OCS Study
MMS 90-0054

Arthur D Little

Monitoring Hydrocarbons and Trace Metals in Beaufort Sea Sediments and Organisms

Final Report to:
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Contract No.:
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October 1, 1990

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FINAL REPORT

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Submitted to:

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Alaska OCS Region
Anchorage, AK 99510

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Table of Contents

PROJECT ORGANIZATION

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		Major Author(s)	Contributor(s)
Section 1	Introduction	P. Boehm P. Marajh-Whittemore	L. LeBlanc
Section 2	Field Program	J. Brown P. Marajh-Whittemore	L. LeBlanc
Section 3	Analytical Methods	J. Brown P. Marajh-whittemore	L. LeBlanc
Section 4	Presentation of Results	J. Brown J. Trefry L. LeBlanc	P. Marajh-Whittemore A. Schutzberg A. Kick
Section 5	Data Analysis and Interpretation	L. LeBlanc P. Boehm	A. Schutzberg
Section 6	Summary and Conclusions	P. Boehm L. LeBlanc	

Table of Contents (continued)

List of Tables

List of Tables (continued)

List of Figures

List of Figures (continued)

Abstract

As part of the Minerals Management Service's environmental studies of oil and gas exploration and production activities in the Alaskan Beaufort Sea, a study was conducted in 1989 to monitor the marine environment for inputs of chemicals related to drilling and exploration. This study represented a continuation of the Beaufort Sea Monitoring Program (BSMP) first begun in 1984 (Boehm et al., 1987). As before, the 1989 BSMP was designed to monitor sediments and selected benthic organisms for trace metals and hydrocarbons so as to infer any changes that might have resulted from drilling and production activities. A series of forty-nine (49) stations were sampled during this program, thirty-nine (39) of which had been previously studied in the 1984-1986 BSMP. The study area extended from Cape Halkett on the western end of Harrison Bay to Griffin Point, east of Barter Island. The sampling design combined an area-wide approach in which stations were treated as replicates of eight (8) specific geographic regions, with an activity-specific approach, which focused on the potential establishment of metal or hydrocarbon concentration gradients with distance from the Endicott Production Field in Prudhoe Bay. The analytical program focused on the analysis of the fine-fraction of the sediment for a series of trace metals and elements and the analysis of a suite of saturated and aromatic hydrocarbons in the bulk sediment. The total organic carbon (TOC) content and the grain size distribution in the sediments were determined as well. Benthic bivalve molluscs, representative of several feeding types (Astarte borealis, Portlandia arctica, Macoma calcarea, Cyrtodaria kurriana) were collected from those stations for which data previously existed from the 1984-1986 BSMP, and were analyzed for metals and saturated and aromatic hydrocarbons. The benthic amphipods Anonyx sp. were collected, pooled by station or region, and analyzed as well.

Total concentrations of the trace metals in the sediment fine fraction were relatively uniform throughout the study area, suggesting that the fine fraction (<62.5 µm) of sediment was reasonably homogenous across the inner shelf. Ba and Cr were found to be significantly higher in Region 5 adjacent to the Colville River than in other regions and Cr, Cu, and V levels were higher in Region 4. Normalization of trace metal results to percent Fe or Al helped to reduce variability due to sediment mineralogy differences. Regional means for the 1989 metal data set were in close agreement with the previous data. However, systematic differences were observed for Ba and V where the 1989 results were higher (approximately +200 ppm for Ba; +20-40 ppm for V) than previously observed. These differences were believed mainly to be related to the use of ICP in the previous program. Differences were also observed between the 1989 and previous tissue results, although agreement was excellent after correction was made for the reporting basis (i.e. dry weight - weight wet discrepancy). This result indicated that no regional changes in tissue trace metals were detected.

Results for the hydrocarbon analyses indicated that total saturated hydrocarbon levels observed in the 1989 data set were lower than previously observed. These differences can be attributed to improved methods in determining the unresolved complex mixture (UCM) in the 1989 samples as well as overestimated percent recoveries in the 1986 dataset. However, excellent agreement in saturated hydrocarbon (alkane) composition, as evidenced by the LALK/TALK ratio as well as other alkane diagnostic ratios, was observed between the 1989 and previous data sets. This result indicated that no petroleum hydrocarbons attributable to recent drilling or production inputs were detected at any locations. The newly sampled Griffin Point area to the East of Barter Island, contained the lowest levels of all saturated hydrocarbons; however the composition of these hydrocarbons was very similar to those in the other regions. In the Endicott Development area variability between stations can be ascribed to variability in sediment grain size rather than to any source believed to the drilling activities. Metals results also supported this finding.

Concentrations of PAH compounds found in the 1989 samples did not differ significantly those observed previously. Regional differences were ascribed to differences in depositional processes rather than to local pollutant inputs. Significant amounts of petrogenic PAH were observed in all sediments as confirmed in the alkyl homologue distributions. This result confirmed previous findings on PAH levels and distributions. Neither the absolute PAH concentrations nor the compositional information suggested significant input of Prudhoe Bay-type crude oil inputs to the Endicott Development area. No gradients, other than those attributable to grain size differences were observed adjacent to the development area. Use of additional PAH diagnostics (e.g. ratios of individual alkylated P and D compounds) confirmed this result. PAH results for the tissue samples indicated very low levels of PAH - petrogenic or combustion-derived in the tissues. The absence of the sensitive petroleum marker compounds, the dibenzothiophenes and the phenanthrenes, supported the finding that no significant drilling or production-related chemical inputs were detected in the benthic animals of the study area.

List of Abbreviations and Acronyms

AAS - Atomic absorption spectrophotometry
ADL - Arthur D. Little
AHD - Alkyl homologue distribution
ANOVA - Analysis of Variance
ANWR - Arctic Wildlife National Refuge
BSMP - Beaufort Sea Monitoring Program
CHN - Carbon Hydrogen Nitrogen Analyzer
CV - Coefficient of variation (SD/Mean) x 100
DDW - Distilled deionized water
DOI - Department of Interior
EICP - Extraction ion current profile
EPA - Environmental Protection Agency
FFPI - Fossil fuel pollution index
FIT - Florida Institute of Technology
GC - Gas chromatography
GC/FID - Gas chromatography/Flame Ionization Detection
GC/MS - Gas Chromatography/Mass Spectrometry
GFAA - Graphite furnace atomic absorption spectrophotometry
GPS - Global positioning system
ICP - Inductively coupled plasma
INAA - Instrumental neutron activation analysis
ISO - Isoprenoid alkanes
K-D - Kuderna - Danish appartus
LALK - Lower-molecular-weight alkanes
MDL - Method detection limit
MMS - Minerals Management Service
MSD - Mass selective detector
N/P - Naphthalenes/phenanthrenes
NOAA - National Oceanic Atmospheric Association
NOAA/NIST - NOAA/National Institute of Standards
NODC - National Oceanic Data Center
OCS - Outer continental shelf
OEPI - Odd even preference index
P/D - Phenanthrenes/dibenzothiophenes
PPB - Parts per billion (ng/g, µg/L)
PPM - Parts per million (µg/g, or mg/L)
PAH - Polynuclear aromatic hydrocarbons
RF - Response factor
RRI - Relative retention indices
RSD - Relative standard deviation
SD - Standard deviation
SHC - Saturated hydrocarbons
SIM - Selected ion monitoring
SRM - Standard reference material

TALK	Total alkanes
TOC	Total organic carbon (μg/g)
TOT	Total resolved plus unresolved saturated hydrocarbons concentrations (μg/g)
TPAH	Total polynuclear aromatic hydrocarbons (ng/g)
UCM	Unresolved complex mixture (unresolved "envelope")
XRF	X-ray fluorescence

1.0 Introduction

1.1 General Background

Under the Outer Continental Shelf Lands Act (P.L. 92-372), as amended, the Department of Interior (DOI), Minerals Management Service (MMS) is charged with a regulatory mandate requiring the performance of environmental studies in support of offshore oil and gas leasing activities. The marine environment is to be monitored in order to gather information required for assessing potential impacts on the marine environment resulting from oil and gas exploration and development activities. Environmental information is needed to support current and future leasing decisions.

The first lease offering in the Beaufort Sea, held on December 11, 1979, was the joint Federal/State Beaufort Sea Oil and Gas Lease sale. Additional federal lease offerings were held in October 1982 (Sale 71), in August 1984 (Sale 87), and in March 1988 (Sale 97). One additional Beaufort Sea lease offering (Sale 124) is scheduled for February 1991. In response to the high resource potential in the Beaufort Sea, the oil industry has been very active in federal and state leasing areas (Table 1.1). Three-hundred and seventy-two leases were issued as part of these three sales in the Beaufort Sea Planning Area. According to MMS, great interest was shown by industry in the eastern and western Beaufort Sea. This eastern area lies in the coastal plain of the Arctic Wildlife National Refuge (ANWR).

In response to the need to conduct environmental monitoring related to these activities in the Beaufort Sea, MMS and the National Oceanic Atmospheric Association (NOAA) jointly sponsored a workshop in September 1983. This workshop focused on developing approaches to assess the potential for environmental changes and impacts. The proceedings of the workshop (Dames and Moore, 1984) established a framework for environmental monitoring and for implementing the initial phase of the Beaufort Sea Monitoring Program (BSMP). The objective of the initial three-year program was to determine if changes in key toxic and source-diagnostic chemicals were detectable in the Beaufort Sea environment. The three-year study was performed in 1984-1986; the final report of that study was completed in December, 1987 (Boehm et al. 1987).

The 1984-1986 BSMP focused mainly on the areas offered for lease in Beaufort Sea Sales (BF, 71 and 87). The BSMP combined reconnaissance and monitoring effort in the nearshore Beaufort Sea from Pitt Point to Barter Island, concentrating on hydrocarbon and trace metal levels, compositions, and geographical distributions in the study area (Figures 1.1 and 1.2) (Boehm et al., 1985, 1986, 1987; Crecelius et al., 1990; Steinhauer and Boehm, 1990). The design of the program was initially established using the recommendations of the 1983 workshop as a guide. During the course of the BSMP, the sampling and analytical designs were revised in order to better meet the program objectives.

Table 1.1 Summary of Oil and Gas Activities in the Beaufort Sea Planning Area[a]

Sale	Prospect	Block No./OPD	Lease No.	Operator	Wells
71	Antares	971 (NR 5-2)	0280	Exxon	2
87	Orion	8 (NR 5-4)	0804	Exxon	1
BF	Seal Island	472 (NR 6-3)	0180	Shell	1
		516 (NR 6-3)	0181	Shell	1
		State Lease	--		
71	Sandpiper	424 (NR 6-3)	0370	Shell	1
		425 (NR 6-3)	0371	Amoco	1
71	Mars	140 (NR 5-4)	0302	Amoco	1
87	Hammerhead	624 (NR 6-4)	0849	Union	2
87	Corona	678 (NR 6-4)	0871	Shell	1
BF	Northstar	State Lease	--	Amerada Hess	2
--	Niakuk	State Lease	--	Sohio	6
--	Endicott[b]	State Lease	--	Sohio	25[c]
BF	Beechy Point	654 (NR 6-3)	0191	Exxon	2
BF	Tern Island	744 (NR 6-3)	0195	Shell	1
		745 (NR 6-3)	0196	Shell	1
		789 (NR 6-3)	0197	Shell	1
71	Mukluk	280 (NR 5-4)	0334	Sohio	1
71	Phoenix	284 (NR 5-4)	0338	Tenneco	1
87	Eric	705 (NR 7-3)	0912	Amoco	d
87	Belcher	725 (NR 7-3)	0917	Amoco	1
87	Aurora	890 (NR 7-3)	0943	Tenneco	1
87	Thorgisi	495 (NR 7-3)	0903	Amoco	d
BF	Karluk	State Lease	--	Chevron	

[a] Source: MMS, Alaska OCS Region, Anchorage, AK, 1990
[b] In production
[c] As of 10-21-87
[d] Proposed activity

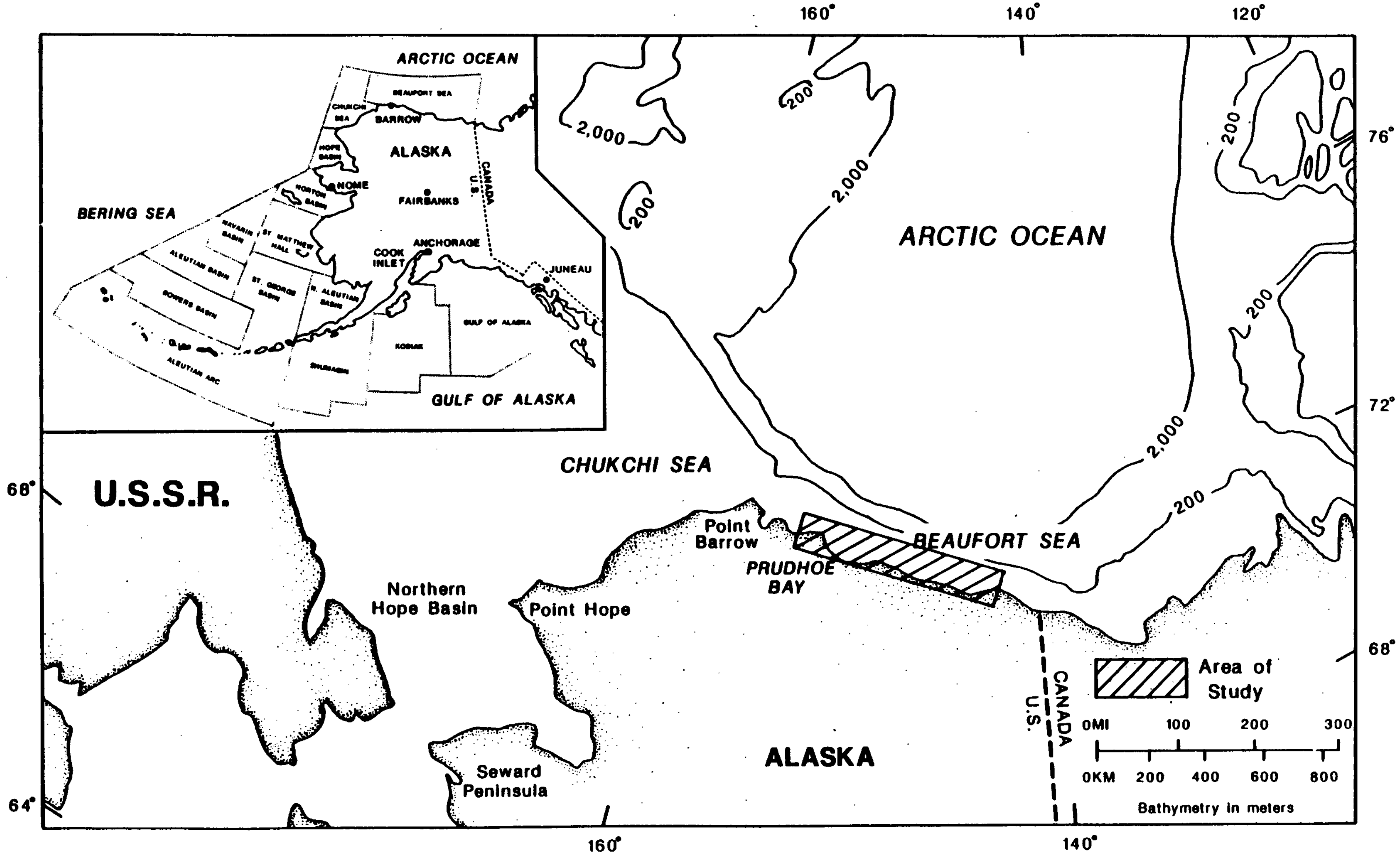

Figure 1.1 Arctic Subregion Planning Area Indicating Location of 1984-1986 Study Area (Alaska OCS Region Shown in Inset)

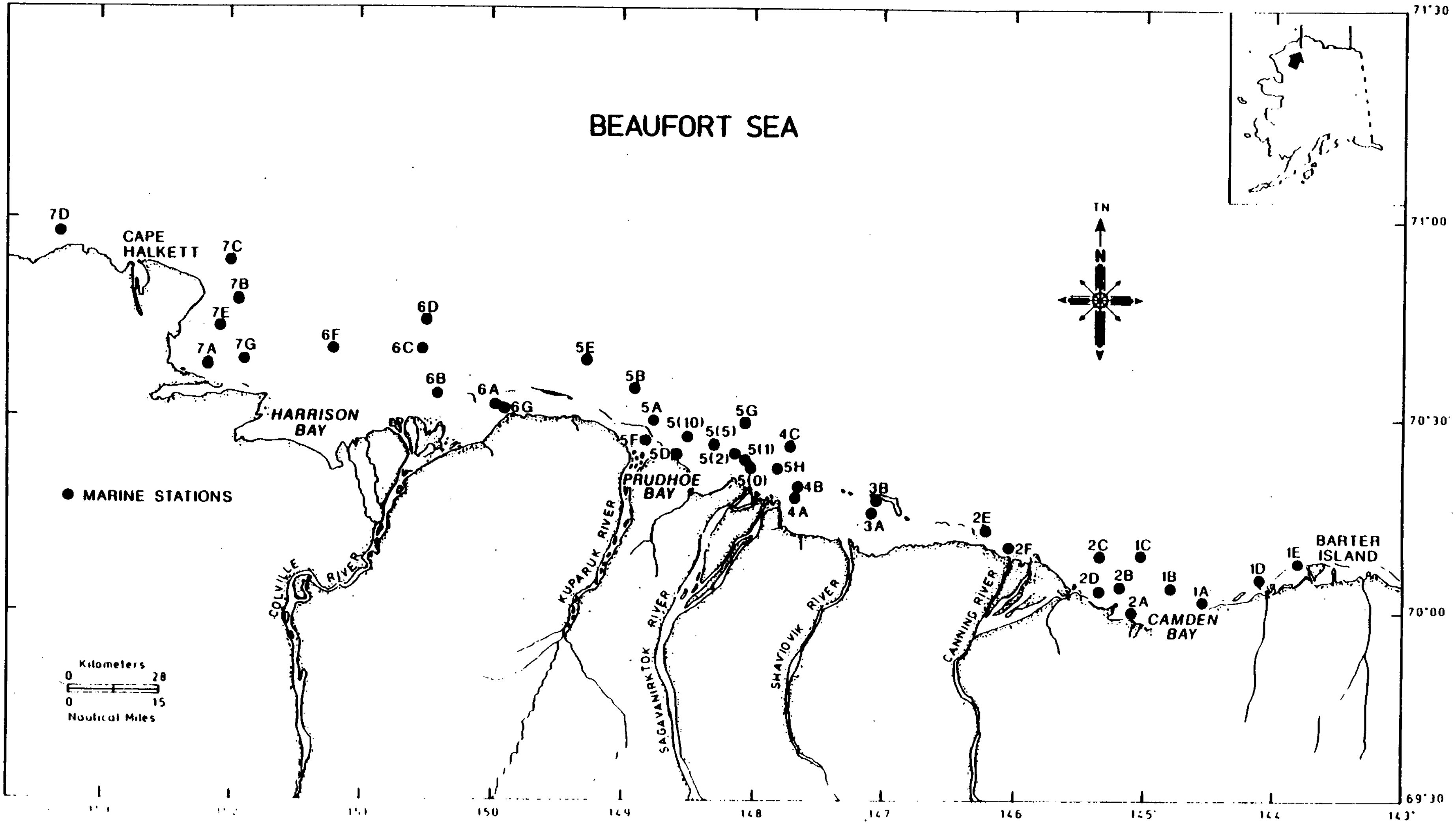

Figure 1.2 1984-1986 Beaufort Sea Monitoring Program Study Area and Station Locations (from Boehm et. al. 1987)

The 1989 BSMP continued and added to the 1984-86 program. The design strategy was linked to the previous approaches of Boehm et al. (1985, 1986, 1987), but included modifications to provide a more efficient and focused technical approach to the program while enhancing the areal coverage of the study.

1.2 Program Objectives

The BSMP was developed to evaluate the impact of oil and gas exploration and production on the marine environment of the Beaufort Sea. The objectives of the 1989 program were as follows:

- To detect and quantify changes in the concentrations of trace metals and hydrocarbons in the Beaufort Sea sediments and sentinel organisms that may
    - result from discharges from outer continental shelf (OCS) oil and gas development activities,
    - adversely affect or induce adverse effects on humans or on the environment, and
    - influence federal OCS regulatory management decisions.
- To identify potential causes of these changes.

In order to address these objectives, and following the recommendations of the design workshop (Dames and Moore, 1983), the following null hypotheses were developed for testing within the framework of the program design:

- Ho1: There will be no change in sediment concentrations of selected metals or hydrocarbons.
- Ho2: Changes in concentrations of selected metals or hydrocarbons in sediments are not related to oil and gas development.
- Ho3: There will be no change in the concentrations of selected metals or hydrocarbons in selected sentinel organisms.
- Ho4: Changes in concentrations of selected metals or hydrocarbons in selected sentinel organisms are not related to OCS oil and gas development.

The following activities, measurements and data analysis techniques were developed and used (Boehm et al., 1987) to test the null hypotheses:

- Collection of continental shelf surface sediments (0-1 cm), and a mixed assemblage of benthic bivalves and gammarid amphipods.
- Laboratory analyses for trace metals and hydrocarbons in sediments and animals, and sediment grain size and total organic carbon in sediments.
- Statistical analyses to test the null hypotheses for evaluating effects of OCS oil and gas-related activities.
- Evaluation of the efficacy of the monitoring program design based on the results, and the recommendation of refinements.

1.3 Summary of the Previous Monitoring Approach

In the 1984-1986 BSMP, the region between Pitt Point and Barter Island was studied for evidence of anthropogenic inputs resulting from oil drilling and production activities. The study focused on hydrocarbons and trace metals in surface sediments, the deposit and adherence of contaminants onto sediment particles, and animal tissues of various feeding types. Three sampling strategies were employed:

1) A regional or area-wide approach.

2) An activity-specific approach at the Endicott development.

3) A gradient approach at Endicott and offshore from the Colville River delta. Thirty-nine (39) sampling stations were selected from within "blocks" (Figure 1.3) having high or highest potential drilling activity and hence "risk" (Dames and Moore, 1983). The selected stations were sampled at least once during the 1984-1986 study. Each station was sampled for surface sediment; for the most part these stations were sampled annually for three years. Each set of station measurements was replicated. A mixture of bivalve molluscs and gammarid amphipods was obtained from a subset of stations. Natural source material river sediments and coastal peat were also examined to aid in the assessment of offshore sediment sources and potential impacts.

The annual and three-year mean values and variances of all measurements were determined at each station. The annual and three-year mean values and variances for all measurements were determined for each of the six delineated regions in the 1984-1986 study. Hydrocarbon and metals measurements were converted to a set of source-diagnostic ratios in order to determine the source of any differences between stations, or at the same stations over the three-year study.

1.4 Design Modifications for the 1989 Study

In the 1984-1986 study, the designs of the sampling and analytical programs were revised annually based on information and data collected as part of the program. In the final report for the 1984-1986 study (Boehm et al., 1987), additional modifications were recommended to the existing program design. The 1989 study incorporated several of the recommendations and the future needs of MMS into the Figure 1.3 program design. Two primary aspects of the original design were:

1) A focus on station locations within lease Sale No. 71 and BF study areas, and

2) A combination of an "area-wide" sampling strategy with an "activity-specific" strategy. The former strategy included mixed placement and random selection of stations within the areas of "highest" and "high" risk, as defined in Dames and Moore, 1983 (Figure 1.3).

The following are the primary design features and modifications that were incorporated in the 1989 program:

1) All 1984-1986 sediment sampling stations were resampled.

2) Stations that were part of the "regional" (area-wide) strategy were re-sampled. Replicate samples from these stations were composited in the laboratory. Each station was treated as a replicate for the region. The hypotheses were tested by comparing three-year regional mean values, to the new, 1989 regional mean value.

3) All replicates of regional stations were analyzed for total organic carbon (TOC), one station in each of the regions were analyzed in replicate for all parameters.

4) The regional strategy was expanded to include 3 stations in a new region east of Barter Island. Samples from these new stations were considered replicates and were analyzed separately.

5) The "activity-specific" and "gradient" strategies focused on the Endicott development area. Six new stations, in addition to the existing five stations were located around Endicott Island. All replicates from the "activity-specific" stations were analyzed for all parameters.

These design modifications are discussed in greater detail later in this report.

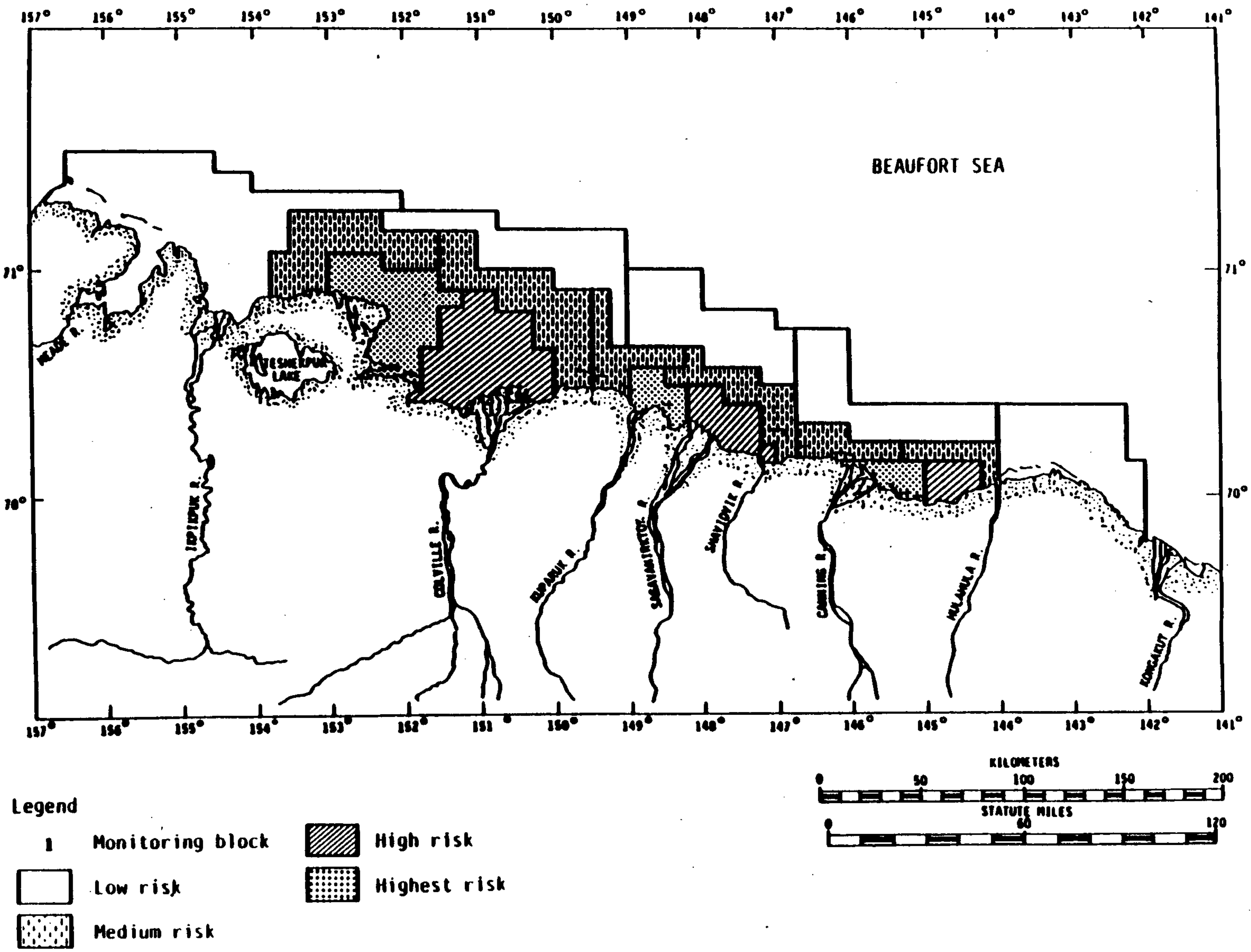

Figure I.3 Sediment Monitoring Network Blocks Showing Assumed Risk Levels and Locations of Potential Sampling Sites

1.5 Analytical Rationale

The analytical program involved the determination of trace metals, saturated hydrocarbons (SHCs), polynuclear aromatic hydrocarbons (PAHs), TOC, and grain size. These analytes were selected on the basis of their association with oil and gas exploration and production, as chemical tracers or important constituents of environmental concern.

TOC and grain size measurements are useful geochemical tools and were used to assist in interpreting trace metals and hydrocarbon distributions in sediments. TOC measurements were used to normalize the hydrocarbon concentrations so that anomalies in the sediment may be correctly attributed to the presence of anthropogenic hydrocarbons (Boehm et al., 1987). Sediment grain size is the measure of the frequency and distribution of particles of differing size ranges within the sediment matrix. Grain-size analysis provided general information on the extent of deposition at the various regions and was used as a normalizing parameter accounting for variability related to particle size.

Nine elements in sediments and seven elements in animal tissues were selected for analysis: barium (Ba), chromium (Cr), vanadium (V), lead (Pb), copper (Cu), zinc (Zn), and cadium (Cd) in both sediment and tissue; iron (Fe) and aluminum (Al) were analyzed in sediment only. Barium, Cr, Pb, and Zn are the metals most frequently present in drilling fluids at concentrations significantly higher than in natural marine sediments. Vanadium is a useful inorganic indicator of oil contamination. Copper and Cd are toxic, but are found only as trace impurities in drilling fluids. Iron and Al can be used to factor out different sediment mineralogy, changes in which may mask differences in the concentration of metals in sediment due to drilling-related contamination.

The hydrocarbon analytical program focused on determinations of total hydrocarbon content as well as detailed saturated hydrocarbon (normal and isoprenoid alkanes) and aromatic hydrocarbon (individual homologous series of two- to five-ring PAHs) distributions.

The concentrations of the major saturated hydrocarbons, which include the C_{10}-to-C_{34} normal alkanes and selected isoprenoids (relative retention indices [RRI] 1380, 1470-farnesane, 1650, 1708-pristane and 1810-phytane), were determined in sediment and tissue samples. These were used to evaluate the nature of the source of hydrocarbons in the samples, and to differentiate biogenic from anthropogenic inputs of hydrocarbons. A number of diagnostic parameters and ratios (Boehm et al., 1987) calculated from results of saturated analysis (e.g., total alkanes, TALK; lower-molecular-weight alkanes, LALK) were used to distinguish between sources of hydrocarbons in the environmental samples (see Section 5, Data Analysis and Interpretation for definitions of these diagnostic parameters and ratios) and to test hypotheses Ho2 and Ho4, which relate to whether pollutant inputs can be attributed to Beaufort Sea oil and gas exploration and production activities.

In recent studies, aromatic compounds, particularly the 2- through 5-ringed PAHs, have been found to be extremely useful in examining both fate and effects issues related to anthropogenic pollution. Additionally, the Beaufort Sea sediments have been determined to contain anomalous PAH concentrations and compositions compared with other OCS sediments (Boehm and Requejo, 1986; Boehm et al., 1987). The PAHs selected for analysis in the sediment and animal samples are listed in Section 3 and include the priority-pollutant PAHs, as well as other environmentally important PAHs. The PAHs of environmental concern include the lower-molecular-weight compounds that may contribute to the acute toxicity in organisms, and the higher- molecular-weight compounds that may produce chronic effects in organisms (Neff and Anderson, 1981). The other PAHs and heterocyclic compounds (dibenzothiophene and its alkyl homologues) targeted, which include parent and alkyl-substituted compounds, were used as part of the determination of the source of hydrocarbons in environmental samples. Concentrations of the selected PAHs in the samples were also used to calculate diagnostic source parameters and ratios.

The concentrations of unsubstituted and alkylated aromatic compounds were used to calculate ratios and geochemical indices that are used to fingerprint petroleum, the degree of weathering, and petrogenic or pyrogenic origins. Specific analytical methods and the significance of the various ratios and indices are further discussed in Section 5.

1.6 Review Of The Study Area

1.6.1 Location. The Beaufort Sea, which is a part of the Arctic Ocean, lies north of Alaska and western Canada, at latitudes approximately 71°N. The Planning Area covers more than 200,000 km^2. However, the proposed Sale 124 lease extends to about the 1,000-m isobath, and would offer approximately 89,000 km^2 for lease. The Planning Area extends from the disputed United States/Canadian jurisdiction line (approximately 141 °W longitude) in the east to 162 °W longitude in the Chukchi Sea in the west. The study area (Figure 1.1) encompasses a distance of approximately 400 km

1.6.2 Physical environment. The nearshore coastal zone of the Beaufort Sea is characterized by numerous narrow barrier islands, particularly between Harrison Bay and Camden Bay. Several rivers drain into the area, the largest being the Colville River. This river accounts for a large fraction of the sediment input into the region. The Alaskan Beaufort Sea continental shelf is quite shallow with an average water depth of 37 meters. It is a relatively narrow feature and the distance from the shore to the shelf break ranges from 60-120 meters. Depths in the Beaufort Sea study area, which extends beyond the shelf break to the upper continental slope, range from 2 meters to slightly more than 1000 meters (MMS, 1990). A dominant oceanographic feature of the Beaufort Sea is sea ice. There are several ice zones defined in this area. Ice scour influences the bottom of the Stamuki zone, a zone of ice shear characterized by massive ice ridges. Circulation on the inner shelf is primarily wind driven. The year-round mean surface current direction along the Beaufort Sea coast, from Barter Island to Point Barrow is to the west. East of Barter Island, there is a mean westward flow in the summer and a mean eastward flow in the winter. Other factors contributing to water movement in the inner shelf waters (depths less than 40 meters) include river discharge, ice melt and geomorphology of the coast (Hachmeister and Vinelli, 1984, from MMS, 1990). Circulation in the outer continental shelf waters and slope waters (depths greater than 40 meters) are dominated by the Beaufort Gyre, which moves water in a westerly direction. Tides are semidiurnal with an amplitude of only 15 to 20 cm (Matthews, 1981) and do not contribute substantially to current flows in areas of open water, such as bays. They are important however within and between barrier islands, and in winter are accelerated by the decreased thickness of the unfrozen water layer (MMS, 1987).

1.6.3 Sediment environment. Primary sources of sediment in this area are riverine input of suspended particulate matter and erosional transport of coastal peat. The riverine and coastal peat contribute significant amounts of organic carbon and fossil hydrocarbons to coastal sediments. Inputs of sediments are characterized by large episodic fluxes of river and erosional inputs. Major mechanisms of large-scale sediment transport and dispersion in the region include transport in suspension, on-ice transport from river overflows, storm-driven bed transport, and ice rafting (Sharma, 1983). Net sediment transport is generally to the west due to prevailing westerly winds. Storms account for large scale shoreline erosion and sediment transport.

1.6.4 Biological environment. Terrestrial carbon, primarily in the form of peat, predominates the coastal marine environment of the Beaufort Sea. The major source of carbon for secondary production appears to be marine primary production rather than peat (Schell et al., 1984). Apparently, amphipods such as Onisimus spp., which are an important food source for major marine predators, have a limited ability to assimilate peat carbon. In contrast, freshwater food chains of the Colville and other rivers in the area are peat-based because the dominant primary consumers, aquatic insects, can utilize peat carbon. Therefore, freshwater food chains are peat-based while marine food chains are phytoplankton-based. Despite the presence of ice cover for much of the year, zooplankton diversity in the nearshore Beaufort Sea is moderately high (Horner and Schrader, 1984). The nearshore benthic infauna and epifauna are extremely depauperate due to seasonal scouring from bottom-fast ice (Broad, 1979). Benthic faunal diversity increases with water depth, seaward from the bottom-fast ice zone, except in the Stamukhi zone. Highly motile animals (i.e., amphipods and isopods) "invade" the area in large numbers during open water season (Griffiths and Dillinger, 1981). Infaunal biomass is quite low ranging from 3.1 g/m^2 in shallow waters (<2 m) to greater than 40 g/m^2 in coastal lagoons.

1.6.5 Chemical and geochemical environment. The chemical environment has been characterized as part of several previous studies (Shaw et al., 1979; Kaplan and Venketesan, 1981; Naidu et al., 1981; Venkatesen and Kaplan, 1982; Boehm et al., 1987; Steinhauer and Boehm, 1990; and Crecelius et al., 1990). The major findings of the recent studies include the following:

- Chemical distributions of metals and hydrocarbons in surface sediments are closely linked to the grain size of the sediment, and to a lesser extent on the total organic carbon levels.

- Riverine inputs are the major source of petrogenic (e.g., PAH) and terrigenous (e.g., normal alkane) biogenic hydrocarbons, with coastal peat also contributing significantly to the alkane and (to a lesser extent) PAH sediment load. Metals levels are also linked to river and peat inputs.

- The geographic distributions of metals and hydrocarbons tend to follow the Colville River influence, with the Harrison Bay region exhibiting higher levels than elsewhere. Some of the differences between regions are significant (see Figures 1.4, 1.5), while others are not (Figure 1.6).

- Levels of trace metals are higher in fine-grained sediment generally furthest from shore.

- Annual variations in chemical levels at any given station are small.

- Levels of Ba and other metals in sediments are relatively high compared with other OCS regions owing to large-scale riverine and peat input.

- Levels of metals in animals are low, but are relatively constant and are highly species-specific (Figure 1.7).

- Ratios of metals in the sediments and those in source materials from platforms (i.e., drilling muds) appear to be quite different, suggesting that metal ratios may parallel hydrocarbon ratios in their importance for monitoring anthropogenic inputs.

- Hydrocarbon assemblages in the sediments are dominated by a combination of terrigenous plant wax inputs (e.g., peat) and fossil inputs. Fossil-fuel-derived PAHs are found in significant abundance throughout the study area due to fossil (coal, oil) inputs, presumably from river discharges and offshore oil seeps. A gas chromatogram (GC) (Figure 1.8) exhibits the fossil inputs quite dramatically.

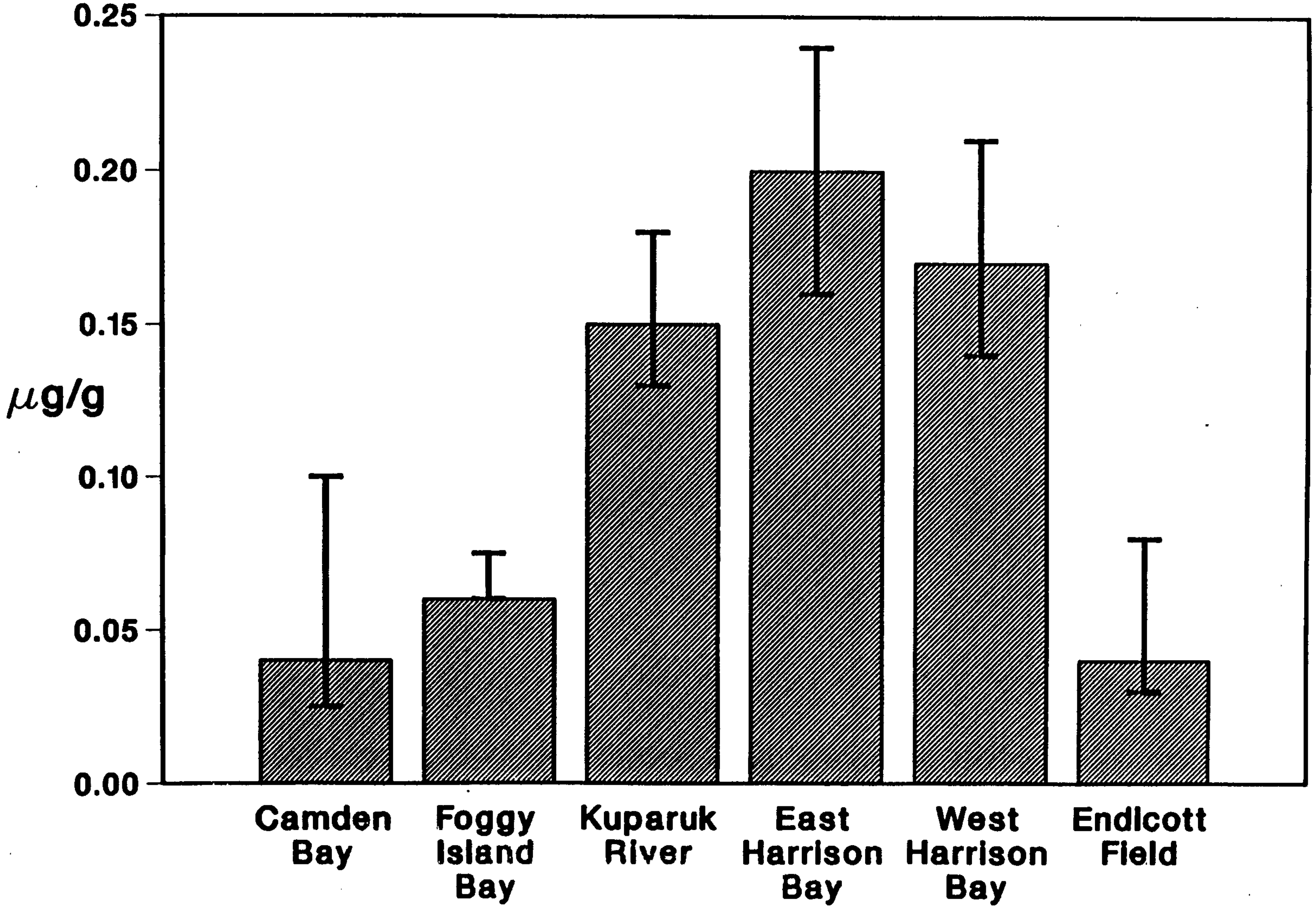

Figure 1.4 **Three-Year Concentration (µg/g) of PAHs in Sediment from Regions in the Beaufort Sea Study Area (from Boehm et al. 1987)**

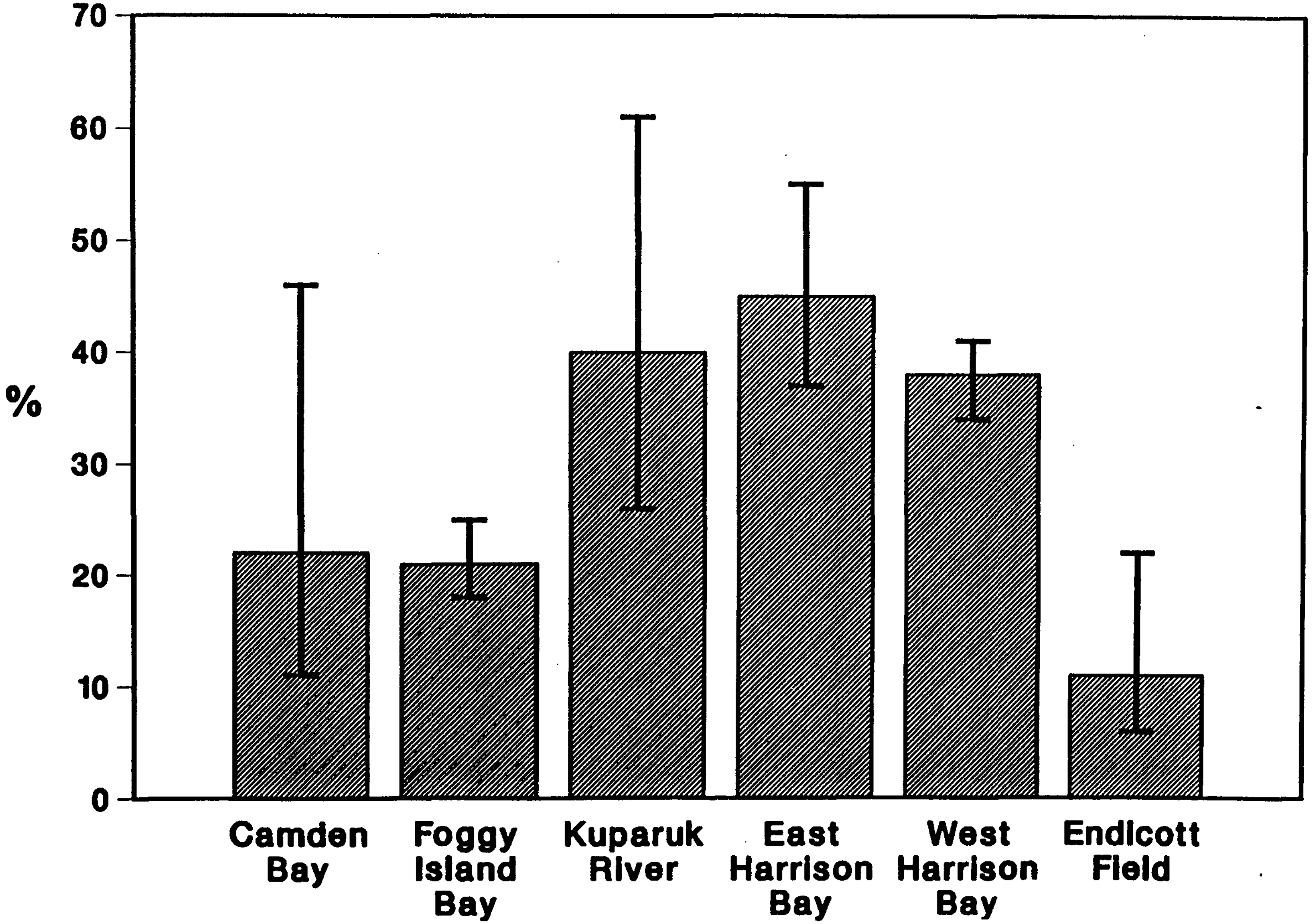

Figure 1.5 Three-Year Mean Percentage of Mud in Sediment from Regions in the Beaufort Sea Study Area (from Boehm et al. 1987)

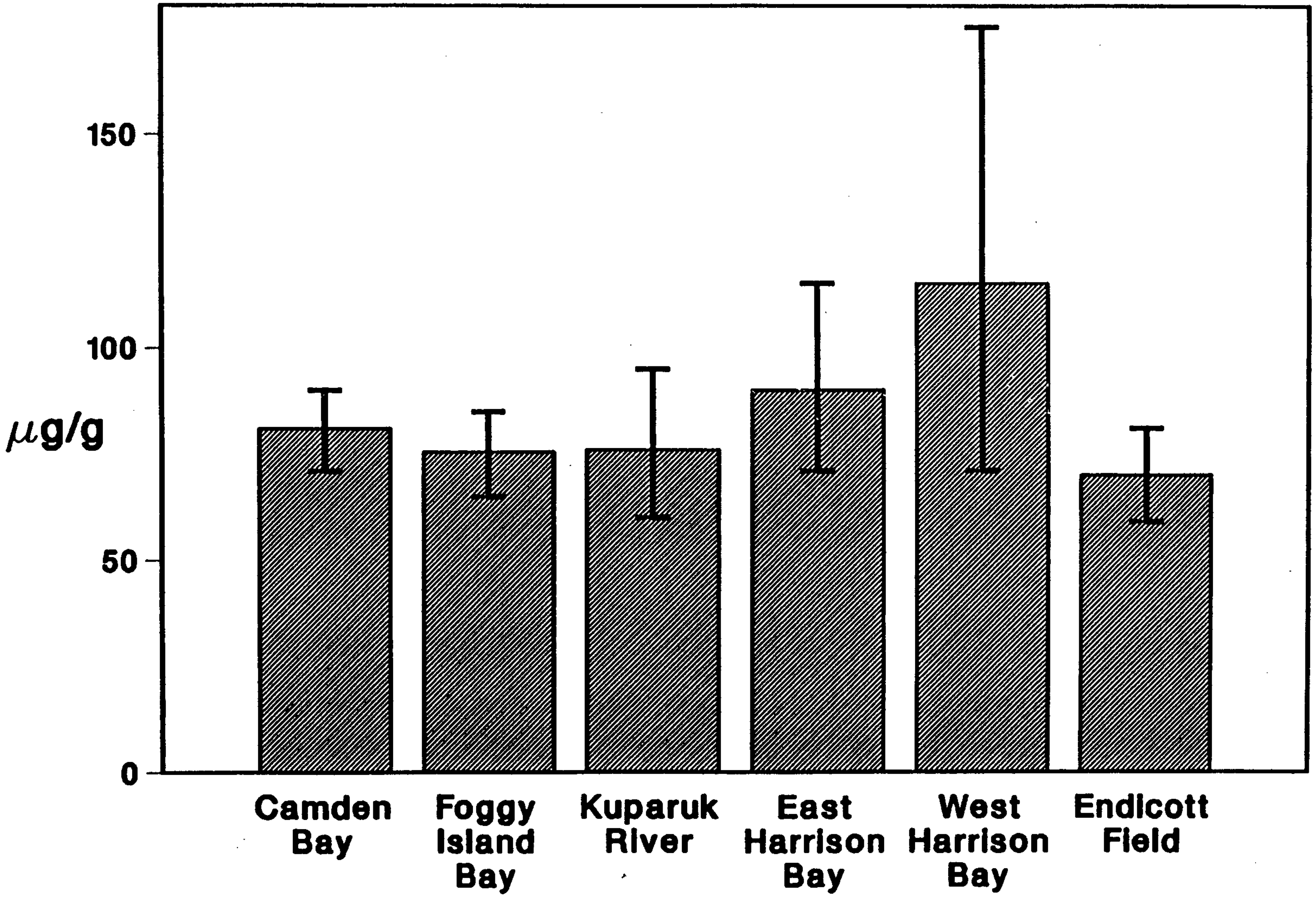

Figure 1.6 Three-Year Mean Concentration (ug/g) of Chromium in Sediment from Regions in the Beaufort Sea Study Area (from Boehm et al. 1987)

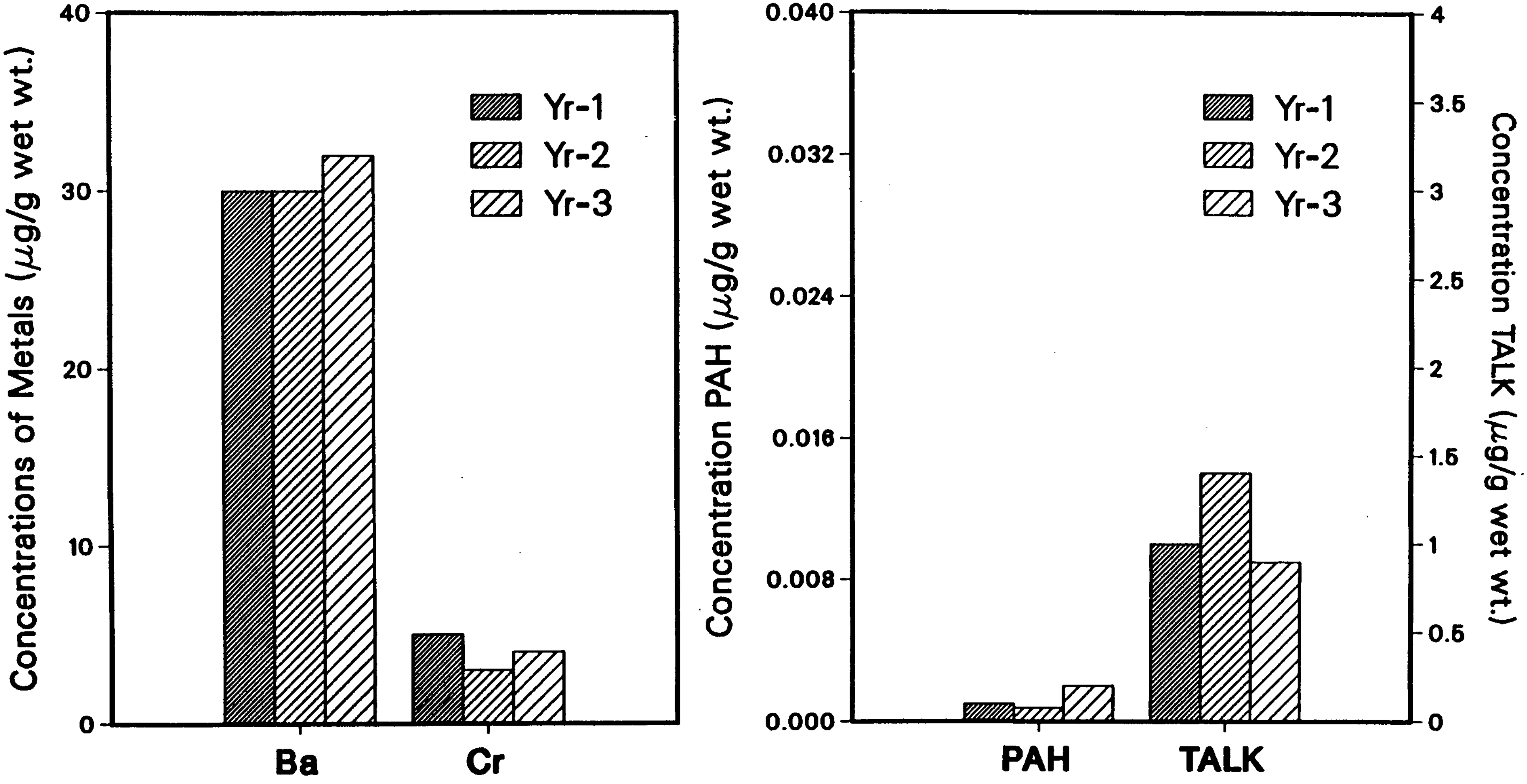

Figure 1.7 Year-to-Year Values of Key Parameters in *Astarte sp.* (Station 6D) in the Beaufort Sea Study Area (from Boehm et al. 1987)

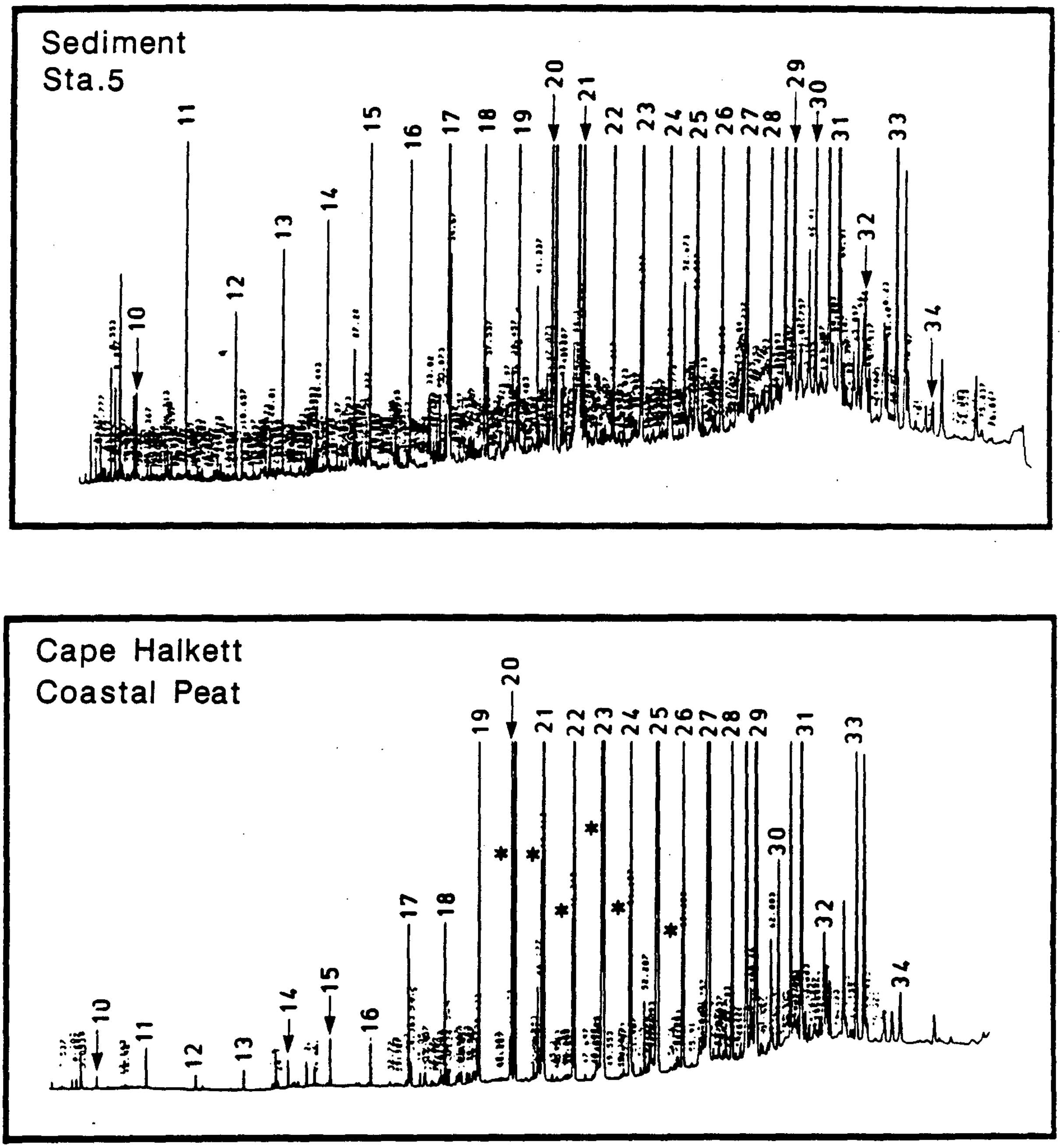

Figure 1.8 Beaufort Sea Saturated Hydrocarbon Composition (from Boehm et. al. 1987)

- The PAH composition as shown in a PAH composition plot (e.g., alkyl homologue distribution plot) (Figure 1.9) is dominated by fossil-fuel-like distributions.
- Key diagnostic SHC and PAH ratios are relatively constant throughout the study area (Figures 1.10 and 1.11), but are different (e.g. phenanthrenes/dibenzothiophenes) than Prudhoe Bay crude oil. These diagnostic parameters were used in source-related hypothesis testing (i.e., Ho2 and Ho4).
- SHC and PAH levels in animals are very low, making animal measurements quite sensitive indicators of future anthropogenic input.
- Due to the relatively high background levels of metals and hydrocarbons in sediments, parameter ratios may be very important for future monitoring studies.
- There is no apparent correlation of chemical levels in animals and sediment.

1.6.6 Quantities of Discharges from Drilling Activities. Summaries of the types of drilling units and estimates of discharges by each unit type in the Beaufort Sea study area are available in the EIS statements of Lease Sales 97 and 124 (MMS, 1987 and 1990). Estmated discharge loads of drilling muds and cuttings are available from the NPDES document for Lease Sale 97 (EPA, 1988). Presented in Table 1.2 is a summary of the amount of solids discharged in the Endicott Development area (ENSR, 1988 report to Standard Alaska Production Company). Locations and quantities of discharges of drilling muds and cuttings throughout the Beaufort Sea region are availabe from the EPA office of Region 10 (C. Flint, personal communication).

1.7 Program Organization

The 1989 study was conducted by scientists from Arthur D. Little, Inc.'s Marine Sciences Unit at Cambridge, Massachusetts, under the direction of Dr. Paul D. Boehm, Program Manager and principal investigator (PI) for hydrocarbons. John Brown, directed the field program and was the task manager for hydrocarbon chemistry; Lawrence LeBlanc, assisted in the data analysis and interpretation. The Florida Institute of Technology (FIT) and EG&G Alaska Operations were subcontractors in this effort. Dr. John Trefry (FIT), served as PI and task manager for metals analyses. Stephen Pace (EG&G), provided critical field sampling and logistical support. Dr. Woolcott Smith (Temple University) consulted on all aspects of the statistical analyses.

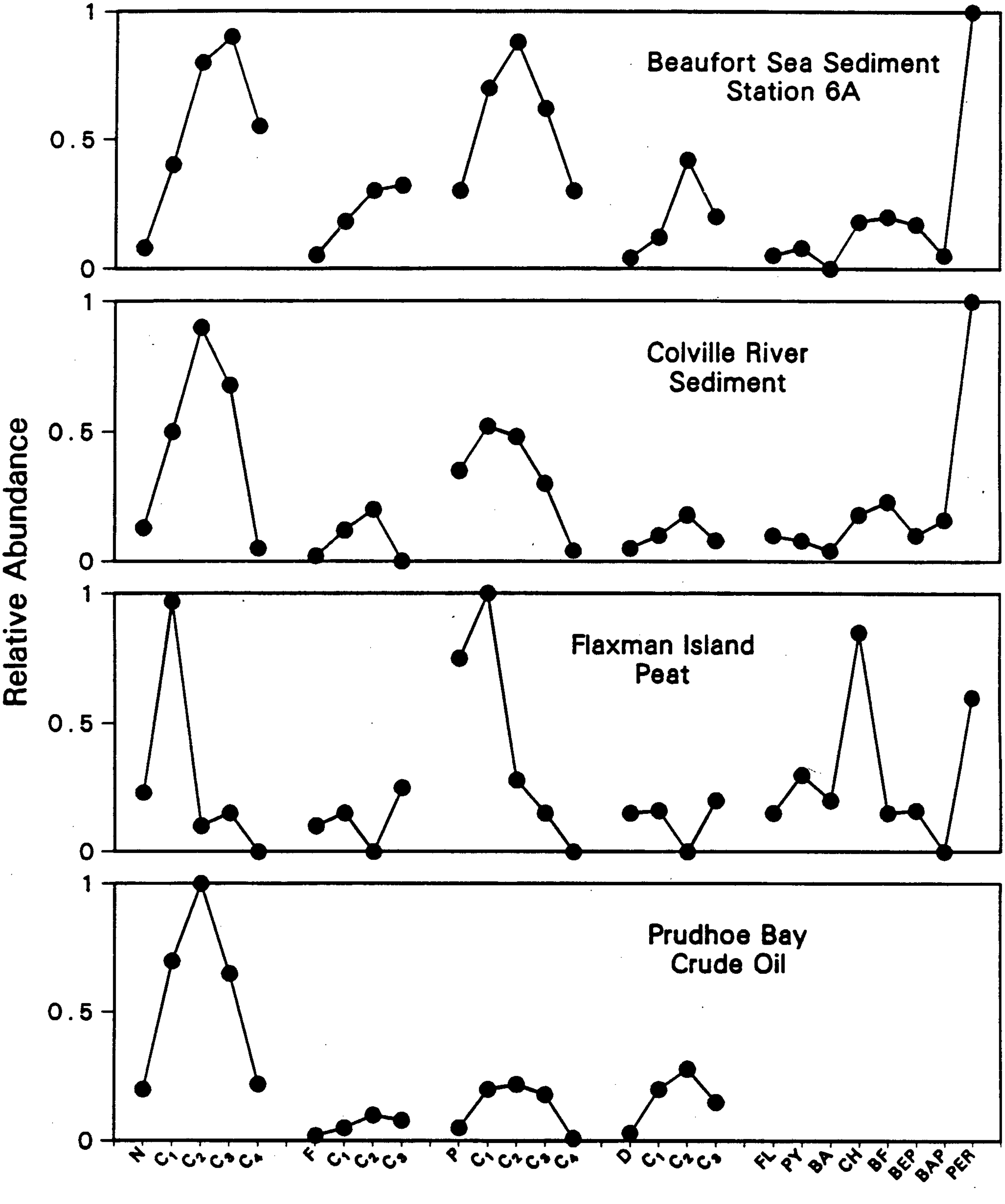

Figure 1.9 Relative Abundance of Aromatic Hydrocarbons in Beaufort Sea Sediments, River Sediments, Shoreline Peat, and Prudhoe Bay Crude Oil (from Boehm, et. al. 1987)

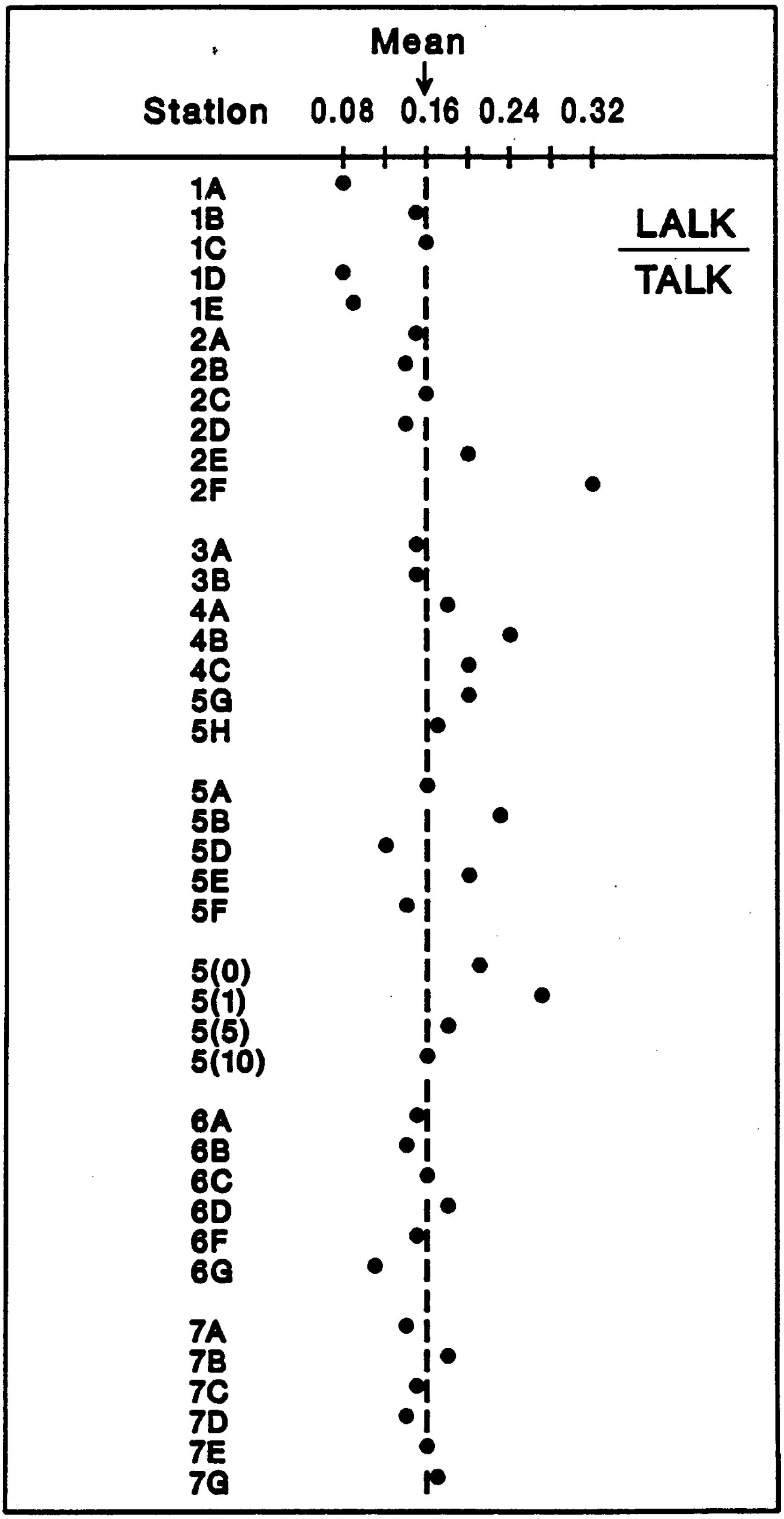

Figure 1.10 Mean Sediment LALK/TALK Ratios at Sample Stations in the Beaufort Sea Study Area

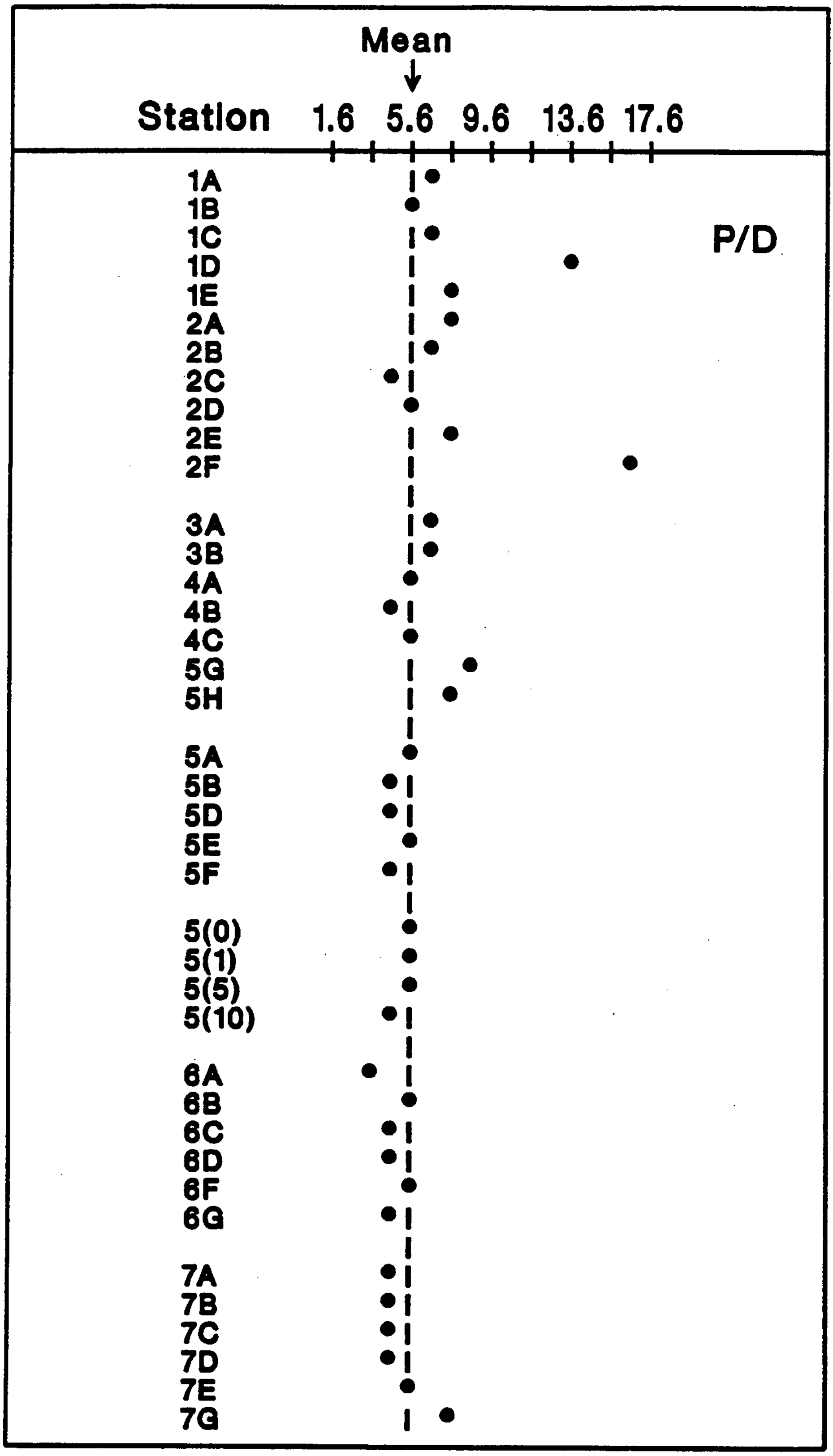

Figure 1.11 Mean Sediments P/D Ratios at Sample Station in the Beaufort Sea Study Area

Table 1.2 Summary of Measured and Estimated Solids Introduced to the Marine Environment as a Result of the Endicott Development*

	Volume of Material (m^3)			
Source	1985	1986	1987	Total
Drilling Mud**,***				
MPI	0	819	1275	2094
SDI	0	0	992	992
Subtotal	0	819	2267	3086
Cuttings**				
MPI	0	2137	3035	5172
SDI	0	1785	3198	4984
Subtotal	0	3922	6234	10156
Total Actual Mud and Cuttings	0	4741	8501	13242

* from ENSR, 1988

** Based on discharge records of the Standard Alaska Production Company. Volumes discharged after October were assumed to be discharges of above-ice disposal sites and would not enter the marine environment until the following year.

*** Values reflect estimated conservative volume of the solids portions of the drilling mud 30% of the total volume.

2.0 Field Program

The field sampling plan was designed to focus on the 1989 program objectives. The sampling design took into account the following:

- The nature and extent of oil and gas exploration and production activity in the study area.
- The previous design of the program, which included the mixed sampling strategy combining area-wide (or regional, area-specific activity) and gradient-specific approaches.
- Statistical design aspects related to hypothesis testing.
- Defensible monitoring science.

2.1 Sample Locations and Sampling Scheme

The 1989 Beaufort Sea Monitoring Program study area with locations of all the sampling stations is presented in Figures 2.1, 2.2 and 2.3. Detailed station locations, depths and number and types of samples collected are included in Table 2.1. All of the sediment and tissue stations sampled in the 1984-1986 program were revisited and resampled (Regions 1 through 6) in the 1989 field program. Geographic regions were delineated by similar geochemical behavior. The low risk regions were Regions 1, 2, 3, 4, and 5. The high risk region was Region 6. The study area was extended to include two new regions in the 1989 program (Regions 7 and 8). Region 7 (low risk region) was located east of Kaktovik and Barter Island and was comprised of 3 stations (Figure 2.2). The study area was extended to this region because of several Amoco prospects and lease sale 97 as well as the potential influence of drilling in the Mackenize River Delta. Region 8 (high risk region) included six additional stations in the Endicott Area (Figure 2.3). These additional sampling stations were located in transects around the Endicott Development Island in order to increase the intensity of monitoring at this important offshore drilling facility.

In this study, a "Station" was defined as an area within 0.3 nautical miles (nm) of a documented location (ie. the station center). This definition is consistent with the previous BSMP and was based on the need to have a large enough area to conduct replicated sampling. The definition of a station and the overall sampling design was based on the assumption that the variability in sediments and animals within a 0.3 nm radius of the center of the station was known based on the previous BSMP data.

The following is a list of the Regions, the stations and the corresponding areas of the Beaufort Sea:

- Region 1 (Camden Bay) - 1A, 1B, 1C, 1D, 1E, 2A, 2B 2D, 2C, 2D, 2E, and 2F

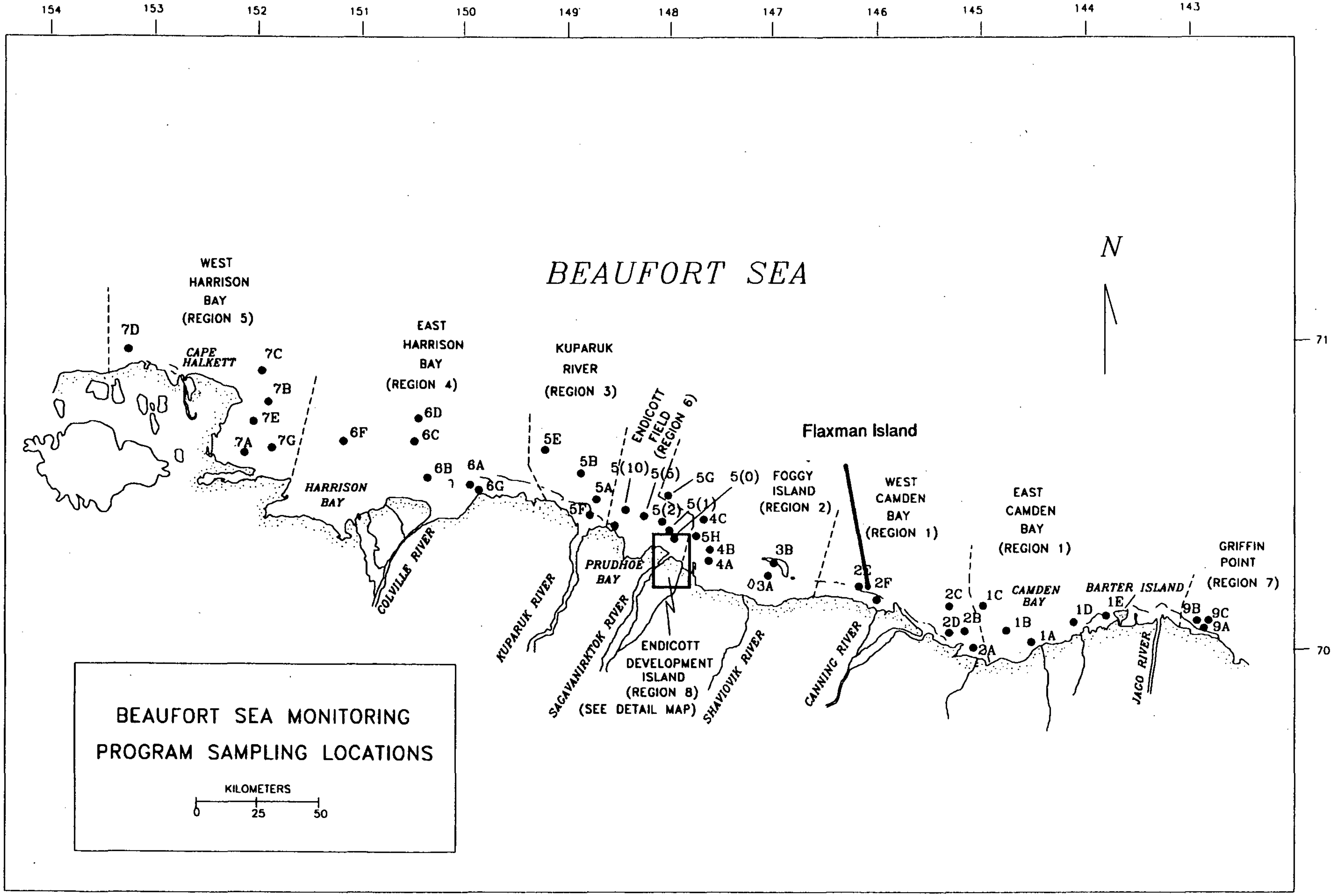

Figure 2.1 Location of Regions and Sampling Stations for the 1989 Beaufort Sea Monitoring Program

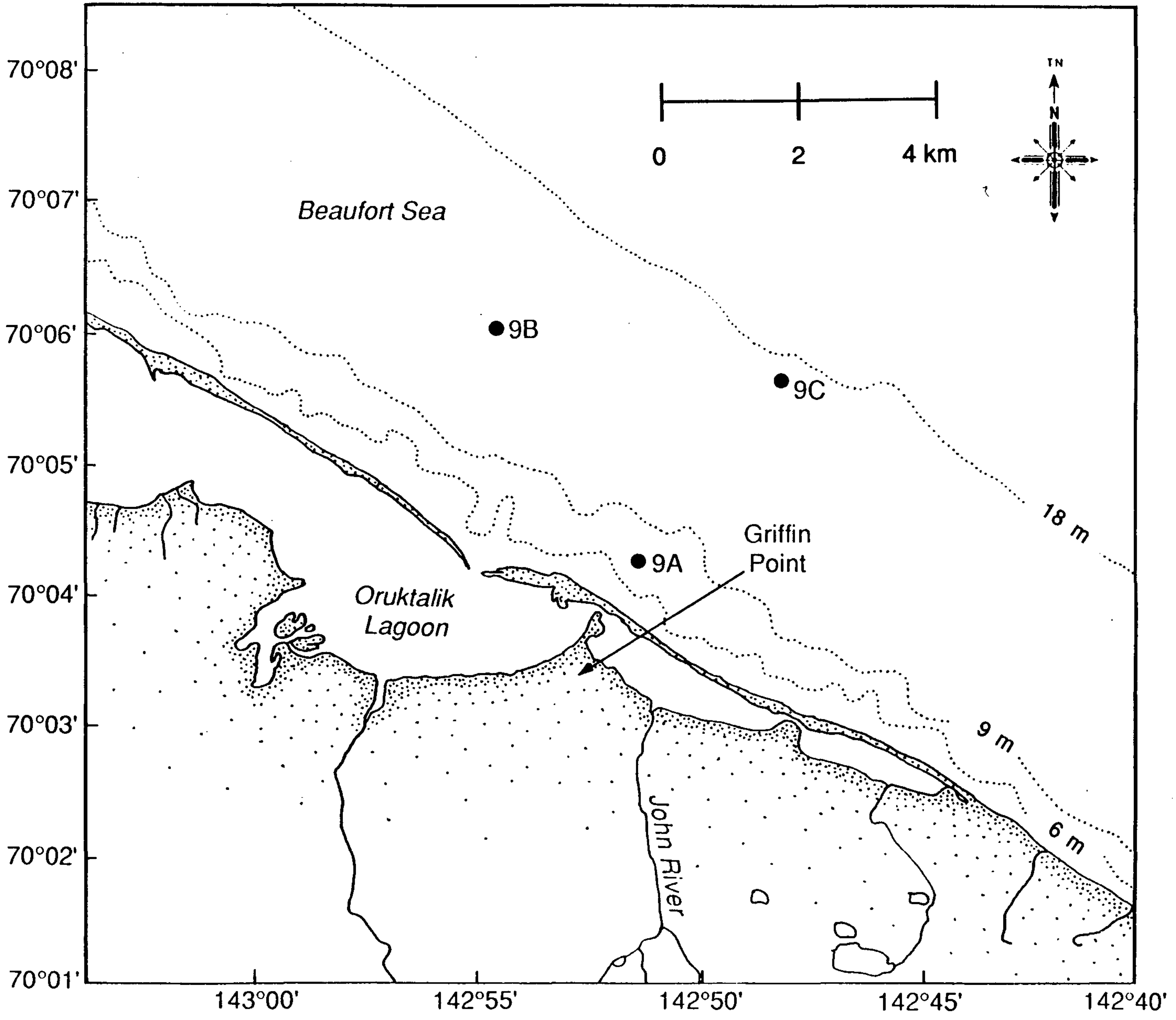

Figure 2.2 Station Locations in Griffin Point (Region 7)

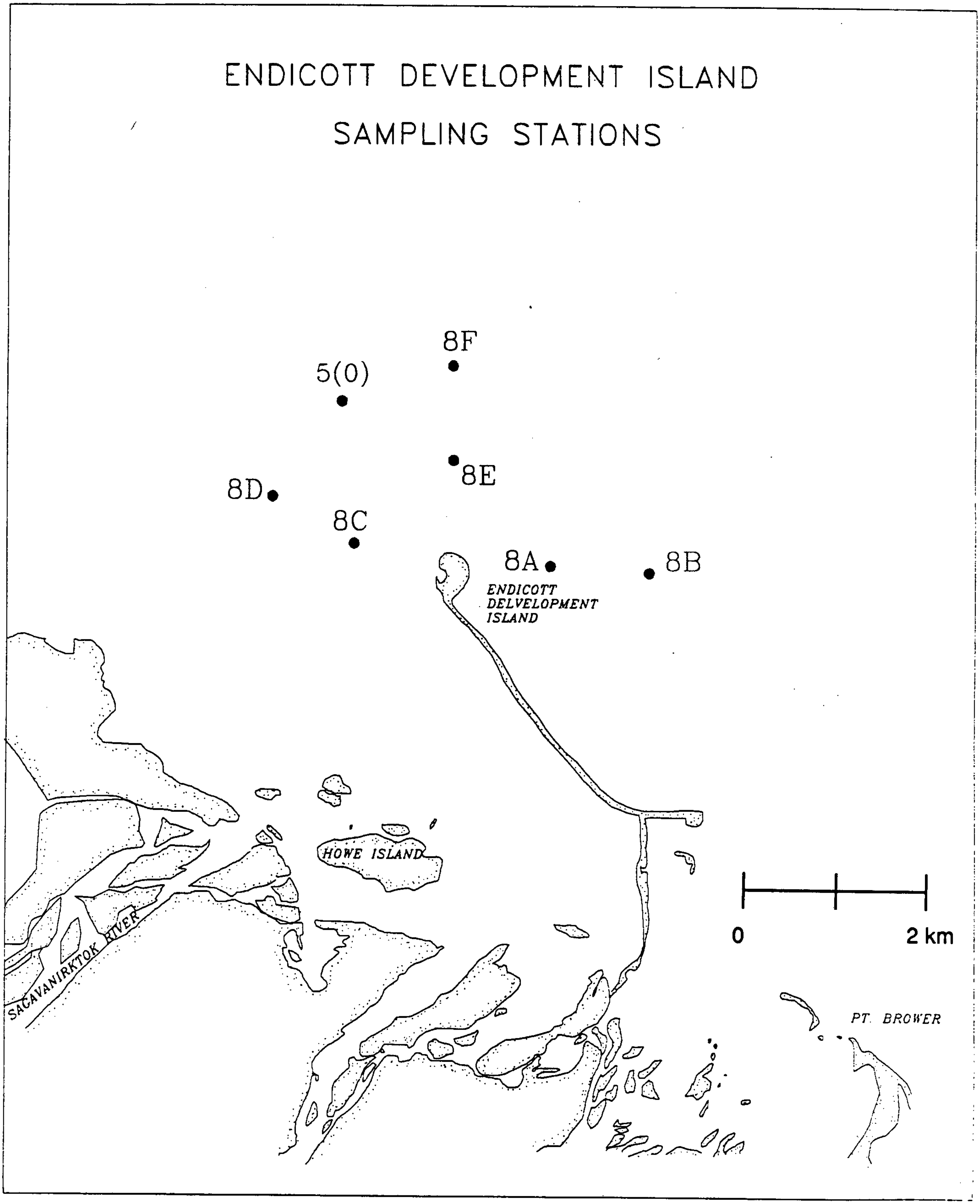

Figure 2.3 Sampling Stations in Endicott Development Island (Region 8). Also included is Station 5(0) from Endicott Field (Region 6)

TABLE 2.1 Summary of Station Locations, Station Depths, and Sample Types Collected During the 1989 BSMP Field Survey

Station	Position Latitude	 Longitude	Depth (m)	Sample Types Collected[1]
1A	70° 01.60'	144° 32.82'	9.8	Marine Sediment, Anonyx, Astarte*, Portlandia
1B	70° 04.20'	144° 47.60'	16.0	Marine Sediment, Anonyx, Astarte
1C	70° 09.19'	145° 01.46'	26.2	Marine Sediment
1D	70° 05.65'	144° 05.41'	7.0	Marine Sediment
1E	70° 06.13'	143° 46.50'	1.8	Marine Sediment, Anonyx*
2A	70° 00.50'	145° 05.70'	5.2	Marine Sediment
2B	70° 04.09'	145° 12.39'	12.2	Marine Sediment
2C	70° 09.80'	145° 20.17'	24.0	Marine Sediment
2D	70° 03.60'	145° 19.30'	7.0	Marine Sediment, Anonyx
2E	70° 12.90'	146° 11.70'	8.0	Marine Sediment
2F	70° 10.30'	146° 02.10'	2.0	Marine Sediment
3A	70° 17.01'	147° 05.55'	6.1	Marine Sediment, Astarte
3B	70° 17.90'	147° 02.40'	4.4	Marine Sediment
4A	70° 18.48'	147° 40.25'	5.3	Marine Sediment
4B	70° 20.98'	147° 39.79'	6.8	Marine Sediment, Anonyx
4C	70° 26.11'	147° 43.10'	9.6	Marine Sediment
5A	70° 29.70'	148° 46.10'	12.1	Marine Sediment
5B	70° 34.90'	148° 55.00'	14.5	Marine Sediment, Anonyx
5D	70° 24.51'	148° 33.57'	2.4	Marine Sediment
5E	70° 38.91'	149° 16.54'	20.0	Marine Sediment
5F	70° 26.48'	148° 49.56'	2.0	Marine Sediment, Cyrtodaria
5G	70° 29.31'	148° 02.59'	10.2	Marine Sediment
5H	70° 22.19'	147° 47.81'	8.0	Marine Sediment, Anonyx*, Astarte
5(0)	70° 22.74'	148° 00.41'	5.5	Marine Sediment
5(1)	70° 25.00'	148° 03.49'	6.7	Marine Sediment, Astarte
5(5)	70° 26.10'	148° 18.09'	7.3	Marine Sediment
5(10)	70° 27.34'	148° 30.12'	8.6	Marine Sediment
6A	70° 32.20'	149° 57.72'	4.0	Marine Sediment. Anonyx
6B	70° 33.36'	150° 24.62'	6.1	Marine Sediment
6C	70° 40.31'	150° 32.12'	16.0	Marine Sediment
6D	70° 44.93'	150° 28.51'	19.9	Marine Sediment, Anonyx, Astarte, Macoma*
6F	70° 40.17'	151° 12.12'	12.7	Marine Sediment
6G	70° 31.40'	149° 54.60'	2.2	Marine Sediment, Anonyx, Cyrtodaria
7A	70° 37.66'	152° 09.89'	1.9	Marine Sediment
7B	70° 47.39'	151° 56.23'	6.7	Marine Sediment
7C	70° 54.85'	152° 00.30'	14.6	Marine Sediment
7D	70° 57.60'	153° 17.57'	6.9	Marine Sediment
7E	70° 43.55'	152° 04.40'	4.2	Marine Sediment, Anonyx
7G	70° 38.90'	151° 53.64'	3.1	Marine Sediment
8A	70° 21.40'	147° 55.13'	4.6	Marine Sediment
8B	70° 21.41'	147° 52.86'	5.6	Marine Sediment
8C	70° 21.66'	148° 59.61'	1.7	Marine Sediment
8D	70° 21.91'	148° 01.55'	1.9	Marine Sediment
8E	70° 22.10'	147° 57.43'	6.0	Marine Sediment
8F	70° 22.90'	147° 57.36'	5.7	Marine Sediment
9A	70° 04.06'	142° 51.15'	8.0	Marine Sediment
9B	70° 05.96'	142° 54.10'	16.0	Marine Sediment, Macoma sp.*, Portlandia*
9C	70° 05.72'	142° 48.60'	20.7	Marine Sediment

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[1] Marine sediment indicates four sample replicates consisting of ~350 g each.

