37-47% of the total. Cyclopoid copepods, especially immature stages (copepodids) and rotifers were also abundant at the four stations. Cyclopoid densities ranged from $888-14,413/\text{m}^3$ (8-44%) and rotifer densities ranged from $3,676-6,518/\text{m}^3$ (12-35%).

Cladocera were moderately abundant, with densities ranging from $1,058-4,345/\text{m}^3$ (6-14%). Calanoid copepod densities were relatively low at $52-205/\text{m}^3$ (0.3-0.6%).

Harpacticoid copepods, ostracods and zebra mussel (*Dreissena polymorpha*) veligers were scarce at 0-45/m³ (0-0.3%).

4.2.2.2 Comparisons Among Stations

A total of 54 taxa (excluding copepodids and copepod nauplii zooplankton) were identified in the 4 samples (Table 4-5), with Cladocera and Rotifera represented by the largest number of species (19 and 20 species, respectively). Cyclopoid and calanoid copepod groups were each represented by 6 different species. A total of 24, 28, 33 and 40 different taxa of zooplankton were found in samples from Stations PIB10, PIB12, PIB18 and PIB20, respectively.

PIB20 was represented by a greater variety of cladoceran species than the other stations. All of the cladocerans unique to Station 20 were members of the family Chydoridae, which contains species specialized for living amid aquatic vegetation (Fryer, 1968). Aquatic plants were abundant at this location in Presque Isle Bay at the time of sampling (Eric Obert, PADER, personal communication), and a fragment of *Potamogeton* was present in the sample collected there. Occurrence of submerged aquatic plants at PIB20 may also account for the poorer representation (in that sample) of calanoid copepod species (Table 4-5), which generally prefer open-water habitats (Balcer *et al.*, 1984).

The dominant cyclopoid at all four stations was *Diacyclops thomasi* (Table 5), with higher adult densities at the two deeper stations - PIB10 and PIB12 (2,248 and 2,756/m³) - than at the shallower sites (36 and 787/m³ at PIB18 and PIB20, respectively). Calanoid species were scarce at all four stations, only one station, PIB12, had densities of individual species exceeding 10/m³ only at Station PIB12. Harpacticoid copepods, which are considered benthic organisms (Balcer *et al.*, 1984), occurred in low densities only at Station PIB20. *Bosmina longirostris* was the dominant cladoceran (1,022-2,900/m³ and 5-11% of the total) at all stations except PIB20, where it was exceeded in density and relative importance (863/m³ and 3%) by *Chydorus sphaericus* (3,361/m³ and 11%). *C. sphaericus* was less abundant (24-194/m³ and 0.2-0.7%) at the other three stations. Moderately low densities of *Daphnia retrocurva* were found at the four stations. It was least abundant at the shallowest site - PIB18 (12/m³ and 0.1%) and most abundant at PIB12 (155/m³ and 0.5%).

Zebra mussel veligers were found at low densities only at the two shallowest stations - PIB18 and PIB20 (36 and 15/m³, respectively). Ostracods, which are primarily benthic organisms, were most abundant at Station 20 at 45/m³ and absent or rare at other stations.

The dominant rotifer at all four sites was *Synchaeta lakowitziana*, with densities ranging from 1,630-4,496/m³ (6-17% of the total count). Another numerically important rotifer was *Conochilus unicornis*, although it was more abundant at

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Table 4-5. Densities of zooplankton (number per cubic meter) and percent relative abundance of total zooplankton observed at sampling stations in Presque Isle Bay - May 16-18, 1994.

Taxon	Density (No./m ³) and Percent Composition (%) of Total			
	PIB10 No./m ³ (%)	PIB12 No./m ³ (%)	PIB18 No./m ³ (%)	PIB20 No./m ³ (%)
CYCLOPOIDA				
<i>Acanthocyclops vernalis</i>		11 (0.03%)	1 (0.01%)	8 (0.03%)
<i>Diacyclops thomasi</i>	2248 (8.6%)	2756 (8.4%)	36 (0.3%)	787 (2.5%)
<i>Eucyclops agilis</i>			<1 (<0.01%)	2 (0.01%)
<i>Eucyclops speratus</i>	4 (0.01%)		<1 (<0.01%)	5 (0.02%)
<i>Mesocyclops edax</i>		15 (0.05%)	<1 (<0.01%)	3 (0.01%)
<i>Tropocyclops prasinus mexicanus</i>		4 (0.01%)		3 (0.01%)
Cyclopoid copepodids	4204 (16.0%)	11627 (35.5%)	851 (7.5%)	10551 (33.8%)
Subtotal	6456 (24.6%)	14413 (44.0%)	888 (7.8%)	11359 (36.4%)
Copepod nauplii	10003 (38.1%)	12365 (37.8%)	5378 (47.2%)	11671 (37.4%)
CALANOIDA				
<i>Epischura lacustris</i>	7 (0.03%)	15 (0.05%)	<1 (<0.01%)	
<i>Eurytemora affinis</i>	<1 (<0.01%)	44 (0.1%)	1 (0.01%)	2 (0.01%)
<i>Leptodiaptomus ashlandi</i>	<1 (<0.01%)	4 (0.01%)		
<i>Leptodiaptomus minutus</i>			8 (0.07%)	
<i>Leptodiaptomus sicilis</i>	4 (0.01%)	15 (0.05%)	2 (0.02%)	
<i>Skistodiaptomus oregonensis</i>	7 (0.03%)	11 (0.03%)	5 (0.04%)	1 (<0.01%)
Calanoid copepodids	135 (0.5%)	116 (0.4%)	36 (0.3%)	91 (0.3%)
Subtotal	153 (0.6%)	205 (0.6%)	52 (0.5%)	94 (0.3%)
HARPACTICOIDA				6 (0.02%)
CLADOCERA				
<i>Acroperus harpae</i>			<1 (<0.01%)	3 (0.01%)
<i>Alona affinis</i>				1 (<0.01%)
<i>Alona circumfimbriata</i>				2 (0.01%)

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Table 4-5. Densities of zooplankton (number per cubic meter) and percent relative abundance of total zooplankton observed at sampling stations in Presque Isle Bay - May 16-18, 1994. (cont.)

Taxon	Density (No./m ³) and Percent Composition (%) of Total			
	PIB16 No./m ³ (%)	PIB12 No./m ³ (%)	PIB18 No./m ³ (%)	PIB20 No./m ³ (%)
<i>Aiona guttata</i>				3 (0.01%)
<i>Bosmina longirostris</i>	2900 (11.1%)	1514 (4.6%)	1022 (9.0%)	863 (2.8%)
<i>Camptocercus rectirostris</i>			<1 (<0.01%)	3 (0.01%)
<i>Ceriodaphnia lacustris</i>			<1 (<0.01%)	
<i>Ceriodaphnia quadrangula</i>	<1 (<0.01%)	4 (0.01%)	<1 (<0.01%)	5 (0.02%)
<i>Chydorus sphaericus</i>	180 (0.7%)	194 (0.6%)	24 (0.2%)	3361 (10.8%)
<i>Daphnia ambigua</i>	<1 (<0.01%)			
<i>Daphnia retrocurva</i>	26 (0.1%)	155 (0.5%)	12 (0.1%)	76 (0.2%)
<i>Diaphanosoma birgei</i>	<1 (<0.01%)	<1 (<0.01%)		2 (0.01%)
<i>Eubosmina coregoni</i>		19 (0.06%)		
<i>Eurycercus longirostris</i>				2 (0.01%)
<i>Graptoleberis testudinaria</i>				15 (0.05%)
<i>Leptodora Kindti</i>	<1 (<0.01%)			
<i>Pleuroxus denticulatus</i>				5 (0.02%)
<i>Pleuroxus procurvus</i>			<1 (<0.01%)	2 (0.01%)
<i>Simocephalus serrulatus</i>			<1 (<0.01%)	2 (0.01%)
Subtotal	3106 (11.8%)	1886 (5.8%)	1058 (9.3%)	4345 (13.9%)
OSTRACODA		<1 (<0.01%)		45 (0.1%)
MOLLUSCA				
<i>Dreissena polymorpha veligers</i>			36 (0.3%)	15 (0.05%)
ROTIFERA				
<i>Asplanchna priodonta</i>	315 (1.2%)	330 (1.0%)	12 (0.1%)	166 (0.5%)
<i>Conochilus unicornis</i>	1011 (3.9%)	951 (2.9%)	1192 (10.5%)	121 (0.4%)
<i>Filinia terminalis</i>		39 (0.1%)		227 (0.7%)
<i>Gastropus stylifer</i>			24 (0.2%)	257 (0.8%)

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Table 4-5. Densities of zooplankton (number per cubic meter) and percent relative abundance of total zooplankton observed at sampling stations in Presque Isle Bay - May 16-18, 1994. (cont.)

Taxon	Density (No./m ³) and Percent Composition (%) of Total			
	PIE10 No./m ³ (%)	PIB12 No./m ³ (%)	PIB18 No./m ³ (%)	PIB20 No./m ³ (%)
<i>Kellicottia bostoniensis</i>			12 (0.1%)	
<i>Keratella cochlearis</i>	202 (0.8%)	136 (0.4%)	316 (2.8%)	363 (1.2%)
<i>Keratella quadrata</i>	22 (0.1%)	19 (0.06%)	85 (0.7%)	30 (0.1%)
<i>Notholca acuminata</i>		19 (0.06%)	12 (0.1%)	30 (0.1%)
<i>Ploesoma hudsoni</i>			12 (0.1%)	
<i>Ploesoma lenticulare</i>	45 (0.2%)			
<i>Polyarthra dolichoptera</i>	90 (0.3%)	194 (0.6%)	462 (4.1%)	409 (1.3%)
<i>Polyarthra major</i>	45 (0.2%)	58 (0.2%)		
<i>Polyarthra remata</i>			12 (0.1%)	
<i>Polyarthra vulgaris</i>	67 (0.3%)	19 (0.06%)	109 (1.0%)	106 (0.3%)
<i>Synchaeta kirina</i>	225 (0.9%)	291 (0.9%)	97 (1.0%)	30 (0.1%)
<i>Synchaeta lakowitziana</i>	4496 (17.1%)	1805 (5.5%)	1630 (14.3%)	1877 (6.0%)
<i>Synchaeta</i> sp.				30 (0.1%)
<i>Trichocerca lophoessa</i>				15 (0.05%)
<i>Trichocerca multirinis</i>		19 (0.06%)		
<i>Trichocerca porcellus</i>				15 (0.05%)
Subtotal	6518 (24.8%)	3880 (11.8%)	3975 (34.9%)	3676 (11.8%)
Total Density	26236 (100%)	32749 (100%)	11387 (100%)	31211 (100%)
Total Number of Species	24	28	33	40

Stations PIB10, PIB12 and PIB18 (951-1,192/m³ and 3-10%) than at Station PIB20 (121/m³ and 0.4%). *Keratella cochlearis* (136-363/m³) and *Polyarthra dolichoptera* (90-462/m³) were moderately abundant at all four stations. *Asplanchna priodonta* was moderately abundant (166-330/m³) at Stations PIB10, PIB12 and PIB20, but produced low numbers (12/m³) at shallow PIB18. *Synchaeta kitina* numbers were higher at Stations PIB10, PIB12 and PIB18 (97-291/m³), but low at Station PIB20 (30/m³). *Keratella quadrata* and *Polyarthra vulgaris* occurred in samples from all four stations at moderate to low densities (19-109/m³).

4.2.2.3 Comparison with Previous Studies of Presque Isle Bay

The total densities of zooplankton observed in these samples (11,387-32,749/m³) were about one-tenth the densities found in samples collected by EPA in October 1992 at the same four stations (109,000-326,000/m³) which were enumerated by the same subcontractor. Every major group was found in lower numbers in the present study than in the fall 1992 study, although the magnitude of the difference varied among groups.

The present study found about half the density of copepod nauplii and less than one-fourth the number of cyclopoid copepods determined for samples collected in 1992. Cladoceran and calanoid copepod densities in the present study were less than one-tenth the numbers reported in October 1992, and rotifer densities were lower by a factor of about 30. The relative importance of rotifers in the present study (12-35%) was lower than what was observed in fall 1992 (40-70%) and cyclopoid copepods and nauplii were relatively more important.

EPA (1993) reported that the net plankton densities determined for the October 1992 sampling probably underestimated actual population densities and, therefore, the previous figures probably understate the actual differences between fall 1992 zooplankton densities and those observed in the present study. Nevertheless, the lower zooplankton densities observed in this study may well reflect normal seasonal variations in zooplankton abundance.

A greater number of copepod and rotifer species (12 and 20 species, respectively) was found in the present study than in the October 1992 samples (6 and 8 species, respectively). The lower lake water temperatures observed in the present study (11-14°C) may have been favorable to colder-water zooplankton species that would not likely be present in October.

Total zooplankton densities observed in the present study were approximately one order of magnitude lower than the numbers reported by Zagorski and O'Toole (1970) for early June samples collected at approximately the same sites in 1969 (91,000-204,000/m³). However, their counts may not be directly comparable to those obtained in the current study due to differences in the methods used to collect and enumerate zooplankton. Zagorski and O'Toole collected water at one-meter

intervals throughout the water column with a Kemmerer sampler and concentrated their samples using a 10-micron mesh net. The samples were then filtered a second time in the laboratory and a single subsample per sample was enumerated by strip counts in a Sedgewick-Rafter chamber. Their report does not provide sufficient information to evaluate their sampling efficiency or the precision and accuracy of their counting procedure.

The abundant cladocerans found in the present study are consistent with observations reported in Campbell (1993) regarding occurrence of Cladocera at various locations in Presque Isle Bay. The dominant species found in the present study (*B. longirostris*, *C. sphaericus* and *D. retrocurva*) were also the most frequently occurring taxa in collections taken in the bay by Campbell during early June 1988 and mid July 1990.

4.2.2.4 Comparison with Recent Studies of Lake Erie

Makarewicz (1993b) summarized the results of zooplankton analyses of spring and summer samples collected at offshore sites in Lake Erie from 1983-1987. The densities observed in the present study for two of the dominant crustaceans, *D. thomasi* (synonymous with *Cyclops bicuspidatus thomasi*) and *B. longirostris*, were in the same general range as the average to maximum densities reported for those taxa by Makarewicz (1993b) at offshore sites in Lake Erie. Densities of *C. sphaericus* observed in the present study were higher than what Makarewicz found at offshore sites in the central and eastern basins, but were close to the range he reported for this cladoceran in the shallow western basin of Lake Erie.

The densities of copepod nauplii, calanoid copepods and *D. retrocurva* observed in the present study were lower than the range of average densities reported for these taxa at offshore sites in Lake Erie. Likewise, densities of all of the main rotifer species found in this study were lower than average densities reported by Makarewicz (1993b) for offshore sites. However, it may not be fair to compare this study to the numbers reported by Makarewicz, since his data is based upon samples collected during 33 separate cruises, and probably included one or more sampling dates when the major zooplankton taxa were at or near their seasonal maxima. The comparison may not be fair also because many species of zooplankton exhibit definite preferences for inshore versus offshore habitats (Balcer *et al.* 1984).

The findings of the present investigation can be compared to a recent study at an inshore area of Lake Erie. Krieger and Klarer (1991) studied effects of periodic stormwater discharges on the crustacean zooplankton communities of a coastal (Ohio) marsh along Lake Erie's south shore, approximately 200 km west of PIB. The structure and species composition of the crustacean component of the zooplankton community found in PIB in the present study is remarkably similar to the community found by Krieger and Klarer (7 species each of cyclopoid and calanoid copepods and 25 species of Cladocera). The densities of the dominant

crustaceans observed in the present study fall within the ranges of median to maximum densities reported for those same taxa by Krieger and Klarer (1991). However, the densities of calanoid copepods observed in the present study were much lower than median densities for calanoids reported by Krieger and Klarer.

4.3 DISCUSSION

Few conclusions can be drawn about water quality conditions in Presque Isle Bay and potential effects of pollutants on its plankton communities based upon sampling on a single date. Plankton populations (especially phytoplankton) in temperate lakes normally undergo dramatic seasonal changes (thousandfold variations in density), and annual patterns of change tend to be less predictable in systems perturbed by human activities (Wetzel, 1983). The density and composition of the plankton community may also change abruptly under the influence of abiotic factors related to weather conditions, such as wind-induced vertical mixing, and nutrient-loading or turbidity changes associated with runoff from major precipitation events (Wetzel, 1983). Presque Isle Bay is especially susceptible to such events since it does not develop thermal water column stratification (Obert, 1991).

Interpretation of the present study is further limited by an insufficient historical database on plankton communities in the bay and the fact that previous studies of the plankton in PIB (other than October 1992 samples analyzed by the same contractor) employed different sampling and analytical methods, thereby precluding valid comparisons. It is also likely that interpreting potential effects of pollutants on plankton is confounded by effects of the zebra mussel population now established in the PIB ecosystem (Obert, 1991). Recent studies documenting the negative impact of zebra mussels in other areas of Lake Erie (Holland, 1993 and Nicholls and Hopkins, 1993) have indicated that shallow inshore locations experience more dramatic declines in phytoplankton than deeper offshore sites.

4.3.1 Indications Regarding Trophic Status

Obert (1991) recently analyzed the trophic status of PIB in a study involving sampling at three sites in the bay on three dates (in April, August and October) during 1990. Obert used a computer-based phosphorus-loading model and measurements of secchi disc transparency, chlorophyll *a* and total phosphorus concentrations to calculate Carlson's (1977) Trophic State Index (TSI) for PIB. Obert's analyses indicated that the bay was borderline between mesotrophic and eutrophic.

Some of the phytoplankton taxa that occurred in the whole water samples from PIB in the present and previous (October 1992) studies have been identified as indicators of trophic status. *Rhodomonas minuta*, the most abundant phytoplankton in PIB during both recent studies, and the *Fragilaria* spp., which occurred at all four

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stations but were not very abundant, were considered "eutrophic species" in Lake Erie by Makarewicz (1993a). *Asterionella formosa* and *Cyclotella*, which were more abundant than *Fragilaria* spp. in the recent studies, were considered "mesotrophic species" by Makarewicz (1993a). Colonial phytoplankters found in recent studies of PIB that are considered indicators of oligotrophic conditions include *Dinobryon divergens* and *Melosira islandica* (Schelske and Stoermer, 1972) and *Tabellaria fenestrata* (Wetzel, 1983). The eutrophic species *R. minuta* was the only abundant indicator found in PIB, and the other species do not give a consistent indications about trophic status. Therefore the phytoplankton data provide no compelling evidence to modify Obert's (1991) conclusion that PIB is mesotrophic/eutrophic.

Facts regarding the indicator status of the most abundant and frequently occurring zooplankton species in the vertical tow samples from PIB are summarized in Table 4-6. The dominant zooplankton taxa in the present study included two cold stenotherm species (*D. thomasi* and *S. lakowitziana*) and two cladocerans that are spurious indicators of eutrophic conditions (*B. longirostris* and *C. sphaericus*). Among the non-dominant taxa of zooplankton present were a cyclopoid copepod (*A. vernalis*) and a calanoid copepod (*L. sicilis*) considered indicators of eutrophy and oligotrophy, respectively. Most of the remaining zooplankton taxa were not species considered indicators of trophic state. Many of the crustaceans were described as characteristic inhabitants of shallow habitats, and a few of the rotifers were described as cold stenotherm species in the Great Lakes. But none of the 14 species of rotifers listed as indicators of eutrophy by Gannon and Stemberger (1978) occurred in zooplankton samples collected during recent studies of PIB. In general, zooplankton species found in PIB represent what would normally be expected at any inshore location of Lake Erie during the spring, and provide little conclusive evidence regarding the trophic status of the bay.

The ratio of calanoid copepods to cyclopoid copepods plus cladocerans has been used by several investigators to compare the trophic status among locations within the Great Lakes (Gannon and Stemberger, 1978; Krieger, 1981; Makarewicz, 1993b). The index is based on assumptions that calanoid copepods are the group best adapted for oligotrophic conditions, and cyclopoid copepods and cladocerans are relatively more abundant in eutrophic waters (Gannon and Stemberger, 1978). Lower ratio values are thought to indicate greater eutrophy. The ratio was calculated for each of the four sampling stations in PIB for the October 1992 and present study (Table 4-7) and compared to ratios calculated for other locations in Lake Erie, including offshore sites in each of the three major basins (Table 4-8) and southern nearshore sites in the vicinity of Cleveland, Ohio (Table 4-9).

The ratio values calculated for PIB (Table 4-7) are lower overall than all of the ratios determined for recent collections from other inshore and offshore sites in Lake Erie. This would indicate that PIB is more eutrophic than all of these other recently sampled locations. The ratios for PIB are close to the range of ratios

PLANKTON CHARACTERIZATION STUDY

Table 4-6. Indicator status of most abundant and frequently occurring zooplankton species in each major group found at sampling stations in Presque Isle Bay in May 16-18, 1994. Species preceded by an "*" were numerically dominant (> 5% of total at any station).

Taxon	Ecological Indications ^{1,2,3}
COPEPODS	
* <i>Diacyclops thomasi</i> (syn. <i>Cyclops bicuspidatus thomasi</i>)	A cold water species; one of the most common copepods in North America. ¹
<i>Acanthocyclops vernalis</i> (syn. <i>Cyclops vernalis</i>)	Most abundant in warm, eutrophic nearshore areas and shallow harbors and bays. ¹ An indicator of eutrophy. ²
<i>Eurytemora affinis</i>	Found in the Great Lakes since the late 1960's with the largest concentrations in harbors and bays; a euryhaline species that prefers warm epilimnetic and littoral waters.
<i>Epischura lacustris</i>	Found in the littoral region; prefers warm upper waters during stratification.
<i>Leptodiaptomus sicilis</i> (syn. <i>Diaptomus sicilis</i>)	Commonly found in large, deep, clear and cold northern lakes; usually scarce in the littoral zone but will move into shallow water in winter months. ¹ Characteristic of oligotrophy. ²
<i>Skistodiaptomus oregonensis</i> (syn. <i>Diaptomus oregonensis</i>)	One of the most widely distributed diaptomids; the most common diaptomid in Lake Erie where it has been found in swarms in the littoral areas. ¹
CLADOCERANS	
* <i>Bosmina longirostris</i>	Prefers cool, well-oxygenated waters and littoral areas; often most numerous in the upper water layers. ¹ Once considered an indicator of advancing eutrophication but now questionable due to taxonomic uncertainties. ²
* <i>Chydorus sphaericus</i>	A nearshore and littoral species; tolerant of a wide range of physical conditions. ¹ Has been used as an indicator of eutrophic conditions although abundance in open water more directly related to abundance of algal filaments used as substrate. ²
<i>Daphnia retrocurva</i>	One of the most abundant cladocerans in the Great Lakes; most common in nearshore areas. ¹
<i>Ceriodaphnia quadrangula</i>	Usually found nearshore or in the warmer upper layers of the water column. ¹ Identified as a eutrophic indicator species in Finland. ²
ROTIFERS	
* <i>Synchaeta lakowiziana</i>	A cold water stenotherm species; a major <i>Synchaeta</i> species in the Great Lakes in winter. ³
* <i>Conochilus unicornis</i>	An important limnetic species in the Great Lakes with peak abundance during summer. ³
<i>Keratella cochlearis</i>	Perhaps the most common limnetic rotifer in fresh water. ³

PLANKTON CHARACTERIZATION STUDY

Table 4-6. Indicator status of most abundant and frequently occurring zooplankton species in each major group found at sampling stations in Presque Isle Bay in May 16-19, 1994. Species preceded by an "*" were numerically dominant (> 5% of total at any station). (cont.)

Taxon	Ecological Indications ^{1,2,3}
<i>Polyarthra dolichoptera</i>	Cold stenotherm species. ² Occurs from March through June in the Great Lakes with maximum abundance during May in Lake Huron. ³
<i>Asplanchna priodonta</i>	Predominant <i>Asplanchna</i> species in the Great Lakes; peak abundance in spring and summer.
<i>Synchaeta kirina</i>	May display both spring and fall maxima in the Great Lakes. ³
<i>Polyarthra vulgaris</i>	One of the major rotifer species in the Great Lakes; maximum abundance occurs from June through October. ³
<i>Keratella quadricauda</i>	Eurythermous; may be present throughout the year. ³
<i>Notholca acuminata</i>	Common at inshore areas in winter and spring. ³
<i>Filinia terminalis</i>	Cold stenotherm species. ² Occurs primarily in winter and spring. ³
<i>Gastropus stylifer</i>	Only numerically important <i>Gastropus</i> species in Great Lakes; occurs from spring through fall. ³

¹Balcer et al. (1984).

²Gannon and Stemberger (1978).

³Stemberger (1979).

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Table 4-7. Ratios of calanoid copepods to cyclopoid copepods plus cladocerans calculated for stations in Presque Isle Bay sampled during October 1992 and May 1994.

Sampling Date	PIB10	PIB12	PIB18	PIB20
May 1994	0.016	0.013	0.008	0.006
October 1992	0.012	0.038	0.043	0.008

Table 4-8. Ratios of calanoid copepods to cyclopoid copepods plus cladocerans calculated for offshore Lake Erie locations sampled during 1983-1987 (Makarewicz, 1993b), and 1967 (Davis, 1968) and 1969 (Krieger, 1981).

Study	Basin Ratio		
	Western	Central	Eastern
1983 to 1987 Range Mean	0.17 - 0.34 0.27	0.32 - 0.95 0.58	0.44 - 0.89 0.69
July 1967	0.024	0.098	0.067
Oct and Jan 1968	0.10	0.066	0.054

Table 4-9. Ratios of calanoid copepods to cyclopoid copepods plus cladocerans calculated for locations in the southern nearshore zone of the Central Basin of Lake Erie during May and October 1978 (Krieger, 1981).

Study	Lorain-Vermillion	Cleveland	Fairport Harbor Ashtabula	Harbor
May 1978	0.62	0.18	0.07	0.30
October 1978	0.38	0.36	0.25	0.40

calculated for offshore sites in Lake Erie during the late 1960s (Table 4-8), when the lake was considered highly eutrophic (Makarewicz, 1993a). Ratio values for PIB are low mainly due to suppressed numbers of calanoid copepods - which Krieger (1981) suggested is indicative of adverse environmental conditions. However, Krieger (1981) suggested that calanoid to cyclopoid plus cladoceran ratios calculated for single dates are not reliable, and that a more accurate indication of trophic status would be obtained by determining the average of ratios calculated for collections taken at monthly or biweekly intervals throughout the ice-free season.

4.3.2 Summary

In general, the composition of the phyto- and zooplankton communities and the densities observed were not judged to be unusual based upon comparisons to previous studies in PIB and recent studies at other locations (both inshore and offshore) in Lake Erie, except for the apparent low abundance of calanoid copepods in the zooplankton community. The main differences observed among sampling stations within the bay were most likely due to variations in depth, occurrence of aquatic vegetation and chance phenomena influencing local population dynamics. There was no evidence of consistent differences that might be attributed to variations among stations in water quality and/or the presence of contaminants in the underlying sediments.

The plankton indicator species present provided no consistent evidence to contradict the conclusions of Obert (1991) that PIB is mesotrophic/eutrophic. However, the low ratios of calanoid copepods to cyclopoid copepods plus cladocerans determined for zooplankton community at all sampled sites in PIB suggests that PIB is more eutrophic than other recently sampled locations in Lake Erie. Apparent low numbers of calanoid copepods found in recent studies could be due to seasonal phenomena, but this can only be verified with further investigation. Regular zooplankton sampling throughout the ice-free season (at one or more sites inside and one site of similar depth outside the bay) would serve to confirm whether or not calanoid copepods in PIB are significantly suppressed, and would help to clarify whether a problem might exist that requires remediation.

4.4 REFERENCES

- APHA, AWWA, WPCF. 1985. Standard Methods for the Examination of Water and Wastewater, 16th ed. American Public Health Association, Washington, DC. 1268 pp.
- Balcer, M.D., N.L. Korda and S.I. Dodson. 1984. Zooplankton of the Great Lakes: a guide to the identification and ecology of the common crustacean species. University of Wisconsin Press, Madison Wisconsin: 174 pp.

PLANKTON CHARACTERIZATION STUDY

- Bardarik, D.G., J.C. Alden and R.L. Shema. 1973. A study of the effects of the operation of a steam electric generating station on the aquatic ecology of Presque Isle Bay, Erie, PA. Aquatic Ecology Associates, Pittsburgh, PA for Pennsylvania Electric Company, April 1973.
- Brooks, J.L. 1957. The systematics of North American *Daphnia*. Memoirs of the Connecticut Academy of Arts and Sciences 13:1-180.
- Campbell, J.M. 1993. The cladoceran species of inshore habitats of Lake Erie at Presque Isle. J. PA Academy of Science 67: 115-119.
- Carlson, R.E. 1977. A trophic state index for lakes. Limnology and Oceanography 22: 361-369.
- Davis, C.C. 1968. The July 1967 zooplankton of Lake Erie. Proc. 11th Conf. Great Lakes Res. 11: 61-75.
- Davis, C.C. 1969. Seasonal distribution, constitution, and abundance of zooplankton in Lake Erie. J. Fish. Res. Bd. Canada 26: 2459-2476.
- Dodson, S.I. and D.G. Frey. 1991. Cladocera and other Branchiopoda. In: Ecology and classification of North American freshwater invertebrates, J.H. Thorp and A.P. Covich, eds. Academic Press, Inc.
- EPA Region III. March 1993. Special Study, Presque Isle Bay Sediment Quality Evaluation. Prepared by Gannett Fleming, Inc.
- Fryer, G. 1968. Evolution and adaptive radiation in the Chydoridae (Crustacea: Cladocera): a study in comparative functional morphology and ecology. Proc. Royal Soc. London Phil. Trans. Ser. B 254:221-385.
- Gannett Flemming, Inc. 1993. Special Study Presque Isle Bay Sediment Quality Evaluation. Prepared under contract to USEPA Region 3, PA.
- Gannon, J.E. and R.S. Stemberger. 1978. Zooplankton (especially crustaceans and rotifers) as indicators of water quality. Trans. Amer. Microsc. Soc. 97: 16-35.
- Hann, B.J. 1982. Two new species of *Eurycercus* (*Bullatifrons*) from Eastern North America (Chydoridae, Cladocera). Taxonomy, Ontogeny, and Biology. Int. Revue ges. Hydrobiol. 67:585-610.
- Holland, R.E. 1993. Changes in planktonic diatoms and water transparency in Hatchery Bay, Bass Island Area, Western Lake Erie since the establishment of the zebra mussel. J. Great Lakes Res. 19:617-624.