* Indicates tissue sample too small for replicate analysis.

In addition, a total of 28 field blanks (atmospheric, seawater system, container, and grab rinse) were collected.

- Region 2 (Foggy Island Bay) - 3A, 3B, 4A, 4B, 4C, 5G, and 5H
- Region 3 (Kuparuk River Bay Area) - 5A, 5B, 5D, 5E and 5F
- Region 4 (East Harrison Bay) - 6A, 6B, 6C, 6D 6F and 6G
- Region 5 (West Harrison Bay) - 7A, 7B, 7C, 7D, 7E and 7G
- Region 6 (Endicott Field) - 5(0), 5(1), 5(5), and 5(10)
- Region 7 (Griffin Point) - 9A, 9B and 9C.
- Region 8 (Endicott development Island) - 8A, 8B, 8C, 8D, 8E, and 8F

The sampling and field processing techniques used in the 1989 study were identical to those used in the previous BSMP study. Sampling composite and individual replicate analytical strategies were consolidated in the 1989 study in order to improve the efficiency of the program. The sample composite and replicate scheme is summarized in Table 2.2.

2.2 Cruise Narrative

The field operations for the 1989 BSMP started in late July 1989. The field sampling program involved the reoccupation of all of the year 3 BSMP stations (with the exception of river sediment stations) as well as the addition of three new stations east of Barter Island (off Griffin Point) and six new stations in transects off Endicott development island. Emphasis was placed on obtaining bivalves and amphipods for tissue analysis at stations where they had been collected previously.

The 1989 sampling program was accomplished with two field scientists (John Brown, ADL Field Party Chief and Steve Pace, EG&G) and the NOAA vessel 1273 ship's captain (Pat Harmon, NOAA). There were several modifications to the vessel and equipment additions which enabled the survey to be conducted efficiently by a survey crew of three. The major vessel modification was the addition of a mast amidships (which extended the ship's exhaust an additional three feet above the deck) with a seining boom which aided in the loading of cargo and scientific gear. The equipment additions included; a Magnavox global positioning system (GPS), a Furuno weather FAX, a Furuno 48-mile range radar, a Ray Jeff video depth finder, and an ARNAV aviation Loran.

John Brown and Steve Pace arrived in Prudhoe Bay on July 30, 1989. The scientific gear was assembled aboard NOAA Vessel 1273 and the seawater system inspected and cleaned on July 30-31. A preliminary reconnaissance overflight was made to observe the ice conditions which proved to be favorable. NOAA vessel 1273 was

TABLE 2.2 Field Sampling Summary

Sample Type	# of Stations	Replicates	Total
SURFACE SEDIMENTS	8(a)	3	24
	6(b)	3	18
	3(c)	3	9
	31(d)	1*	31
BIVALVES			
Astarte	6(e)	3	18
Cyrtodaria	2(f)	3	6
Portlandia	2(g)	3	6
Macoma	2(h)	3	6
AMPHIPODS			
Anonyx	5(i)	3**	15
	2(j)	3***	6
TOTAL			139

Notes:

(a) Stations 1E, 3B, 5A, 5-0, 5-1, 5-5, 6D, 7B.
(b) Additional 6 stations in Endicott Area designated 8A, 8B, 8C, 8D, 8E, 8F.
(c) New stations East of Barter Island in Amoco prospect area - designated 9A, 9B, 9C.
(d) Stations 1A, 1B, 1C, 1D; 2A, 2B, 2C, 2D, 2E, 2F; 3A; 4A, 4B, 4C; 5B, 5D, 5E, 5F, 5G, 5H; 5-10; 6A, 6B, 6C, 6F, 6G; 7A, 7C, 7D, 7E, 7G.
(e) Stations 1A/B, 3A, 5-1, 5-H, 6D.
(f) Stations 5F, 6G.
(g) Stations 1A and 9B (new).
(h) Stations 6D and 9B (new).
(i) Composite samples from combined stations in Regions 1, 2, 3, 4, and 5.
(j) Stations from region 1 (Stations 1A, 1B, 1E) and Region 4 (Stations 6A, 6D, 6G).
* Denotes composite samples of 3 replicates.
** Denotes single station animal composite, split into three (3) laboratory replicates.
*** Denotes combined samples from different stations in same general area, which are then split into three (3) laboratory replicates.

launched on August 1, 1989, initiating the field survey. The field survey was essentially accomplished in three cruise legs as follows:

Leg 1 - Camden Bay and points east to Griffin Point: August 1-7 1989

The first stations occupied were those farthest east, off Griffin Point. The ship was refueled at Barter Island and four current meters were deployed for the U.S. Fish and Wildlife Service (another program) prior to arriving at Griffin Point. The passage through Mary Sachs entrance was accomplished without difficulty; however, heavy ice floes were encountered at the historical choke point north of Barter Island. Passage to the east of Barter Island was accomplished by following leads through the ice floes which increased transit time. Sediment samples were collected at stations 9A, 9B, and 9C and two small bivalve samples were obtained at 9B. The collection of amphipods, however, proved unsuccessful at all three stations. Camden Bay stations 1A, 1B, 1C, 2A, 2B, 2C, and 2D and Canning River stations 2E and 2F were all occupied for sediment chemistry grab samples. Bivalves were collected at stations 1A and 1B and amphipods sufficient for sampling were obtained at stations 1A, 1B, 1E, and 2D. On the return trip to Prudhoe Bay, sediment samples were taken at stations 3A and 3B and bivalves collected an station 3B. The vessel arrived back at Prudhoe Bay on August 7, 1989 and was refueled and resupplied in preparation for Leg 2.

Leg 2 - Harrison Bay and Oliktok Point Area: August 9-12, 1989

An aerial reconnaissance flight was made on the morning of August 9 to determine the ice conditions in Harrison Bay and points west. The ice situation proved to be very favorable, in some areas the floe ice was up to 30 miles offshore. On the second leg of the survey, Oliktok point stations 6A and 6G were sampled enroute to Harrison Bay. Amphipods were successfully collected at both stations and bivalves of the genus Cyrtodaria were collected. Sediment grab samples were taken at Harrison Bay and Cape Halkett stations (6C, 6D, 6F, 7A, 7B, 7C, 7D, 7E, 7F, and 7G). Astarte and Macoma clams were obtained at station 6D and Anonyx spp. amphipods were taken at stations 6D and 7G. Strong winds and the long fetch due to the ice free conditions hampered the sampling operations in Harrison Bay and the field party worked a 24 hour shift to finish the Harrison Bay stations and return to more protected waters before the onset of a storm forecasted by the weather FAX. Stations 5B and 5E were occupied on the return trip to Prudhoe Bay. Sediments were collected at both stations and amphipods were captured at station 5B. The field party arrived back at Prudhoe Bay on the evening of August 12, the vessel was refueled and resupplied on August 13, however bad weather delayed the start of the third leg of the survey until August 15.

Leg 3 - Prudhoe Bay Area and Endicott Development Island: August 15-19, 1989

On Survey Leg 3 the eastern Prudhoe Bay area stations (4A, 4B and 4C) and the Endicott Development Island stations (8A, 8B, 8C, 8D, 8E, 8F and 5(0)) were sampled first. Sediment chemistry grab samples were collected at all stations and amphipods were taken at station 4B. Fine sand substrate was encountered at most of the new Endicott Island stations (8A-F). Strong northeast winds continued to build throughout the sampling operations and boat was forced to anchor at west dock in Prudhoe Bay on August 17 to wait for a shift in the weather pattern. A break in the weather occurred on August 19 and sampling activities were resumed. Stations 5(1), 5(5), 5(10), 5A, 5D, 5F, and 5G were all sampled on August 19. Sediments were collected at all stations; Cyrtodaria clams were obtained at station 5F and Astarte were collected at station 5(1). All sampling was completed before midnight on August 19, 1990.

There were numerous factors which contributed to the successful completion of the 1989 BSMP field effort. The lead time for planning, preparation and implementation was adequate thus reducing logistical problems. The ability to refuel at Barter Island allowed access to the eastern most stations which would otherwise have been outside the range of the vessel. Most importantly, the global positioning system (GPS) enabled real-time navigation throughout the sampling area. The GPS provided approximately 10 hours per day coverage, at different time intervals, where accurate navigational information could be obtained. The extended daylight hours in August enabled the crew to take full advantage of the GPS navigation windows, two of which were between 1 and 4 AM. In most instances the weather FAX provided ample warning of the onset of adverse weather conditions and allowed sampling activities to be planned accordingly. The reconnaissance flights were also beneficial in planning and executing the cruise track.

Finally, the experience and dedication of the field party in conjunction with the previously mentioned factors resulted in the successful completion of the 1989 BSMP field survey, 9 days ahead of the originally proposed schedule.

2.3 Sampling Equipment and Methods

All field sampling was conducted according to methods and protocols specified in the field sampling manual specifically drafted for this program.

2.3.1 Sediment Sampling. All sediment samples were collected with a 0.1 m^2 stainless steel Kynar coated, modified Van Veen grab (T.Young, Sandwich, MA). Sub-samples of the sediment grabs from 0-1 cm depth interval were obtained with a Kynar coated, calibrated scoop, designed to reproducibly obtain the required sample. After the grab sampler was deployed and retrieved, the overlying water was removed using a suction system attached to a Teflon tube. Four (4) grab samples were collected at each station, three for analysis (either individually or as part of a composite), and one for archival. The minimum sample size collected was approximately 300 g, which ensured sufficient sample for analysis (150 g for hydrocarbons, 10 g for metals, 10 g for TOC and 50 g for grain size). Each grab was sub-sampled with a 1 cm calibrated scoop and the sediment from both sides of the grab was transferred to a pre-cleaned 250 mL glass jar.

2.3.2 Bivalve and Amphipod Sampling. Bivalves were collected at the stations indicated in Table 2.2, with the 0.1 m^2 modified Van Veen grab used to collect sediments. Sediment collected with the grab sampler was sieved for bivalves through a 5-mm Nytex screen using a high-volume Jabsco epoxy/polyethylene pumping system (seawater) to wash the sediment. The bivalves remaining on the sieve were transferred with forceps to pre-cleaned 250 mL glass jars. Approximately 40-80 grab samples were collected at each station to obtain a sample of sufficient size for replicate analyses (~50-80 g).

The air lift system proved to be unsuccessful in collecting bivalves of sufficient number for the sample size required. The air compression system was incapable of providing the necessary lift to collect clams which were buried in the fine silt/clay substrate and a more powerful compressor could not be obtained without delaying the survey. As a result, all the bivalve samples for the 1989 survey were collected using the repetitive grab sampling technique. The type of compressor used was a portable compressor used to fill scuba tanks. This compressor was designed to deliver a low volume of air to a high pressure (up to approximately 2500 psi), and consisted of an engine driving multiple pistons of gradually decreasing size, which increased the pressure of the air travelling through the compressor. In retrospect, it was realized a compressor to deliver a high volume of air at a lower pressure (as in the type of compressor used to power air tools) was needed. The type of compressor used, rather than the size of the engine, was the important factor. Sampling for bivalves was also complicated by patchy distribution of organisms and sediment types. It is believed that this airlift system could be successful in soft substrate, and moderately successful in harder substrates (S. Pace, personal communication), but additional testing would be required prior to actual use in the monitoring program.

Amphipods were collected at the stations indicated in Table 2.1, using baited minnow traps. At every historical amphipod station, Kynar coated minnow traps with a fine mesh Nytex liner were deployed. The traps were baited with tuna or sardines and marked with a radar reflecting surface float which was secured to a small anchor. After 2 to 6 hours of deployment the traps were retrieved and Anonyx amphipod samples of sufficient size (>50 g) were collected in pre-cleaned glass jars. As in previous years of the program, the distribution of Anonyx proved to be patchy, with some stations yielding an abundance of organisms and other stations producing only a few individuals. However, amphipod samples of sufficient size were obtained from the majority of stations where they had been collected previously.

2.3.3 Field Data Management and Sampling Handling. The field manual for this study served as a guide to the field personnel for all phases of the field program. The manual included general protocols for the sampling of sediments, bivalves and amphipods, precautions to minimize sample contaminants, sample custody and identification forms, and field logs.

All information and data pertaining to the field survey and sampling activities were recorded in one of four log books. These included the station log, the cast log, the sample identification log, and the Field Party Chief's log. The type of information included in each of the logs was as follows:

Station Log. Station coordinates (latitude and longitude), the date and time of sampling operations, water depth, and type of navigation used.

Cast Log. All information concerning the deployment of the different types of sampling gear and the success of every cast at each station was recorded in the Cast Log. The lowering of each gear was assigned a consecutive cast number at each station. The cast number, success of the cast, and sample number that was assigned to samples collected was indicated. The date and time of the cast were also recorded.

Sample Identification Log. These forms recorded the identification of all samples collected in the field including the sample number assigned. The sample identification number consisted of an alphanumeric identification number which included the station number, the sample type, and the replicate number.

Field Party Chief's Log. The Field Party Chief maintained a log book documenting the field survey. This log included information about each station occupied, ice conditions, weather conditions, time at station and other relevant information.

All sediment, bivalve and amphipod samples were frozen immediately after collection in pre-cleaned glass jars. The samples were frozen in polyethylene foam coolers containing dry ice (-78 °C). The samples were air-freighted in the coolers to EG&G's Anchorage office, where the coolers were repacked with dry ice and air-freighted to ADL headquarters in Cambridge, Massachusetts. Prior to shipment, the sample identification number of each sample was verified, and transferred to an ADL Sample Custody Form. One copy of each signed form was enclosed with the sample shipment, a copy was mailed to the Program Manager, and one was kept by the Field Party Chief.

3.0 Analytical Methods

The following sections describe the analytical methods used for the analysis of marine sediments and biological tissue samples for hydrocarbons, metals, and TOC and grain size (sediments only).

3.1 Replication Scheme

The design of the analytical program called for random selection and pooling of three of the four sediment station replicates as well as pooling of bivalve specimens from each station for chemical analyses. As discussed in Section 2.2, the four replicate samples were obtained from a 0.1 m^2 Van Veen grab. Bivalve replicates were obtained by subsampling a pool of all animals collected at a station.

Four sediment grab samples were obtained at each station, three of which were analyzed (either individually or composited), and one of which was archived. Thirty-one stations were selected for replicate compositing. Three of the four replicates of the remaining 17 stations were analyzed individually. Each composited or individual sample was then split accordingly for analysis (Figure 3.1).

Tissue samples were pooled in the laboratory, pooled samples were split into 4 replicates. Three of the replicates were analyzed and one archived. Each replicate was analyzed for saturated and aromatic hydrocarbon and trace metals (Fig 3.2). For each replicate analysis, at least 10 g wet weight was used for the hydrocarbon analysis and a minimum of 2 g wet weight for the trace metals analysis.

3.2 Trace Metals

3.2.1 Sediment preparation methods. Sediments from the Beaufort Sea were delivered frozen in acid-washed polystyrene vials to the Chemical Oceanography Laboratory at Florida Institute of Technology (FIT) and logged upon receipt. Initially, each sediment sample was thawed and carefully homogenized with a Teflon mixing rod. The sample was then split into two separate aliquots. One aliquot was set aside to be sieved; the remaining aliquot was archived for possible future reference.

Each wet sediment sample was passed through a 62.4-µm nylon mesh sieve to obtain the fine fraction (silt/clay). Previous sediment analyses for metals in the BSMP have been carried out on the fine fraction to increase the likelihood of identifying anthropogenic perturbations. Trace metals are generally associated with the fine fraction and in some samples this fraction is less than 10 percent of the total bulk sediment. In such instances, analysis of the relatively metal-poor bulk samples increases the difficulty of clearly identifying contaminant inputs. During the sieving process, samples were washed through the sieve using pH 7.5 (pH adjusted with ultra-pure ammonium hydroxide) distilled, deionized water (DDW) to control contamination as well as leaching of metals into the rinsing solution.

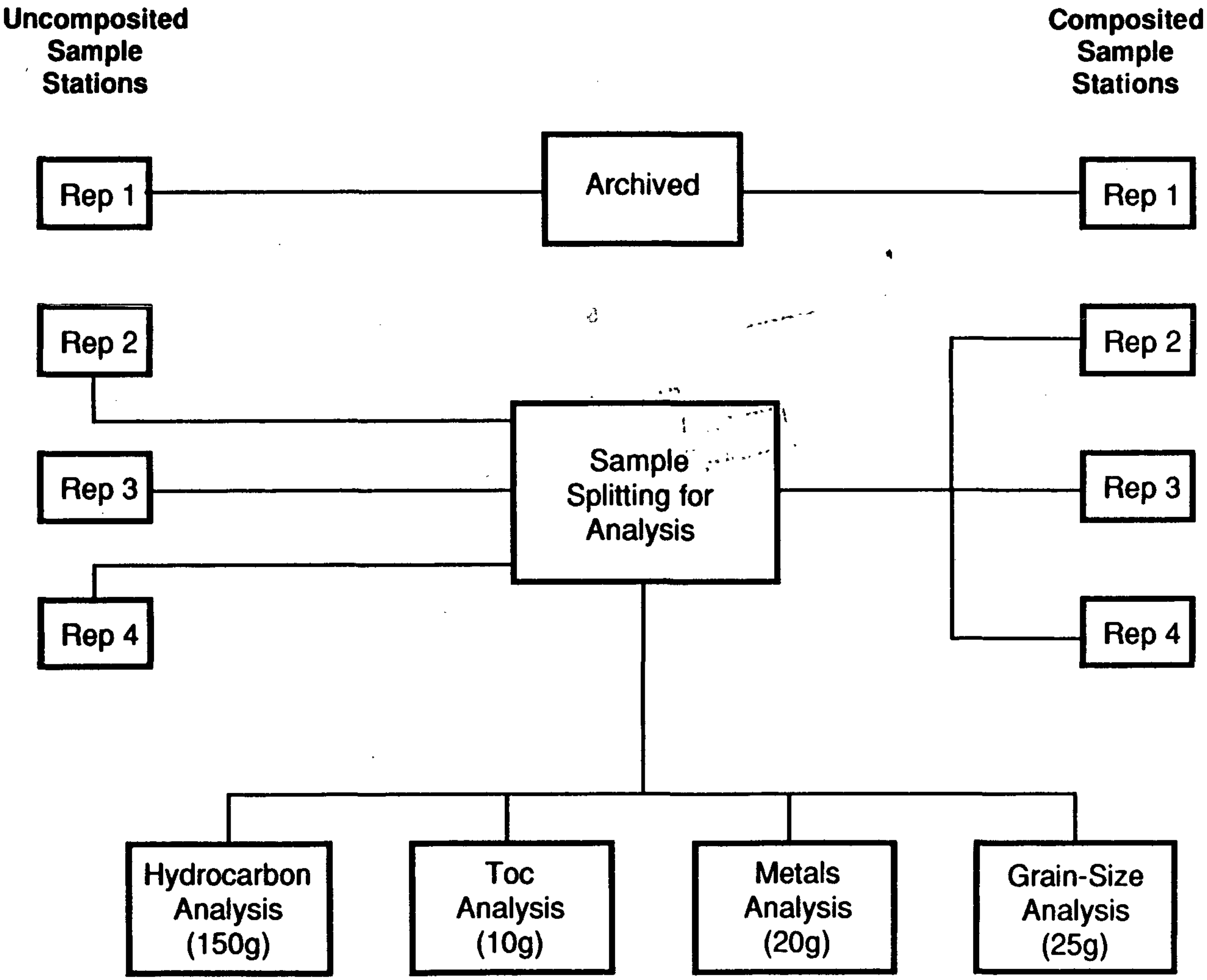

Figure 3.1 Sediment Replicate Compositing and Splitting Strategy

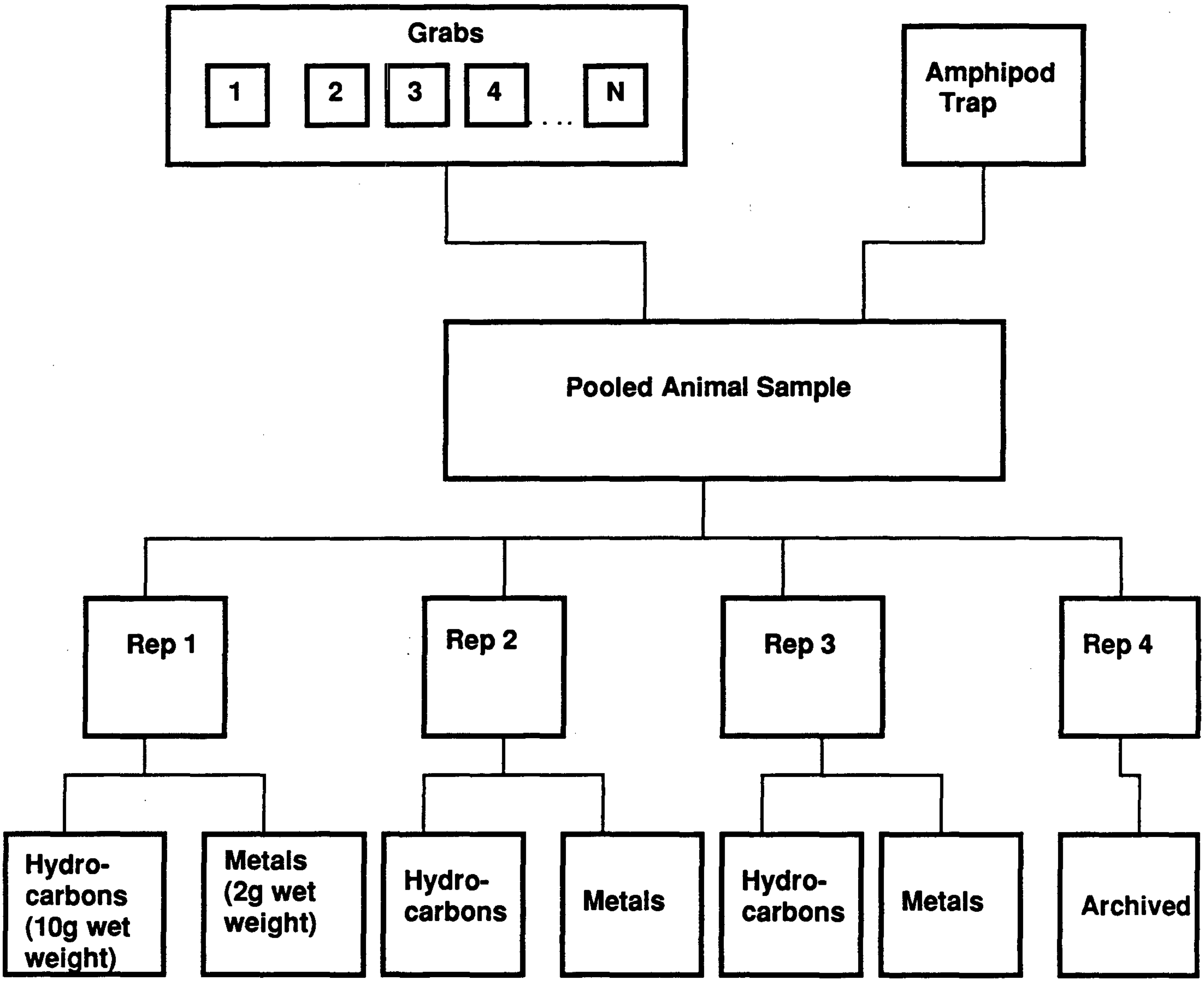

Figure 3.2 Bivalve and Amphipod Sampling, Pooling and Splitting Procedure

Prior to analysis by atomic absorption spectrophotometry (AAS), 0.4-g aliquots of sediment (fine fraction) and standard reference materials were totally digested in Teflon beakers using concentrated, high-purity HF-HNO_3-$HCLO_4$. Total digestion of the sediments is preferred because then no doubt remains about the absolute amount of metal associated with a sediment sample. In the digestion process, 1 mL $HClO_4$, 1 mL of HNO_3 and 3 mL HF were first added to the sediment in a Teflon beaker and heated at 50°C with a watch cover in place until a moist paste is formed. The mixture was heated for another 3 hours at 80°C with an additional 2 mL HNO_3 and 3 mL HF before being heated to dryness. Finally, 1 mL of HNO_3 and about 30 mL of DDW were added to the sample and heated strongly to dissolve perchlorate salts and reduce the volume. The completely dissolved and clear samples were then diluted to 20 mL with DDW. This technique, which has been used at the FIT Chemical Oceanography Laboratory for many years with a variety of sediment types, is 100 percent efficient with no loss of the elements analyzed for this program.

Labware used in the digestion process was washed with acid and rinsed with DDW. Procedural blanks and triplicate samples were prepared with each batch of (15) samples. Standard Reference Material #1646, an estuarine sediment sample provided by the U.S. National Institute of Standards and Technology (NIST), was also prepared by the method described above.

Determination of Ba concentrations in sediments that contain significant amounts of barite is difficult by acid digestion/AAS. Problems may result from incomplete dissolution of barite or inherent difficulties in analysis by AAS. Thus, sediment samples were also analyzed by instrumental neutron activation analysis (INAA). Sample preparation for INAA involves weighing out 0.5-g aliquots of sediment into polyethylene vials and sealing a cap in place. The technique is non destructive for sediment samples.

3.2.2 Tissue preparation methods. Samples of bivalve and amphipod from the Beaufort Sea were delivered frozen to the Chemical Oceanography Laboratory at FIT and logged in upon receipt. In the laboratory, the biological samples were thawed and rinsed with DDW to remove salts and adhering particles. All preliminary tissue separations were conducted in a laminar flow hood. Samples of soft tissue from the bivalves and whole amphipods were placed into acid-washed 180-mL beakers and freeze-dried. Complete digestion of tissue samples was carried out using 3 mL of HNO_3 and 1 mL of $HCLO_4$ at about 60°C. The samples were heated with a watch glass in place until a clear solution formed. The final solution was diluted to 20 mL using DDW.

All glassware used in the procedure was washed with acid and rinsed with DDW. Procedural blanks and triplicate samples were prepared with each set of samples. Standard Reference Material TORT-1, a sample of lobster hepatopancreas, provided by the National Research Council of Canada, was also prepared by methods described above.

3.2.3 Instrumental methods. Samples, reference standards and procedural and reagent blanks were analyzed by AAS using flame or flameless techniques. Determinations by AAS were performed using a Perkin-Elmer 4000 instrument equipped with a HGA-400 heated graphite atomizer, an AS-40 autosampler and deuterium/tungsten background correction. Matrix interferences were carefully monitored for all elements using the method of standard additions. Table 3.1 summarizes the instrumental methods and conditions used for each metal. For flame conditions, the choice of oxidant and fuel are listed. For refractory elements such as Al, Ba, Cr, and V, the higher temperature nitrous oxide/acetylene flame is preferred. For graphite furnace AAS, the temperature of atomization is listed. Other instrumental parameters follow specifications outlined by the manufacturer.

Analysis of sediments by instrumental neutron activation analysis (INAA) was carried out using the 1 megawatt TRIGA reactor at Texas A&M University. The reactor provides a neutron flux of 10^{12} neutrons/cm^2 . The samples were irradiated for 10 hours, cooled for about 1 week and then the gamma activities of Ba, Cr and Fe were counted using a Li-drifted germanium detector. Comparison of AAS and INAA results for Fe and Cr were excellent (r^2 = 99 and .98, respectively) and the AAS values were used in data compilations. For Ba, the AAS versus INA results were somewhat more variable (r^2 = .85) and the INAA values have been used here.

3.2.4 Quality control methods. The quality control measures implemented for trace metals analyses included use of high purity acids, scrupulous care in contamination control, replicate analysis of samples, and analysis of standard reference materials. All acids used for the digestion of sediments and tissues were redistilled, high-purity products. Such purity is necessary for the low levels of some trace metals in these pristine samples. Each new bottle of acid was routinely checked to assure that it was free of contamination.

To control contamination, all sample preparation was carried out in laminar flow hoods or clean, fiberglass fume hoods. All labware was cleaned in concentrated nitric acid and rinsed with DDW. Procedural blanks were routinely analyzed and concentrations of the metals of interest were consistently below analyte detection limits. If any blank value contained analyte concentrations that could interfere with sample quantitation, corrective action was taken immediately.

Table 3.1 Analytical Scheme For Analysis Of Trace Metals

Element	Sample	Instrumental Method	Instrumental Conditions
Fe	Sediment	AAS (INAA)	Air/Acetylene
	Tissue	AAS	Air/Acetylene
Al	Sediment	AAS	Nitrous oxide/Acetylene
Ba	Sediment	INAA (AAS)	10 hr irradiation
	Tissue	GFAAS	2400°C atomization
Cd	Sediment	GFAAS	900°C atomization
	Tissue	AAS	Air/Acetylene
Cr	Sediment	AAS (INAA)	Nitrous oxide/Acetylene
	Tissue	GFAAS	2300°C atomization
Cu	Sediment & Tissue	AAS	Air/Acetylene
Pb	Sediment & Tissue	GFAAS	1100°C atomization
V	Sediment	AAS	Nitrous oxide/Acetylene
	Tissue	GFAAS	2700°C atomization
Zn	Sediment & Tissue	AAS	Air/Acetylene

AAS - Atomic absorption Spectrophotometry with flame atomization
GFAAS - Graphite Furance Atomic Absorption spectrophotometry

INAA - Instrumental Neutron Activation Analysis

Analytical precision was established by analysis of six sets of triplicate sediment samples, 11 replicates of NIST estuarine sediment sample, and 8 replicates of the Canadian standardized tissue sample. In addition to analysis of replicates for analytical precision, replicate samples (12 sets of separate triplicate within-site organism samples) and 17 sets of triplicate within-site sediment samples) were also analyzed to determine the station variability. Standard reference sediment (SRM 1646) from the U.S. NIST and standardized tissue from the National Research Council of Canada were analyzed to establish the accuracy of the sample data.

3.3 Hydrocarbons

3.3.1 Sediment preparation methods. Sediment extraction and extract cleanup procedures were those used by Brown et al. (1979) and Boehm et al. (1982). These procedures are outlined in Figure 3.3. Approximately 100 g wet sediment (from individual or composite replicates) were thawed at room temperature and weighed into clean, solvent-rinsed glass jars. Internal standards were added to the samples prior to extraction. Ten micrograms (10 µg) of the internal standards (d_{50}-tetracosane for SHC; d_8-naphthalene, d_{10}-phenanthrene, and d_{12}-benzo(a)pyrene for PAH) were added to all samples. To each sample were added 100 mL of 1:1 CH_2Cl_2:acetone, approximately 20 g of activated copper, and 60 g of sodium sulfate. The jars were placed on a shaker table for 12 h, or overnight. The jars were then centrifuged at approximately 1500 rpm, and the extract decanted into an Erlenmeyer flask. The dried sediments were then extracted three times with 100-mL aliquots of dichloromethane:acetone (9:1) by agitating on a platform shaker, 4 h for each extraction. The extracts, from each extraction were also combined into the Erlenmeyer flasks.

Combined extracts were dried over sodium sulfate and transferred into 500-mL round-bottomed flasks fitted with Kuderna-Danish (K-D) concentrators. Samples were concentrated to a volume of approximately 4 mL, using K-D techniques, in a hot water (75-85°C) bath. Extracts were then transferred to 4 mL vials and further concentrated to 1 mL under nitrogen. Single aliquots of the extracts were weighed on a Cahn Model 29 microbalance to determine the total extract weight.

The sediment extracts were exchanged from dichloromethane to hexane and fractionated by silica gel/alumina column chromatography into saturated (f_1) and aromatic (f_2) fractions (Figure 3.3). The column chromatography was performed using a 30 cm x 1 cm column that was wet-packed (in dichloromethane) with 100 percent activated silica/5% deactivated alumina/activated copper (11:1:2 g), and prepared by eluting with 30 mL dichloromethane followed by 30 mL hexane.

The sample extract, which was less than 50 mg in 1.0 mL hexane, was loaded onto the column and eluted with 18 mL hexane to isolate the (f_1) fraction, followed by 21 mL hexane:dichloromethane (1:1) to isolate the aromatic hydrocarbons (f_2).

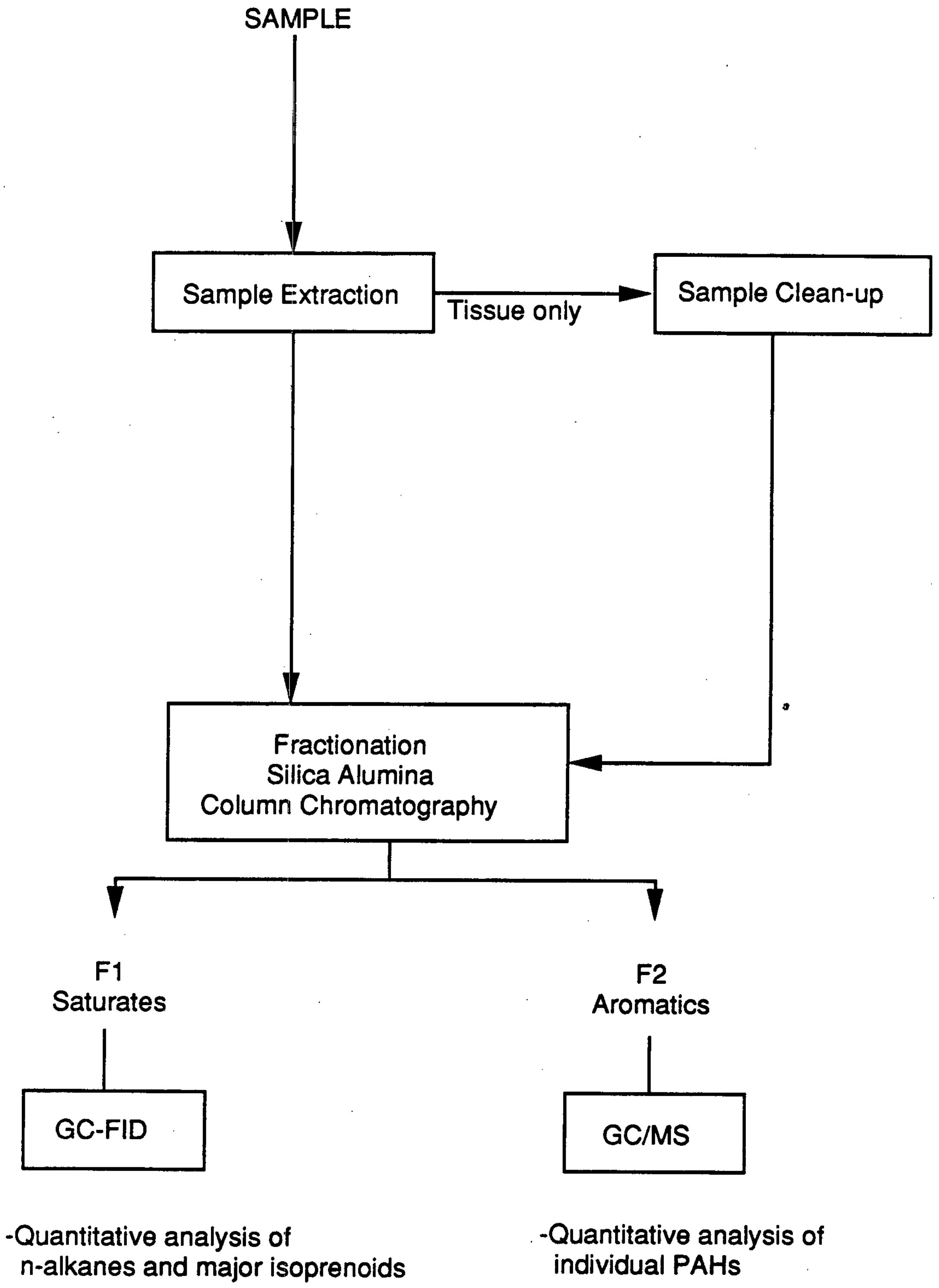

Figure 3.3 **Analytical Scheme for Hydrocarbons in Sediments and Animal Tissues**

3.3.2 Tissue preparation methods. This section outlines the extraction and analytical procedures used in the processing of bivalve mollusc and amphipod tissue samples. Tissue samples were prepared and analyzed according to the procedures published by Warner (1976) as modified by Boehm et al. (1982).

Approximately 5-10 g wet weight of tissue was prepared for extraction. Partially thawed bivalves tissues were removed from the shells with solvent-rinsed stainless steel utensils and weighed on a top-loading balance. Whole amphipod samples and shucked bivalves samples were completely homogenized using a Tissumizer. An aliquot of each homogenized sample was removed for dry weight determination, and the remaining sample (approximately 2 to 5 g wet weight) was transferred to a clean Teflon centrifuge tube for digestion. The remainder of the homogenate, if any, was relabeled, stored and refrozen as archived samples.

Thirty (30) mL of pre-extracted 6N potassium hydroxide, and 10 µg of the SHC (d_{50}-tetracosane) and PAH (d_8-naphthalene, d_{10}-phenanthrene, and d_{12}-benzo(a)pyrene) internal standards were added to each homogenized tissue sample. The mixture was then flushed with purified nitrogen, sealed, and allowed to digest overnight in a hot water bath (ca. 35°C). After digestion, 30 mL of ethyl ether was added to each sample and agitated on an orbital shaker for 5 min. The samples were then centrifuged at 2000 rpm for 5 min to facilitate phase separation. The ether layer was removed with a pasteur pipet and filtered through sodium sulfate into a 250 mL K-D apparatus. The ether extraction of the digest was repeated twice, and the ether extracts combined in the K-D apparatus. The combined ether extract from each sample was reduced in volume to ca. 1 mL by K-D and nitrogen concentration techniques. The extracts were then transferred to dichloromethane and an aliquot was removed and weighed on an electrobalance for total non-saponifiable lipid weight determinations.

The tissue sample extracts were loaded on a glass column (30 cm x 1 cm) filled with 10 g alumina (activated overnight at 130 °C prior to use) and 1 g anhydrous sodium sulfate. Sample extracts, containing no more than 300 mg of extractable organic material, were loaded onto the alumina column and eluted with 100 mL of dichloromethane. The extracts were concentrated to 5 mL using a K-D concentrator. All extracts were further reduced in volume and exchanged into hexane using nitrogen evaporation. The tissue sample extracts were then fractionated into f_1 and f_2 fractions with the silica/alumina column procedure described in Section 3.3.1.

Several analytical options existed at the outset of the program. One involved analyzing a combined f1/f2 fraction by gas chromatography/mass spectrometry (GC/MS) for both saturated and aromatic hydrocarbons, as opposed to analyzing a separate f1 fraction by gas chromatography/flame ionization detection (GC/FID). The advantage afforded by this technique is a potential gain of efficiency (saturated and aromatic hydrocarbons can be analyzed with one instrumental analysis). The procedure involves using selected ion monitoring (SIM) to obtain an extracted ion current profile (EICP) of mass ion 57, and measuring the area under this envelope, to obtain a measure of the unresolved complex mixture (UCM) commonly found in environmental samples, from petroleum contamination. Concerns based on the comparability of the unresolved envelope derived from the EICP (GC/MS analysis) and the unresolved envelope obtained by GC/FID analysis of the f1 fraction led to the decision to utilize the instrumental methods employed in previous studies and reported in Boehm et al., 1987 in which the f1 and f2 fractures were analyzed separately.

3.3.3 Instrumental methods

3.3.3.1 GC/FID. Saturated hydrocarbons, which included normal-chained alkanes (nC_{10} - nC_{34}) and selected isoprenoid hydrocarbons, were determined in samples using GC/FID (GC-FID equipment and analytical conditions are listed in Table 3.2). Concentrations of these compounds were also used to calculate diagnostic ratios and parameters for use in assessing the geochemical composition of sediments and biological tissues in the study area.

Immediately prior to instrumental analysis, 5 µg of the recovery standards (d_{62}-triacontane for the f_1 fraction; d_{10}-fluorene for the f_2 fraction) were added to the samples. The hydrocarbon concentrations (nC_{10} - nC_{34} alkanes and the selected isoprenoids) were identified by retention time comparisons to n-alkane standards. Concentrations of the n-alkanes and isoprenoids were corrected for instrumental response using response factors generated by a 5 point calibration curve, described in Section 3.3.8. Quantification of individual analytes was performed by comparing instrumental response of the analytes to surrogate/internal standards added at the beginning of the sample extraction procedure.

Calculation of analyte concentration was based on the methods of internal standards. The general formula is as follows:

$$\text{PHC or analyte } (\mu g/L \text{ or } g) = \frac{(\text{Analyte})\ (C_{is})}{(\text{Area}_{is})\ (RF)}$$

Where:

A = Area of nC_{10} - nC_{34} or (in the core of PHC) the corrected area of the sample chromatogram (A_c = total resolved + unresolved area).

C_{is} = µg of surrogate/internal standard (d_{50}-tetracosane) added to the sample.

A_{is} = Area response of the d_{50}-tetracosane.

Table 3.2 **Fused Silica Capillary Gas Chromatography/Flame Ionization Detection Analytical Conditions.**

Instrument:	Hewlett Packard 5880A
Features:	Split/splitless capillary inlet system; VG data acquisition system
Inlet:	Splitless
Detector:	Flame ionization
Column (F1):	0.25 mm ID x 30 m DB5 fused silicia (J & W Scientific)
Gases:	Hydrogen 1-2 mL/min
Carrier:	Helium 25-30 mL/min
Make-UP:	Air 240 mL/min
Detector:	Hydrogen 50 mL/min
Temperature:	
Injection port:	300 °C
Detector:	325 °C
Oven Program:	60 °C for 1 min then 6 °C/min to 300 °C hold 5 min
Daily Calibration:	Mid-level calibration solution; Retention index solution
Quantification:	Internal standard/calibration standard.

RF = Average response factor of the continuing calibration standard.

Also,

$$RF = \text{Average of } \frac{(A_s \times C_{is})}{A_{is} \times C_s}$$

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Where:

A_s = Response of analyte to be measured.

C_{is} = Concentration of internal/surrogate standards (d_{50}-tetracosane).

A_{is} = Response of the internal standard.

C_s = Concentration of the analyte in the standard.

Raw data from the instruments were transferred directly to a personal-computer-based data acquisition system developed by VG (Mini-Chrome, Danvers, MA). Peak area, relative retention time, as well as response factor and concentration were calculated automatically using this system. This data system automatically identified components by comparing retention times of peaks in the samples to retention times of known compounds in a standard mixture. Retention time windows were established (3 x the standard elevation of the retention time of a compound) and checked daily with a calibration standard. The area under the unresolved "envelope" or the UCM (unresolved complex mixture) was determined by the software system after a baseline was established by the analyst. The total area was adjusted to remove the area response of the internal standards, surrogates and GC column bleed. The concentrations of n-alkanes and isoprenoids were expressed in µg/g on a dry-weight basis for sediment and on a wet-weight basis for tissue. Finalized sample concentrations were electronically transferred to a centralized data base (also PC-based), which used Quattro Pro (1989, Borland International), a Lotus-compatible spreadsheet program, for the generation of tables, graphs and the calculation of the diagnostic ratios described in Section 5.

3.3.3.2 GC/MS. The determination of PAHs in the sediment and tissue sample extracts were performed by GC/MS using a Hewlett-Packard model 5970 mass selective detector (MSD) coupled to a Hewlett-Packard model 5890 GC by a capillary direct interface (equipment and analytical conditions are listed in Table 3.3). The MS was operated in the SIM mode and programmed to acquire the primary ions listed in Table 3.4 plus one confirmation ion (EPA, 1986 [SW 846 3rd addition) for each target analyte.

Table 3.3 Gas Chromatography/Mass Spectrometry Instrumental Conditions

Instrument:	Hewlett-Packard model 5970 MSD coupled to a Hewlett-Packard model 5890 GC
Features:	Hewlett Packard RTE-A data system using Aquarius software
Inlet:	Splitless
Detector:	
Scan Rate:	50-450 amu
Ionization Voltage:	200 volts
Column:	0.25 mm ID x 30 m SE54 fused silica (J & W Scientific)
Interface:	
Carrier gas:	Helium, 1-2 mL/min
Temperature:	
Injection port:	300 °C
GC oven:	40 °C to 290 °C at 6 °C/min, with a 1 min initial hold and a 20 min hold at the final temperature
Daily Calibration	
Quantification:	Internal standard response factor

Table 3.4 Parameters For Target Analytes

Analyte	Quant.	Conf.	% Rel. Abund. of Conf. Ions[B]
d_8-Naphthalene[A]	136	134	15
Naphthalene	128	127	15
C_1-Naphthalenes	142	141	80
C_2-Naphthalenes	156	141	
C_3-Naphthalenes	170	155	
C_4-Naphthalenes	184	169,141	
d_{10}-Acenaphthene	164	162	95
Acenaphthylene	152	153	15
Acenaphthene	154	153	98
d_{10}-Fluorene	176	174	85
Fluorene	166	165	95
C_1-Fluorenes	180	165	100
C_2-Fluorenes	194	179	25
C_3-Fluorenes	208	193	
d_{10}-Phenanthrene[A]	188	184	
Phenanthrene	178	176	20
Anthracene	178	176	20
C_1-Phenanthrenes/anthracenes	192	191	60
C_2-Phenanthrenes/anthracenes	206	191	
C_3-Phenanthrenes/anthracenes	220	205	
C_4-Phenanthrenes/anthracenes	234	219,191	
Dibenzothiophene	184	152,139	15
C_1-Dibenzothiophenes	198	184,197	25
C_2-Dibenzothiophenes	212	197	
C_3-Dibenzothiophenes	226	211	
Fluoranthene	202	101	15
d_{12}-Chrysene[A]	240	236	
Pyrene	202	101	15
C_1-Fluoranthenes/pyrenes	216	215	60
Benzo[a]anthracene	228	226	20
Chrysene	228	226	30
C_1-Chrysenes	242	241	
C_2-Chrysenes	256	241	
C_3-Chrysenes	270	255	
C_4-Chrysenes	284	269,241	
d_{12}-Benz(a)pyrene[A]	264	260	20
Benzo[b]fluoranthene	252	253,125	30,10
Benzo[k]fluoranthene	252	253,125	30,10
Benzo[a]pyrene	252	253,125	30,10
Indeno[1,2,3-c,d]pyrene	276	277,138	25,30
Dibenzo[a,h]anthracene	278	279,139	25,20
Benzo[g,h,i]perylene	276	277,138	25,20

[A] Denotes spiking compound

[B] Note: Relative abundance of ions within any given isomer group will vary considerably, depending on isomer of interest. Relative abundance should be determined in analysis of crude solution.

Individual PAHs were identified by comparing retention times and extracted ion profiles to those of the standards. The concentrations of PAHs were corrected for instrumental response based on response factors generated from the analysis of authentic PAH standards. Quantification of individual components was made using response factors determined in the initial calibration. Alkyl homologues for which authentic standards do not exist were assigned the response factors of the next lowest-substituted alkyl homologue, or the unsubstituted parent compound. Concentrations of individual PAHs were calculated by the Hewlett Packard RTE-A data system using Aquarius software (Environmental Testing and Certification Corp.).

Concentrations of the identified compounds were determined by measuring peak areas (ion currents) of the quantitation ion (usually the parent ion) in the selected ion chromatograms and relating them to the peaks of the internal standards. The concentrations of PAH were determined in ng/g on a dry-weight basis for sediments and on a wet-weight basis for tissues.

3.3.4 Quality control methods. Several quality control measures were implemented in conjunction with hydrocarbon analyses in order to provide a measure of analytical accuracy, precision, and possible contamination. The following sections describe the specific measures taken to assure data quality.

3.3.4.1 Determination of accuracy. Accuracy can be defined as the percent recovery of a surrogate compound spiked into a sample at the beginning of an extraction, or the percent recovery of a compound of known concentration in a standard reference material. The accuracy of the analytical methods was monitored through the calculation of the percent recoveries of surrogate compounds added as internal standards, and analysis of spiked blanks (spiked with natural hydrocarbons and processed/analyzed with each batch of samples). The blanks were spiked with 10 µg of each compound in the matrix/blank spiking solution. Recovery (percent) was calculated for each analyte in a spiked blank, based on the recovery internal standard. The accuracy of the hydrocarbon analytical methods was also determined through the analysis of standard reference materials (Canadian test sediment, HS-2, from the Marine Analytical Research Laboratory, Halifax, Nova Scotia), and participation in NOAA/NIST intercalibration exercises. The results of the analysis of Canadian test sediment and the NOAA/NIST intercalibration exercises are presented in section 4.4.2.

The percent recovery of standards, surrogate compounds, and spiked analytes was calculated by the following equation:

$$\text{Percent Recovery} = \frac{X}{T} \times 100$$

Where:

X = the calculated amount of surrogate standard in the sample, of certified compound in SRM, or of spiked analyte in spiked blank

T = the known quantity of surrogate standard or compound in SRM

3.3.4.1.1 Spiked blank analysis. A spiked blank is a procedural blank to which the appropriate surrogate and natural compounds are added before processing. The results of a spiked blank analysis provide information on the analytical recovery (i.e., accuracy) of spiked analytes. Spiked blanks are often used in place of spiked matrix samples when, as in this case no suitable matrix material is available. At least one spiked blank was processed and analyzed with each batch of samples (up to 20 samples in a batch).

3.3.4.1.2 Standard reference material analysis. A common method used in evaluating the accuracy of environmental data is to analyze standard reference materials, samples for which consensus or "accepted" analyte concentrations exist. Sediment standard reference material, Canadian test sediment HS-2, was obtained from the Marine Analytical Research Laboratory, Halifax, Nova Scotia, and analyzed.

3.3.4.1.3 NOAA/NIST Intercalibration exercise. The PAH component of the NIST intercalibration exercise was analyzed and reported to NIST. Results of the first and second exercise are presented in Tables 4.25 and 4.26.

3.3.4.1.4 Analysis of archived sample. As part of the 1989 program, one archived sample from the 1984-1989 program was analyzed in triplicate. Results are presented in Table 4.11.

3.3.4.2 Determination of precision. Precision is defined in this study as the percent variation of target compounds in replicate samples. It is commonly expressed as relative percent difference or relative standard deviation depending upon the number of replicates. The precision of the analyses was monitored throughout the study by comparison of the results for the duplicate spiked blanks. In addition, seven subsamples of a single sediment sample and seven subsamples of a single amphipod sample were processed in one batch of each type of analysis (sediment and tissue, respectively).

The precision of the analytical measurements was calculated from variations in the results for both analytes and surrogate compounds in duplicate and replicate sample analyses. For duplicate analysis, precision was measured by relative percent difference (%RPD):

$$\text{Relative Percent Difference} = \frac{C_1 - C_2}{(C_1 + C_2)/2} \times 100$$

Where: C_1 = concentration of duplicate 1
C_2 = concentration of duplicate 2

Precision of analytical measurements was estimated in replicate sample analyses by calculating the standard deviation (SD):

$$\text{Standard deviation (absolute units)} = \left[\frac{\sum\limits_{i=1} (x_i - \bar{x})^2}{n-1} \right]^{1/2}$$

where:

x_i = the experimentally determined value for the i^{th} measurement,
n = the number of measurements performed (>2), and

$\bar{x}$ = the mean of the experimentally determined values.

Precision is frequently expressed as the relative standard deviation (RSD) or coefficient of variation, (CV) which is the variation about the mean, x, and is expressed as a percentage. The following equation is used to calculate the %RSD:

$$\text{RSD (\%)} = \frac{(SD)\,(100)}{\bar{X}}$$

To determine the analytical precision of analytes in actual field samples, five subsamples of one selected homogenous sample (sediment or tissue) were analyzed in one batch of each type sample and the results were used to calculate precision. The same sediment samples were analyzed for grain-size distribution and TOC to determine the precision of these analyses.

3.3.4.3 Procedural blank analysis. A procedural blank was processed and analyzed with each batch (up to 20) of samples in order to monitor potential contamination resulting from laboratory solvents, reagents, glassware, and processing procedures.

resulting from laboratory solvents, reagents, glassware, and processing procedures. Internal standards and recovery internal standards were added as with field and other quality control samples. Recoveries of the surrogate standards were calculated to ensure that the minimum requirements for analytical acceptability was achieved. Acceptance criteria for the percent recovery of surrogate/internal standards was 40 - 120%.

Prior to sample analysis, every lot of solvent used in analyzing sediment and tissue samples was analyzed in triplicate by GC/MS to determine potential contamination from solvents. After the solvent analyses, three sediment and tissue procedural blanks were also analyzed to assess potential labware and reagent contamination.

3.3.4.4 Detection limits determination. There are a number of methods used to determine detection limits of analytes in different matrices. Some methods, such as that recommended by EPA (40 CFR, 136, App. B), measure analytical precision. Other methods such as the signal-to-noise method are measurements of instrument sensitivity or response. The selection of the appropriate method depends on analytical experience, type of instrumentation used in the analysis, and the objectives of the particular project. For the 1989 program, the standard deviation associated with the analysis of seven replicate samples was used to determine detection limits, in accordance with EPA guidelines.

3.3.4.5 Data quality objectives. The data quality objectives for precision and accuracy of the target saturated and aromatic hydrocarbons were less than 40 percent RSD for precision, and greater than 60 percent for accuracy. The precision and accuracy requirements for PAHs are more stringent than those typically accepted by EPA. Accuracy and precision values not within the suggested limits were documented.

Data quality and adherence to program protocols was ensured through the auditing of all ADL-generated by ADL's Quality Assurance Unit. Any deviations from program protocols were documented; any data failing to meet data quality objectives were brought to the attention of the Program Manager for a decision regarding data reporting and corrective action.

3.4 Auxiliary Analyses

In addition to the trace metals and hydrocarbon analyses, grain size and TOC concentrations were determined for sediments to aid in the interpretation of the geochemical data.

3.4.1 Sediment grain size. The sediment grain size analysis was performed by Dr. John Boothroyd at the University of Rhode Island. The method used for grain size the sand fraction into Phi classes was performed in accordance to the procedures described by Holme and McIntyre (1971). The silt/clay fraction (<0.063 mm) was subdivided into Phi classes by pipette analysis in distilled water containing sodium metaphosphate dispersant.

A 25-g aliquot of the sediment sample was dried at 100°C to a constant weight, cooled in a desiccator, and weighed to 0.01 mg on an analytical balance. The dried sample was added to a sodium metaphosphate dispersant solution and agitated on an orbital shaker. The solution was allowed to settle for 12 h, then resuspended by further shaking. The sediment solution was wet-sieved through a 0.063 mm sieve to separate the sand and silt/clay fractions. The silt/clay fraction was resuspended and subdivided into whole Phi interval classes by the pipette method.

The sand fraction was transferred to an aluminum weighing pan, dried to a constant weight, weighed on an analytical balance, then transferred to a set of standard nested sieves (2.0 mm, 1.0 mm, 0.5 mm, 0.25 mm, 0.125 mm and 0.063 mm mesh sizes), and agitated on a sieve shaker to further subdivide the fraction into whole Phi class intervals. The percent of sediment in each Phi class was determined by transferring the sediment remaining on each screen to a tared container and weighed to the nearest 0.01 g.

As a quality control measure, two samples were processed in duplicate, and one sample was processed in triplicate. No SRMs were available for this analysis.

3.4.2 Total organic carbon. TOC analysis was performed by Global Geochemistry in Canoga Park, California. The method used for TOC analysis was that described by Froelich (1980). Sediment samples were acidified with 6N HCL in order to remove calcium carbonate, and dried at high temperature. Combustion was achieved using a Carlo Erba Model 1106 Carbon Hydrogen Nitrogen (CHN) analyzer to convert organic carbon to carbon dioxide.

As a quality control measure, six samples were analyzed in triplicate. No SRMs were available for this analysis.

4.0 Presentation of Results

This section presents the data generated as part of the 1989 Beaufort Sea field sampling program. These data represent the results of the laboratory analyses for trace elements and hydrocarbons in marine sediment and animal tissues. In addition, results of the auxiliary parameters, grain size and total organic carbon, are presented for sediments. The results of the quality control activities are also presented. Comparison of the 1989 data to the previous BSMP data is discussed in the data analysis and interpretation of this report (Section 5).

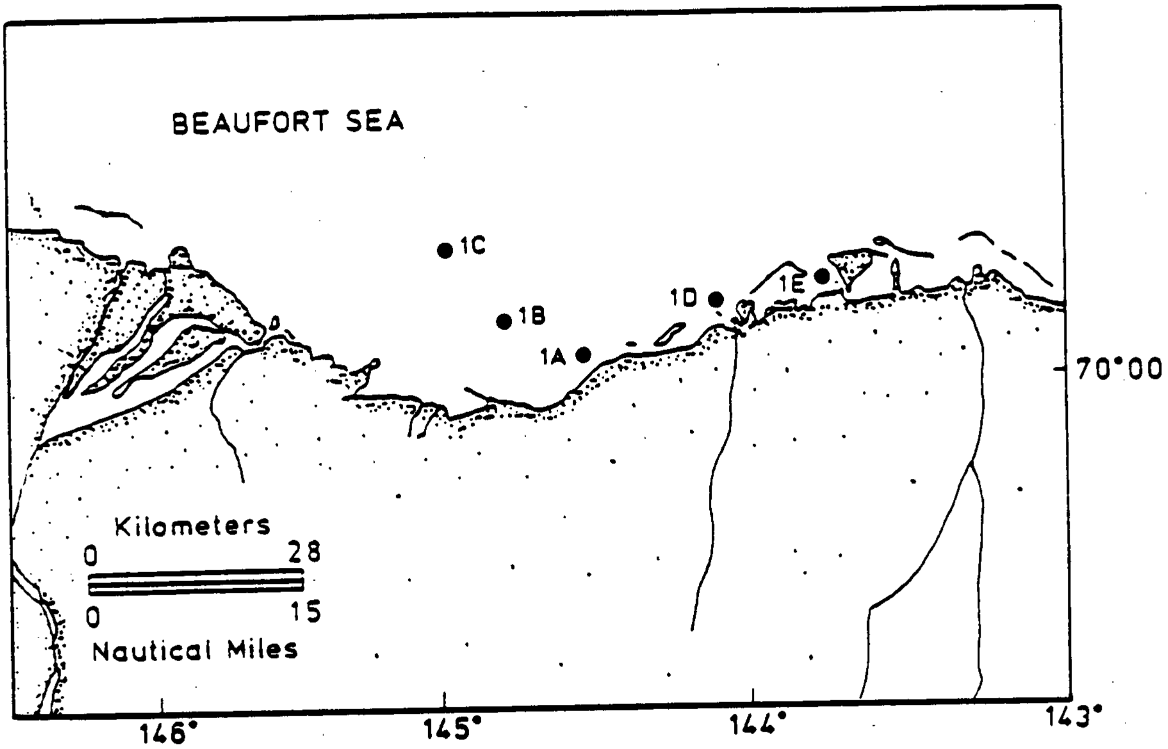
The results of the analyses are presented in four separate subsections for metals, hydrocarbons, auxiliary parameters, and quality control results. The data has been reduced in format to include only the analytes and parameters which are most important for analysis and interpretation and to allow ease of comparison to the previous BSMP data. A complete listing of the 1989 data is included in Appendix A of this report and is presently stored in the ADL Marine Sciences data base for transmittal to the National Oceanic Data Center (NODC).

The results are presented in tables which correspond to the delineated regions of the study area and include a map of each region to aid in the identification of the station locations.

4.1 Metals Results

The concentrations of trace metals were determined in marine sediments and animal tissues. For sediments, the analyses for each station were performed on the fine fraction (silt/clay) of three pooled sample replicates from separate grab samples. However, for one station in each region, with the exception of regions 7 and 8, the three replicates were analyzed separately and are reported as the mean with the standard deviation in parentheses. For regions 7 and 8 the three replicates for each station were analyzed separately and are reported as the mean value ± one standard deviation. All tissue samples for which there was sufficient biomass were analyzed in triplicate and mean values are reported ± the standard deviation. One replicate of tissue samples with insufficient biomass was analyzed and the results are reported as a single value.

4.1.1 Metals in Sediments. Figures 4.1 through 4.9 present the concentrations of the metals in the fine fraction of the 48 stations sampled in the 1989 survey. The barium levels were higher than all other metals in the study area with regional means ranging from 600 to 840 u/g. The barium levels were consistent throughout the regions with the exception of Region 5 where the concentrations of barium in stations 7A, 7B, and 7G were significantly higher at 1100, 910, and 1082 µg/g respectively. Cadmium levels were low in all stations with regional means ranging from 0.13 to 0.20 µg/g. The concentrations of lead and copper were in the range of 8.37 to 27.0 µg/g, while the regional means of chromium, vanadium and zinc ranged from 87 to 191 µg/g. The levels of aluminum and iron were generally constant at stations within a region

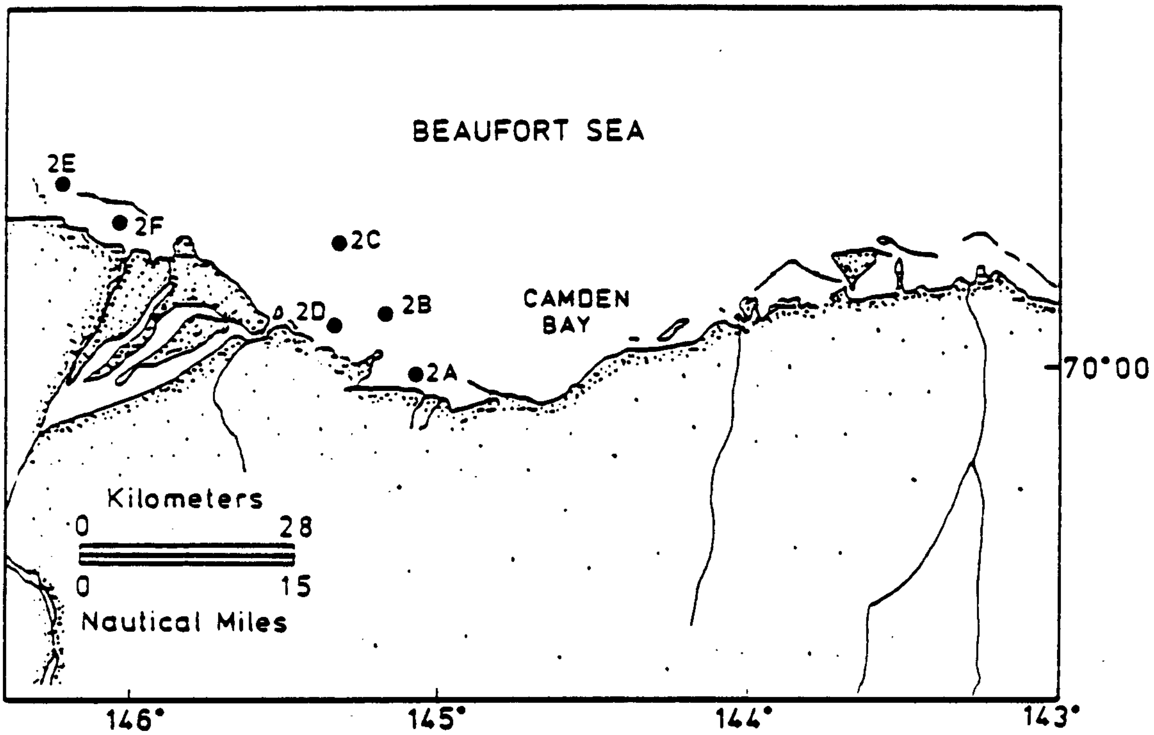


METALS
(ug/g)*

STATION	1A	1B	1C	1D	1E
REGION	1	1	1	1	1
Cd	0.11	0.11	0.07	0.14	(0.12, 0.05)
Pb	13	12	12	23	(15, 4.3)
Ba	640	680	760	860	(540, 22)
Cr	95	96	98	94	(73, 6.1)
Cu	30	23	27	23	(19, 0.53)
V	150	170	200	110	(88, 6.7)
Zn	110	110	120	100	(80, 2.9)
% Fe	3.6	3.5	3.7	3.9	(3.1, 0.09)
% Al	6.0	6.2	7.1	8.2	(5.4, 0.2)
% FINES	74	15	76	67	(82, 14)

* All concentrations reported as average means and standard deviation in parentheses.

Figure 4.1 1989 Mean Trace Metal Concentrations and Percent Fines in East Camden Bay Area Bulk Sediments.



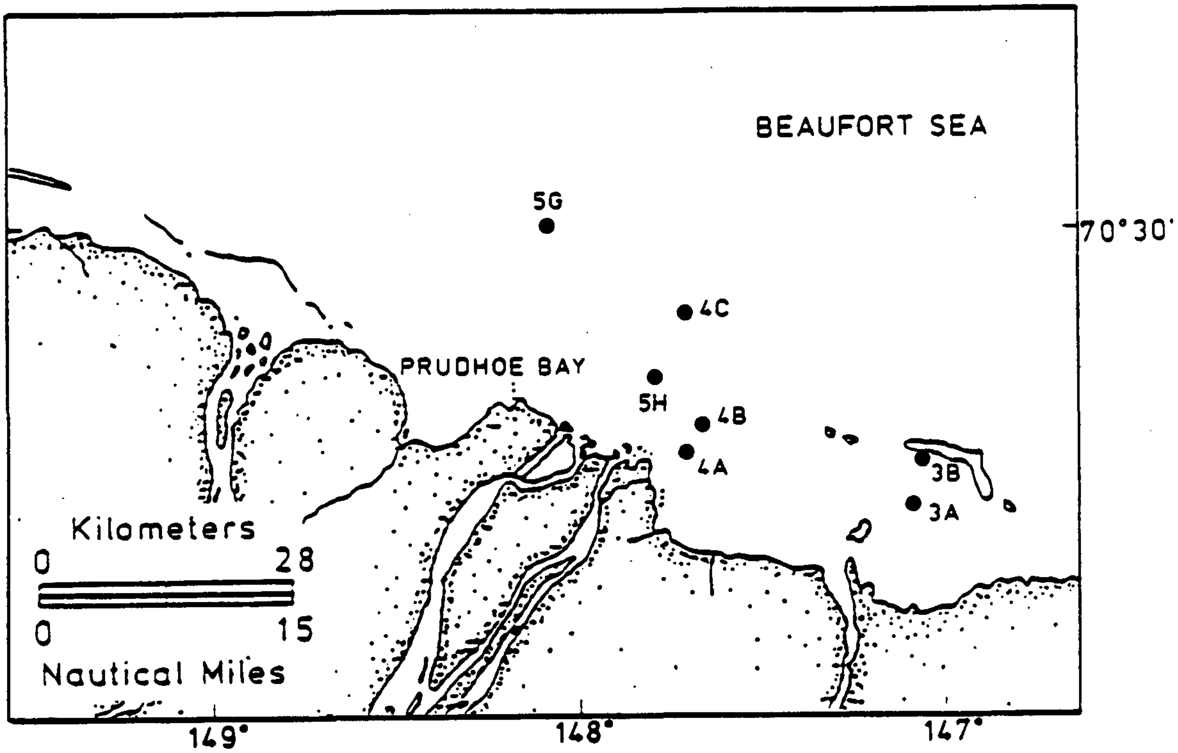
METALS
(ug/g)*

STATION	2A	2B	2C	2D	2E	2F		
REGION	1	1	1	1	1	1	Mean(Rgn1)**	Std(Rgn1)
Cd	0.26	0.13	0.12	0.28	0.25	0.15	0.16	0.07
Pb	20	13	16	10	12	7	14	5
Ba	730	190	770	580	640	500	660	110
Cr	110	86	96	83	117	90	94	12
Cu	38	20	25	25	19	18	24	6
V	200	160	200	160	140	130	160	36
Zn	130	99	120	120	100	96	110	13
% Fe	4.3	3.2	3.8	3.0	2.9	2.6	3.4	0.51
% Al	7.3	5.9	7.1	5.6	4.7	4.5	6.2	1.1
% FINES	87	20	75	8.2	4.3	14	53	34

* All concentrations reported as average means and standard deviation in parentheses.

** Regional means are averages calculated from the above mean station concentrations.

Figure 4.2 1989 Mean Trace Metal Concentrations and Percent Fines in West Camden Bay Area Bulk Sediments.

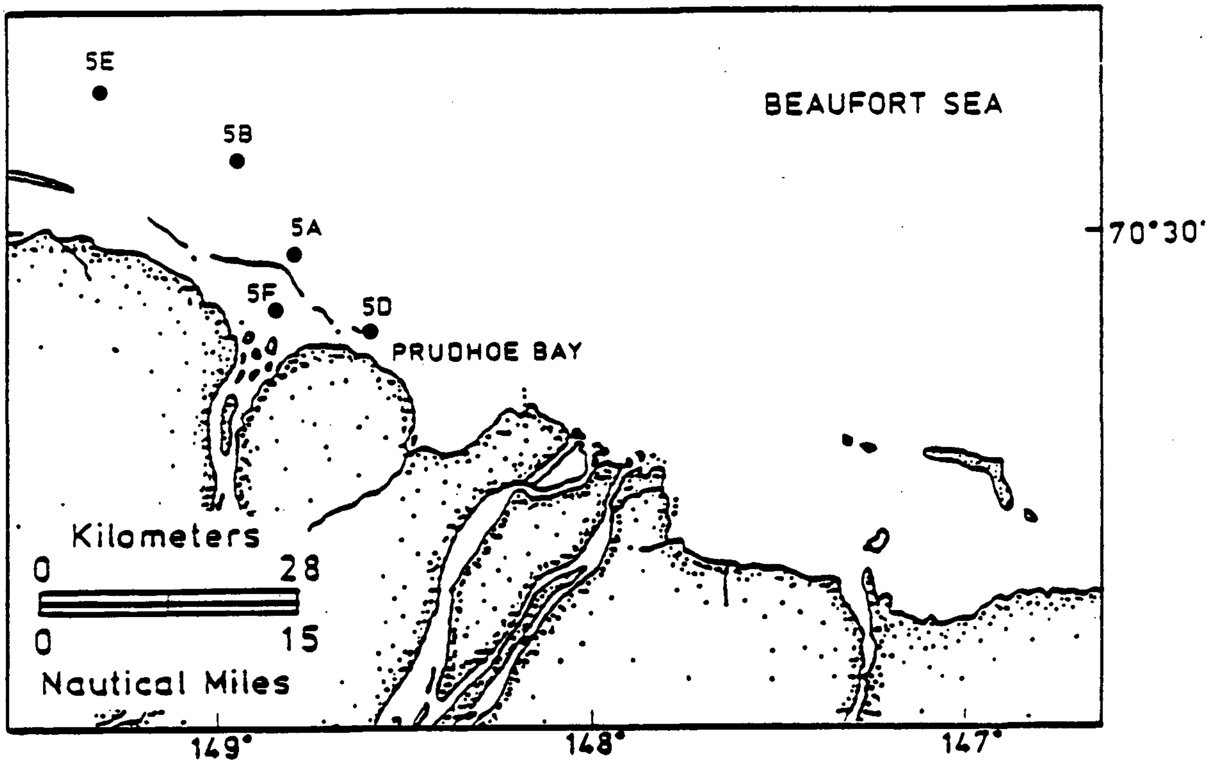


METALS
(ug/g)*

STATION	3A	3B	4A	4B	4C	5G	5H		
REGION	2	2	2	2	2	2	2	Mean(Rgn2)**	Std(Rgn2)
Cd	0.17	(0.12, 0.01)	0.14	0.17	0.12	0.16	0.10	0.14	0.03
Pb	11.4	(10, 0.96)	5.9	5.8	12.2	11.9	6.6	9.11	2.91
Ba	587	(580, 15)	585	635	670	690	580	620.00	47.00
Cr	80	(79, 2.1)	81	86	97	104	82	87.00	9.70
Cu	22.6	(18, 1.3)	22.2	23.3	24.8	24.1	22.7	23.00	2.20
V	149	(134, 3.3)	142	153	191	177	147	160.00	20.00
Zn	103	(88, 2.7)	111	123	122	108	102	110.00	12.00
% Fe	3.2	(2.9, 0.1)	3.1	3.3	3.8	3.6	3.1	3.30	0.31
% Al	6	(5.1, 0.05)	5.5	5.9	6.4	6.2	5.4	5.70	0.44
% FINES	85	(78, 1.1)	18	17	3.8	43	35	49	32

* All concentrations reported as average means and standard deviation in parentheses.
** Regional means are averages calculated from the above mean station concentrations.

Figure 4.3 1989 Mean Trace Metal Concentrations and Percent Fines in Foggy Island Bay Area Bulk Sediments.

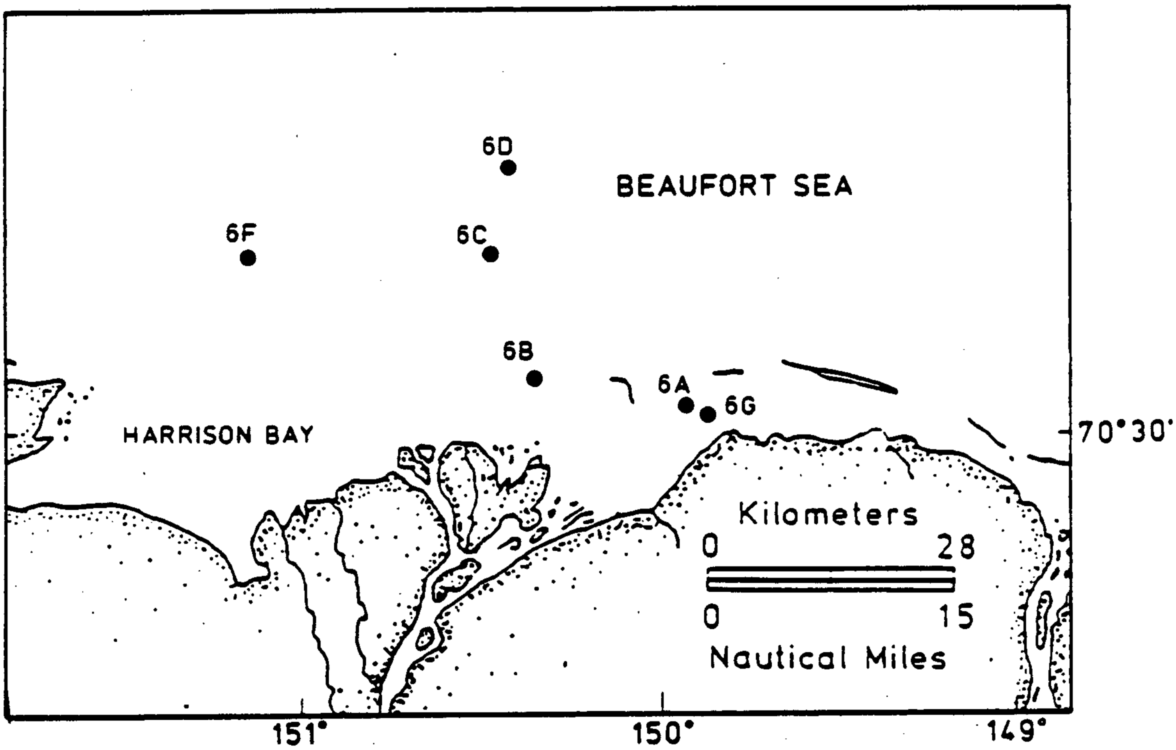


METALS
(ug/g)*

STATION	5A	5B	5D	5E	5F		
REGION	3	3	3	3	3	Mean(Rgn3)**	Std(Rgn3)
Cd	(0.17, 0.06)	0.14	0.27	0.16	0.10	0.17	0.06
Pb	(10, 2.0)	15.3	10.2	15.8	3.9	11.04	4.84
Ba	(620, 28)	778	653	700	530	660.00	92.00
Cr	(88, 0.85)	94	89	102	88	92.00	6.00
Cu	(23, 0.76)	27.5	22.5	26.9	14.3	23.00	5.30
V	(160, 7.9)	221	153	221	106	170.00	49.00
Zn	(110, 4.5)	134	110	120	90	110.00	16.00
% Fe	(3.2, 0.2)	4.3	2.8	4.2	2.5	3.40	0.80
% Al	(5.8, 0.2)	7.7	5.6	7.2	4.6	6.20	1.30
% FINES	(31, 7.1)	3.5	64	27	53	36	24

* All concentrations reported as average means and standard deviation in parentheses.
** Regional means are averages calculated from the above mean station concentrations.

Figure 4.4 1989 Mean Trace Metal Concentrations and Percent Fines in Kuparuk River Bay Area Bulk Sediments.

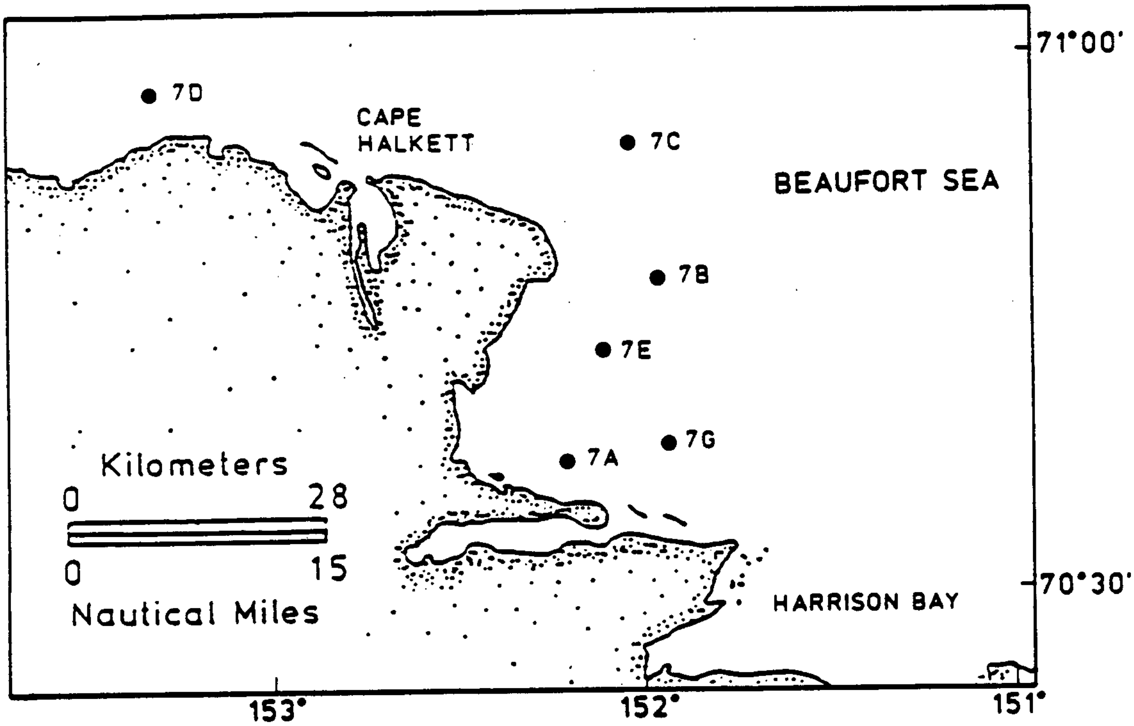


METALS (ug/g)*

STATION	6A	6B	6C	6D	6F	6G		
REGION	4	4	4	4	4	4	Mean(Rgn4)**	Std(Rgn4)
Cd	0.19	0.20	0.15	(0.11, 0.01)	0.10	0.13	0.15	0.04
Pb	11.4	17.1	14.4	(17.0, 1.2)	12.2	9.6	13.62	3.07
Ba	568	790	660	(760.0, 28.00)	650	555	663.83	96.33
Cr	91	102	108	(120.0, 4.2)	115	102	106.33	10.37
Cu	25.8	30.8	28.5	(30.0, 0.57)	27.0	23.7	27.63	2.67
V	174	185	219	(230.0, 4.9)	187	154	191.50	28.33
Zn	111	119	122	(130.0, 1.0)	113	107	117.00	8.37
% Fe	3.5	4.2	4.2	(4.4, 0.2)	3.9	3.5	3.95	0.38
% Al	6.2	7.3	7.5	(7.5, 0.4)	6.8	5.9	6.87	0.69
% FINES	96	93	45	(18, 5.5)	51	75	63	30

* All concentrations reported as average means and standard deviation in parentheses.
** Regional means are averages calculated from the above mean station concentrations.