PLANKTON CHARACTERIZATION STUDY

- Krieger, K.A. and D.M. Klarer. 1991. Zooplankton dynamics in a Great Lakes coastal marsh. *J. Great Lakes Res.* 17:255-269.
- Lind, O.T. 1979. Handbook of common methods in limnology 2nd ed. C.V. Mosby Company, St. Louis.
- Macarewicz, J.C. 1993a. Phytoplankton biomass and species composition in Lake Erie, 1970 to 1987. *J. Great Lakes Res.* 19:258-274.
- Macarewicz, J.C. 1993b. A lakewide comparison of zooplankton biomass and its species composition in Lake Erie, 1983-87. *J. Great Lakes Res.* 19:275-290.
- Megard, R.O. 1967. Three new species of *Alona* (Cladocera, Chydoridae) from the United States. *Int. Revue ges. Hydrobiol.* 52:37-50.
- Nicholls, K.H. and G.J. Hopkins. 1993. Recent changes in Lake Erie (north shore) phytoplankton: cumulative impacts of phosphorus loading reductions and the zebra mussel introduction. *J. Great Lakes Res.* 19:637-647.
- Obert, E.C. 1991. Trophic state analysis of Presque Isle Bay Erie County. Unpublished report. Available from Pennsylvania Department of Environmental Resources, Bureau of Water Quality Management, Meadville, PA.
- Patrick, R. and C.W. Reimer. 1966. The Diatoms of the United States Vol. I: Fragilariaceae, Eunotiaceae, Achnantheaceae, Naviculaceae. Monographs of The Academy of Natural Sciences of Philadelphia 13. 688 pp.
- Pennak, R.W. 1978. Fresh-water invertebrates of the United States, 2nd ed. John Wiley & Sons, New York: 350-387.
- Prescott, G.W. 1962. Algae of the Western Great Lakes Area. Wm. C. Brown Company Publishers, Dubuque, Iowa: 977 pp.
- Prescott, G.W. 1978. How to Know the Freshwater Algae, 3rd ed. Wm. C. Brown Company Publishers, Dubuque, Iowa: 293 pp.
- Schelske, C.L. and E.F. Stoermer. 1972. Phosphorus, silica, and eutrophication of Lake Michigan. pp.157-171 in (G.E. Likens, Ed.) Nutrients and eutrophication: the limiting nutrient controversy. Special Symposia Vol. I, The American Society of Limnology and Oceanography.
- Stemberger, R.S. 1979. A guide to rotifers of the Laurentian Great Lakes. U.S. Environmental Protection Agency, EPA 600/4-79-021.

PLANKTON CHARACTERIZATION STUDY

- Ward, H.W. and G.C. Whipple. 1959. Fresh-water Biology, 2nd ed., W T. Edmondson, ed. John Wiley & Sons, New York. 1248 pp.
- West, D. and H. Trulli. 1994. Final QAPP for Presque Isle Bay Sediment Study Prepared under contract No. 68-C2-0134, Work Assignment 1-107 to USEPA. 56pp.
- Wetzel, R.G. 1983. Limnology. CBS College Publishing, New York.
- Whitford, L.A. and G.J. Schumacher. 1984. A manual of fresh-water algae. Sparks Press, Raleigh, NC: 337 pp.
- Zagorski, S.J. and A.J. O'Toole. 1970. A study of phytoplankton and zooplankton of the Bay of Lake Erie at Erie, Pennsylvania, Summer 1969. J. PA Acad. Sci. 44:127-140.

5.0 TOXICITY STUDY USING *HYALELLA AZTECA*

5.1 Toxicity Test Design

Sediment toxicity was measured using a 10-day, static renewal acute toxicity test with the amphipod *Hyaella azteca*. The toxicity test was conducted at the Environmental Protection Agency's (EPA) laboratory in Wheeling, West Virginia following procedures outlined in the *Proposed Guide for Conducting Solid Phase Sediment Toxicity Tests with Freshwater Invertebrates* (Draft, 1993). Toxicity tests were conducted on sediments collected at 12 of the 21 Presque Isle Bay stations. (See Figure 5-1).

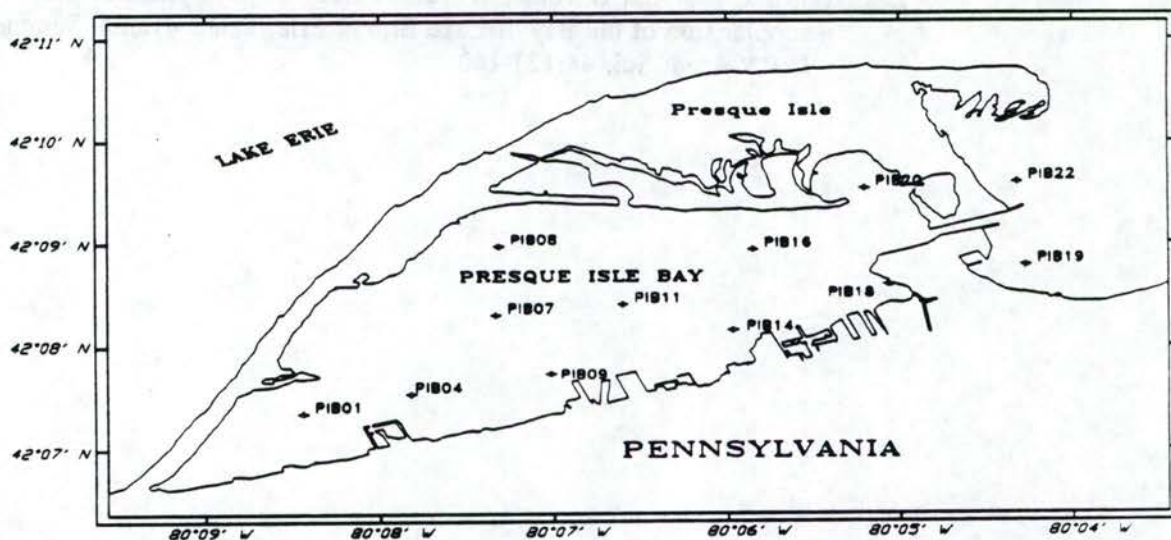


Figure 5-1. Station locations for Presque Isle Bay sediment toxicity study.

Toxicity tests were performed in two batches. Batch 1 included samples from Stations PIB01, PIB08, PIB18, PIB19, PIB20, and PIB22 and batch 2 included samples from Stations PIB04, PIB07, PIB09, PIB11, PIB14, and PIB16. Control sediment from Bear Rock Lake was run with each batch. (The control site was chosen by EPA Wheeling, WV.) There were four replicates per treatment for each of the 12 stations and the 2 control sediments. Each replicate sample and each control sample contained eight test organisms. Students t-tests were calculated to identify those stations that were statistically different from the control samples.

Sediment preparation

The sediment from each station was wet screened through two different sieves to remove large clumps of sediment and debris; the final sieve size was 2.36 mm. Following sieving, the sediment was homogenized for 30 minutes using a rotor mixer

TOXICITY STUDY USING *HYALELLA AZTECA*

and then placed in replicate test chambers. The toxicity test chambers contained 100 mL volumes of sediment, approximately 3.5 - 4 cm in depth, and 175 mL of overlay water. Testing on the first batch of sediment began within 12 days of sample collection; testing of the second batch began within 15 days of collection.

Test Procedures

The overlay water was collected at each station in Presque Isle Bay on the same day as the sediment. The overlay water was renewed every 48 hours. Dechlorinated tap water was used to overlay the sediment in the control test chambers. Water quality parameters in the test chambers (dissolved oxygen, pH, specific conductivity, and temperature) were monitored immediately after and before each renewal. On day 10 of the test, final biological observations and water quality measurements were conducted for each test chamber. Analysts sorted through the sediment for survival and mortality scoring.

Test Organism Maintenance

Cultures of *Hyaella azteca*, which were obtained from EPA's Wheeling, West Virginia laboratory, were 7-12 days old at the start of the toxicity tests. The amphipods were fed 2 mg of soaked, ground TetraMin® fish flakes on day 0 and immediately after each renewal of overlay water in the test chamber.

5.2 RESULTS AND DISCUSSION

Survival results for each station are presented in Table 5-1. Toxicity test results for the individual replicates are presented in Appendix A5-1. Replication among the four replicate mortality measurements was very good for all of the test results. The toxicity results for the Presque Isle Bay sediments ranged from 15.6% of survival at Station PIB20 to 93.8% at Station PIB04. The two control sediments had 84.4% and 90.6% survival. A summary of the water quality parameters is presented in Appendix C. The water quality parameters fell within acceptable levels for organism survival.

Students t-tests were run at the 95% ($\alpha = 0.05$) and the 99% ($\alpha = 0.01$) confidence limits to determine if the mortality at the Presque Isle Bay stations differed significantly from the control sample (see Table 5-2). Students t-tests revealed a 95% probability that sediment toxicity at five stations (PIB01, PIB08, PIB20, PIB07, and PIB16) was different from the control sites. Biologists generally consider only control:station mortality differences greater than 10 to 20% to be ecologically meaningful (Word, personal communication). Therefore, stations PIB01, PIB08, PIB20, and PIB07 are of particular interest because the percent mortality at these stations differed by more than 20% of the average control mortality.

TOXICITY STUDY USING *HYALELLA AZTECA*

Table 5-1. Presque Isle Bay toxicity test

Sample ID	Number of Individuals		% Survival
	Initial	Final	
Control	32	27	84.4
PIB01	32	20	62.5
PIB08	32	18	56.3
PIB18	32	29	90.6
PIB19	32	28	87.5
PIB20	32	5	15.6
PIB22	32	29	90.6
Control	32	29	90.6
PIB04	32	30	93.8
PIB07	32	21	65.6
PIB09	32	28	87.5
PIB11	32	28	87.5
PIB14	32	28	87.5
PIB16	32	25	78.1

Table 5-2. Results of Students t-test

Sample ID	Significant Difference from Control $\alpha = 0.05$	Significant Difference from Control $\alpha = 0.01$
PIB01	yes	no
PIB08	yes	yes
PIB18	no	no
PIB19	no	no
PIB20	yes	yes
PIB22	no	no
PIB04	no	no
PIB07	yes	no
PIB09	no	no
PIB11	no	no
PIB14	no	no
PIB16	yes	no

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The survival rate of the amphipods was compared with several sediment parameters including total polynuclear aromatic hydrocarbons (PAH), total polychlorinated biphenyls (PCB), total amines, total DDT, grain size, and total organic carbon (TOC). (See Section 2) The concentration of organic contaminants in the sediment appeared to have no effect on *Hyaella azteca* mortality. In fact, *Hyaella azteca* survived equally well in the control sediment as in the sediments containing the highest concentrations of total PAH (Figure 5-2) and DDT (Figure 5-3), whereas the samples exhibiting the greatest toxicity to *Hyaella azteca* contained some of the lowest sediment concentrations of these contaminants. Sediment TOC was the only parameter to show any correlation with *Hyaella azteca* mortality as shown in Figure 5-4. An increase in mortality with increasing TOC concentrations is common when prolonged sediment storage produces ammonia and mortality. In this study, the sediment TOC/*Hyaella* relationship could not be confirmed because ammonia was not measured during the test, although precautions to reduce ammonia production were taken by storing the sediment at 4°C until toxicity testing was begun. It is also possible that *Hyaella azteca* predation could cause high mortality at the stations with high TOC. The composition of the sediment (silt + clay or sand) on *Hyaella azteca* mortality was also investigated. No correlation between sediment composition and *Hyaella azteca* mortality was found.

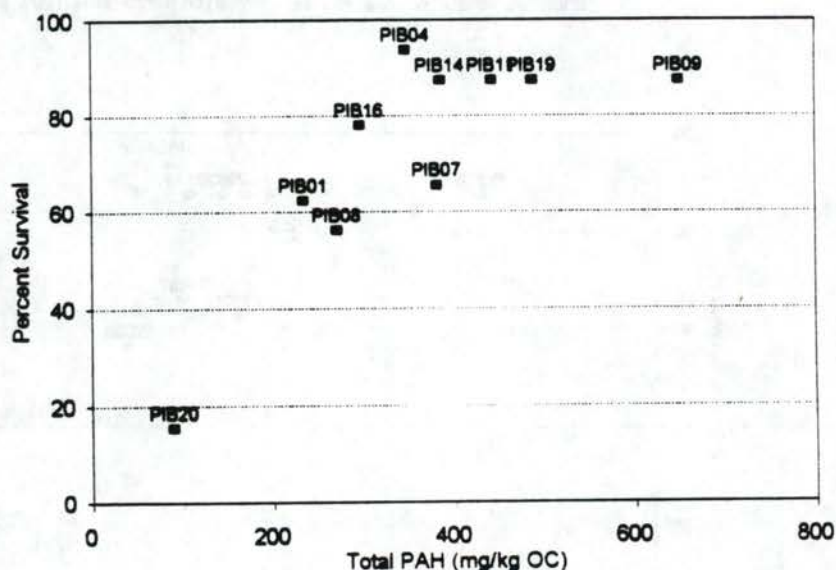


Figure 5-2. Percent *Hyaella azteca* survival versus Total PAH normalized to TOC. Because TOC for both Stations PIB18 and PIB22 was < 0.2%, these stations are not included.