Figure 4.5 1989 Mean Trace Metal Concentrations and Percent Fines in East Harrison Bay Area Bulk Sediments.

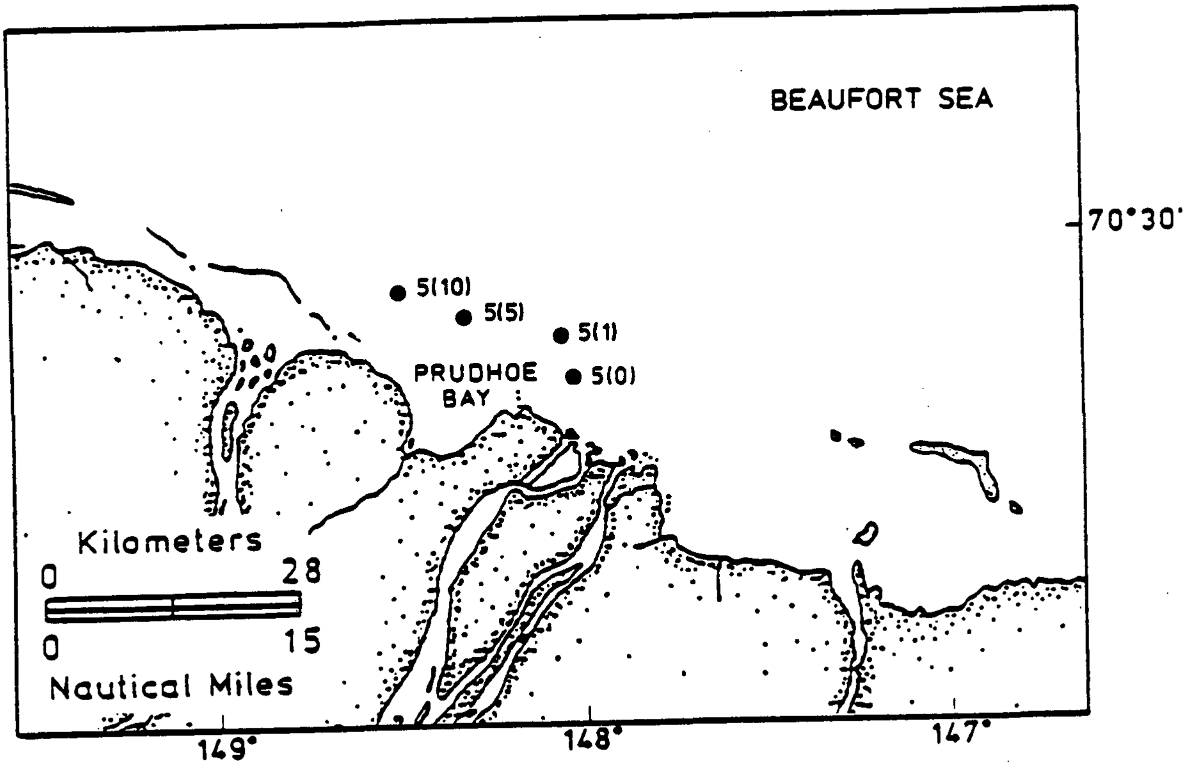


METALS
(ug/g)*

STATION	7A	7B	7C	7D	7E	7G		
REGION	5	5	5	5	5	5	Mean(Rgn5)**	Std(Rgn5)
Cd	0.06	(0.09, 0.01)	0.19	0.19	0.10	0.20	0.14	196.90
Pb	10.6	(11, 0.87)	14.9	13.8	7.7	11.1	11.52	205.87
Ba	1100	(910, 180)	625	675	650	1082	840.00	220.00
Cr	219	(160, 7.5)	97	103	105	185	140.00	59.00
Cu	18.4	(20, 1.1)	23.2	21.6	21.1	17.4	20.00	65.00
V	145	(160, 13)	168	163	142	136	150.00	67.00
Zn	100	(100, 1.2)	107	107	101	92	100.00	55.00
% Fe	3.5	(3.6, 0.2)	3.5	3.6	3.3	3	3.40	2.50
% Al	5.7	(6.0, 0.3)	6	6.3	5.4	5.3	5.80	3.10
% FINES	34	(15, 3.8)	75	32	86	26	37	28

*** All concentrations reported as average means and standard deviation in parentheses.**
**** Regional means are averages calculated from the above mean station concentrations.**

Figure 4.6 **1989 Mean Trace Metal Concentrations and Percent Fines in West Harrison Bay Area Bulk Sediments.**

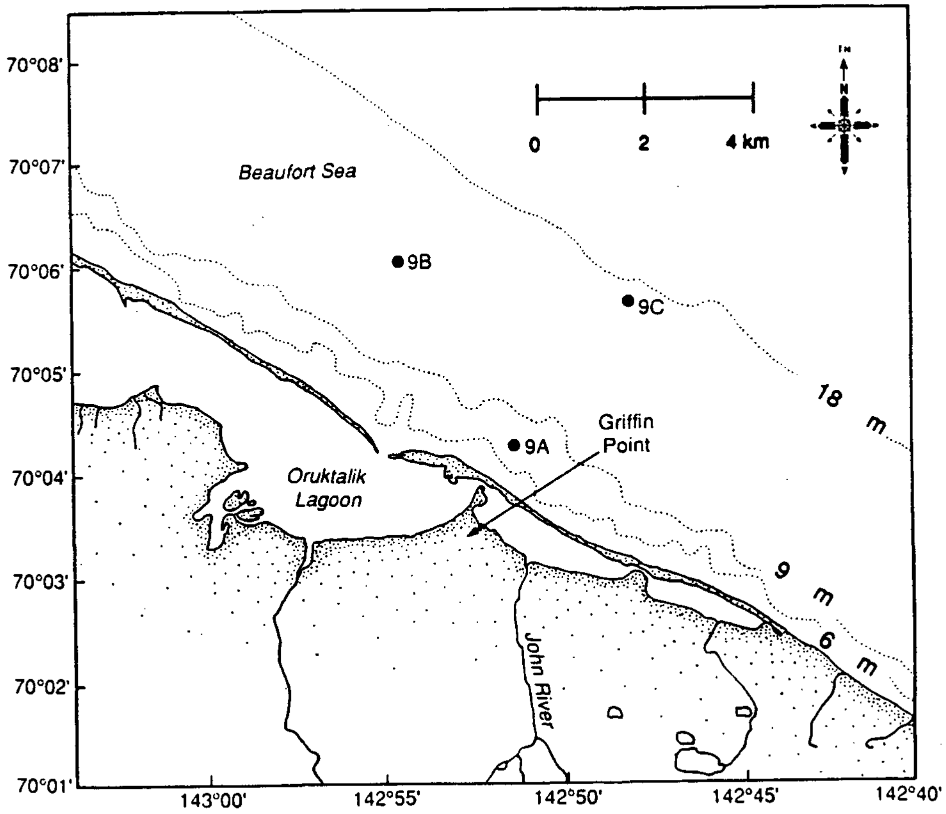


METALS
(ug/g)*

STATION	5(0)	5(1)	5(5)	5(10)		
REGION	6	6	6	6	Mean(Rgn6)**	Std(Rgn6)
Cd	(0.25, 0.04)	(0.22, 0.08)	(0.15, 0.06)	0.19	0.20	0.04
Pb	(8.2, 1.3)	(10, 2.1)	(8.2, 1.2)	10.5	9.23	1.20
Ba	(600, 41)	(620, 45)	(600, 45)	585	600.00	14.00
Cr	(88, 0.58)	(96, 1.2)	(90, 1.2)	84	89.00	5.00
Cu	(25, 0.26)	(24, 0.70)	(25, 0.35)	21.5	24.00	1.70
V	(150, 2.08)	(170, 9.1)	(160, 10)	168	160.00	9.10
Zn	(110, 2.5)	(110, 3.2)	(110, 0.58)	105	110.00	2.50
% Fe	(3.2, 0.13)	(3.2, 0.1)	(3.2, 0.1)	3.3	3.20	0.06
% Al	(5.9, 0.05)	(5.8, 0.2)	(5.7, 0.2)	5.8	5.80	0.09
% FINES	(29, 2.6)	(3.6, 0.93)	(36, 3.7)	69	27	20

* All concentrations reported as average means and standard deviation in parentheses.
** Regional means are averages calculated from the above mean station concentrations.

Figure 4.7 1989 Mean Trace Metal Concentrations and Percent Fines in Endicott Field Area Bulk Sediments.

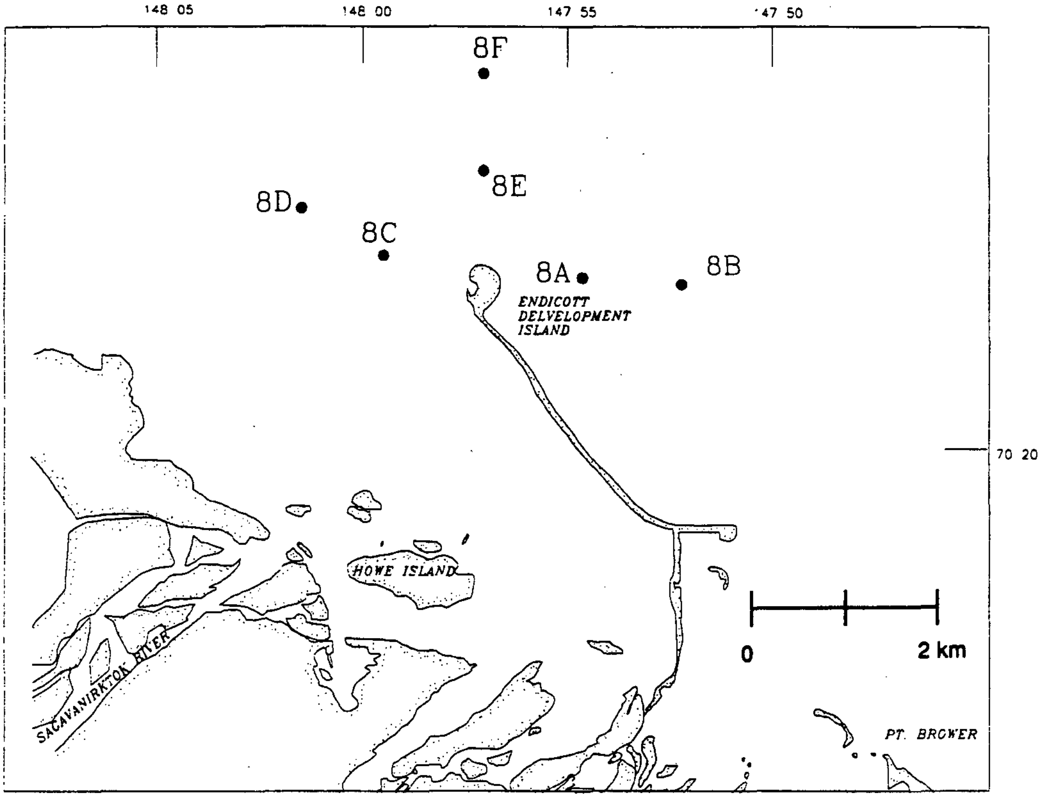


METALS
(ug/g)*

STATION	**9A**	**9B**	**9C**		
REGION	7	7	7	**Mean(Rgn7)****	**Std(Rgn7)**
Cd	(0.18, 0.04)	(0.13, 0.08)	(0.10, 0.01)	0.14	0.04
Pb	(17, 6.4)	(15, 3.9)	(12, 1.3)	14.67	2.52
Ba	(690, 24)	(710, 15)	(740, 60)	710.00	25.00
Cr	(85, 8.7)	(93, 4.4)	(90, 3.5)	89.00	4.00
Cu	(24, 0.96)	(23, 0.79)	(25, 1.3)	24.00	1.00
V	(140, 13)	(180, 5.0)	(160, 14)	160.00	20.00
Zn	(110, 2.7)	(110, 5.0)	(105, 3.1)	110.00	2.80
% Fe	(3.5, 0.073)	(3.5, 0.17)	(3.5, 0.13)	3.50	0.00
%Al	(6.3, 0.079)	(6.5, 6.5)	(6.4, 0.17)	6.50	0.07
% FINES	(2.6, 0.29)	(9.5, 1.0)	(61, 6.3)	24	28

*** All concentrations reported as average means and standard deviation in parentheses.**
**** Regional means are averages calculated from the above mean station concentrations.**

Figure 4.8 **1989 Mean Trace Metal Concentrations and Percent Fines in Griffin Point Area Bulk Sediments.**



METALS (ug/g)*

STATION	8A	8B	8C	8D	8E	8F		
REGION	**8**	**8**	**8**	**8**	**8**	**8**	**Mean(Rgn8)****	**Std(Rgn8)**
Cd	(0.15, 0.02)	(0.22, 0.00)	(0.15, 0.02)	(0.17, 0.02)	(0.20, 0.05)	(0.19, 0.03)	0.18	0.03
Pb	(5.1, 1.3)	(10, 0.53)	(7.5, 2.6)	(9.4, 2.6)	(8.8, 0.25)	(9.4, 3.6)	8.37	1.81
Ba	(610, 50)	(670, 38)	(490, 169)	(680, 26)	(600, 10)	(580, 22)	600.00	69.00
Cr	(88, 1.7)	(94, 3.6)	(86, 17)	(95, 2.9)	(88, 1.7)	(87, 1.5)	89.00	3.80
Cu	(23, 1.4)	(24, 0.36)	(19, 0.83)	(23, 0.35)	(26, 0.78)	(26, 0.23)	24.00	2.60
V	(140, 9.3)	(153, 6.1)	(120, 11)	(150, 8.6)	(160, 5.8)	(150, 13)	150.00	14.00
Zn	(110, 5.1)	(120, 3.5)	(120, 6.1)	(130, 4.9)	(120, 6.1)	(120, 4.5)	120.00	6.30
% Fe	(2.9, 0.21)	(3.3, 0.03)	(3.5, 0.1)	(3.4, 0.1)	(3.2, 0.2)	(3.3, 0.05)	3.30	0.21
% Al	(5.1, 0.2)	(6.1, 0.2)	(4.7, 0.7)	(5.5, 0.3)	(6.0, 0.2)	(5.7, 0.2)	5.50	0.54
% FINES	(38, 12)	(8.0, 3.5)	(0.57, 0.44)	(1.3, 0.15)	(66, 9.2)	(19, 2.3)	22	24

*** All concentrations reported as average means and standard deviation in parentheses.**

**** Regional means are averages calculated from the above mean station concentrations.**

Figure 4.9 1989 Mean Trace Metal Concentrations and Percent Fines in Endicott Development Island Area Bulk Sediments.

and evidenced little variability between regions. The percent aluminum and iron values ranged from 3.1 to 6.5 percent.

Overall, metal concentrations for the fine-fraction (<62 µm) of sediments from the Beaufort Sea for 1989 were relatively uniform. In almost every instance, the average metal concentrations for a given region were in close agreement with the grand average for all samples (Table 4.1). The overall standard deviations for the complete data set were also reasonably small for such a large geographic area (Table 4.1). For example, the coefficients of variation for the grand means were only about 12-20% for Al, Fe, Ba, Cu, V and Zn. Larger standard deviations for Cd and Pb resulted from the relatively low numbers obtained for these pristine sediments. This inherent uniformity in metal concentrations simplified the identification of anomalous values.

Two notable deviations from uniformity in the summary (Table 4.1) were for Ba and Cr in region 5, West Harrison Bay. Three sites in West Harrison Bay (stations 7A, 7B and 7G) had high Ba (900-1100 ppm) and Cr (160-219 ppm) concentrations relative to other locations throughout the Beaufort Sea study area. These values were well above levels observed at any other sites and were higher than expected for natural coastal marine sediments. These anomalies are discussed in Section 5.2.2

When compared with data for average continental crust, the primary source material for marine sediments, the Beaufort Sea sediments were comparable (Table 4.1). From Table 4.1 alone, no outstanding deviations were observed, realizing that a sizeable natural variation in crustal composition can be observed globally.

4.1.2 Trace Metals in Tissues. Five different organisms (Astarte, Cyrtodaria, Portlandia, Macoma and Anonyx) were collected from 13 different sites during the 1989 sampling season. This resulted in 19 data sets, distributed as follows:

Organism	Stations
Astarte (clams)	1A, 1B, 3A, 5(1), 5H, 6D
Cyrtodaria (clams)	5F, 6G
Portlandia (clams)	1A, 9B
Macoma (clams)	6D, 9B
Anonyx (amphipods)	1A/B/E(pooled), 2D, 4B, 5B, 5H, 6D, 7E

With this distribution of sampling, data for Astarte and Anonyx provided the best opportunity for comparing variations from site to site. Metal concentrations for each of the other organisms were just from two sites. Despite this limited data set, some very useful trends were observed (Table 4.2).

For the Astarte clams, concentrations of Fe, Cr, Cu, Pb, V and Zn were relatively uniform for all regions sampled. The low Fe values showed that the organisms were reasonably well rinsed free of any sediment. The low values observed for the other

Table 4.1 Regional Mean Concentrations for Trace Metals in Sediments

Region	Fe	Al	Ba	Cd	Cr	Cu	Pb	V	Zn
	(%)	(%)	(Concentrations in ppm)						
1	3.43	6.18	660	0.16	94	24	14	160	110
2	3.3	5.7	620	0.14	82	23	9	160	110
3	3.4	6.2	660	0.17	92	23	11	170	110
4	3.95	6.87	664	0.15	106	28	14	192	117
5	3.4	5.8	840	0.14	140	20	12	150	100
6	3.2	5.8	600	0.2	89	24	9	160	110
7	3.5	6.5	710	0.14	89	24	15	160	110
8	3.3	5.5	600	0.18	89	24	8	150	120
Grand Average (+/- SD)	3.38 (0.41)	5.93 (0.74)	651 (117)	0.16 (0.06)	96 (23)	23 (4)	11 (4)	155 (30)	109 (13)
Ave. Cont. Crust	4.1	8.2	500	0.11	100	50	14	160	75

Region	Stations
1	1A, 1B, 1C, 1D, 1E, 2A, 2B, 2C, 2D, 2E, 2F
2	3A, 3B, 4A, 4B, 4C, 5G, 5H
3	5A, 5B, 5D, 5E, 5F
4	6A, 6B, 6C, 6D, 6F, 6G
5	7A, 7B, 7C, 7D, 7E, 7G
6	5(0), 5(1), 5(5), 5(10)
7	9A, 9B, 9C
8	8A, 8B, 8C, 8D, 8E, 8F

Table 4.2 Summary Metal Concentrations for Beaufort Sea Organisms

Station	Fe	Ba	Cd	Cr	Cu	Pb	V	Zn
	(%)	(Concentration in ppm, dry weight)						
Astarte (clams)								
1A	0.12	10.5	17.5	1.4	10.5	0.35	2.9	84
1B	0.10	15.4	30.2	1.7	10.8	1.09	3.5	84
3A	0.11	31.1	4.2	1.3	16.2	0.36	2.9	91
5(1)	0.12	15.6	5.4	2.0	22.6	0.64	3.9	103
5H	0.08	30.9	6.5	1.5	15.0	0.33	2.5	78
6D	0.19	40.4	15.4	2.7	26.7	0.58	5.8	101
Cyrtodaria (clams)								
5F	0.22	27.7	1.9	3.1	20.4	0.59	8.4	81
6G	0.25	36.4	3.7	3.0	20.7	0.65	6.8	78
Portlandia								
1A	0.54	53.7	5.5	8.3	16.3	2.3	12.9	148
9B	0.55	81.7	7.2	8.3	22.2	1.4	15.3	170
Macoma (clams)								
6D	0.59	80.0	6.2	8.8	28	1.0	18.6	204
9B	0.59	85.6	1.4	9.7	10	1.5	10.4	100
Anonyx (amphipods)								
1A	0.04	31.6	4.3	0.8	110	0.48	3.6	149
2D	0.03	33.6	1.2	0.9	116	0.33	4.0	100
4B	0.02	39.7	1.6	0.7	138	0.30	2.5	109
5B	0.01	17.9	2.5	0.5	60	0.42	1.5	177
5H	0.04	57.5	1.7	1.2	90	0.50	4.1	121
6D	0.04	31.0	2.5	1.0	115	0.37	3.9	27
7E	0.04	79.4	0.8	1.6	100	0.47	3.4	80

metals did not suggest any obvious contamination. The Cd trend for Astarte showed lower values in the central regions (stations 3A, 5(1) and 5H) than at offshore site 6D and Camden Bay sites 1A and 1B. This trend may be related to the bioavailability and natural cycling of Cd and will be discussed along with the other metals in Section 5.2.

The data sets for the other clams were limited and the metal concentrations in the various clam species are not always interrelated. Metal data for Cyrtodaria compared well with values for Astarte. The data for Portlandia and Macoma showed naturally higher concentrations for Ba, Cr, Cu, V and Zn.

For the amphipod Anonyx, relatively uniform values were observed among regions for all metals with some minor exceptions. These exceptions were as follows: the Ba level at station 7E was higher than the overall trend, the Cu values for station 5B were low, and the Zn value for station 6D was low. These minor deviations were masked by the overall uniformity of the data; however, they will be discussed below.

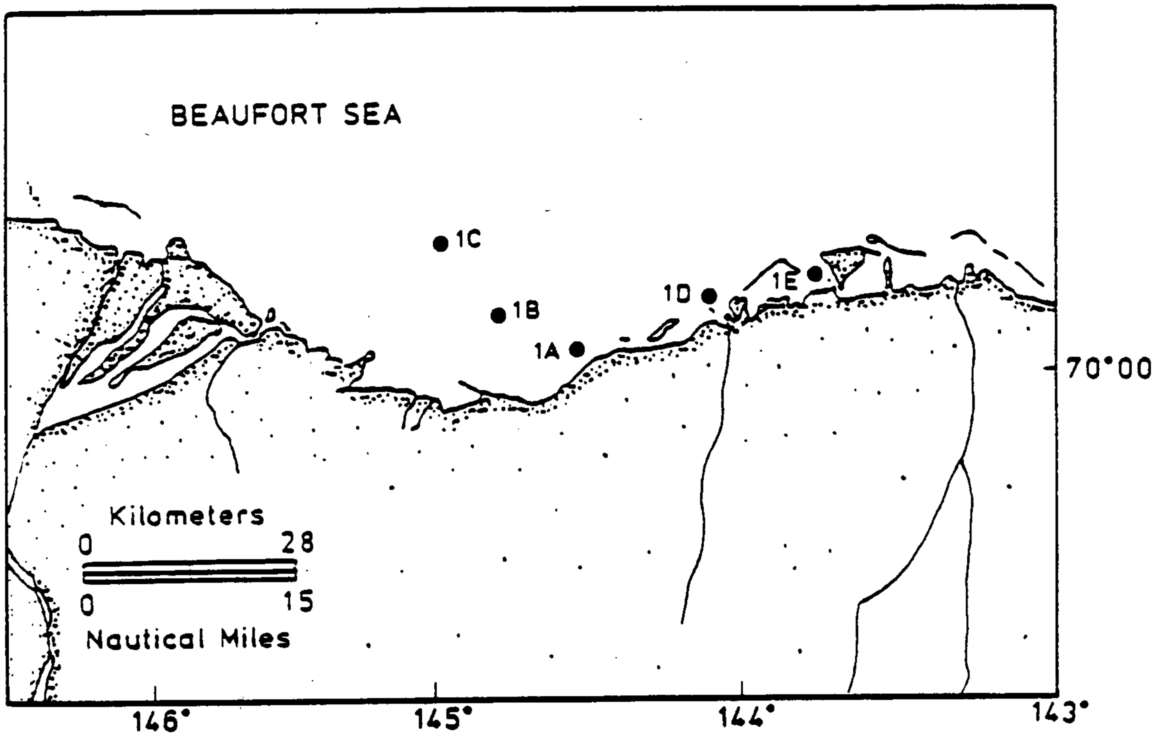
Overall, only a limited number of minor variations occurred in the site by site and region by region patterns for concentrations of trace metals. Thus, the organism data set provides a good baseline for future reference.

4.2 Hydrocarbon Results.

GC/FID analyses for saturated hydrocarbons and GC/MS analyses for aromatic hydrocarbons were performed on marine sediments and animal tissues. The hydrocarbon analyses were performed on bulk sediment samples. The samples for each station were analyzed as either pooled grab replicates or three individual replicates in the same manner as sediments for metals analysis. The results for pooled samples are reported as one value while the replicate analyses are reported as the mean with the standard deviation in parentheses. All of the tissue samples of sufficient quantity were analyzed in triplicate and are reported as the mean ± the standard deviation. Results of the three tissue samples analyzed as a single replicate are reported as one value.

The saturated and aromatic hydrocarbon data are presented in the form of key parameters and ratios which most relevant to the interpretation of the data and testing of the hypotheses. The total organic carbon and percent fines (silt/clay) are presented along with the hydrocarbon data for comparison.

4.2.1 Saturated Hydrocarbons in Sediments. Figures 4.10 through 4.18 present the saturated hydrocarbon data for the 48 stations sampled during 1989 and the regional saturated hydrocarbon means. The total alkanes (TALK), the C10 through C34 normal alkanes, ranged from 0.12 to 15.1 μg/g (dry weight) throughout the study area. The low molecular weight alkanes (LALK), n-C10 through n-C20 compounds,

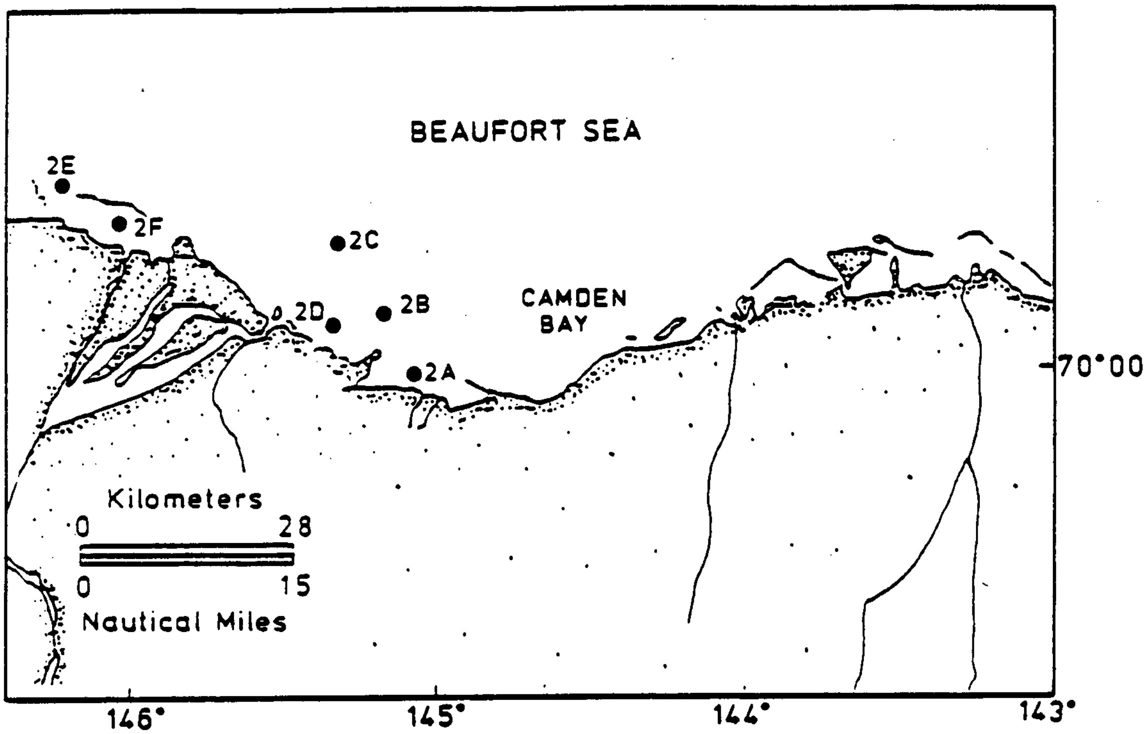


SATURATED HYDROCARBON (ug/g)*

STATION	1A	1B	1C	1D	1E
REGION	1	1	1	1	1
pris	0.021	0.0083	0.047	0.0042	(0.0058, 0.0016)
phyt	0.015	0.0046	0.036	0.0028	(0.0066, 0.0014)
TOT	5.7	0.86	8.9	1.5	(6.1, 2.1)
LALK	0.28	0.06	0.34	0.12	(0.24, 0.067)
TALK	2.6	0.32	2.2	1.1	(3.5, 1.4)
TOC	9.9	23	7.8	4.4	(10, 2.9)
% FINES	74	15	76	67	(82, 14)

* All concentrations reported as average means and standard deviation in parentheses.

Figure 4.10 1989 Mean Saturated Hydrocarbon Concentrations, Percent Fines, And Total Organic Carbon in East Camden Bay Area Bulk Sediments.



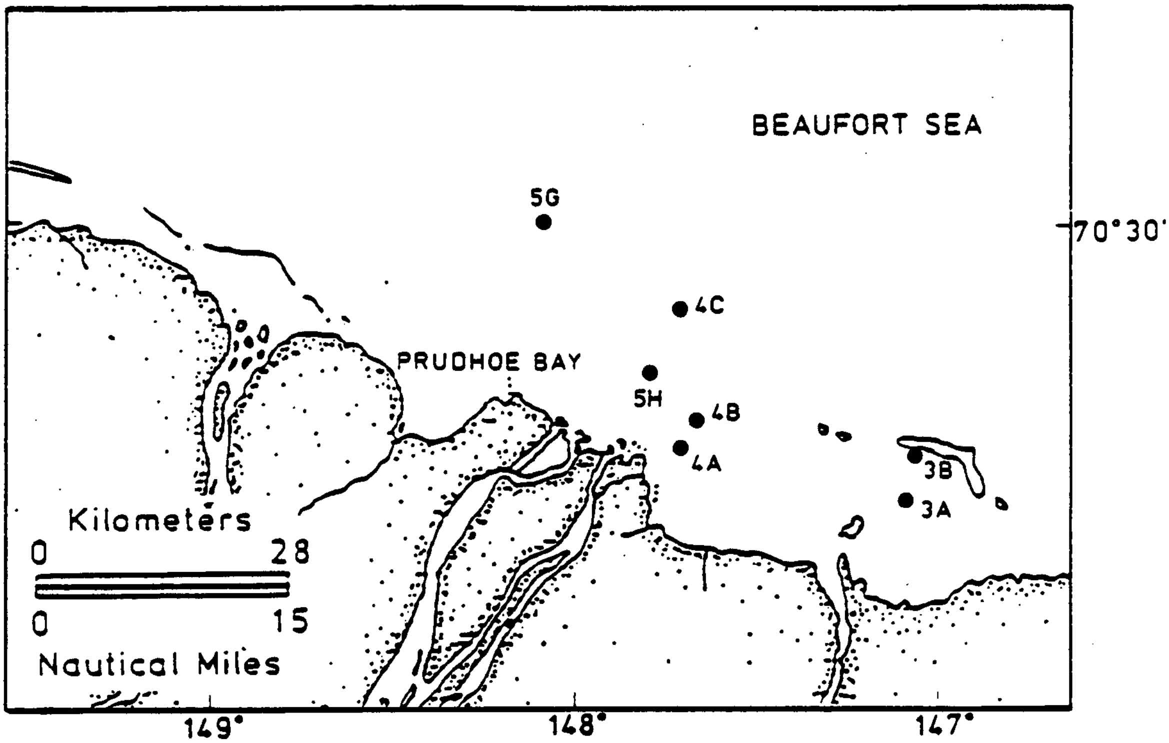
SATURATED HYDROCARBON (ug/g)*

STATION	2A	2B	2C	2D	2E	2F		
REGION	1	1	1	1	1	1	Mean(Rgnl)**	Std(Rgnl)
pris	0.11	0.01	0.069	0.015	0.0043	0.015	0.028	0.037
phyt	0.066	0.0057	0.055	0.0091	0.0032	0.0095	0.019	0.024
TOT	18	1.5	9.7	2.2	1.1	3.1	5.3	5.8
LALK	1.3	0.12	0.64	0.17	0.06	0.19	0.32	0.40
TALK	6.4	0.64	2.70	0.69	0.33	1.0	1.7	1.9
TOC	19.0	2.6	8.4	0.11	1.5	4.1	6.0	5
% FINES	87	20	75	8.2	4.3	14	53	34

* All concentrations reported as average means and standard deviation in parentheses.

** Regional means are averages calculated from the above mean station concentrations.

Figure 4.11 1989 Mean Saturated Hydrocarbon Concentrations, Percent Fines, And Total Organic Carbon in West Camden Bay Area Bulk Sediments.



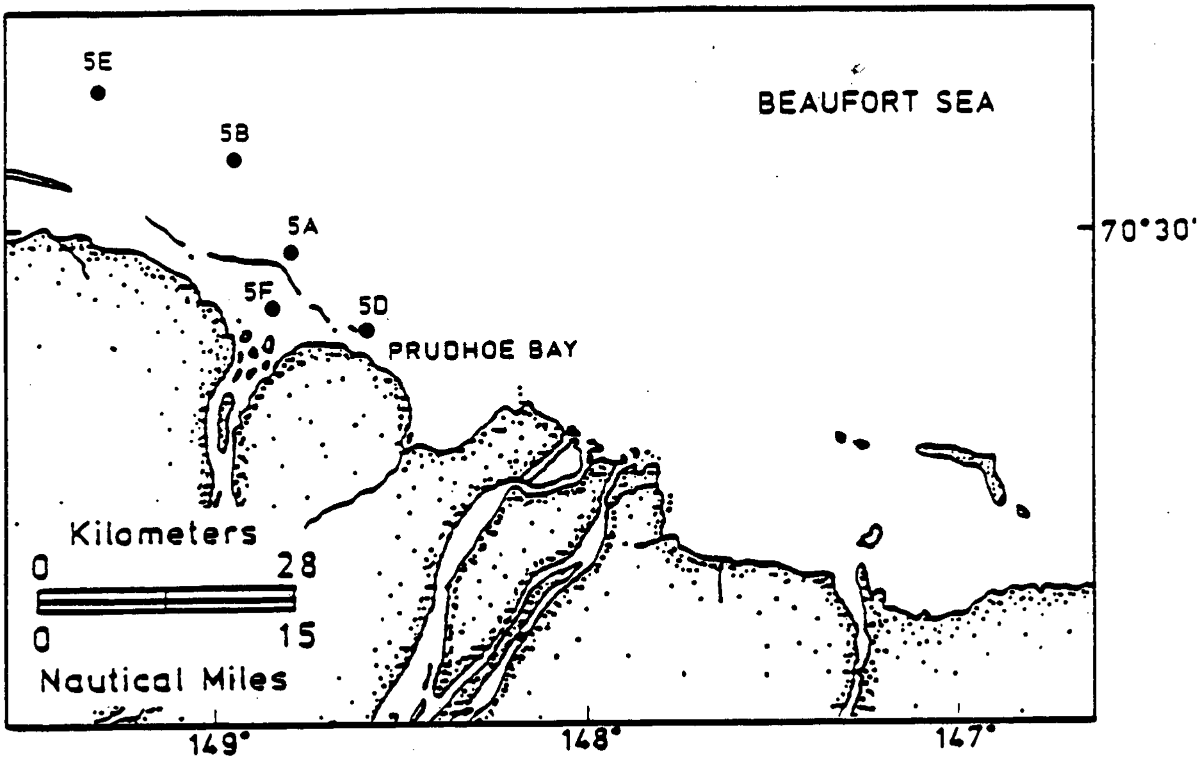
SATURATED HYDROCARBON (ug/g)*

STATION	3A	3B	4A	4B	4C	5G	5H		
REGION	2	2	2	2	2	2	2	Mean(Rgn2)**	Std(Rgn2)
pris	0.063	(0.036, 0.0015)	0.02	0.016	0.0071	0.016	0.025	0.026	0.019
phyt	0.041	(0.023, 0.0006)	0.013	0.0099	0.0033	0.0091	0.015	0.016	0.012
TOT	10	(5.1, 0.70)	3.8	2.0	0.61	3.3	3.6	4.1	3.0
LALK	0.67	(0.45, 0.019)	0.23	0.18	0.06	0.15	0.27	0.29	0.21
TALK	3.3	(2.2, 0.016)	1.5	0.95	0.36	1.0	1.4	1.5	0.96
TOC	9.8	(7.8, .4)	2.7	2.5	0.9	6.4	4.2	4.9	3.2
% FINES	85	(78, 1.1)	18	17	3.8	43	35	49	32

* All concentrations reported as average means and standard deviation in parentheses.

** Regional means are averages calculated from the above mean station concentrations.

Figure 4.12 1989 Mean Saturated Hydrocarbon Concentrations, Percent Fines, And Total Organic Carbon in Foggy Island Bay Area Bulk Sediments.



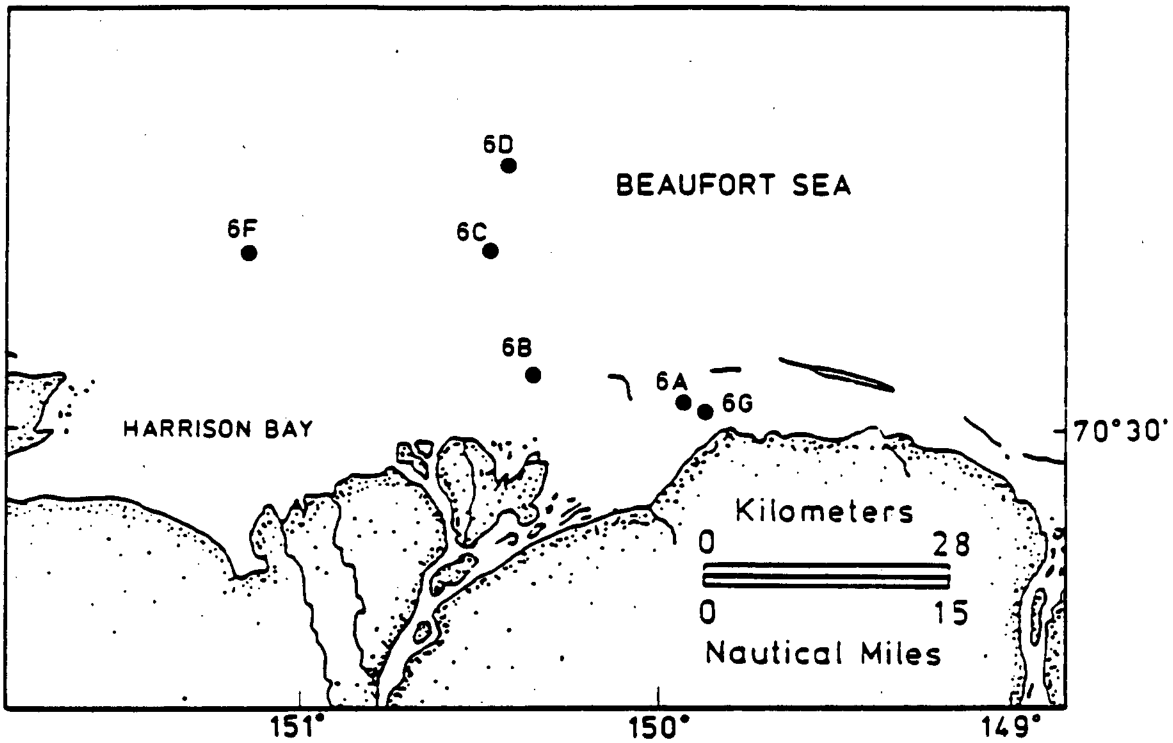
SATURATED HYDROCARBON (ug/g)*

STATION	5A	5B	5D	5E	5F		
REGION	3	3	3	3	3	Mean(Rgn3)**	Std(Rgn3)
PRIS	(0.018, 0.0069)	0.0041	0.074	0.06	0.041	0.039	0.029
PHYT	(0.0099, 0.0036)	0.0018	0.043	0.033	0.022	0.022	0.017
TOT	(2.97, 1.1)	0.26	19	6.8	8.6	7.5	7.2
LALK	(0.19, 0.087)	0.04	1.0	0.57	0.55	0.48	0.39
TALK	(1.1, 0.44)	0.18	7.3	2.2	3.9	2.9	2.8
TOC	(4.4, 14)	0.7	30	3.8	9.1	9.6	12
% FINES	(31, 7.1)	3.5	64	27	53	36	24

* All concentrations reported as average means and standard deviation in parentheses.

** Regional means are averages calculated from the above mean station concentrations.

Figure 4.13 **1989 Mean Saturated Hydrocarbon Concentrations, Percent Fines, And Total Organic Carbon in Kuparuk River Bay Area Bulk Sediments.**



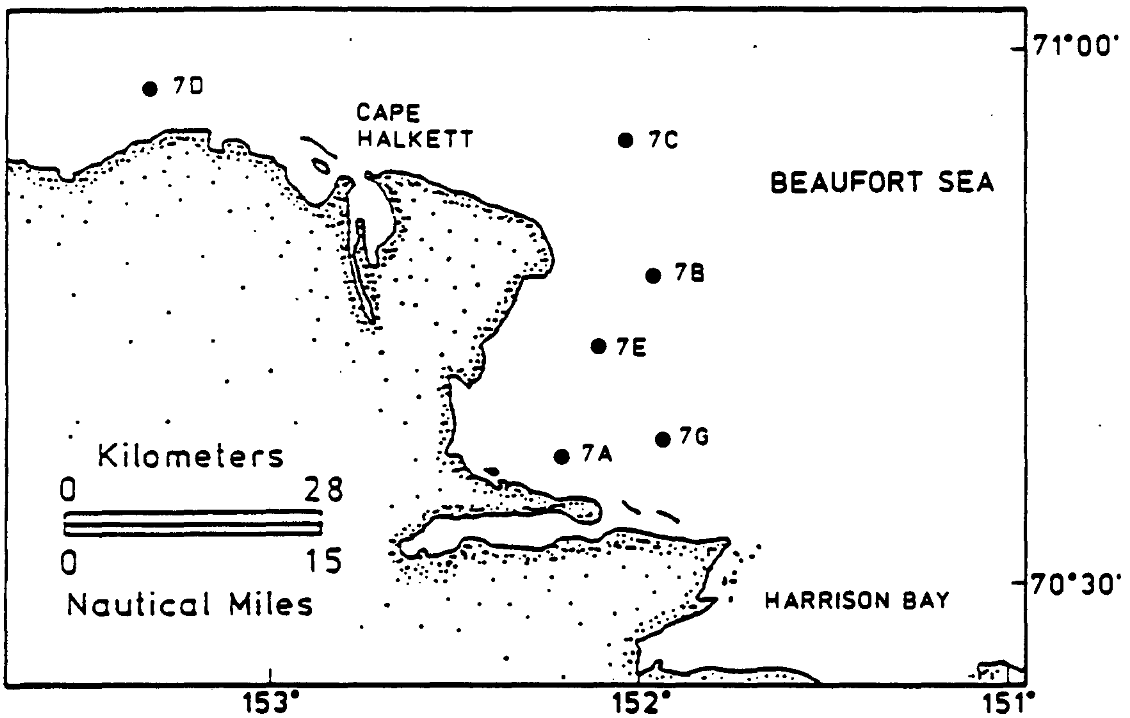
SATURATED HYDROCARBON (ug/g)*

STATION	6A	6B	6C	6D	6F	6G		
REGION	4	4	4	4	4	4	Mean(Rgn4)**	Std(Rgn4)
PRIS	0.017	0.23	0.0058	(0.032, 0.0066)	0.0063	0.097	0.065	0.088
PHYT	0.01	0.13	0.0031	(0.016, 0.0040)	0.004	0.057	0.037	0.050
TOT	2.3	38	0.72	(2.20, 0.40)	0.47	21	11	15
LALK	0.18	2.5	0.05	(0.31, 0.069)	0.06	1.7	0.8	1.1
TALK	0.95	15	0.20	(1.4, 0.21)	0.31	8.8	4.5	6.2
TOC	15	15	7.5	(3.4, 0.6)	6.7	16	11	5.3
% FINES	96	93	45	(18, 5.5)	51	75	63	30

* All concentrations reported as average means and standard deviation in parentheses.

** Regional means are averages calculated from the above mean station concentrations.

Figure 4.14 1989 Mean Saturated Hydrocarbon Concentrations, Percent Fines, And Total Organic Carbon in East Harrison Bay Area Bulk Sediments.

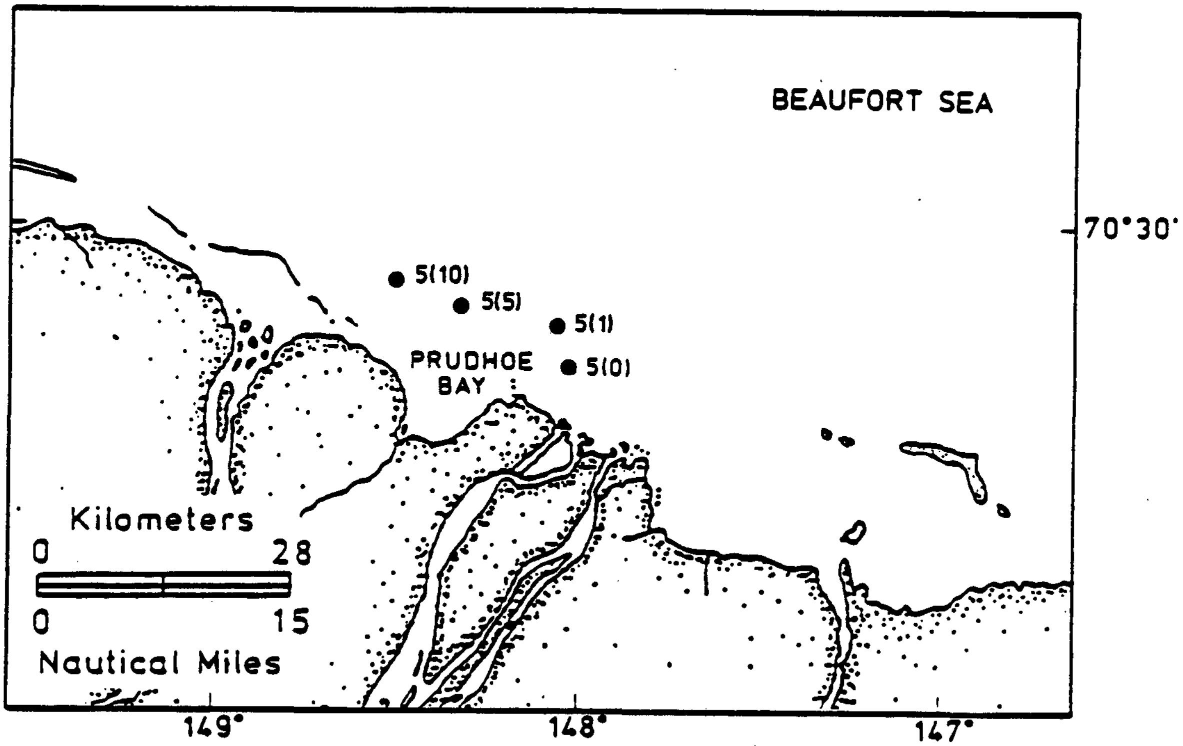


SATURATED HYDROCARBON (ug/g)*

STATION	7A	7B	7C	7D	7E	7G		
REGION	5	5	5	5	5	5	Mean(Rgn5)**	Std(Rgn5)
PRIS	0.036	(0.0210, 0.0044)	0.098	0.049	0.12	0.1	0.071	0.037
PHYT	0.021	(0.011, 0.0020)	0.054	0.024	0.055	0.025	0.032	0.017
TOT	5.9	(2.9, 0.61)	12	5.8	16	6.0	8.1	4.5
LALK	0.41	(0.22, 0.045)	1.0	0.53	1.0	0.46	0.61	0.30
TALK	2.4	(1.2, 0.18)	4.8	2.7	7.1	2.00	3.4	2.0
TOC	6.0	(2.9, 8.0)	9.3	6.4	13.0	7.6	7.60	3.20
% FINES	34	(15, 3.8)	75	32	86	26	37	28

* All concentrations reported as average means and standard deviation in parentheses.
** Regional means are averages calculated from the above mean station concentrations.

Figure 4.15 1989 Mean Saturated Hydrocarbon Concentrations, Percent Fines, And Total Organic Carbon in West Harrison Bay Area Bulk Sediments

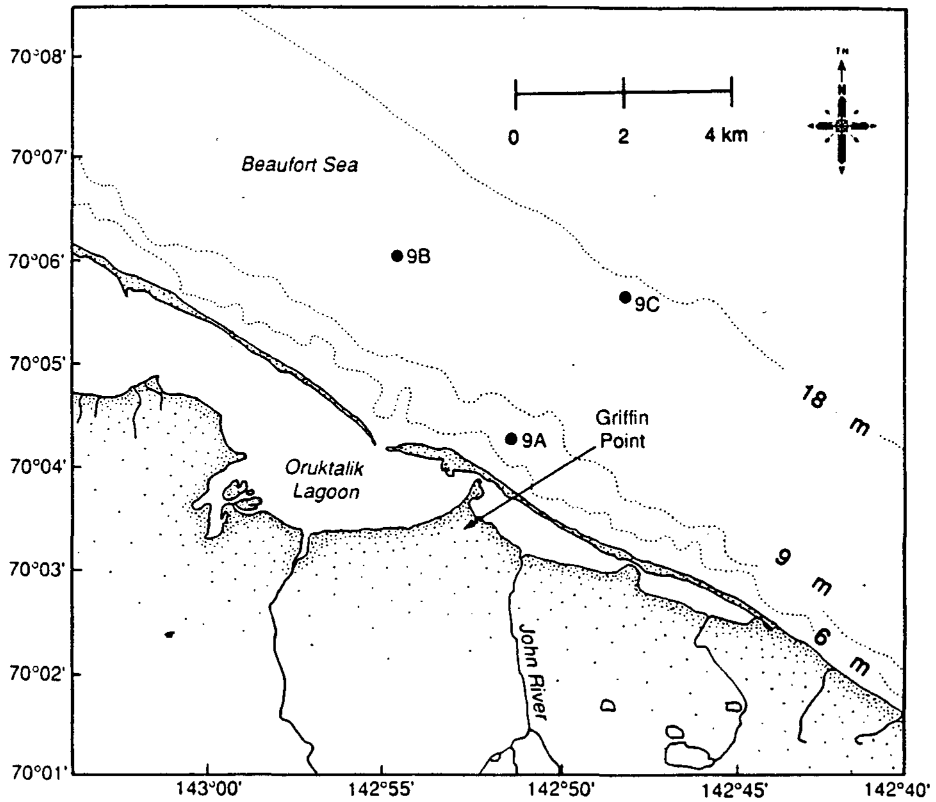


SATURATED HYDROCARBON (ug/g)*

STATION	5(0)	5(1)	5(5)	5(10)		
REGION	6	6	6	6	Mean(Rgn6)**	Std(Rgn6)
PRIS	(0.032, 0.0035)	(0.0041, 0.0009)	(0.027, 0.0036)	0.026	0.022	0.011
PHYT	(0.018, 0.0020)	(0.0025, 0.0007)	(0.015, 0.0020)	0.015	0.013	0.006
TOT	(4.6, 1.7)	(0.51, 0.071)	(2.6, 0.21)	3.5	2.8	1.5
LALK	(0.057, 0.037)	(0.058, 0.015)	(0.39, 0.016)	0.3	0.19	0.14
TALK	(0.40, 0.058)	(0.39, 0.057)	(2.2, 0.27)	1.1	1.0	0.74
TOC	(4.5, 1.4)	(1.1, 0.1)	(5.7, 0.6)	12	5.9	4.0
% FINES	(29, 2.6)	(3.6, 0.93)	(36, 3.6)	69	27	20

* All concentrations reported as average means and standard deviation in parentheses.
** Regional means are averages calculated from the above mean station concentrations.

Figure 4.16 1989 Mean Saturated Hydrocarbon Concentrations, Percent Fines, And Total Organic Carbon in Endicott Field Bulk Area Bulk Sediments.

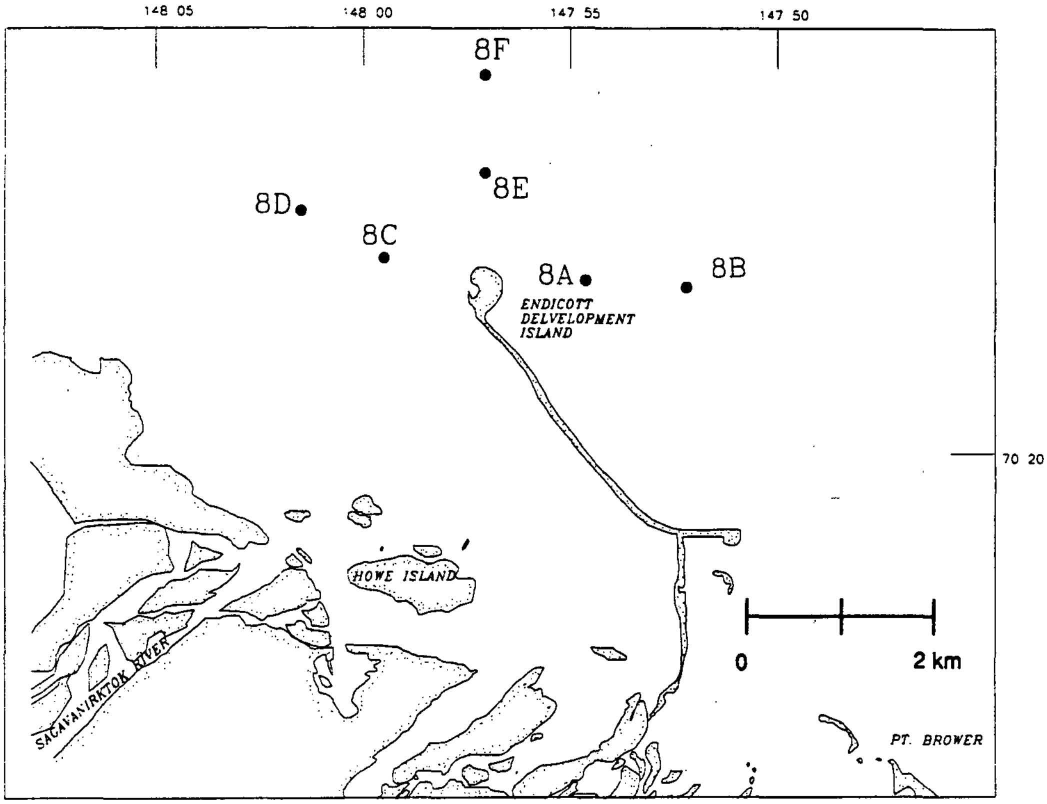


SATURATED HYDROCARBON (ug/g)*

STATION	9A	9B	9C		
REGION	7	7	7	Mean(Rgn7)**	Std(Rgn7)
PRIS	(0.0046, 0.0043)	(0.0083, 0.0014)	(0.043, 0.0025)	0.019	0.021
PHYT	(0.0046, 0.0042)	(0.0045, 0.0011)	(0.030, 0.0015)	0.013	0.015
TOT	(0.70, 0.12)	(1.0, 0.42)	(6.1, 0.55)	2.6	3.0
LALK	(0.40, 0.040)	(0.054, 0.016)	(0.31, 0.024)	0.25	0.18
TALK	(2.0, 0.24)	(0.31, 0.040)	(1.6, 0.18)	1.3	0.88
TOC	(1.0, 0.1)	(2.1, 0.1)	(7.1, 1.1)	3.4	3.3
% FINES	(2.6, 0.29)	(9.5, 1.0)	(61, 6.3)	24	28

*** All concentrations reported as average means and standard deviation in parentheses.**
**** Regional means are averages calculated from the above mean station concentrations.**

Figure 4.17 **1989 Mean Saturated Hydrocarbon Concentrations, Percent Fines, And Total Organic Carbon in Griffin Point Area Bulk Sediments.**



SATURATED HYDROCARBON (ug/g)*

STATION	8A	8B	8C	8D	8E	8F		
REGION	8	8	8	8	8	8	Mean(Rgn8)**	Std(Rgn8)
PRIS	(0.034, 0.0095)	(0.0084, 0.0032)	(0.0018, 0.0001)	(0.0015, 0.0004)	(0.073, 0.0069)	(0.017, 0.0021)	0.023	0.025
PHYT	(0.019, 0.0059)	(0.0047, 0.0017)	(0.0014, 0.0007)	(0.0016, 0.0009)	(0.041, 0.0038)	(0.0097, 0.0014)	0.013	0.014
TOT	(7.3, 2.1)	(0.94, 0.20)	(0.26, 0.059)	(0.24, 0.11)	(14.00, 2.30)	(3.2, 0.47)	4.3	5.0
LALK	(0.40, 0.12)	(0.090, 0.031)	(0.03, 0.0032)	(0.021, 0.0080)	(0.90, 0.072)	(0.20, 0.026)	0.27	0.31
TALK	(2.47, 0.77)	(0.56, 0.15)	(0.12, 0.025)	(0.13, 0.067)	(5.2, 0.73)	(1.1, 0.16)	1.6	1.8
TOC	(6.4, 1.8)	(2.0,0.4)	(0.8, 0.0)	(0.9, 0.0)	(11, 1.4)	(2.8, 0.3)	4.0	3.7
% FINES	(38, 12)	(8.0, 3.5)	(0.57, 0.44)	(1.3, 0.15)	(66, 9.2)	(19, 2.3)	22	25

* All concentrations reported as average means and standard deviation in parentheses.
** Regional means are averages calculated from the above mean station concentrations.

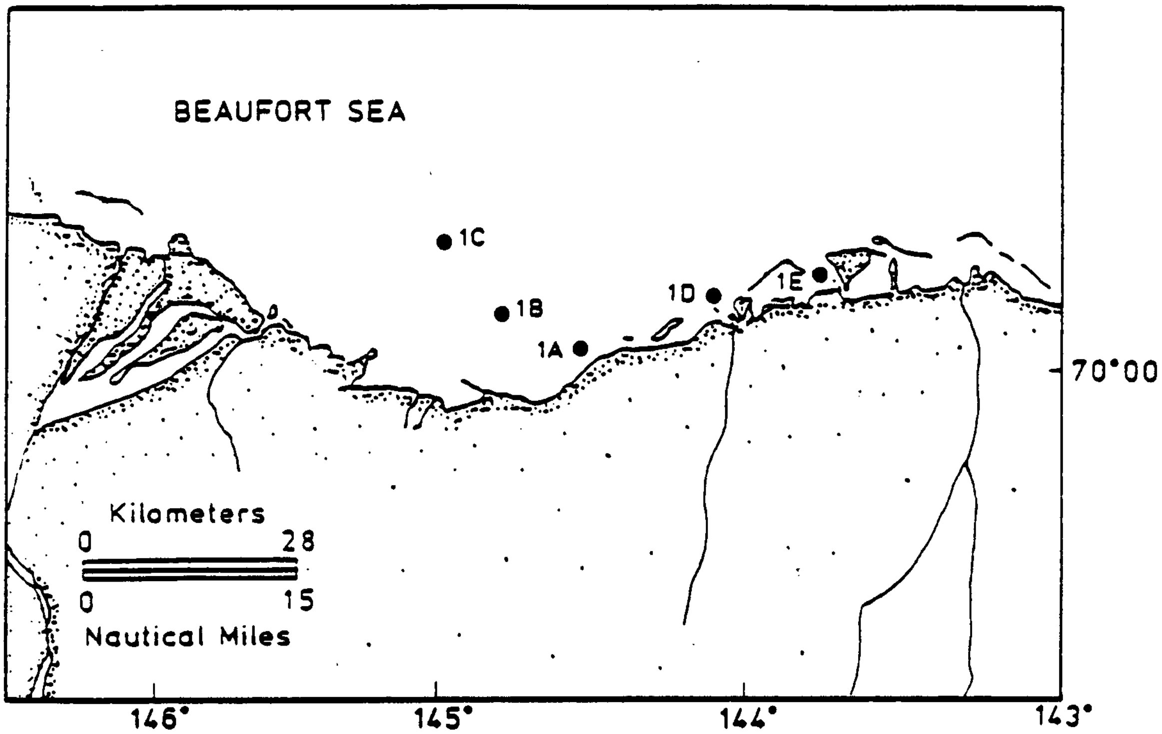
Figure 4.18 1989 Mean Saturated Hydrocarbon Concentrations, Percent Fines, And Total Organic Carbon in Endicott Development Island Bulk Sediments.

ranged from 0.02 to 2.52 µg/g. The concentrations of the isoprenoids pristane and phytane were low at all stations and ranged from 0.0015 to 0.23 µg/g. The total resolved plus unresolved saturated hydrocarbons concentrations (TOT) ranged from 0.25 to 38 µg/g. The percent fine values varied extensively from 0.56 to 96 percent, and the total organic carbon levels range from 0.11 to 19 mg/g dry weight.
The regional means of the saturated hydrocarbon parameters demonstrated the variations in the saturated hydrocarbons from region to region. Sediments from East Harrison Bay (Region 4) which are closest to the mouth of the Colville River, evidenced the highest mean TOT concentration of 11 µg/g. This region also had the highest percent fine value of 63 percent (Figure 4.14). Griffin Point, east of Barter Island had the lowest total saturated hydrocarbon concentration of 2.6 µg/g and also had one of the lowest percent fine values (Figure 4.17). The remaining regions exhibited mean TOT concentrations intermediate to East Harrison Bay and Griffin Point. The regional means clearly showed a relationship between the total saturated hydrocarbon concentration and the percent fines and TOC values. The regions with the highest TOT values generally had the highest percent fines and TOC concentrations. The one exception is the Endicott Development Island (Region 8) which had the lowest percent fines value for all regions, but had an intermediate mean TOT concentration.

4.2.2 Aromatic Hydrocarbons in Sediments. The aromatic hydrocarbon parameters for the 48 stations sampled during the 1989 field survey are presented in Figures 4.19 through 4.27. Total naphthalenes (TOT N) are the sum of the concentrations of the parent compound naphthalene and its alkyl homologues (C_1naphthalene - C_4naphthalene). Total fluorenes (TOT F), total dibenzothiophenes (TOT D), total phenanthrenes/anthracenes (TOT P) and total chrysenes (TOT C) are also the sums of the concentrations of the parent compounds and their corresponding alkyl homologues. Table 3.4 lists all of the target PAH analytes. Total PAH (TOT PAH) is the sum of the concentrations of all of these anlaytes. The percent fines and TOC values are also presented for comparison.

The regional means for each PAH parameter are also provided. The regional trends for the PAH data were similar to those observed for the saturated hydrocarbons. The overall highest concentrations of aromatics were present in Region 4, while the lowest PAH levels were found in the Griffin Point area.

The PAH data for the Camden Bay area (Region 1) are presented in Figures 4.19 and 4.20. The TOT PAH concentrations in this region were low and ranged from 47 to 1,200 ng/g with a regional mean of 500 ng/g. The PAH concentrations were variable from station to station and there were no discernable nearshore-to offshore gradients. The highest PAH levels in the region were associated with offshore station 1C and nearshore station 2A. The sediment PAH concentrations for the Mikelson Bay-Foggy Island Bay area (Region 2) are presented in Figure 4.21. The TOT PAH concentrations ranged from 210 ng/g at station 4C to 1,300 ng/g at 3A, with a

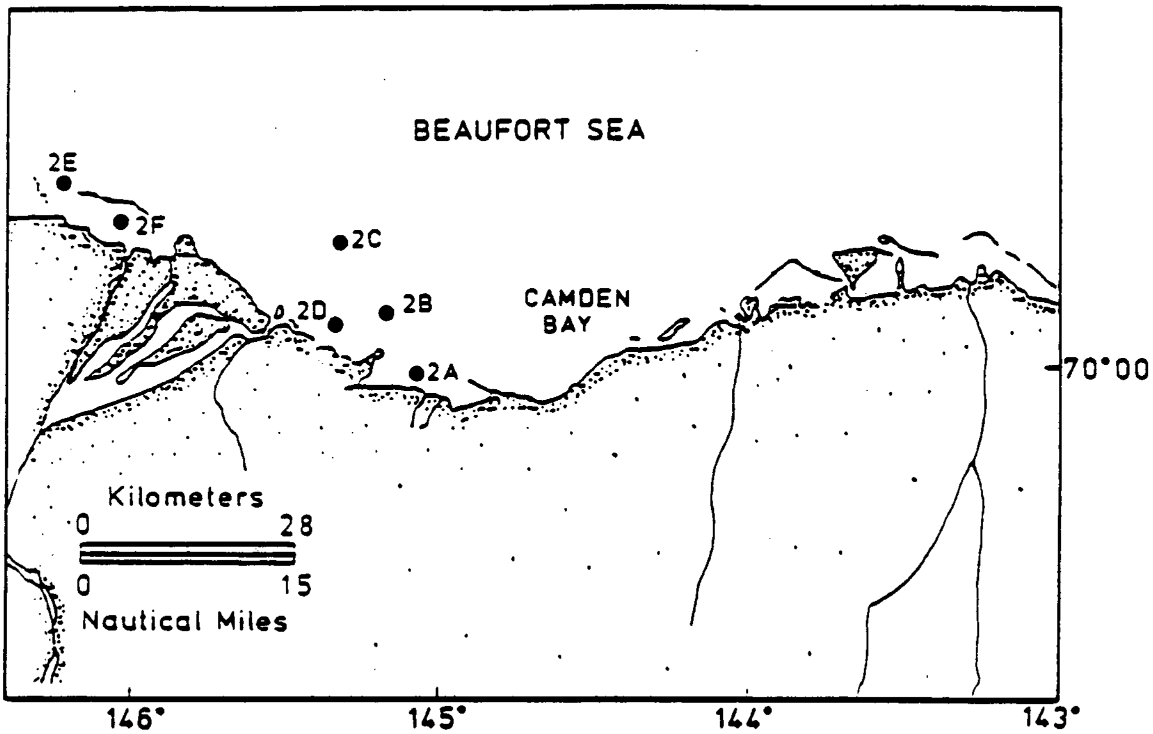


AROMATIC HYDROCARONS (ng/g)*

STATION	1A	1B	1C	1D	1E
REGION	1	1	1	1	1
TOT N	100	86	530	24	(50, 4.9)
TOT F	37	0	190	2.1	(24, 18)
TOT D	3.2	0	29	0	(3.4, 4.9)
TOT P	130	68	260	12	(29, 14)
TOT C	15	0	48	2.0	(2.1, 0.6)
TOT PAH	330	160	1200	48	(130, 30)
TOC	9.9	2.3	7.8	4.4	(10, 2.9)
% FINES	74	15	76	67	(82, 14)

*All concentrations reported as average means and standard deviation in parentheses.

Figure 4.19 1989 Mean Aromatic Hydrocarbon Concentrations, Percent Fines, And Total Organic Carbon in East Camden Bay Area Bulk Sediments.

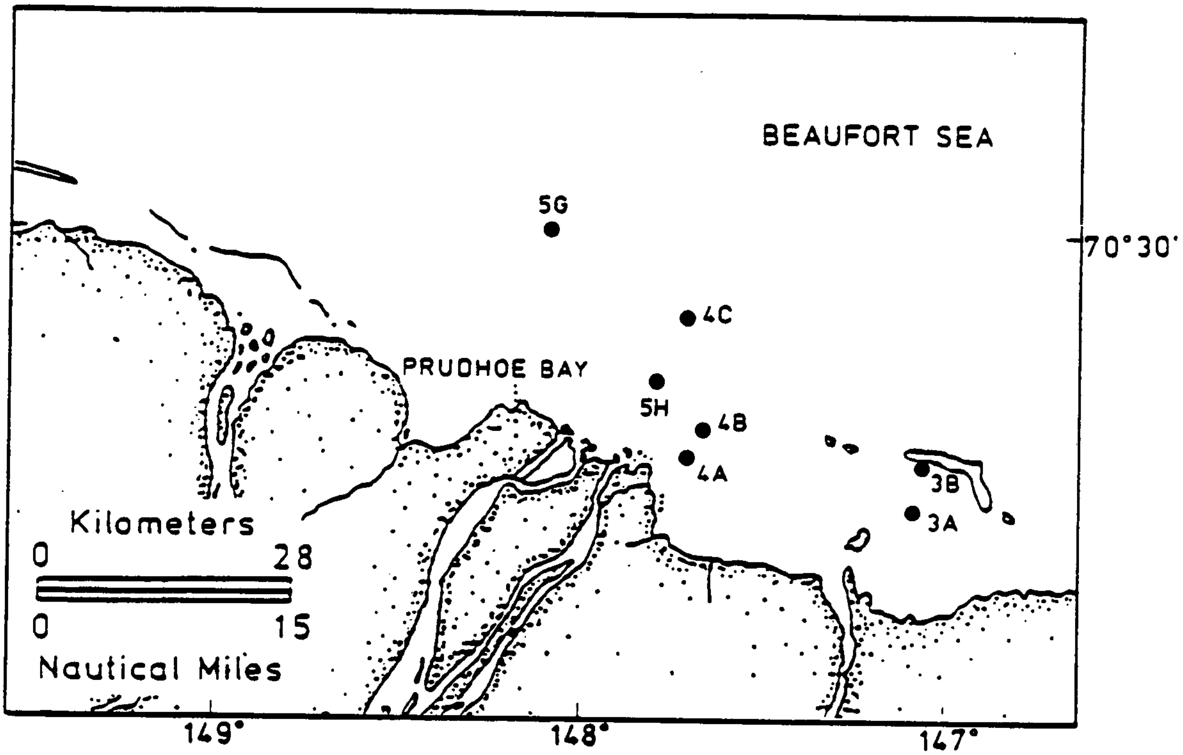


AROMATIC HYDROCARBONS (ng/g)*

STATION	2A	2B	2C	2D	2E	2F		
REGION	1	1	1	1	1	1	N	(Rgn1)
TOT N	590	66	32	85	30	97		00
TOT F	260	17	0	34	17	36	56	
TOT D	70	0.65	0	10	3.0	.7	12	
TOT P	650	46	7.6	83	24	86	130	
TOT C	190	4.8	0	11	2.8	13	26	
TOT PAH	2100	158	47	260	89	290	491	
TOC	19	2.6	8.4	1.1	1.5	4.1	6	
% FINES	87	20	75	8.2	4.3	14	53	34

* All concentrations reported as average means and standard deviation in parentheses.
** Regional means are averages calculated from the above mean station concentrations.

Figure 4.20 1989 Mean Aromatic Hydrocarbon Concentrations, Percent Fines, And Total Organic Carbon in West Camden Bay Area Bulk Sediments.

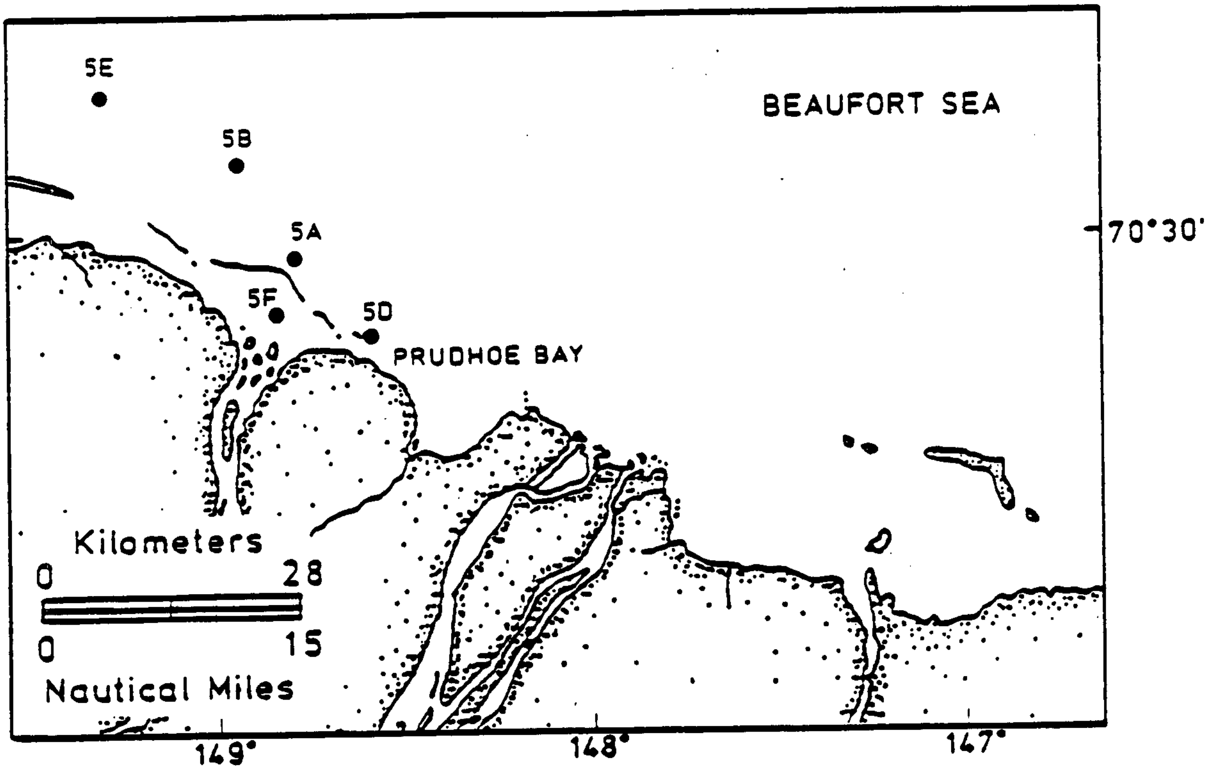


AROMATIC
HYDROCARBON
(ng/g)*

STATION	3A	3B	4A	4B	4C	5G	5H		
REGION	2	2	2	2	2	2	2	Mean(Rgn2)**	Std(Rgn2)
TOT N	540	(230, 39)	270	180	120	160	200	210	167
TOT F	200	(62,20)	120	66	27	87	110	87	66
TOT D	30	(31,4.6)	19	16	5.1	16	18	15	10
TOT P	340	(190, 7.3)	130	120	33	100	180	129	111
TOT C	79	(21, 3.5)	31	20.29	5.2	28	41	29	26
TOT PAH	1300	(640, 56)	650	460	210	390	620	519	413
TOC	9.8	(7.8, 0.4)	2.7	2.5	0.9	6.4	4.2	4.9	3.2
% FINES	85	(78, 1.1)	18	17	3.8	43	35	49	32

* All concentrations reported as average means and standard deviation in parentheses.
** Regional means are averages calculated from the above mean station concentrations.

Figure 4.21 1989 Mean Aromatic Hydrocarbon Concentrations, Percent Fines, And Total Organic Carbon in Foggy Island Bay Area Bulk Sediments.

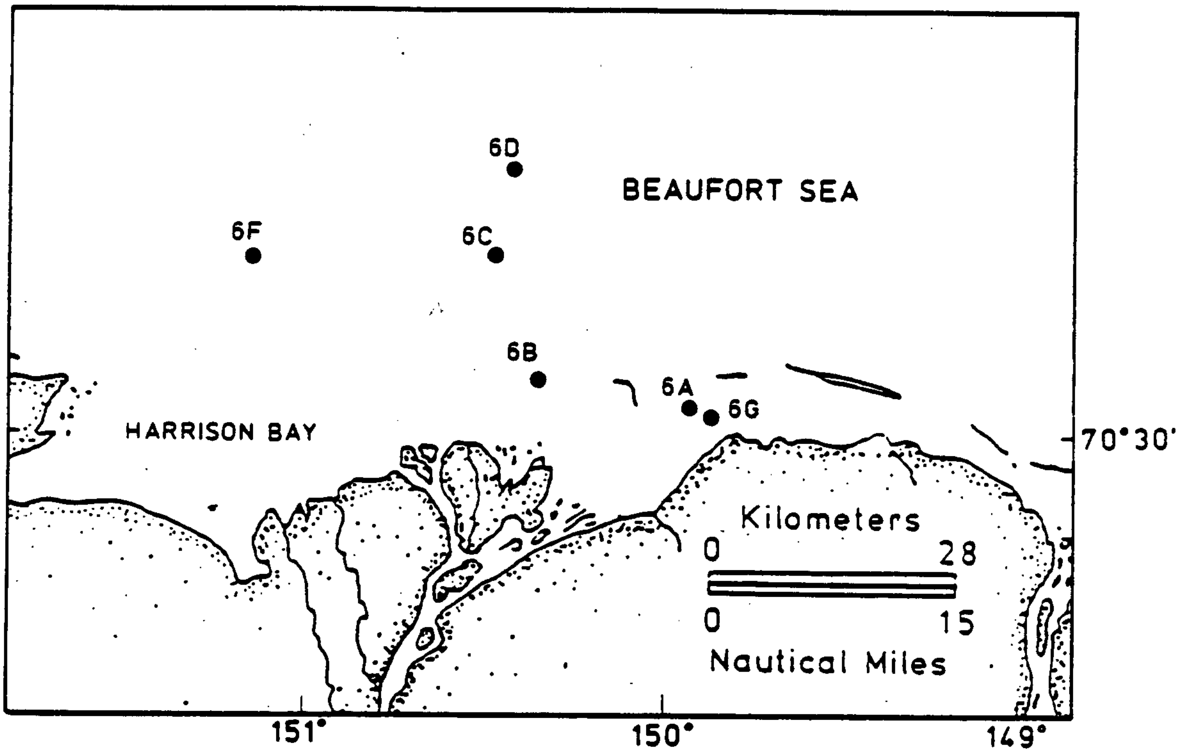


AROMATIC
HYDROCARBON
(ng/g)*

STATION	5A	5B	5D	5E	5F		
REGION	3	3	3	3	3	Mean(Rgn3)**	Std(Rgn3)
TOT N	(180, 37)	34	460	700	320	340	260
TOT F	(21, 29)	0	140	170	71	80	74
TOT D	(24, 3.5)	0	71	52	44	38	27
TOT P	(190, 42)	46	450	300	260	250	150
TOT C	(15, 21)	0	88	63	62	46	37
TOT PAH	(460, 11)	80	1400	1500	890	870	600
TOC	(4.4, 14)	0.7	30	3.8	9.1	9.60	12.0
% FINES	(31, 7.1)	3.5	64	27	53	36	24

* All concentrations reported as average means and standard deviation in parentheses.
** Regional means are averages calculated from the above mean station concentrations.

Figure 4.22 1989 Mean Aromatic Hydrocarbon Concentrations, Percent Fines, And Total Organic Carbon in Kuparuk River Bay Area Bulk Sediments.

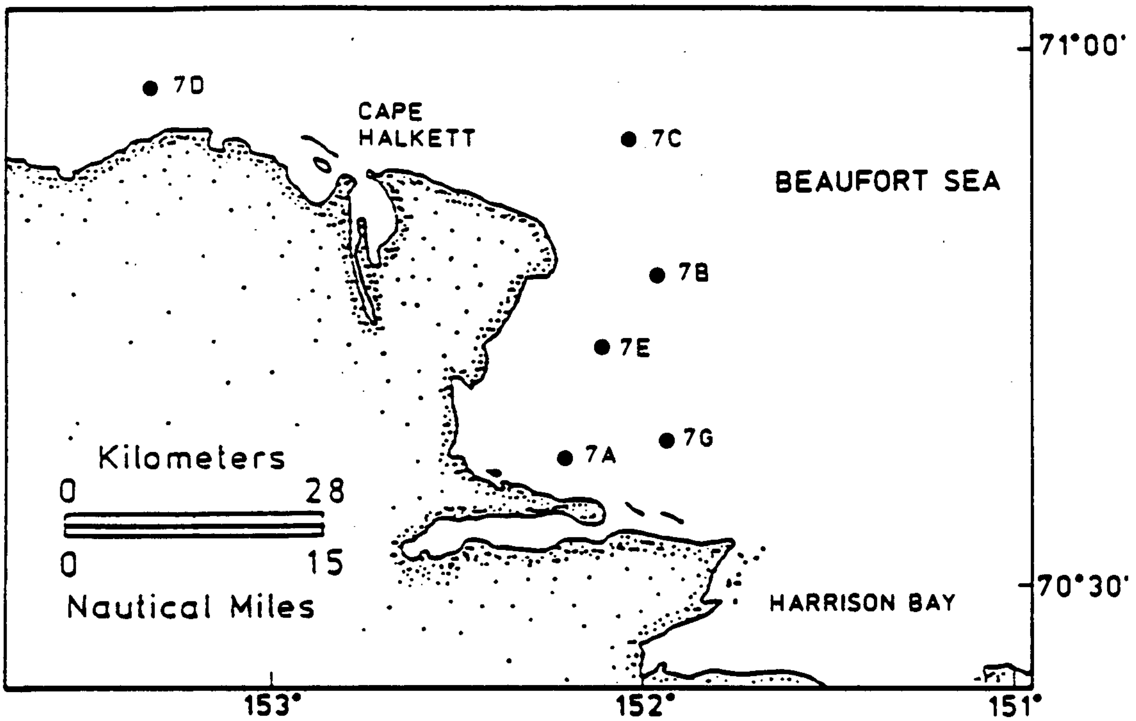


AROMATIC
HYDROCARBON
(ng/g)*

STATION	6A	6B	6C	6D	6F	6G		
REGION	4	4	4	4	4	4	Mean(Rgn4)**	Std(Rgn4)
TOT N	360	880	150	(370, 130)	220	5900	1300	2100
TOT F	61	200	4.1	(120,43)	33	980	230	340
TOT D	20	74	6.2	(26, 4.9)	7.2	220	59	76
TOT P	160	900	56	(170, 44)	53	1900	540	680
TOT C	11	96	7.1	(37, 14)	1.4	250	67	88
TOT PAH	670	2500	230	(810, 240)	330	10000	2400	350
TOC	15	15.0	7.5	(3.4, 0.6)	6.7	16.0	11.0	5.3
% FINES	96	93	45	(18, 5.5)	51	75	63	30

* All concentrations reported as average means and standard deviation in parentheses.
** Regional means are averages calculated from the above mean station concentrations.

Figure 4.23 1989 Mean Aromatic Hydrocarbon Concentrations, Percent Fines, And Total Organic Carbon in East Harrison Bay Area Bulk Sediments.



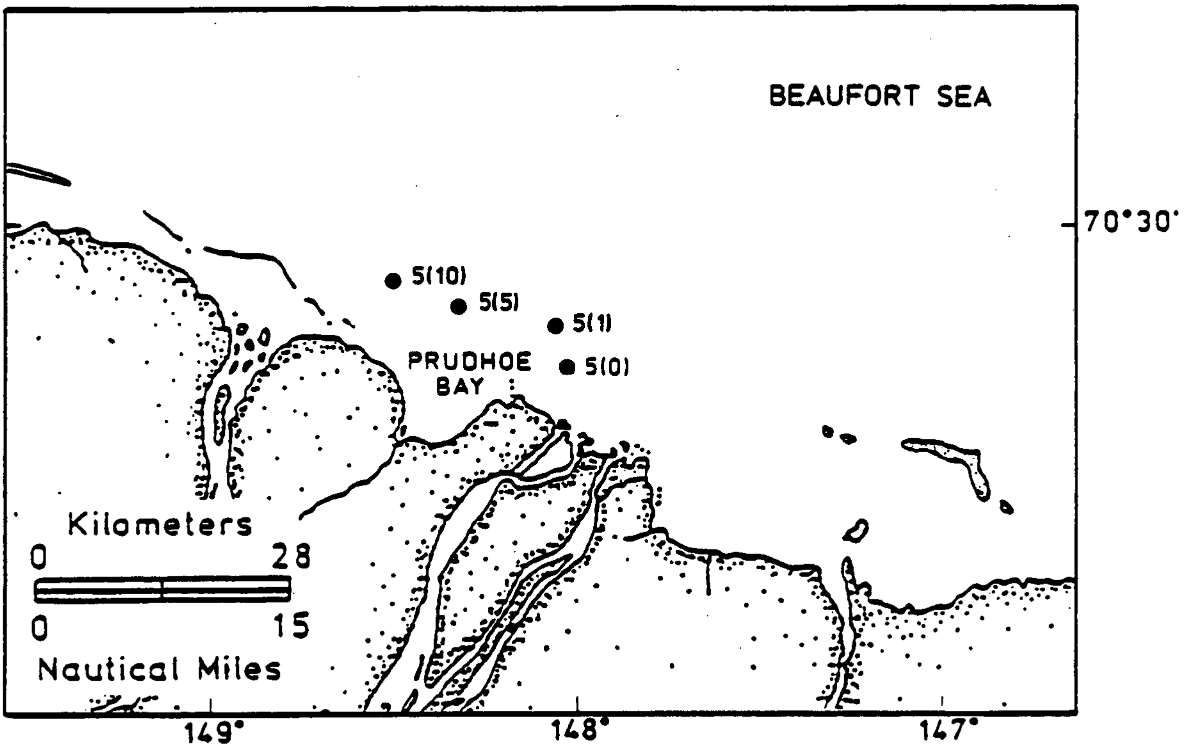
AROMATIC HYDROCARBON (ng/g)*

STATION	7A	7B	7C	7D	7E	7G		
REGION	5	5	5	5	5	5	Mean(Rgn5)**	Std(Rgn5)
TOT N	300	(120, 25)	1200	490	1300	1100	750	460
TOT F	67	(31, 7.6)	310	140	380	58	160	130
TOT D	27	(19, 7.7)	100	41	84	37	51	30
TOT P	240	(97, 27)	780	280	590	390	400	230
TOT C	37	(9.0, 1.3)	140	55	100	62	67	43
TOT PAH	800	(320, 76)	2800	1100	2800	1800	1600	1000
TOC	6	(2.9, 8.0)	9.3	6.4	13.0	7.6	7.6	3.2
% FINES	34	(15, 3.8)	75	32	86	26	37	28

* All concentrations reported as average means and standard deviation in parentheses.

** Regional means are averages calculated from the above mean station concentrations.

Figure 4.24 1989 Mean Aromatic Hydrocarbon Concentrations, Percent Fines, And Total Organic Carbon in West Harrison Bay Area Bulk Sediments.

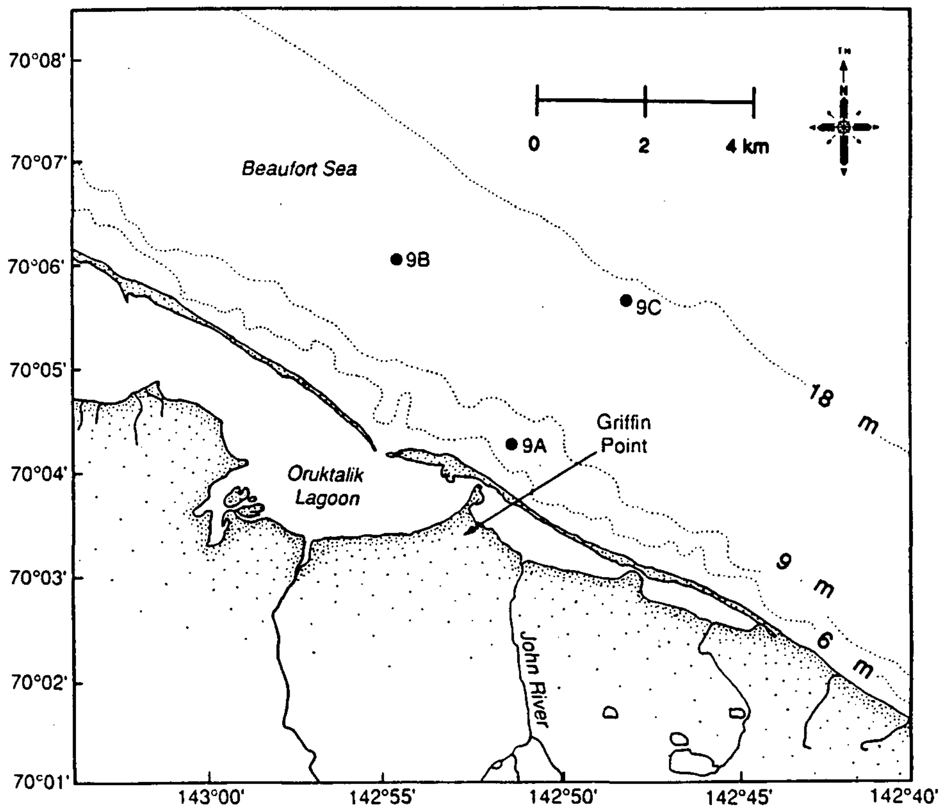


AROMATIC
HYDROCARBON
(ng/g)*

STATION	5(0)	5(1)	5(5)	5(10)		
REGION	6	6	6	6	Mean(Rgn6)**	Std(Rgn6)
TOT N	(460, 130)	(55, 17)	(340, 79)	200	260	150
TOT F	(120, 58)	(22, 7.2)	(97, 62)	95	84	37
TOT D	(46, 7.8)	(2.3, 2.1)	(23, 1.9)	19	23	16
TOT P	(260, 60)	(17, 4.4)	(180, 23)	120	140	89
TOT C	(44, 5.6)	(3.1, 1.4)	(38, 11)	19	26	16
TOT PAH	(1100, 190)	(110, 30)	(760, 150)	480	600	360
TOC	(4.5, 1.4)	(1.1, 0.1)	(5.7, 0.6)	12	5.90	4.0
% FINES	(29, 26)	(3.6, 0.93)	(36, 3.6)	69	27	20

*** All concentrations reported as average means and standard deviation in parentheses.**
**** Regional means are averages calculated from the above mean station concentrations.**

Figure 4.25 1989 Mean Aromatic Hydrocarbon Concentrations, Percent Fines, And Total Organic Carbon in Endicott Field Area Bulk Sediments.



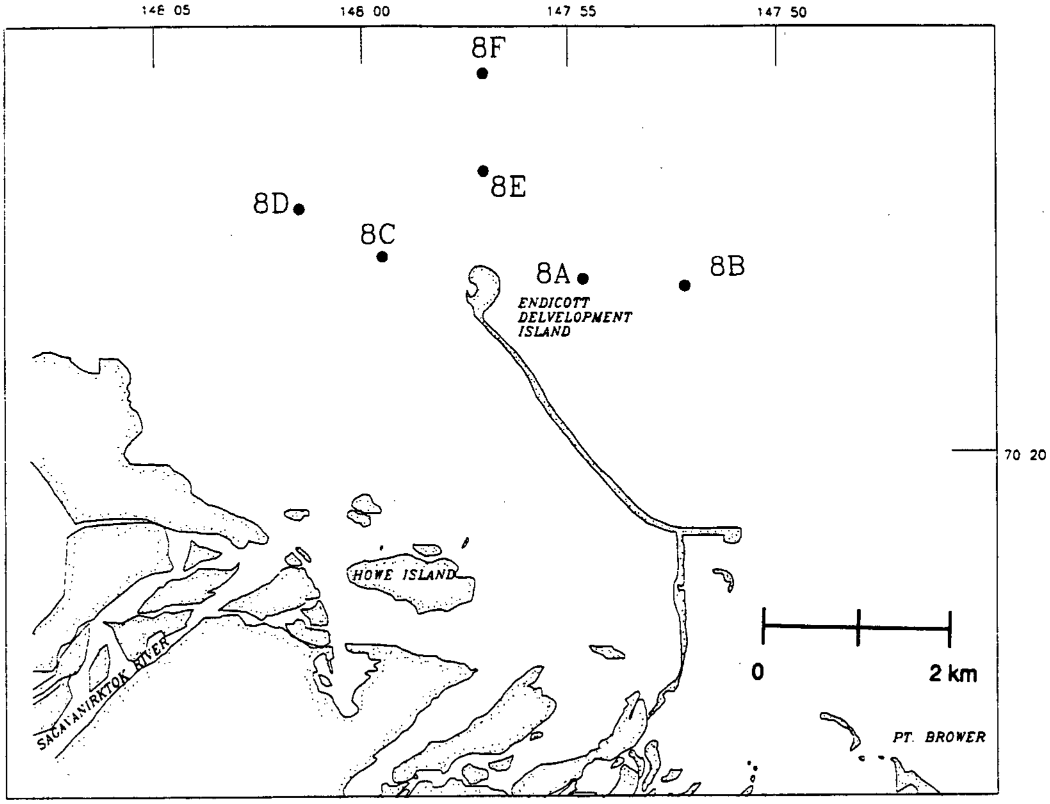
AROMATIC HYDROCARBON (ng/g)*

STATION	9A	9B	9C		
REGION	7	7	7	Mean (Rgn7)**	Std (Rgn7)
TOT N	(6.8, 0.69)	(31, 32)	(190, 16)	76	100
TOT F	(0.0, 0.0)	(0.30, 0.52)	(83, 7.8)	28	48
TOT D	(0.075, 0.13)	(1.7, 3.0)	(23, 1.2)	8	13
TOT P	(5.2, 0.5)	(43, 52)	(170, 3.6)	73	86
TOT C	(0.73, 0.03)	(1.4, 2.4)	(38, 2.1)	13	21
TOT PAH	(16, 1.3)	(83, 82)	(600, 37)	230	320
TOC	(1.0, 0.1)	(2.1, 0.1)	(7.1, 1.1)	3.4	3.3
% FINES	(2.6, 0.29)	(9.5, 1.0)	(61, 6.3)	24	28

*** All concentrations reported as average means and standard deviation in parentheses.**

**** Regional means are averages calculated from the above mean station concentrations.**

Figure 4.26 **1989 Mean Aromatic Hydrocarbon Concentrations, Percent Fines, And Total Organic Carbon in Griffin Point Area Bulk Sediments.**



AROMATIC
HYDROCARBON
(ng/g)*

STATION	8A	8B	8C	8D	8E	8F		
REGION	8	8	8	8	8	8	Mean(Rgn8)**	Std(Rgn8)
TOT N	(330, 120)	(120, 26)	(14, 2.7)	(11, 8.2)	(700, 140)	(330, 69)	250	240
TOT F	(130, 46)	(44, 36)	(2.4, 2.2)	(1.1, 2.0)	(170, 89)	(100, 32)	75	64
TOT D	(37, 11)	(7.3, 5.9)	(3.0, 0.49)	(0.67, 1.2)	(95, 10)	(23, 1.9)	28	33
TOT P	(220, 62)	(52, 23)	(12, 3.1)	(11, 3.6)	(500, 40)	(130, 17)	150	170
TOT C	(50, 11)	(9.1, 5.1)	(1.5, 0.16)	(1.2, 0.35)	(110, 10)	(22, 9.3)	32	39
TOT PAH	(900, 270)	(260, 100)	(36, 8.5)	(26, 10.7)	(1900, 300)	(670, 130)	630	650
TOC	(6.4, 1.8)	(2.0, 0.4)	(0.8, 0.0)	(0.9, 0.0)	(11, 1.4)	(2.8, 0.3)	4.0	3.7
% FINES	(38, 12)	(8.0, 3.5)	(0.57, 0.44)	(1.3, 0.15)	(66, 9.2)	(19, 2.3)	22	25

* All concentrations reported as average means and standard deviation in parentheses.

** Regional means are averages calculated from the above mean station concentrations.

Figure 4.27 **1989 Mean Aromatic Hydrocarbon Concentrations, Percent Fines, And Total Organic Carbon in Endicott Development Island Bulk Sediments.**

regional mean of 640 ng/g. The Kuparik River area (Region 3, Figure 4.22) exhibited PAH concentrations in the same range as Region 2 with a mean total PAH concentration of 870 ng/g.

The highest concentrations of aromatic hydrocarbons were observed in the East Harrison Bay area (Region 4, Figure 4.23), with a TOT PAH value of 2,400 ng/g. This region is nearest to the mouth of the Colville River. Stations 6A and 6G had the highest TOT PAH concentrations, of 10,000 and 2,500 ng/g respectively, and are located directly adjacent to the Colville River delta. The remaining stations in Region 4 had variable TOT PAH concentrations ranging from 230 to 810 ng/g. The PAH compositions of Region 4 stations were predominated by the naphthalenes and phenanthrenes (N and P), which comprised up to 90 percent of the total PAH concentration at some stations.

Figure 4.24 presents the aromatic hydrocarbon data for West Harrison Bay stations (Region 5). The mean TOT PAH concentration for region 5 ranged from 320 to 2,800 ng/g with a mean total aromatic value of 1,600 ng/g. There were no obvious gradient trends with respect to station proximity to the Colville River, however, the PAH concentrations generally varied in conjunction with the TOC and percent fines levels.

Aromatic data for the Endicott Field area (Region 6) are presented in Figure 4.25. The TOT PAH concentrations ranged from 110 to 1,100 ng/g, with a regional mean of 600 ng/g. The PAH levels in the Endicott Field area were average in comparison to the entire study area. No concentration gradient associated with distance away from the Endicott Field was observed. The station located closest to the field (5[0]) exhibited the highest PAH concentration, while the adjacent station had the lowest PAH levels.

The PAH data for the Griffin Point area (Region 7) are presented in Figure 4.26. The mean total PAH concentration of 230 ng/g was the lowest for all regions. The PAH distribution was comprised primarily of the naphthalenes and phenanthrenes and the aromatic concentrations co-varied with the percent fines and TOC levels.

Figure 4.27 presents the PAH concentrations for the smaller scale Endicott Development Island transects. The TOT PAH values ranged from 26 ng/g at station 8D to 1,900 ng/g at 8E, with a regional mean of 630 ng/g. The PAH data set corresponded quite closely to the trends observed in the saturated hydrocarbons, with the highest hydrocarbon concentrations associated with stations 8A and 8E. The PAH regional mean for this area was average in comparison to the entire study area. These data also compared well with those from Region 6.

4.2.3 Hydrocarbons in Tissues. The concentrations of aromatic and saturated hydrocarbons were determined in amphipod and bivalve tissues from 15 stations. The saturated hydrocarbon and aromatic hydrocarbon data are presented in Tables 4.3 and 4.4 respectively. The mean value and standard deviation is presented for those samples which were analyzed in triplicate. The results for Anonyx sample 1A/B/E represent the mean of replicate analyses of a pooled sample from stations 1A, 1B, and 1E. Overall, the saturated hydrocarbon concentrations in tissues were comparable to the levels observed in the sediments, while the total PAH concentrations were considerably lower than those for the sediments.

The total saturated hydrocarbon concentrations varied less than one order of magnitude for all organisms and ranged from 2.2 to 11 µg/g wet weight. There were no regional trends are apparent with respect to any of the saturated hydrocarbon parameters. However, the pristane concentrations of the Anonyx amphipods were one to two orders of magnitude higher than any of the bivalve genera (Astarte, Cyrtodaria, Macoma, and Portlandia) and comprised up to 70 percent of the total saturates.

The total aromatic hydrocarbons concentrations were low in all samples and ranged from below the detection limit to 240 ng/g wet weight. There were no discernable trends in the tissue PAH levels with respect to geographical distribution. However, the Astarte sample from station 5(1), the tissue station closest to the Endicott Development Island, was the only tissue sample where trace levels of dibenzothiophenes were observed.

4.3 Auxiliary Analyses Results

The auxiliary analyses consisted of grain size and TOC measurements of sediments collected from the 48 stations sampled during the 1989 field survey. The results of the grain size analyses are presented in condensed form in Table 4.5 as percent gravel, sand, silt, clay, and silt+clay. The sediment grain size was quite variable throughout the study area and ranged from 95 percent sand and no silt/clay to 87 percent silt/clay with no gravel. Table 4.6 presents the results of the total organic carbon analyses for the sediment at all stations. The TOC values ranged from 0.7 to 30 mg/g dry weight. There did not appear to be any regional trends for the grain size and TOC data. However, stations with higher percentages of silt/clay generally had the highest values for TOC.

4.4 Quality Control Results

4.4.1 Trace Metals. Reagent and procedural blanks were consistently below detection limits. The choice of chemicals and analytical instrumentation (Table 3.1) was designed to achieve a reliable signal above detection limit with no detectable blank. With very few exceptions, the absolute trace metal concentrations of any

Table 4.3 Summary of Saturated Hydrocarbons in Tissue Samples (μg/g).

Organism	Station	Pristane	Phytane	Lalk	Talk	TOT
Anonyx	1A/B/E	(0.86, 0.0088)*	(0.0074, 0.0004)	(0.47, 0.01)	(1.53, 0.48)	(5.53, 0.57)
	2D	(1.2, 0.075)	(0.0047, 0.0041)	(0.17, 0.03)	(0.43, 0.09)	(2.13, 0.25)
	4B	(4.2, 0.0070)	(0.0046, 0.0044)	(0.42, 0.02)	(0.93, 0.28)	(6.0, 0.29)
	5B	(0.56, 0.015)	(0.0038, 0.0033)	(0.14, 0.16)	(0.99, 0.91)	(2.6, 3.9)
	5H	(6.1, 0.071)	(0.0076, 0.011)	(0.42, 0.06)	(1.4, 0.39)	(11, 1.4)
	6D	(1.3, 0.13)	(0.0076, 0.0073)	(0.32, 0.04)	(1.2, 0.59)	(5.8, 1.3)
	7E	(1.33, 0.12)	(0.014, 0.0052)	(0.48, 0.06)	(3.1, 2.7)	(7.8, 3.7)
Astarte	1A	0.03	0.035	0.58	1.36	4
	1B	(0.018, 0.0093)	(0.020, 0.011)	(0.31, 0.07)	(3.67, 3.61)	(8.1, 7.8)
	3A	(0.03, 0.013)	(0.015, 0.0064)	(0.42, 0.13)	(2.1, 1.9)	(4.9, 2.7)
	5(1)	(0.017, 0.0075)	(0.020, 0.0064)	(0.44, 0.14)	(2.06, 0.99)	(4.3, 1.8)
	5H	(0.023, 0.0056)	(0.0083, 0.0074)	(0.36, 0.080)	(1.8, 1.4)	(10.6, 13.4)
	6D	(0.019, 0.0045)	(0.012, 0.011)	(0.44, 0.16)	(2.41, 0.52)	(5.3, 1.4)
Cyrtadaria	5F	(0.010, 0.0034)	(0.014, 0.0060)	(0.66, 0.03)	(1.8, .77)	(3.5, 1.2)
	6G	(0.0200, 0.0035)	(0.011, 0.0052)	(0.57, 0.11)	(2.6, 1.3)	(4.6, 1.8)
Macoma	6D	0.15	0.012	0.22	2.3	4.1
	9B	0.046	ND	0.44	0.99	2.2
Portlandia	9B	0.029	ND	0.24	1.41	3.1
	1A	0.022	0.026	0.36	4.6	6.9

* All concentrations reported as means and standard deviation are in parentheses, numbers not in parentheses are means only.

ND - Not Detected.

Table 4.4 Summary of Aromatic Hydrocarbons in Tissue Samples (ng/g).

Organism	Station	Total N	Total P	Total D	Total F	Total C	Total PAH
Anonyx	1A/B/E	(16, 3.2)*	ND	ND	(9.6, 2.1)	ND	(26, 3.5)
	2D	(14, 7.8)	(2.3, 0.28)	ND	ND	(68, 95)	(90, 105)
	5H	(37, 15)	(2.6, 2.4)	ND	(2.6, 4.6)	ND	(57, 27)
	4B	(13, 0.81)	(5.0, 4.2)	ND	ND	(1.4, 2.4)	(34, 20)
	5B	(17, 4.4)	(5.3, 3.9)	ND	ND	(28, 49)	(67, 46)
	6D	(24, 7.0)	ND	ND	(5.3, 4.6)	ND	(32, 7.9)
	7E	(18, 4.0)	ND	ND	(12, 3.9)	ND	(30, 7.8)
Astarte	1A	15	5.7	ND	36	ND	79.6
	1B	(13, 0.58)	(3.1, 0.42)	ND	ND	(5.8, 7.2)	(34, 18)
	3A	(41, 10)	(3.0, 0.07)	ND	ND	(0.75, 1.1)	(55, 4.9)
	5H	(14, 7.2)	(3.7, 0.59)	ND	ND	(61, 100)	(89, 110)
	5(1)	(15, 6.1)	(13, 15)	(1.2, 2.1)	(70, 69)	(84, 140)	(84, 140)
	6D	(21, 5.7)	(9.3, 8.4)	ND	(48, 84)	(2.4, 3.5)	(110, 79)
Cyrtadria	5F	(20, 5.6)	(11, 11)	ND	(43, 74)	(0.93, 0.81)	(96, 90)
	6G	(28, 10)	(58, 49)	ND	(12, 10)	(4.4, 3.1)	(130, 48)
Macoma	6D	40.9	6.6	ND	ND	ND	67.08
	9B	11	16	ND	4.4	1.2	68.6
Portlandia	1A	30.7	73.8	ND	93.8	1.3	237.5
	9B	ND	ND	ND	ND	ND	ND

* All concentrations reported as means and standard deviation are in parentheses, numbers not in parentheses are means only.
ND - Not Detected.

Table 4.5 Summary of Grain Size Data for All Sediments Stations

STATION	REGION	%GRAVEL	%SAND	%SILT	%CLAY	%SILT+CLAY
1A	1	0	26	52	22	74
1B	1	0	85	8.3	6.6	15
1C	1	0	24	39	37	76
1D	1	0	33	50	18	67
1E	1	0.17	18	73	8.2	82
2A	1	0	13	47	40	87
2B	1	0	80	14	6.4	20
2C	1	0.38	25	42	33	75
2D	1	3.2	89	NC	NC	8.2
2E	1	0.04	96	NC	NC	4.3
2F	1	0	86	NC	NC	14
3A	2	0	15	56	29	85
3B	2	0	21	60	19	78
4A	2	46	36	10	7.5	18
4B	2	0.05	83	9.9	7.2	17
4C	2	8.8	87	NC	NC	3.8
5G	2	8.2	48	32	11	43
5H	2	0.44	64	23	12	35
5A	3	1.3	68	20	11	31
5B	3	0.08	96	NC	NC	3.6
5D	3	0	36	61	3	64
5E	3	0	73	14	13	27
5F	3	0.32	47	47	5.9	53
6A	4	0	4	68	28	96
6B	4	0	6.6	65	28	93
6C	4	0	54	23	23	46
6D	4	0.057	81	8.7	9.8	19
6F	4	0.06	49	32	19	51
6G	4	0	25	61	14	75
7A	5	0	66	30	3.4	34
7B	5	0	85	11	4.1	15
7C	5	0.06	25	50	25	75
7D	5	0	68	24	7.9	32
7E	5	0.35	14	68	18	86
7G	5	0	74			26
5(0)	6	0	71	20	9.2	29
5(1)	6	0.62	89	NC	NC	3.6
5(5)	6	0.063	64	21	14	3.6
5(10)	6	0.43	30	47	22	69
8A	7	0.06	61	28	11	38
8B	7	0.017	92	NC	NC	8
8C	7	1.3	98	NC	NC	0.57
8D	7	0.047	99	NC	NC	1.3
8E	7	0	34	46	20	66
8F	7	0.25	81	11	7.4	19
9A	8	0.013	97	NC	NC	2.6
9B	8	0	91	6.8	3.1	9.5
9C	8	0.2	39	41	20	61

NC= Not Calculated

Table 4.6 Summary of Total Organic Carbon for All Sediment Stations

STATION	REGION	TOC (mg/g)
1A	1	9.9
1B	1	2.3
1C	1	7.8
1D	1	4.4
1E	1	10
2A	1	19
2B	1	2.6
2C	1	8.4
2D	1	0.11
2E	1	1.5
2F	1	4.1
3A	2	9.8
3B	2	7.8
4A	2	2.7
4B	2	2.5
4C	2	0.9
5G	2	6.4
5H	2	4.2
5A	3	4.4
5B	3	0.7
5D	3	30
5E	3	3.8
5F	3	9.1
6A	4	15
6B	4	15
6C	4	7.5
6D	4	3.4
6F	4	6.7
6G	4	16
7A	5	6
7B	5	2.9
7C	5	9.3
7D	5	6.4
7E	5	13
7G	5	7.6
5(0)	6	4.5
5(1)	6	1.1
5(5)	6	5.7
5(10)	6	12
8A	7	6.4
8B	7	2
8C	7	0.8
8D	7	0.9
8E	7	11
8F	7	2.8
9A	8	0.97
9B	8	2.1
9C	8	7.1

environmental sample can be determined by the proper choice of instrument or use of preconcentration techniques. Overall, the lowest sample concentration was typically >100 times higher than the detection limit with a range of about 10 to >4000 (Table 4.7).

A series of field blanks were analyzed, that focused on sample containers and the seawater system used to rinse equipment. All blanks were below the detection limits for this program (Table 4.7) and neither the containers nor the seawater system were a source of contamination.

Analytical precision was generally better than 2% for most elements (Table 4.7). For Cd and Pb, larger precisions resulted from very low levels in the Beaufort Sea samples. Thus, the actual analytical variation for Cd and Pb concentrations in sediments was on the order of ± 0.008 ppm and 0.2 ppm, respectively (Table 4.7). Samples of the Standard Reference Material 1646, an estuarine sediment, provided by U.S. National Institute of Standards and Technology, were digested and analyzed 11 separate times, once with each digest. The results compared well with certified values for this standard (Table 4.8). No certified value was available for Ba and so what was used was a number compiled from several different U.S. laboratories. For organisms, samples of lobster hepatopancreas (TORT-1), provided by the National Research Council of Canada, were analyzed 8 times and observed values compared well to certified concentrations. Again, no certified Ba data was available and it was not possible to obtain a sufficient data set to provide a Ba estimate.

4.4.1.1 Analysis of Archived Sediment. One archived sediment sample collected in 1986 was analyzed in 1986 (Boehm et al., 1987) and again in 1989 in this study. Concentrations of Cd, Cr, Cu and Pb determined for archived sediment from station 5A during 1986 compared well with values obtained in 1989 (Table 4.9). However, values for Ba, V and Zn were 19-28% lower in the 1986 data set than for the 1989 data.

There are several possible explanations for the observed differences for this one sample. First, variations in the sieving process can yield different families of particles. For the archived sample and all of the 1989 samples, the sediment was wet sieved through 62.5 µm Nylon screen until the pH-adjusted (7.5) rinse water was completely clear. This may have enhanced the amount of fine-grained, more metal-rich sediment obtained. The 1989 samples were completely digested with absolutely no residue. Complete digestion is especially important for the more refractory elements such as Ba and V. The original 1986 sieving procedure may have varied slightly.

Concentrations of Ba in the 1989 sediments were determined by INAA and AAS and typically agreed within $\pm$ 50 ppm. The INAA data for Ba was chosen as the better data set for 1989 although in many cases the numbers agreed extremely well.

Table 4.7 Precision, Detection Limits, and Blanks for Metal Analyses.

Element	Average Precision (% CV)*	Sediments		Organisms		Blanks***
		Detection Limits** (ppm)	Lowest Value (ppm)	Detection Limits** (ppb)	Lowest Value (ppb)	(ppb)
Fe	1.4	6	26000	500	2000	<100
Al	1.6	38	41800	-	-	<900
Ba	1.8	58	309	5	2000	<500
Cd	12.5	0.0004	0.06	0.2	180	< 0.2
Cr	1.2	4	67	0.6	100	< 50
Cu	1.8	2	14	0.2	1800	< 40
Pb	5.9	0.0006	3.9	0.9	30	<0.01
V	1.7	12	79	1.7	260	<100
Zn	1.7	0.5	77	80	5600	< 10

* CV = Coefficient of Variance = (Mean/Standard Deviation) x 100%

** Detection limits are based on dilutions used for sample analysis and the instrumental technique of choice.

*** All Blanks had concentrations below detection limits.

Blanks:	Number	Identification
	5A-BL-2	Container
	5E-BL-2	Seawater System
	5(1)-BL-2	Container
	6A-BL-2	Seawater System
	8C-BL-2	Seawater System
	8D-BL-4	Container

Table 4.8 Results of Trace Metal Analyses of Standard Reference Materials (SRM) Showing Means with Standard Deviation in Parentheses

	Fe	Al	Ba	Cd	Cr	Cu	Pb	V	Zn
	(%)	(%)	(Concentrations in ppm)						
U.S. National Inst. of Standards and Technology, SRM 1646, Estuarine Sediment									
Certified Values	3.35 (0.1)	6.25 (0.2)	(450)	0.36 (0.07)	76 (3)	18 (3)	28.2 (1.8)	94 (1)	138 6
Observed Values	3.31 (0.04)	6.19 (0.1)	464 (12)	0.31 (0.02)	78 (1)	16.5 (0.3)	28.1 (1.3)	94 (1)	135 2
National Research Council of Canada, SRM TORT-1, Lobster Hepatopancreas									
Certified Values	0.0186 (0.011)	-	-	26.3 (2.1)	2.4 (0.6)	439 (22)	10.4 (2.0)	1.4 (0.3)	177 (10)
Observed Values	0.0189 (0.002)	-	3.2 (0.3)	25.9 (0.5)	2.2 (0.2)	432 (6)	9.2 (1.2)	1.2 (0.1)	176 (4)

Table 4.9 Comparison of Trace Metal Concentrations in Archived Sample 5A

	Fe (%)	Al (%)	Ba	Cd	Cr	Cu	Pb	V	Zn
			(Concentrations in ppm)						
1989 - N = 3									
1989 Values	3.18 (0.02)	6.05 (0.04)	562 (20)	0.20 (0.02)	89 (1)	21.6 (0.1)	11.9 (0.5)	138 (3)	96 (3)
1986-87 - N = 6									
1986-87 Values	- -	- -	401 (56)	0.19 (0.03)	73 (9)	19.4 (0.7)	10.8 (0.8)	106 (7)	79 (5)

Inconsistency in Ba values between the 1987 report (Boehm et al., 1987) and the present 1990 study may be due to differences in analytical results between x-ray fluorescence (XRF) and inductively coupled plasma (ICP) for the 1987 Ba data. At Ba values >400 ppm, the XRF data averaged 200 ppm greater than the ICP values (Boehm et al., 1987; Appendix B, Tables B21 and B22). As a result, a systematic offset occurred in the 1989 Ba data relative to the 1986-87 data, most likely a function of ICP calibration in 1986-1987.

Differences in the V and Zn data were more difficult to pinpoint. The Zn trend was not common throughout the complete data set, as was the V trend. Sieving styles, digestion techniques and instrumental analyses all may have contributed to discrepancies in this one sample.

4.4.2 Hydrocarbons. The quality control program for saturated and aromatic hydrocarbon analyses included initial and ongoing determinations of analytical precision and accuracy through the analysis of standard reference material, an archived sediment from the 1986 survey, method blanks, spiked blanks, detection limit determinations, and participation in a NOAA/NIST intercomparison exercise.

The standard reference material Canadian Test Sediment (HS-3) from the National Research Council of Canada was analyzed in triplicate by GC/MS for aromatic hydrocarbons. The results of the PAH analyses are presented in Table 4.10 and compared well with the certified values for this sediment. The one exception is benzo[k]fluoranthene which had a laboratory value approximately 1.5 times greater than the acceptable range. The laboratory precision for all individual analytes was less than 15 percent. HS-3 had no certified values for saturated hydrocarbons, so no GC/FID analyses were performed for this SRM.

The procedural blanks for the analysis of saturated hydrocarbons revealed mean concentrations of individual normal alkanes ranging from 0.00024 to 0.018 μg/g dry weight for sediments (Table 4.11) and from 0.0025 to 0.1 μg/g wet weight for tissues (Table 4.12). The procedural blanks analyzed by GC/MS for PAH revealed mean concentrations of individual analytes ranging from 0.00028 to 0.41 ng/g dry weight for sediments (Table 4.13) and from 0.8 to 36 ng/g wet weight for tissues (Table 4.14). All the procedural blank data were normalized to an average dry weight and wet weight for sediment and tissue samples respectively. The hydrocarbon concentrations in the procedural blanks were all below the detection limit of the individual analytes for sediments. The mean value for the sum of the alkanes in the procedural blanks was lower than the lowest TOT value reported for the sediment samples. The tissue blanks exhibited significant levels of naphthalene, which is a common laboratory contaminant. However, naphthalene contamination was not evident in the tissue samples as demonstrated by total naphthalene (the sum of naphthalene and its alkyl homologues) concentrations in the tissues which were less than the values determined for naphthalene alone in the blanks.

Table 4.10 **Certified Values and Laboratory Values for PAH in SRM Canadian Test Sediment HS-3.**

PAH	Certified Values (μg/g)	Lab. Value (μg/g) (n=3)
Naphthalene	9.0 ± 0.7	9.1 ± 0.21
Acenaphthylene	0.3 ± 0.1	0.55 ± 0.08
Acenaphthene	4.5 ± 1.5	7.7 ± 0.46
Fluorene	13.6 ± 3.1	18 ± 1.7
Phenanthrene	85 ± 20	63 ± 4.36
Anthracene	13.4 ± 0.5	9.3 ± 0.64
Fluoranthene	60 ± 9	46 ± 3.5
Pyrene	39 ± 9	31 ± 2.3
Benz[a]anthracene	14.6 ± 2.0	14 ± 0
Chrysene	14.1 ± 2.0	14 ± 0
Benzo[a]pyrene	7.4 ± 3.6	7.1 ± 0.15
Benzo[b]fluoranthene	7.7 ± 1.2	9.93 ± 0.95
Benzo[k]fluoranthene	2.8 ± 2.0	8.1 ± 1.7
Benzo[ghi]perylene	5.0 ± 2.0	4.7 ± 0.21
Dibenz[a,h]anthracene	1.3 ± 0.5	1.5 ± 0.15
Indeno[1,2,3-cd]pyrene	5.4 ± 1.3	6.7 ± 0.32

Table 4.11 Results of 4 Replicate Analyses of Procedural Blanks for Sediment Alkane Determinations.

Compound	Replicate Concentration (ug/g)* 1	2	3	4	Mean	Standard Deviation
nC10	ND	0.0093	0.0016	ND	0.0027	0.0044
nC11	0.0005	0.0011	0.0008	ND	0.0006	0.00047
nC12	0.0007	0.0040	0.0051	0.0006	0.0026	0.0023
nC13	0.0005	0.0008	0.0005	0.0008	0.00068	0.00018
1380	0.0013	0.0005	0.0009	ND	0.00067	0.00055
nC14	0.0005	0.0041	0.0034	0.0044	0.0031	0.0018
1470	ND	0.00043	0.0006	ND	0.00026	0.00031
nC15	0.00037	0.0007	0.0008	0.00024	0.00052	0.00026
nC16	ND	0.0021	0.0021	0.00049	0.0012	0.0011
1650	ND	ND	0.00094	ND	0.00024	0.00047
nC17	0.00099	0.002	0.0023	0.00054	0.0015	0.00082
pristane	0.00029	0.0012	0.0010	ND	0.00063	0.00057
nC18	0.00053	0.0014	0.0020	0.00041	0.0011	0.00075
phytane	0.00059	0.0012	0.0011	ND	0.00071	0.00054
nC19	0.001	0.0017	0.0020	0.00041	0.0013	0.00071
nC20	0.002	0.0031	0.0027	0.00039	0.0021	0.0012
nC21	0.0047	0.0091	0.0041	0.00079	0.0047	0.0034
nC22	0.0094	0.016	0.0047	0.0014	0.0079	0.0063
nC23	0.016	0.023	0.0066	0.0017	0.012	0.0095
nC24	0.019	0.03	0.0054	0.002	0.014	0.013
nC25	0.024	0.036	0.0071	0.002	0.017	0.016
nC26	0.026	0.036	0.0053	0.0014	0.017	0.017
nC27	0.026	0.037	0.0079	0.0011	0.018	0.016
nC28	0.023	0.031	0.004	0.00084	0.015	0.015
nC29	0.023	0.03	0.006	0.00093	0.015	0.014
nC30	0.017	0.023	0.0029	0.0016	0.011	0.011
nC31	0.014	0.017	0.0044	0.00063	0.009	0.0078
nC32	0.0099	0.012	0.0016	ND	0.0059	0.006
nC33	0.0081	0.0081	0.0023	ND	0.0046	0.0041
nC34	0.0066	0.0053	0.0014	0.0011	0.0036	0.0028
Alkanes	0.24	0.35	0.092	0.024	0.18	0.15

*Concentrations are related to the source material (ug/g).

Table 4.12 Results of 4 Replicate Analyses of Procedural Blanks for Tissue Alkane Determinations.

Compound	Replicate Concentration (ug/g)* 1	2	3	4	Mean	Standard Deviation
nC10	0.019	0.027	0.046	0.057	0.037	0.017
nC11	0.043	0.34	0.0091	0.013	0.1	0.16
nC12	0.037	0.026	0.086	0.025	0.044	0.029
nC13	0.0089	0.011	0.012	0.013	0.011	0.0018
1380	ND	ND	0.01	ND	0.0025	0.005
nC14	0.029	0.021	0.049	0.024	0.031	0.013
1470	0.012	ND	0.0066	ND	0.0047	0.0058
nC15	0.12	0.0037	0.015	0.0091	0.037	0.056
nC16	0.018	0.0051	0.021	0.0089	0.013	0.0075
1650	0.011	ND	0.011	0.019	0.01	0.0078
nC17	0.012	0.0089	0.024	0.0074	0.013	0.0075
pristane	0.031	0.0051	0.012	ND	0.012	0.014
nC18	0.031	0.011	0.018	0.021	0.02	0.0083
phytane	ND	0.0094	0.013	ND	0.0056	0.0066
nC19	ND	0.012	0.012	0.012	0.009	0.006
nC20	0.02	0.017	0.027	0.0086	0.018	0.0076
nC21	0.027	0.043	0.031	0.02	0.03	0.0096
nC22	0.037	0.094	0.04	0.034	0.051	0.029
nC23	0.026	0.14	0.051	0.043	0.065	0.051
nC24	0.034	0.18	0.051	0.049	0.079	0.068
nC25	0.034	0.21	0.051	0.057	0.088	0.082
nC26	0.054	0.2	0.051	0.049	0.089	0.074
nC27	0.034	0.2	0.034	0.054	0.081	0.08
nC28	0.026	0.17	0.04	0.054	0.073	0.066
nC29	0.022	0.15	0.031	0.043	0.062	0.06
nC30	0.034	0.11	0.028	0.025	0.05	0.041
nC31	0.016	0.086	0.02	0.019	0.035	0.034
nC32	0.01	0.069	0.011	0.024	0.029	0.028
nC33	0.008	0.054	0.0071	0.0054	0.019	0.024
nC34	0.043	0.01	ND	0.023	0.019	0.019
Alkanes	0.8	2.2	0.82	0.72	1.1	0.72

*Concentrations are related to the source material (ug/g).

Table 4.13 Results of 5 Replicate Analyses of Procedural Blanks for Sediment PAH Determinations.

Compound	Replicate Concentration (ng/g)* 1	2	3	4	5	Mean	Standard Deviation
Naphthalene	0.51	0.4	0.79	ND	0.36	0.41	0.29
C1N	0.57	ND	ND	ND	ND	0.11	0.25
C2N	ND	ND	ND	ND	ND	0	0
C3N	ND	ND	ND	ND	ND	0	0
C4N	ND	ND	ND	ND	ND	0	0
Acenaphthylene	ND	ND	ND	ND	ND	0	0
Acenaphthene	ND	ND	ND	ND	ND	0	0
Biphenyl	ND	ND	ND	ND	0.27	0.054	0.12
Fluorene	ND	ND	ND	ND	ND	0	0
C1F	ND	ND	ND	ND	ND	0	0
C2F	ND	ND	ND	ND	ND	0	0
C3F	ND	ND	ND	ND	ND	0	0
Dibenzothiophene	ND	ND	ND	ND	ND	0	0
C1D	ND	ND	ND	ND	ND	0	0
C2D	ND	ND	ND	ND	ND	0	0
C3D	ND	ND	ND	ND	ND	0	0
Phenanthrene	0.46	ND	0.3	ND	ND	0.15	0.22
Anthracene	ND	ND	ND	ND	ND	0	0
C1P/A	0.74	ND	ND	ND	ND	0.15	0.33
C2P/A	0.47	ND	ND	ND	ND	0.094	0.21
C3P/A	ND	ND	ND	ND	ND	0	0
C4P/A	ND	ND	ND	ND	ND	0	0
Fluoranthene	ND	0.0044	ND	ND	ND	0.00088	0.002
Pyrene	ND	0.014	ND	ND	ND	0.0028	0.0063
C1F/P	ND	ND	ND	ND	ND	0	0
Benz(a)Anthracene	ND	ND	ND	ND	ND	0	0
Chrysene	ND	0.0046	ND	ND	ND	0.00092	0.0021
C1C	ND	ND	ND	ND	ND	0	0
C2C	ND	ND	ND	ND	ND	0	0
C3C	ND	ND	ND	ND	ND	0	0
C4C	ND	ND	ND	ND	ND	0	0
Benzo[b]fluoranthene	ND	0.0021	ND	ND	ND	0.00042	0.00094
Benzo[k]fluoranthene	ND	ND	ND	ND	ND	0	0
Benzo(e)pyrene	0.1	ND	ND	ND	ND	0.02	0.045
Benzo(a)pyrene	0.47	ND	0.44	ND	ND	0.18	0.25
Perylene	0.63	0.46	0.11	ND	ND	0.24	0.29
Indeno(1,2,3cd)pyrene	ND	0.00059	ND	ND	ND	0.00012	0.00026
Dibenz(a,h)anthracene	ND	0.0014	ND	ND	ND	0.00028	0.00063
Benzo(g,h,i)perylene	0.099	0.0011	ND	ND	ND	0.02	0.044

*Concentrations are related to source material (ng/g).

Table 4.14 Results of 3 Replicate Analyses of Procedural Blanks for Tissue PAH Determinations.

Compound	Replicate Concentration (ng/g)* 1	2	3	Mean	Standard Deviation
Naphthalene	40	43	27	36	8.5
C1N	ND	ND	ND	0	0
C2N	ND	ND	ND	0	0
C3N	ND	ND	ND	0	0
C4N	ND	ND	ND	0	0
Acenaphthylene	ND	11	ND	3.7	6.4
Acenaphthene	ND	12	ND	4	6.9
Biphenyl	6	ND	4.6	3.5	3.1
Fluorene	ND	ND	ND	0	0
C1F	ND	ND	ND	0	0
C2F	ND	ND	ND	0	0
C3F	ND	ND	ND	0	0
Dibenzothiophene	ND	ND	ND	0	0
C1D	ND	ND	ND	0	0
C2D	ND	ND	ND	0	0
C3D	ND	ND	ND	0	0
Phenanthrene	4.3	18	ND	7.4	9.4
Anthracene	ND	13	ND	4.3	7.5
C1P/A	ND	ND	ND	0	0
C2P/A	ND	ND	ND	0	0
C3P/A	ND	ND	ND	0	0
C4P/A	ND	ND	ND	0	0
Fluoranthene	ND	5.7	ND	1.9	3.3
Pyrene	ND	5.7	ND	1.9	3.3
C1F/P	ND	ND	ND	0	0
Benz(a)Anthracene	ND	2.4	ND	0.8	1.4
Chrysene	ND	2.9	ND	0.97	1.7
C1C	ND	ND	ND	0	0
C2C	ND	ND	ND	0	0
C3C	ND	ND	ND	0	0
C4C	ND	ND	ND	0	0
Benzo[b]fluoranthene	ND	ND	ND	0	0
Benzo[k]fluoranthene	ND	ND	ND	0	0
Benzo(e)pyrene	ND	ND	ND	0	0
Benzo(a)pyrene	ND	ND	ND	0	0
Perylene	ND	ND	ND	0	0
Indeno(1,2,3cd)pyrene	ND	ND	ND	0	0
Dibenz(a,h)anthracene	ND	ND	ND	0	0
Benzo(g,h,i)perylene	ND	ND	ND	0	0

*Concentrations are related to source material (ng/g).

The percent recoveries of the n-alkanes in the spiked blanks for sediments and tissues are presented in Tables 4.15 and 4.16 respectively. The mean percent recoveries of n-alkanes for sediments and tissues ranged from 27 percent for nC10 to 104 percent for nC25. The percent recoveries of the alkanes were within acceptable limits, with the exception of the more volatile compounds (nC10 - nC13) which are commonly lost during the concentration of the sample extracts. The percent recoveries of the PAH analytes in the spiked blanks for sediments and tissues are presented in Tables 4.17 and 4.18 respectively. The mean percent recoveries of the individual aromatic analytes ranged from 55 to 160 percent. With the exception of acenaphthene and fluorene in the tissue spiked blanks, the mean percent recoveries for all of the individual aromatic hydrocarbon analytes were within acceptable limits. The acenaphthene and fluorene recoveries were significantly higher in two of the replicates resulting in mean percent recoveries of 160 percent.

Analytes in the field samples were not corrected for recovery based on the spiked blanks, nor should they be. (Note that quantification of all analytes in the samples is from the internal standard. This method automatically takes into account any variations in the absolute recovery of the analytes.) Comparisons of recoveries based on spiked blanks, for years 2 (1985) and 3 (1986) of the Beaufort Sea Monitoring Program (Boehm et al., 1987) and the 1989 program are presented in Tables 4.19 and 4.20 for saturated and aromatic hydrocarbons, respectively. The mean percent recoveries for the saturated hydrocarbons were similar for 1985 and 1989, although the variability was greater in the lower end compounds for 1985, as reflected in the coefficients of variance (%). The variability associated with the mean percent recovery for the 1986 spiked blank samples was greater than that of 1985, or 1989, and recoveries had a much greater tendency towards overestimation (i.e., values greater than 100%). Percent recoveries for the 1986 method spike blanks were a factor of two greater than those of other years. Percent recoveries of the spiked blanks for PAHs were more similar between the three years. Recoveries for 1989 showed greater precision than the other two years, as reflected by the CV.

Method detection limits (MDL) for saturated and aromatic hydrocarbons in sediments and tissues were calculated following the EPA recommended guidelines in the Federal Register, Vol.49, No. 209. The sediment detection limits for the alkanes are presented in Table 4.21 and ranged from 0.0018 to 0.05 µg/g dry weight. The results for the PAH sediment detection limit determination are presented in Table 4.22, and ranged from 0.27 to 5.3 ng/g dry weight. The detection limits for the individual saturated hydrocarbons and aromatics in sediments were generally below the concentrations reported for the samples. The results of the SHC and PAH MDL's in tissue are presented in Tables 4.23 and 4.24 respectively. The tissue detection limits were higher and ranged from 0.02 to 0.12 µg/g wet weight for alkanes and from 2.2 to 18.9 ng/g wet weight for PAH.

Table 4.15 Results of 10 Replicate Analyses of Spiked Method Blanks for Sediment Alkane Procedure - GC/FID.

	Sediment Replicate (Percent Recovery)												
Compound	1	2	3	4	5	6	7	8	9	10	Mean	SD*	CV**
nC10	57	42	9.6	37	33	67	34	34	69	58	44	18	41
nC11	70	55	23	50	37	60	43	41	73	66	52	16	31
nC12	75	61	40	61	45	66	47	47	76	71	59	13	22
nC13	77	64	54	68	45	62	50	47	77	71	62	12	19
nC14	80	67	65	74	55	67	54	52	79	75	67	10	15
nC15	83	71	74	79	57	65	58	56	78	75	70	9.9	14
nC16	88	77	84	86	67	71	64	66	81	78	76	8.7	11
nC17	92	83	92	91	73	75	71	74	83	80	81	8.2	10
pristane	91	82	92	90	71	74	70	73	82	80	81	8.4	10
nC18	96	87	97	94	79	80	76	80	85	82	86	7.6	8.8
phytane	95	86	96	94	76	79	75	78	85	82	85	8	9.4
nC19	90	82	92	89	74	79	75	77	78	76	81	6.7	8.3
nC20	100	95	100	98	85	88	87	87	89	87	92	6	6.5
nC21	110	100	100	98	90	90	90	89	90	89	95	7.1	7.5
nC22	110	110	100	100	94	93	92	92	91	91	97	7.5	7.7
nC23	110	120	100	99	97	94	93	91	92	92	99	9.4	9.5
nC24	110	130	100	98	99	92	92	91	92	93	100	12	12
nC25	110	140	110	100	100	93	95	91	94	95	103	15	15
nC26	110	140	100	99	100	91	93	90	93	94	101	15	15
nC27	110	140	110	100	100	92	94	90	93	94	102	15	15
nC28	110	130	110	99	99	90	93	90	93	93	101	13	13
nC29	110	130	100	98	97	91	93	90	93	93	100	12	12
nC30	110	120	98	92	89	85	86	83	93	93	95	12	13
nC31	108	138	104	96	96	84	92	88	96	96	100	15	15
nC32	100	110	100	94	84	79	90	87	93	92	93	8.9	9.6
nC33	100	100	100	93	82	74	89	87	93	92	91	8.4	9.2
nC34	100	99	99	89	69	58	86	83	95	93	87	14	16

*SD = Standard Deviation
**CV = Coefficient of Variation = (SD/Mean) x 100

Table 4.16 Results of 6 Replicate Analyses of Spiked Method Blanks for Tissue Alkanes Procedure - GC/FID.

	Tissue Replicate (Percent Recovery)								
Compound	1	2	3	4	5	6	Mean	SD*	CV**
nC10	10	5.7	20	42	66	17	27	23	85
nC11	19	11	31	58	66	23	35	22	63
nC12	31	20	24	49	69	37	38	18	47
nC13	44	31	29	50	73	48	46	16	35
nC14	55	43	40	55	81	59	56	15	27
nC15	66	54	50	61	87	66	64	13	20
nC16	77	63	61	69	94	74	73	12	16
nC17	84	71	71	77	99	82	81	10	12
pristane	86	73	71	77	99	81	81	10	12
nC18	91	78	81	86	100	88	87	7.8	9
phytane	91	79	79	85	100	87	87	8	9.2
nC19	86	74	82	85	100	85	85	8.4	9.9
nC20	98	85	94	96	110	94	96	8.1	8.4
nC21	100	86	98	97	110	95	98	7.8	7.9
nC22	100	87	100	99	120	98	101	11	11
nC23	100	87	110	98	120	98	102	11	11
nC24	100	88	110	97	110	97	100	8.5	8.5
nC25	100	88	120	98	120	99	104	13	12.5
nC26	100	89	120	97	120	97	104	13	12.5
nC27	100	88	120	98	120	98	104	13	12.5
nC28	100	88	120	98	120	97	104	13	12.5
nC29	100	89	110	98	120	97	102	11	11
nC30	100	89	100	92	110	91	97	7.9	8.1
nC31	108	94	116	98	118	96	105	10	9.5
nC32	100	89	100	96	120	96	100	11	11
nC33	100	88	100	95	120	97	100	11	11
nC34	100	88	93	90	110	94	96	8.1	8.4

*SD = Standard Deviation
**CV = Coefficient of Variation = (SD/Mean) x 100

Table 4.17 Results of 12 Replicate Analyses of Spiked Method Blanks for Sediment PAH Procedure - GC/MS.

Compound	Sediment Replicate (Percent Recovery) 1	2	3	4	5	6	7	8	9	10	11	12	Mean	Standard Deviation
Naphthalene	65	65	65	70	70	70	65	75	60	60	70	70	65	5
Acenaphthylene	95	70	65	85	65	75	70	70	60	60	65	70	70	10
Acenaphthene	95	75	70	95	70	75	80	85	55	60	75	80	75	12
Fluorene	110	80	75	110	75	90	85	85	55	60	75	75	80	17
Phenanthrene	60	60	65	65	65	65	70	80	60	60	75	80	65	8
Anthracene	65	60	60	65	60	60	90	75	60	65	55	60	65	10
Fluoranthene	60	60	60	65	65	65	80	80	65	65	70	75	70	7
Pyrene	65	60	65	70	70	65	80	80	60	60	70	75	70	7
Benz(a)Anthracene	75	70	85	85	80	110	75	105	75	75	85	130	90	18
Chrysene	70	70	85	85	75	110	75	115	65	65	90	135	85	23
Benzo[b]fluoranthene	70	70	75	70	70	80	75	100	65	60	80	115	80	16
Benzo[k]fluoranthene	70	70	80	80	80	80	75	115	60	65	85	115	80	18
Benzo(a)pyrene	70	70	80	75	70	80	75	90	70	70	80	0	70	23
Indeno(1,2,3cd)pyrene	85	75	70	0	0	60	85	85	85	85	75	100	65	33
Dibenz(a,h)anthracene	115	105	80	65	75	65	110	110	115	125	85	120	100	22
Benzo(g,h,i)perylene	75	70	70	65	70	60	80	95	65	65	75	95	75	12

Table 4.18 PAH Tissue Spike Blanks (Percent Recovery).

Hydrocarbon	Tissue Replicate (Percent Recoveries) 1	2	3	4	5	6	Mean	Standard Deviation
Naphthalene	75	75	80	80	75	70	75	4
Acenaphthylene	80	95	195	210	120	85	130	55
Acenaphthene	90	135	225	270	140	95	160	75
Fluorene	80	49	280	305	160	95	160	110
Phenanthrene	80	95	65	75	75	75	80	10
Anthracene	65	105	39	100	105	125	90	32
Fluoranthene	55	46	60	70	95	95	70	21
Pyrene	65	105	60	75	100	100	85	20
Benz(a)Anthracene	80	340	100	75	90	65	125	105
Chrysene	80	245	95	70	90	60	105	70
Benzo[b]fluoranthene	70	75	95	65	55	60	70	14
Benzo[k]fluoranthene	60	70	60	48	41	40	55	13
Benzo(a)pyrene	0	17	80	75	80	70	55	36
Indeno(1,2,3cd)pyrene	95	32	105	55	34	55	65	31
Dibenz(a,h)anthracene	145	31	145	75	38	65	85	51
Benzo(g,h,i)perylene	90	43	75	65	50	60	65	17

Table 4.19 **Comparison of Saturated Hydrocarbon Spiked Blanks for the Years 1985, 1986 and 1989.**

No. of Samples	8		11		10	
	(Percent Recovery)					
Program Year	1985		1986		1989	
Compound	Mean	CV*	Mean	CV*	Mean	CV*
nC10	63	67	100	27	44	41
nC11	257	127			52	31
nC14	51	43	124	38	67	15
nC15	53	49	141	21	70	14
nC24	89	17	202	51	100	12
nC25	81	19	201	48	103	15
nC32	75	20	154	22	93	10
nC34	77	13	159	23	87	16

*CV = coefficient of variation = (SD/Mean) x 100

Means for 1985 and 1986 data from Boehm et al., 1987.

Table 4.20 **Comparison of Aromatic Hydrocarbon Spiked Blanks for the Years 1985, 1986 and 1989.**

No. of Samples	8		10		12	
	(Percent Recovery)					
Program Year	1985		1986		1989	
Compound	Mean	CV*	Mean	CV*	Mean	CV*
Naphthalene	54	109	85	53	65	7
Phenanthrene	87	16	102	24	65	12
Pyrene	93	43	124	19	70	10
Chrysene	109	16	110	13	85	26
Benzo(a)pyrene	45	100	97	23	70	32

*CV = coefficient of variation = (std dev./mean) x 100

Table 4.21 Alkane Sediment Detection Limits (μg/g).

Alkane Sediment Detection Limits (ug/g)

Analyte	Mean	Standard Deviation	CV*	Method Detection Limit
nC10	0.0037	0.0013	36	0.0042
nC11	0.0041	0.0010	25	0.0032
nC12	0.0079	0.0018	22	0.0055
nC13	0.0096	0.0010	11	0.0033
1380	0.0032	0.0004	11	0.0011
nC14	0.014	0.002	11	0.0050
1470	0.0068	0.0008	12	0.0026
nC15	0.017	0.001	8.7	0.005
nC16	0.019	0.002	11	0.007
1650	0.0064	0.0006	9.2	0.0018
nC17	0.029	0.003	9.6	0.009
pristane	0.016	0.001	8.0	0.004
nC18	0.020	0.001	7.4	0.005
phytane	0.0094	0.0007	7.9	0.0023
nC19	0.026	0.002	8.6	0.007
nC20	0.024	0.002	7.6	0.006
nC21	0.049	0.005	9.8	0.015
nC22	0.041	0.006	14	0.018
nC23	0.088	0.010	12	0.033
nC24	0.043	0.009	20	0.028
nC25	0.10	0.02	15	0.05
nC26	0.038	0.011	30	0.036
nC27	0.14	0.02	14	0.06
nC28	0.032	0.010	33	0.033
nC29	0.12	0.02	14	0.05
d62-C30	0.21	0.02	11	0.08
nC30	0.022	0.006	27	0.018
nC31	0.091	0.011	12	0.034
nC32	0.012	0.004	34	0.013
nC33	0.033	0.005	14	0.015
nC34	0.006	0.002	30	0.006

*CV = coefficient of variation = (SD/Mean) x 100

Table 4.22 PAH Sediment Detection Limits (ng/g).

PAH Sediment Detection Limits (ng/g)

Analyte	Mean	Standard Deviation	CV*	Method Detection Limit
Naphthalene	5.0	0.35	7.1	1.1
C1N	NA	NA	NA	1.1**
C2N	NA	NA	NA	1.1**
C3N	NA	NA	NA	1.1**
C4N	NA	NA	NA	1.1**
Acenaphthylene	NA	NA	NA	1.1***
Acenaphthene	NA	NA	NA	1.1***
Biphenyl	7.4	1.65	22	5.2
Fluorene	6.5	1.68	26	5.3
C1F	NA	NA	NA	5.3**
C2F	NA	NA	NA	5.3**
C3F	NA	NA	NA	5.3**
Dibenzothiophene	1.6	0.26	17	0.83
C1D	4.3	0.46	11	1.5
C2D	6.4	0.95	15	3.0
C3D	4.9	0.48	10	1.5
Phenanthrene	9.4	1.01	11	3.2
Anthracene	0.072	0.176	245	0.6
C1P/A	NA	NA	NA	0.55**
C2P/A	NA	NA	NA	0.55**
C3P/A	NA	NA	NA	0.55**
C4P/A	NA	NA	NA	0.55**
Fluoranthene	1.5	0.15	10	0.49
Pyrene	2.0	0.23	11	0.72
C1F/P	9	1.0	11	3.1
Benz(a)Anthracene	0.73	0.149	21	0.47
Chrysene	5.5	0.70	13	2.2
C1C	7.1	0.84	12	2.6
C2C	3.2	0.66	21	2.1
C3C	4.2	0.76	18	2.4
C4C	NA	NA	NA	2.2**
Benzo[b]fluoranthene	2.6	0.34	13	1.1
Benzo[k]fluoranthene	0.48	0.093	19	0.29
Benzo(e)pyrene	3.7	0.68	19	2.1
Benzo(a)pyrene	0.16	0.39	245	1.2
Perylene	21	2.6	13	8.1
Indeno(1,2,3,cd)pyrene	0.53	0.138	26	0.43
Dibenz(a,h)anthracene	0.36	0.084	23	0.27
Benzo(g,h,i)perylene	2.2	0.44	20	1.4

*CV = Coefficient of Variation = (Std Dev./Mean)x100

** Alkyl homologue detection limit based on MDL for parent compound.

*** Compound assigned MDL of next closest PAH (Naphthalene).

Table 4.23 Alkane Tissue Detection Limits Wet Weight (µg/g).

Analyte	Mean	Standard Deviation	CV*	Method Detection Limit
nC10	0.098	0.027	28	0.085
nC11	0.10	0.029	28	0.090
nC12	0.12	0.027	22	0.084
nC13	0.13	0.027	22	0.086
nC14	0.15	0.021	14	0.065
nC15	0.15	0.016	10	0.050
nC16	0.13	0.015	11	0.047
nC17	0.16	0.012	7.5	0.038
pristane	0.15	0.013	8.2	0.039
nC18	0.098	0.006	6.4	0.020
phytane	0.12	0.011	9.0	0.034
nC19	0.11	0.0079	7.4	0.025
nC20	0.13	0.013	10	0.042
nC21	0.17	0.0076	4.5	0.024
nC22	0.18	0.011	6.0	0.034
nC23	0.17	0.023	14	0.073
nC24	0.20	0.033	16	0.102
nC25	0.18	0.023	13	0.074
nC26	0.18	0.022	12	0.069
nC27	0.17	0.019	11	0.059
nC28	0.19	0.019	10	0.059
nC29	0.33	0.037	11	0.12
nC30	0.17	0.011	6.2	0.034
nC31	0.19	0.029	16	0.092
nC32	0.16	0.014	8.8	0.043

*CV = Coefficient of Variation (SD/Mean) x 100

Table 4.24 PAH Tissue Detection Limits Wet Weight (ng/g).

Analyte	Mean	Standard Deviation	CV*	Method Detection Limit
Naphthalene	10	4.5	45	14.1
C1N	NA	NA	NA	14.1**
C2N	NA	NA	NA	14.1**
C3N	NA	NA	NA	14.1**
C4N	NA	NA	NA	14.1**
Acenaphthylene	4.7	2.8	59	8.8
Acenaphthene	6	3.6	60	11.3
Biphenyl	0.83	0.7	84	2.2
Fluorene	4.6	2.8	60	8.8**
C1F	NA	NA	NA	8.8**
C2F	NA	NA	NA	8.8**
C3F	NA	NA	NA	8.8**
Dibenzothiophene	NA	NA	NA	11.6**
C1D	NA	NA	NA	11.6**
C2D	NA	NA	NA	11.6**
C3D	NA	NA	NA	11.6**
Phenanthrene	7.4	3.7	50	11.6
Anthracene	5.6	3.2	58	10.1
C1P/A	NA	NA	NA	11.6**
C2P/A	NA	NA	NA	11.6**
C3P/A	NA	NA	NA	11.6**
C4P/A	NA	NA	NA	11.6**
Fluoranthene	7.1	3.8	53	11.9
Pyrene	6.4	3.8	58	11.9**
C1F/P	NA	NA	NA	11.9**
Benz(a)anthracene	9.3	5.4	58	17.0**
Chrysene	10	6	58	18.9
C1C	NA	NA	NA	18.9**
C2C	NA	NA	NA	18.9**
C3C	NA	NA	NA	18.9**
C4C	NA	NA	NA	18.9**
Benzo[b]fluoranthene	8.2	4.9	59	15.4
Benzo[k]fluoranthene	7.5	4.3	58	13.5
Benzo(e)pyrene	0.84	1.6	190	5.0
Benzo(a)pyrene	7.2	4.2	58	13.2
Perylene	NA	NA	NA	13.2**
Indeno(123cd)pyrene	5.7	3.3	58	10.4
Dibenz(a,h)anthracene	5.7	3.5	61	11.0

*CV = Coefficient of Variation = (SD/Mean) x 100

** Analyte assigned MDL of parent compound or nearest comparable PAH compound

The reported concentrations of some analytes in the data base may be below the MDL limits as determined by this method. However all values reported are above the detection limits of the instruments and are thus valid results.

As an additional measure of analytical accuracy ADL participated in the 1990 NOAA/NIST intercomparison exercise. Intercalibration solutions were analyzed and the concentrations of NIST PAH compounds were determined. The results of the first exercise are presented in Table 4.25. Precision between sample replicates A, B and C, as well as between samples 1, 2 and 3, as reflected by the CV of the replicate mean and sample mean respectively, was quite good, with the CV not exceeding 8%. Accuracy was determined by the mean absolute % error relative to the NIST gravimetric values and ranged from 20% - 49% for replicates S1a, S1b and S1c and from 20% - 40% for samples S1, S2 and S3. Results from the second exercise, as reported to NIST are presented in Table 4.26. Precision, as reflected in the within and between sample variability was quite high, with the CV never exceeding 4%. Results were not available from NIST for this second exercise at the time of publication of this report.

4.4.2.1 Analysis of Archived Sediment. Three 1986 archived samples from station 5A were pooled and analyzed in triplicate for saturated and aromatic hydrocarbons as part of the QC program for 1989. It should be noted that this sample was archived at temperatures of approximately -20°C, for about three years. The effect of storage on the target analytes is not known and may effect the ability to compare results.

The results for the SHC and PAH hydrocarbons are presented in Tables 4.27 and 4.28 respectively. The PAH data for the parent compounds generally agreed quite well. One exception was the concentration of perylene which was approximately a factor of two lower than the 1986 value. Perylene, however, is prone to photo-oxidization and may have degraded during storage. The alkyl homologues series of the naphthalenes and phenanthrenes were approximately a factor of two higher in the 1989 data set. These differences can most likely be attributed to differences in the instrumental integration algorithms used to quantify the complex mixtures within an alkyl homologue series. This was reflected also in the diagnostic ratio, total P/total D. The ratio of total N/total P was quite similar between the two years. The relative abundance of the alkyl homologue series was consistent between the 1986 and 1989 data. This was reflected in the ratios of the individual alkyl homologue series, such as C0N/C0P and C0P/C0D, which were similar between the two years (Table 4.28).

The saturated hydrocarbon concentrations for the 1989 data set were consistently 40 to 50 percent lower than the 1986 data. This is the case for all of the individual normal alkane anlaytes as well as the total resolved plus unresolved saturated hydrocarbons (TOT), which includes the unresolved complex mixture (UCM). It is unlikely that the saturates degraded during storage, and the trend of lower saturated hydrocarbon concentrations is observed in the 1989 field sample data as well.

Table 4.25 Results of the First Exercise of the NIST/NOAA AQA Program for FY 1990.

Within Sample Variation (S1 - A,B,C)

Compound	NIST Gravimetric Values (ug/ml)	S1 Rep A (ug/ml)	S1 Rep B (ug/ml)	S1 Rep C (ug/ml)	S1 Mean (ug/ml)	Reps A-C CV* (%)	Mean Absolute %Error**
Biphenyl	2.69	3.51	3.46	3.61	3.5	2.2	31
Fluorene	3.27	4.33	4.34	4.47	4.4	1.8	34
Chrysene	9.49	15.1	13	14.4	14.2	7.5	49
Benzo(e)pyrene	5.1	7.4	6.83	7.06	7.1	4.0	39
Benzo(a)pyrene	3.54	5.32	4.89	4.81	5.0	5.5	41
Benzo(ghi)perylene	2.53	3.23	3.06	3.12	3.1	2.7	24

Between Sample Variation (S1,S2,S3)

Compound	NIST Gravimetric Values (ug/ml)	Mean S1 (3 reps) (ug/ml)	S2 (ug/ml)	S3 (ug/ml)	Mean (S1-S3) (ug/ml)	S1-S3 CV	Mean Absolute %Error***
Biphenyl	2.69	3.53	3.39	3.85	3.59	2.2	33
Fluorene	3.27	4.38	4.4	3.97	4.25	1.8	30
Chrysene	9.49	14.17	13.5	13.2	13.62	7.5	44
Benzo(e)pyrene	5.1	7.1	6.88	6.63	6.87	4.0	35
Benzo(a)pyrene	3.54	5.01	4.73	4.52	4.75	5.5	34
Benzo(ghi)perylene	2.53	3.14	3.23	3.22	3.20	2.7	26

*CV = Coefficient of Variation = (SD/Mean) x 100
**Absolute error of the replicate mean relative to the NIST values
***Absolute error of the sample mean relative to the NIST values

Table 4.26 Results of the Second Exercise of the NIST/NOAA AQA Program for FY 1990.

Within Sample Variation (S1 - A,B,C)

Compound	S1 Rep A (ug/ml)	S1 Rep B (ug/ml)	S1 Rep C (ug/ml)	S1 MEAN (ug/ml)	Reps A-C CV* (%)
Biphenyl	2.7	2.7	2.69	2.70	0.2
Fluorene	3.42	3.45	3.43	3.43	0.4
Chrysene	8.36	8.37	8.45	8.39	0.6
Benzo(e)pyrene	4.93	4.89	4.93	4.92	0.5
Benzo(a)pyrene	3.83	3.83	3.85	3.84	0.3
Benzo(ghi)perylene	2.27	2.17	2.14	2.19	3.1

Between Sample Variation (S1,S2,S3)

Compound	Mean S1 (3 reps) (ug/ml)	S2 (ug/ml)	S3 (ug/ml)	Mean (S1-S3) (ug/ml)	S1-S3 CV* (%)
Biphenyl	2.70	2.59	2.72	2.67	2.6
Fluorene	3.43	3.36	3.48	3.42	1.8
Chrysene	8.39	8.43	9.01	8.61	4.0
Benzo(e)pyrene	4.92	4.86	5.14	4.97	3.0
Benzo(a)pyrene	3.84	3.8	3.99	3.88	2.6
Benzo(ghi)perylene	2.19	2.09	2.24	2.17	3.5

*CV = Coefficient of Variation = (std dev./mean)x100

Table 4.27 Comparison of Alkane Data for Archived 1986 Sediment Sample from Station 5(a) Analyzed in 1986 and 1989.

	1986 Samples, Analyzed 1986		1986 Samples, Analyzed 1990	
Analyte	Average Conc. (ug/g)	Standard Deviation (ug/g)	Average Conc. (ug/g)	Standard Deviation (ug/g)
nC10	0.0106	0.0011	0.0093	0.0049
nC11	NA	NA	0.0120	0.0020
nC12	0.0245	0.0006	0.0150	0.0010
nC13	0.0340	0.0011	0.0200	0.0020
1380	0.0101	0.0006	0.0057	0.0008
nC14	0.0409	0.0023	0.0237	0.0025
1470	0.0240	0.0031	0.0130	0.0010
nC15	0.0491	0.0027	0.0277	0.0015
nC16	0.0504	0.0029	0.0283	0.0006
1650	0.0183	0.0014	0.0105	0.0008
nC17	0.0828	0.0038	0.0397	0.0015
pristane	0.0511	0.0028	0.0243	0.0012
nC18	0.0624	0.0028	0.0317	0.0015
phytane	0.0233	0.0012	0.0150	0.0000
nC19	0.0903	0.0085	0.0423	0.0012
nC20	0.0801	0.0050	0.0400	0.0010
nC21	0.1770	0.0087	0.0877	0.0032
nC22	0.1395	0.0084	0.0673	0.0025
nC23	0.3657	0.0235	0.1733	0.0058
nC24	0.1505	0.0104	0.0733	0.0032
nC25	0.4437	0.0433	0.2233	0.0058
nC26	0.1149	0.0130	0.0603	0.0049
nC27	0.6579	0.0588	0.2933	0.0321
nC28	0.1041	0.0135	0.0480	0.0061
nC29	0.5695	0.0384	0.2100	0.0173
nC30	0.0743	0.0207	0.0320	0.0050
nC31	0.3541	0.0191	0.1567	0.0153
nC32	0.0540	0.0194	0.0170	0.0010
nC33	0.1528	0.0071	0.0550	0.0044
nC34	0.0185	0.0060	0.0102	0.0014
TOT	12.6033	2.4885	5.2333	0.2082
Diagnostic Ratios				
ISO/ALK	0.36	0.01	0.35	0.01
LALK/TALK	0.13	0.00	0.16	0.00
OEPI	6.18	0.49	5.35	0.75
PRIS/PHY	2.19	0.02	1.62	0.08

NA = Not Reported

Table 4.28 Comparison of PAH Data for Archived 1986 Sediment Sample from Station 5(a), Analyzed in 1986 and 1989.

Analyte	Year 3 (1986) Archived Sample Analyzed 1986		Year 3 (1986) Archived Sample Analyzed 1990	
	Average Conc. (ng/g)	Standard Deviation (ng/g)	Average Conc. (ng/g)	Standard Deviation (ng/g)
Naphthalene	6.00	0.00	8.73	0.61
C1N	29.67	0.58	39.67	5.69
C2N	53.00	5.29	86.33	11.15
C3N	56.67	16.20	110.00	17.32
C4N	32.00	19.97	42.33	4.16
Biphenyl			6.97	0.81
Fluorene	4.00	0.00	4.90	0.70
C1F	11.67	2.31	12.67	2.89
C2F	13.00	1.73	23.63	17.10
C3F	12.00	1.00	35.33	6.51
Dibenzothiophene	3.33	0.58	2.00	0.53
C1D	9.00	1.73	6.43	0.15
C2D	11.67	2.89	10.17	0.76
C3D	11.50	0.71	8.97	0.31
Phenanthrene	22.33	0.58	17.67	3.79
Anthracene			0.94	
C1P/A	37.00	5.29	46.33	2.08
C2P/A	41.50	0.71	67.67	2.08
C3P/A	24.67	9.07	51.67	3.51
C4P/A	13.50	2.12	23.33	3.06
Fluoranthene	4.33	0.58	4.17	2.71
Pyrene	5.33	0.58	4.20	1.39
C1F/P			15.67	0.58
Benz(a)Anthracene	NA	NA	1.73	0.67
Chrysene	10.33	1.53	9.63	0.55
C1C	NA	NA	13.00	1.00
C2C	NA	NA	7.63	0.45
C3C	NA	NA	7.80	0.95
C4C	NA	NA	2.87	0.25
Benzo[b]fluoranthene	9.00	1.00	4.37	0.45
Benzo[k]fluoranthene	NA	NA	0.98	0.29
Benzo(e)pyrene	8.33	0.58	5.60	0.10
Benzo(a)pyrene	2.67	0.58	1.50	0.36
Perylene	62.00	8.72	28.67	0.58
TOT PAH	472.33	83.03	656.28	58.35
Diagnostic parameters				
C0N/C0P*	0.27	0.01	0.51	0.12
C0P/C0D*	6.83	1.17	9.73	5.18
C0P/C0C*	2.19	0.78	1.83	0.32
N/P**	1.53	0.25	1.39	0.18
P/D**	3.78	0.15	7.51	0.29
FFPI	0.78	0.07	0.91	0.01

NA = Not Reported

*Ratios reported are that of the parent compounds, i.e., C0N/C0P

**Ratios reported are the sums of the parent compounds plus alkyl homologues, i.e., C0N+C1N+C3N+C4N/C0N+C1N+C2N+C3N+C4N

Differences between the type of instrument and data system used to analyze and quantify the saturated hydrocarbon data may account for the trend towards lower concentrations determined in 1989. We feel that the 1989 data set more accurately reflects the true values for total saturates because the data system used to generate the 1989 data was capable of subtracting column bleed from the UCM. That individual saturated hydrocarbon concentrations may have been overestimated in year 3 (1986) of the former study is also suggested by the high percent recoveries (greater than 100%) discussed in Section 4.4.2, which may be related to inaccurate spiking levels in 1986. High percent recoveries in spiked blanks may be the result of low internal standard spiking levels, which may in turn cause an overestimation in sample analyte amounts.

While differences existed in the absolute concentrations of saturated hydrocarbons between the 1986 and 1989 analyses of saturated hydrocarbons, it can be seen that the values of the diagnostic ratios were similar between the two analyses (Table 4.26). These ratios are therefore important in the continuity of the data in the monitoring programs. These similarities can also be seen for the PAH diagnostic ratios (Table 4.27).

4.4.3 Auxiliary Parameters. The quality control for grain size and TOC consisted of the analysis of duplicate and triplicate samples since there were no available standard reference materials for these parameters. Two duplicate and one triplicate analyses were performed for sediment grain size. The variability of the replicate analyses for the percent gravel, sand, silt and clay was less than 35 percent, which is within the acceptable limits for this analysis. The coefficient of variance was 25 percent or less for all of the five triplicate TOC analyses, reflecting acceptable reproducibility for this measurement.

5.0 Data Analysis and Interpretation

5.1 Introduction

The analysis of the data set from the 1989 sampling year followed the approaches used in previous reports (Boehm et al., 1985, 1986, 1987). These approaches included the following:

- Evaluation of the data from geochemical and biogeochemical perspectives
- Statistical analysis of the data to test hypotheses

5.1.1 Geochemical and biogeochemical evaluation. The first approach involves interpreting the spatial distribution of target elemental and organic analytes in sediments and tissues, as well as the hydrocarbon and elemental composition of sediments and tissues within a station or region. Included in this interpretation is an evaluation of key diagnostic parameters and parameter ratios. These parameters have been used in past studies to determine sources of hydrocarbons and trace metals and to evaluate their usefulness in monitoring for the effects of oil and gas drilling. The emphasis this year was to determine whether any changes had occurred in the chemistry of sediments or in the tissues of benthic organisms in the three year hiatus of sampling, as the result of oil and gas drilling.

Chemical concentrations in sediment and tissues and diagnostic ratios were examined on a regional basis. These regions, listed in Table 5.1 with their associated stations, were selected in previous studies (Boehm et al., 1985, 1986, 1987). Individual station concentrations were examined from Endicott Development Island (Region 8), a new transect in Endicott Field, as well as Griffin Point (Region 9), which was also sampled for the first time in 1989.

5.1.2 Statistical analysis. The second interpretive approach involved statistical analysis of the data in order to evaluate temporal changes in chemical concentrations and in key diagnostic parameters and ratios. The statistical test that was used was analysis of variance (ANOVA); the main comparison was between 1989 regional mean sediment concentrations and the 1984 - 1986 regional mean sediment concentrations.

5.2 Trace Metal Chemistry

5.2.1 Metals in Sediments - Previous Results Total (Bulk) Metal Concentrations. Results from the previous three-year study of trace metals along the inner shelf of the western Beaufort Sea (Boehm et al., 1987) showed reasonable consistency with data for other coastal areas in the Arctic and with predictions based on average continental crust (Table 5.2). The large range in total (bulk) metal concentrations for sediments from the Beaufort shelf (Table 5.2) is best explained by variations in grain size. Metal concentrations are typically higher in fine-grained, clay-rich sediments because

Table 5.1 List of Regions and their Associated Stations for the 1989 Beaufort Sea Monitoring Program

Region	Name	Stations
Region 1	Camden Bay	1A, 1B, 1C, 1D, 1E, 2A, 2B, 2C, 2D, 2E, 2F
Region 2	Fogg Island Bay	3A, 3B, 4A, 4B, 4C, 5G, 5H
Region 3	Kuparuk River Bay Area	5A, 5B, 5D, 5E, 5F
Region 4	East Harrison Bay	6A, 6B, 6C, 6D, 6F, 6G
Region 5	West Harrison Bay	7A, 7B, 7C, 7D, 7E, 7G
Region 6	Endicott Field	5(0), 5(1), 5(5), 5(10)
Region 7	Griffin Point	9A, 9B, 9C
Region 8	Endicott Development Island	8A, 8B, 8C, 8D, 8E, 8F

Table 5.2 **Ranges and Means for Trace Metal Concentrations in Various Arctic Coastal Sediments and Average Continental Crust. Concentrations in μg/g.**

Metal	Beaufort Sea[a]	Beaufort Sea[b]	Baffin Bay[c]	Ave. Cont. Crust[d]	Beaufort Sea[e]
Ba	185 - 745	---	---	500	348
Cd	0.04 - 0.31	---	---	0.11	0.14
Cr	17 - 91	82 - 97	16 - 139	100	49
Cu	5 - 37	<1 - 61	4 - 42	50	16
Pb	4 - 20	---	4 - 42	14	9
V	33 - 153	25 - 275	47 - 156	160	79
Zn	19 - 116	38 - 130	17 - 83	75	62

[a] Boehm et al (1987).

[b] Naidu et al. (1982).

[c] Campbell and Loring (1981).

[d] Taylor (1964).

[e] This study

of their greater surface area and differences in mineralogy.

Variations in sediment grain size along the Beaufort Shelf were sizeable with the fine-fraction (silt + clay, <62.5 µm) ranging from <5 to >85% for all samples collected during the previous study (Boehm et al., 1987). This range in the fine-fraction content of the Beaufort sediments is directly related to the range of values shown in Table 5.2. Overall, patterns for grain size distribution were complex with no straightforward trends. Only a weak trend ($r = 0.54$; $p = 0.02$) of increasing clay fraction with increasing distance offshore (water depth) was observed.

Total organic carbon concentrations for Beaufort shelf sediments from the previous study (Boehm et al., 1987) ranged from <1 to about 30 mg/g. The TOC concentrations correlated with silt plus clay except where peat deposits were sampled. Carsola (1954) reported TOC values of 2-12 mg/g for Beaufort Sea sediments. Again, a greater concentration of fine-grained, TOC-rich sediments with higher metal levels were found in the offshore sediments (Boehm et al., 1987; Naidu et al., 1982).

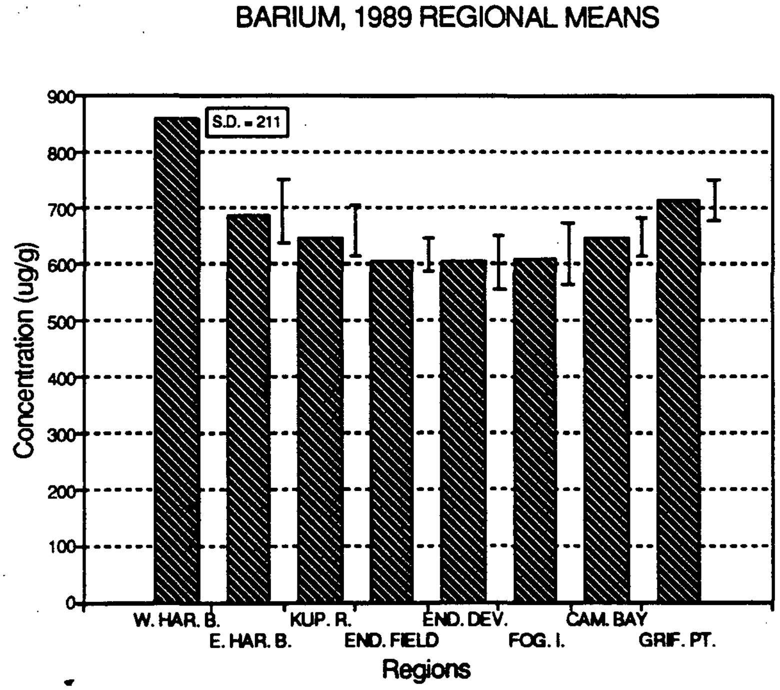
Total concentrations of Cu, Cr, Pb, V and Zn correlated relatively well with each other in the previous work (Boehm et al., 1987). Concentrations of total Ba also compared well with the exception of higher values at stations 5A, 5D and all of the area 7 stations from West Harrison Bay. The most likely explanation given for these anomalies was an increased illite-mica content in the finer-grained sediments at the western sites.