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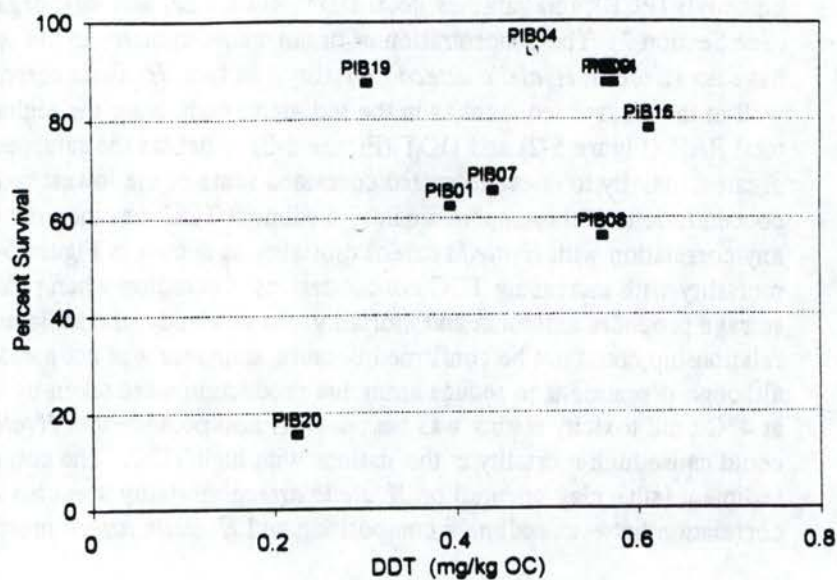


Figure 5-3. Percent *Hyalella azteca* survival versus DDT concentrations normalized to TOC. Because TOC for both Stations PIB18 and PIB22 was <0.2%, these stations are not included.

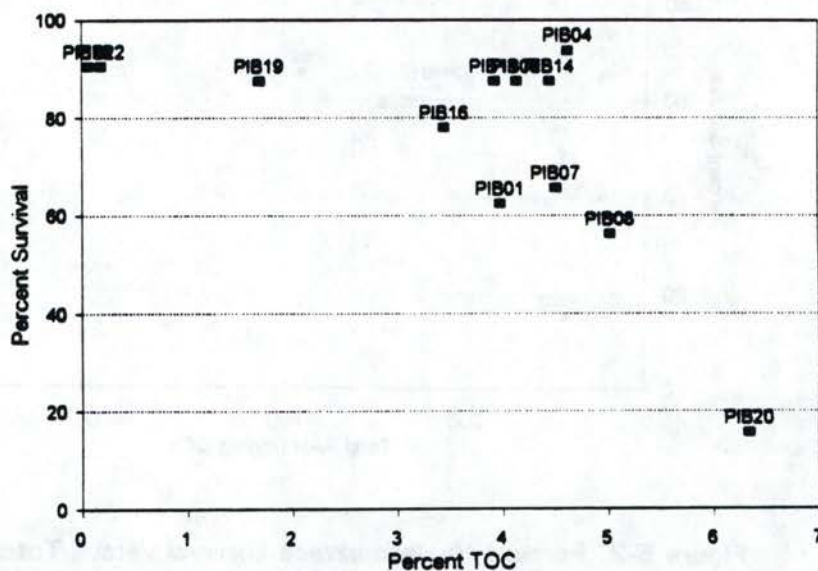


Figure 5-4. Percent *Hyalella azteca* survival versus percent TOC.

TOXICITY STUDY USING *HYALELLA AZTECA*

In summary, sediment from four of the twelve Presque Isle Bay stations (PIB20, PIB08, PIB01, and PIB07) within the study area were more toxic to *Hyalomma azteca* as determined by the student t-test. It is possible that the mortality rate at these stations may have been due to concentrations of ammonia produced during sediment storage. There appeared to be no relationship between *Hyalomma azteca* mortality and the concentrations of organic contaminants measured in the sediment or with grain size distribution.

5.3 REFERENCES

Proposed Guide for Conducting Solid Phase Sediment Toxicity Testing. 1993.

6.0 CONCLUSIONS

Generally, the concentrations of contaminants of concern are below available sediment quality criteria although some stations exhibit concentrations for some compounds that exceed ER-L and ER-M values. Stations PIB09 and PIB10 consistently showed the highest levels of organic contaminants for the various compounds analyzed. Both stations contained concentrations of dieldrin, fluoranthene, and phenanthrene less than the sediment quality criteria but higher than Long and Morgan's ER-M value. In addition, these two stations also contain elevated concentrations (above ER-M values) of chlordane and benz[a]anthracene. Sediment toxicity tests at Station PIB09 using *Hyaella azteca* (amphipod) did not show significant mortality (88% survival rate) which was not significantly different from control sediments. Sediment from Station PIB10 was not tested in the toxicity study. The sediments from stations with the highest *Hyaella azteca* mortality (Stations PIB20 and PIB08), tended to have lower concentrations of organic contaminants than the stations that had higher survival rates. Thus, sediment toxicity tests could demonstrate no clear relationships between toxicity and organic contaminant concentrations of the compounds analyzed. The available data also indicate that station and benthic species community structure did not correspond to PAH concentration levels. Rather, the benthic community appears to be distributed more in relation to sediment texture than sediment quality. Further, the Presque Isle Bay benthic community is characterized primarily by pollutant tolerant taxa, chironomid larvae and oligochaets, with pollution sensitive species such as trichopterans and amphipods present. This suggests that the concentrations of organic contaminants measured in the sediments of Presque Isle Bay, although elevated at locations, are not the major factor influencing the benthic community structure nor toxicity to the amphipod *Hyaella azteca*.

The relatively strong relationship between sediment texture (percent fines) and organic contaminant concentrations and lack of correspondence between contaminants, toxicity, and benthic community suggests that there are no "hot spots" in the Bay. Moreover, *Hyaella azteca*, the test animal used in the sediment toxicity testing, was not found at Station PIB18 even though the sandy substrate at this site is suitable for this species and the survival rate of this organism in the toxicity tests suggested that this sediment is an acceptable habitat for *Hyaella azteca*. The data suggest that other factors influence the distribution of this and probably other species in the system. Additional evaluations are warranted to describe the status of the system and to fully understand the toxic responses measured at the other stations.

Finally, the phytoplankton data did not identify any unusual patterns or species relative to previous data. The available data suggest, however, that the Bay is likely experiencing eutrophication and its resultant effects. These effects may be greater than in other parts of Lake Erie. However, further studies to verify this suggestion are needed.

APPENDIX A CHEMISTRY DATA

APPENDIX CHEMISTRY DATA

Station ID	NA	PIB01	PIB02	PIB02-D	PIB03	PIB03-D
Battelle ID	OK01PB	OJ77	OJ78	OJ83	OJ78	OJ80
Receipt Date	NA	24-May-94	24-May-94	24-May-94	24-May-94	24-May-94
E.xtraction Date	07-Jun-94	07-Jun-94	07-Jun-94	07-Jun-94	07-Jun-94	07-Jun-94
Analysis Date	21-Jun-94	28-Jun-94	28-Jun-94	28-Jun-94	28-Jun-94	28-Jun-94
Sample Size (g)	23.571 **	20.018	17.820	19.992	34.216	33.777
Percent Moisture (%)	NA	61.290	64.772	60.356	33.606	34.275
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
naphthalene	0.0008 J	0.124	0.179	0.170	0.0117	0.0119
C1-naphthalenes	0.0000 ND	0.151	0.214	0.214	0.0154	0.0162
C2-naphthalenes	0.0000 ND	0.213	0.312	0.322	0.0267	0.0274
C3-naphthalenes	0.0000 ND	0.232	0.331	0.341	0.0366	0.0396
C4-naphthalenes	0.0000 ND	0.234	0.339	0.349	0.0472	0.0551
biphenyl	0.0000 ND	0.0280	0.0418	0.0432	0.0031	0.0027
acenaphthylene	0.0000 ND	0.0640	0.0904	0.0999	0.0063	0.0073
acenaphthene	0.0000 ND	0.0644	0.0918	0.0988	0.0048	0.0045
dibenzofuran	0.0000 ND	0.0775	0.100	0.0952	0.0076	0.0073
fluorene	0.0000 ND	0.119	0.154	0.150	0.0133	0.0144
C1-fluorenes	0.0000 ND	0.0679	0.0859	0.0928	0.0089	0.0117
C2-fluorenes	0.0000 ND	0.135	0.157	0.166	0.0308	0.0303
C3-fluorenes	0.0000 ND	0.261	0.366	0.336	0.0495	0.0528
phenanthrene	0.0000 ND	0.652	0.931	0.916	0.0652	0.0668
anthracene	0.0000 ND	0.137	0.200	0.207	0.0131	0.0120
C1-phenanthrenes/anthracenes	0.0000 ND	0.406	0.562	0.556	0.0615	0.0636
C2-phenanthrenes/anthracenes	0.0000 ND	0.427	0.563	0.550	0.0923	0.0912
C3-phenanthrenes/anthracenes	0.0000 ND	0.379	0.431	0.432	0.0884	0.0934
C4-phenanthrenes/anthracenes	0.0000 ND	0.310	0.430	0.500	0.0738	0.0772
dibenzothiophene	0.0000 ND	0.0564	0.0790	0.0771	0.0065	0.0066
C1-dibenzothiophenes	0.0000 ND	0.0612	0.0802	0.0794	0.0109	0.0128
C2-dibenzothiophenes	0.0000 ND	0.108	0.123	0.133	0.0238	0.0255
C3-dibenzothiophenes	0.0000 ND	0.118	0.136	0.150	0.0300	0.0305
fluoranthene	0.0000 ND	1.241	1.71	2.31	0.132	0.139
pyrene	0.0000 ND	1.287	1.81	2.51	0.141	0.147
C1-fluoranthenes/pyrenes	0.0000 ND	0.714	0.956	0.933	0.0638	0.0913
benz[a]anthracene	0.0000 ND	0.615	0.872	0.837	0.0568	0.0523
chrysene	0.0000 ND	0.777	1.04	0.977	0.0882	0.0903
C1-chrysenes	0.0000 ND	0.387	0.456	0.477	0.0488	0.0498
C2-chrysenes	0.0000 ND	0.332	0.393	0.421	0.0522	0.0555
C3-chrysenes	0.0000 ND	0.203	0.251	0.230	0.0345	0.0428
C4-chrysenes	0.0000 ND	0.183	0.188	0.144	0.0187	0.0191
benzo[b]fluoranthene	0.0000 ND	1.28	1.75	1.63	0.131	0.130
benzo[k]fluoranthene	0.0000 ND	0.361	0.505	0.468	0.0388	0.0392
benzo[e]pyrene	0.0000 ND	0.644	0.874	0.811	0.0700	0.0703
benzo[a]pyrene	0.0000 ND	0.715	0.999	0.946	0.0648	0.0633
perylene	0.0000 ND	0.331	0.380	0.351	0.0855	0.0867
indeno[1,2,3-c,d]pyrene	0.0000 ND	0.736	0.982	0.952	0.0743	0.0744
dibenz[a,h]anthracene	0.0000 ND	0.189	0.233	0.224	0.0156	0.0156
benzo[g,h,i]perylene	0.0000 ND	0.616	0.845	0.808	0.0659	0.0669
Total PAH (priority pollutants)	0.0008	8.96	12.4	13.3	0.924	0.934
N-Nitroso-N-methylethylamine	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
N-Nitrosodiethylamine	0.0000 ND	0.0000 ND	0.0000 ND	0.0033 J	0.0000 ND	0.0000 ND
N-Nitrosodi-n-propylamine	0.0000 ND	0.0000 ND	0.0000 ND	0.0128 J	0.0031 J	0.0035 J
N-Nitrosodi-N-butylamine	0.0000 ND	0.0130 J	0.0000 ND	0.0047 J	0.0000 ND	0.0000 ND
N-Nitrosodiphenylamine	0.0000 ND	0.0533 E	0.0669 E	0.0693 E	0.0018 J	0.0160 J
Total nitrosamines	0.0000	0.0664	0.0669	0.0900	0.0048	0.0195
Surrogate Recoveries (%)						
naphthalene-d8	49	45	43	45	43	45
acenaphthene-d10	50	52	51	57	47	49
chrysene-d12	58	50	52	59	52	57

Qualifiers

J = Detected, but below established Method Detection Limit (MDL)

E = Estimate, significant interferences, all reported values for N-Nitrosodiphenylamine

ND = Not detected

& = QC result is outside the acceptance criteria goal (SRM, surrogate, matrix spike, and blank spike recovery data)

* QC value outside the precision criteria goal (%RPD in matrix spike/matrix spike duplicate and sample duplicates)

** = Sample concentration of the Procedural Blank adjusted for the average sample size of the batch (field samples)

APPENDIX CHEMISTRY DATA

Station ID	PIB04	PIB05	PIB06	PIB07	PIB08	PIB09
Battelle ID	OJ81	OJ82	OJ84	OJ85	OJ86	OJ87
Receipt Date	24-May-94	24-May-94	24-May-94	24-May-94	24-May-94	24-May-94
Extraction Date	07-Jun-94	07-Jun-94	07-Jun-94	07-Jun-94	07-Jun-94	07-Jun-94
Analysis Date	28-Jun-94	06-Aug-94	29-Jun-94	29-Jun-94	29-Jun-94	29-Jun-94
Sample Size (g)	19.818	19.033	19.119	17.712	15.913	20.372
Percent Moisture (%)	60.932	62.371	62.073	64.889	68.211	59.355
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
naphthalene	0.196	0.230	0.223	0.216	0.217	0.262
C1-naphthalenes	0.238	0.320	0.293	0.269	0.304	0.398
C2-naphthalenes	0.349	0.474	0.432	0.377	0.455	0.551
C3-naphthalenes	0.369	0.460	0.470	0.385	0.452	0.558
C4-naphthalenes	0.415	0.343	0.430	0.378	0.420	0.457
biphenyl	0.0458	0.0481	0.0489	0.0471	0.0509	0.0570
acenaphthylene	0.102	0.112	0.262	0.109	0.142	0.113
acenaphthene	0.138	0.0956	0.0964	0.0878	0.0812	0.181
dibenzofuran	0.138	0.142	0.128	0.126	0.107	0.173
fluorene	0.199	0.171	0.164	0.163	0.132	0.215
C1-fluorenes	0.112	0.109	0.119	0.094	0.100	0.142
C2-fluorenes	0.213	0.223	0.225	0.187	0.198	0.259
C3-fluorenes	0.385	0.480	0.439	0.332	0.386	0.466
phenanthrene	1.20	1.09	0.888	0.859	0.792	1.83
anthracene	0.325	0.315	0.326	0.248	0.199	0.408
C1-phenanthrenes/anthracenes	0.781	0.771	0.695	0.625	0.607	1.02
C2-phenanthrenes/anthracenes	0.730	0.848	0.741	0.693	0.652	1.02
C3-phenanthrenes/anthracenes	0.564	0.825	0.674	0.585	0.564	0.695
C4-phenanthrenes/anthracenes	0.595	0.851	0.591	0.641	0.444	0.595
dibenzothiophene	0.109	0.0939	0.0996	0.0849	0.0782	0.129
C1-dibenzothiophenes	0.107	0.110	0.100	0.0857	0.0828	0.109
C2-dibenzothiophenes	0.141	0.232	0.197	0.165	0.165	0.266
C3-dibenzothiophenes	0.204	0.278	0.263	0.214	0.227	0.287
fluoranthene	2.15	2.49	2.12	2.67	1.74	3.67
pyrene	1.92	2.41	2.35	3.21	1.94	3.44
C1-fluoranthenes/pyrenes	1.27	1.60	1.33	1.18	1.07	1.41
benz[a]anthracene	1.19	1.15	1.11	1.07	0.879	1.94
chrysene	1.23	1.39	1.24	1.24	1.05	2.00
C1-chrysenes	0.708	0.835	0.730	0.714	0.570	1.11
C2-chrysenes	0.527	0.725	0.616	0.649	0.558	1.18
C3-chrysenes	0.336	0.526	0.391	0.416	0.340	0.626
C4-chrysenes	0.211	0.324	0.335	0.297	0.288	0.678
benzo[b]fluoranthene	2.28	2.38	2.32	2.18	1.94	3.35
benzo[k]fluoranthene	0.631	0.741	0.690	0.594	0.579	0.784
benzo[e]pyrene	1.07	1.26	1.19	1.14	0.98	1.60
benzo[a]pyrene	1.26	1.35	1.35	1.30	1.09	2.04
perylene	0.504	0.502	0.499	0.496	0.413	0.592
indeno[1,2,3-c,d]pyrene	1.31	1.37	1.41	1.34	1.15	2.78
dibenz[a,h]anthracene	0.312	0.353	0.317	0.312	0.269	1.00
benzo[g,h,i]perylene	1.09	1.16	1.22	1.10	0.970	2.30
Total PAH (priority pollutants)	15.5	16.8	16.2	16.7	13.2	26.3
N-Nitroso-N-methylethylamine	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
N-Nitrosodiethylamine	0.0046 J	0.0066 J	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
N-Nitrosodi-n-propylamine	0.0000 ND	0.0082 J	0.0000 ND	0.0122 J	0.0000 ND	0.0000 ND
N-Nitrosodi-N-butylamine	0.0068 J	0.0546	0.0000 ND	0.0111 J	0.0000 ND	0.0000 ND
N-Nitrosodiphenylamine	0.0826 E	0.1155 E	0.1031 E	0.0843 E	0.0861 E	0.1311 E
Total nitrosoamines	0.0929	0.186	0.103	0.108	0.0861	0.131
Surrogate Recoveries (%)						
naphthalene-d8	50	54	48	45	31 &	61
acenaphthene-d10	56	69	57	50	42	66
chrysene-d12	60	86	63	51	44	34 &