Metals in the Fine-Fraction of Sediment

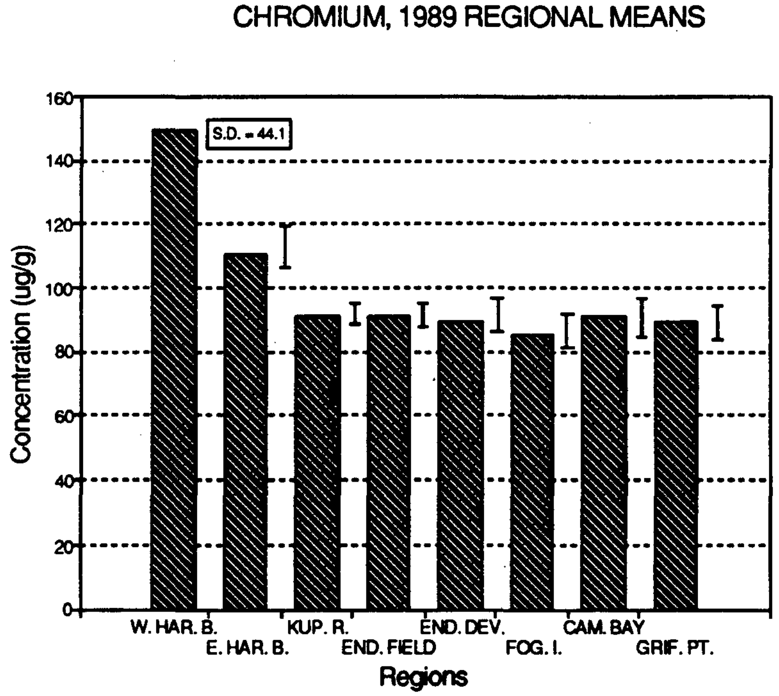
A shift in analytical procedure for sediments during 1985 yielded two different sets of data, one for bulk sediments with <2 mm grain size and one for sediments with <62.5 µm grain size. Thus, in the 1987 study (Boehm et al., 1987), data was presented for bulk sediments (from 1984 and 1985 collections) as described above and for the fine-fraction (from 1985 and 1986 collections). This shift was designed to increase the likelihood of identifying anthropogenic perturbations. Trace metals were generally associated with the fine fraction and in some samples this fraction is <10% of the total bulk sediments. In such instances, analysis of the relatively metal poor bulk samples increased the difficulty of identifying contaminant inputs.

Metal concentrations in the fine-fraction were at higher levels and showed less variability (Table 4.1) than observed for the bulk sediments (Table 5.2).

5.2.2 Metals in Sediments - 1989 Samples, Fine Fraction. Regional means for concentrations of metals in the fine-fraction of the 1989 sediments were relatively uniform (Table 4.1 and Figures 5.1 to 5.4). This overall trend suggested that the fine fraction (<62.5 m) of sediment analyzed was reasonably homogeneous across the inner shelf of the western Beaufort Sea. The major exceptions to the trend were



(a)



(b)

Figure 5.1 **Regional Mean Concentrations of (a) Ba and (b) Cr in the Fine Fraction of Sediments from the Beaufort Sea for 1989. Error Bars Represent the Standard Deviation (± .5 SD).**

W. HAR. B. - West Harrison Bay
E. HAR. B. - East Harrison Bay
KUP. R. - Kuparuk River
END. FIELD - Endicott Field
END. DEV. - Endicott Development Island
FOG. I. - Foggy Island
CAM. BAY - Camden Bay
GRIF. PT. - Griffin Point

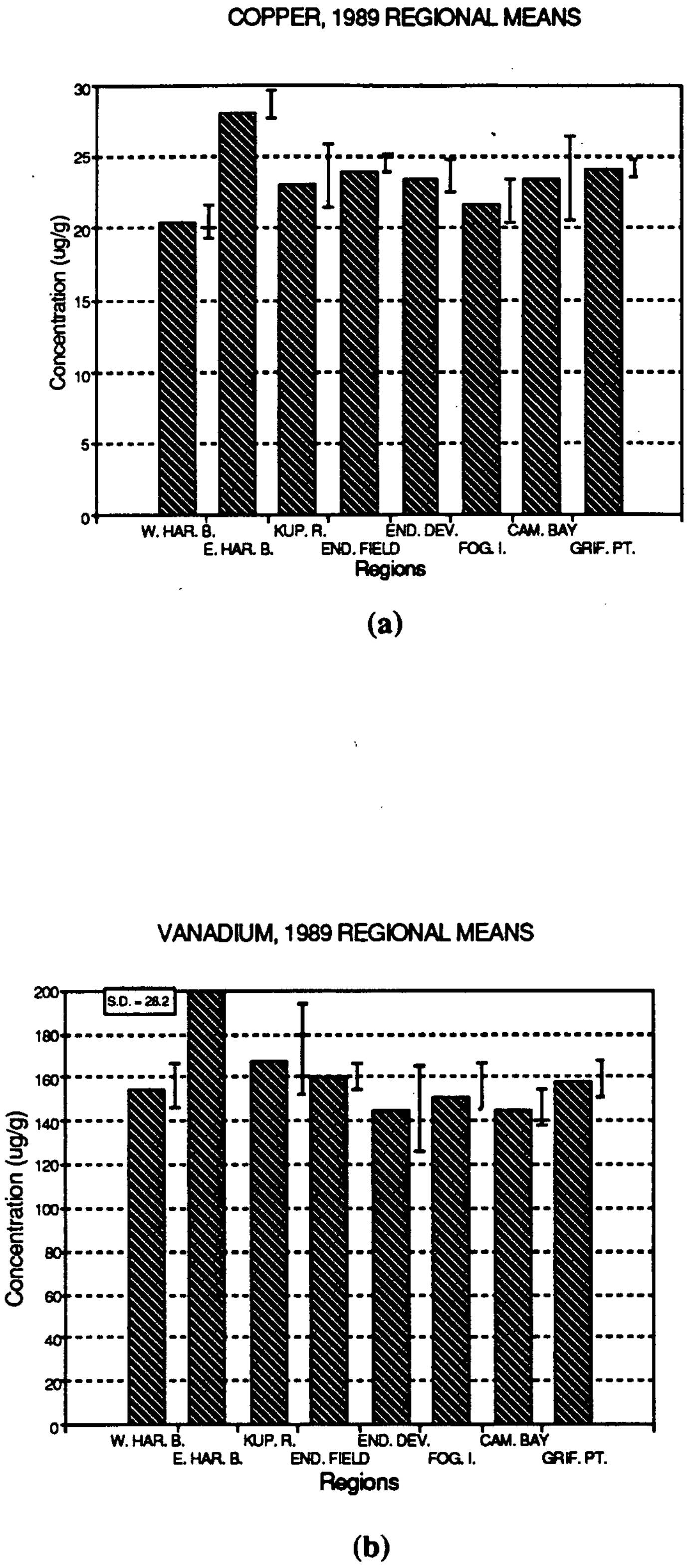
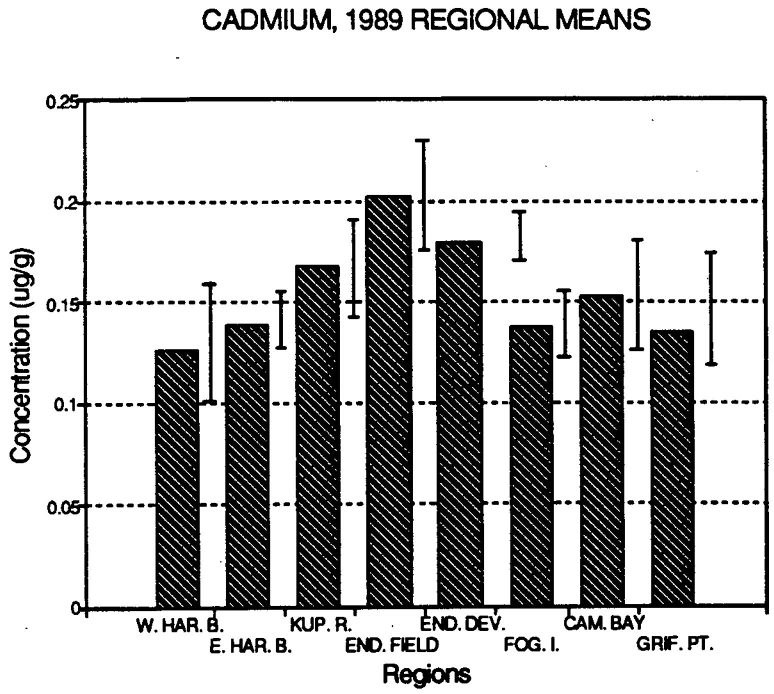
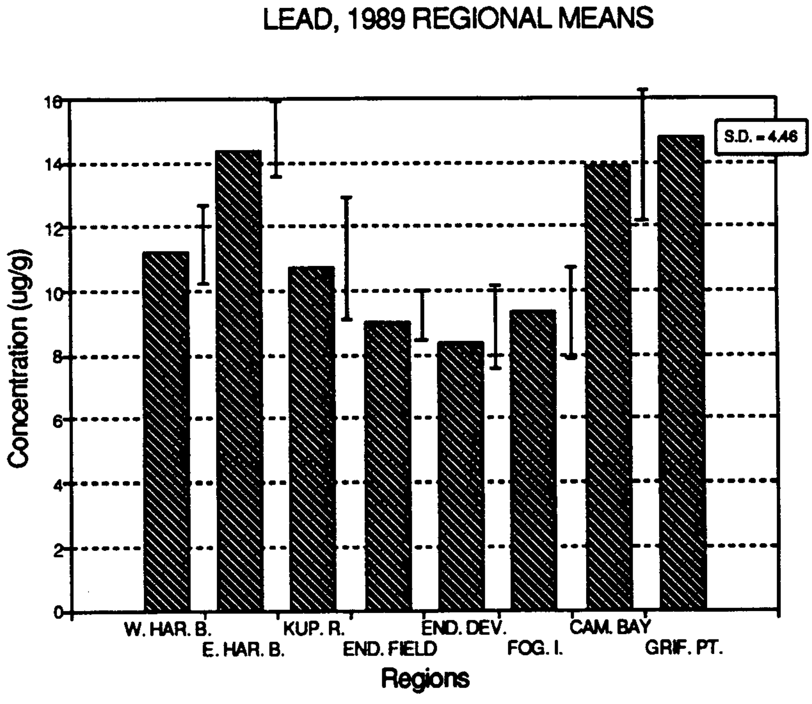


Figure 5.2 Regional Mean Concentrations of (a) Cu and (b) V in the Fine Fraction of Sediments from the Beaufort Sea for 1989. Error Bars Represent the Standard Deviation (± .5 SD).
(See Figure 5.1 for the Legend pertaining to the Regions).



(a)



(b)

Figure 5.3 Regional Mean Concentrations of (a) Cd and (b) Pb in the Fine Fraction of Sediments from the Beaufort Sea for 1989. Error Bars Represent the Standard Deviation (± .5 SD).
(See Figure 5.1 for the Legend pertaining to the Regions).

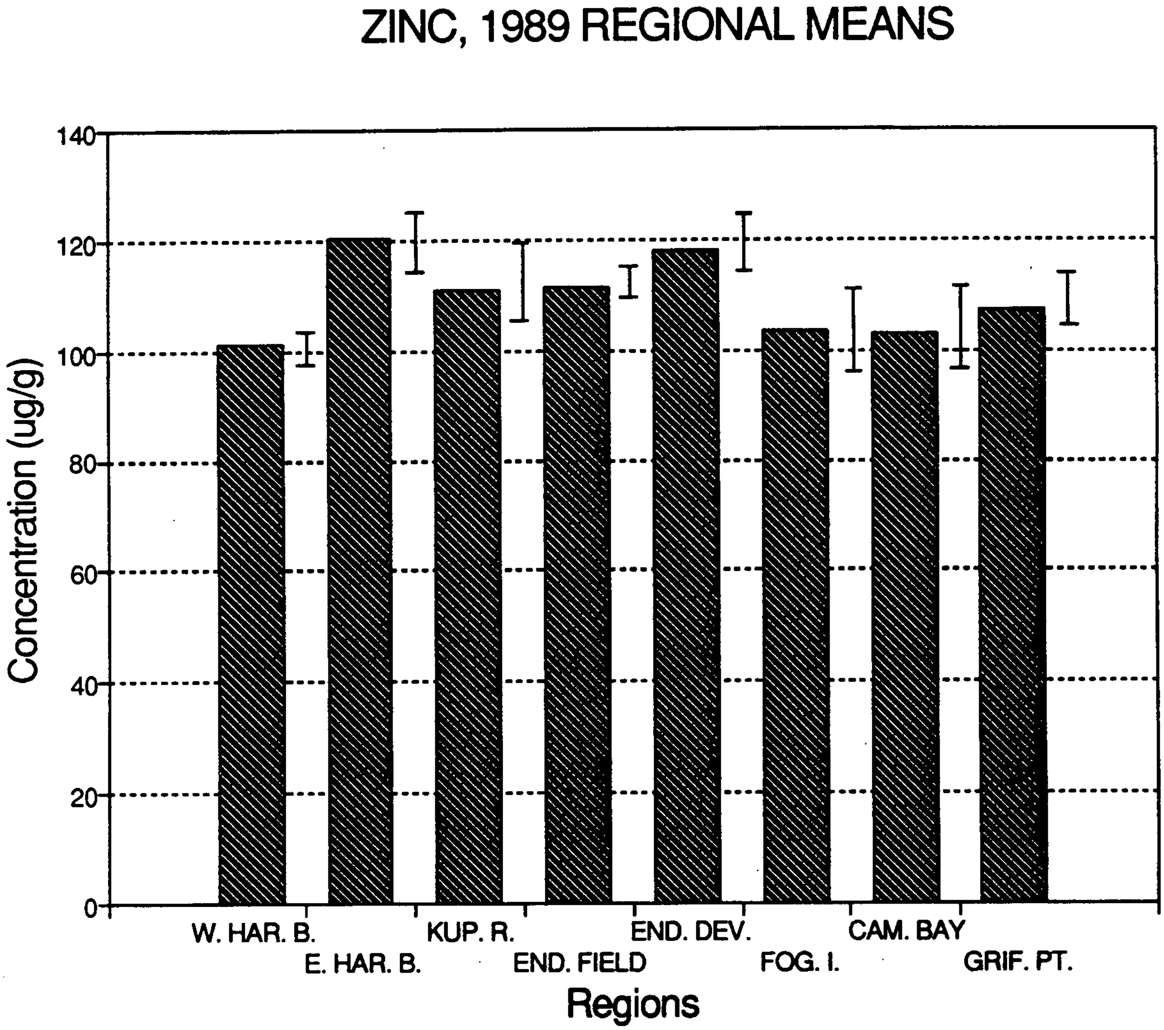


Figure 5.4 Regional Mean Concentrations of Zn in the Fine Fraction of Sediments from the Beaufort Sea for 1989. Error Bars Represent the Standard Deviation (± .5 SD).
(See Figure 5.1 for the Legend pertaining to the Regions).

higher Ba and Cr values for region 5 (Figure 5.1) and higher Cr, Cu and V levels for region 4 (Figures 5.1 b and 5.2).

Excluding the five exceptions listed above, the variations in regional means were relatively small at ± 50 ppm for Ba, ± 0.06 ppm for Cd, ± 4 ppm for Cr, ppm for Cu, ± 4 ppm for Pb, ± 7 ppm for V, and ± 13 ppm for Zn. As a result, the histograms showing regional means for each elements (Figures 5.1 to 5.4) showed rather uniform metal concentrations.

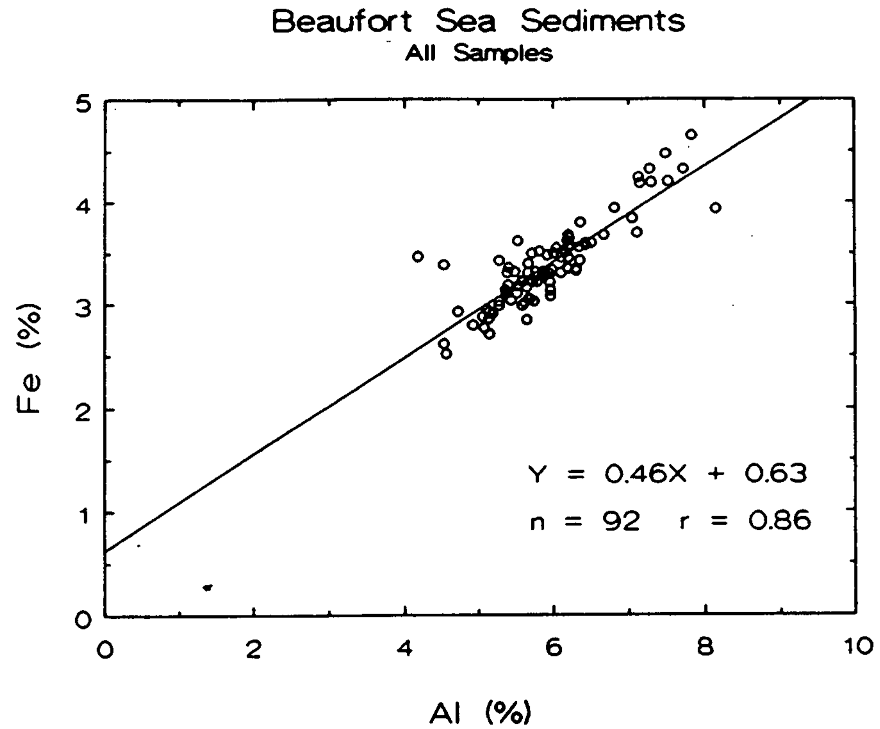
The overall uniformity in the trace metal data was also evident in the sediment Fe and Al concentrations which averaged 3.38 ± 0.41% and 5.93 ± 0.74%, respectively, and showed only minor variations among the eight regional mean values (Table 4.1). Despite the small standard deviations and narrow range of metal concentrations for most samples, we observed a factor of two range in values for Fe (2.52-4.65%) and Al (4.18-8.15%) (Figure 5.5). Individual trace metal levels will thus vary to some degree in proportion to the Fe and Al values. By normalizing trace metal concentrations to Fe or Al, natural variability can sometimes be factored out of the data set. In addition, enormously high metal concentrations may also be more clearly identified (Figure 5.5 through 5.7).

Table 5.3 shows the grand means and standard deviations in the metal/Al ratios for the 1989 samples. Once again the uniformity of values in the data set was shown by the generally small standard deviations in the metal to Al ratios. Below the grand means for metal/Al ratios, 10 data points have been identified because the metal/Al ratio was more than two standard deviations above the mean. This degree of metal enhancement at those stations may be related to natural deposits or anthropogenic inputs. Enhanced levels of Ba (stations 7A and 7G) have been previously noted for West Harrison Bay and were believed to be a natural phenomenon related to an abundance of K- and Ba-bearing illite-mica minerals. These Ba anomalies showed up clearly on the scatter plot of Ba versus Al (Figure 5.6 a). The Cr anomalies at stations 7A and 7G had not been previously reported. Along with station 2E and replicates, three stations showed Cr anomalies in Table 5.3 and in Figure 5.6 b. The origins of these elevated levels are unknown; however, they were not at concentrations that would be generally considered an environmental hazard. They do provide a marker for future reference. The Cd elevations at three sites were just above the 2 standard deviation break point and the actual Cd concentrations of 0.25-0.28 ppm were still low by comparison with most nearshore sediments.

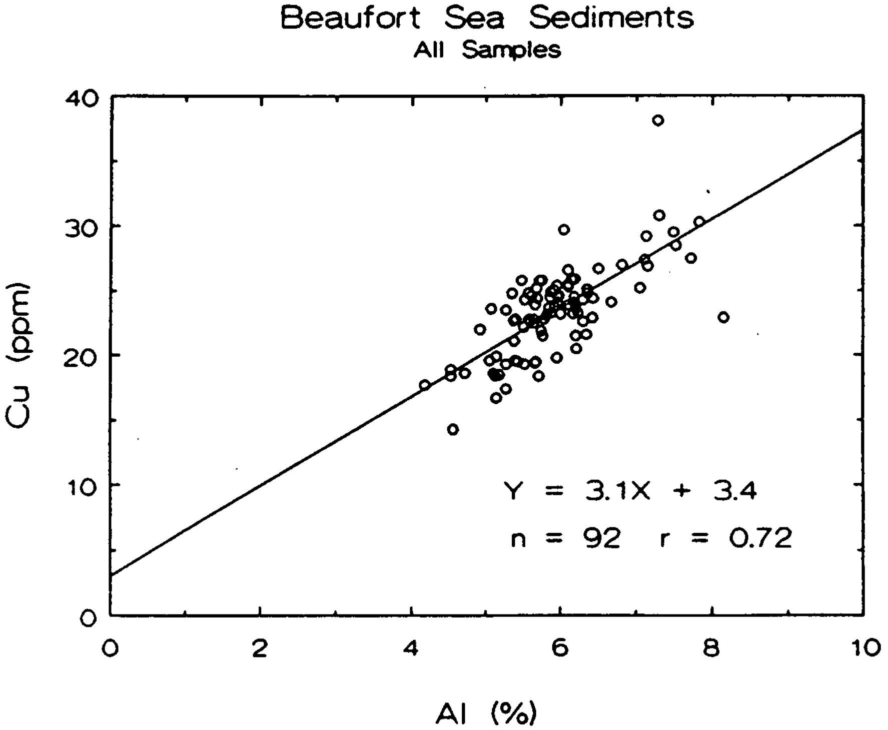
The other elements showed, even with the more sensitive metal/Al approach, no significant deviations from expected trends and no indications of elevated levels in the sediments from the study area.

5.2.3 Comparison of Metals in Sediments of 1989 Versus Previous Studies.

Regional mean concentrations for Cd, Cr, Cu, Pb and Zn in sediments from the



(a)



(b)

Figure 5.5 Scatter Plot Showing (a) Fe Versus Al (b) Cu Versus Al. Solid Circles indicate ratio values that are outliers by more than 2 Standard Deviations from the Mean Established in Table 5.3, and are not included in the Linear Regression.

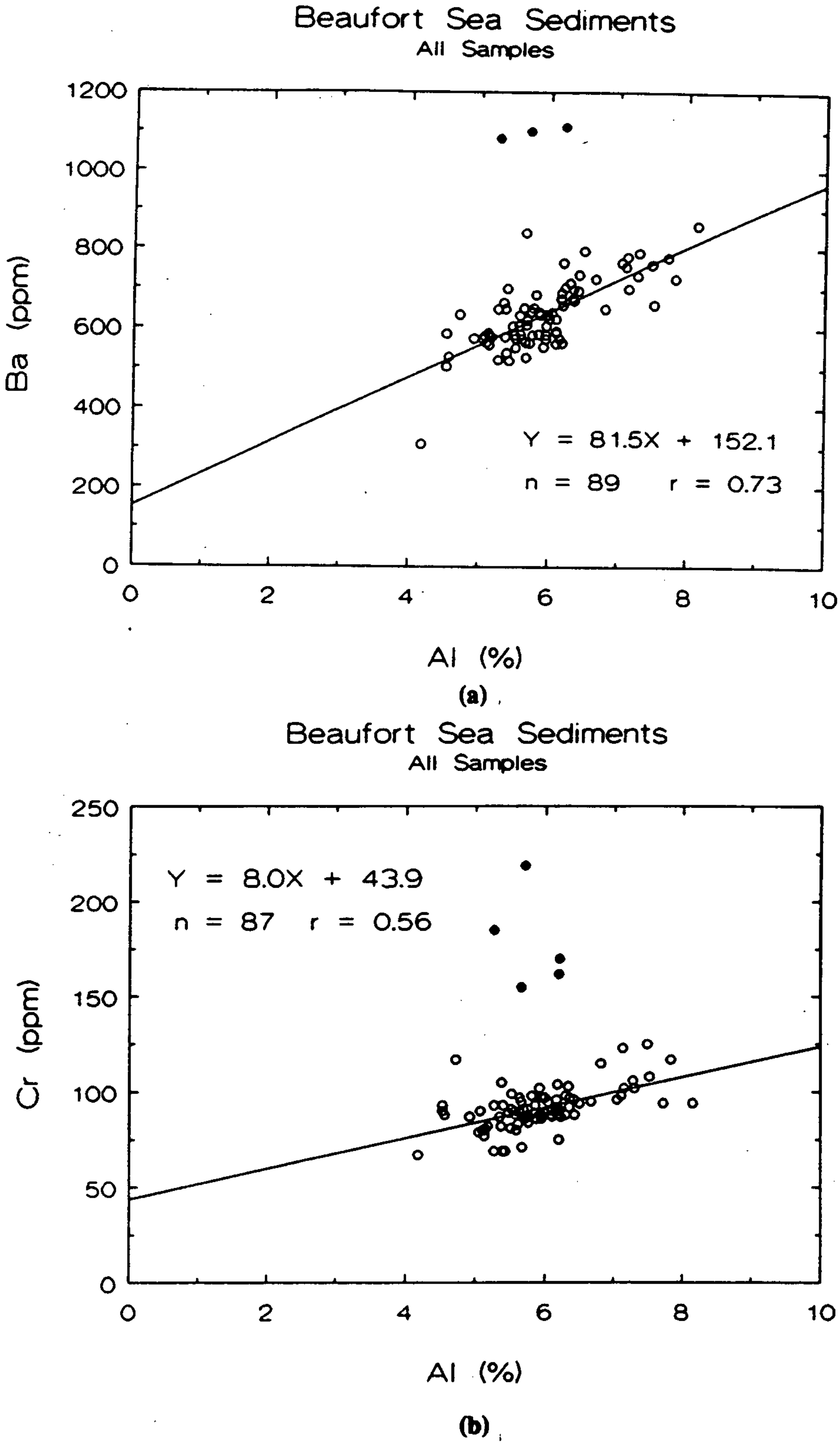


Figure 5.6 Scatter Plot Showing (a) Ba Versus Al (b) Cr Versus Al. Solid Circles indicate ratio values that are outliers by more than 2 Standard Deviations from the Mean Established in Table 5.3, and are not included in the Linear Regression.

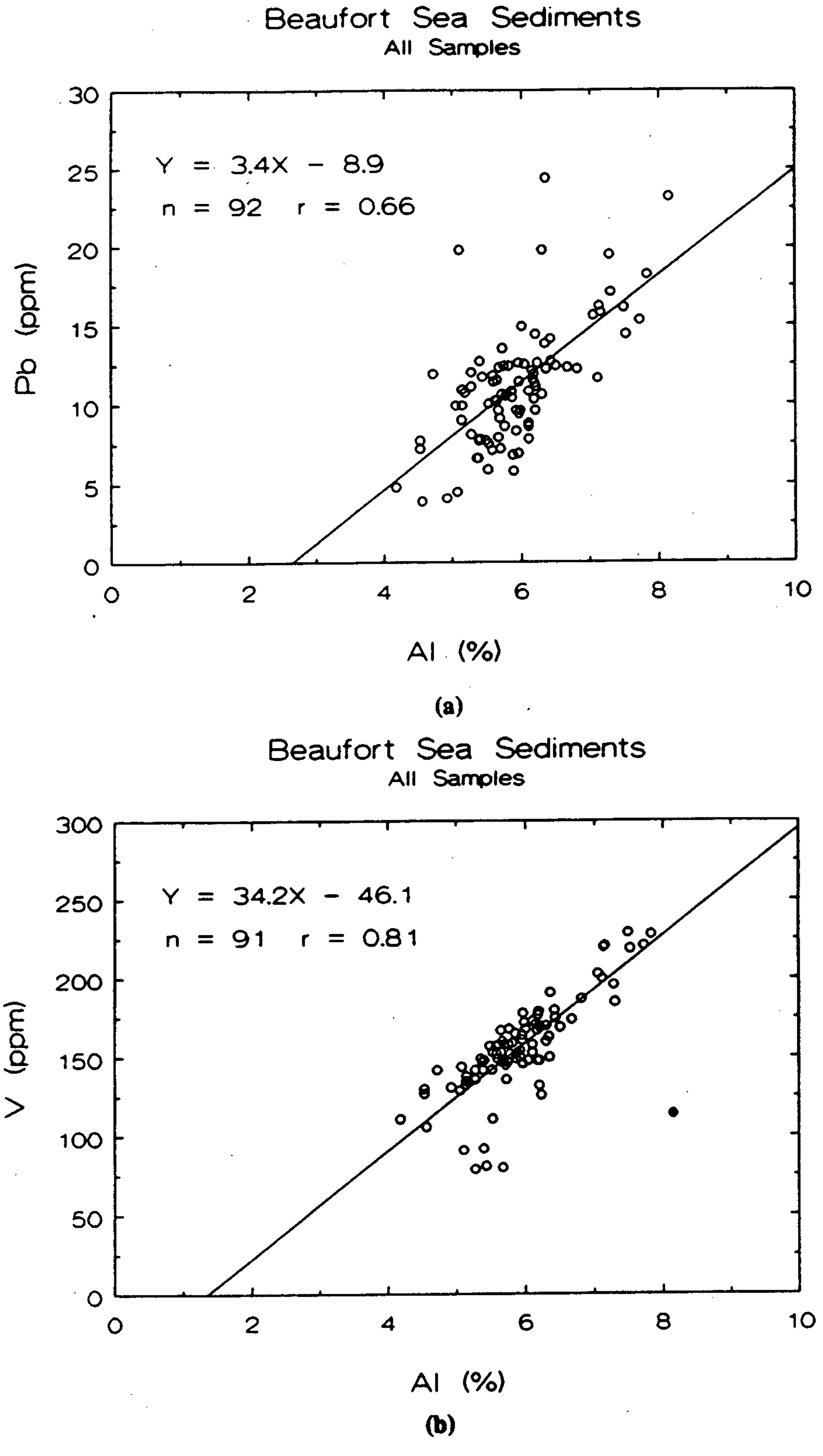


Figure 5.7 Scatter Plot Showing (a) Pb Versus Al (b) V Versus Al. Solid Circles indicate ratio values that are outliers by more than 2 Standard Deviations from the Mean Established in Table 5.3, and are not included in the Linear Regression.

Table 5.3 Metal to Aluminum Ratios for Beaufort Sea Sediments[1]

Sample	Fe/Al	Ba/Al	Cd/Al	Cr/Al	Cu/Al	Pb/Al	V/Al	Zn/Al
		Values x 10,000						
Beaufort Sea - 1989 - Fine Fraction								
Grand Mean (± S.D)	0.572 (0.043)	110 (19)	0.027 (0.010)	16.3 (4.1)	4.0 (0.4)	1.9 (0.5)	26.1 (3.5)	18.5 (2.4)
Station 2D			0.050					
Station 2E			0.053	24.8				
Station 5D			0.048					
Station 7A		193		38.4				
Station 7G		205		35.1				
Station 8C	0.745							25.7
Average Continental Crust	0.500	61	0.013	12.2	6.1	1.7	19.5	9.1

[1] Values shown are for samples with metal to aluminum ratios that exceed natural levels. Where data are not included, the ratios are within normal limits.

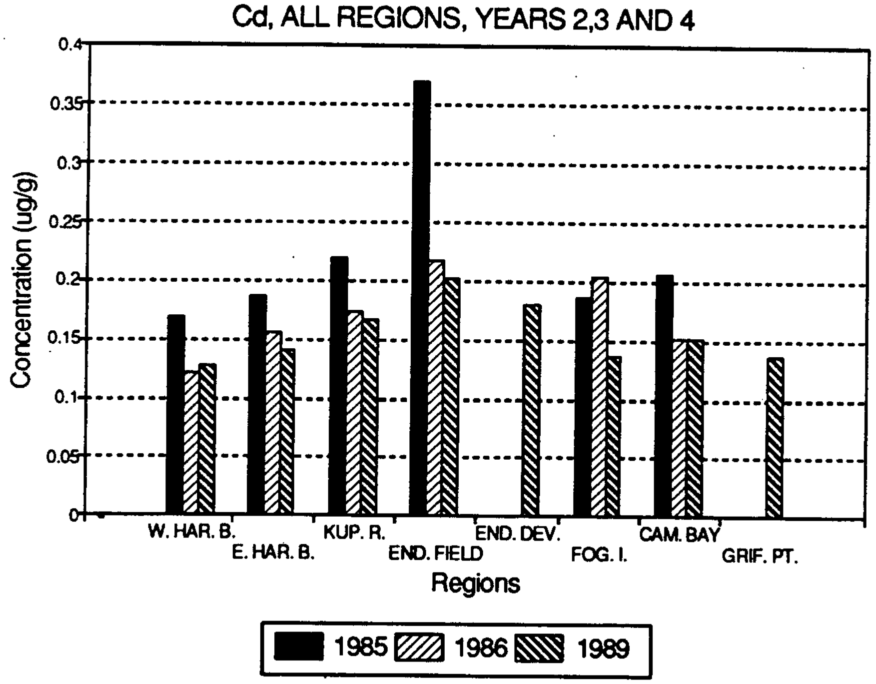
1984 - 1986 study were in close agreement with those for the 1989 samples (Figures 5.8 and 5.9). For example, the means generally agreed within 10 ppm for Cr and Zn, 5 ppm for Cu and Pb and 0.05 ppm for Cd. Considering the analytical precision and the standard deviations for a given metal in a specific region, no distinct differences of consequence was observed. However, systematically higher values for Ba (+200 ppm) and V (+20-40 ppm) were observed for 1989 relative to 1987 (Figure 5.10). The Ba offset was previously discussed in Section 4.4.1.1 and is believed to be related to an instrumental difference in the use of ICP in 1986-1987. Sieving, digesting and other possible explanations previously described in section 4.4.1.1 may have also influenced the Ba offset as well as the slightly higher V levels.

5.2.4 Metals in Tissues. Metal concentrations are now available for 1985, 1986, and 1989 (years 2, 3 and 4) for several clam species and the amphipod Anonyx from a limited number of sites. Data for clam Astarte for 1989 showed relatively uniform trends from site to site as shown by the relatively small standard deviation in Table 5.4. Furthermore the 1989 means and standard deviations were in good agreement with those for the 1986-1987 data (Table 5.4). Metal concentrations for organisms in the 1986-1987 data set were originally reported as ppm (wet weight) when the values were actually calculated as ppm (dry weight). The earlier data sets (Boehm et al., 1987) should be re-labelled to show this discrepancy. When mean concentrations for metals in Astarte in the 1986-1987 data set were compared with those for 1989 (by the correct wet or dry weight), the agreement was excellent (Table 5.4).

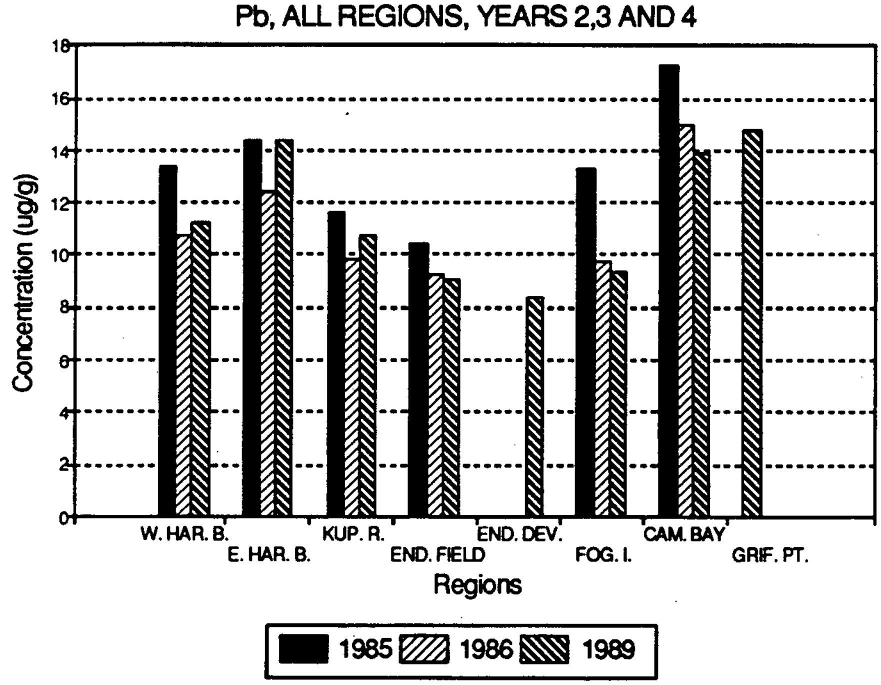
No significant regional trends were observed for Ba, Cr, Cu, Pb, V or Zn in the 1989 data set for Astarte. A slightly higher Ba value was observed at station 6D and a higher Pb level was observed at station 1B. The Cd values followed a trend of lowest levels at stations 3A and 5(1), medium values at stations 5H and 6D, and higher concentrations at stations 1A and 1B. This same general trend was found in the 1986-1987 data. Although no definitive reason for this trend is available, it may be related to a greater natural availability of Cd at sites away from the river deltas where the particle-bound fraction of the total Cd decreases.

The clam Cyrtodaria was collected from stations 5F and 6G in 1989 and no significant differences were observed between two sites. Furthermore, the data for Cyrtodaria from 1986-1987 compared very well with the 1989 data (Table 5.4). Thus, no spatial or regional trends were identified and there is good data base for future comparisons.

Concentrations of all metals in the clams Portlandia were similar at station 1A relative to 9B with no significant differences. However, the 1989 data for Portlandia at station 1A was consistently lower than observed in 1986-1987. No clear explanation could be made for this difference and at present there is not a large enough data base to establish the natural variation in metal concentrations for this organism.



(a)



(b)

Figure 5.8 Regional Mean Concentrations in Sediment Fine Fraction of (a) Cd and (b) Pb for Years 2, 3 and 4.
(See Figure 5.1 for the Legend pertaining to the Regions).

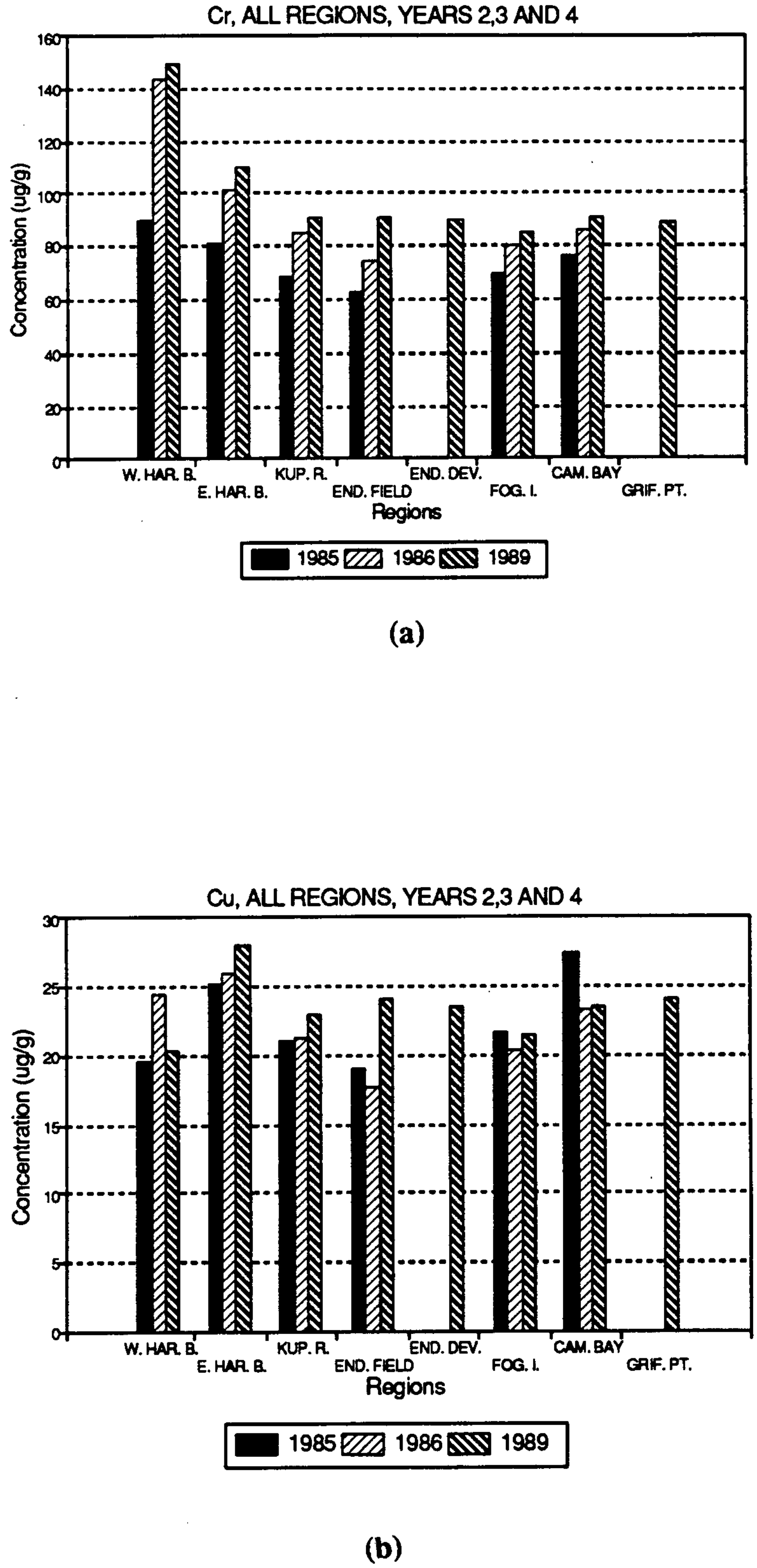
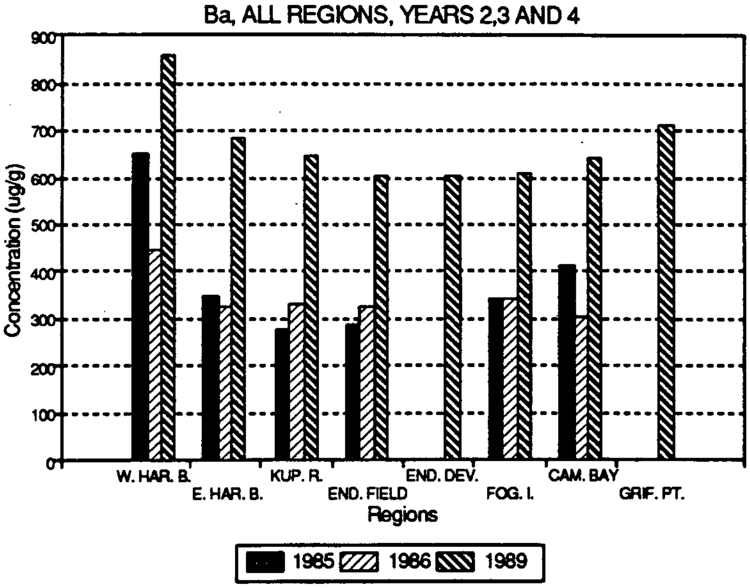
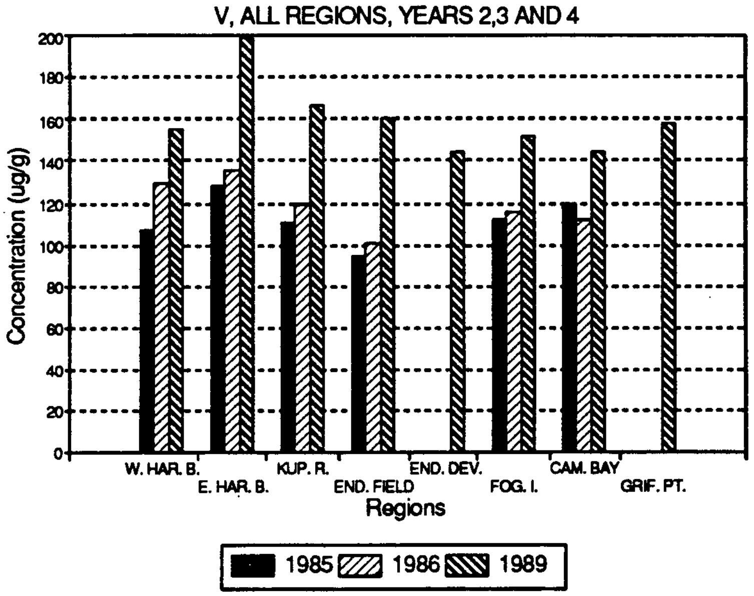


Figure 5.9 Regional Mean Concentrations in Sediment Fine Fraction of (a) Cr and (b) Cu for Years 2, 3 and 4.
(See Figure 5.1 for the Legend pertaining to the Regions).



(a)



(b)

Figure 5.10 **Regional Mean Concentrations in Sediment Fine Fraction of (a) Ba and (b) V for Years 2, 3 and 4. (See Figure 5.1 for the Legend pertaining to the Regions).**

Table 5.4 Comparison of Metal Concentrations for Beaufort Sea Organisms, 1986-1987 versus 1989

Study Period		Ba	Cd	Cr	Cu	Pb	V	Zn
		(Concentrations in ppm, dry weight)[1]						
Astarte (clams)								
1986-1987	Mean	21	14	2.6	15	0.5	3.9	81
	±SD	(6)	(7)	(0.6)	(5)	(0.4)	(2.5)	(13)
1989		22	13	1.8	17	0.6	3.6	90
		(11)	(10)	(0.5)	(6)	(0.3)	(1.2)	(10)
Cyrtodaria (clams)								
1986-1987		26	1.4	2.6	22	0.6	6.0	75
1989		32	2.8	3.0	21	0.6	7.6	80
Portlandia (clams)								
1986-1987 (1A)		98	12	12	35	5.6	23	179
1989 (1A)		54	6	8	16	2.3	13	148
Macoma (clams)								
1986-1987 (6D)		117	5	9	25	3.1	21	168
1989 (6D)		80	6	9	28	1.0	19	204
Anonyx (amphipods)								
1986-1987	Mean	37	0.8	1.7	106	<D.L.	1.6	107
	±SD	(15)	(0.4)	(1.0)	(32)		(1.4)	(24)
1989	Mean	42	2.1	1.0	104	0.41	3.3	109
	±SD	(20)	(1.2)	(0.4)	(24)	(0.08)	(1.0)	(48)

[1] Numbers in parentheses are ± 1 standard deviation from the mean concentrations.

Amphipods (Anonyx) were collected from 7 sites during the 1989 sampling and the means for 1989 compared well with those for 1986-1987. Thus, overall a database has been developed with relatively good continuity to establish a usable baseline for the future.

5.3 Hydrocarbon Chemistry

5.3.1 Framework for Interpretation. In previous reports from the BSMP, it has been concluded that the sediments from this area differ from OCS sediments in both hydrocarbon content and composition, in that they contain significant background concentrations of both biogenic and fossil fuel derived hydrocarbons. The major sources of these hydrocarbons are the rivers which empty into the Beaufort Sea, through a terrain which is mostly tundra, and has coal and shale outcrops as well as natural petroleum seeps (Boehm et al., 1987). These rivers, and especially the Colville River, are important contributors of sediment to the study area. Erosion of the coastline and river banks contribute to offshore sediment loadings as well. With the significant natural background hydrocarbon concentration, it may be difficult to detect, using conventional techniques, small inputs of petroleum resulting from drilling and exploration. In such a situation, specific diagnostic saturated and aromatic hydrocarbon ratios can aid in the evaluation of change due to drilling activity in an environmental monitoring program.

Table 5.5 lists the key diagnostic source ratios and parameters used for saturated hydrocarbons. The ratio of the lower-molecular-weight hydrocarbons (nC10-nC20, LALK) to the total alkanes (nC10-nC34, TALK) is a measure of the amount of petroleum derived alkanes present in the sediments. This ratio ranges between 0.01 and 0.1 in pristine sediments, and approaches 1 as the concentration of LALKs increase, due to petroleum inputs characteristic of North Slope crudes. In Beaufort Sea sediments, this ratio ranged from 0.14 to 0.36 and had a fairly constant mean value of approximately 0.17 in all regions (Boehm et al., 1987). The ratio of the isoprenoid hydrocarbons pristane to phytane is an important diagnostic parameter. Pristane, a chlorophyll degradation product, is found in petroleum and other biogenic sources, whereas phytane is found mainly in oil. Sediments from this region had values that ranged between 1.5 and 2.8. Boehm et al., (1987) suggested that episodic inputs of peat were the cause of the high ratios, and downstream transport of petroleum-derived compounds as causing the low end of the ratio.

Table 5.6 presents the key diagnostic ratios for aromatic hydrocarbons. These include phenanthrenes/dibenzothiophenes (P/D), naphthalenes/phenanthrenes (N/P) and the fossil fuel pollution index (FFPI). Sulfur heterocyclic compounds, such as dibenzothiophenes, are a prominent component of many oils, including Prudhoe Bay crude oil, while phenanthrenes have mixed digenetic, petrogenic and pyrogenic sources. Increasing inputs of oil cause an increase in D relative to P until the ratio approaches the value of the oil, which for Prudhoe Bay crude is 1.1. "Typical clean"

TABLE 5.5 Diagnostic Ratios and Parameters of Saturated Hydrocarbons[a,b]

Parameter/Ratio	Relevance in Environmental Samples
ISO/ALK	Measures the relative abundance of branched isoprenoid alkanes to straight-chain alkanes in the same boiling range; useful indicator of biodegradation.
LALK/TALK	Diagnostic alkane compositional ratio used to determine the relative abundance of lower molecular weight alkanes to total alkanes which includes those of biogenic origin.
PRIS/PHY	Source of phytane is mainly petroleum, whereas pristane is derived from both biological matter and oil. In "clean" environmental samples, this ratio is very high and decreases as oil is added.
OEPI	Odd-even carbon preference index. Describes the relative amounts of odd-and even-chain alkanes within a specific boiling range. As oil additions increase the OEPI is lowered.
TOT	Total saturated hydrocarbons (resolved plus unresolved).

[a] TALK = Sum of the total n-alkanes (n-C_{10} to n-C_{34}).
LALK = Sum of low molecular weight n-alkanes (n-C_{10} to n-C_{20}).
PRIS = A C_{19} isoprenoid (pristane) with a relative retention index (RRI) of 1708.
PHY = A C_{20} isoprenoid (phytane) with a RRI of 1810.

[b] Adopted from Boehm et al. (1987)

TABLE 5.6 Diagnostic Parameters and Ratios of PAHs[a]

Parameter/ Ratio	Relevance in Environmental Samples
P/D	The ratio of the 3-ring phenanthrenes/anthracenes (P) to the sulfur-containing dibenzothiophenes (D) is useful for determining the relative contribution of petrogenic and pyrogenic hydrocarbons and in differentiating petroleum sources.
P/C	The phenanthrenes/anthracenes (P) to chrysenes (C) ratio is another useful diagnostic parameter used to diagnose the source of hydrocarbons in environmental samples.
N/P	The naphthalenes (N) to phenanthrenes/anthracenes (P) ratio is particularly diagnostic for inputs of fresh petroleum. Although phenanthrenes/anthracenes may be of pyrogenic, petrogenic, or diagenic origin in environmental samples, naphthalenes are characteristic of fresh crude oil
C1P/C1D	Ratios of individual phenanthrene (P) and dibenzothiophene (D) homologues are very useful in source matchings.
Alkyl Homologue Distributions (AHDs)	Graphical presentation of the 2- and 3-ring aromatics showing the relative quantities of the unsubstituted parent compound and the alkyl-substituted homologues in each series. AHDs are used to show the relative importance of pyrogenic and petrogenic PAH sources. Combustion sources are generally characterized by a greater abundance of the parent compounds relative to the substituted compounds. Petroleum sources have a greater quantity of the alkyl homologues relative to the parent aromatic compound.
ΣPAH	The sum of 2- to 5- ring polynuclear aromatic hydrocarbons (N + F + P + D + 4,5-PAH). In conjunction with the 4,5-PAH parameter, ΣPAH can be used to determine relative contributions of pyrogenic and petrogenic sources.
FFPI[b]	Fossil Fuel Pollution Index; ratio of fossil fuel-derived PAHs to total (fossil + pyrogenic + diagenic) PAHs. FFPI for fossil PAHs approaches 1.0; FFPI for combustion PAHs approaches 0.

[a] N = Naphthalene Series (C0P + C1N + C2N + C3N + C4N).
F = Fluorene Series (C0F + C1F + C2F + C3F).
P = Phenanthrene/Anthracene Series (C0P/A + C1P/A + C2P/A + C3P/A + C4P/A).
D = Dibenzothiophene Series (C0D + C1D + C2D + C3D).
C = Chrysene Series (C0C + C1C + C2C + C3C + C4C).
4,5-PAH = 4- and 5-ring polynuclear aromatic hydrocarbons (FLAN/PYEN (and alkyl homologues) + BAA + CHRY (and alkyl homologues) + BFA + BAP = BEP + PERY); origin is usually pyrogenic (combustion of fossil fuel and wood fuels). Adapted from Boehm et al. (1987); Boehm and Farrington (1984).

[b] FFPI = (N + F + P + D)/ΣPAH.

OCS sediments have P/D ratio values that range from 10 to 100 or higher (Steinhauer and Boehm, 1989). Naphthalenes are abundant in unweathered crude oil and are found in low concentrations in pristine sediments. Thus the ratio of N/P has values between 0.2 and 1.5 in pristine sediments and a value of 4.0 for Prudhoe Bay crude oil. Boehm et al., 1987 found average values of P/D to range between 4 and 12 and average N/P values between 0.5 and 2.5 in offshore Beaufort Sea sediments. The fossil fuel pollution index (Boehm and Farrington, 1984) was designed to determine the relative percentage of fossil-fuel-derived PAHs relative to total PAHs. The equation is presented in Table 5.6. Combustion-derived PAH assemblages contain high concentrations of three-to-five ring compounds whereas fossil fuels are enriched in two-to-three ring PAH compounds, as well as polynuclear organo-sulfur compounds (e.g., the dibenzothiophene series). This ratio ranges between 100 for fossil fuel PAHs to close to 0 for combustion-derived PAHs. Boehm et al., 1987 found values between 75 and 92, which indicated a predominance of the fossil fuel compounds in these sediments. Alternatively, the ratio of 2,3 ring PAH compounds to 4,5 ring PAH compounds is used to assess PAH composition and evaluate sources.

5.3.2 Saturated Hydrocarbons in Sediments. In general, little change was seen in the concentrations of saturated hydrocarbons or their composition in sediments collected from the 1989 survey, compared with the 1984 - 1986 results. Previous work (Boehm et al.,1987) reported concentrations for total saturates (TOT) of 2 µg/g to 52 µg/g throughout the study area. The area of the highest concentration was reported to be the East Harrison Bay area (mean TOT = 30.2 µg/g, which was shown to be strongly influenced by discharge from the Colville River (Figure 5.11). The Kuparuk River and West Harrison Bay regions also had high TOT concentrations due to discharges from the Kuparuk and Colville Rivers. The effects of riverine discharge, combined with physical factors such as currents and tides cause these regions to be enriched in fine grained material, relative to the other regions. The 1989 survey showed similar relative results, with East Harrison Bay having a mean TOT concentration of 8.8 µg/g (Figure 5.12). However, the overall range of the saturates was less and the absolute concentrations lower in 1989 sediments. However, when concentration differences were factored out by normalizing TOT to TOC, the pattern of regional abundances of TOT over the four years was very similar, indicating that the differences observed between regions in 1989 may be related to the TOC content of the sediments (Figure 5.13 a). Figure 5.12 shows that the greatest abundances of TOT found in 1989 were in the aforementioned regions (3,4 and 5) that were influenced by riverine discharge. These discharges vary seasonally and yearly. Normalizing hydrocarbon concentrations to factors such as total organic carbon (TOC) and % silt + clay size fraction (% fines) are two ways to factor out natural, temporal and spatial differences in the depositional environment of an area, and emphasize the source inputs. Normalizing the average regional TOT concentrations to TOC and % fines had little effect on reducing variability between regions, but resulted in interesting changes in the relative geochemistries of the

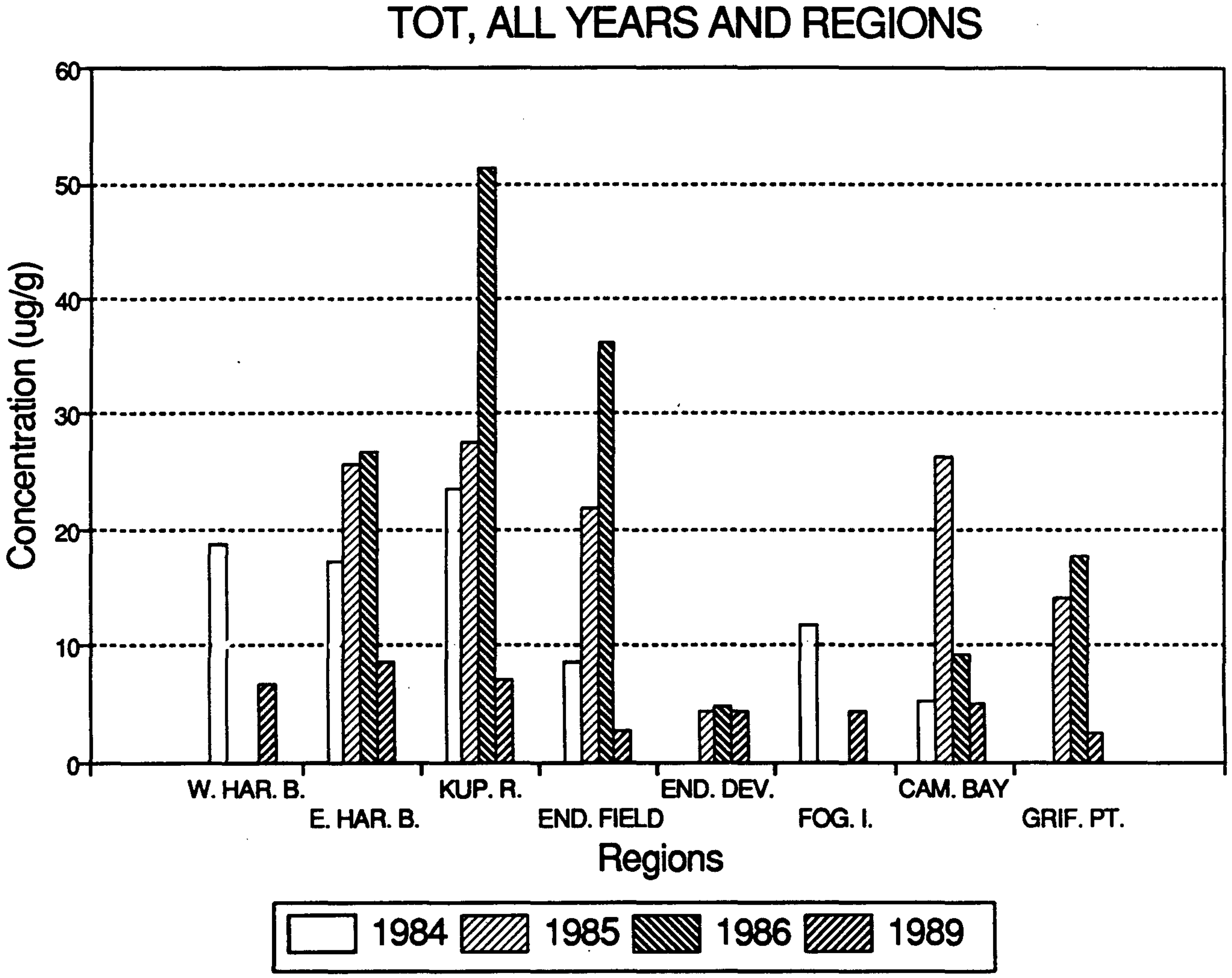


Figure 5.11 Mean Concentrations of the Total Saturated Hydrocarbons (TOT) in Sediments for all Four Years in all Study Regions. (See Figure 5.1 for the Legend pertaining to the Regions).

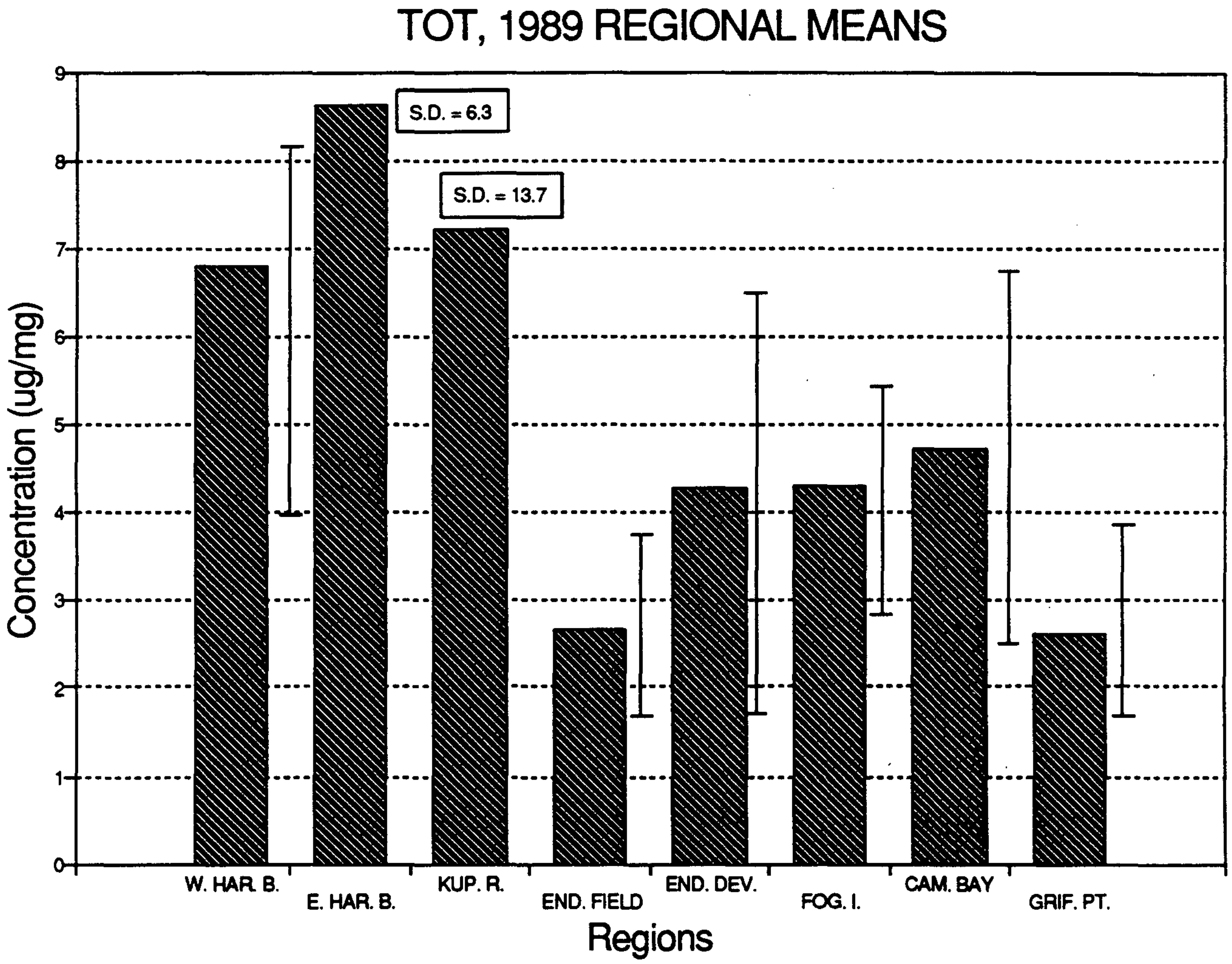


Figure 5.12 Regional Mean Concentrations of Total Saturated Hydrocarbons (TOT) in Sediments for all Regions in 1989. Error Bars Represent the Standard Deviation (± .5 SD).
(See Figure 5.1 for the Legend pertaining to the Regions).

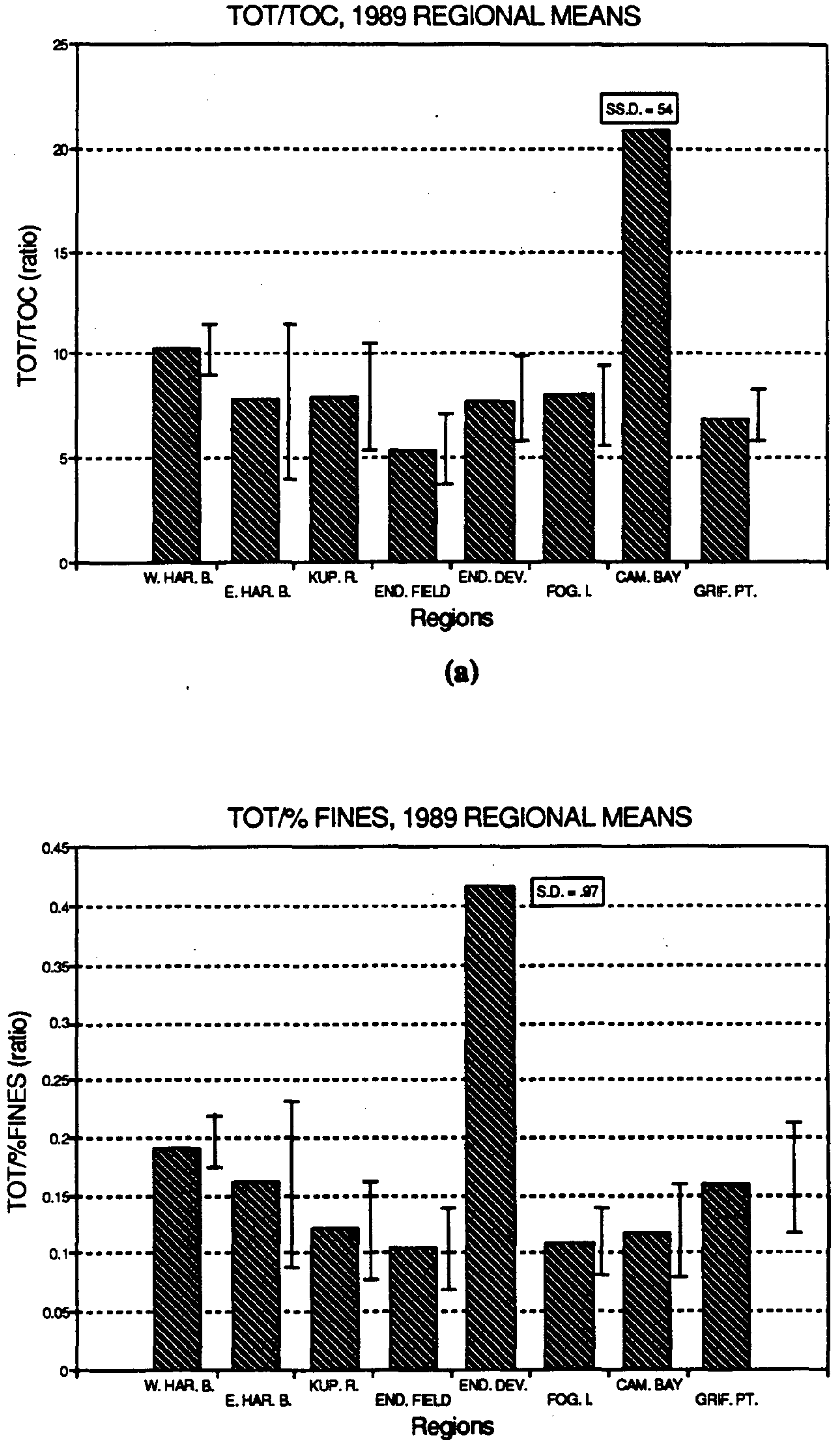


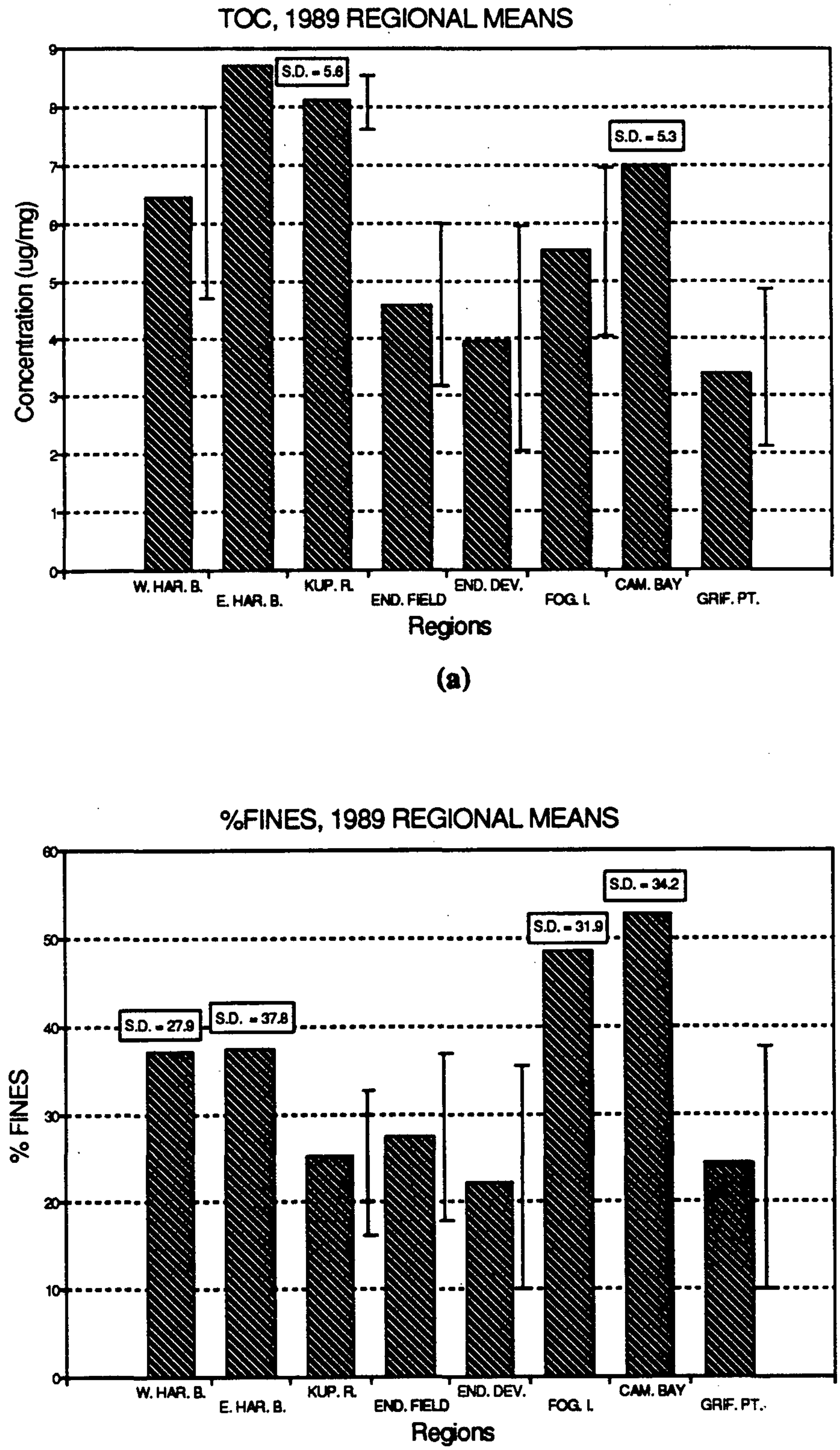
Figure 5.13 Mean Concentrations of Total Saturated Hydrocarbons (TOT) Normalized to (a) Total Organic Carbon (TOC) and (b) % Fines in Sediments for all Regions in 1989. Error Bars Represent the Standard Deviation (± .5 SD). (See Figure 5.1 for the Legend pertaining to the Regions).

Camden Bay and the Endicott Development regions. Normalized TOT values were two to four times higher in these regions than in the other regions (Figure 5.13 a,b). To better understand what these normalized parameters signify, it is best to examine them in conjunction with the actual measurements (Figure 5.14 a,b). The fact that Camden Bay had a high value of TOT/TOC, along with relatively no significant TOC enrichment (Figure 5.14 a) suggests that there may be a source related TOT input to this region. One potential source to the Camden Bay region is the spill of Crowley Maritime's barge No. 570, which spilled an estimated 68,000 gallons of light heating oil off of Flaxman Island at the edge of Region 1 (Figure 2.1) on August 20, 1988 (UPI release August 22, 1988). This is not believed to be a significant source of hydrocarbons to region 1 sediments, based on the SHC and PAH diagnostic ratios, discussed below and in section 5.5.3. At Endicott Development Island (Region 8), the high value of TOT/% fines along with the lower abundance of fines (and correspondingly higher abundances of coarser grained sands), meant that although absolute TOT concentrations were low, the fine material that was deposited in this region was enriched in TOT. High to moderate correlations were observed between TOT and TOC and TOT and % fines ($r = 0.75$ and 0.59, respectively), which were similar to values reported in Boehm et al., 1987.

While the concentrations of saturates varied markedly between stations and regions, the alkane composition of sediments was fairly consistent throughout the study area, a finding that was also described in the 1987 report. Histograms of alkane distributions from representative stations are presented in Figure 5.15. Alkane distributions were dominated by biogenic higher-molecular-weight alkanes (nC21-nC34), with a marked odd-even preference. Low-molecular-weight hydrocarbons (LALK) were present in most sediments at levels up to 20% of the total alkane (TALK) content. The ratio of LALK/TALK varied between 0.14 and 0.21 for all regions (Figure 5.16 a) and did not differ significantly from the other years (Figure 5.16 b), thus indicating no year-to-year change in saturated hydrocarbon composition. This is a very important finding and indicates again the diagnostic power of this ratio. The consistent LALK/TALK ratio indicates that no regions were affected by oil-related inputs from drilling activities. Similarly for the isoprenoids, the total concentration of the sum of the isoprenoid analytes (ISO) ranged from 0.05 to 0.45 µg/g. However, the iso/alk ratio and the pristane/phytane ratio were fairly constant throughout all of the study regions (Figure 5.17 a,b and 5.18 a,b).

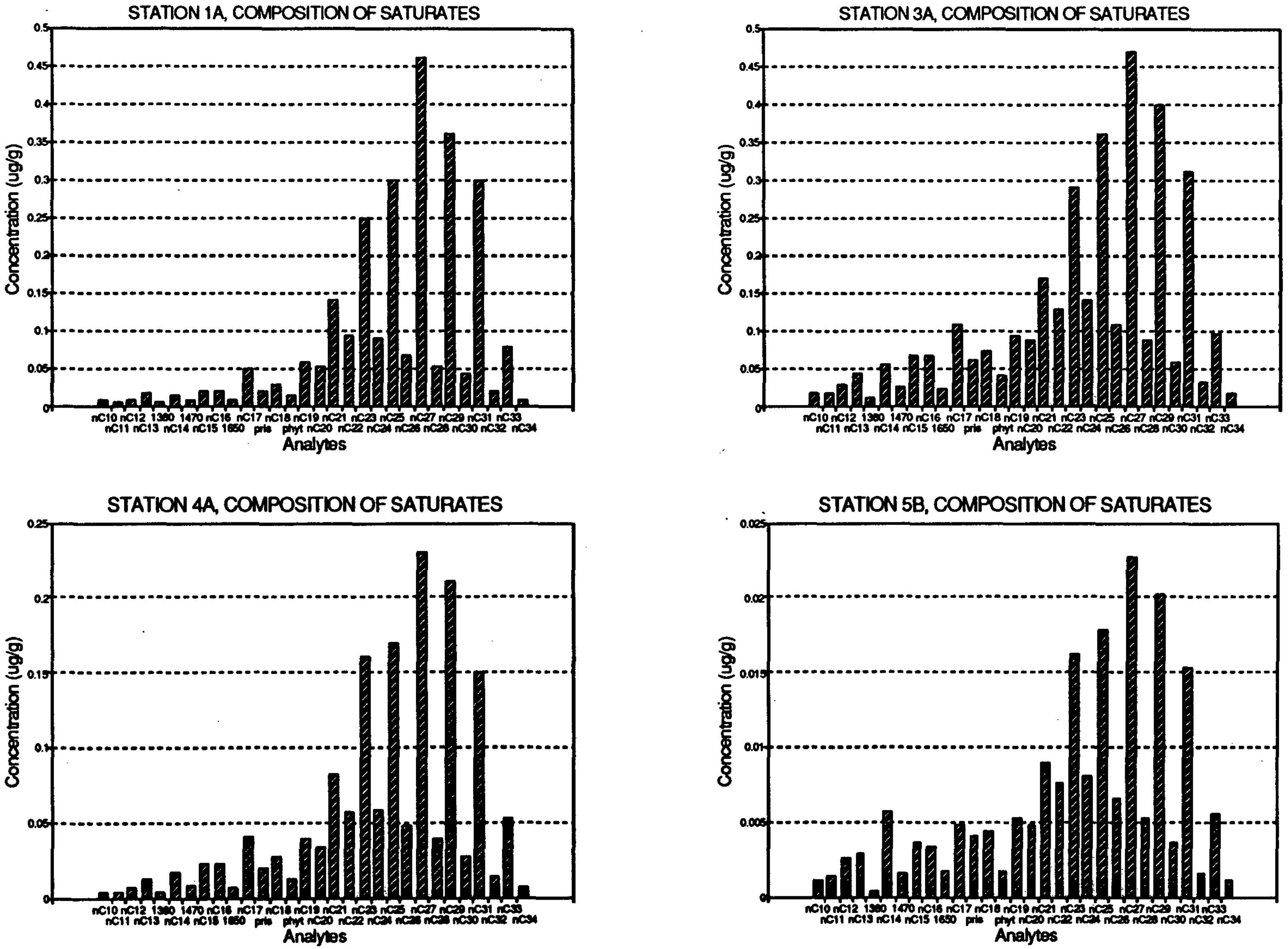
Griffin Point

Griffin Point (Region 7) contained hydrocarbon concentrations that were the lowest in the study area. This region had the lowest values of TOT, LALK and TALK of all of the study regions (Table 4.3 and figure 5.12). However, the sediment hydrocarbon composition was similar to that of the other regions. Station 9A had higher than normal concentrations of high molecular weight even chained alkanes, indicating a marked input of terrigenous biogenic material (Figure 5.19). An examination of



(b)

Figure 5.14 (a) Concentrations of Total Organic Carbon (TOC) in All of the 1989 Study Regions (b) Mean Concentrations of % Fines in All of the 1989 Study Regions. Error Bars Represent the Standard Deviation (± .5 SD). (See Figure 5.1 for the Legend pertaining to the Regions).


STATION 1A, COMPOSITION OF SATURATES

STATION 3A, COMPOSITION OF SATURATES

STATION 4A, COMPOSITION OF SATURATES

STATION 5B, COMPOSITION OF SATURATES

Figure 5.15 Composition of Saturated Hydrocarbons in Representative Sediment Samples for 1989 Beaufort Sea Stations.

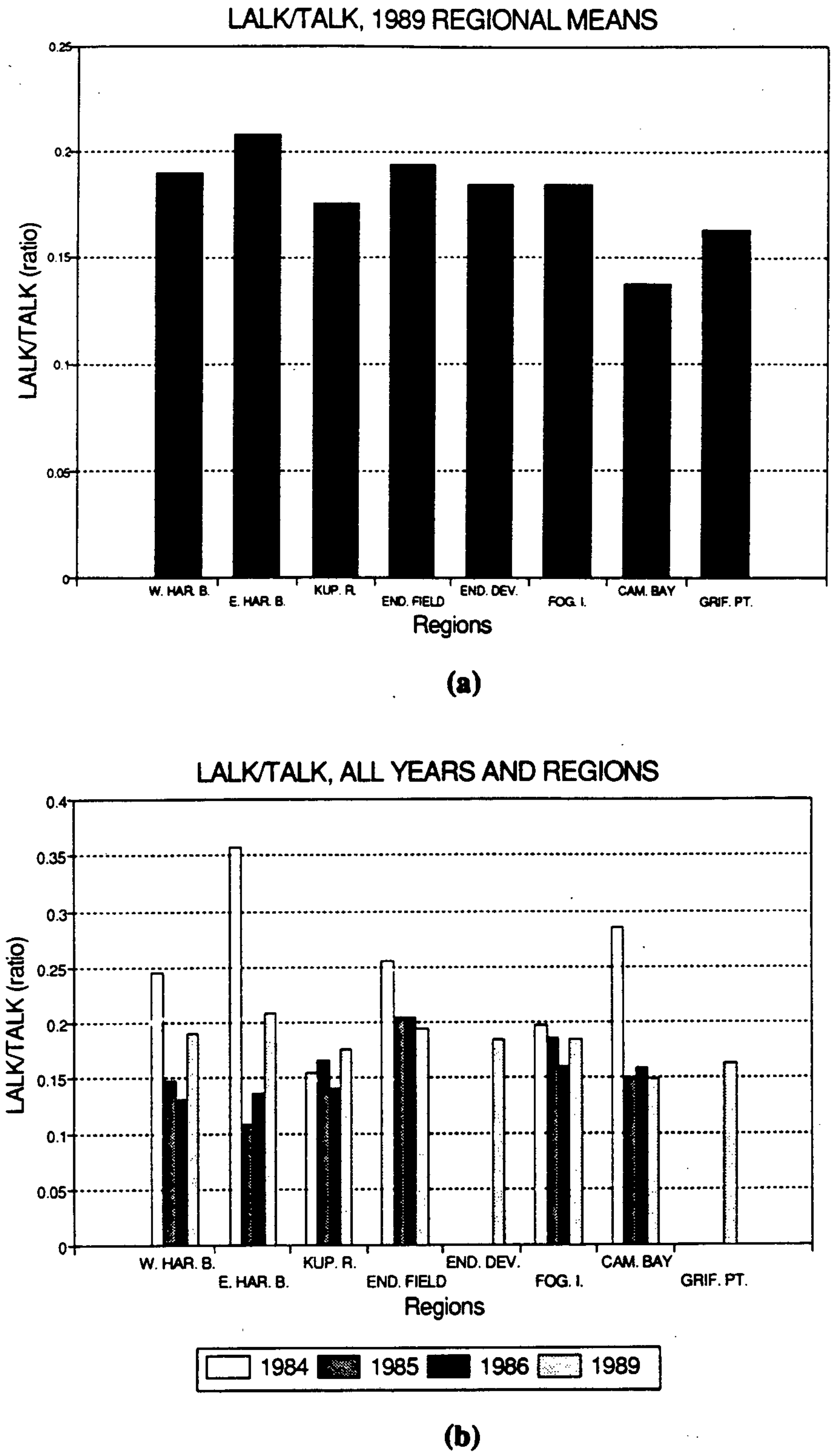


Figure 5.16 Mean Values of the Ratio of the Lower Molecular Weight Alkanes (LALK) to the Sum of all of the Normal Chain Alkanes (TALK).
(a) 1989 Regional Mean Values (b) Regional Mean Values for all Four Years.
The Value for Prudhoe Bay Crude Oil is 0.68.
(See Figure 5.1 for the Legend pertaining to the Regions).

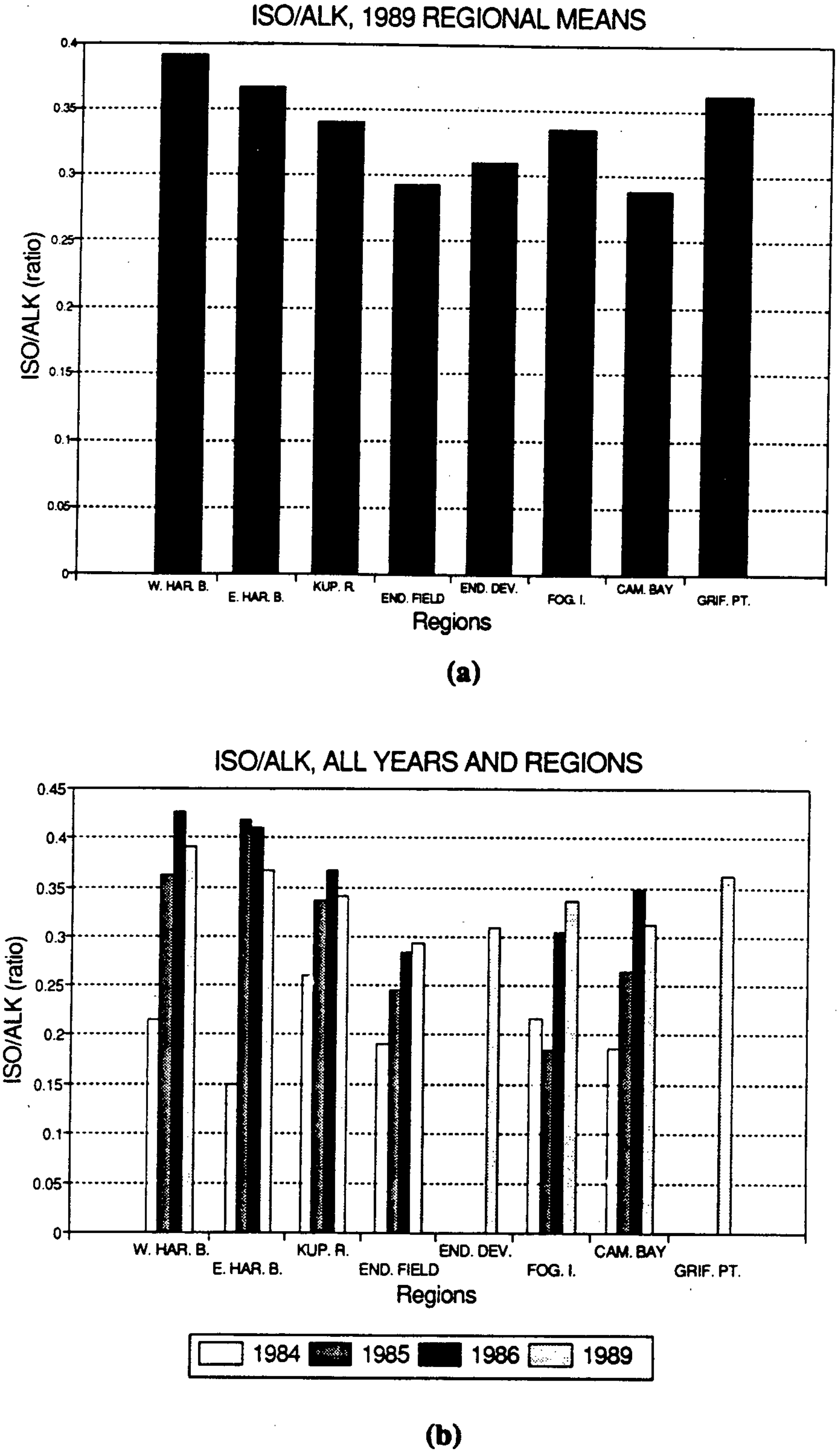
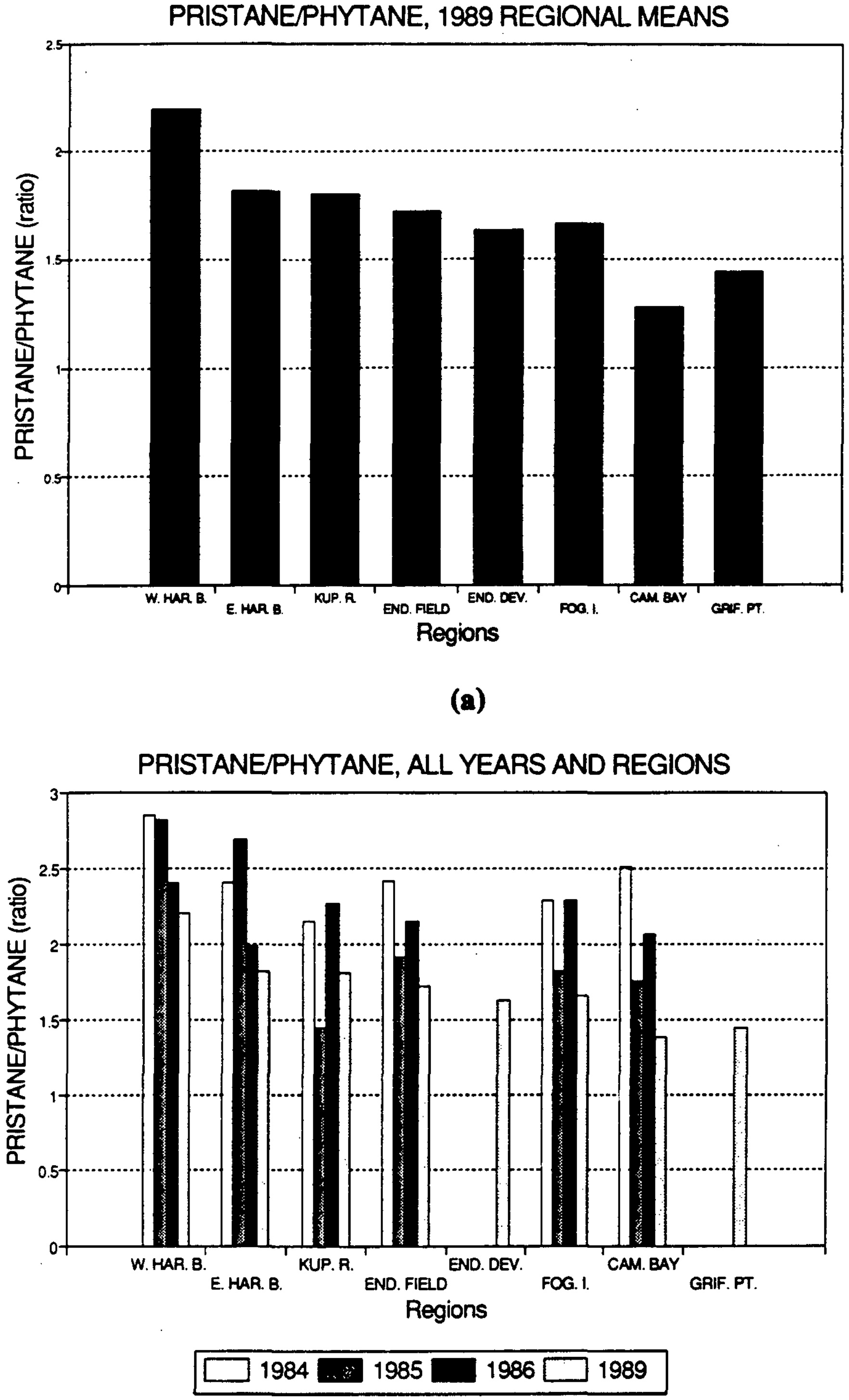


Figure 5.17 **Mean Values of the Ratio of Selected Isoprenoid Hydrocarbons (ISO) to Normal Chain Alkanes in the Same Boiling Range (ALK) in Sediments for all Regions.**
(a) 1989 Values (b) Mean Values for All Four Years of the Study.
(See Figure 5.1 for the Legend pertaining to the Regions).



(a)

(b)

Figure 5.18 **Mean Values of the Ratio of Pristine to Phytane (Pris/Phyt) in Sediments for all Regions (a) 1989 Values (b) Mean Values for all Four Years of the Study. (See Figure 5.1 for the Legend pertaining to the Regions).**

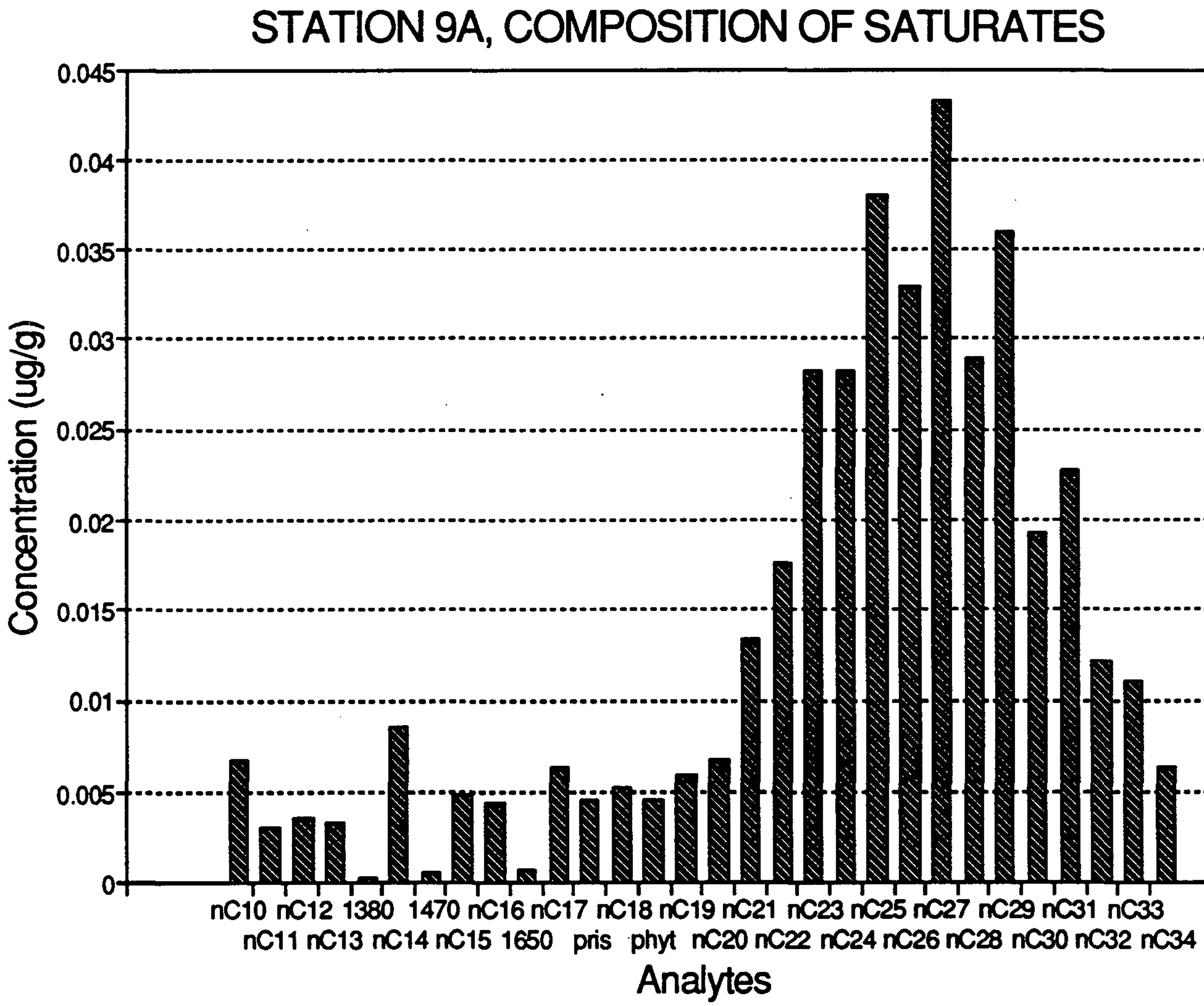


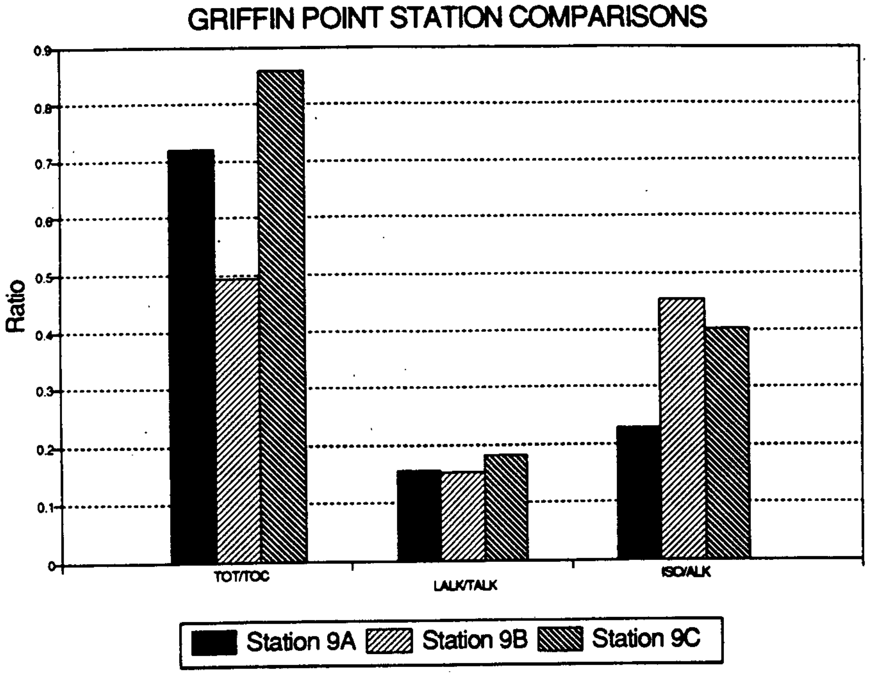
Figure 5.19 Mean Distribution of Saturated Hydrocarbons in Sediments From Station 9A, Griffin Point (Region 7).

diagnostic parameters revealed gradients in TOT, OEPI, % fines and TOC in this region (Figure 5.20 a). However, other diagnostic ratios such as LALK/TALK and pristane/phytane were similar between stations, indicating that offshore transport and deposition of biogenic material, was creating these differences (Figure 5.20 b). Sediments from station 9A were coarse, due in part to currents and ice scouring. Normalizing TOT to TOC successfully removed these depositional differences between the stations (Figure 5.20 b). This example demonstrates how differences in sediment hydrocarbon chemistry due to the inputs of petroleum can be separated out from natural geochemical processes.

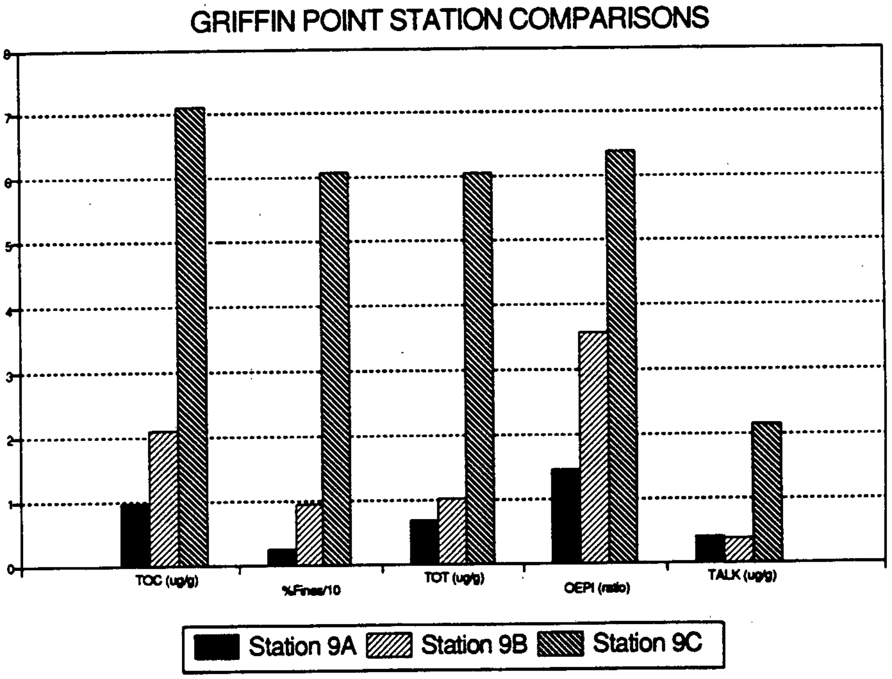
Endicott Development Island

In the Endicott Development Island Region (Region 8), the highest TOT concentrations were observed at stations 8E and 8A, which were situated to the north and northeast of the island (Figure 5.21). These stations also had the highest concentrations of TOC and fine material (Figure 5.22b). Variability in the depositional processes occurring at these stations could have been caused by the construction of the causeway, which can serve to entrain sediment, or create an artificial settling area on its eastern side (the main current flow is to the west). However, TOT concentrations remained high at these stations when TOT concentrations were normalized to TOC. Normalizing TOT to TOC also had the effect of elevating TOT concentrations at station 8F, which is in the same northeast quadrant, relative to the tip of the development island. Normalizing TOT concentrations to % fines had a dramatic effect on station 8C, making it stand out above all other stations (Figure 5.22a). This was due to the grain size composition of the sediment at this site, which was 98% sand (Table 4.5). No clear trend was seen with the LALK/TALK ratios to suggest petroleum inputs, although the pristane/phytane ratio for station 8D was noticeably lower than at other stations, and the LALK/TALK ratio was slightly higher at station 8C. Metals results (Figure 4.9) support the finding of no significant inputs at these stations.

5.3.3 Aromatic Hydrocarbons in Sediments. The concentrations of the sum of all aromatic hydrocarbons analytes (TOT PAH) from sediments collected in 1989 did not differ significantly from those sampled in previous years (Figure 5.23). The highest concentrations from 1989 were at the East Harrison Bay, West Harrison Bay and Kuparuk River areas (regions 4, 5 and 3 respectively, Figure 5.24). The sediments from these regions were also enriched in fines (Figure 5.14 b). As mentioned previously in section 5.3.2, year to year variability in hydrocarbon concentrations are largely due to differences in various transport processes such as riverine transport and shoreline erosion. When differences in depositional environments were factored out by normalizing sediment concentrations of TOT PAH to TOC and % fines, the regional differences decreased, but region 4 still had high concentrations of TOT PAH. This finding indicates that a strong source function (i.e, rivers) was responsible for the hydrocarbon input (Figure 5.25 a,b). It can be seen from Figures



(a)



(b)

Figure 5.20 (a,b) Station to Station Comparison of Various Parameters and Key Diagnostic Ratios in Sediments from Griffin Point (Region 7).

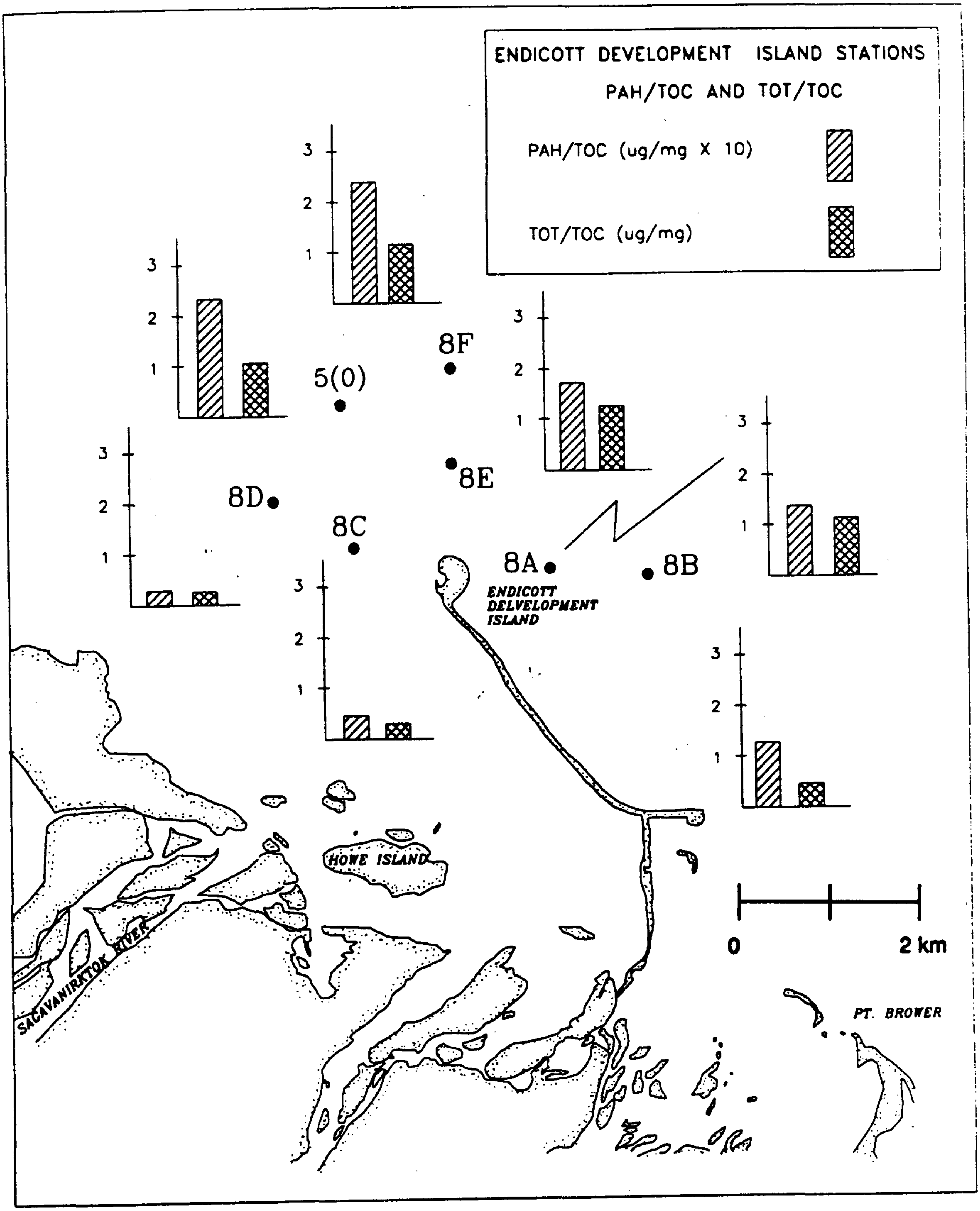
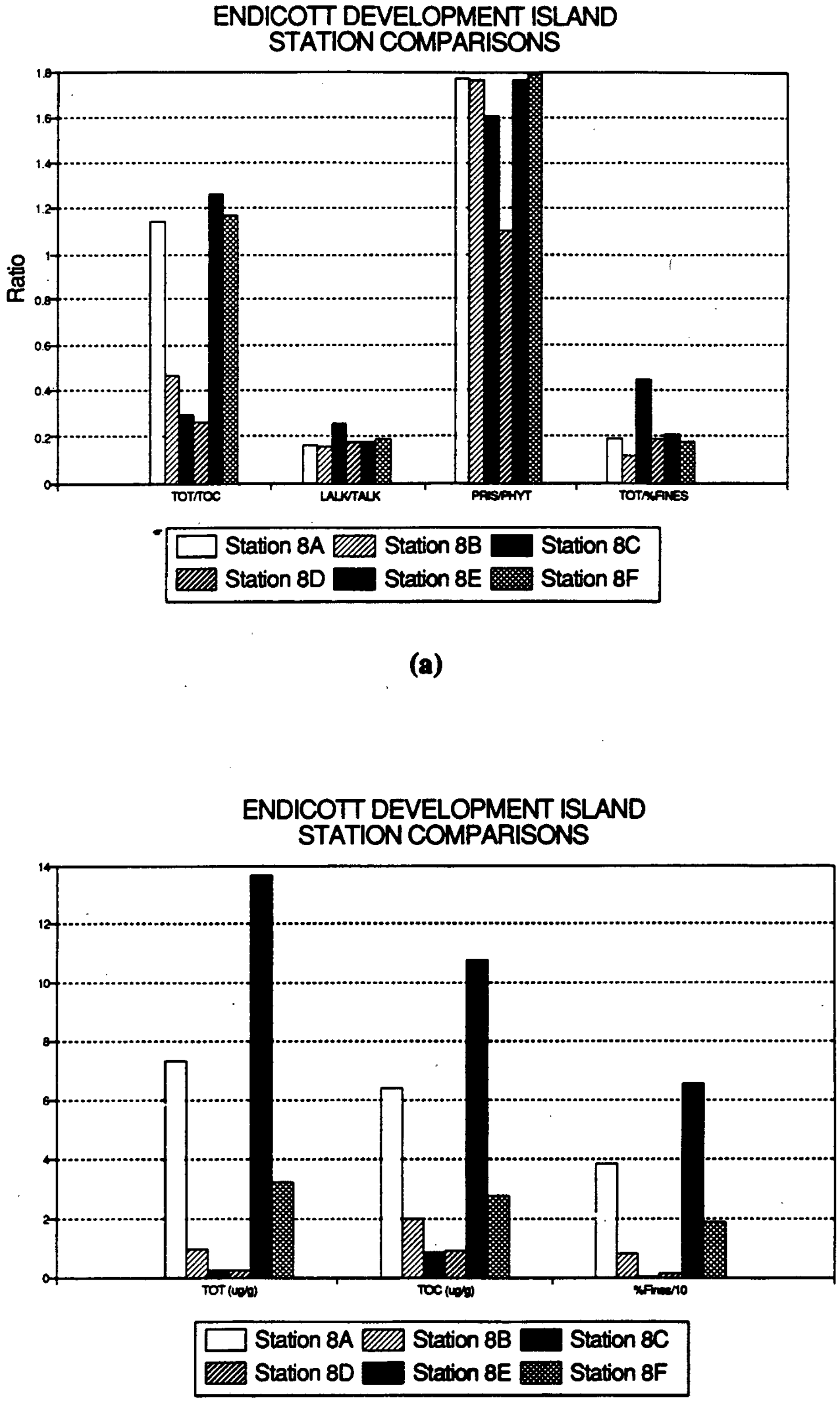


Figure 5.21 Station to Station Comparison of Total Saturated Hydrocarbons (TOT) and Total Aromatic Hydrocarbons (PAH) Normalized to Total Organic Carbon (TOC) in Sediments for Endicott Development Island.



(a)

(b)

Figure 5.22 (a,b) **Station to Station Comparison of Various Parameters and Key Diagnostic Ratios in Sediments from Endicott Development Island (Region 8).**

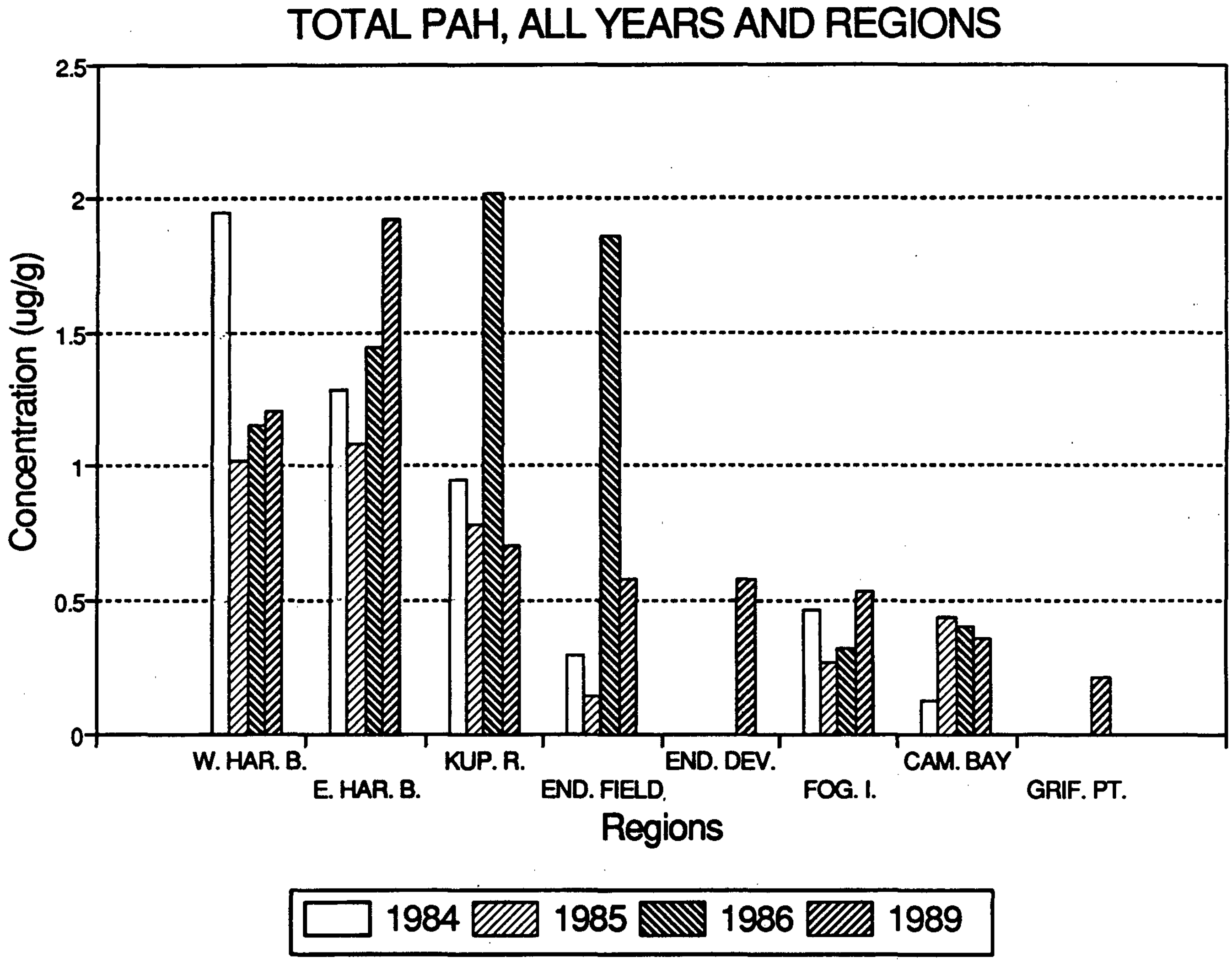


Figure 5.23 Mean Concentration of Total PAH in Sediments for All Four Years in All Study Region.
(See Figure 5.1 for the Legend pertaining to the Regions).

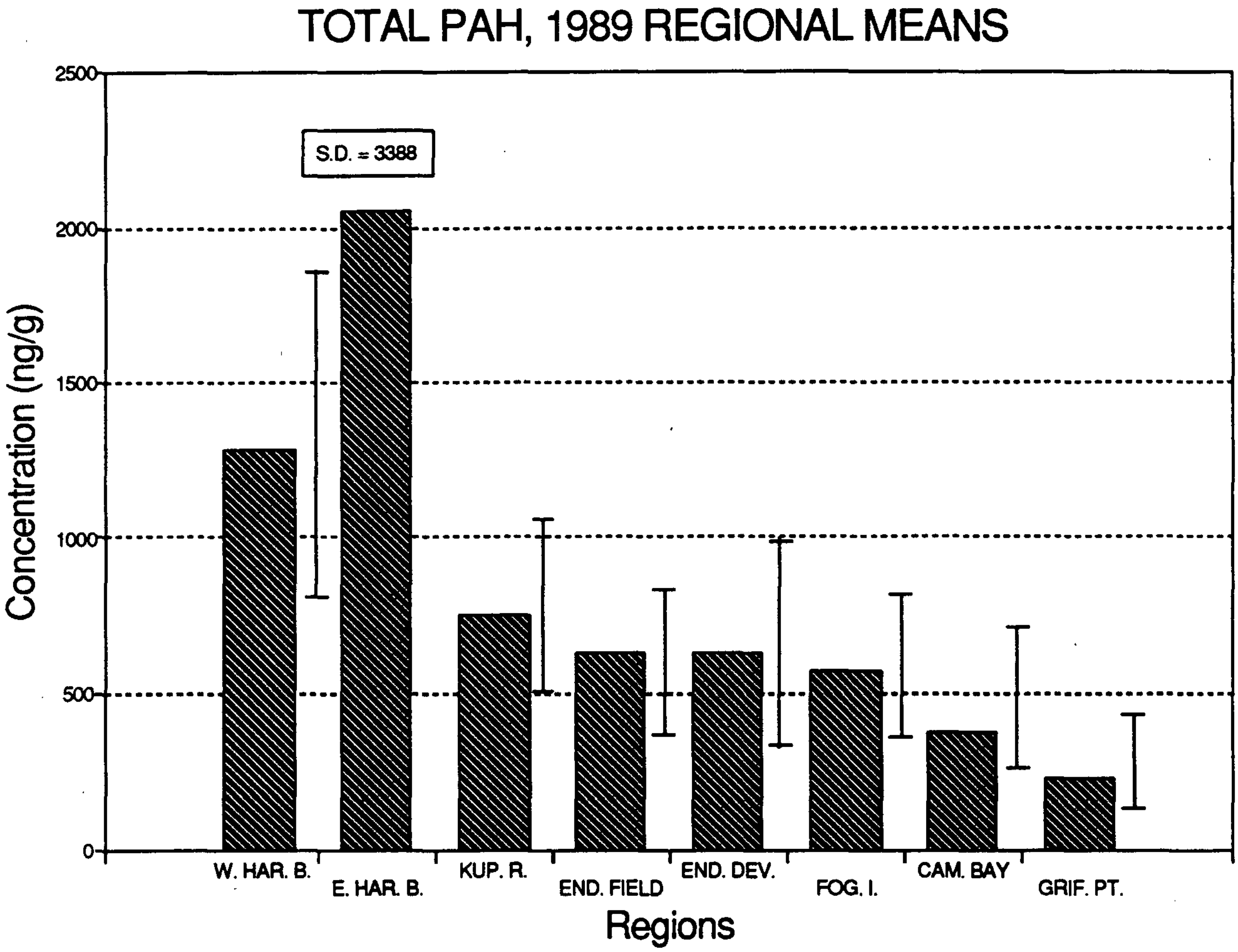
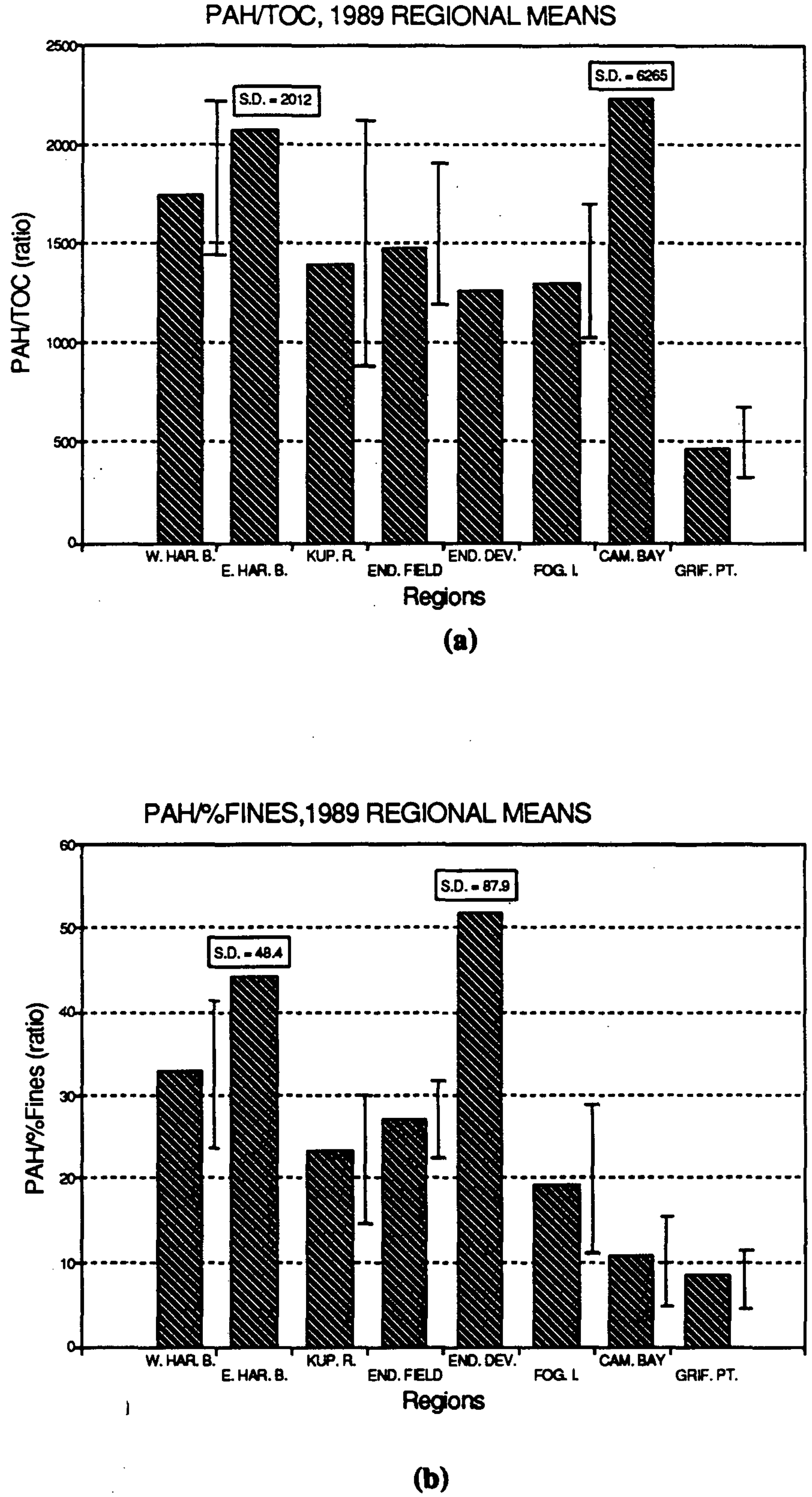


Figure 5.24 Mean Concentration of Total PAH for all regions in 1989. Error Bars Represent the Standard Deviation (± .5 SD). (See Figure 5.1 for the Legend pertaining to the Regions).



PAH/TOC, 1989 REGIONAL MEANS

(a)

PAH/%FINES,1989 REGIONAL MEANS

(b)

Figure 5.25 Mean Concentration of Total PAH Normalized to a) TOC and b) % Fines in Sediments for All Regions in 1989. Error Bars Represent the Standard Deviation (± .5 SD). (See Figure 5.1 for the Legend pertaining to the Regions).

5.25 a,b that regions 1 and 8 (Camden Bay and Endicott Development Island) became prominent, with normalized PAH concentrations, for the same reasons discussed in section 5.3.2. Once again, based upon the diagnostic ratios it does not appear that the oil spill mentioned in section 5.3.2 had a significant effect upon the sediment hydrocarbon chemistry in region 1. It should be noted that the variability between the stations of these regions is quite high (Figure 5.25 a,b). Figure 5.26 displays a significant correlation ($P > 0.05$) for a linear regression analysis between TOT and TOT PAH.

While there was variability between stations and regions in the concentration of PAHs, the composition of the sediments was fairly uniform in all regions. Regional mean concentrations of parent compounds and corresponding alkyl homologues are presented in Figure 5.27. Figure 5.28 presents regional mean concentrations of the sum of 2,3 ring PAH compounds and 4,5 ring PAH compounds. The PAH composition of Beaufort Sea sediments was characterized by a dominance of C2 and C3 alkyl homologue versus parent compounds (Figure 5.27 a-e) and a dominance of two and three ringed aromatic compounds (naphthalenes and phenanthrenes) over those with four and five rings (fluorenes, chrysenes, fluoranthenes and others Figure 5.28). The alkyl homologue distribution of Beaufort Sea sediments suggests petrogenic and diagenic source for the PAHs in this area with evidence of only low level pyrogenic inputs. One piece of evidence of pyrogenic input can be found upon closer examination of the alkyl homologue distribution of chrysene. Figure 5.29 shows the mean alkyl homologue distribution of the chrysenes, each expressed as a fraction of the most abundant homologue within each grouping. For comparative purposes, the alkyl homologue distribution of Prudhoe Bay Crude, analyzed in the Marine Sciences Organic Chemistry Laboratory is shown. It can be seen that the parent compound, (C0C) is more abundant in sediments relative to the Prudhoe Bay crude oil in all regions, suggesting pyrogenic input of chrysene. This is the first year that the alkyl homologue distribution of chrysene has been examined in the Beaufort Sea Monitoring Program. Boehm et al. (1987) had previously noted the lack of pyrogenically derived aromatic hydrocarbons in Beaufort Sea sediments, as being unique relative to other outer continental shelf (OCS) sediments, which are characterized by mixed pyrogenic and petrogenic sources. This still holds true, as evidenced by the preceding figures; The one four ring PAH compound found in abundance Beaufort Sea sediments is perylene, which is biogenic and/or diagenic in origin (Boehm et al, 1987).

The aromatic hydrocarbon composition of sediments from stations within each region showed these same characteristics. Alkyl homologue distributions for several representative stations from various regions are presented in Figure 5.30. That patterns of alkyl homologue averaged over an entire region are nearly identical to alkyl homologue patterns from individual stations within the regions (Figure 5.27) demonstrates the usefulness of the regional strategy in describing general trends.

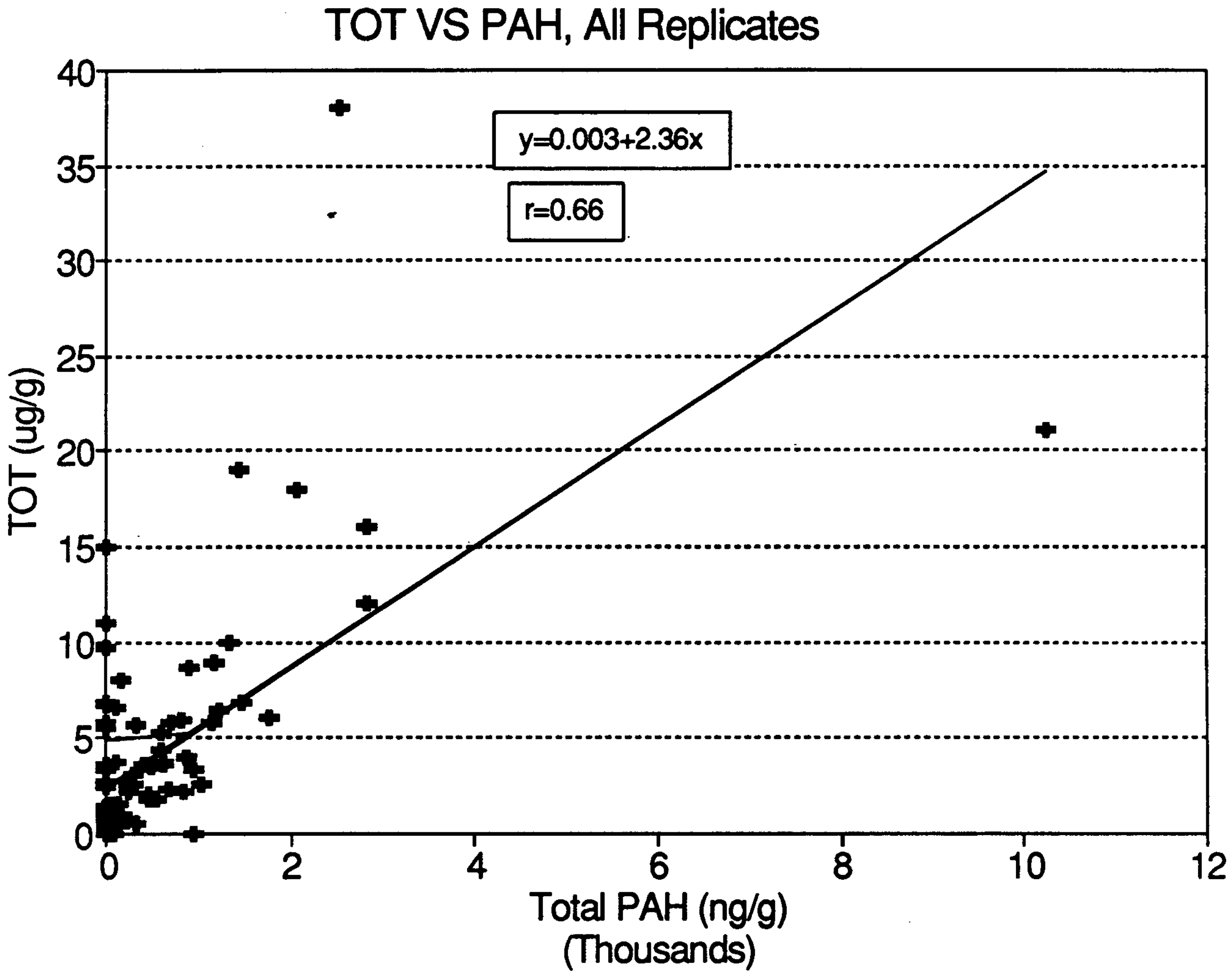
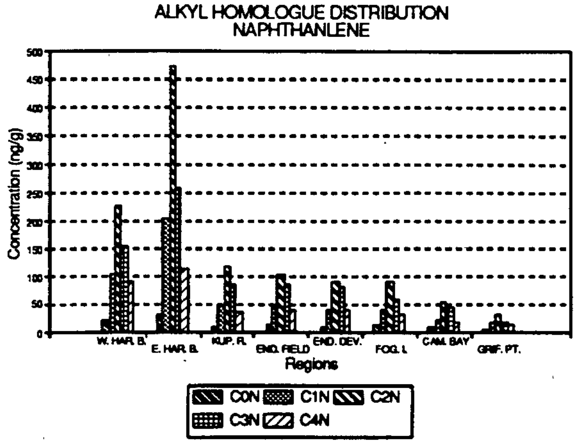
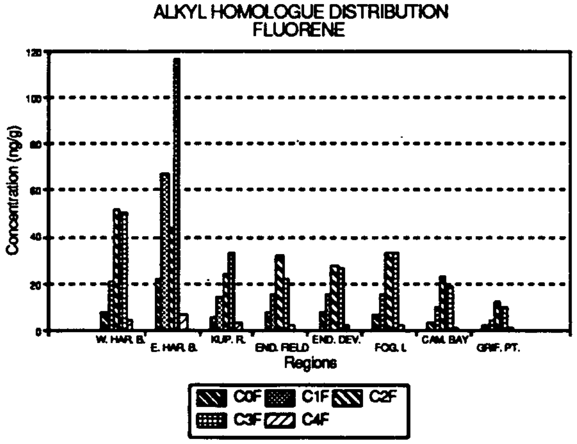


Figure 5.26 **Regression of Total Saturated Hydrocarbons (TOT) Versus Total PAH (TOT PAH) in Sediments for All Stations in 1989.**



(a)



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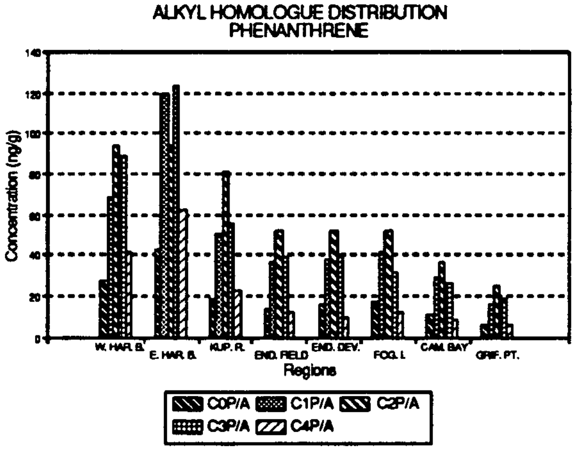
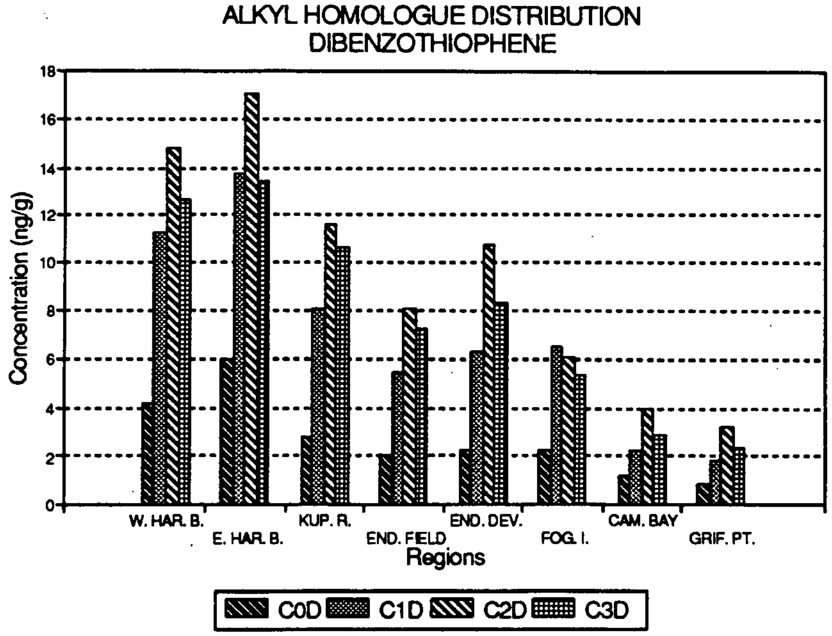


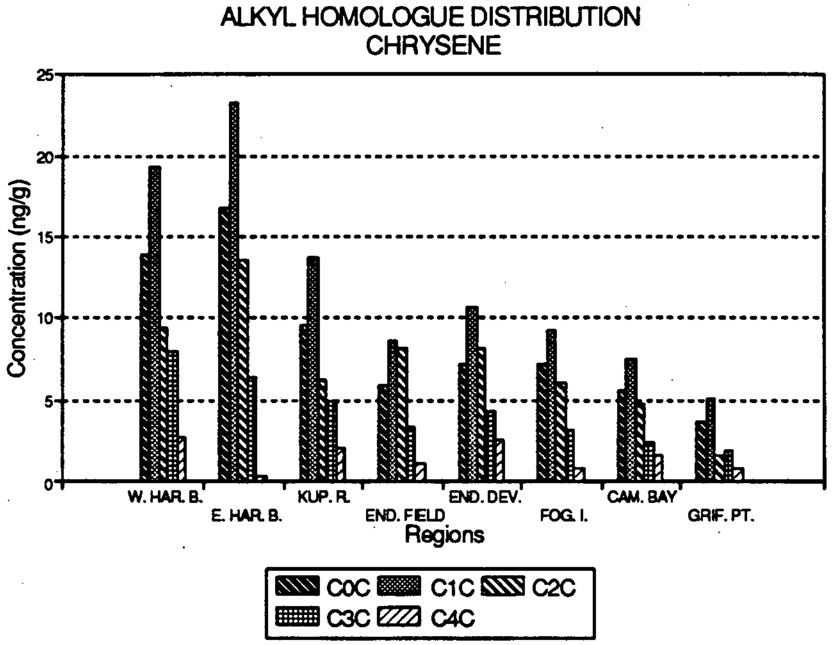
(c)

Figure 5.27 Mean Alkyl Homologue Distribution in Sediments from Beaufort Sea Region in 1989.

a) Naphthalene Series
b) Fluorene Series
c) Phenanthrene Series
d) Dibenzothiophene Series
e) Chrysene Series



(d)



(e)

Figure 5.27 (Cont'd) Mean Alkyl Homologue Distribution in Sediments from Beaufort Sea Region in 1989.

- **a) Naphthalene Series**
- **b) Fluorene Series**
- **c) Phenanthrene Series**
- **d) Dibenzothiophene Series**
- **e) Chrysene Series**

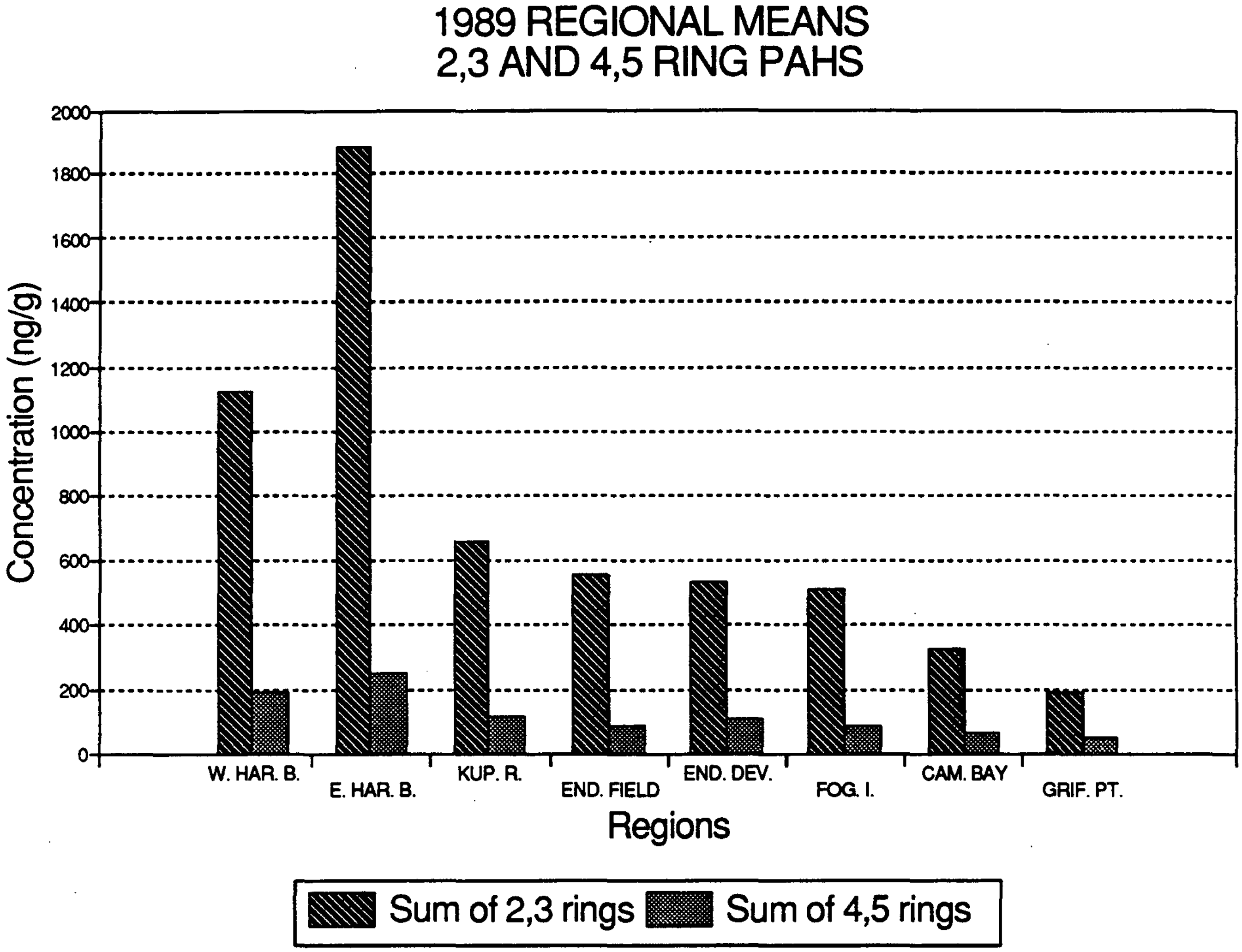


Figure 5.28 Mean Concentration of 2,3 Ring PAHs and 4,5 Ring PAHs in Sediments for All Regions in 1989.
(See Figure 5.1 for the Legend pertaining to the Regions).

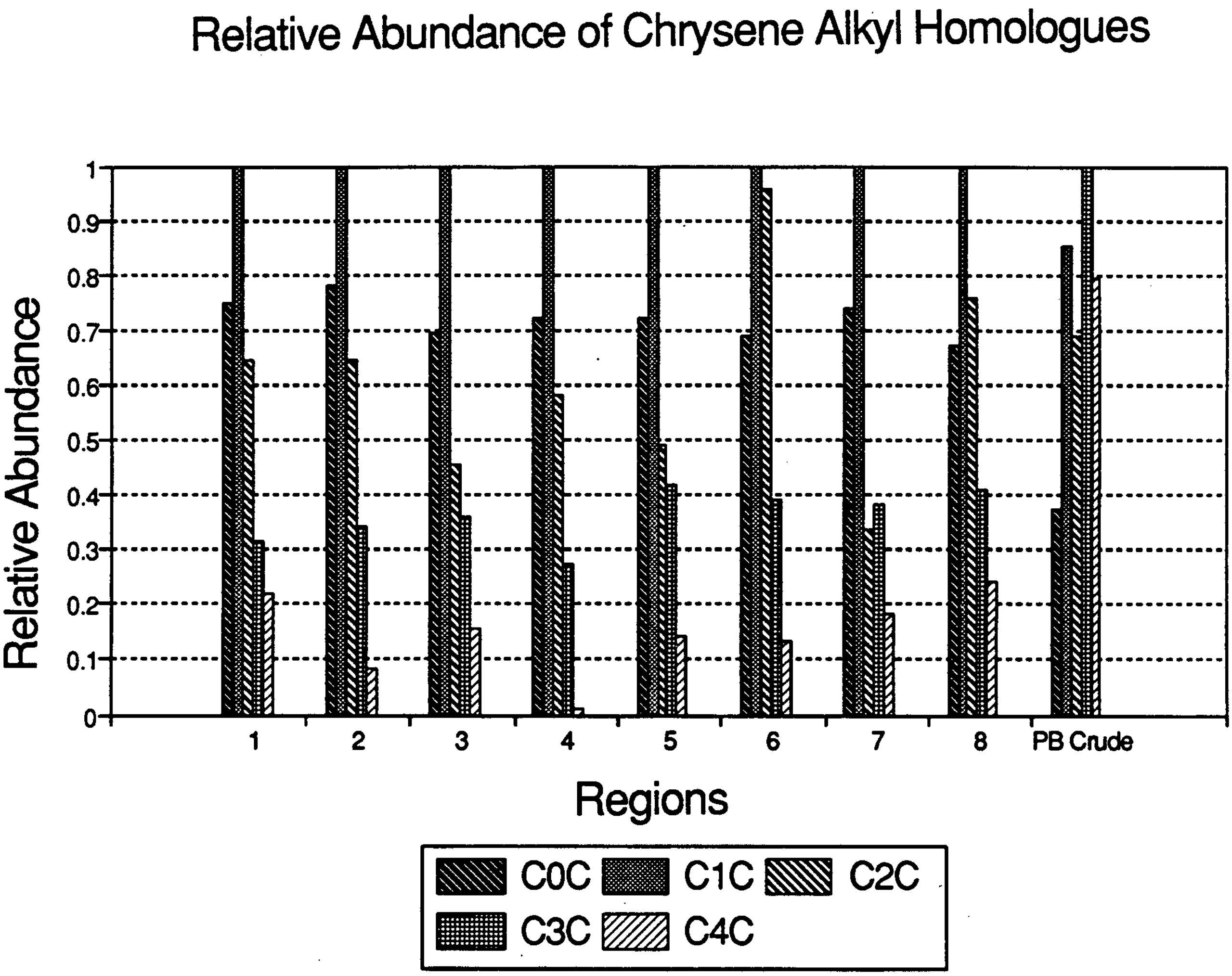


Figure 5.29 Relative Abundances of Chrysene Homologue Series in Sediments for All Regions in 1989. For Each Region, Each Homologue is Expressed as a Fraction of the Homologue with the Greatest Abundance. Prudhoe Bay Crude Oil is Shown for Comparative Purposes.

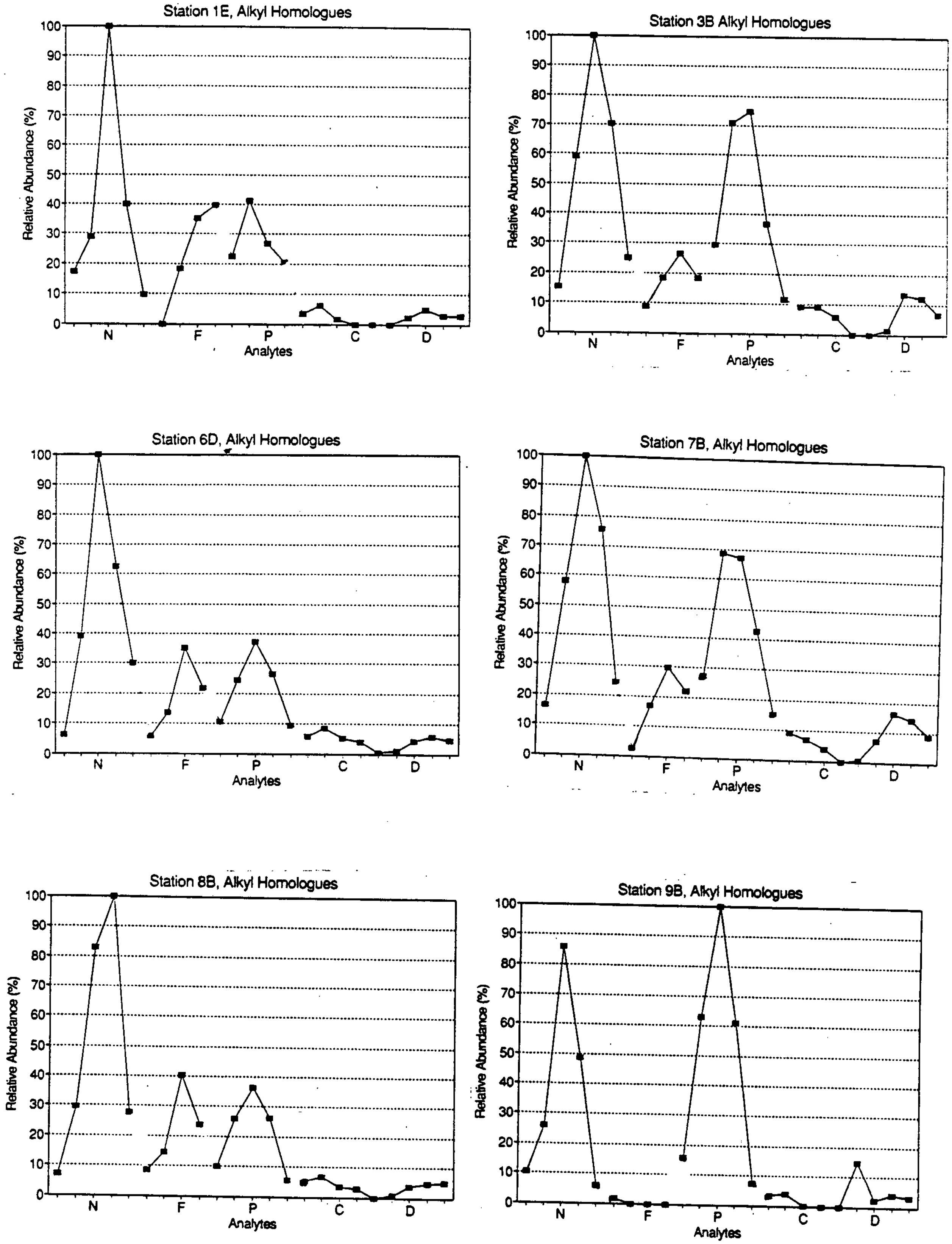


Figure 5.30 Alkyl Homologue Distributions in Sediments for Representative Stations in 1989. N = Naphthalenes, F = Fluorenes, P = Phenanthrenes, C = Chrysenes, D = Dibenzothiophenes.

Given the high background of fossil aromatic compounds in Beaufort Sea sediments, monitoring for incremental additions of PAHs from drilling activity is very difficult. Aromatic hydrocarbons, particularly the detailed aspects of the parent-alkyl homologue assemblages, as well as the diagnostic ratios play a key role in the environmental monitoring strategy. Ratios of total naphthalenes to total phenanthrenes (N/P), and total phenanthrenes to total dibenzothiophenes (P/D), as well as the ratios of individual parent and alkyl homologue compounds (C_0N/C_0P, C_1N/C_1P, etc.) can be used to detect changes in the hydrocarbon chemistry that otherwise would be masked. Furthermore, Prudhoe Bay crude oil has been well characterized by the Marine Sciences Organic Chemistry Laboratory, through the use of Prudhoe Bay Crude as a standard reference material (Table 5.7). The variability of these ratios from crude oils within the Beaufort Sea regions has not been tested, and so in using Prudhoe Bay crude as a reference for the entire Beafort Sea region one has to make the assumption that crudes from regions other than Prudhoe Bay would have similar distributions of parent and alkyl homologue compounds. The Beaufort Sea has been divided into two major petroleum provinces, based upon the classification used by Craig, Sherwood and Johnson (1985) to describe the geological framework and hydrocarbon potential of the area (from MMS, 1990). Much of the study area lies within what is called the Artic Platform, and consist of geologic basins formed in the mid-Paleozoic to mid Mesozoic on a continental basement complex. Based upon this information, it seems reasonable to assume that crude oil from this basin would have similar chemical characteristics. However, given that there exists a number of smaller basins in the study region of different geological characteristics (for example the Kaktovic and Camden basins located in region 1), and that there exist numerous small individual accumulations that have been subjected to different geological and physical conditions, there may be subtle differences in the chemical composition of different crudes from the study area (Seifert, et al., 1979).

The ratios of N/P are presented for all four years in Table 5.8, along with the value for Prudhoe Bay crude oil. Values for N/P were high in all regions reflecting the high naphthalene sediment concentrations in this area (Figure 5.31 a, Boehm et al., 1987). Values of the ratio were larger in 1989 for regions 2,4 and 6. Ratio values of P/D are also presented in Table 5.8. P/D, which is low in Prudhoe Bay crude oil, showed no clear yearly trend over the four years of sampling (Figure 5.31 b). P/D ratios in the sediment are much higher than the value of the crude oil. Thus, there is no strong evidence of this crude oil in sediments, as reflected by the aromatic composition of the sediments, and by the diagnostic ratio parameters.

Endicott Development Island

The composition of the sediments from within the Endicott Development Island region (Region 8) were examined more closely, because of the significant drilling and production activity in that region. Station to station variability was apparent. The

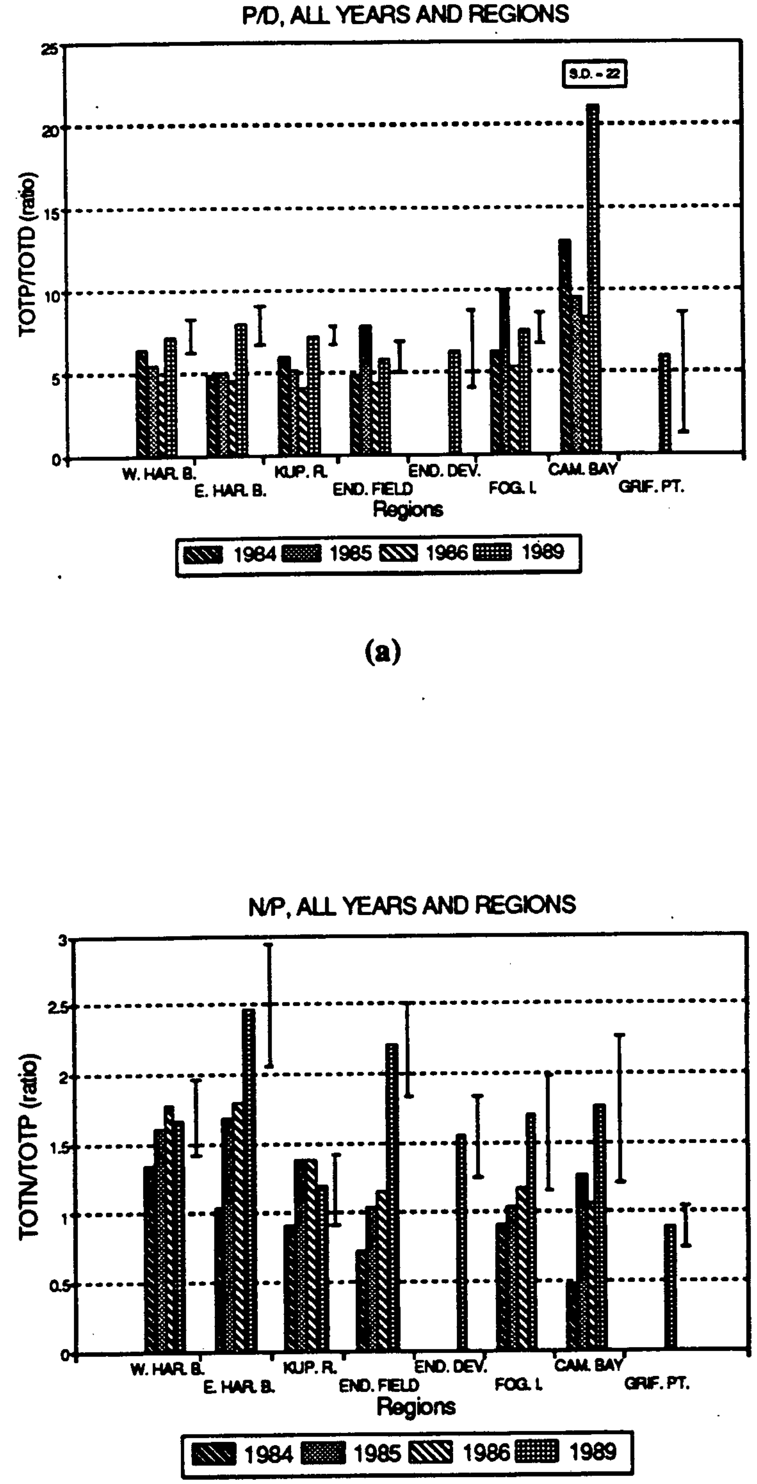
Table 5.7 Diagnostic Ratios for Prudhoe Bay Crude Oil

Diagnostic Ratios	Mean (N=17)	Standard Deviation
TOTN/TOTP	3.0	0.48
C0N/C0P	2.9	0.56
C1N/C1P	2.7	0.54
C2N/C2P	3.0	0.53
C3N/C3P	3.3	0.47
C4N/C4P	3.2	0.47
TOTP/TOTD	1.2	0.07
C0P/C0D	1.2	0.06
C1P/C1D	1.3	0.09
C2P/C2D	1.1	0.10
C3P/C3D	0.8	0.05

Table 5.8 Regional Mean Values of N/P and P/D in Sediments for All Four Years

	1984					1985			
Region	N/P	SD	P/D	SD	Region	N/P	SD	P/D	SD
1	0.48	0.07	13.07	6.93	1	1.15	0.22	8.79	5.12
2	0.91	0.12	6.29	2.22	2	1.22	1.09	10.48	8.19
3	0.92	0.17	6	1.48	3	1.38	0.3	5.18	1.25
4	1.04	0.24	4.83	0.94	4	1.67	0.36	5.1	0.81
5	1.34	0.26	6.47	2.35	5	1.61	0.48	5.58	1.35
6	0.73	0.11	4.82	0.68	6	1.04	0.4	7.85	4.84

	1986					1989			
Region	N/P	SD	P/D	SD	Region	N/P	SD	P/D	SD
1	1.05	0.38	8.22	5.5	1	1.76	1.13	21.13	20.719
2	1.17	0.3	5.35	3.76	2	1.69	0.83	7.58	3.137
3	1.37	0.25	4.1	1.65	3	1.19	0.52	7.18	3.021
4	1.78	0.47	4.54	0.94	4	2.47	0.92	8.02	1.992
5	1.78	0.3	4.57	1.37	5	1.66	0.58	7.19	1.997
6	1.15	0.26	4.4	2.14	6	2.13	0.66	6.33	2.564
					7	1.12	0.25	9.62	6.814
					8	1.71	0.77	6.44	4.473



(a)

(b)

Figure 5.31 Mean Ratios of a) Total Naphthalenes/Total Phenanthrenes (N/P) and b) Total Phenanthrenes/Total Dibenzothiophenes (P/D) for All Regions in All Years. Error Bars Represent the Standard Deviation (± .5 SD). (See Figure 5.1 for the Legend pertaining to the Regions).

greatest concentration of total PAHs were found at 8A and 8E, which are to the north and east of the development island (Figure 5.32). When PAH concentrations were normalized to TOC, these stations remained prominent, although station 8F, north of 8E had the highest PAH/TOC value (Figure 5.33). Figure 5.34 depicts TOT and TOT PAH concentrations normalized to TOC on a map of the Endicott Development region. Station 5(0) from region 6 has been included because of its proximity to the other stations. Stations with the highest concentrations of these normalized parameters are located slightly to the northwest and east of the development island. Stations due west are clearly lower in concentration. Evidence from the aromatic diagnostic ratios indicates that the distribution of these hydrocarbons is not due to oil and gas inputs.

Values of P/D showed variability within the region, with station 8D and 8C having values closest to Prudhoe Bay crude oil (Figure 5.35 a). Examination of the distribution of all of the alkyl homologue ratios of P/D (i.e., C1P/C1D, C2P/C2D, etc.) showed station 8C to be the closest to the oil in the pattern of the ratios and in the overall ratio values (Figure 5.35 b). This station had one of the lowest concentrations of normalized TOT and TOT PAH in the region. Values of total N/total P are presented in Figure 5.36 a,b. Stations 8B and 8E had values that most closely resembled crude oil for N/P. No clear trend for any of the stations was apparent when the N/P ratios of the alkyl homologue were examined.

Finally, there was only slight evidence of pyrogenic inputs of PAHs in any of the regions. This finding can be seen when the ratio of the sum of the 4 and 5 ringed PAH compounds (minus the digenetic compound perylene) and the sum of the two and three ring compounds is taken (Figure 5.37). This figure indicates that between 9 and 15% of the PAHs were of an obvious pyrogenic nature.

5.3.4 Hydrocarbons in Tissues. Organisms collected from the Beaufort Sea represented two feeding types. Those that feed from the water column (filter feeders) acquire anthropogenic contaminants from the water column, such as the bivalves Astarte and Cyrtodaria. Those that reside at the sediment-water interface, such as the deposit feeding bivalves Macoma and Portlandia, and the amphipod Anonyx, acquire pollutants by processing sediment and/or detritus on the ocean floor.

The aromatic and saturated hydrocarbon composition of the tissues from these organisms was investigated and discussed in detail in Boehm et al., 1987, and will only be mentioned briefly in this report. The main focus of the current study was to determine whether any significant increases in tissue concentrations had occurred in the three year hiatus of the Beaufort Sea Monitoring Program (1986-1989), as the result of increased oil drilling and exploration.

Representative GCFID traces showing the saturated hydrocarbon composition of the organisms sampled in 1989 are presented in Figures 5.38, a-e. Pristane was present

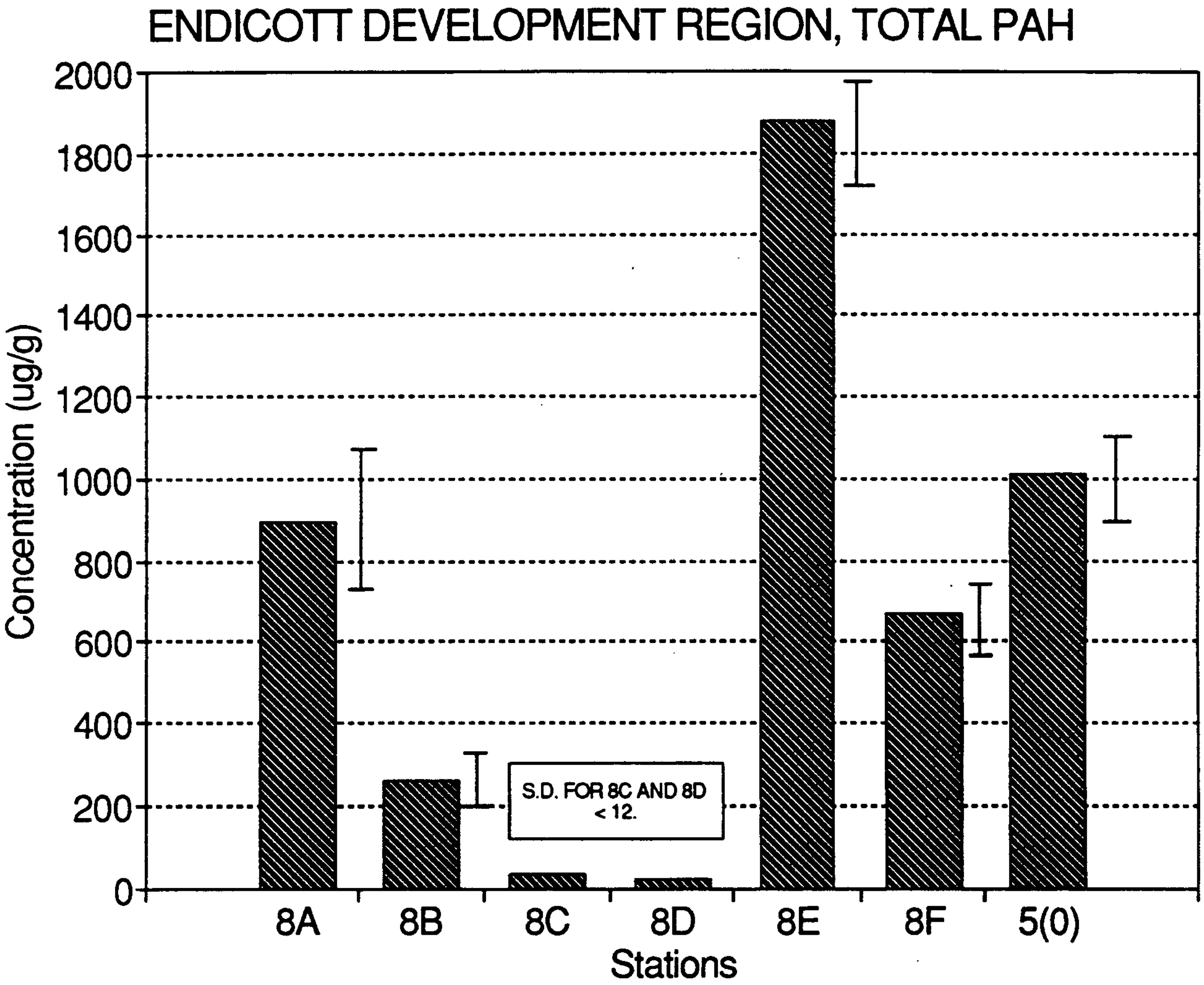


Figure 5.32 Mean Concentrations of Total PAHs in Sediments from Stations in the Endicott Development Island Region. Error Bars Represent the Standard Deviation (± .5 SD).

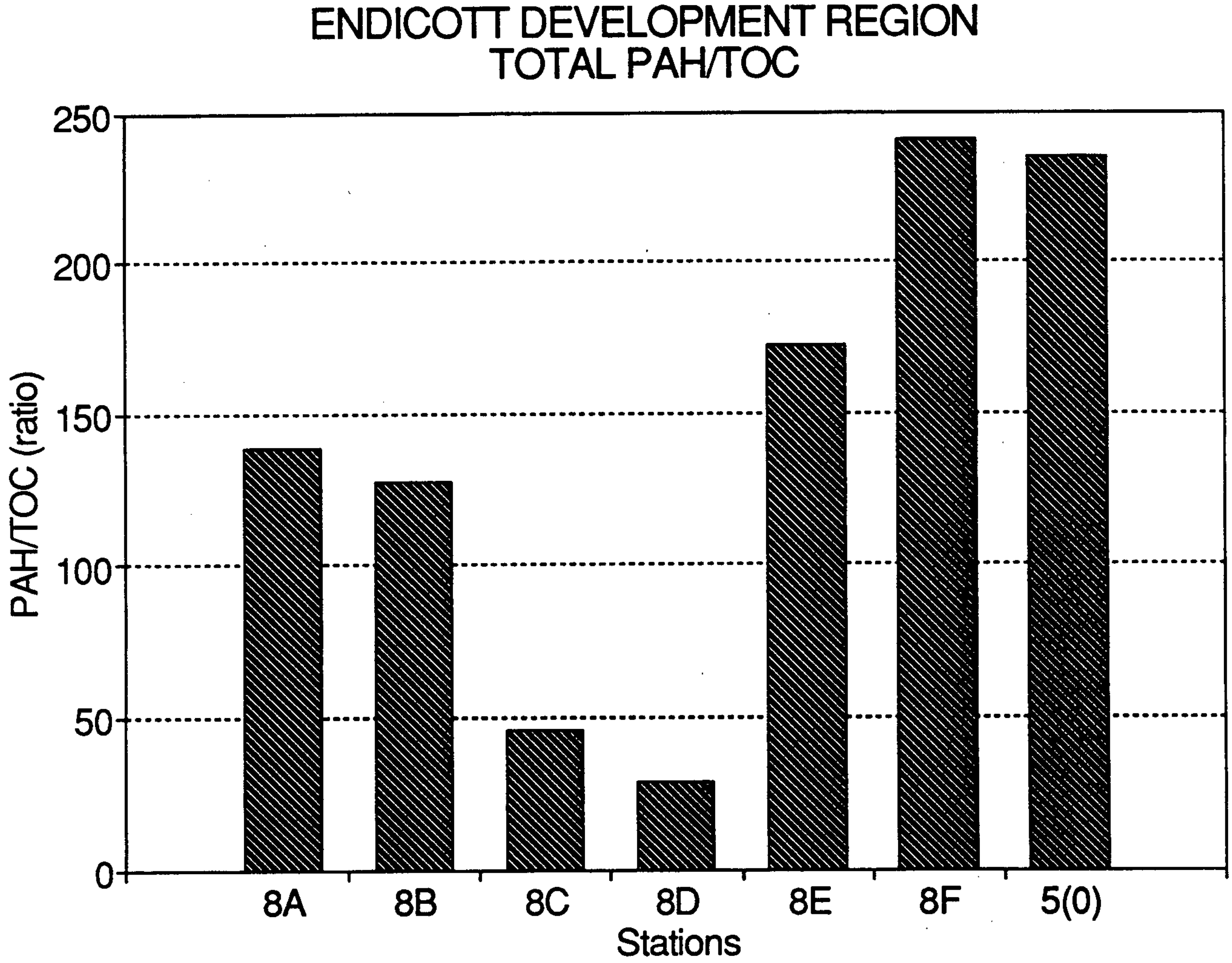


Figure 5.33 Mean Concentrations of Total PAH Normalized to TOC at Endicott Development Island Stations.