Qualifiers

J = Detected, but below established Method Detection Limit (MDL)

E = Estimate, significant interferences, all reported values for N-Nitrosodiphenylamine

ND = Not detected

& = QC result is outside the acceptance criteria goal (SPM, surrogate, matrix spike, and blank spike recovery data)

* QC value outside the precision criteria goal (%RPD in matrix spike/matrix spike duplicate and sample duplicates)

** = Sample concentration of the Procedural Blank adjusted for the average sample size of the batch (field samples)

APPENDIX CHEMISTRY DATA

Station ID	PIB10	PIB11	PIB12	PIB13	PIB14	PIB15
Battelle ID	OJ88	OJ89	OJ90	OJ91	OJ92	OJ93
Receipt Date	24-May-94	24-May-94	24-May-94	24-May-94	24-May-94	24-May-94
Extraction Date	07-Jun-94	07-Jun-94	07-Jun-94	07-Jun-94	07-Jun-94	07-Jun-94
Analysis Date	28-Jun-94	06-Aug-94	21-Jun-94	28-Jun-94	30-Jun-94	30-Jun-94
Sample Size (g)	22.428	18.781	16.338	20.293	20.297	21.979
Percent Moisture (%)	55.427	63.486	67.579	59.420	59.878	56.633
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
naphthalene	0.292	0.2277	0.153	0.247	0.242	0.228
C1-naphthalenes	0.467	0.2628	0.201	0.290	0.377	0.224
C2-naphthalenes	0.630	0.4260	0.289	0.418	0.541	0.348
C3-naphthalenes	0.662	0.4339	0.292	0.436	0.562	0.373
C4-naphthalenes	0.598	0.4709	0.288	0.442	0.450	0.342
biphenyl	0.0562	0.0396	0.0342	0.0503	0.0667	0.0382
acenaphthylene	0.139	0.0862	0.0947	0.117	0.142	0.105
acenaphthene	0.160	0.0811	0.0629	0.0920	0.113	0.0878
dibenzofuran	0.174	0.1255	0.0864	0.115	0.117	0.0976
fluorene	0.231	0.1702	0.1152	0.1409	0.166	0.135
C1-fluorenes	0.180	0.1172	0.0885	0.1030	0.118	0.0953
C2-fluorenes	0.260	0.2473	0.1466	0.1982	0.216	0.181
C3-fluorenes	0.485	0.5473	0.2723	0.3129	0.351	0.300
phenanthrene	2.02	1.0241	0.8790	0.8311	1.16	0.911
anthracene	0.467	0.2454	0.1634	0.2495	0.288	0.248
C1-phenanthrenes/anthracenes	1.18	0.7111	0.4580	0.5925	0.741	0.585
C2-phenanthrenes/anthracenes	1.02	0.7314	0.5194	0.6484	0.721	0.603
C3-phenanthrenes/anthracenes	0.755	0.8691	0.4464	0.4321	0.552	0.531
C4-phenanthrenes/anthracenes	0.900	0.7646	0.3816	0.4157	0.658	0.525
dibenzothiophene	0.140	0.0908	0.0595	0.0801	0.0888	0.0837
C1-dibenzothiophenes	0.124	0.1008	0.0639	0.0609	0.0715	0.0623
C2-dibenzothiophenes	0.240	0.2322	0.1321	0.1750	0.182	0.165
C3-dibenzothiophenes	0.288	0.3213	0.1545	0.1883	0.189	0.204
fluoranthene	3.68	2.0061	1.4552	1.6774	2.16	2.19
pyrene	3.77	2.2424	1.5859	1.8579	2.41	1.99
C1-fluoranthenes/pyrenes	1.90	1.5468	0.8301	0.8258	1.18	1.10
benzo[a]anthracene	1.98	1.1588	0.7180	0.9613	1.29	1.00
chrysene	2.25	1.3812	0.9107	0.8921	1.42	1.16
C1-chrysenes	0.946	0.8839	0.4844	0.7160	0.711	0.571
C2-chrysenes	0.757	0.7220	0.4277	0.7273	0.574	0.511
C3-chrysenes	0.412	0.5893	0.2619	0.3916	0.393	0.311
C4-chrysenes	0.417	0.3119	0.2652	0.4370	0.349	0.249
benzo[b]fluoranthene	3.68	2.5818	1.64	1.97	2.38	1.92
benzo[k]fluoranthene	0.967	0.8281	0.478	0.411	0.639	0.500
benzo[e]pyrene	1.49	1.2491	0.811	0.823	1.11	0.916
benzo[a]pyrene	2.07	1.4515	0.906	1.01	1.44	1.12
perylene	0.554	0.5135	0.320	0.324	0.442	0.379
indeno[1,2,3-c,d]pyrene	1.78	1.5461	0.974	1.33	1.35	1.02
dibenz[a,h]anthracene	0.400	0.4182	0.222	0.519	0.3292	0.251
benzo[g,h,i]perylene	1.44	1.4355	0.812	1.69	1.10	0.830
Total PAH (priority pollutants)	25.3	16.9	11.0	14.1	16.7	13.7
N-Nitroso-N-methylethylamine	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
N-Nitrosodiethylamine	0.0062 J	0.3003	0.0000 ND	0.0000 ND	0.0065 J	0.0000 ND
N-Nitrosodi-n-propylamine	0.0000 ND	0.0000 ND	0.0113 J	0.0081 J	0.0000 ND	0.0000 ND
N-Nitrosodi-N-butylamine	0.0218 J	0.0466	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
N-Nitrosodiphenylamine	0.1508 E	0.1050 E	0.0644 E	0.0946 E	0.1222 E	0.0801 E
Total nitrosamines	0.179	0.452	0.0757	0.103	0.128	0.0901
Surrogate Recoveries (%)						
naphthalene-d8	48	47	39 &	46	51	52
acenaphthene-d10	53	45	45	55	58	57
chrysene-d12	57	67	48	29 &	53	58

Qualifiers

J = Detected, but below established Method Detection Limit (MDL)

E = Estimate, significant interferences, all reported values for N-Nitrosodiphenylamine

ND = Not detected

& = QC result is outside the acceptance criteria goal (SPM, surrogates, matrix spike, and blank spike recovery data)

* QC value outside the precision criteria goal (%RPD in matrix spike/matrix spike duplicate and sample duplicate)

** = Sample concentration of the Procedural Blank adjusted for the average sample size of the batch (field samples)

APPENDIX CHEMISTRY DATA

Station ID	P1816	P1818	P1819	P1820	P1821	P1822
Battelle ID	OJ94	OJ95	OJ96	OJ97	OJ98	OJ99
Receipt Date	24-May-94	24-May-94	24-May-94	24-May-94	24-May-94	24-May-94
Extraction Date	07-Jun-94	07-Jun-94	07-Jun-94	07-Jun-94	07-Jun-94	07-Jun-94
Analysis Date	30-Jun-94	30-Jun-94	01-Jul-94	01-Jul-94	21-Jun-94	01-Jul-94
Sample Size (g)	20.927	40.650	32.819	10.063	40.475	39.285
Percent Moisture (%)	58.585	19.701	34.418	70.695	20.743	21.585
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
naphthalene	0.227	0.0031	0.342	0.128	0.0017	0.0077
C1-naphthalenes	0.231	0.0034	0.155	0.131	0.0013	0.0089
C2-naphthalenes	0.335	0.0086	0.220	0.191	0.0016	0.0152
C3-naphthalenes	0.356	0.0136	0.243	0.199	0.0033	0.0269
C4-naphthalenes	0.361	0.0186	0.184	0.154	0.0037	0.0350
biphenyl	0.0401	0.0009 J	0.0254	0.0224	0.0000 ND	0.0013 J
acenaphthylene	0.110	0.0065	0.0560	0.0638	0.0007 J	0.0019 J
acenaphthene	0.0677	0.0059	0.0461	0.0274	0.0005 J	0.0011 J
dibenzofuran	0.101	0.0042	0.0793	0.0497	0.0006 J	0.0032
fluorene	0.112	0.0062	0.103	0.0661	0.0010 J	0.0032
C1-fluorenes	0.0926	0.0056	0.0446	0.0613	0.0011 J	0.0052
C2-fluorenes	0.155	0.0107	0.0923	0.0951	0.0043	0.0163
C3-fluorenes	0.289	0.0181	0.162	0.171	0.0079	0.0379
phenanthrene	0.685	0.0787	0.891	0.335	0.0054	0.0216
anthracene	0.211	0.0196	0.172	0.0915	0.0018 J	0.0039
C1-phenanthrenes/anthracenes	0.531	0.0410	0.343	0.264	0.0061	0.0301
C2-phenanthrenes/anthracenes	0.585	0.0364	0.316	0.316	0.0112	0.0476
C3-phenanthrenes/anthracenes	0.524	0.0293	0.231	0.292	0.0129	0.0527
C4-phenanthrenes/anthracenes	0.405	0.0343	0.197	0.218	0.0075	0.0319
dibenzothiophene	0.0712	0.0055	0.0521	0.0305	0.0006 J	0.0028 J
C1-dibenzothiophenes	0.0615	0.0061	0.0304	0.0373	0.0012 J	0.0062
C2-dibenzothiophenes	0.161	0.0103	0.0739	0.0913	0.0045	0.0144
C3-dibenzothiophenes	0.201	0.0123	0.0722	0.120	0.0043 J	0.0168
fluoranthene	0.771	0.171	1.4129	0.674	0.0129	0.0359
pyrene	1.50	0.181	1.3257	0.750	0.0126	0.0425
C1-fluoranthenes/pyrenes	0.937	0.0649	0.466	0.492	0.0076	0.0273
benz(a)anthracene	0.781	0.0907	0.563	0.393	0.0041	0.0154
chrysene	0.769	0.0962	0.631	0.506	0.0078	0.0296
C1-chrysenes	0.565	0.0399	0.232	0.294	0.0047	0.0207
C2-chrysenes	0.538	0.0326	0.180	0.307	0.0061	0.0290
C3-chrysenes	0.383	0.0195	0.137	0.212	0.0036	0.0209
C4-chrysenes	0.335	0.0185	0.107	0.159	0.0000 ND	0.0195
benzo(b)fluoranthene	1.34	0.153	0.855	0.804	0.0074	0.0290
benzo(k)fluoranthene	0.379	0.0500	0.214	0.239	0.0023 J	0.0078
benzo(e)pyrene	0.684	0.0725	0.388	0.410	0.0050	0.0177
benzo(a)pyrene	0.832	0.0964	0.502	0.440	0.0032	0.0136
perylene	0.344	0.0299	0.188	0.184	0.0091	0.0246
indeno(1,2,3-c,d)pyrene	1.01	0.0861	0.414	0.457	0.0037 J	0.0140
dibenz(a,h)anthracene	0.255	0.0209	0.107	0.118	0.0010 J	0.0034
benzo(g,h,i)perylene	0.827	0.0705	0.335	0.398	0.0037 J	0.0137
Total PAH (priority pollutants)	9.88	1.14	8.07	5.48	0.0697	0.244
N-Nitroso-N-methylethylamine	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
N-Nitrosodiethylamine	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
N-Nitrosodi-n-propylamine	0.0000 ND	0.0012 J	0.0079 J	0.0082 J	0.0000 ND	0.0027 J
N-Nitrosodi-N-butylamine	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
N-Nitrosodiphenylamine	0.0795 E	0.0032 J	0.0444 E	0.0341 E	0.0014 J	0.0074 J
Total nitrosoamines	0.0795	0.0045	0.0524	0.0424	0.0014	0.0101
Surrogate Recoveries (%)						
naphthalene-d8	50	57	52	38 &	43	50
acenaphthene-d10	55	61	63	49	52	62
chrysene-d12	53	64	65	51	65	68

Qualifiers

J = Detected, but below established Method Detection Limit (MDL)

E = Estimate, significant interferences, all reported values for N-Nitrosodiphenylamine

ND = Not detected

& = QC result is outside the acceptance criteria goal (SPM, surrogate, matrix spike, and blank spike recovery data)

* QC value outside the precision criteria goal (%RPD in matrix spike/matrix spike duplicate and sample duplicates)