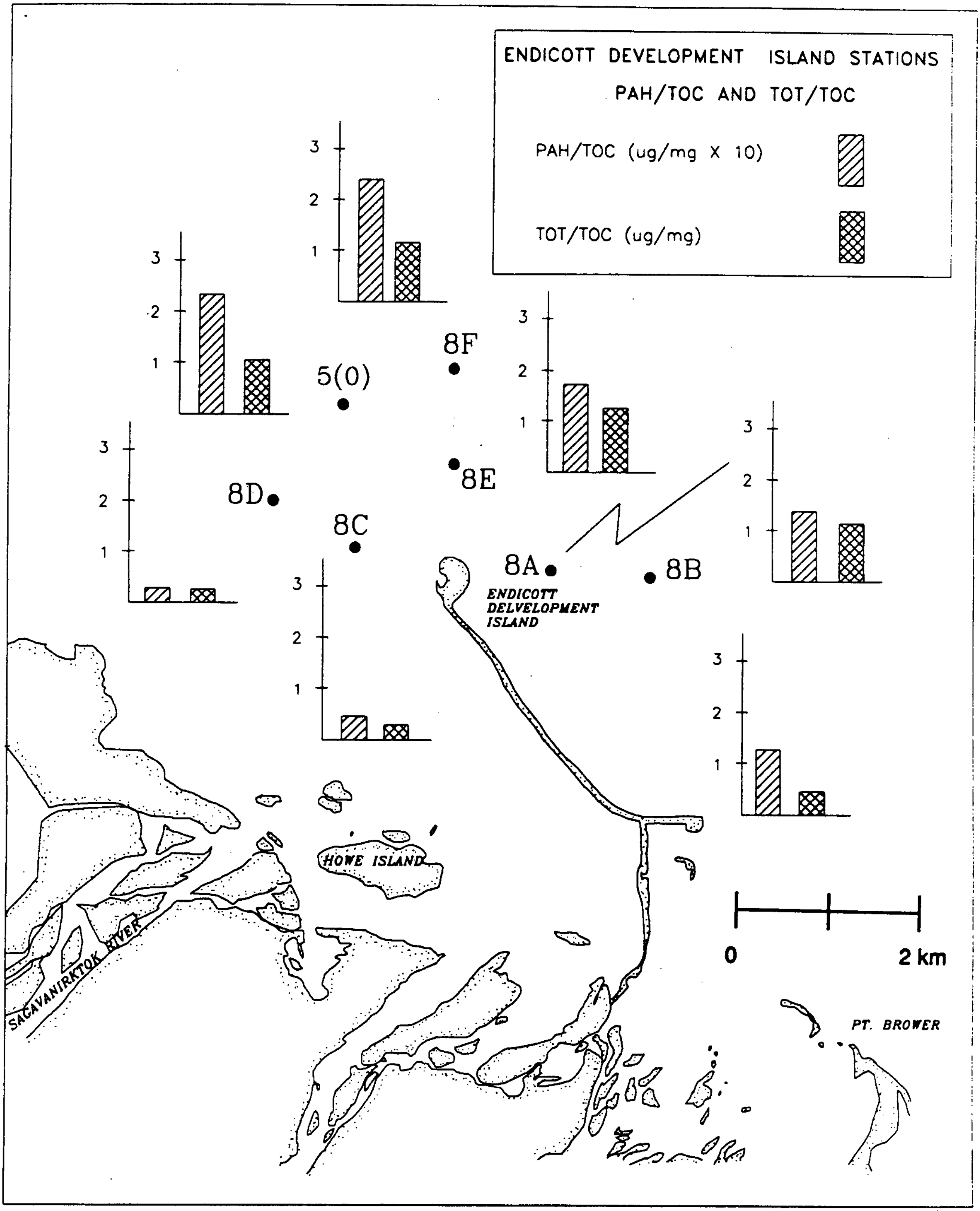
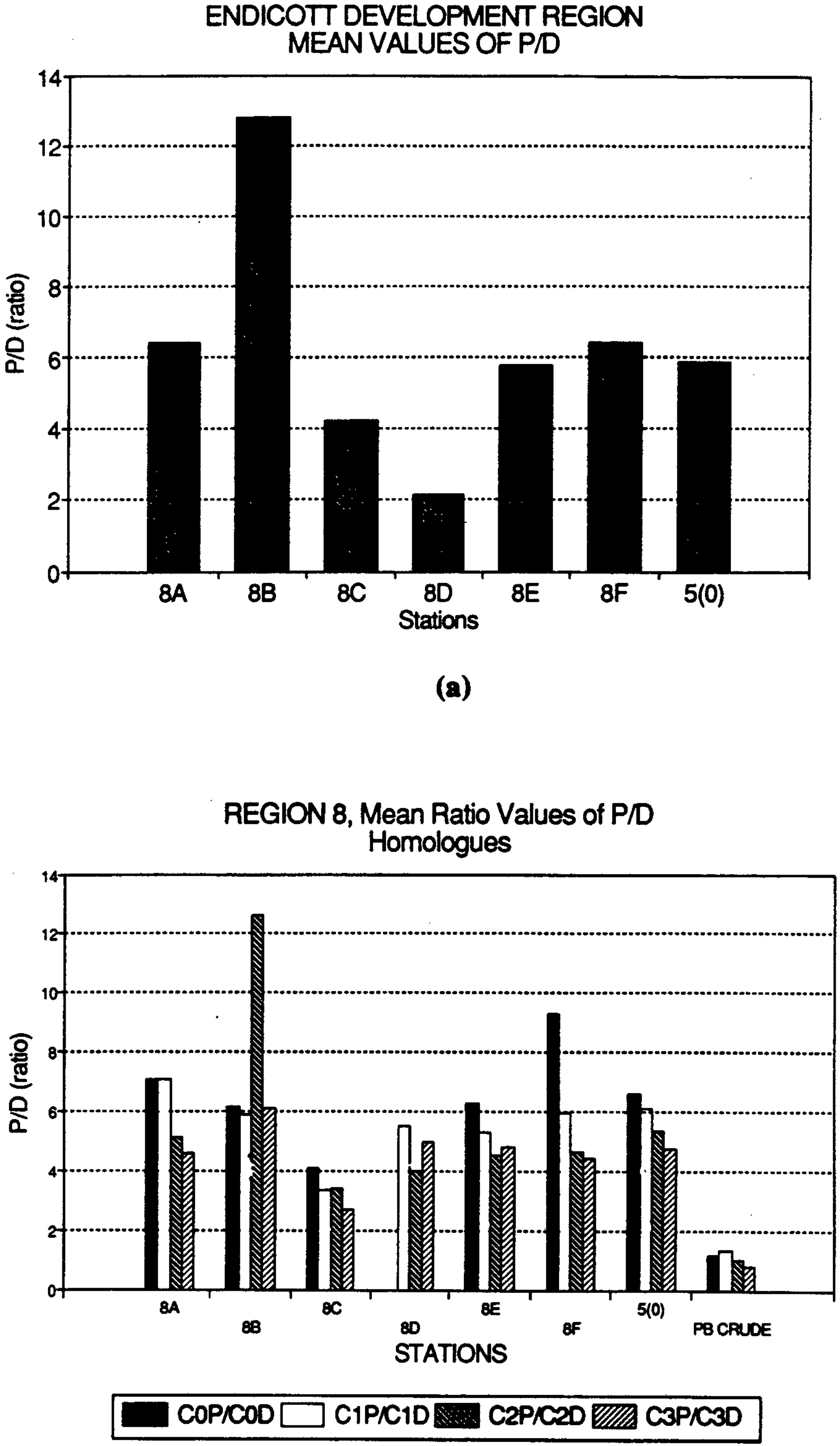


Figure 5.34 Station to Station Comparison of Total Saturated Hydrocarbons (TOT) and Total Aromatic Hydrocarbons (TOT PAH) Normalized to Total Organic Carbon (TOC) in Sediments for All Endicott Development Island (Region 8) Stations. Also Included is Station 5(0) from Endicott Field (Region 6).

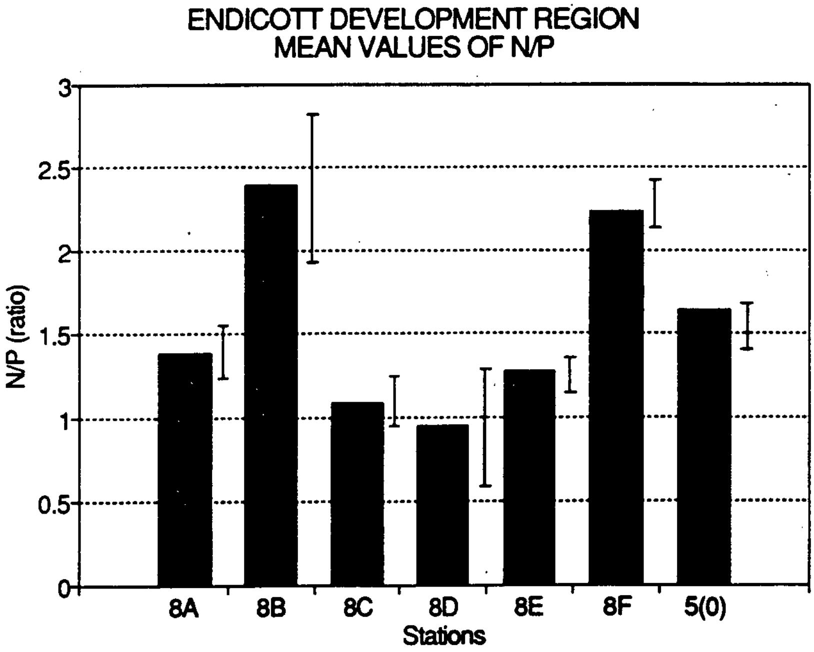


(a)

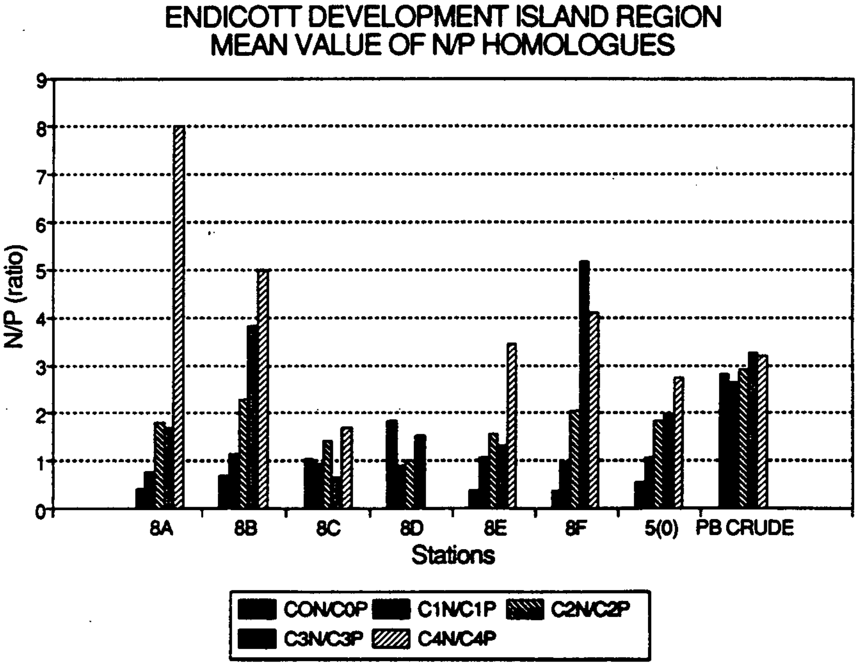
(b)

Figure 5.35 a) Mean Values of Total P/Total D in Sediments for Endicott Development Island (Region 8) Stations and Station 5(0). P/D for Prudhoe Bay Crude Oil is 1.19.

b) Mean Alkyl Homologue Values of P/D in Sediments for All Endicott Development Island (Region 8) Stations, Station 5(0), and Prudhoe Bay Crude Oil.



(a)



(b)

Figure 5.36 a) Mean Values of Total N/Total P in Sediments for All Endicott Development Island (Region 8) Stations and Station 5(0). N/P for Prudhoe Bay Crude Oil is 2.96.

b) Mean Alkyl Homologue Values of N/P in Sediments for All Endicott Development island (Region 8) Stations, Station 5(0) and Prudhoe Bay Crude Oil.

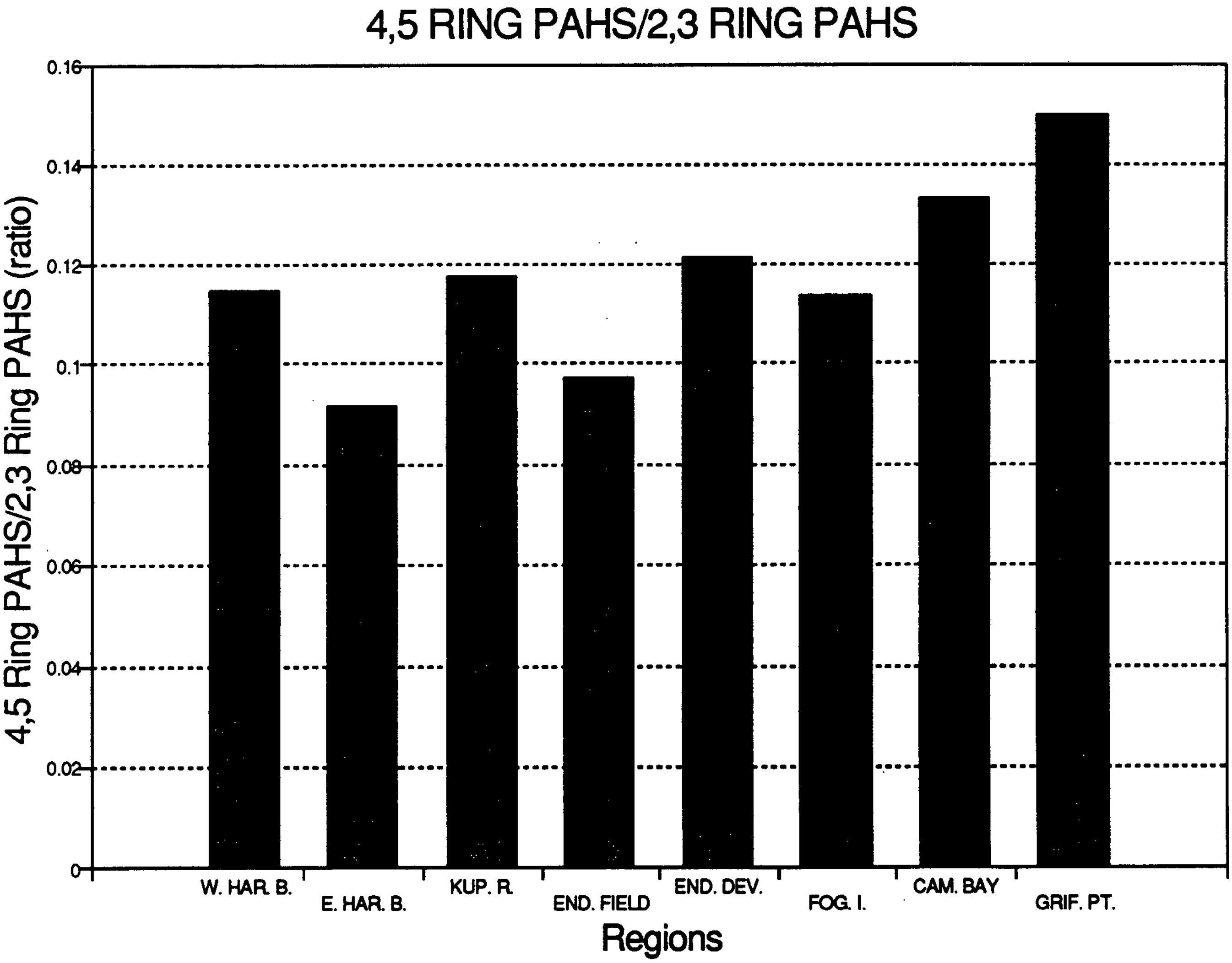
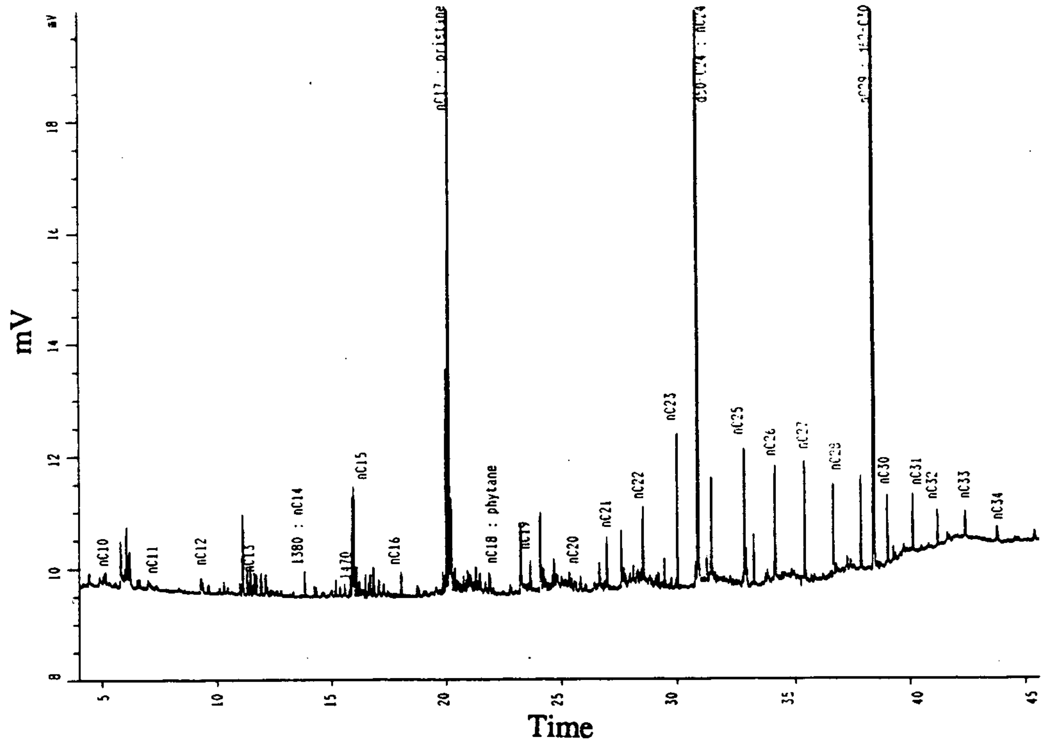


Figure 5.37 Ratio of 4,5 Ring PAH Compounds to 2,3 Ring PAH Compounds in Sediments for All Regions.
(See Figure 5.1 for the Legend pertaining to the Regions)

a) Anonyx, Station 7E



b) Astarte, Station 1B

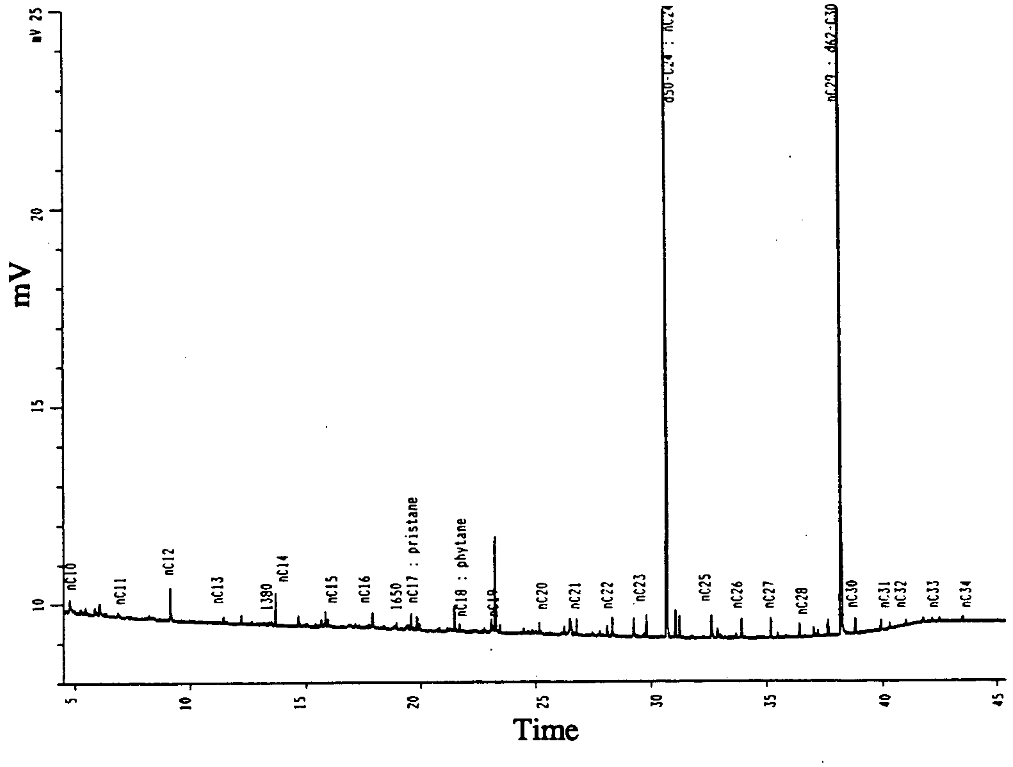
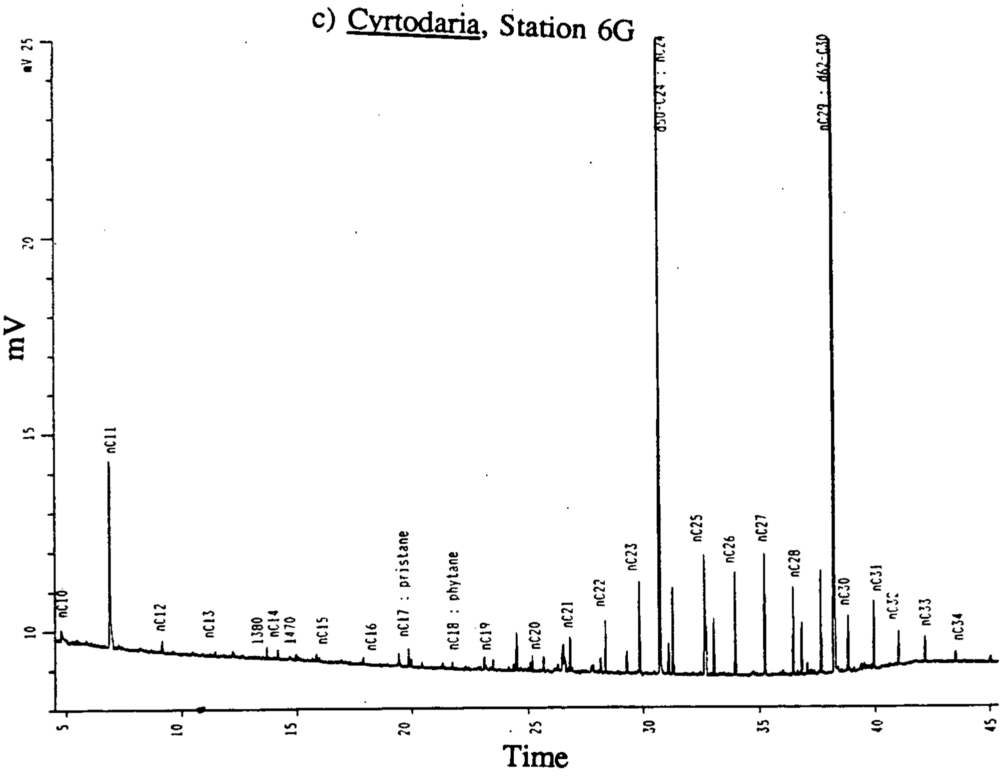


Figure 5.38 **Representative GC-FID Traces of the Alkane Fraction of Organisms from the 1989 Study.**

a) Anonyx, Station 7E
b) Astarte, Station 1B
c) Cyrtodaria, Station 6G
d) Macoma, Station 9B
e) Portlandia, Station 9B


c) Cyrtodaria, Station 6G

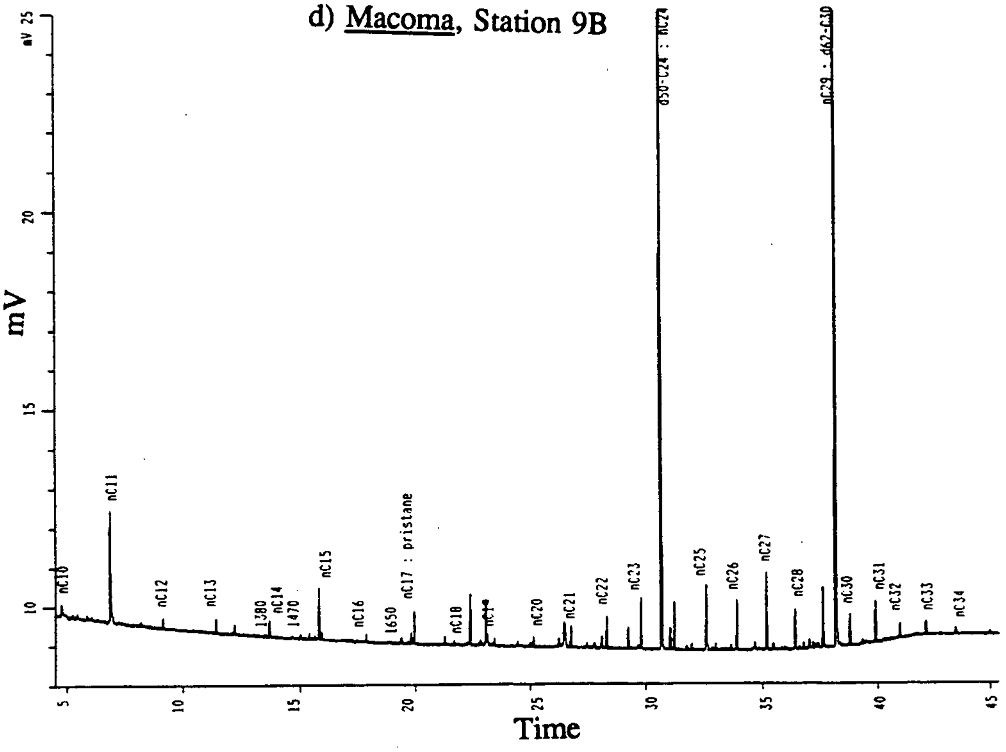

d) Macoma, Station 9B

Figure 5.38 **Representative GC-FID Traces of the Alkane Fraction of Organisms from the 1989 Study.**

a) Anonyx, Station 7E
b) Astarte, Station 1B
c) Cyrtodaria, Station 6G
d) Macoma, Station 9B
e) Portlandia, Station 9B

e) Portlandia, Station 9B

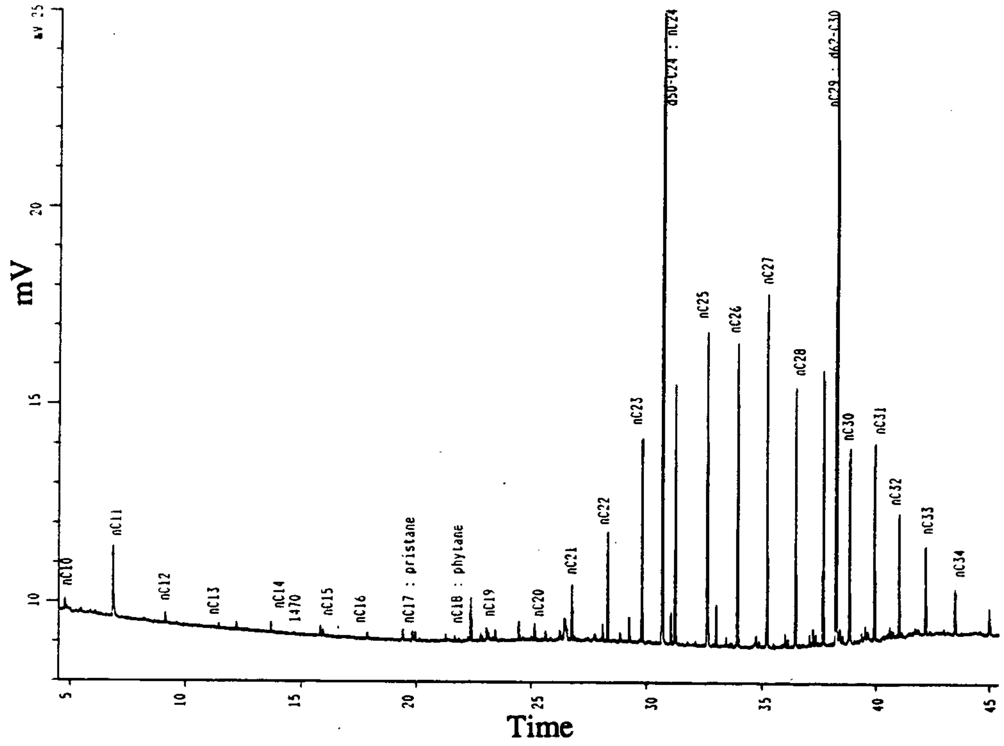


Figure 5.38

Representative GC-FID Traces of the Alkane Fraction of Organisms from the 1989 Study.

a) Anonyx, Station 7E
b) Astarte, Station 1B
c) Cyrtodaria, Station 6G
d) Macoma, Station 9B
e) Portlandia, Station 9B

at trace levels in all species, although it was a major component in Anonyx. Phytane was observed in trace levels in all organisms. Influence of sedimentary hydrocarbons, primarily plant wax alkanes from terrestrial sources was observed, at various concentrations, as a pattern of normal chain alkanes from nC21 to nC34 with a distinct odd to even preference. A distinguishing feature of GC/FID traces of Anonyx was small clusters of partially resolved saturated hydrocarbons in the lower (nC10-nC20) boiling point range and a small range unresolved complex mixture (UCM) of compounds in the nC27 to nC34 range, possibly of microbial origin. These features of Anonyx were also noted in Boehm et al., 1987.

A station-by-station comparison between mean concentrations of the various summed hydrocarbon parameters is presented in Table 5.9. It can be seen that in 1989 the saturated hydrocarbons were generally either lower in concentration, or similar in concentration to the two-to-three year mean values from the previous study. Overall the numbers were quite similar between the two studies, especially given the low concentrations found at most stations.

Levels of aromatic hydrocarbons in tissues were generally low and near the limit of detection for many of the individual analytes. In most cases, the most abundant PAH compounds were the naphthalenes (Table 5.9), most likely due to the high sediment concentrations of naphthalenes, which has already been discussed. Boehm et al., 1987, noted the low tissue concentrations of aromatics, in spite of an abundance of PAHs in the sediments.

Figure 5.39, a-e presents regional mean values of total PAH for the species examined. There appears in some instances PAH that are higher in 1989 than in years past. In the case of Astarte, Portlandia and Cyrtodaria, concentrations in past years were at or below detection limits, and so values obtained this year do not necessarily constitute a trend. One species, Macoma, did not show an increase. Any increases that did occur did not seem to be the result of increased uptake of petroleum PAH because dibenzothiophenes were absent in all but one bivalve sample (Tables 4.4 and 5.9). Also, N/P ratios did not show a consistent trend over time for any species (Figure 5.40, a-e).

5.4 Summary of Statistical Analyses

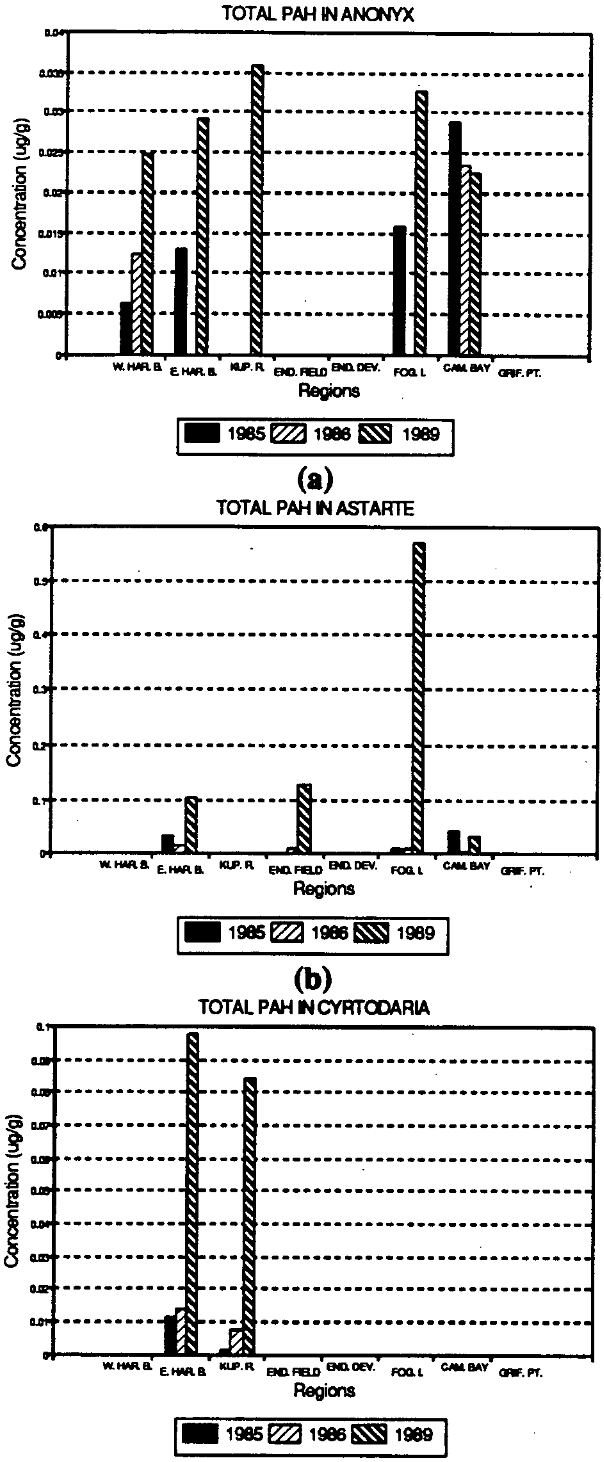
Statistical analyses were performed on metal and hydrocarbon sediment concentrations. The total number of observations in the data set was 462 with 99 variables. Analysis of variance, the main statistical test used for hypothesis testing, was performed on log transformed data to conform with other analyses developed in previous reports. Results from the analysis were back transformed to geometric means and relative standard deviations, as described in Boehm et al., 1987.

One way to summarize a data set with a large number of variables and observations,

Table 5.9 Station-by-Station Comparison of Hydrocarbon Parameters Between 1987 and 1989 Study

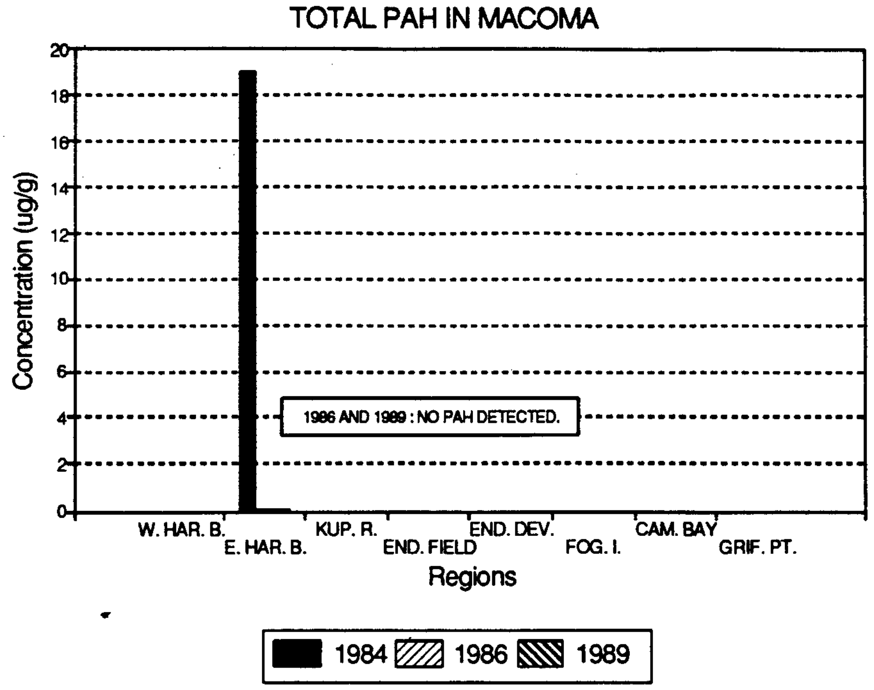
STATION	YEAR	SPECIES	PHC	LALK	TALK	TOTN	TOTF	TOTP	TOTD	TPAH	P/D	N/P	2,3RNG	4,5RNG
1A/B/E	YEAR 2,3	Anonyx	17.428	0.780	4.707	0.015	ND	ND	ND	0.015	ND	ND	0.015	ND
1A/B/E	YEAR 4		5.530	0.472	1.510	0.016	0.010	ND	ND	0.026	ND	ND	0.026	ND
2F	YEAR 3	Anonyx	9.180	0.197	1.628	0.007	ND	0.001	0.039	0.047	0.013	14.700	0.047	ND
2D	YEAR 4		2.133	0.165	0.427	0.014	ND	0.002	ND	0.019	ND	8.848	0.015	0.004
4B	YEAR 2	Anonyx	60.790	0.653	9.143	0.015	ND	ND	ND	0.016	ND	ND	0.015	0.001
4B	YEAR 4		5.967	0.417	0.922	0.013	ND	0.005	ND	0.030	ND	2.596	0.018	0.012
6G	YEAR 2	Anonyx	18.308	1.542	2.404	0.012	ND	0.001	ND	0.013	ND	12.000	0.013	ND
6D	YEAR 4		5.867	0.322	1.140	0.024	0.005	ND	ND	0.029	ND	ND	0.029	ND
7E	YEAR 2,3	Anonyx	11.312	0.908	2.015	0.012	ND	0.0002	ND	0.018	ND	57.800	0.012	0.006
7E	YEAR 4		7.800	0.482	3.045	0.013	0.012	ND	ND	0.025	ND	ND	0.025	ND
1A	YEAR 2,3	Astarte	6.245	1.477	3.004	0.012	0.007	0.003	0.001	0.027	2.500	4.800	0.023	0.005
1A	YEAR 4		4.000	0.579	1.267	0.015	0.036	0.006	ND	0.073	ND	2.632	0.057	0.016
1B	YEAR 3	Astarte	1.653	0.072	0.701	0.005	ND	ND	ND	0.005	ND	ND	0.005	ND
1B	YEAR 4		8.100	0.309	3.640	0.013	ND	0.003	ND	0.022	ND	4.043	0.016	0.006
3A	YEAR 1,2,3	Astarte	7.552	0.422	2.743	0.002	0.0003	0.001	ND	0.009	ND	3.075	0.003	0.006
3A	YEAR 4		4.867	0.416	2.050	0.284	ND	0.635	ND	1.116	ND	0.447	0.919	0.197
5(1)	YEAR 3	Astarte	1.475	0.100	1.101	0.011	ND	ND	ND	0.011	ND	ND	0.011	0.0004
5(1)	YEAR 4		4.267	0.438	1.996	0.015	0.070	0.013	0.001	0.128	10.861	1.125	0.099	0.029
5H	YEAR 2,3	Astarte	4.460	1.446	3.191	0.003	0.001	0.001	ND	0.006	ND	2.333	0.005	0.001
5H	YEAR 4		10.567	0.361	1.780	0.014	ND	0.004	ND	0.024	ND	3.782	0.018	0.006
6D	YEAR 1,2,3	Astarte	20.865	0.980	5.075	0.006	0.0003	0.001	0.0003	0.010	3.500	7.000	0.008	0.003
6D	YEAR 4		5.333	0.437	2.626	0.021	0.048	0.009	ND	0.101	ND	2.222	0.078	0.023
5F	YEAR 1,2,3	Cyrtadaria	8.843	0.219	36.435	0.006	0.001	0.004	0.001	0.014	4.333	1.413	0.012	0.002
5F	YEAR 4		3.533	0.657	2.180	0.020	0.043	0.006	ND	0.084	ND	3.175	0.069	0.015
6G	YEAR 2,3	Cyrtadaria	4.396	0.301	1.022	0.006	ND	0.005	ND	0.015	ND	1.211	0.011	0.005
6G	YEAR 4		4.567	0.570	2.915	0.028	0.012	0.043	ND	0.098	ND	0.645	0.082	0.016
6D	YEAR 1,2	Macoma	28.703	0.711	10.579	6.611	1.155	1.450	0.299	9.524	4.849	4.560	9.515	0.009
6D	YEAR 4		4.100	0.224	2.244	0.041	ND	0.007	ND	0.065	ND	6.197	0.048	0.017
1A	YEAR 2,3	Portlandia	13.030	0.247	4.962	0.012	0.002	0.006	0.000	0.030	17.000	1.953	0.021	0.009
1A	YEAR 4		6.900	0.364	4.752	0.031	0.094	0.029	ND	0.189	ND	1.066	0.153	0.036

ND - Not Detected



(c)

Figure 5.39 **Mean Concentrations of TOT PAH in Organisms for 1989 Study Regions (a) Anonyx, (b) Astarte, (c) Cyrtodaria, (d) Macoma, (e) Portlandia.**



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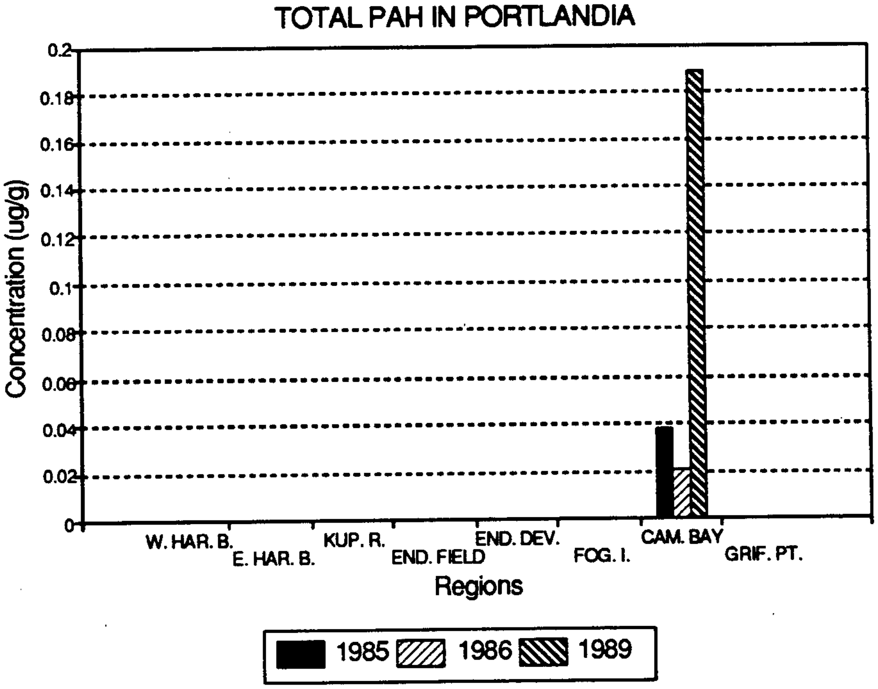
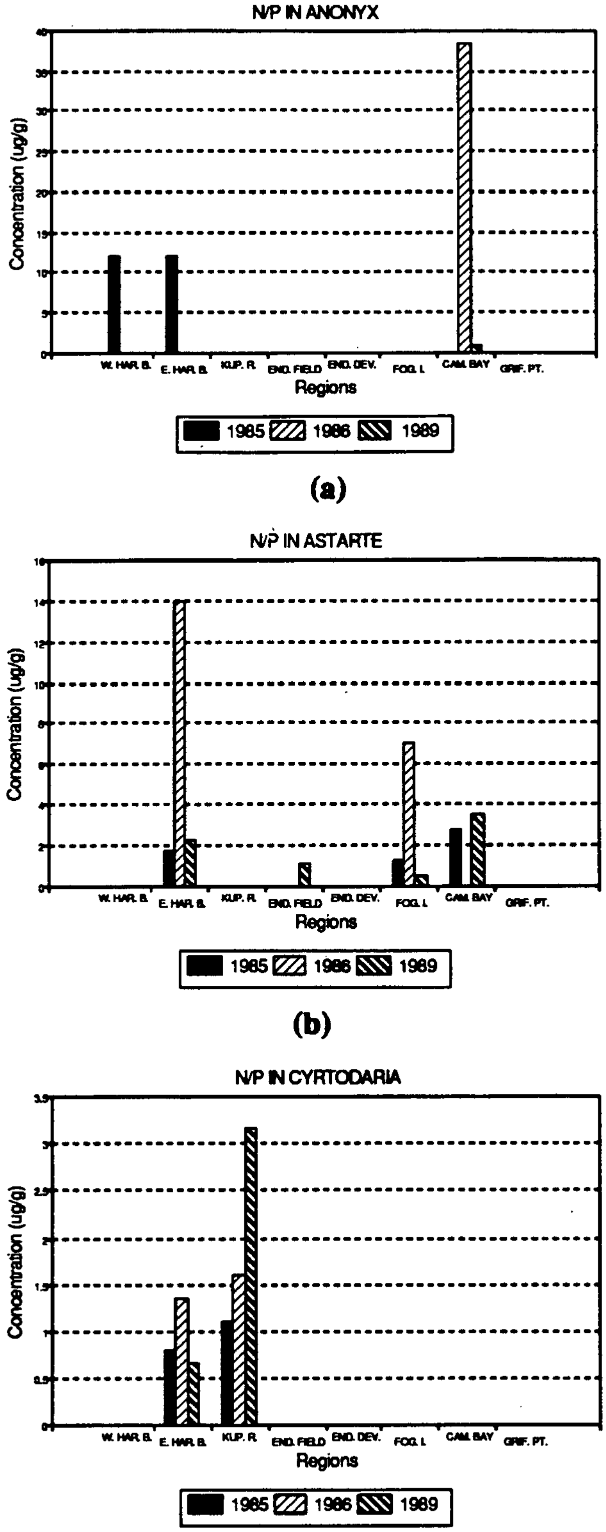


(e)

Figure 5.39 **Mean Concentrations of TOT PAH in Organisms for 1989 Study Regions (a) <u>Anonyx</u>, (b) <u>Astarte</u>, (c) <u>Cyrtodaria</u>, (d) <u>Macoma</u>, (e) <u>Portlandia</u>.**



(a)

(b)

(c)

Figure 5.40 Mean Values of N/P in Organisms for 1989 Study Regions (a) Anonyx, (b) Astarte, (c) Cyrtodaria, (d) Macoma, (e) Portlandia (See Figure 5.1 for the Legend pertaining to the Regions).

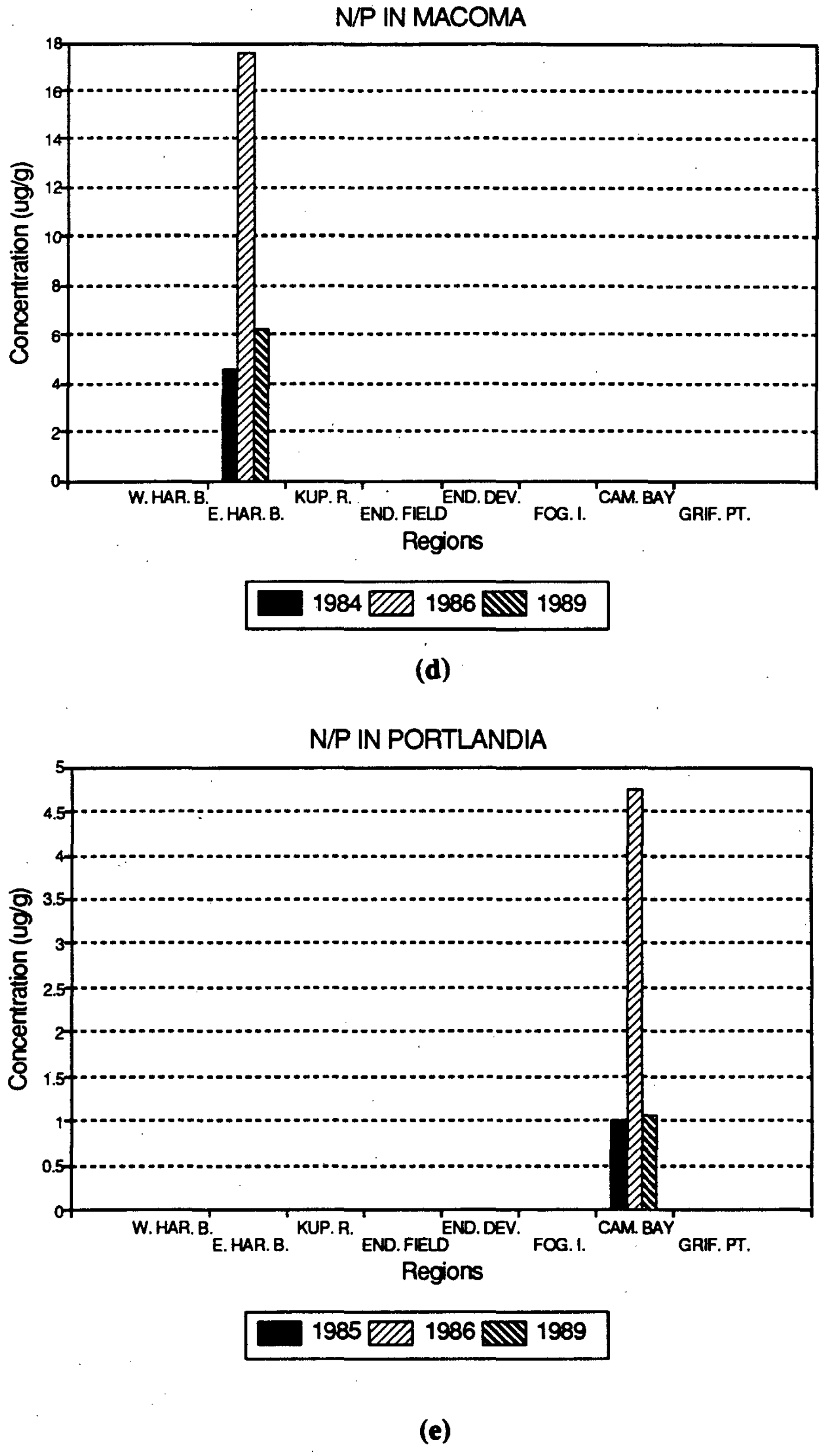


Figure 5.40 Mean Values of N/P in Organisms for 1989 Study Regions (a) Anonyx, (b) Astarte, (c) Cyrtodaria, (d) Macoma, (e) Portlandia (See Figure 5.1 for the Legend pertaining to the Regions).

uses a variance component model. The following example, illustrates how this model is used to describe data. Consider a measurement, such as TOT in µg/g, on a single sample drawn at random. The variability in that measurement is probably due to several multiplicative components: within station sampling variability, variability due to random station selection, regional variability and variation due to time. A variance component model seeks to allocate the total variance inherent in a sample measurement into these various components. These results can be used to provide insight into the performance of various measurements and derived variables, for purposes of future monitoring programs. Use of the variance component model is a way to examine the sources of variability of measurements made in this study in a descriptive fashion.

Results of the variance component analysis are presented in Table 5.10. Values in the table are the relative standard deviation associated with the following components: region, station, year, station x year and replicate. The relative standard deviations multiplied by the arithmetic means will approximate the standard deviations of the untransformed error components.

Analysis of variance was performed on sediments to test for the presence of trends over time and space and to address the following null hypotheses:

- Ho1: There will be no change in sediment concentrations of selected metals or hydrocarbons.
- Ho2: Changes in concentrations of selected metals or hydrocarbons in sediments are not related to OCS oil and gas development activity.

Several diagnostic parameters and the summed hydrocarbon parameters TOT PAH and TOT were analyzed, using a fixed effects analysis of variance. The interaction of station versus time was treated as the error term. The probability, expressed as the probability (Pr) that the actual result of the ANOVA was greater than the calculated F value ($Pr > F$) was determined for several factors. The model value looked at the differences between stations for all years. TOC was treated as a covariate for all ratios and summed values, that is variability due to changes in sediment TOC content were accounted for. Change in TOC was not found to be a significant interaction effect ($P < 0.05$) for any variables. Significant differences between years (year effect) were seen for all diagnostic ratios and summed parameters, due in part to the sensitivity of the test and the large number of degrees of freedom. Significant station-to-station differences ($p < 0.05$) were seen for pristane/phytane, P/D, N/P, TOT, and TOT PAH, but not for LALK/TALK or FFPI.

However, the main question being addressed is whether the pattern of change of regional values in 1989 was different than during years 1984 - 1986, suggesting a perturbation beyond random variability. To test for this a class called year 4 was

Table 5.10 **Variance Component Analysis for Selected Parameters in Beaufort Sea Sediments**

	Relative Standard Deviation				
Variable	Region	Station	Year	STAT x Yr	Rep
FFPI	0.04	0.03	0.09	0	0.3
ISO/ALK	0	0.23	0.27	0.18	0.26
LALK	0.54	0.47	0.43	0.53	0.43
LALK/TALK	0	0.29	0.17	0.13	0.28
OEPI	0	0.18	0.11	0.06	0.33
4,5 RING PAHS	0.71	0.73	0.36	0.71	0.84
PHC	0.68	0.69	0.6	0.67	0.68
PR/PHT	0.08	0.12	0.12	0	0.23
TOTPAH/TOC	0.6	0.44	0.4	0.53	0.76
TALK	0.6	0.7	0.49	0.54	0.49
TOC	0.14	0.6	0.18	0.42	1.06
TOTD	1.04	0.83	0.23	0.53	0.8
TOTF	0.66	0.86	0.33	0.65	1.15
TOTN	1.16	0.84	0.24	0.53	0.78
TOTP	0.84	0.78	0.19	0.58	0.58
TOTPAH	0.89	0.82	0.05	0.52	0.76
Ba	0.13	0.24	0.38	0.33	0.3
Cd	0.13	0.26	0.15	0.13	0.3
Cr	0.17	0.1	0.16	0.08	0.08
Cu	0.05	0.17	0	0.1	0.14
Pb	0.19	0.18	0.13	0.17	0.16
V	0	0.17	0.18	0.07	0.08
Zn	0	0.1	0.09	0.07	0.15

introduced into the fixed effects model, which tested for a change in regional patterns between years 1-3 and year 4. The results of this analysis are summarized in Table 5.11. Differences were found to be significant for TOT, TOT PAH and N/P. The difference between the TOT measurements was due, in part to analytical differences between laboratories, as discussed in section 4.4.2. While the differences seen in the other observations are probably real, there is no convincing evidence, based upon the chemical analysis of sediments, that these differences were due to oil and gas exploration and activity as evidenced by the lack of significant changes in the diagnostic ratios, therefore Ho2 is not rejected. Results of this analysis proved no significant differences for the diagnostic ratios, LALK/TALK, PRIS/PHYT or P/D.

The degree of correlation between hydrocarbon and metal parameters was examined using Pearson product moment correlations. Three years of data (1985, 1986 and 1989) where metal and hydrocarbon analyses were performed on sediments from the same stations, were analyzed using simple Pearson correlations. A number of significant correlations ($P < 0.05$) appeared. These correlations, while interesting, are difficult to interpret since they are due to a number of different effects: variation between years, between stations and within stations.

In order to separate out the year effect, i.e., random effects due to variations between years, Pearson correlation coefficients were computed for each year separately. These results are presented in Tables 5.12 to 5.14. For each interaction, the correlation coefficient (R) and the probability (P) value is listed. Interactions that are significant are highlighted. Significant correlations were present in each year, although there did not appear to be a consistent pattern from year to year. Vanadium, an inorganic indicator of oil, was positively correlated to total PAH in years 2 and 3 but not in year 4 (1989). It was positively correlated with FFPI only in year 4.

To sort out random effects due to station-to-station variation as well as year-to-year variation an analysis of covariance model was used. The model included station and year main effects and two covariates, log TOC and the log concentration of a metal. In most cases, after the station, year and TOC effects were removed, there was not a significant relationship between metals and the hydrocarbon indices.

In summary, while there appeared to be some degree of correlation between hydrocarbon and metal parameters, consistent trends that can be related to drilling activities were difficult to discern.

Table 5.11 **Results of the ANOVA Testing 1989 Regional Means Against 3 Year (1984-1986) Regional Means**

Parameter	Significant Difference? (P < .05)	P Value
TOT	Yes	P < .01
TPAH	Yes	P < .003
LALK/TALK	No	P < .15
PRIS/PHYT	No	P < .44
N/P	Yes	P < .001
P/D	No	P < .34
FFPI	No	P < .71

Table 5.12 **Pearson Correlation Coefficients for the Interaction of Sediment and Hydrocarbon Parameters for 1985 Sediment Data.**

Year 2 (1985)						
	TOTPAH	FFPI	LALK/TALK	PRYS/PHYT	ISO/ALK	OEPI
CD	-0.35501	-0.09917	0.28360	-0.25615	**-0.39176**	-0.12090
	0.0751	0.6298	0.1603	0.2066	**0.0478**	0.5563
PB	**0.44661**	0.38678	-0.34312	0.09321	0.18812	-0.21954
	0.0222	0.0509	0.0862	0.6506	0.3574	0.2812
BA	**0.39603**	**0.39661**	-0.24726	**0.59960**	0.28185	0.06249
	0.0452	**0.0449**	0.2233	**0.0012**	0.1630	0.7617
CR	**0.47150**	0.38146	-0.34865	**0.50959**	**0.48539**	-0.22656
	0.0150	0.0545	0.0809	**0.0078**	**0.0120**	0.2657
CU	0.37443	0.29793	-0.36478	-0.17841	0.14053	-0.25600
	0.0595	0.1393	0.0669	0.3832	0.4935	0.2068
V	**0.53064**	0.29147	**-0.52048**	-0.11284	0.36716	-0.23245
	0.0053	0.1485	**0.0064**	0.5831	0.0650	0.2532
ZN	**0.59310**	0.30011	**-0.58798**	-0.13561	0.37811	-0.27707
	0.0014	0.1363	**0.0016**	0.5089	0.0568	0.1706

*The top number of each interaction grouping is the correlation coefficient (R).
The second (lower) number is the statistical significance (P) of the correlation
All statistically significant interactions ($P<0.05$) are highlighted

Table 5.13 **Pearson Correlation Coefficients for the Interaction of Sediment and Hydrocarbon Parameters for 1986 Sediment Data.**

	Year 3 (1986)					
	TOTPAH	FFPI	LALK/TALK	PRYS/PHYT	ISO/ALK	OEPI
CD	-0.07522	-0.08311	0.08042	0.25050	-0.32898	**0.60852**
	0.7150	0.6865	0.6961	0.2171	0.1008	**0.0010**
PB	**0.48780**	0.02292	-0.21735	-0.24917	**0.55226**	-0.19932
	0.0115	0.9115	0.2862	0.2196	**0.0034**	0.3290
BA	**0.54798**	0.00451	**-0.67372**	0.23485	0.35151	0.21436
	0.0038	0.9826	**0.0002**	0.2481	0.0783	0.2930
CR	**0.44646**	0.23323	-0.33794	0.13731	**0.65525**	**-0.57435**
	0.0222	0.2515	0.0913	0.5036	**0.0003**	**0.0022**
CU	**0.63329**	0.15197	-0.34757	-0.14905	**0.57980**	-0.20787
	0.0005	0.4586	0.0819	0.4674	**0.0019**	0.3082
V	**0.58026**	0.13406	-0.29626	-0.13346	**0.48895**	-0.19621
	0.0019	0.5138	0.1417	0.5157	**0.0113**	0.3367
ZN	**0.50248**	0.33214	-0.06851	0.07344	**0.40597**	-0.14913
	0.0089	0.0974	0.7395	0.7214	**0.0396**	0.4672

*The top number of each interaction grouping is the correlation coefficient (R).
The second (lower) number is the statistical significance (P) of the correlation
All statistically significant interactions ($P<0.05$) are highlighted

Table 5.14 Pearson Correlation Coefficients for the Interaction of Sediment and Hydrocarbon Parameters for 1989 Sediment Data.

	Year 4 (1989)					
	TOTPAH	FFPI	LALK/TALK	PRYS/PHYT	ISO/ALK	OEPI
CD	-0.00851	0.13430	0.11001	-0.06158	-0.03845	-0.22600
	0.9678	0.5221	0.6006	0.7700	0.8552	0.2774
PB	-0.00831	0.37274	**0.48653**	0.09268	0.31608	-0.23310
	0.9685	0.0665	**0.0137**	0.6595	0.1237	0.2621
BA	0.13498	-0.05244	0.15449	**0.56594**	**0.54052**	0.14289
	0.5200	0.8034	0.4609	**0.0032**	**0.0053**	0.4956
CR	0.04937	00.08967	0.14823	**0.48176**	**0.47009**	-0.01704
	0.8147	0.6699	0.4795	**0.0147**	**0.0177**	0.9356
CU	-0.03333	**0.46418**	0.24343	-0.11749	0.10498	-0.16963
	0.8743	**0.0194**	0.2410	0.5760	0.6175	0.4176
V	-0.18024	**0.56880**	**0.45530**	0.00856	0.19797	-0.27106
	0.3886	**0.0030**	**0.0222**	0.9676	0.3428	0.1900
ZN	-0.25102	**0.49689**	0.16482	-0.13390	-0.02037	-0.19877
	0.2262	**0.0115**	0.4311	0.5234	0.9230	0.3408

*The top number of each interaction grouping is the correlation coefficient (R).
The second (lower) number is the statistical significance (P) of the correlation
All statistically significant interactions ($P<0.05$) are highlighted

6.0 Summary and Conclusions

6.1 Program Design

- Beaufort Sea stations were reoccupied during 1989 after a 3 year sampling hiatus
- The monitoring program built upon approaches developed, and reported in Boehm et al., 1987
- Differences included:
  1. Increasing sampling efficiency by pooling station replicates
  2. Sampling in a new region (Griffin Point, Region 9), east of Barter Island
  3. Creating a new transect at Endicott Development, called Endicott Development Island (Region 8).
- The design included combining an <u>area wide</u> approach, in which regions, composed of sampling stations were studied; an <u>activity-specific</u> approach, where specific drilling and production activities are monitored through a gradient approach.

6.2 Field Program

- The field program was completed successfully. Important factors contributing to its success were adequate lead time, the use of Global Positioning Navigational Systems (GPS) and the ability to refuel at Barter Island, before heading further to the east.
- The air lift system proved to be unsuccessful in collecting bivalves of sufficient number. A high-volume-lower-pressure air compressor may make the air lift system a viable option in future monitoring efforts.
- The Modified Van Veen Grab proved successful in providing undisturbed sediment and organism samples
- 49 Stations from the Harrison Bay Region to Griffin Point, east of Barter Island, were sampled.

6.3 Analytical Procedures

- Analytical methods provided precise, quantitative trace metal and hydrocarbon data.

- Improved instrumental sensitivity of GCMS analyses of PAH compounds was provided by the use of selected ion monitoring (SIM).

- Differences in the concentrations of metals and hydrocarbons between the 1989 analysis of an archived 1986 sample and the analyses performed in 1986 were due in part to different analytical procedures, which are felt to provide improved results in 1989.

- For metals, values for Cd, Cr, Cu and Pb from 1986 agreed to within 10% of the 1989 concentrations and provided a good basis for long term comparability. Values for Ba, V and Zn were 19 - 28% lower for the 1986 measurements than for the 1989 measurements. For PAHs, concentrations of the parent compounds were in close agreement between the two years, with the exception of perylene, which is susceptible to photo oxidation. Concentrations of the alkyl homologue series for naphthalenes and phenanthrenes were higher by a factor of two in the 1989 analysis. Concentrations of individual alkanes as well as TOT were 40 - 50% lower in the 1989 analysis than in the 1986 analysis. Reasons for these discrepancies were discussed in sections 4 and 5.

- To avoid problems with comparability, it is recommended that in the future, three archived samples be utilized, analyzed in triplicate. Also, for calibrating different analytical techniques, such as ICP and XRF, more than one reference material should be used. Correcting for percent recoveries, based upon spiked blanks may be a way to correct for interlaboratory differences in instrumental methods, such as the calculation of the UCM, discussed in section 5.

- Samples should be archived in liquid N_2 to improve the ability to conduct these retrospective analyses.

6.3.1 Metal Chemistry

- Sediment concentrations of metals were characterized by relative homogeneity across all regions.

- Regional mean concentrations of metals in sediments from 1989 were in close agreement to concentrations from 1984 - 1986.

- Systematically higher concentrations of Ba (+200 ppm) and V (+20 ppm to +40 ppm) in sediments were observed in 1989. These are believed to be due to different preparation and instrumental methods between the two years. The Ba offset is believed to be related to difficulties with calibration of the ICP in the 1986 work. The V offset may be related to subtle differences in the sieving and acid digestion techniques. To avoid these offsets in the future it is recommend (1) that sieving be carried out until no visible material passes through the sieve, (2) that digestion of sediment be complete with no visible residue, and (3) that more than one SRM be used to calibrate a different analytical technique, as mentioned above.

- Metal concentrations in organisms showed relatively uniform trends from site to site.

- Differences that were detected between sites, such as Ba and Cd in Astarte, were slight and believed to be due differences in bioavailability of these metals.

- There was good agreement between metals concentrations in organisms for the 1989 dataset and those from previous years when the prior (1986) values were correctly expressed on a dry weight basis. These combined datasets provide a good baseline for future monitoring.

6.3.2 Hydrocarbon Chemistry

- Concentrations of saturated and aromatic hydrocarbons in sediments from the study area were relatively high compared to other OCS sediments.

- Regional differences were seen in both saturated and aromatic hydrocarbon sediment concentrations, the highest concentrations being found in Region 4 (East Harrison Bay), near the mouth of the Colville River and the lowest concentrations found in Region 7 (Griffin Point), east of Barter Island.

- Differences between regions were attributed to natural depositional processes; key diagnostic ratios did not indicate the effects of oil-drilling related inputs.

- The sediment composition of saturates was characterized by high molecular weight hydrocarbons, with a marked odd-even preference, indicative of terrestrial biogenic input combined with lesser quantities of lower molecular weight petrogenic alkanes. The aromatic composition of sediments was characterized by a predominance of naphthalenes and phenanthrenes, indicative of an area-wide input of fossil hydrocarbons, and a general scarcity of pyrogenic PAH compounds.

- Tissue concentrations of hydrocarbons did not reveal significant regional trends and indicated the presence of very low levels of aromatics.

- Comparison of 1989 PAH concentrations with 1984 - 1986 values did not reveal any consistent trends. For some species, higher concentrations may be the result of increased instrumental sensitivity.

6.4 Statistical Analysis

- Results of the statistical analysis of sediments confirmed the observed trends.

- Due to the sensitivity of the ANOVA test, coupled with the large degrees of freedom, significant yearly differences were detected between stations and regions.

- When Year 4 regional means were compared with the regional means from 1984 -1986 for hydrocarbon and metals parameters, significant differences were seen in the pattern of the variation for only a few variables. While significant differences were observed for some parameters (TOT, TPAH and N/P), the lack of consistency in this change across several diagnostic parameters suggests that there was no significant change in the sediment chemistry of hydrocarbons or metals, outside of the normal pattern of random variation.

- Correlation analysis and analysis of covariance of hydrocarbon and metals variables across the 1985, 1986 and 1989 datasets revealed some correlation between hydrocarbons and metals. However, the lack of strong trends made it difficult to attribute this to source related inputs, such as drilling mud discharges.

6.5 Recommendations

- Return to area every 3 years, as recommended in the Beaufort Sea Monitoring Workshop.

- Focus sampling activities on regions with active drilling.

- Use sampling and analytical approaches previously developed for BSMP. An exception to this is the use of ICP for metals analysis.

- Use interpretive approaches (concentrations to test Ho_1, ratios to test Ho_2).

APPENDIX I

Concentrations of Saturated Hydrocarbons, Polycyclic Aromatic Hydrocarbons, and Metals in Beaufort Sea Sediments from 1989

SATURATED HYDROCARBONS IN 1989 SURFACE SEDIMENTS (ug/g)

LABSAMP	STATION	REGION	REP	nC10	nC11	nC12	nC13	1380	nC14	1470	nC15	nC16	1650	nC17	pristane	nC18	phytane	nC19	nC20
1A-SS-P F1	1A	1	1	0.0078	0.0063	0.0096	0.016	0.0046	0.015	0.0087	0.021	0.021	0.0077	0.049	0.021	0.03	0.015	0.057	0.052
1B-SS-P F1	1B	1	1	0.0014	0.0016	0.0024	0.0039	0.00099	0.0049	0.0025	0.0092	0.0068	0.0025	0.0096	0.0083	0.007	0.0046	0.0086	0.0087
1C-SS-P F1	1C	1	1	0.0016	0.0036	0.0072	0.016	0.006	0.023	0.015	0.035	0.04	0.017	0.058	0.047	0.044	0.036	0.049	0.058
1D-SS-P	1D	1	1	0.0033	0.0016	0.0035	0.0031	0.0013	0.01	0.0019	0.0084	0.0046	0.0021	0.023	0.0042	0.011	0.0028	0.026	0.023
1-E-SS-2 F1	1E	1	2	0.0032	0.0042	0.0066	0.0069	0.0016	0.0066	0.0041	0.011	0.0095	0.0023	0.0035	0.004	0.021	0.0049	0.055	0.045
1-E-SS-3 F1	1E	1	3	0.003	0.0033	0.0062	0.01	0.0025	0.0092	0.0061	0.016	0.014	0.0034	0.0039	0.0065	0.033	0.0074	0.088	0.072
1-E-SS-4 F1	1E	1	4	0.0021	0.0039	0.0041	0.0077	0.0021	0.0074	0.0068	0.018	0.015	0.0024	0.0073	0.0069	0.038	0.0074	0.11	0.09
2A-SS-P	2A	1	1	0.0052	0.019	0.048	0.1	0.032	0.11	0.061	0.14	0.13	0.044	0.23	0.11	0.14	0.066	0.2	0.16
2B-SS-P F1	2B	1	1	0.0053	0.0061	0.0065	0.0085	0.0021	0.0097	0.0046	0.012	0.011	0.0035	0.016	0.01	0.012	0.0057	0.014	0.014
2C-SS-P-2	2C	1	2	0.0144	0.026	0.0302	0.0414	0.0114	0.0521	0.0269	0.0683	0.0692	0.0264	0.0893	0.0696	0.076	0.0551	0.0881	0.087
2D-SS-P F1	2D	1	1	0.01	0.0075	0.011	0.012	0.0035	0.014	0.0063	0.019	0.015	0.0054	0.022	0.015	0.017	0.0091	0.021	0.019
2E-SS-P F1	2E	1	1	0.0017	0.0028	0.0031	0.0042	0.0013	0.0048	0.0026	0.0065	0.0064	0.0023	0.008	0.0043	0.0065	0.0032	0.008	0.0085
2F-SS-P F1	2F	1	1	0.0047	0.0077	0.01	0.015	0.0042	0.016	0.0081	0.02	0.02	0.0069	0.026	0.015	0.02	0.0095	0.023	0.023
3A-SS-P	3A	2	1	0.016	0.018	0.03	0.044	0.012	0.055	0.027	0.069	0.067	0.024	0.11	0.063	0.075	0.041	0.095	0.087
3B-SS-2 F1	3B	2	2	0.017	0.022	0.029	0.039	0.0098	0.04	0.019	0.045	0.045	0.015	0.065	0.038	0.048	0.024	0.059	0.057
3B-SS-3 F1	3B	2	3	0.012	0.018	0.025	0.036	0.0093	0.036	0.018	0.043	0.041	0.014	0.061	0.035	0.045	0.023	0.056	0.055
3B-SS-4 F1	3B	2	4	0.014	0.022	0.027	0.039	0.0098	0.038	0.018	0.044	0.043	0.015	0.062	0.036	0.046	0.023	0.058	0.055
4A-SS-P	4A	2	1	0.0035	0.0036	0.0077	0.013	0.0039	0.017	0.0092	0.023	0.024	0.0078	0.041	0.02	0.028	0.013	0.039	0.034
4C-SS-P	4C	2	1	0.001	0.00089	0.0022	0.0023	0.00081	0.0038	0.0019	0.006	0.0066	0.0022	0.01	0.0071	0.0069	0.0033	0.0088	0.0086
5H-SS-P	5H	2	1	0.008	0.0087	0.013	0.015	0.0049	0.02	0.011	0.027	0.029	0.0099	0.044	0.025	0.032	0.015	0.041	0.037
5A-SS-2 F1	5A	3	2	0.0057	0.0094	0.012	0.017	0.005	0.02	0.011	0.025	0.025	0.0085	0.037	0.022	0.027	0.012	0.036	0.035
5A-SS-3 F1	5A	3	3	0.0037	0.006	0.01	0.017	0.0044	0.019	0.0098	0.023	0.024	0.0082	0.036	0.022	0.026	0.012	0.035	0.034
5A-SS-4 F1	5A	3	4	0.00037	0.00048	0.0012	0.003	0.0011	0.0056	0.0035	0.0094	0.011	0.0039	0.016	0.01	0.012	0.0057	0.016	0.016
5B-SS-P-2 F1	5B	3	2	0.0012	0.0015	0.0026	0.0029	0.0004	0.0057	0.0016	0.0037	0.0034	0.0017	0.0049	0.0041	0.0044	0.0018	0.0053	0.0048
5D-SS-P	5D	3	1	0.024	0.035	0.05	0.074	0.021	0.079	0.045	0.087	0.087	0.029	0.17	0.074	0.1	0.043	0.18	0.15
5E-SS-P	5E	3	1	0.013	0.02	0.025	0.04	0.011	0.054	0.026	0.064	0.061	0.022	0.08	0.06	0.065	0.033	0.076	0.072
5F-SS-P	5F	3	1	0.011	0.017	0.022	0.036	0.0095	0.041	0.024	0.049	0.053	0.017	0.088	0.041	0.059	0.022	0.094	0.084
5G-SS-P F1	5G	3	1	0.0033	0.0041	0.0052	0.0082	0.0023	0.01	0.0057	0.015	0.015	0.0056	0.024	0.016	0.017	0.0091	0.022	0.024
6A-SS-P F1	6A	4	1	0.0048	0.0049	0.0071	0.01	0.0033	0.014	0.0081	0.016	0.019	0.0064	0.025	0.017	0.021	0.01	0.027	0.027
6B-SS-P-2	6B	4	1	0.027	0.06	0.11	0.19	0.061	0.22	0.14	0.27	0.27	0.093	0.33	0.23	0.3	0.13	0.39	0.35
6C-SS-P F1	6C	4	1	0.0015	0.0011	0.0025	0.0025	0.00076	0.0041	0.002	0.0048	0.006	0.0023	0.0071	0.0058	0.006	0.0031	0.0068	0.0073
6D-SS-2	6D	4	2	0.01	0.0099	0.019	0.021	0.0064	0.038	0.014	0.034	0.033	0.013	0.045	0.033	0.037	0.017	0.045	0.043
6D-SS-3	6D	4	3	0.0027	0.0058	0.0093	0.016	0.0043	0.026	0.01	0.023	0.024	0.0088	0.032	0.025	0.027	0.012	0.033	0.031
6D-SS-4	6D	4	4	0.0034	0.0071	0.015	0.023	0.0074	0.031	0.016	0.039	0.039	0.015	0.052	0.038	0.044	0.02	0.055	0.051
6F-SS-P F1	6F	4	1	0.0014	0.00027	0.0037	0.0021	0.00074	0.0056	0.0025	0.0048	0.0072	0.0029	0.0083	0.0063	0.0079	0.004	0.0092	0.01
6G-SS-P-2 F1	6G	4	1	0.044	0.047	0.068	0.098	0.029	0.1	0.061	0.11	0.11	0.04	0.16	0.097	0.13	0.057	0.2	0.66
7A-SS-P F1	7A	5	1	0.018	0.023	0.028	0.035	0.0098	0.034	0.02	0.038	0.038	0.014	0.048	0.036	0.043	0.021	0.057	0.052
7B-SS-2 F1	7B	5	2	0.0097	0.013	0.015	0.018	0.0065	0.022	0.013	0.025	0.026	0.01	0.033	0.026	0.03	0.013	0.039	0.038
7B-SS-3 F1	7B	5	3	0.004	0.0071	0.0096	0.013	0.0044	0.015	0.0088	0.017	0.019	0.0071	0.024	0.018	0.021	0.0093	0.027	0.027
7B-SS-4 F1	7B	5	4	0.0048	0.008	0.012	0.013	0.0048	0.017	0.0095	0.019	0.02	0.0077	0.025	0.019	0.023	0.01	0.03	0.029
7C-SS-P	7C	5	1	0.021	0.025	0.045	0.075	0.021	0.084	0.046	0.1	0.1	0.036	0.14	0.098	0.12	0.054	0.15	0.14
7D-SS-P	7D	5	1	0.011	0.021	0.027	0.039	0.011	0.046	0.023	0.051	0.052	0.017	0.071	0.049	0.058	0.024	0.079	0.072
7E-SS-P	7E	5	1	0.019	0.03	0.047	0.071	0.024	0.082	0.053	0.097	0.099	0.037	0.14	0.12	0.12	0.055	0.17	0.16
7G-SS-P	7G	5	1	0.005	0.0099	0.018	0.03	0.015	0.046	0.038	0.047	0.05	0.024	0.06	0.1	0.062	0.025	0.071	0.064
8A-SS-2	8A	8	2	0.012	0.015	0.02	0.027	0.0072	0.028	0.015	0.034	0.035	0.012	0.054	0.029	0.037	0.017	0.051	0.045
8A-SS-3	8A	8	3	0.0045	0.0055	0.01	0.018	0.0051	0.022	0.013	0.029	0.031	0.011	0.049	0.028	0.034	0.015	0.05	0.051

SATURATED HYDROCARBONS IN 1989 SURFACE SEDIMENTS (ug/g)

LABSAMP	STATION	REGION	REP	nC10	nC11	nC12	nC13	1380	nC14	1470	nC15	nC16	1650	nC17	pristane	nC18	phytane	nC19	nC20
8A-SS-4	8A	8	4	0.01	0.017	0.026	0.039	0.011	0.044	0.023	0.053	0.053	0.017	0.086	0.045	0.055	0.026	0.078	0.067
8B-SS-2	8B	8	2	0.0012	0.0022	0.0047	0.0055	0.0021	0.0089	0.0045	0.011	0.013	0.0045	0.02	0.011	0.014	0.0062	0.019	0.017
8B-SS-3	8B	8	3	0.0014	0.0019	0.0043	0.0042	0.0018	0.0073	0.0041	0.0093	0.011	0.0038	0.018	0.0093	0.012	0.0052	0.016	0.013
8B-SS-4	8B	8	4	0.0015	0.0018	0.003	0.0028	0.0014	0.0044	0.0021	0.0049	0.0062	0.002	0.0096	0.0048	0.0062	0.0028	0.0082	0.0076
8C-SS-2	8C	8	2	0.0073	0.00021	0.00053	0.0015	0.00097	0.0019		0.0014	0.0029		0.0034	0.0017	0.0032	0.00062	0.0029	0.0025
8C-SS-3	8C	8	3	0.0053	0.0013	0.00095	0.0018	0.00035	0.0018	0.0013	0.0024	0.0025	0.00074	0.0038	0.0019	0.0031	0.002	0.0033	0.0034
8C-SS-4	8C	8	4		0.0022	0.0044	0.0017	0.00051	0.0042	0.0013	0.0022	0.0044	0.0019	0.0044	0.0018	0.0031	0.0016	0.0034	0.004
8D-SS-2	8D	8	2	0.00014	0.00029	0.00018	0.0004	0.00018	0.00027	0.00016	0.00052	0.0014	0.00065	0.0025	0.0012	0.0022	0.001	0.0027	0.0027
8D-SS-3	8D	8	3	0.0019	0.0025	0.0038	0.0013	0.00064	0.0026	0.0013	0.0016	0.0028	0.00095	0.0037	0.0019	0.0028	0.0026	0.003	0.0033
8D-SS-4	8D	8	4	0.002	0.00081	0.0013	0.0013	0.00051	0.0014	0.00061	0.0015	0.002	0.00066	0.0029	0.0015	0.0022	0.0011	0.0027	0.0024
8E-SS-2	8E	8	2	0.029	0.027	0.043	0.059	0.017	0.068	0.036	0.081	0.08	0.026	0.13	0.065	0.083	0.037	0.12	0.1
8E-SS-3	8E	8	3	0.024	0.028	0.043	0.067	0.02	0.075	0.042	0.093	0.092	0.031	0.15	0.077	0.097	0.044	0.14	0.12
8E-SS-4	8E	8	4	0.024	0.03	0.047	0.073	0.018	0.079	0.043	0.095	0.091	0.031	0.16	0.077	0.098	0.043	0.14	0.12
8F-SS-2	8F	8	2	0.0034	0.0044	0.0078	0.012	0.0034	0.015	0.0078	0.02	0.021	0.0073	0.033	0.018	0.023	0.01	0.031	0.027
8F-SS-3	8F	8	3	0.0046	0.0059	0.0096	0.012	0.0035	0.015	0.0081	0.018	0.019	0.0061	0.028	0.015	0.019	0.0082	0.025	0.021
8F-SS-4	8F	8	4	0.0057	0.0059	0.013	0.015	0.005	0.019	0.009	0.022	0.023	0.0082	0.037	0.019	0.025	0.011	0.033	0.03
5(0)-SS-2	5(0)	6	2	0.012	0.021	0.028	0.033	0.0081	0.034	0.017	0.04	0.04	0.013	0.064	0.032	0.041	0.018	0.053	0.046
5(0)-SS-3	5(0)	6	3	0.012	0.013	0.019	0.026	0.0065	0.029	0.015	0.035	0.035	0.012	0.056	0.028	0.037	0.016	0.048	0.042
5(0)-SS-4	5(0)	6	4	0.018	0.015	0.02	0.031	0.0083	0.035	0.018	0.043	0.043	0.014	0.069	0.035	0.045	0.02	0.059	0.05
5(1)-SS-2	5(1)	6	2	0.0082	0.0021	0.0036	0.0034	0.0016	0.011	0.0025	0.0053	0.0055	0.0021	0.0093	0.0051	0.0068	0.0033	0.0088	0.0084
5(1)-SS-3	5(1)	6	3	0.0052	0.0011	0.0031	0.0018	0.00085	0.0049	0.0018	0.0032	0.0044	0.0013	0.006	0.0036	0.0043	0.0021	0.0056	0.0058
5(1)-SS-4	5(1)	6	4	0.0054	0.0018	0.0032	0.0019	0.00058	0.0054	0.0012	0.003	0.0042	0.0013	0.0057	0.0035	0.0041	0.0022	0.0051	0.0056
5(5)-SS-2	5(5)	6	2	0.0101	0.013	0.0167	0.0213	0.0053	0.0302	0.0124	0.0291	0.0325	0.0106	0.0447	0.0244	0.0329	0.015	0.0445	0.0415
5(5)-SS-3	5(5)	6	3	0.0039	0.0078	0.01	0.02	0.0057	0.026	0.014	0.036	0.034	0.012	0.055	0.031	0.038	0.017	0.05	0.044
5(5)-SS-4	5(5)	6	4	0.014	0.0078	0.013	0.018	0.0053	0.022	0.012	0.028	0.029	0.0093	0.044	0.025	0.03	0.013	0.039	0.035
5(10)-SS-P F1	5(10)	6	1	0.0046	0.0066	0.011	0.016	0.005	0.022	0.011	0.027	0.027	0.0097	0.045	0.026	0.031	0.015	0.042	0.039
9A-SS-2	9A	7	2		0.0016	0.0017	0.0014		0.0088	0.00056	0.0029	0.0022	0.0014	0.0047	0.0021	0.0034	0.0024	0.0033	0.0049
9A-SS-3	9A	7	3	0.0069	0.0061	0.008	0.0072	0.00037	0.01	0.00056	0.0091	0.0093	0.00037	0.011	0.0095	0.01	0.0095	0.011	0.011
9A-SS-4	9A	7	4	0.0066	0.0012	0.0012	0.0013		0.0069	0.00061	0.0027	0.002	0.00035	0.0036	0.0021	0.0023	0.002	0.0035	0.0042
9B-SS-2	9B	7	2	0.0026	0.0013	0.003	0.0036	0.001	0.0075	0.0028	0.008	0.0067	0.0025	0.0104	0.0076	0.0083	0.0057	0.0106	0.0117
9B-SS-3 F1	9B	7	3	0.0019	0.00071	0.0042	0.0021	0.00057	0.0049	0.0016	0.0048	0.0056	0.0021	0.0082	0.0074	0.0064	0.0044	0.0081	0.0089
9B-SS-4 F1	9B	7	4	0.0011	0.0014	0.0015	0.0024	0.00058	0.0029	0.0015	0.0049	0.0045	0.0017	0.0067	0.0099	0.0048	0.0035	0.0062	0.0075
9C-SS-2	9C	7	2	0.0072	0.012	0.016	0.023	0.0062	0.036	0.015	0.037	0.035	0.014	0.06	0.04	0.042	0.029	0.056	0.052
9C-SS-3	9C	7	3	0.0038	0.007	0.013	0.026	0.0061	0.034	0.016	0.04	0.04	0.015	0.069	0.045	0.047	0.032	0.068	0.06
9C-SS-4	9C	7	4	0.011	0.0085	0.014	0.022	0.0066	0.03	0.016	0.039	0.037	0.014	0.064	0.043	0.044	0.03	0.06	0.055

VALUES BELOW INSTRUMENAL
DETECTION LIMITS (ND) ARE
INDICATED BY BLANK SPACES

SATURATED HYDROCARBONS IN 1989 SURFACE SEDIMENTS (ug/g)