** = Sample concentration of the Procedural Blank adjusted for the average sample size of the batch (field samples)

APPENDIX CHEMISTRY DATA

Station ID	NA	PIB01	PIB02	PIB02-D	PIB03	PIB03-D
Battelle ID	OK01PB	OJ77	OJ78	OJ83	OJ79	OJ80
Receipt Date	NA	5/24/94	5/24/94	5/24/94	5/24/94	5/24/94
Extraction Date	7-June-94	7-June-94	7-June-94	7-June-94	7-June-94	7-June-94
Analysis Date	22-June-94	22-June-94	23-June-94	23-June-94	23-June-94	23-June-94
Sample Size (g)	23.57 **	20.02	17.82	19.99	34.22	33.78
Percent Moisture (%)	NA	61.29	64.77	60.39	33.61	34.28
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
A-BHC	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL2(06)	0.0000 ND	0.0084	0.0085	0.0079	0.0014 J	0.0008 J
B-BHC	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
G-BHC	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL3(18)	0.0000 ND	0.0042	0.0005 J	0.0036	0.0004 J	0.0005 J
D-BHC	0.0002 J	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL3(28)	0.0000 ND	0.0017	0.0023	0.0026	0.0005	0.0004 J
HEPTACHLOR	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL4(52)	0.0000 ND	0.0054	0.0047	0.0070	0.0014	0.0012
ALDRIN	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL4(44)	0.0002 J	0.0026	0.0029	0.0032	0.0008 J	0.0005 J
HEPTACHLOR EPOXIDE	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL4(66)	0.0000 J	0.0109	0.0038	0.0085	0.0009	0.0010
G-CHLORDANE	0.0000 ND	0.0000 ND	0.0024	0.0032	0.0004 J	0.0003 J
ENDOSULFAN I	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL5(101)	0.0000 ND	0.0118	0.0111	0.0148	0.0023	0.0022
A-CHLORDANE	0.0000 ND	0.0023	0.0023	0.0026	0.0008 J	0.0005 J
DIELDRIN	0.0000 ND	0.0039	0.0044	0.0031	0.0004 J	0.0005 J
4,4-DDD	0.0000 ND	0.0088	0.0101	0.0108	0.0024	0.0025
CL4(77)	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
ENDRIN	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
ENDOSULFAN II	0.0000 ND	0.0033	0.0042	0.0041	0.0008	0.0007
CL5(118)	0.0000 ND	0.0083	0.0089	0.0087	0.0015	0.0016
4,4-DDD	0.0000 ND	0.0083	0.0085	0.0081	0.0018	0.0018
ENDRIN ALDEHYDE	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL8(153)	0.0000 ND	0.0121	0.0116	0.0104	0.0017	0.0017
CL5(105)	0.0000 ND	0.0033	0.0036	0.0054	0.0008 J	0.0008 J
ENDOSULFAN SULFATE	0.0000 ND	0.0018	0.0021	0.0000 ND	0.0001 J	0.0000 ND
4,4-DDT	0.0000 ND	0.0016	0.0000 ND	0.0023	0.0000 ND	0.0000 ND
CL8(138)	0.0000 ND	0.0115	0.0123	0.0147	0.0024	0.0024
CL5(126)	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL7(187)	0.0000 ND	0.0040	0.0053	0.0050	0.0007 J	0.0007 J
CL8(128)	0.0000 ND	0.0032	0.0037	0.0031	0.0006 J	0.0005 J
ENDRIN KETONE	0.0000 ND	0.0007	0.0007	0.0027	0.0002 J	0.0002 J
METHOXYCHLOR	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0014
CL7(180)	0.0000 ND	0.0089	0.0075	0.0085	0.0012	0.0012
CL7(170)	0.0000 ND	0.0050	0.0050	0.0070	0.0005 J	0.0008 J
CL8(195)	0.0000 ND	0.0017	0.0025	0.0024	0.0002 J	0.0002 J
CL9(206)	0.0000 ND	0.0033	0.0088	0.0073	0.0002 J	0.0002 J
CL10(209)	0.0000 ND	0.0024	0.0036	0.0041	0.0001 J	0.0002 J
TOXAPHENE	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
AROCLOR 1018/1242	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
AROCLOR 1221	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
AROCLOR 1232	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
AROCLOR 1248	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
AROCLOR 1254	0.0000 ND	0.1848	0.1844	0.1909	0.0352	0.0353
AROCLOR 1260	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
Total DDT	0.0000	0.0157	0.0158	0.0220	0.0041	0.0043
Total PCB (as predominant aroclor)	0.0000	0.185	0.184	0.191	0.0352	0.0353
Surrogate Recoveries (%)						
DBOFB	57	54	66	66	49	63
CL5(112)	63	51	58	58	51	53

Qualifiers

J = Detected, but below established Method Detection Limit (MDL)

ND = Not Detected

& = QC result is outside the acceptance criteria goal (SRM, surrogate, matrix spike, and blank spike recovery data)

* QC value outside the precision criteria goal (%RPD in matrix spike/matrix spike duplicate and sample duplicate quantifications)

** = Sample concentration of the Procedural Blank adjusted for the average sample size of the batch (field samples)

APPENDIX CHEMISTRY DATA

Station ID	PIB04	PIB05	PIB06	PIB07	PIB08	PIB09
Battelle ID	OJ81	OJ82	OJ84	OJ85	OJ86	OJ87
Receipt Date	5/24/94	5/24/94	5/24/94	5/24/94	5/24/94	5/24/94
Extraction Date	7-June-94	7-June-94	7-June-94	7-June-94	7-June-94	7-June-94
Analysis Date	23-June-94	23-June-94	23-June-94	24-June-94	24-June-94	24-June-94
Sample Size (g)	19.62	19.03	19.12	17.71	15.91	20.37
Percent Moisture (%)	80.83	82.37	82.07	84.89	88.21	89.38
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
A-BHC	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL2(06)	0.0055	0.0072	0.0076	0.0106	0.0098	0.0074
B-BHC	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
G-BHC	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL3(18)	0.0028	0.0074	0.0137	0.0092	0.0053	0.0078
D-BHC	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL3(28)	0.0038	0.0043	0.0048	0.0041	0.0030	0.0037
HEPTACHLOR	0.0000 ND	0.0000 ND	0.0005 J	0.0000 ND	0.0000 ND	0.0000 ND
CL4(52)	0.0084	0.0151	0.0083	0.0089	0.0039	0.0074
ALDRIN	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL4(44)	0.0030	0.0053	0.0050	0.0027	0.0021	0.0054
HEPTACHLOR EPOXIDE	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL4(66)	0.0088	0.0098	0.0078	0.0045	0.0032	0.0055
G-CHLORDANE	0.0089	0.0043	0.0036	0.0040	0.0028	0.0091
ENDOSULFAN I	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL5(101)	0.0187	0.0184	0.0182	0.0179	0.0101	0.0230
A-CHLORDANE	0.0048	0.0032	0.0033	0.0029	0.0014	0.0092
DIELDRIN	0.0043	0.0029	0.0032	0.0020	0.0021	0.0073
4,4-DDD	0.0118	0.0121	0.0129	0.0098	0.0135	0.0102
CL4(77)	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
ENDRIN	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
ENDOSULFAN II	0.0081	0.0059	0.0084	0.0046	0.0058	0.0052
CL5(118)	0.0089	0.0131	0.0152	0.0088	0.0134	0.0097
4,4-DDD	0.0082	0.0108	0.0140	0.0085	0.0137	0.0099
ENDRIN ALDEHYDE	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL8(153)	0.0125	0.0149	0.0173	0.0158	0.0198	0.0199
CL5(105)	0.0074	0.0078	0.0078	0.0038	0.0058	0.0058
ENDOSULFAN SULFATE	0.0028	0.0038	0.0028	0.0017	0.0023	0.0017
4,4-DDT	0.0025	0.0028	0.0018	0.0018	0.0011	0.0038
CL8(138)	0.0189	0.0232	0.0280	0.0157	0.0223	0.0220
CL5(128)	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL7(187)	0.0085	0.0088	0.0103	0.0054	0.0079	0.0086
CL8(128)	0.0035	0.0043	0.0050	0.0032	0.0043	0.0033
ENDRIN KETONE	0.0038	0.0034	0.0048	0.0028	0.0048	0.0035
METHOXYCHLOR	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL7(180)	0.0115	0.0147	0.0188	0.0092	0.0140	0.0155
CL7(170)	0.0103	0.0098	0.0103	0.0089	0.0095	0.0152
CL8(195)	0.0033	0.0038	0.0038	0.0020	0.0031	0.0035
CL9(208)	0.0078	0.0084	0.0053	0.0027	0.0053	0.0058
CL10(209)	0.0067	0.0053	0.0054	0.0025	0.0054	0.0048
TOXAPHENE	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
AROCLOR 1018/1242	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
AROCLOR 1221	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
AROCLOR 1232	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
AROCLOR 1248	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
AROCLOR 1254	0.2441	0.2975	0.2500	0.1884	0.3044	0.2603
AROCLOR 1260	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
Total DDT	0.0224	0.0255	0.0287	0.0199	0.0282	0.0239
Total PCB (as predominant aroclor)	0.244	0.298	0.250	0.188	0.304	0.280
Surrogate Recoveries (%)						
DBOFS	62	67	56	53	78	80
CL5(112)	51	72	53	71	47	63

Qualifiers

J = Detected, but below established Method Detection Limit (MDL)

ND = Not Detected

& = QC result is outside the acceptance criteria goal (SRM, surrogate, matrix spike, and blank spike recovery data)

* QC value outside the precision criteria goal (%RPD in matrix spike/matrixspike duplicate and sample duplicate quantifications)

APPENDIX CHEMISTRY DATA

Station ID	PIB10	PIB11	PIB12	PIB13	PIB14	PIB15
Battelle ID	OJ88	OJ89	OJ90	OJ91	OJ92	OJ93
Receipt Date	5/24/94	5/24/94	5/24/94	5/24/94	5/24/94	5/24/94
Extraction Date	7-June-94	7-June-94	7-June-94	7-June-94	7-June-94	7-June-94
Analysis Date	24-June-94	24-June-94	24-June-94	24-June-94	24-June-94	24-June-94
Sample Size (g)	22.43	18.78	16.34	20.29	20.30	21.88
Percent Moisture (%)	55.43	63.49	67.58	59.42	59.88	56.83
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
A-BHC	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL2(08)	0.0036	0.0055	0.0045	0.0077	0.0084	0.0039
B-BHC	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
G-BHC	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL3(18)	0.0039	0.0087	0.0053	0.0099	0.0091	0.0102
D-BHC	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL3(28)	0.0025	0.0029	0.0021	0.0043	0.0042	0.0043
HEPTACHLOR	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0001 J
CL4(52)	0.0120	0.0046	0.0036	0.0092	0.0079	0.0057
ALDRIN	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL4(44)	0.0029	0.0024	0.0023	0.0040	0.0044	0.0033
HEPTACHLOR EPOXIDE	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL4(66)	0.0042	0.0043	0.0043	0.0078	0.0059	0.0048
G-CHLORDANE	0.0135	0.0026	0.0020	0.0083	0.0089	0.0034
ENDOSULFAN I	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL5(101)	0.0185	0.0103	0.0095	0.0212	0.0188	0.0127
A-CHLORDANE	0.0132	0.0023	0.0016	0.0040	0.0048	0.0021
DIELDRIN	0.0100	0.0022	0.0014	0.0021	0.0043	0.0017
4,4-DDD	0.0100	0.0101	0.0083	0.0100	0.0112	0.0088
CL4(77)	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
ENDRIN	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
ENDOSULFAN II	0.0054	0.0044	0.0034	0.0049	0.0082	0.0041
CL5(118)	0.0098	0.0110	0.0089	0.0117	0.0103	0.0102
4,4-DDD	0.0106	0.0105	0.0083	0.0111	0.0124	0.0097
ENDRIN ALDEHYDE	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL8(153)	0.0134	0.0166	0.0135	0.0171	0.0171	0.0180
CL5(105)	0.0040	0.0044	0.0035	0.0052	0.0070	0.0036
ENDOSULFAN SULFATE	0.0016	0.0014	0.0014	0.0018	0.0020	0.0015
4,4-DDT	0.0028	0.0019	0.0007 J	0.0020	0.0019	0.0018
CL8(138)	0.0201	0.0190	0.0125	0.0180	0.0196	0.0180
CL5(126)	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL7(187)	0.0075	0.0084	0.0043	0.0075	0.0078	0.0059
CL8(128)	0.0031	0.0034	0.0024	0.0028	0.0030	0.0028
ENDRIN KETONE	0.0034	0.0036	0.0021	0.0042	0.0031	0.0023
METHOXYCHLOR	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL7(180)	0.0120	0.0121	0.0079	0.0123	0.0126	0.0101
CL7(170)	0.0114	0.0074	0.0056	0.0116	0.0106	0.0082
CL8(195)	0.0028	0.0026	0.0015	0.0034	0.0042	0.0025
CL9(206)	0.0083	0.0040	0.0018	0.0041	0.0040	0.0044
CL10(209)	0.0040	0.0036	0.0024	0.0040	0.0037	0.0045
TOXAPHENE	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
AROCLOR 1018/1242	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
AROCLOR 1221	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
AROCLOR 1232	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
AROCLOR 1248	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
AROCLOR 1254	0.2323	0.2436	0.1391	0.2580	0.2504	0.2085
AROCLOR 1260	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
Total DDT	0.0234	0.0225	0.0154	0.0232	0.0255	0.0203
Total PCB (as predominant aroclor)	0.232	0.244	0.139	0.258	0.250	0.208
Surrogate Recoveries (%)						
DBOFS	68	66	63	52	72	75
CL5(112)	52	50	73	57	60	61

Qualifiers

J = Detected, but below established Method Detection Limit (MDL)

ND = Not Detected

& = QC result is outside the acceptance criteria goal (SRM, surrogate, matrix spike, and blank spike recovery data)

* QC value outside the precision criteria goal (%RPD in matrix spike/matrixspike duplicate and sample duplicate quantifications)

APPENDIX CHEMISTRY DATA

Station ID	PIB18	PIB18	PIB19	PIB20	PIB21	PIB22
Battelle ID	OJ94	OJ95	OJ96	OJ97	OJ98	OJ99
Receipt Date	5/24/94	5/24/94	5/24/94	5/24/94	5/24/94	5/24/94
Extraction Date	7-June-94	7-June-94	7-June-94	7-June-94	7-June-94	7-June-94
Analysis Date	24-June-94	24-June-94	25-June-94	25-June-94	25-June-94	25-June-94
Sample Size (g)	20.93	40.65	32.62	10.06	40.48	39.29
Percent Moisture (%)	54.55	19.70	54.42	73.70	20.74	21.58
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
A-BHC	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL2(06)	0.0047	0.0002 J	0.0004 J	0.0028	0.0000 ND	0.0001 J
B-BHC	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
G-BHC	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL3(18)	0.0089	0.0002 J	0.0018	0.0026	0.0000 J	0.0001 J
D-BHC	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL3(28)	0.0055	0.0002 J	0.0020	0.0021	0.0000 J	0.0001 J
HEPTACHLOR	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL4(52)	0.0071	0.0003 J	0.0018	0.0033	0.0001 J	0.0002 J
ALDRIN	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL4(44)	0.0037	0.0003 J	0.0011 J	0.0017	0.0001 J	0.0002 J
HEPTACHLOR EPOXIDE	0.0000 ND	0.0002 J	0.0002 J	0.0000 ND	0.0000 ND	0.0000 ND
CL4(66)	0.0049	0.0002 J	0.0008	0.0019	0.0000 J	0.0002 J
G-CHLORDANE	0.0028	0.0001 J	0.0002 J	0.0007	0.0000 J	0.0001 J
ENDOSULFAN I	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL5(101)	0.0151	0.0005 J	0.0029	0.0073	0.0001 J	0.0003 J
A-CHLORDANE	0.0022	0.0002 J	0.0007	0.0008	0.0000 J	0.0001 J
DIELDRIN	0.0018	0.0005 J	0.0018	0.0005 J	0.0001 J	0.0008
4,4-DDE	0.0088	0.0007	0.0025	0.0080	0.0001 J	0.0008
CL4(77)	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
ENDRIN	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
ENDOSULFAN II	0.0049	0.0002 J	0.0010	0.0033	0.0001 J	0.0003
CL5(118)	0.0102	0.0004 J	0.0034	0.0081	0.0001 J	0.0003 J
4,4-DDD	0.0102	0.0007 J	0.0021	0.0052	0.0001 J	0.0008 J
ENDRIN ALDEHYDE	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL6(153)	0.0172	0.0004 J	0.0035	0.0110	0.0001 J	0.0004 J
CL5(105)	0.0039	0.0002 J	0.0018	0.0032	0.0001 J	0.0002 J
ENDOSULFAN SULFATE	0.0032	0.0003 J	0.0005 J	0.0019	0.0000 J	0.0001 J
4,4-DDT	0.0021	0.0003 J	0.0005 J	0.0000 ND	0.0000 ND	0.0005 J
CL6(138)	0.0183	0.0008 J	0.0048	0.0135	0.0001 J	0.0004 J
CL5(126)	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
CL7(187)	0.0070	0.0001 J	0.0017	0.0048	0.0000 J	0.0001 J
CL6(128)	0.0026	0.0002 J	0.0010	0.0027	0.0000 J	0.0001 J
ENDRIN KETONE	0.0029	0.0002 J	0.0011	0.0021	0.0000 J	0.0001 J
METHOXYCHLOR	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0007
CL7(180)	0.0156	0.0003 J	0.0028	0.0089	0.0000 J	0.0002 J
CL7(170)	0.0101	0.0003 J	0.0030	0.0087	0.0000 ND	0.0001 J
CL8(195)	0.0031	0.0001 J	0.0007 J	0.0013	0.0000 ND	0.0000 J
CL9(208)	0.0048	0.0002 J	0.0015 J	0.0021	0.0003 J	0.0000 ND
CL10(209)	0.0058	0.0002 J	0.0010 J	0.0017	0.0000 ND	0.0000 ND
TOXAPHENE	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
AROCLOR 1018/1242	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
AROCLOR 1221	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
AROCLOR 1232	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
AROCLOR 1248	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
AROCLOR 1254	0.2022	0.0103	0.0754	0.1872	0.0000 ND	0.0083
AROCLOR 1260	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND	0.0000 ND
Total DDT	0.0211	0.0017	0.0051	0.0142	0.0003	0.0017
Total PCB (as predominant aroclor)	0.202	0.010	0.0754	0.167	0.0000	0.0083
Surrogate Recoveries (%)						
DBOFS	80	72	73	85	67	88
CL5(112)	62	59	58	64	57	70

Qualifiers

J = Detected, but below established Method Detection Limit (MDL)

ND = Not Detected

& = QC result is outside the acceptance criteria goal (SRM, surrogate, matrix spike, and blank spike recovery data)

* QC value outside the precision criteria goal (%RPD in matrix spike/matrixspike duplicate and sample duplicate quantifications)

APPENDIX B

PLANKTON DATA

APPENDIX PLANKTON DATA

Water Quality Data on Plankton Collection Forms WA 1-107 G4571-0720

Station: PIB10

Date: 5-18-94

Time: 1647

Water Depth: 7.0 m

Comments: Water Clarity 2-3 m

Depth	Temperature	pH	Diss. Oxygen	Conductivity
Surface	11.8	7.3	9.4	322
1.0	11.8	7.3	9.5	323
2.0	11.7	7.3	9.6	323
3.0	11.8	7.3	9.6	322
4.0	11.8	7.3	9.5	323
5.0	11.7	7.3	9.5	323
6.0	11.7	7.3	9.5	323
7.0	11.6	7.3	9.8	326

Station: PIB12

Date: 5-17-94

Time: 1000

Water Depth: 6.0 m

Comments: Clear water

Depth	Temperature	pH	Diss. Oxygen	Conductivity
Surface	11.7	7.4	9.3	321
1.0	11.7	7.4	9.3	322
2.0	11.7	7.4	9.3	321
3.0	11.7	7.3	9.3	322
4.0	11.6	7.4	9.3	321
5.0	11.5	7.4	9.3	322
6.0	11.4	7.4	9.3	322

APPENDIX PLANKTON DATA

Water Quality Data on Plankton Collection Forms WA 1-107 G4571-0720

Station: PIB18

Date: 5-17-94

Time: 1520

Water Depth: 1 m

Comments: Shallow depth 1.0 m; Did lateral tow

Depth	Temperature	pH	Diss. Oxygen	Conductivity
Surface	11.7	7.3	9.6	313
1.0	11.8	7.3	9.6	314

Station: PIB20

Date: 5-16-94

Time: 0815

Water Depth: 3.7 m

Comments: Cold - Rain - Misery Bay

Depth	Temperature	pH	Diss. Oxygen	Conductivity
Surface	13.7	7.8	10.1	310
1.0	13.7	7.8	10.1	310
2.0	13.7	7.8	10.1	310
3.0	13.6	7.8	10.2	311
3.7	12.9	7.6	9.8	313

APPENDIX C
TOXICITY DATA

APPENDIX TOXICITY DATA

Appendix A5-1. Presque Isle Bay Sediment Toxicity Study

Batch 1 Test Date Start: 5-28-94 End: 6-7-94				Batch 2 Test Date Start: 6-7-94 End: 6-12-94			
Number of Test Animals				Number of Test Animals			
Replicate		Initial	Final	Replicate		Initial	Final
Control:	A	8	6	Control:	A	8	8
	B	8	7		B	8	7
	C	8	7		C	8	7
	D	8	7		D	8	7
% Survival			84.4	% Survival			90.6
PIB 01:	A	8	4	PIB 04:	A	8	8
	B	8	5		B	8	8
	C	8	6		C	8	8
	D	8	5		D	8	6
% Survival			62.5	% Survival			93.8
PIB 08:	A	8	5	PIB 07:	A	8	6
	B	8	5		B	8	4
	C	8	5		C	8	6
	D	8	3		D	8	5
% Survival			56.3	% Survival			65.6
PIB18:	A	8	8	PIB 09:	A	8	7
	B	8	5		B	8	7
	C	8	8		C	8	6
	D	8	8		D	8	8
% Survival			90.6	% Survival			87.5
PIB 19:	A	8	7	PIB 11:	A	8	8
	B	8	7		B	8	7
	C	8	6		C	8	7
	D	8	8		D	8	6
% Survival			87	% Survival			87.5
PIB 20:	A	8	1	PIB 14:	A	8	7
	B	8	2		B	8	8
	C	8	2		C	8	6
	D	8	0		D	8	7
% Survival			15	% Survival			87.5
PIB 22:	A	8	6	PIB 16:	A	8	6
	B	8	8		B	8	7
	C	8	7		C	8	6
	D	8	8		D	8	6
% Survival			90.6	% Survival			78.1

APPENDIX TOXICITY DATA

Appendix A5-2. Water Quality Parameters for Toxicity Study

Sample ID	Date (1994)	Initial/Final Measure	DISS Oxygen (mg/l)	pH	Specific Conductivity (µmhos/cm)	Temperature
Control	5/28	I	3.8	7.04	337	22.6
	5/30	F	2.1	7.24		22.4
	5/30	I	4.4	6.93	321	23.2
	6/1	F	3.4	7.31		23.0
	6/1	I	3.5	7.17	357	23.0
	6/3	F	3.3	7.18		22.8
	6/3	I	3.9	7.04	362	23.1
	6/5	F	3.1	7.19		22.9
	6/5	I	3.2	7.01	362	23.2
	6/7	F	3.9	7.18		23.4
	Average Read		3.6	7.13	348	23.0
PIB01	5/28	I	5.9	7.63	321	22.5
	5/30	F	5.9	7.49		22.4
	5/30	I	4.5	7.35	322	23.0
	6/1	F	6.0	7.60		23.0
	6/1	I	5.8	7.55	333	23.0
	6/3	F	6.2	7.50		22.8
	6/3	I	4.9	7.39	338	23.1
	6/5	F	6.1	7.55		22.9
	6/5	I	6.5	7.53	336	23.2
	6/7	F	6.5	7.73		23.4
	Average Read		5.8	7.53	330	22.9
PIB19	5/28	I	5.2	7.55	375	22.6
	5/30	F	4.9	7.70		22.4
	5/30	I	6.9	7.61	335	23.2
	6/1	F	5.7	7.78		23.2
	6/1	I	5.9	7.73	323	23.0
	6/3	F	6.0	7.75		23.0
	6/3	I	6.6	7.62	331	23.1
	6/5	F	5.9	7.80		22.9
	6/5	I	7.9	7.76	323	23.2
	6/7	F	6.0	7.89		23.4
	Average Read		6.1	7.72	337	23.0
PIB20	5/28	I	4.6	7.51	325	22.6
	5/30	F	5.1	7.55		22.4
	5/30	I	4.1	7.41	327	23.2
	6/1	F	6.2	7.84		23.0
	6/1	I	5.7	7.71	336	23.2
	6/3	F	6.0	7.72		22.9
	6/3	I	4.4	7.53	348	23.2
	6/5	F	6.2	7.81		23.0
	6/5	I	7.9	7.58	334	23.2
	6/7	F	6.4	7.83		23.3
	Average Read		5.7		334	23.0

APPENDIX TOXICITY DATA

Sample ID	Date (1994)	Initial/Final Measure	DISS Oxygen (mg/l)	pH	Specific Conductivity (µmhos/cm)	Temperature
PIB04	6/2	I	6.3	7.70	376	23.1
	6/4	F	6.0	7.40		22.8
	6/4	I	4.6	7.33	344	23.0
	6/6	F	5.7	7.51		23.1
	6/6	I	4.5	7.40	334	23.2
	6/8	F	5.7	7.52		23.0
	6/8	I	5.9	7.42	342	23.0
	6/10	F	6.2	7.52		23.0
	6/10	I	4.9	7.36	331	23.0
	6/12	F	5.8	7.58		22.7
	Average Read		7.45	7.48	345	23.0
PIB07	6/2	I	6.2	7.59	328	23.2
	6/4	F	5.8	7.47		22.8
	6/4	I	4.2	7.30	337	23.2
	6/6	F	5.7	7.48		23.1
	6/6	I	4.2	7.46	345	23.1
	6/8	F	5.5	7.42		23.2
	6/8	I	4.2	7.50	341	23.0
	6/10	F	5.6	7.45		23.0
	6/10	I	4.2	7.30	332	23.0
	6/12	F	5.2	7.52		22.7
	Average Read		5.1	7.45	337	23.0
PIB09	6/2	I	6.3	7.76	356	23.2
	6/4	F	6.2	7.81		22.9
	6/4	I	5.2	7.46	344	23.1
	6/6	F	5.8	7.71		23.2
	6/6	I	5.2	7.47	353	23.2
	6/8	F	5.5	7.71		23.0
	6/8	I	5.2	7.70	352	23.0
	6/10	F	5.7	7.72		23.0
	6/10	I	4.9	7.45	344	23.0
	6/12	F	6.0	7.67		22.7
	Average Read		5.6	7.65	350	23.0

APPENDIX TOXICITY DATA

Sample ID	Date (1994)	Initial/Final Measure	DISS Oxygen (mg/l)	pH	Specific Conductivity (µmhos/cm)	Temperature
PIB08	5/28	I	5.9	7.76	334	22.4
	5/30	F	6.1	7.79		22.4
	5/30	I	4.5	7.45	328	23.1
	6/1	F	6.2	7.87		23.0
	6/1	I	5.8	7.68	342	23.1
	6/3	F	6.2	7.72		22.9
	6/3	I	4.4	7.49	348	23.2
	6/5	F	6.1	7.76		23.0
	6/5	I	5.6	7.57	337	23.3
	6/7	F	6.5	7.79		23.3
	Average Read		5.7	7.69	338	23.0
PIB18	5/28	I	6.5	7.87	312	22.4
	5/30	F	6.7	7.90		22.4
	5/30	I	7.9	7.76	303	23.0
	6/1	F	7.3	8.02		23.0
	6/1	I	7.0	7.93	325	23.1
	6/3	F	7.4	8.02		22.9
	6/3	I	7.6	7.77	324	23.2
	6/5	F	7.3	7.96		23.0
	6/5	I	6.1	7.77	324	23.3
	6/7	F	7.4	7.98		23.4
	Average Read		7.1	7.90	318	23.0
PIB22	5/28	I	5.2	7.61	368	22.4
	5/30	F	5.7	7.83		22.4
	5/30	I	7.2	7.74	343	23.1
	6/1	F	6.3	7.92		23.0
	6/1	I	6.4	7.95	329	23.1
	6/3	F	6.8	7.98		22.9
	6/3	I	7.0	7.82	321	23.2
	6/5	F	6.5	7.92		23.0
	6/5	I	8.0	7.83	319	23.3
	6/7	F	6.6	7.99		23.4
	Average Read		6.6	7.86	336	23.0
Control	6/2	I	5.4	7.17	362	23.1
	6/4	F	5.2	7.29		22.8
	6/4	I	4.6	6.93	353	23.0
	6/6	F	4.6	7.25		23.1
	6/6	I	4.9	6.92	362	23.2
	6/8	F	4.1	7.21		23.0
	6/8	I	4.6	6.95	368	23.2
	6/10	F	4.9	7.23		23.0
	6/10	I	4.0	6.94	360	23.0
	6/12	F	5.1	7.17		22.7
	Average Read		4.7	7.11	361	23.0

STATION	DATE	TIME	WIND	WAVE	SEA	TEMP.	WIND
1	1902	10	10	10	10	10	10
2	1902	10	10	10	10	10	10
3	1902	10	10	10	10	10	10
4	1902	10	10	10	10	10	10
5	1902	10	10	10	10	10	10
6	1902	10	10	10	10	10	10
7	1902	10	10	10	10	10	10
8	1902	10	10	10	10	10	10
9	1902	10	10	10	10	10	10
10	1902	10	10	10	10	10	10
11	1902	10	10	10	10	10	10
12	1902	10	10	10	10	10	10
13	1902	10	10	10	10	10	10
14	1902	10	10	10	10	10	10
15	1902	10	10	10	10	10	10
16	1902	10	10	10	10	10	10
17	1902	10	10	10	10	10	10
18	1902	10	10	10	10	10	10
19	1902	10	10	10	10	10	10
20	1902	10	10	10	10	10	10
21	1902	10	10	10	10	10	10
22	1902	10	10	10	10	10	10
23	1902	10	10	10	10	10	10
24	1902	10	10	10	10	10	10
25	1902	10	10	10	10	10	10
26	1902	10	10	10	10	10	10
27	1902	10	10	10	10	10	10
28	1902	10	10	10	10	10	10
29	1902	10	10	10	10	10	10
30	1902	10	10	10	10	10	10
31	1902	10	10	10	10	10	10
32	1902	10	10	10	10	10	10
33	1902	10	10	10	10	10	10
34	1902	10	10	10	10	10	10
35	1902	10	10	10	10	10	10
36	1902	10	10	10	10	10	10
37	1902	10	10	10	10	10	10
38	1902	10	10	10	10	10	10
39	1902	10	10	10	10	10	10
40	1902	10	10	10	10	10	10
41	1902	10	10	10	10	10	10
42	1902	10	10	10	10	10	10
43	1902	10	10	10	10	10	10
44	1902	10	10	10	10	10	10
45	1902	10	10	10	10	10	10
46	1902	10	10	10	10	10	10
47	1902	10	10	10	10	10	10
48	1902	10	10	10	10	10	10
49	1902	10	10	10	10	10	10
50	1902	10	10	10	10	10	10
51	1902	10	10	10	10	10	10
52	1902	10	10	10	10	10	10
53	1902	10	10	10	10	10	10
54	1902	10	10	10	10	10	10
55	1902	10	10	10	10	10	10
56	1902	10	10	10	10	10	10
57	1902	10	10	10	10	10	10
58	1902	10	10	10	10	10	10
59	1902	10	10	10	10	10	10
60	1902	10	10	10	10	10	10
61	1902	10	10	10	10	10	10
62	1902	10	10	10	10	10	10
63	1902	10	10	10	10	10	10
64	1902	10	10	10	10	10	10
65	1902	10	10	10	10	10	10
66	1902	10	10	10	10	10	10
67	1902	10	10	10	10	10	10
68	1902	10	10	10	10	10	10
69	1902	10	10	10	10	10	10
70	1902	10	10	10	10	10	10
71	1902	10	10	10	10	10	10
72	1902	10	10	10	10	10	10
73	1902	10	10	10	10	10	10
74	1902	10	10	10	10	10	10
75	1902	10	10	10	10	10	10
76	1902	10	10	10	10	10	10
77	1902	10	10	10	10	10	10
78	1902	10	10	10	10	10	10
79	1902	10	10	10	10	10	10
80	1902	10	10	10	10	10	10
81	1902	10	10	10	10	10	10
82	1902	10	10	10	10	10	10
83	1902	10	10	10	10	10	10
84	1902	10	10	10	10	10	10
85	1902	10	10	10	10	10	10
86	1902	10	10	10	10	10	10
87	1902	10	10	10	10	10	10
88	1902	10	10	10	10	10	10
89	1902	10	10	10	10	10	10
90	1902	10	10	10	10	10	10
91	1902	10	10	10	10	10	10
92	1902	10	10	10	10	10	10
93	1902	10	10	10	10	10	10
94	1902	10	10	10	10	10	10
95	1902	10	10	10	10	10	10
96	1902	10	10	10	10	10	10
97	1902	10	10	10	10	10	10
98	1902	10	10	10	10	10	10
99	1902	10	10	10	10	10	10
100	1902	10	10	10	10	10	10

*Comments re: 1994 Sediment Study
Wellington, B.*



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July 3, 1997

Mr. Charles Sapp
U.S. Environmental Protection Agency
3WP11
841 Chestnut Building
Philadelphia, PA 19107

RE: Final Report
Presque Isle Bay Sediment Study - Data Review
EPA Contract No. 68-C2-0134
Work Assignment 4-456

Dear Mr. Sapp:

We are writing on behalf of several members of the Presque Isle Bay Public Advisory committee regarding certain issues in the Final Report - Presque Isle Bay Sediment Study, done for your agency by Battelle Ocean Sciences.

At our May 28, 1997 public meeting at the Stull Nature Center on Presque Isle State Park the committee discussed the final report. We realize that a lot of work has been conducted and meaningful information presented. However, as a group, the general consensus seemed that we would not be willing to "sign our names" to the report as written and presented. We were concerned that future reviewers might review and accept the report as technically correct, when in fact errors exist.

Earlier this year when the draft report was presented, some committee members put many hours into reviewing and commenting on the draft report prior to its final edition. After having sent some written comments to Battelle through the Pennsylvania Department of Environmental Protection and also meeting face to face with Battelle to discuss issues, we were less than pleased to find that some of our concerns were not addressed and that actual errors were still in the final report. We realize that at times certain issues can be perceived from different viewpoints with both parties being correct from their respective viewpoints. However, certain shortcomings are not matters of opinion but matters of fact.

An example of incorrect information can be found on page 2-1, last paragraph, which reads, "... three out of four cores were collected within 1,000 m of where Cascade Creek discharges to the Bay." In fact, only one of the sites (site 10) is located within that distance. While this may seem insignificant regarding the overall scope of the report, it does not instill public confidence in the rest of the report. If the public sees such a mistake, they may have trouble believing more subjective or interpretive information. Incidentally, site PIB10 is actually off the center pier, not as the map shows off the 3rd pier. While this may seem insignificant at first, it should be pointed out that PIB10 is on a "hump" between two previously dredged channels. It is possible and, in fact, probable that sediments were in the past stirred up, as large boats used these channels, and that some "silt" was likely deposited on this site.

Another error which is less obvious is on page 4-6. Stations 5 and 6 regarding the arsenic sampling are within the "lagoon system" of Presque Isle State Park and are not the same stations listed in the Battelle report as in the central basin or off Cascade Creek. They are entirely separate stations.

On page 2-1, there is a reference to the evaluation of lead 210, Presque Isle Bay sediment core, EPA contract 68-C2-0137, work assignment 2-107, amendment 2, by Battelle Marine Science Laboratory. While we are in no position to challenge the methodology of that report, some of us believe the dating should have been verified by other means, such as C137 and visual observations, e.g., flecks of coal dust, soot, etc. When the RV Mudpuppy was here taking core samples, had we known that only a select few samples were to be tested perhaps we could have been some help in selecting sites, as some of us are quite familiar with some of the history of various dredge and/or fill sites, etc. For example, extensive filling took place in the area of PIB18 at the Port Authority land near the mouth of Mill Creek. Site PIB12 is off the dredged channel to the marina on Presque Isle State Park. The site is so close to the natural contour that one cannot tell for certain if the PIB12 area was dredged circa 1960 or not.

It was clearly pointed out to Battelle prior to the final report that PIB3 had been dredged from perhaps 2 ft. deep to 23 ft. deep circa 1958, when the beaches were built up on Presque Isle State Park by dredging the bay. Thus, there should not be much "recent" sediment in that hole. The layer before 1957 should be very old because 20 ft. of material had been removed. So in effect we know the graph in Appendix E, PIB3, is in error. There is also a question on graph PIB4 - are we to believe the PAHs were 0 between about 1910 and 1950?

The issue of 0.92 cm/yr. sediments in the bay does seem excessive to us. At that rate we would need well over 490,000,000 lbs. of solids per year at a very conservative specific gravity (dry wt.) of 1.5 gr/cm³ to cover the 3,718 acres of Presque Isle bay. The Potomac Hudson report, page V-22, calculated 10,000,000 lbs. input to the bay of suspended solids for the entire 25 sq. mi. watershed. This figure agrees with the "rough loading" of suspended solids calculated by the Erie County Department of Health when it looked only at Cascade and Mill Creeks. The Erie County Department of Health also looked at Pa. Code Title 25, Environmental Protection, page 25, section 131.4, regarding air quality. Assuming we were at the maximum particulate of

The first part of the report deals with the general situation of the country. It is a very interesting and informative study of the country's development. The author has done a great deal of research and has gathered a wealth of material. The report is well written and is a valuable contribution to the study of the country's development.

The second part of the report deals with the economic situation of the country. It is a very interesting and informative study of the country's economic development. The author has done a great deal of research and has gathered a wealth of material. The report is well written and is a valuable contribution to the study of the country's economic development.

The third part of the report deals with the social situation of the country. It is a very interesting and informative study of the country's social development. The author has done a great deal of research and has gathered a wealth of material. The report is well written and is a valuable contribution to the study of the country's social development.

The fourth part of the report deals with the political situation of the country. It is a very interesting and informative study of the country's political development. The author has done a great deal of research and has gathered a wealth of material. The report is well written and is a valuable contribution to the study of the country's political development.

The fifth part of the report deals with the cultural situation of the country. It is a very interesting and informative study of the country's cultural development. The author has done a great deal of research and has gathered a wealth of material. The report is well written and is a valuable contribution to the study of the country's cultural development.

Mr. Charles Sapp

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July 3, 1997

0.8 mg/cm²/month and all the solids fell into the bay, that still is less than 5 million pounds/year for atmospheric input. We believe the actual number to be much less than that, due to our relatively clean air and predominant winds from the west or southwest directions. While we acknowledge that there would be a bed loading of settleable solids deposited near the stream mouths during floods and very high water, we do not believe this would affect the bay outside the immediate area of the mouths of the tributary streams. Even assuming very rare events with very heavy silt loading during seiches from Lake Erie with a generous 100% settling rate, we are still missing >400,000,000 lbs. Even if we use the 0.5 cm/year settling rate, we are still off by 200,000,000+ lbs. Some solids undoubtedly come from the settling of algae. However, we do not believe that this source could account for the large difference. We have many data points where the suspended solids in the water column are less than 2 mg/l.

On pages 3-4 and 3-5 we were disappointed that the sediment depths overlapped, e.g., 0-13 cm for Site 1 and 0-53 cm for Site 1. We really can't tell if the 1.54 mg/kg PAH was from the past or is part of the 8.96 mg/kg PAH since 1987. It would have been helpful had PAHs in deeper sediments been qualified as petrogenic or pyrogenic and compared to surface sediments. We suspect that changes in composition and sources of PAHs have changed over time, e.g. road runoff from automobile-related issues may now be a major issue compared to coal-burning activities in the past.

We are at a loss to explain why PIB9, for example, does not show more petrogenic sources of PAHs, when we know that more recently there had been discharges of petroleum products to the creek.

On page 3-13 and subsequent graphs we find it difficult to compare stations to each other or to known standards because the concentrations are in different units. It's virtually impossible for us to compare PIB22 with an upper limit on the graph of 0.06 mg/kg to coal tar with the graph's upper limit on the next page at 18,000 mg/kg. We wonder if selective density sorting by water currents and natural breakdown of PAHs may be affecting the judgment call of approximately 50-50 pyrogenic-petrogenic at PIB22.

We are also curious as to why the naphthalene in the bile (table 15, page 44 of the 1992-1993 Presque Isle Bay Brown Bullhead Tumor Study, Eric Obert, PA DEP, is 1,000 times less in the sediment than it is in the fish. Was naphthalene lost in the collection? Should VOA vials have been used?

We see more BAP in the sediment than in the bullhead bile, yet there is less naphthalene in the sediment and more in the bile. While it probably was beyond the scope of this work agreement to determine this, we are concerned that this does not seem consistent with the sediment data. There may be a biological or physical explanation for this, but at this time we do not know what it is.

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Mr. Charles Sapp

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July 3, 1997

There may be more issues at stake, but at this time we wanted to let you know this report is not sufficient for many of the members of the Presque Isle Bay Advisory committee to make any major decisions regarding the fate of Presque Isle Bay. On page 5-4 of the final report, second paragraph under recommendations, suggest in the future more core samples be taken to find out more precisely what came into the Bay and when it happened. Many of us on the Presque Isle Bay Public Advisory Committee thought that is pretty much what was to have been done when the RV Mudpuppy showed up three years ago in May of 1994.

We would appreciate hearing from your agency and/or your consultant regarding concerns we have regarding what we perceive as shortcomings and/or errors as well as any explanation for data that does not seem consistent with existing information.

If you have any questions, please call Robert Wellington at 814/451-6700.

Sincerely,



Robert J. Wellington
Aquatic Biologist
Erie County Department of Health



Sr. Pat Lupo, OSB
Eco Justice Director
Glinodo Center

RJW/cas

cc Kelly Burch, DEP
Jerry M. Neff

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*Comments re: 1994 Sediment Study
Wellington, B.*



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March 18, 1998

Mr. Charles W. Sapp
Great Lakes Coordinator
U.S. Environmental Protection Agency
841 Chestnut Building
Philadelphia, PA 19107-4431

RE: Final Report – Presque Isle Bay Sediment Study

Dear Mr. Sapp:

Thank you for considering and commenting on our concerns about certain aspects of the Final Report – Presque Isle Bay Sediment Study, 1994.

I agree with your comment that an errata sheet should be added to the report. I suggest that the contractor review and comment on the biological data in the context of the correct sampling stations, especially with respect to arsenic. I would assume the contractor would correct the errors at no additional charge to the government agencies.

It's unfortunate that there are some data gaps and unanswered questions in the report. I do believe, however, that some questions were answered and we now know a lot more about Presque Isle Bay than we did before the study was undertaken.

I have been able to use an old Presque Isle Bay chart published by the Department of the Army in 1923. It is based, in part, on some work done in 1908. I have been able to compare past and present water depths at some of the various sampling sites by using 570 ft. above sea level as a common reference point. I am also incorporating historic information, such as dredging/filling activities and known polluttional sources in an effort to better understand the nature of the changes in the rates of deposition and in sediment quality.

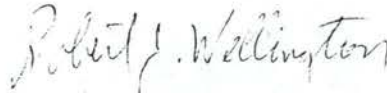
The metals data on sediment that was collected by the Mudpuppy for the Pennsylvania Department of Environmental Resources in 1994 is also being reviewed. I have focused attention on three key metals: arsenic, mercury and lead and their abundance in the core samples as they relate to anthropogenic activities.

Mr. Charles W. Sapp
Page 2
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Eventually I hope to complete a report that integrates some data from your formal 1994 sediment study with metal concentrations.

Thanks again for your concern. If you have any questions, please call me at 814/451-6700.

Sincerely,



Robert J. Wellington
Aquatic Biologist II

cas

cc Kelly Burch
Eric Obert
Sr. Pat Lupo

PS: I also noted that in the 1994 final report, September 29, 1994, Table 3-2, page 3-5, *Mytilopsis leucophaeata* was reported in Presque Isle Bay. If this is so, it would indicate a "new species" for this area. Is it possible for your consultant to verify the species? I suspect that because we have two species of *Dreissena* in the area that one of the two species may have been mistakenly identified as *Mytilopsis*.