LABSAMP	STATION	REGION	REP	nC21	nC22	nC23	nC24	nC25	nC26	nC27	nC28	nC29	nC30	nC31	nC32	nC33	nC34	PHC	LALK
1A-SS-P F1	1A	1	1	0.14	0.093	0.25	0.09	0.3	0.067	0.46	0.052	0.36	0.045	0.3	0.021	0.078	0.0078	5.7	0.28
1B-SS-P F1	1B	1	1	0.017	0.013	0.027	0.015	0.033	0.013	0.045	0.011	0.032	0.0082	0.023	0.0044	0.0071	0.0025	0.86	0.06
1C-SS-P F1	1C	1	1	0.096	0.096	0.16	0.13	0.22	0.15	0.26	0.14	0.22	0.11	0.16	0.06	0.062	0.028	8.9	0.34
1D-SS-P	1D	1	1	0.067	0.047	0.11	0.046	0.12	0.037	0.19	0.028	0.15	0.018	0.12	0.01	0.033	0.0031	1.5	0.12
1-E-SS-2 F1	1E	1	2	0.15	0.095	0.27	0.082	0.27	0.057	0.37	0.038	0.26	0.026	0.21	0.014	0.055	0.0045	3.8	0.17
1-E-SS-3 F1	1E	1	3	0.25	0.15	0.44	0.13	0.43	0.086	0.6	0.06	0.47	0.042	0.39	0.023	0.1	0.0065	6.6	0.26
1-E-SS-4 F1	1E	1	4	0.33	0.2	0.6	0.18	0.71	0.11	1.1	0.074	0.61	0.047	0.45	0.027	0.11	0.0068	7.9	0.30
2A-SS-P	2A	1	1	0.36	0.25	0.59	0.22	0.64	0.17	0.9	0.13	0.8	0.092	0.68	0.055	0.2	0.025	18	1.28
2B-SS-P F1	2B	1	1	0.028	0.027	0.048	0.036	0.06	0.039	0.081	0.036	0.066	0.025	0.044	0.014	0.017	0.0073	1.5	0.12
2C-SS-P-2	2C	1	2	0.141	0.1108	0.2042	0.105	0.2399	0.0837	0.3247	0.0735	0.3244	0.0484	0.2682	0.0278	0.0904	0.0182	9.68	0.64
2D-SS-P F1	2D	1	1	0.037	0.028	0.06	0.027	0.068	0.021	0.097	0.015	0.076	0.0095	0.057	0.0057	0.017	0.0029	2.2	0.17
2E-SS-P F1	2E	1	1	0.015	0.015	0.026	0.019	0.031	0.019	0.042	0.016	0.034	0.011	0.023	0.0062	0.0087	0.0036	1.1	0.06
2F-SS-P F1	2F	1	1	0.046	0.044	0.082	0.056	0.11	0.055	0.14	0.045	0.099	0.03	0.065	0.017	0.023	0.0091	3.1	0.19
3A-SS-P	3A	2	1	0.17	0.13	0.29	0.14	0.36	0.11	0.47	0.089	0.4	0.057	0.31	0.031	0.096	0.017	10	0.67
3B-SS-2 F1	3B	2	2	0.11	0.084	0.19	0.082	0.22	0.064	0.32	0.048	0.27	0.034	0.2	0.02	0.066	0.01	4.4	0.47
3B-SS-3 F1	3B	2	3	0.11	0.084	0.19	0.085	0.23	0.069	0.31	0.054	0.27	0.04	0.2	0.023	0.066	0.011	5.8	0.43
3B-SS-4 F1	3B	2	4	0.11	0.082	0.19	0.079	0.22	0.059	0.32	0.046	0.27	0.036	0.2	0.019	0.064	0.0088	5.2	0.45
4A-SS-P	4A	2	1	0.082	0.058	0.16	0.059	0.17	0.049	0.23	0.039	0.21	0.028	0.15	0.015	0.053	0.0076	3.8	0.23
4C-SS-P	4C	2	1	0.018	0.018	0.033	0.021	0.037	0.019	0.046	0.015	0.038	0.0088	0.027	0.0053	0.01	0.003	0.61	0.06
5H-SS-P	5H	2	1	0.074	0.056	0.13	0.054	0.15	0.041	0.2	0.032	0.17	0.022	0.13	0.011	0.042	0.0065	3.6	0.27
5A-SS-2 F1	5A	3	2	0.074	0.058	0.13	0.062	0.14	0.053	0.18	0.041	0.14	0.034	0.11	0.019	0.039	0.0098	3.6	0.25
5A-SS-3 F1	5A	3	3	0.072	0.058	0.13	0.064	0.14	0.056	0.19	0.046	0.15	0.031	0.11	0.019	0.04	0.0089	3.6	0.23
5A-SS-4 F1	5A	3	4	0.034	0.028	0.063	0.033	0.066	0.028	0.078	0.022	0.059	0.016	0.043	0.0091	0.014	0.0042	1.7	0.09
5B-SS-P-2 F1	5B	3	2	0.009	0.0077	0.0162	0.0081	0.0178	0.0067	0.0227	0.0053	0.0202	0.0036	0.0153	0.0016	0.0056	0.0011	0.255	0.04
5D-SS-P	5D	3	1	0.43	0.29	0.82	0.28	0.93	0.21	1.2	0.15	0.84	0.11	0.64	0.094	0.21	0.03	19	1.04
5E-SS-P	5E	3	1	0.12	0.096	0.21	0.091	0.21	0.07	0.26	0.054	0.23	0.033	0.17	0.018	0.062	0.012	6.8	0.57
5F-SS-P	5F	3	1	0.22	0.16	0.43	0.16	0.46	0.12	0.6	0.089	0.48	0.059	0.39	0.031	0.14	0.017	8.6	0.55
5G-SS-P F1	5G	3	1	0.053	0.045	0.092	0.056	0.11	0.057	0.14	0.049	0.11	0.036	0.073	0.019	0.026	0.0096	3.3	0.15
6A-SS-P F1	6A	4	1	0.06	0.044	0.12	0.045	0.11	0.034	0.13	0.027	0.091	0.017	0.064	0.0096	0.022	0.0047	2.3	0.18
6B-SS-P-2	6B	4	1	0.79	0.61	2	0.57	1.7	0.43	2.1	0.35	1.7	0.25	1.4	0.13	0.5	0.059	38	2.52
6C-SS-P F1	6C	4	1	0.013	0.01	0.023	0.011	0.021	0.0081	0.023	0.0057	0.017	0.0039	0.011	0.002	0.0041	0.00084	0.72	0.05
6D-SS-2	6D	4	2	0.076	0.06	0.14	0.057	0.13	0.04	0.16	0.031	0.14	0.018	0.1	0.01	0.036	0.0044	2.2	0.33
6D-SS-3	6D	4	3	0.063	0.052	0.11	0.054	0.12	0.045	0.15	0.037	0.13	0.021	0.093	0.013	0.033	0.0081	1.8	0.23
6D-SS-4	6D	4	4	0.092	0.073	0.16	0.07	0.16	0.051	0.2	0.039	0.17	0.021	0.12	0.013	0.043	0.0064	2.6	0.36
6F-SS-P F1	6F	4	1	0.018	0.016	0.034	0.017	0.033	0.014	0.035	0.011	0.027	0.0079	0.019	0.0044	0.0069	0.0023	0.47	0.06
6G-SS-P-2 F1	6G	4	1	0.47	0.34	1	0.32	1	0.23	1.3	0.17	0.98	0.13	0.8	0.071	0.27	0.026	21	1.73
7A-SS-P F1	7A	5	1	0.13	0.094	0.3	0.09	0.29	0.069	0.36	0.051	0.27	0.037	0.19	0.021	0.07	0.0093	5.9	0.41
7B-SS-2 F1	7B	5	2	0.078	0.06	0.15	0.055	0.14	0.042	0.19	0.03	0.14	0.019	0.1	0.011	0.036	0.0056	3.6	0.27
7B-SS-3 F1	7B	5	3	0.058	0.052	0.11	0.062	0.12	0.061	0.15	0.053	0.13	0.036	0.084	0.02	0.035	0.01	2.6	0.18
7B-SS-4 F1	7B	5	4	0.058	0.045	0.11	0.041	0.1	0.03	0.13	0.021	0.1	0.013	0.074	0.0082	0.027	0.0045	2.5	0.20
7C-SS-P	7C	5	1	0.27	0.21	0.5	0.19	0.5	0.14	0.66	0.11	0.55	0.072	0.41	0.036	0.14	0.02	12	1.00
7D-SS-P	7D	5	1	0.16	0.12	0.31	0.11	0.29	0.079	0.39	0.056	0.32	0.035	0.24	0.019	0.081	0.0071	5.8	0.53
7E-SS-P	7E	5	1	0.36	0.27	0.8	0.27	0.93	0.19	1.3	0.14	0.85	0.1	0.61	0.057	0.21	0.023	16	1.04
7G-SS-P	7G	5	1	0.11	0.092	0.23	0.092	0.23	0.063	0.23	0.047	0.18	0.026	0.13	0.021	0.074	0.0085	6	0.46
8A-SS-2	8A	8	2	0.1	0.079	0.19	0.085	0.22	0.072	0.31	0.058	0.26	0.045	0.2	0.025	0.072	0.013	5.6	0.36
8A-SS-3	8A	8	3	0.11	0.074	0.19	0.072	0.22	0.052	0.31	0.047	0.28	0.03	0.2	0.015	0.063	0.0042	6.8	0.30

SATURATED HYDROCARBONS IN 1989 SURFACE SEDIMENTS (ug/g)

LABSAMP	STATION	REGION	REP	nC21	nC22	nC23	nC24	nC25	nC26	nC27	nC28	nC29	nC30	nC31	nC32	nC33	nC34	PHC	LALK
8A-SS-4	8A	8	4	0.16	0.13	0.31	0.14	0.39	0.13	0.51	0.1	0.4	0.077	0.3	0.046	0.11	0.024	9.6	0.53
8B-SS-2	8B	8	2	0.036	0.029	0.066	0.029	0.078	0.023	0.1	0.018	0.082	0.012	0.06	0.0069	0.023	0.0044	1.1	0.12
8B-SS-3	8B	8	3	0.031	0.025	0.058	0.028	0.068	0.024	0.089	0.019	0.073	0.013	0.054	0.007	0.02	0.0039	1	0.10
8B-SS-4	8B	8	4	0.018	0.017	0.034	0.022	0.042	0.024	0.05	0.02	0.042	0.012	0.03	0.0077	0.012	0.0044	0.72	0.06
8C-SS-2	8C	8	2	0.0053	0.0062	0.0096	0.011	0.012	0.01	0.015	0.0092	0.011	0.0083	0.007	0.0035	0.0037	0.0033	0.28	0.03
8C-SS-3	8C	8	3	0.0052	0.0042	0.0072	0.0049	0.0073	0.0033	0.01	0.0025	0.0083	0.0021	0.0061	0.001	0.0025	0.0016	0.19	0.03
8C-SS-4	8C	8	4	0.0065	0.0071	0.0094	0.0088	0.012	0.0083	0.012	0.0064	0.011	0.0053	0.0062	0.0023	0.0039	0.0026	0.3	0.03
8D-SS-2	8D	8	2	0.0048	0.0039	0.0064	0.0034	0.0065	0.0026	0.0083	0.002	0.0067	0.0015	0.0053	0.0011	0.002	0.00074	0.16	0.01
8D-SS-3	8D	8	3	0.0078	0.011	0.014	0.013	0.018	0.016	0.021	0.014	0.018	0.011	0.012	0.0057	0.0062	0.004	0.36	0.03
8D-SS-4	8D	8	4	0.0051	0.0054	0.0086	0.0071	0.011	0.0075	0.013	0.0064	0.01	0.0039	0.0067	0.0025	0.0034	0.0015	0.19	0.02
8E-SS-2	8E	8	2	0.23	0.16	0.42	0.16	0.49	0.12	0.68	0.085	0.53	0.058	0.4	0.033	0.14	0.017	11	0.82
8E-SS-3	8E	8	3	0.28	0.21	0.54	0.23	0.66	0.19	0.86	0.15	0.68	0.11	0.51	0.062	0.18	0.03	15	0.93
8E-SS-4	8E	8	4	0.28	0.2	0.54	0.21	0.65	0.16	0.88	0.13	0.7	0.096	0.53	0.051	0.19	0.025	15	0.96
8F-SS-2	8F	8	2	0.057	0.047	0.11	0.05	0.13	0.042	0.16	0.036	0.13	0.024	0.096	0.013	0.036	0.0069	3.4	0.20
8F-SS-3	8F	8	3	0.047	0.036	0.085	0.035	0.098	0.026	0.13	0.021	0.11	0.016	0.078	0.0074	0.028	0.0057	2.7	0.18
8F-SS-4	8F	8	4	0.062	0.048	0.11	0.048	0.13	0.038	0.17	0.03	0.14	0.023	0.11	0.012	0.039	0.0053	3.6	0.23
5(0)-SS-2	5(0)	6	2	0.1	0.079	0.19	0.087	0.23	0.077	0.31	0.063	0.26	0.041	0.2	0.025	0.078	0.012	3.3	0.41
5(0)-SS-3	5(0)	6	3	0.088	0.065	0.16	0.066	0.19	0.049	0.26	0.038	0.2	0.026	0.15	0.015	0.058	0.008	4	0.35
5(0)-SS-4	5(0)	6	4	0.11	0.078	0.2	0.077	0.23	0.058	0.31	0.046	0.26	0.034	0.2	0.018	0.074	0.0099	6.5	0.43
5(1)-SS-2	5(1)	6	2	0.017	0.015	0.032	0.018	0.039	0.015	0.048	0.012	0.036	0.0068	0.025	0.0033	0.0074	0.0022	0.59	0.07
5(1)-SS-3	5(1)	6	3	0.012	0.014	0.025	0.021	0.034	0.024	0.04	0.021	0.033	0.013	0.022	0.0069	0.0081	0.0028	0.5	0.05
5(1)-SS-4	5(1)	6	4	0.011	0.012	0.022	0.017	0.027	0.019	0.033	0.016	0.026	0.01	0.018	0.0052	0.0063	0.0018	0.45	0.05
5(5)-SS-2	5(5)	6	2	0.0852	0.0671	0.1588	0.0694	0.1858	0.0549	0.2522	0.0419	0.2244	0.0328	0.1833	0.0171	0.0648	0.0099	2.69	0.32
5(5)-SS-3	5(5)	6	3	0.09	0.07	0.16	0.074	0.18	0.061	0.24	0.052	0.2	0.033	0.16	0.018	0.061	0.01	2.8	0.32
5(5)-SS-4	5(5)	6	4	0.071	0.055	0.13	0.056	0.15	0.046	0.2	0.038	0.17	0.025	0.14	0.014	0.054	0.0078	2.4	0.28
5(10)-SS-P F1	5(10)	6	1	0.077	0.056	0.12	0.051	0.11	0.036	0.13	0.026	0.095	0.018	0.066	0.0097	0.023	0.0054	3.5	0.27
9A-SS-2	9A	7	2	0.014	0.02	0.034	0.035	0.047	0.041	0.053	0.036	0.044	0.022	0.028	0.015	0.013	0.008	0.81	0.03
9A-SS-3	9A	7	3	0.014	0.015	0.02	0.017	0.024	0.019	0.028	0.017	0.024	0.014	0.015	0.0095	0.01	0.0061	0.57	0.10
9A-SS-4	9A	7	4	0.012	0.018	0.031	0.033	0.043	0.039	0.049	0.034	0.04	0.022	0.025	0.012	0.01	0.0052	0.71	0.04
9B-SS-2	9B	7	2	0.0196	0.0159	0.0315	0.0156	0.0385	0.0126	0.0618	0.0107	0.0549	0.0076	0.0467	0.0052	0.0143	0.0019	0.57	0.07
9B-SS-3 F1	9B	7	3	0.016	0.015	0.028	0.017	0.034	0.015	0.046	0.013	0.033	0.0091	0.024	0.0046	0.0077	0.0024	1.1	0.06
9B-SS-4 F1	9B	7	4	0.016	0.019	0.035	0.03	0.047	0.032	0.057	0.026	0.043	0.019	0.031	0.011	0.012	0.0054	1.4	0.04
9C-SS-2	9C	7	2	0.1	0.073	0.16	0.071	0.19	0.053	0.28	0.042	0.25	0.03	0.21	0.017	0.06	0.0079	5.8	0.38
9C-SS-3	9C	7	3	0.13	0.092	0.21	0.092	0.26	0.07	0.38	0.057	0.33	0.044	0.27	0.025	0.08	0.01	6.7	0.41
9C-SS-4	9C	7	4	0.11	0.079	0.17	0.079	0.21	0.057	0.31	0.045	0.28	0.032	0.23	0.019	0.068	0.0084	5.7	0.38

VALUES BELOW INSTRUMENAL
DETECTION LIMITS (ND) ARE
INDICATED BY BLANK SPACES

SATURATED HYDROCARBONS IN 1989 SURFACE SEDIMENTS (ug/g)

LABSAMP	STATION	REGION	REP	TALK	Tot PHC/ Sum Alk	Iso	Iso/Alk	LALK/TALK	PRIS/PHT	OEPI
1A-SS-P F1	1A	1	1	2.55	2.24	0.06	0.32	0.11	1.4	7.6
1B-SS-P F1	1B	1	1	0.32	2.73	0.02	0.40	0.20	1.8	3.6
1C-SS-P F1	1C	1	1	2.23	4.00	0.12	0.53	0.15	1.3	1.8
1D-SS-P	1D	1	1	1.10	1.37	0.01	0.18	0.11	1.5	6.1
1-E-SS-2 F1	1E	1	2	2.07	1.83	0.02	0.23	0.08	0.8	7.9
1-E-SS-3 F1	1E	1	3	3.44	1.92	0.03	0.26	0.08	0.9	8.6
1-E-SS-4 F1	1E	1	4	4.86	1.63	0.03	0.25	0.06	0.9	11.2
2A-SS-P	2A	1	1	6.39	2.82	0.31	0.34	0.20	1.7	6.5
2B-SS-P F1	2B	1	1	0.64	2.33	0.03	0.30	0.18	1.8	2.2
2C-SS-P-2	2C	1	2	2.70	3.58	0.19	0.41	0.24	1.3	4.7
2D-SS-P F1	2D	1	1	0.69	3.19	0.04	0.31	0.24	1.6	5.7
2E-SS-P F1	2E	1	1	0.33	3.33	0.01	0.31	0.18	1.3	2.5
2F-SS-P F1	2F	1	1	1.01	3.08	0.04	0.31	0.18	1.6	2.7
3A-SS-P	3A	2	1	3.34	3.00	0.17	0.35	0.20	1.5	5.0
3B-SS-2 F1	3B	2	2	2.18	2.01	0.11	0.30	0.21	1.6	6.1
3B-SS-3 F1	3B	2	3	2.17	2.67	0.10	0.31	0.20	1.5	5.3
3B-SS-4 F1	3B	2	4	2.15	2.42	0.10	0.30	0.21	1.6	6.3
4A-SS-P	4A	2	1	1.54	2.46	0.05	0.34	0.15	1.5	5.7
4C-SS-P	4C	2	1	0.36	1.71	0.02	0.39	0.16	2.2	2.9
5H-SS-P	5H	2	1	1.39	2.58	0.07	0.33	0.20	1.7	5.8
5A-SS-2 F1	5A	3	2	1.34	2.69	0.06	0.33	0.19	1.8	3.8
5A-SS-3 F1	5A	3	3	1.35	2.67	0.06	0.34	0.17	1.8	3.8
5A-SS-4 F1	5A	3	4	0.59	2.89	0.02	0.41	0.15	1.8	3.1
5B-SS-P-2 F1	5B	3	2	0.18	1.41	0.01	0.32	0.22	2.3	4.1
5D-SS-P	5D	3	1	7.27	2.61	0.21	0.30	0.14	1.7	6.6
5E-SS-P	5E	3	1	2.21	3.08	0.15	0.36	0.26	1.8	4.6
5F-SS-P	5F	3	1	3.91	2.20	0.11	0.30	0.14	1.9	6.1
5G-SS-P F1	5G	3	1	1.02	3.22	0.04	0.38	0.14	1.8	2.6
6A-SS-P F1	6A	4	1	0.95	2.41	0.04	0.37	0.18	1.7	4.2
6B-SS-P-2	6B	4	1	15.11	2.52	0.65	0.37	0.17	1.8	5.5
6C-SS-P F1	6C	4	1	0.20	3.54	0.01	0.39	0.24	1.9	3.4
6D-SS-2	6D	4	2	1.34	1.65	0.08	0.34	0.25	1.9	5.0
6D-SS-3	6D	4	3	1.16	1.55	0.06	0.36	0.20	2.1	4.0
6D-SS-4	6D	4	4	1.58	1.65	0.10	0.38	0.23	1.9	4.9
6F-SS-P F1	6F	4	1	0.31	1.54	0.02	0.40	0.20	1.6	2.8
6G-SS-P-2 F1	6G	4	1	8.83	2.38	0.28	0.33	0.20	1.7	6.5
7A-SS-P F1	7A	5	1	2.40	2.46	0.10	0.33	0.17	1.7	6.1
7B-SS-2 F1	7B	5	2	1.33	2.72	0.07	0.36	0.20	2.0	5.5
7B-SS-3 F1	7B	5	3	1.16	2.23	0.05	0.37	0.16	1.9	2.8
7B-SS-4 F1	7B	5	4	0.96	2.60	0.05	0.36	0.21	1.9	5.4
7C-SS-P	7C	5	1	4.81	2.50	0.26	0.36	0.21	1.8	5.6
7D-SS-P	7D	5	1	2.74	2.11	0.12	0.33	0.19	2.0	6.3
7E-SS-P	7E	5	1	7.15	2.24	0.29	0.41	0.14	2.2	7.5
7G-SS-P	7G	5	1	2.00	3.01	0.20	0.62	0.23	4.0	4.5
8A-SS-2	8A	8	2	2.09	2.68	0.08	0.31	0.17	1.7	4.9
8A-SS-3	8A	8	3	1.97	3.45	0.07	0.36	0.15	1.9	6.7

SATURATED HYDROCARBONS IN 1989 SURFACE SEDIMENTS (ug/g)

LABSAMP	STATION	REGION	REP	TALK	Tot PHC/ Sum Alk	Iso	Iso/Alk	LALK/TALK	PRIS/PHT	OEPI
8A-SS-4	8A	8	4	3.36	2.86	0.12	0.32	0.16	1.7	4.5
8B-SS-2	8B	8	2	0.68	1.61	0.03	0.35	0.17	1.8	5.1
8B-SS-3	8B	8	3	0.61	1.64	0.02	0.35	0.16	1.8	4.3
8B-SS-4	8B	8	4	0.39	1.84	0.01	0.32	0.14	1.7	2.4
8C-SS-2	8C	8	2	0.14	1.96	0.00	0.15	0.19	2.7	1.4
8C-SS-3	8C	8	3	0.10	1.98	0.01	0.27	0.31	1.0	3.5
8C-SS-4	8C	8	4	0.14	2.21	0.01	0.27	0.25	1.1	1.7
8D-SS-2	8D	8	2	0.07	2.33	0.00	0.40	0.19	1.2	3.7
8D-SS-3	8D	8	3	0.20	1.79	0.01	0.32	0.15	0.7	1.4
8D-SS-4	8D	8	4	0.11	1.69	0.00	0.28	0.18	1.4	1.9
8E-SS-2	8E	8	2	4.34	2.53	0.18	0.30	0.19	1.8	7.0
8E-SS-3	8E	8	3	5.62	2.67	0.21	0.32	0.17	1.8	5.1
8E-SS-4	8E	8	4	5.60	2.68	0.21	0.30	0.17	1.8	6.1
8F-SS-2	8F	8	2	1.14	2.99	0.05	0.33	0.17	1.8	4.2
8F-SS-3	8F	8	3	0.90	3.00	0.04	0.31	0.20	1.8	5.7
8F-SS-4	8F	8	4	1.19	3.02	0.05	0.32	0.19	1.7	5.1
5(0)-SS-2	5(0)	6	2	2.16	1.52	0.09	0.28	0.19	1.8	4.7
5(0)-SS-3	5(0)	6	3	1.73	2.32	0.08	0.30	0.20	1.8	6.1
5(0)-SS-4	5(0)	6	4	2.13	3.05	0.10	0.30	0.20	1.8	6.2
5(1)-SS-2	5(1)	6	2	0.35	1.69	0.01	0.26	0.21	1.5	3.7
5(1)-SS-3	5(1)	6	3	0.32	1.55	0.01	0.28	0.14	1.7	1.8
5(1)-SS-4	5(1)	6	4	0.27	1.67	0.01	0.25	0.17	1.6	1.9
5(5)-SS-2	5(5)	6	2	1.76	1.52	0.07	0.29	0.18	1.6	5.6
5(5)-SS-3	5(5)	6	3	1.73	1.62	0.08	0.35	0.19	1.8	4.4
5(5)-SS-4	5(5)	6	4	1.44	1.67	0.06	0.31	0.19	1.9	5.0
5(10)-SS-P F1	5(10)	6	1	1.09	3.20	0.07	0.35	0.25	1.7	4.2
9A-SS-2	9A	7	2	0.44	1.82	0.01	0.24	0.08	0.9	1.4
9A-SS-3	9A	7	3	0.33	1.72	0.02	0.26	0.30	1.0	1.6
9A-SS-4	9A	7	4	0.41	1.74	0.01	0.18	0.09	1.1	1.4
9B-SS-2	9B	7	2	0.41	1.39	0.02	0.38	0.18	1.3	5.6
9B-SS-3 F1	9B	7	3	0.32	3.43	0.02	0.41	0.17	1.7	3.2
9B-SS-4 F1	9B	7	4	0.43	3.28	0.02	0.57	0.10	2.8	1.9
9C-SS-2	9C	7	2	1.92	3.02	0.10	0.39	0.20	1.4	6.3
9C-SS-3	9C	7	3	2.46	2.73	0.11	0.41	0.17	1.4	6.2
9C-SS-4	9C	7	4	2.08	2.74	0.11	0.41	0.18	1.4	6.6

VALUES BELOW INSTRUMENAL
DETECTION LIMITS (ND) ARE
INDICATED BY BLANK SPACES

POLYCYCLIC AROMATIC HYDROCARBONS IN 1989 SURFACE SEDIMENTS (ng/g)

SAMPID	STATION	REGION	C0N	C1N	C2N	C3N	C4N	ACEY	ACE	BPH	C0F
1A-SS-P	1A	1	6.4	20	46	19	12	0	0	5.3	2.5
1B-SS-P	1B	1	2.6	8	22	53	0	0	0	1.6	0
1C-SS-P	1C	1	9.2	69	190	200	61	0	0	13	12
1D-SS-P F2	1D	1	2.2	4.1	8.5	5.3	4.1	0	0	1.9	0.77
1E-SS-4 F2	1E	1	3.6	11	13	16	3.8	0	0	3.6	0
1E-SS-2 F2	1E	1	3.2	4.9	38	8.5	1.3	0	0	2.2	0
1E-SS-3 F2	1E	1	6.4	6.4	26	6.2	2.4	0	0	2.8	0
2A-SS-P F2	2A	1	16	98	230	160	88	0	0	25	14
2B-SS-P F2	2B	1	3.8	10	33	13	6.5	0	0	1.2	0
2C-SS-P	2C	1	14	18	0	0	0	0	0	0	0
2D-SS-P	2D	1	3.8	15	34	19	13	0	0	3.5	2.5
2E-SS-P F2	2E	1	1.8	5.1	8.9	8	6	0	0	1.1	0
2F-SS-P F2	2F	1	5.2	17	32	27	16	0	0	4.7	3.7
3A-SS-P F2	3A	2	16	89	230	140	69	0	0	18	16
3B-SS-2 F2	3B	2	12	43	73	47	17	0	0	11	6.3
3B-SS-3 F2	3B	2	12	56	96	77	29	0	2.5	14	8.8
3B-SS-4 F2	3B	2	15	54	90	58	19	0	0	11	7.6
4A-SS-P F2	4A	2	6.9	37	110	62	52	0	0	9.5	6.7
4B-SS-P3 F2	4B	2	6	24	67	53	29	0	0	6.4	4.5
4C-SS-P F2	4C	2	5.1	13	42	28	30	0	0	4.1	2.6
5H-SS-P F2	5H	2	6.8	33	80	57	26	0	0	8.3	7.2
5A-SS-3	5A	3	6.3	31	75	33	28	0	0	5.3	2.6
5A-SS-2	5A	3	7.1	31	70	24	21	0	0	4.9	2.2
5A-SS-4	5A	3	0	38	120	48	0	0	0	6.2	0
5B-SS-P	5B	3	2	5.9	20	6.3	0	0	0	0	0
5D-SS-P F2	5D	3	18	84	190	110	58	0	0	15	11
5E-SS-P F2	5E	3	15	94	230	270	98	0	0	15	13
5F-SS-P F2	5F	3	11	54	120	90	45	0.83	0	13	8.5
5G-SS-P	5G	3	0	0	0	0	0	0	0	0	0
6A-SS-P	6A	4	20	81	160	72	30	0	0	9.3	7.2
6B-SS-P-2	6B	4	40	200	390	190	55	0	0	24	16
6C-SS-P-2	6C	4	6	23	38	67	15	0	0	2.3	0
6D-SS-4 F2	6D	4	11	81	210	130	61	0	0	14	12
6D-SS-3 F2	6D	4	7.2	40	100	64	31	0	0	6.3	6.2
6D-SS-2 F2	6D	4	9.8	62	160	99	50	0	0	9.8	9.5
6F-SS-P	6F	4	8.5	44	110	37	17	0	0	5.8	4.7
6G-SS-P	6G	4	150	1100	2600	1400	640	0	0	130	120
7A-SS-P	7A	5	15	63	120	71	30	0	0	6.8	4.5
7B-SS-3 F2	7B	5	5.8	20	30	27	11	0	0	3.7	0
7B-SS-2 F2	7B	5	8.3	31	54	38	13	0	0	5.2	0
7B-SS-4 F2	7B	5	7.4	25	47	34	7.9	0	0	3.8	3.4
7C-SS-P F2	7C	5	30	190	450	260	220	0	0	32	22
7D-SS-P F2	7D	5	18	95	190	120	64	0	0	12	9.1
7E-SS-P F2	7E	5	46	240	530	350	180	0	0	29	20
7G-SS-P F2	7G	5	38	170	380	310	180	0	0	9.5	3.5
8A-SS-4 F2	8A	8	12	70	170	110	76	0	0	15	13
8A-SS-3 F2	8A	8	8.4	49	140	86	58	0	0	11	9.1
8A-SS-2 F2	8A	8	7.5	34	77	49	39	0	0	7.3	5.1
8B-SS-4 F2	8B	8	1.9	6.3	22	71	0	0	0	2.2	1.8
8B-SS-2 F2	8B	8	4.7	19	59	44	26	0	0	5.3	5
8B-SS-3 F2	8B	8	3.9	19	44	36	16	0	0	6.1	6.1

POLYCYCLIC AROMATIC HYDROCARBONS IN 1989 SURFACE SEDIMENTS (ng/g)

SAMPID	STATION	REGION	C0N	C1N	C2N	C3N	C4N	ACEY	ACE	BPH	C0F
8C-SS-2 F2	8C	8	1.8	2.3	7.0	1.6	2.7	0	0	1.2	0.60
8C-SS-4 F2	8C	8	0.78	1.7	3.9	1.7	2.4	0	0	0.59	0.21
8C-SS-3 F2	8C	8	1.1	2.4	6.3	1.7	3.5	0	0	0.93	0.44
8D-SS-4 F2	8D	8	0.93	1.3	5	0	0	0	0	0	0
8D-SS-3 F2	8D	8	1.8	2.6	0	0	0	0	0	0	3.4
8D-SS-2 F2	8D	8	2.6	2.6	5.3	9.4	0	0	0	1.4	0
8E-SS-3 F2	8E	8	23	140	320	210	110	0	0	31	27
8E-SS-2 F2	8E	8	16	92	210	140	82	0	0	19	16
8E-SS-4 F2	8E	8	19	120	290	210	130	0	0	26	23
8F-SS-2 F2	8F	8	5.6	32	92	180	54	0	1.2	8.5	7.6
8F-SS-4 F2	8F	8	6.9	35	95	170	68	0	0	8.5	7.5
8F-SS-3 F2	8F	8	5.1	27	69	120	29	0	0	6.8	5.7
5(0)-SS-2 F2	5(0)	6	13	65	140	87	43	0	0	13	12
5(0)-SS-3 F2	5(0)	6	10	57	140	89	46	0	0	12	12
5(0)-SS-4	5(0)	6	14	75	190	230	92	0	0	14	16
5(1)-SS-2 F2	5(10)	6	2.3	8.7	26	13	11	0	0	2.7	2.2
5(10)-SS-P	5(10)	6	10	41	79	37	28	0	0	8.2	5.1
5(1)-SS-3 F2	5(10)	6	1.9	4.6	20	29	13	0	0	1.9	1.7
5(1)-SS-4 F2	5(10)	6	1.4	3.9	10	17	3.9	0	0	1.1	1.6
5(5)-SS-3 F2	5(5)	6	9.7	58	150	100	48	0	0	15	11
5(5)-SS-4	5(5)	6	11	41	110	150	30	0	0	6.5	5.3
5(5)-SS-2 F2	5(5)	6	16	66	160	100	81	0	0	16	11
9A-SS-4 F2	9A	7	0.89	2.1	3.0	0	0	0	0	0	0
9A-SS-2 F2	9A	7	0.75	1.6	4.8	0	0	0	0	0	0
9A-SS-3 F2	9A	7	0.92	1.7	4.6	0	0	0	0	0	0
9B-SS-4	9B	7	2	4.7	14	5.6	3.1	0	0	1.6	0.9
9B-SS-2	9B	7	3.5	8.9	31	20	0	0	0	0	0
9B-SS-3	9B	7	0	0	0	0	0	0	0	0	0
9C-SS-4 F2	9C	7	6.8	31	66	39	27	0	0	6.8	6.1
9C-SS-2 F2	9C	7	7.9	36	81	39	31	0	0	7.4	6.1
9C-SS-3 F2	9C	7	8.4	38	80	43	30	0	0	8.5	7.2

All values below instrument detection limits (ND) are indicated by blank spaces

POLYCYCLIC AROMATIC HYDROCARBONS IN 1989 SURFACE SEDIMENTS (ng/g)

SAMPID	STATION	REGION	C1F	C2F	C3F	C0D	C1D	C2D	C3D	C0P	C0A
1A-SS-P	1A	1	6.2	13	15	1.6	1.6	0	0	11	0
1B-SS-P	1B	1	0	0	0	0	0	0	0	4.8	0
1C-SS-P	1C	1	37	67	77	3	7	10	9.4	20	0
1D-SS-P F2	1D	1	1.3		0	0	0	0	0	1.7	0
1E-SS-4 F2	1E	1	4	12	28	1.1	3.8	2	2.1	6.2	0
1E-SS-2 F2	1E	1	6.9	11	0.7	0	0	0	0	5.4	0
1E-SS-3 F2	1E	1	3.3	4	1.8	0.7	0	0.3	0.15	5.3	0.2
2A-SS-P F2	2A	1	40	130	80	5.9	14	30	20	57	0.85
2B-SS-P F2	2B	1	3.9	8.5	4.6	0.65	0	0	0	5.9	0
2C-SS-P	2C	1	0	0	0	0	0	0	0	7.6	0
2D-SS-P	2D	1	6.5	13	12	0.57	2.2	3.6	3.8	7.6	0
2E-SS-P F2	2E	1	3.1	3.5	10	0	0.56	2.4	0	2.5	0
2F-SS-P F2	2F	1	7.2	14	11	0.98	0	3.8	2.5	9.3	0
3A-SS-P F2	3A	2	31	84	68	4.7	8.2	5.2	12	32	0.62
3B-SS-2 F2	3B	2	14	17	7.5	3.1	13	12	8.4	26	0
3B-SS-3 F2	3B	2	18	32	25	3.3	11	9.9	4.7	25	0
3B-SS-4 F2	3B	2	16	20	15	3.2	11	9.3	4.6	25	0
4A-SS-P F2	4A	2	19	55	41	1.6	4.7	6.7	5.7	13	0
4B-SS-P3 F2	4B	2	11	28	22	1.6	3.7	6.2	4.3	11	0
4C-SS-P F2	4C	2	8.8	16		0.42	1.3	1.8	1.6	3.1	0
5H-SS-P F2	5H	2	15	40	49	2.3	5.4	3.4	7	14	0.23
5A-SS-3	5A	3	9	24	13	1.5	4.3	7.1	4.2	12	0
5A-SS-2	5A	3	6.9	18	14	1.9	4.9	8.4	6.3	13	0
5A-SS-4	5A	3	0	0		0	8.6	8.6	9.3	8.7	0
5B-SS-P	5B	3	0	0		0	0	0	0	2.5	0
5D-SS-P F2	5D	3	26	59	42	6.5	17	19	28	40	0.98
5E-SS-P F2	5E	3	36	64	56	5.3	13	19	15	29	0.55
5F-SS-P F2	5F	3	18	5.5	39	4.2	9.0	19	12	22	0.95
5G-SS-P	5G	3	0	0		0	0	0	0	0	0
6A-SS-P	6A	4	16	38		2.1	6.4	7.3	4	17	0
6B-SS-P-2	6B	4	47	92	53	9.1	19	27	19	67	0
6C-SS-P-2	6C	4	4.1	0		0.81	2.2	3.2	0	5.6	0
6D-SS-4 F2	6D	4	28	71	55	3.6	6.7	7.3	9.2	19	0.45
6D-SS-3 F2	6D	4	12	37	27	2.0	5.6	7.5	5.9	12	0.36
6D-SS-2 F2	6D	4	24	58	19	3.3	7.7	13	6.8	18	0.40
6F-SS-P	6F	4	13	15		0	2.7	2.2	2.3	6.6	0
6G-SS-P	6G	4	390	41	430	27	60	69	60	190	0.9
7A-SS-P	7A	5	11	27	24	3.7	7.7	8.2	7.3	22	0
7B-SS-3 F2	7B	5	6.5	12	4.1	1.3	7.3	4.9	3.2	9.9	0
7B-SS-2 F2	7B	5	7.5	15	15	2.1	11	8.3	5.8	15	0
7B-SS-4 F2	7B	5	8.1	12	9.5	1.3	3	5.6	2.4	11	0
7C-SS-P F2	7C	5	57	120	110	9.6	24	35	32	53	1.3
7D-SS-P F2	7D	5	21	59	52	4.2	9.8	15	12	24	0.57
7E-SS-P F2	7E	5	47	140	170	8.6	20	30	25	56	1.6
7G-SS-P F2	7G	5	9.6	25	20	3.0	7.8	12	14	28	1.5
8A-SS-4 F2	8A	8	30	75	58	4	13	19	14	31	0
8A-SS-3 F2	8A	8	23	57	53	2.7	7.5	11	8.8	18	0
8A-SS-2 F2	8A	8	13	39	27	2.6	8	12	8.6	18	0
8B-SS-4 F2	8B	8	1.8	0	0	0	0	0.59	0.67	2.7	0
8B-SS-2 F2	8B	8	10	23	16	1.1	3.4	5	3.6	6.6	0
8B-SS-3 F2	8B	8	10	38	20	0.88	2.2	1.3	3.1	5.6	0

POLYCYCLIC AROMATIC HYDROCARBONS IN 1989 SURFACE SEDIMENTS (ng/g)

SAMPID	STATION	REGION	C1F	C2F	C3F	C0D	C1D	C2D	C3D	C0P	C0A
8C-SS-2 F2	8C	8	0.92	0	0	0.31	0.57	1.1	0.73	1.2	0
8C-SS-4 F2	8C	8	0.58	0	0	0.26	0.63	1.1	0.73	1.1	0
8C-SS-3 F2	8C	8	0.67	3.8	0	0.28	0.79	1.3	1.2	1.2	0
8D-SS-4 F2	8D	8	0	0	0	0	0	0	0	0.9	0
8D-SS-3 F2	8D	8	0	0	0	0	0	0	0	1	0
8D-SS-2 F2	8D	8	0	0	0	0	0.49	1.1	0.42	0.97	0
8E-SS-3 F2	8E	8	53	0.95	83	8.4	22	41	32	51	0.65
8E-SS-2 F2	8E	8	27	0	42	6.7	18	34	25	41	0.62
8E-SS-4 F2	8E	8	46	120	73	7.8	21	39	30	50	0.61
8F-SS-2 F2	8F	8	18	53	41	1.8	5.7	8.6	7.2	12	0
8F-SS-4 F2	8F	8	19	52	39	2	5.6	9.8	7.1	13	0
8F-SS-3 F2	8F	8	9.7	26	22	1.4	5	8.2	6.1	9.6	11
5(0)-SS-2 F2	5(0)	6	22	64	31	3.7	9.7	18	14	22	0.27
5(0)-SS-3 F2	5(0)	6	22	55	47	3.2	8.1	13	11	19	0.37
5(0)-SS-4	5(0)	6	30	0	0	3.2	11	17	19	25	0
5(1)-SS-2 F2	5(10)	6	3.7	13	4.6	0.46	0.98	1.4	1.2	2.8	0
5(10)-SS-P	5(10)	6	13	36	41	1.8	4.7	6.8	5.7	12	0
5(1)-SS-3 F2	5(10)	6	2.6	16	8.2	0	0	0	0	1.6	0
5(1)-SS-4 F2	5(10)	6	2.3	5.3	5.1	0.27	0.68	1	0.82	1.6	0
5(5)-SS-3 F2	5(5)	6	23	66	29	2.6	6.4	7.6	7.8	16	0.28
5(5)-SS-4	5(5)	6	9.9	0	0	1.7	5.4	8	5.5	15	0
5(5)-SS-2 F2	5(5)	6	24	66	56	2.8	7.0	7.9	7.2	18	0
9A-SS-4 F2	9A	7	0	0	0	0	0	0	0	0.7	0
9A-SS-2 F2	9A	7	0	0	0	0	0.079	0.078	0.068	0.74	0
9A-SS-3 F2	9A	7	0	0	0	0	0	0	0	0.61	0
9B-SS-4	9B	7	0	0	0	0.38	1.1	2.1	1.6	0.32	2.7
9B-SS-2	9B	7	0	0	0	0	0	0	0	5.2	0
9B-SS-3	9B	7	0	0	0	0	0	0	0	0	0
9C-SS-4 F2	9C	7	9.4	33	31	2.4	4.7	8.5	6.9	15	0.37
9C-SS-2 F2	9C	7	13	37	22	2.6	4.6	9.0	6.5	15	0.42
9C-SS-3 F2	9C	7	13	34	38	2.8	6.0	9.5	6.3	16	0.38

All values below instrument detection limits (ND) are indicated by blank spaces

POLYCYCLIC AROMATIC HYDROCARBONS IN 1989 SURFACE SEDIMENTS (ng/g)

SAMPID	STATION	REGION	C0P/A	C1P/A	C2P/A	C3P/A	C4P/A	FLU	PYR	C1F/P	BAA
1A-SS-P	1A	1	11	31	39	29	19	0	0	7.3	0.92
1B-SS-P	1B	1	4.8	13	26	10	14	0	1	2.2	0
1C-SS-P	1C	1	20	79	73	62	23	3.8	5.6	26	2.2
1D-SS-P F2	1D	1	1.7	3.3	3.4	2.0	1.2	0.20	0.34	0.61	0.17
1E-SS-4 F2	1E	1	6.2	16	11	8.9	0	0.84	0.98	0	0.5
1E-SS-2 F2	1E	1	5.4	2.7	2.6	2.9	0	0.55	0.42	0	0.67
1E-SS-3 F2	1E	1	5.5	13	7.1	4	2.5	0.72	0.86	0	0.61
2A-SS-P F2	2A	1	57.85	150	220	180	42	8.6	13	29	4.2
2B-SS-P F2	2B	1	5.9	17	14	6.5	2.9	0.58	0.89	2.8	0
2C-SS-P	2C	1	7.6	0	0	0	0	0	0	0	0
2D-SS-P	2D	1	7.6	21	30	17	7.6	1.1	1.6	4.3	0.52
2E-SS-P F2	2E	1	2.5	6.4	9.2	4.7	0.97	0	0.46	1.6	0
2F-SS-P F2	2F	1	9.3	28	30	16	2.4	0.96	1.3	6	0.37
3A-SS-P F2	3A	2	32.62	75	120	86	29	5.0	7.0	16	3.1
3B-SS-2 F2	3B	2	26	64	69	38	2.4	3.5	5.3	14	1.2
3B-SS-3 F2	3B	2	25	60	67	30	12	3.6	5.7	16	1.2
3B-SS-4 F2	3B	2	25	60	58	27	15	3	5	12	1.2
4A-SS-P F2	4A	2	13	40	44	28	5.4	1.7	2.2	11	0.81
4B-SS-P3 F2	4B	2	11	33	38	25	7.8	1.4	2	9.3	0.63
4C-SS-P F2	4C	2	3.1	8.9	12	7.5	1.5	0.43	0.62	2.7	0.15
5H-SS-P F2	5H	2	14.23	34	55	38	37	2.4	3.3	7.8	1.2
5A-SS-3	5A	3	12	38	49	43	18	2	2.5	12	0.91
5A-SS-2	5A	3	13	44	61	27	16	1.9	2.8	7.4	1.4
5A-SS-4	5A	3	8.7	43	87	56	25	0	0	11	0
5B-SS-P	5B	3	2.5	11	25	7.2	0	0	0	0	0
5D-SS-P F2	5D	3	40.98	90	150	120	45	9.3	10	19	4.8
5E-SS-P F2	5E	3	29.55	69	110	59	38	4.9	7.3	35	2.4
5F-SS-P F2	5F	3	22.95	54	87	75	16	4.4	6.2	12	2.8
5G-SS-P	5G	3	0	0	0	0	0	0	0	0	0
6A-SS-P	6A	4	17	45	53	40	0	2.6	2.9	16	0.76
6B-SS-P-2	6B	4	67	200	130	190	310	13	14	82	6
6C-SS-P-2	6C	4	5.6	16	18	16	0	0.62	0.86	3.1	0
6D-SS-4 F2	6D	4	19.45	44	68	46	23	3.2	4.8	9.5	1.8
6D-SS-3 F2	6D	4	12.36	27	40	29	11	2.1	2.7	12	1.1
6D-SS-2 F2	6D	4	18.4	43	67	50	11	3.3	4.8	9.9	1.7
6F-SS-P	6F	4	6.6	15	20	11	0	0.96	0.98	4.5	0.25
6G-SS-P	6G	4	190.9	570	360	610	140	33	39	250	14
7A-SS-P	7A	5	22	68	47	90	15	6.4	6.5	31	2.4
7B-SS-3 F2	7B	5	9.9	26	21	15	7.4	1.8	2.9	5	0.53
7B-SS-2 F2	7B	5	15	38	39	26	9.2	2.8	3.8	8.5	0.8
7B-SS-4 F2	7B	5	11	26	28	15	3.1	1.8	2.8	5.7	0.45
7C-SS-P F2	7C	5	54.3	130	210	170	220	9.2	14	63	4.8
7D-SS-P F2	7D	5	24.57	58	93	79	29	4.8	6.6	26	2.3
7E-SS-P F2	7E	5	57.6	130	200	180	18	12	16	34	6.9
7G-SS-P F2	7G	5	29.5	67	120	140	34	6.2	9.0	19	5.2
8A-SS-4 F2	8A	8	31	89	95	63	10	5	5.6	30	2.6
8A-SS-3 F2	8A	8	18	55	61	40	5.1	3.1	3.7	17	1.8
8A-SS-2 F2	8A	8	18	57	58	41	6.5	3.2	3.7	22	1.3
8B-SS-4 F2	8B	8	2.7	6	10	5.5	3.3	0.46	0.69	0.55	0.21
8B-SS-2 F2	8B	8	6.6	20	24	17	5.1	1.1	1.2	5.7	0.5
8B-SS-3 F2	8B	8	5.6	13	21	17	0	1	1.4	2.6	0.48

POLYCYCLIC AROMATIC HYDROCARBONS IN 1989 SURFACE SEDIMENTS (ng/g)

SAMPID	STATION	REGION	C0P/A	C1P/A	C2P/A	C3P/A	C4P/A	FLU	PYR	C1F/P	BAA
8C-SS-2 F2	8C	8	1.2	1.8	3.2	2.0	2.1	0.17	0.23	0.44	0
8C-SS-4 F2	8C	8	1.1	2.2	3.4	1.5	1.2	0.14	0.26	0.21	0
8C-SS-3 F2	8C	8	1.2	2.7	5.5	4.0	1.7	0.18	0.25	0.93	0.059
8D-SS-4 F2	8D	8	0.9	1.8	2.4	1.3	0	0	0	0	0
8D-SS-3 F2	8D	8	1	2.8	3.4	2.8	3.2	0	0	0	0
8D-SS-2 F2	8D	8	0.97	2.7	4.4	2.1	1.7	0	0	0	0
8E-SS-3 F2	8E	8	51.65	120	180	150	34	9.2	12	24	4.4
8E-SS-2 F2	8E	8	41.62	96	160	130	29	7.1	8.5	20	3.7
8E-SS-4 F2	8E	8	50.61	110	180	140	30	9.1	11	23	4.3
8F-SS-2 F2	8F	8	12	36	41	31	13	2.1	2.3	12	0.76
8F-SS-4 F2	8F	8	13	39	45	34	17	2.3	2.7	13	0.9
8F-SS-3 F2	8F	8	20.6	23	38	26	6.8	1.6	1.9	10	0.67
5(0)-SS-2 F2	5(0)	6	22.27	49	78	65	15	3.8	4.7	12	1.8
5(0)-SS-3 F2	5(0)	6	19.37	42	69	57	18	3.2	4.3	8.6	1.7
5(0)-SS-4	5(0)	6	25	90	110	84	33	3.9	4.6	26	1.3
5(1)-SS-2 F2	5(10)	6	2.8	5.5	8.2	2.3	2.3	0.45	0.54	0	0.22
5(10)-SS-P	5(10)	6	12	33	42	28	0	1.7	1.9	8	0.51
5(1)-SS-3 F2	5(10)	6	1.6	3.4	6.1	4	3.8	0.27	0.35	1.2	0
5(1)-SS-4 F2	5(10)	6	1.6	2.8	4.5	2.2	1.5	0.24	0.31	1.4	0.1
5(5)-SS-3 F2	5(5)	6	16.28	38	60	48	14	2.5	3.3	8.9	1.2
5(5)-SS-4	5(5)	6	15	53	67	52	16	2	2.9	15	0.75
5(5)-SS-2 F2	5(5)	6	18	43	68	51	11	2.9	3.9	8.6	1.5
9A-SS-4 F2	9A	7	0.7	1.2	1.9	1.3	0	0	0.19	0.28	0
9A-SS-2 F2	9A	7	0.74	1.4	1.5	1.1	0	0.12	0.2	0.52	0.036
9A-SS-3 F2	9A	7	0.61	1.3	2.4	1.2	0.22	0.1	0.16	0.24	0
9B-SS-4	9B	7	3.02	6.2	9.5	6.1	3.9	0.46	0.67	2.5	0.31
9B-SS-2	9B	7	5.2	27	43	26	0	0	0	0	0
9B-SS-3	9B	7	0	0	0	0	0	0	0	0	0
9C-SS-4 F2	9C	7	15.37	33	52	45	20	3.0	5.1	8.5	1.7
9C-SS-2 F2	9C	7	15.42	34	51	45	18	3.2	5.1	9.0	1.5
9C-SS-3 F2	9C	7	16.38	35	63	40	16	3.2	5.5	14	1.7

All values below instrument
detection limits (ND) are
indicated by blank spaces

POLYCYCLIC AROMATIC HYDROCARBONS IN 1989 SURFACE SEDIMENTS (ng/g)

SAMPID	STATION	REGION	C0C	C1C	C2C	C3C	C4C	BBF	BKF	BEP	BAP
1A-SS-P	1A	1	5.1	5.8	4	0	0	2.6	0	0	0.68
1B-SS-P	1B	1	0	0	0	0	0	0	0	0	0
1C-SS-P	1C	1	10	14	8.6	7.5	8.3	5.5	1.4	7.4	0
1D-SS-P F2	1D	1	0.62	0.82	0.24	0.30	0	0.35	0.062	0.46	0.38
1E-SS-4 F2	1E	1	1.8	0	0	0	0	0	0	1.1	0
1E-SS-2 F2	1E	1	1.2	0.47	0	0	0	0	0	1.4	0
1E-SS-3 F2	1E	1	1.8	0.96	0	0	0	0.41	0	1.2	0
2A-SS-P F2	2A	1	44	63	44	22	13	18	0	23	3.4
2B-SS-P F2	2B	1	1.4	2	0.99	0	0.39	0	0	1.4	0
2C-SS-P	2C	1	0	0	0	0	0	0	0	0	0
2D-SS-P	2D	1	4	4.8	0.94	1	0	1.5	0.3	2.2	0
2E-SS-P F2	2E	1	0.84	1.4	0.59	0	0	0	0	0.95	0
2F-SS-P F2	2F	1	3.2	5.3	4	0	0	2.3	1.5	4	0
3A-SS-P F2	3A	2	20	32	12	12	3.2	0	0	13	2.5
3B-SS-2 F2	3B	2	8.4	8.7	7.8	0	0	6	1.2	6.9	0
3B-SS-3 F2	3B	2	8	7.2	4.2	0	0	4.8	1.7	6.1	0
3B-SS-4 F2	3B	2	7.6	7.6	3.1	0	0	4.3	1.3	5.6	0
4A-SS-P F2	4A	2	6.6	9.7	9.5	5	0	3.9	0	4.6	0
4B-SS-P3 F2	4B	2	5	5.8	5	3.7	0.79	2.9	0	3.7	0
4C-SS-P F2	4C	2	1.3	1.7	1.5	0.74	0	0.66	0	0.86	0
5H-SS-P F2	5H	2	8.3	11	11	7.3	3.1	4.5	0	5.2	0
5A-SS-3	5A	3	5.4	7.2	1.2	0	0	2.8	0.48	3.3	0
5A-SS-2	5A	3	8.6	18	3.7	0	0	2.6	0	3.8	0
5A-SS-4	5A	3	0	0	0	0	0	0	0	0	0
5B-SS-P	5B	3	0	0	0	0	0	0	0	0	0
5D-SS-P F2	5D	3	23	33	11	14	6.6	12	2.0	13	4.1
5E-SS-P F2	5E	3	17	20	11	13	1.9	11	0	12	2.9
5F-SS-P F2	5F	3	13	18	17	7.6	6.6	7.8	0	8.2	3.1
5G-SS-P	5G	3	0	0	0	0	0	0	0	0	0
6A-SS-P	6A	4	4.2	6	0.98	0	0	2.5	0.36	2.2	0
6B-SS-P-2	6B	4	30	41	21	4.4	0	20	5	20	7.7
6C-SS-P-2	6C	4	1.3	0	5.8	0	0	0	0	0.6	0
6D-SS-4 F2	6D	4	11	17	8.4	8.8	0	5.9	0.98	7.2	1.8
6D-SS-3 F2	6D	4	6.6	8.1	2.1	4.4	0	4.5	0	4.7	0
6D-SS-2 F2	6D	4	10	14	14	5.6	2.3	6.9	0	6.7	0
6F-SS-P	6F	4	1.4	0	0	0	0	0.68	0.12	0.74	0
6G-SS-P	6G	4	70	100	56	28	0	55	11	49	21
7A-SS-P	7A	5	10	14	11	2.2	0	7.1	1.5	6.1	2.5
7B-SS-3 F2	7B	5	3.2	3	1.4	0	0	2.4	0.85	2.4	0
7B-SS-2 F2	7B	5	4.9	3.4	1.8	0	0	4.2	0.8	3.9	0
7B-SS-4 F2	7B	5	3.8	2.9	2.1	0	0.53	2.8	0.99	3.4	0
7C-SS-P F2	7C	5	30	45	20	34	12	22	23	22	5.4
7D-SS-P F2	7D	5	14	20	9.3	7.3	4.3	9.8	0	9.3	2.6
7E-SS-P F2	7E	5	31	43	23	7.2	1.5	24	0	20	7.2
7G-SS-P F2	7G	5	14	23	6.9	14	3.7	9.9	0	6.2	4.0
8A-SS-4 F2	8A	8	14	17	15	10	6.3	9	0	8.3	2.3
8A-SS-3 F2	8A	8	9.6	12	12	6.3	1.8	5.5	0	5.6	0
8A-SS-2 F2	8A	8	8.1	12	13	8	5.2	4.5	0.82	5.5	0
8B-SS-4 F2	8B	8	1.4	1.8	0	0	0	0.66	0	0.86	0.24
8B-SS-2 F2	8B	8	3.2	4	2.9	1.4	0	1.4	0.31	1.7	0
8B-SS-3 F2	8B	8	3.2	4.2	2.3	2.8	0	1.8	0	1.9	0

POLYCYCLIC AROMATIC HYDROCARBONS IN 1989 SURFACE SEDIMENTS (ng/g)

SAMPID	STATION	REGION	C0C	C1C	C2C	C3C	C4C	BBF	BKF	BEP	BAP
8C-SS-2 F2	8C	8	0.49	0.63	0.43	0	0.084	0.26	0	0.27	0.32
8C-SS-4 F2	8C	8	0.45	0.69	0.20	0	0	0.20	0.037	0.24	0.45
8C-SS-3 F2	8C	8	0.55	0.75	0.29	0	0	0.23	0	0.29	0.32
8D-SS-4 F2	8D	8	0.43	0.47	0	0	0	0	0	0.23	0.36
8D-SS-3 F2	8D	8	0.51	0.72	0.36	0	0	0	0	0.31	0.32
8D-SS-2 F2	8D	8	0.39	0.45	0.37	0	0	0	0	0	0
8E-SS-3 F2	8E	8	26	42	30	15	10	18	0	16	4.4
8E-SS-2 F2	8E	8	21	35	26	12	9.4	15	16	13	3.6
8E-SS-4 F2	8E	8	25	41	29	13	9.1	18	0	16	4.3
8F-SS-2 F2	8F	8	5.2	6.8	7.1	4.4	2.4	2.4	0.91	3.5	0
8F-SS-4 F2	8F	8	5.7	7.3	7.4	5.8	2.5	2.6	0.88	3.9	0
8F-SS-3 F2	8F	8	4.8	6.5	0	0	0	2.5	0	3	0.76
5(0)-SS-2 F2	5(0)	6	11	17	14	6.1	3.8	7.4	8.0	6.8	1.8
5(0)-SS-3 F2	5(0)	6	9.6	14	5.7	9.2	2.1	6.4	0	5.9	1.5
5(0)-SS-4	5(0)	6	8.1	11	14	6.5	0	3.6	2.7	6.3	0
5(1)-SS-2 F2	5(10)	6	1.4	1.7	0.73	0.72	0	0.44	0	0.87	0.43
5(10)-SS-P	5(10)	6	3.9	5.3	10	0	0	1.2	0.15	1.6	0
5(1)-SS-3 F2	5(10)	6	0.82	1	0.59	0.52	0	0	0	0.57	0.27
5(1)-SS-4 F2	5(10)	6	0.76	0.96	0	0	0	0	0	0.47	0.29
5(5)-SS-3 F2	5(5)	6	8.7	13	15	4.8	3.0	5.1	0	5.6	1.1
5(5)-SS-4	5(5)	6	4.8	6.7	8.1	2.4	0	1.8	1.5	4.3	0
5(5)-SS-2 F2	5(5)	6	10	15	14	3.2	2.3	6.1	0	7.0	1.4
9A-SS-4 F2	9A	7	0.29	0.41	0	0	0	0	0	0.22	0.46
9A-SS-2 F2	9A	7	0.32	0.43	0	0	0	0.19	0	0.23	0.46
9A-SS-3 F2	9A	7	0.29	0.44	0	0	0	0.2	0	0.18	0.37
9B-SS-4	9B	7	1.8	2.2	0.17	0	0	1.1	0	1.2	0
9B-SS-2	9B	7	0	0	0	0	0	0	0	0	0
9B-SS-3	9B	7	0	0	0	0	0	0	0	0	0
9C-SS-4 F2	9C	7	10	14	5.3	6.8	3.0	0	0	8.2	1.8
9C-SS-2 F2	9C	7	10	13	4.6	5.6	2.3	5.6	1.0	7.7	0
9C-SS-3 F2	9C	7	11	15	5.2	5.0	3.0	6.3	1.4	9.0	2.0

All values below instrument detection limits (ND) are indicated by blank spaces

POLYCYCLIC AROMATIC HYDROCARBONS IN 1989 SURFACE SEDIMENTS (ng/g)

SAMPID	STATION	REGION	PER	IND	DAHA	BGHIP	TOT N	TOT F	TOT D	TOTP	TOT C
1A-SS-P	1A	1	27	0	0	2.9	103.4	36.7	3.2	140	14.9
1B-SS-P	1B	1	0	0	0		85.6	0	0	72.6	0
1C-SS-P	1C	1	40	0	0	6	529.2	193	29.4	277	48.4
1D-SS-P F2	1D	1	2.9	0.083	0.11	0.29	24.2	2.07	0	13.3	1.98
1E-SS-4 F2	1E	1	11	0	0	1.0	47.4	44	9	48.3	1.8
1E-SS-2 F2	1E	1	5.1	4.4	5.8	3.8	55.9	18.6	0	19	1.67
1E-SS-3 F2	1E	1	8.2	0	0	0.88	47.4	9.1	1.15	37.6	2.76
2A-SS-P F2	2A	1	170	0	3.1	13	592	264	69.9	707.7	186
2B-SS-P F2	2B	1	5.6	0.95	1.2	2.1	66.3	17	0.65	52.2	4.78
2C-SS-P	2C	1	0	0	0	0	32	0	0	15.2	0
2D-SS-P	2D	1	13	0.42	0.66	1.4	84.8	34	10.17	90.8	10.74
2E-SS-P F2	2E	1	2.7	1.3	1.2	1.6	29.8	16.6	2.96	26.27	2.83
2F-SS-P F2	2F	1	10	4.8	3.8	4.4	97.2	35.9	7.28	95	12.5
3A-SS-P F2	3A	2	79	0	0	8.8	544	199	30.1	375.24	79.2
3B-SS-2 F2	3B	2	40	4	4.6	7.7	192	44.8	36.5	225.4	24.9
3B-SS-3 F2	3B	2	38	3.2	3.4	6.8	270	83.8	28.9	219	19.4
3B-SS-4 F2	3B	2	31	1.1	1.2	4.1	236	58.6	28.1	210	18.3
4A-SS-P F2	4A	2	27	0.62	0	2.4	267.9	121.7	18.7	143.4	30.8
4B-SS-P3 F2	4B	2	21	0.4	0.27	2.2	179	65.5	15.8	125.8	20.29
4C-SS-P F2	4C	2	4.6	0	0	0.42	118.1	27.4	5.12	36.1	5.24
5H-SS-P F2	5H	2	35	0	0	3.2	202.8	111.2	18.1	192.46	40.7
5A-SS-3	5A	3	24	0.77	0.6	2.6	173.3	48.6	17.1	172	13.8
5A-SS-2	5A	3	20	0	0	2.1	153.1	41.1	21.5	174	30.3
5A-SS-4	5A	3	0	0	0	0	206	0	26.5	228.4	0
5B-SS-P	5B	3	0	0	0	0	34.2	0	0	48.2	0
5D-SS-P F2	5D	3	130	0	0	8.4	460	138	70.5	486.96	87.6
5E-SS-P F2	5E	3	57	2.1	2.0	8.8	707	169	52.3	335.1	62.9
5F-SS-P F2	5F	3	71	0	2.3	6.8	320	71	44.2	277.9	62.2
5G-SS-P	5G	3	0	0	0	0	0	0	0	0	0
6A-SS-P	6A	4	16	0.49	0	1.5	363	61.2	19.8	172	11.18
6B-SS-P-2	6B	4	160	4.6	4.8	20	875	208	74.1	964	96.4
6C-SS-P-2	6C	4	3.3	0	0	0	149	4.1	6.21	61.2	7.1
6D-SS-4 F2	6D	4	36	0	0	4.8	493	166	26.8	219.9	45.2
6D-SS-3 F2	6D	4	24	0.79	0.50	3.2	242.2	82.2	21	131.72	21.2
6D-SS-2 F2	6D	4	40	1.0	0.61	4.3	380.8	110.5	30.8	207.8	45.9
6F-SS-P	6F	4	4.1	0	0	0.45	216.5	32.7	7.2	59.2	1.4
6G-SS-P	6G	4	350	18	9.8	53	5890	981	216	2061.8	254
7A-SS-P	7A	5	55	1.7	1.1	4.5	299	66.5	26.9	264	37.2
7B-SS-3 F2	7B	5	14	1.1	1.1	2.5	93.8	22.6	16.7	89.2	7.6
7B-SS-2 F2	7B	5	21	2.6	2.3	3.9	144.3	37.5	27.2	142.2	10.1
7B-SS-4 F2	7B	5	15	1.1	1.1	3	121.3	33	12.3	94.1	9.33
7C-SS-P F2	7C	5	110	4.7	3.4	18	1150	309	100.6	838.6	141
7D-SS-P F2	7D	5	54	0	0	7.2	487	141.1	41	308.14	54.9
7E-SS-P F2	7E	5	150	0	2.3	14	1346	377	83.6	643.2	105.7
7G-SS-P F2	7G	5	65	0	0	3.1	1078	58.1	36.8	420	61.6
8A-SS-4 F2	8A	8	93	1.4	0.76	5.0	438	176	50	319	62.3
8A-SS-3 F2	8A	8	52	0.77	0.8	3.4	341.4	142.1	30	197.1	41.7
8A-SS-2 F2	8A	8	55	0.94	0.82	3.5	206.5	84.1	31.2	198.5	46.3
8B-SS-4 F2	8B	8	6.1	0	0	0.36	101.2	3.6	1.26	30.2	3.2
8B-SS-2 F2	8B	8	14	0	0	0.9	152.7	54	13.1	79.3	11.5
8B-SS-3 F2	8B	8	17	0	0	0.96	118.9	74.1	7.48	62.2	12.5

POLYCYCLIC AROMATIC HYDROCARBONS IN 1989 SURFACE SEDIMENTS (ng/g)

SAMPID	STATION	REGION	PER	IND	DAHA	BGHIP	TOT N	TOT F	TOT D	TOTP	TOT C
8C-SS-2 F2	8C	8	1.7	0	0	0.20	15.4	1.52	2.71	11.5	1.634
8C-SS-4 F2	8C	8	1.2	0	0	0.051	10.48	0.79	2.72	10.5	1.34
8C-SS-3 F2	8C	8	1.5	0.066	0.042	0.18	15	4.91	3.57	16.3	1.59
8D-SS-4 F2	8D	8	0.96	0	0	0	7.23	0	0	7.3	0.9
8D-SS-3 F2	8D	8	1.3	0	0	0	4.4	3.4	0	14.2	1.59
8D-SS-2 F2	8D	8	0.95	0	0	0	19.9	0	2.01	12.84	1.21
8E-SS-3 F2	8E	8	170	0	2.1	11	803	163.95	103.4	587.3	123
8E-SS-2 F2	8E	8	140	0	2.0	9.8	540	85	83.7	498.24	103.4
8E-SS-4 F2	8E	8	180	0	1.2	11	769	262	97.8	561.22	117.1
8F-SS-2 F2	8F	8	28	0	0	1.8	363.6	119.6	23.3	145	25.9
8F-SS-4 F2	8F	8	31	0	0	2.4	374.9	117.5	24.5	161	28.7
8F-SS-3 F2	8F	8	27	0.51	0.37	1.8	250.1	63.4	20.7	135	11.3
5(0)-SS-2 F2	5(0)	6	76	0	0.93	5.0	348	129	45.4	251.54	51.9
5(0)-SS-3 F2	5(0)	6	60	0	0	4.1	342	136	35.3	224.74	40.6
5(0)-SS-4	5(0)	6	81	0	0	3.8	601	46	50.2	367	39.6
5(1)-SS-2 F2	5(10)	6	5.7	0	0	0.54	61	23.5	4.04	23.9	4.55
5(10)-SS-P	5(10)	6	11	0	0	0.63	195	95.1	19	127	19.2
5(1)-SS-3 F2	5(10)	6	3.1	0	0	0.32	68.5	28.5	0	20.5	2.93
5(1)-SS-4 F2	5(10)	6	2.8	0	0	0.27	36.2	14.3	2.77	14.2	1.72
5(5)-SS-3 F2	5(5)	6	38	0	0.77	4.1	365.7	129	24.4	192.56	44.5
5(5)-SS-4	5(5)	6	31	0	0	2.0	342	15.2	20.6	218	22
5(5)-SS-2 F2	5(5)	6	45	0	0.98	4.8	423	157	24.9	209	44.5
9A-SS-4 F2	9A	7	1.4	0	0	0.17	5.99	0	0	5.8	0.7
9A-SS-2 F2	9A	7	1.8	0.064	0.055	0.21	7.15	0	0.225	5.48	0.75
9A-SS-3 F2	9A	7	1.6	0	0	0.083	7.22	0	0	6.34	0.73
9B-SS-4	9B	7	6.7	0.23	0.17	0.86	29.4	0.9	5.18	31.74	4.17
9B-SS-2	9B	7	0	0	0	0	63.4	0	0	106.4	0
9B-SS-3	9B	7	0	0	0	0	0	0	0	0	0
9C-SS-4 F2	9C	7	51	0	0	7.4	169.8	79.5	22.5	180.74	39.1
9C-SS-2 F2	9C	7	48	0	0	7.1	194.9	78.1	22.7	178.84	35.5
9C-SS-3 F2	9C	7	56	0	0	8.1	199.4	92.2	24.6	186.76	39.2

All values below instrument detection limits (ND) are indicated by blank spaces

POLYCYCLIC AROMATIC HYDROCARBONS IN 1989 SURFACE SEDIMENTS (ng/g)

SAMPID	STATION	REGION	TOT PAH	FFPI	P/D	C0P/C0D	C1P/C1D	C2P/C2D	C3P/C3D	P/C	C0P/C0C
1A-SS-P	1A	1	344.9	0.415	43.75	6.875	19.375	0.000	0.000	9.40	2.157
1B-SS-P	1B	1	163	0.525	0.00	0.000	0.000	0.000	0.000	0.00	0.000
1C-SS-P	1C	1	1187.9	0.633	9.42	6.667	11.286	7.300	6.596	5.72	2.000
1D-SS-P F2	1D	1	49.405	0.532	0.00	0.000	0.000	0.000	0.000	6.72	2.742
1E-SS-4 F2	1E	1	169.52	0.592	5.37	5.636	4.211	5.500	4.238	26.83	3.444
1E-SS-2 F2	1E	1	119.51	0.623	0.00	0.000	0.000	0.000	0.000	11.38	4.500
1E-SS-3 F2	1E	1	113.69	0.507	32.70	7.857	0.000	23.667	26.667	13.62	3.056
2A-SS-P F2	2A	1	2129.9	0.435	10.12	9.805	10.714	7.333	9.000	3.80	1.315
2B-SS-P F2	2B	1	157.65	0.533	80.31	9.077	0.000	0.000	0.000	10.92	4.214
2C-SS-P	2C	1	47.2	0.678	0.00	0.000	0.000	0.000	0.000	0.00	0.000
2D-SS-P	2D	1	261.01	0.494	8.93	13.333	9.545	8.333	4.474	8.45	1.900
2E-SS-P F2	2E	1	89.37	0.552	8.88	0.000	11.429	3.833	0.000	9.28	2.976
2F-SS-P F2	2F	1	292.01	0.481	13.05	9.490	0.000	7.895	6.400	7.60	2.906
3A-SS-P F2	3A	2	1379.94	0.560	12.47	6.940	9.146	23.077	7.167	4.74	1.631
3B-SS-2 F2	3B	2	629	0.434	6.18	8.387	4.923	5.750	4.524	9.05	3.095
3B-SS-3 F2	3B	2	728.1	0.526	7.58	7.576	5.455	6.768	6.383	11.29	3.125
3B-SS-4 F2	3B	2	631.8	0.511	7.47	7.813	5.455	6.237	5.870	11.48	3.289
4A-SS-P F2	4A	2	646.23	0.632	7.67	8.125	8.511	6.567	4.912	4.66	1.970
4B-SS-P3 F2	4B	2	456.59	0.570	7.96	6.875	8.919	6.129	5.814	6.20	2.200
4C-SS-P F2	4C	2	206.5	0.729	7.05	7.381	6.846	6.667	4.688	6.89	2.385
5H-SS-P F2	5H	2	636.16	0.522	10.63	6.187	6.296	16.176	5.429	4.73	1.714
5A-SS-3	5A	3	482.06	0.496	10.06	8.000	8.837	6.901	10.238	12.46	2.222
5A-SS-2	5A	3	466.9	0.462	8.09	6.842	8.980	7.262	4.286	5.74	1.512
5A-SS-4	5A	3	478.1	0.486	8.62	0.000	5.000	10.116	6.022	0.00	0.000
5B-SS-P	5B	3	82.4	0.415	0.00	0.000	0.000	0.000	0.000	0.00	0.000
5D-SS-P F2	5D	3	1470.66	0.455	6.91	6.305	5.294	7.895	4.286	5.56	1.782
5E-SS-P F2	5E	3	1486.7	0.624	6.41	5.575	5.308	5.789	3.933	5.33	1.738
5F-SS-P F2	5F	3	913.73	0.476	6.29	5.464	6.000	4.579	6.250	4.47	1.765
5G-SS-P	5G	3	0	0.000	0.00	0.000	0.000	0.000	0.000	0.00	0.000
6A-SS-P	6A	4	681.79	0.651	8.69	8.095	7.031	7.260	10.000	15.38	4.048
6B-SS-P-2	6B	4	2598.6	0.445	13.01	7.363	10.526	4.815	10.000	10.00	2.233
6C-SS-P-2	6C	4	238.39	0.668	9.86	6.914	7.273	5.625	0.000	8.62	4.308
6D-SS-4 F2	6D	4	1040.88	0.659	8.21	5.403	6.567	9.315	5.000	4.87	1.768
6D-SS-3 F2	6D	4	560.21	0.617	6.27	6.180	4.821	5.333	4.915	6.21	1.873
6D-SS-2 F2	6D	4	864.81	0.604	6.75	5.576	5.584	5.154	7.353	4.53	1.840
6F-SS-P	6F	4	335.58	0.764	8.22	0.000	5.556	9.091	4.783	42.29	4.714
6G-SS-P	6G	4	10435.6	0.679	9.55	7.070	9.500	5.217	10.167	8.12	2.727
7A-SS-P	7A	5	826.2	0.475	9.81	5.946	8.831	5.732	12.329	7.10	2.200
7B-SS-3 F2	7B	5	268.18	0.496	5.34	7.615	3.562	4.286	4.688	11.74	3.094
7B-SS-2 F2	7B	5	421.1	0.496	5.23	7.143	3.455	4.699	4.483	14.08	3.061
7B-SS-4 F2	7B	5	311.97	0.534	7.65	8.462	8.667	5.000	6.250	10.09	2.895
7C-SS-P F2	7C	5	2870.7	0.543	8.34	5.656	5.417	6.000	5.313	5.95	1.810
7D-SS-P F2	7D	5	1166.74	0.573	7.52	5.850	5.918	6.200	6.583	5.61	1.755
7E-SS-P F2	7E	5	2870.9	0.629	7.69	6.698	6.500	6.667	7.200	6.09	1.858
7G-SS-P F2	7G	5	1791.6	0.655	11.41	9.833	8.590	10.000	10.000	6.82	2.107
8A-SS-4 F2	8A	8	1223.26	0.543	6.38	7.750	6.846	5.000	4.500	5.12	2.214
8A-SS-3 F2	8A	8	856.97	0.599	6.57	6.667	7.333	5.545	4.545	4.73	1.875
8A-SS-2 F2	8A	8	675.18	0.477	6.36	6.923	7.125	4.833	4.767	4.29	2.222
8B-SS-4 F2	8B	8	151.79	0.699	23.97	0.000	0.000	16.949	8.209	9.44	1.929
8B-SS-2 F2	8B	8	342.67	0.641	6.05	6.000	5.882	4.800	4.722	6.90	2.062
8B-SS-3 F2	8B	8	308.42	0.650	8.32	6.364	5.909	16.154	5.484	4.98	1.750

POLYCYCLIC AROMATIC HYDROCARBONS IN 1989 SURFACE SEDIMENTS (ng/g)

SAMPID	STATION	REGION	TOT PAH	FFPI	P/D	C0P/C0D	C1P/C1D	C2P/C2D	C3P/C3D	P/C	C0P/C0C
8C-SS-2 F2	8C	8	37.554	0.523	4.24	3.871	3.158	2.909	2.740	7.04	2.449
8C-SS-4 F2	8C	8	29.208	0.479	3.86	4.231	3.492	3.091	2.055	7.84	2.444
8C-SS-3 F2	8C	8	46.347	0.507	4.57	4.286	3.418	4.231	3.333	10.25	2.182
8D-SS-4 F2	8D	8	16.98	0.426	0.00	0.000	0.000	0.000	0.000	8.11	2.093
8D-SS-3 F2	8D	8	25.52	0.306	0.00	0.000	0.000	0.000	0.000	8.93	1.961
8D-SS-2 F2	8D	8	38.31	0.572	6.39	0.000	5.510	4.000	5.000	10.61	2.487
8E-SS-3 F2	8E	8	2082.75	0.514	5.68	6.149	5.455	4.390	4.688	4.77	1.987
8E-SS-2 F2	8E	8	1568.04	0.452	5.95	6.212	5.333	4.706	5.200	4.82	1.982
8E-SS-4 F2	8E	8	2111.02	0.535	5.74	6.488	5.238	4.615	4.667	4.79	2.024
8F-SS-2 F2	8F	8	740.87	0.684	6.22	6.667	6.316	4.767	4.306	5.60	2.308
8F-SS-4 F2	8F	8	774.78	0.667	6.57	6.500	6.964	4.592	4.789	5.61	2.281
8F-SS-3 F2	8F	8	537.41	0.622	6.52	14.714	4.600	4.634	4.262	11.95	4.292
5(0)-SS-2 F2	5(0)	6	967.07	0.540	5.54	6.019	5.052	4.333	4.643	4.85	2.025
5(0)-SS-3 F2	5(0)	6	886.34	0.579	6.37	6.053	5.185	5.308	5.182	5.54	2.018
5(0)-SS-4	5(0)	6	1251	0.557	7.31	7.813	8.182	6.471	4.421	9.27	3.086
5(1)-SS-2 F2	5(10)	6	128.88	0.687	5.92	6.087	5.612	5.857	1.917	5.25	2.000
5(10)-SS-P	5(10)	6	490.19	0.631	6.68	6.667	7.021	6.176	4.912	6.61	3.077
5(1)-SS-3 F2	5(10)	6	128.41	0.755	0.00	0.000	0.000	0.000	0.000	7.00	1.951
5(1)-SS-4 F2	5(10)	6	76.17	0.699	5.13	5.926	4.118	4.500	2.683	8.26	2.105
5(5)-SS-3 F2	5(5)	6	841.73	0.617	7.89	6.262	5.938	7.895	6.154	4.33	1.871
5(5)-SS-4	5(5)	6	685.55	0.551	10.58	8.824	9.815	8.375	9.455	9.91	3.125
5(5)-SS-2 F2	5(5)	6	956.58	0.632	8.39	6.429	6.143	8.608	7.083	4.70	1.800
9A-SS-4 F2	9A	7	15.21	0.394	0.00	0.000	0.000	0.000	0.000	8.29	2.414
9A-SS-2 F2	9A	7	17.49	0.422	24.36	0.000	17.722	19.231	16.176	7.31	2.313
9A-SS-3 F2	9A	7	17.223	0.419	0.00	0.000	0.000	0.000	0.000	8.68	2.103
9B-SS-4	9B	7	87.19	0.407	6.13	7.947	5.636	4.524	3.812	7.61	1.678
9B-SS-2	9B	7	169.8	0.373	0.00	0.000	0.000	0.000	0.000	0.00	0.000
9B-SS-3	9B	7	0	0	0	0.000	0.000	0.000	0.000	0	0.000
9C-SS-4 F2	9C	7	585.14	0.465	8.03	6.404	7.021	6.118	6.522	4.62	1.537
9C-SS-2 F2	9C	7	605.64	0.488	7.88	5.931	7.391	5.667	6.923	5.04	1.542
9C-SS-3 F2	9C	7	657.86	0.481	7.59	5.850	5.833	6.632	6.349	4.76	1.489

All values below instrument detection limits (ND) are indicated by blank spaces

POLYCYCLIC AROMATIC HYDROCARBONS IN 1989 SURFACE SEDIMENTS (ng/g)

SAMPID	STATION	REGION	C1P/C1C	C2P/C2C	C3P/C3C	C4P/C4C	N/P	C0N/C0P	C1N/C1P	C2N/C2P	C3N/C3P
1A-SS-P	1A	1	5.345	9.750	0.000	0.000	0.74	0.582	0.645	1.179	0.655
1B-SS-P	1B	1	0.000	0.000	0.000	0.000	1.18	0.542	0.615	0.846	5.300
1C-SS-P	1C	1	5.643	8.488	8.267	2.771	1.91	0.460	0.873	2.603	3.226
1D-SS-P F2	1D	1	4.024	14.167	6.667	0.000	1.82	1.294	1.242	2.500	2.650
1E-SS-4 F2	1E	1	0.000	0.000	0.000	0.000	0.98	0.581	0.688	1.182	1.798
1E-SS-2 F2	1E	1	5.745	0.000	0.000	0.000	2.94	0.593	1.815	14.615	2.931
1E-SS-3 F2	1E	1	13.542	0.000	0.000	0.000	1.26	1.164	0.492	3.662	1.550
2A-SS-P F2	2A	1	2.381	5.000	8.182	3.231	0.84	0.277	0.653	1.045	0.889
2B-SS-P F2	2B	1	8.500	14.141	0.000	7.436	1.27	0.644	0.588	2.357	2.000
2C-SS-P	2C	1	0.000	0.000	0.000	0.000	2.11	1.842	0.000	0.000	0.000
2D-SS-P	2D	1	4.375	31.915	17.000	0.000	0.93	0.500	0.714	1.133	1.118
2E-SS-P F2	2E	1	4.571	15.593	0.000	0.000	1.13	0.720	0.797	0.967	1.702
2F-SS-P F2	2F	1	5.283	7.500	0.000	0.000	1.02	0.559	0.607	1.067	1.688
3A-SS-P F2	3A	2	2.344	10.000	7.167	9.063	1.45	0.490	1.187	1.917	1.628
3B-SS-2 F2	3B	2	7.356	8.846	0.000	0.000	0.85	0.462	0.672	1.058	1.237
3B-SS-3 F2	3B	2	8.333	15.952	0.000	0.000	1.23	0.480	0.933	1.433	2.567
3B-SS-4 F2	3B	2	7.895	18.710	0.000	0.000	1.12	0.600	0.900	1.552	2.148
4A-SS-P F2	4A	2	4.124	4.632	5.600	0.000	1.87	0.531	0.925	2.500	2.214
4B-SS-P3 F2	4B	2	5.690	7.600	6.757	9.873	1.42	0.545	0.727	1.763	2.120
4C-SS-P F2	4C	2	5.235	8.000	10.135	0.000	3.27	1.645	1.461	3.500	3.733
5H-SS-P F2	5H	2	3.091	5.000	5.205	11.935	1.05	0.478	0.971	1.455	1.500
5A-SS-3	5A	3	5.278	40.833	0.000	0.000	1.01	0.525	0.816	1.531	0.767
5A-SS-2	5A	3	2.444	16.486	0.000	0.000	0.88	0.546	0.705	1.148	0.889
5A-SS-4	5A	3	0.000	0.000	0.000	0.000	0.90	0.000	0.884	1.379	0.857
5B-SS-P	5B	3	0.000	0.000	0.000	0.000	0.71	0.800	0.536	0.800	0.875
5D-SS-P F2	5D	3	2.727	13.636	8.571	6.818	0.94	0.439	0.933	1.267	0.917
5E-SS-P F2	5E	3	3.450	10.000	4.538	20.000	2.11	0.508	1.362	2.091	4.576
5F-SS-P F2	5F	3	3.000	5.118	9.868	2.424	1.15	0.479	1.000	1.379	1.200
5G-SS-P	5G	3	0.000	0.000	0.000	0.000	0.00	0.000	0.000	0.000	0.000
6A-SS-P	6A	4	7.500	54.082	0.000	0.000	2.11	1.176	1.800	3.019	1.800
6B-SS-P-2	6B	4	4.878	6.190	43.182	0.000	0.91	0.597	1.000	3.000	1.000
6C-SS-P-2	6C	4	0.000	3.103	0.000	0.000	2.43	1.071	1.438	2.111	4.188
6D-SS-4 F2	6D	4	2.588	8.095	5.227	0.000	2.24	0.566	1.841	3.088	2.826
6D-SS-3 F2	6D	4	3.333	19.048	6.591	0.000	1.84	0.583	1.481	2.500	2.207
6D-SS-2 F2	6D	4	3.071	4.786	8.929	4.783	1.83	0.533	1.442	2.388	1.980
6F-SS-P	6F	4	0.000	0.000	0.000	0.000	3.66	1.288	2.933	5.500	3.364
6G-SS-P	6G	4	5.700	6.429	21.786	0.000	2.86	0.786	1.930	7.222	2.295
7A-SS-P	7A	5	4.857	4.273	40.909	0.000	1.13	0.682	0.926	2.553	0.789
7B-SS-3 F2	7B	5	8.667	15.000	0.000	0.000	1.05	0.586	0.769	1.429	1.800
7B-SS-2 F2	7B	5	11.176	21.667	0.000	0.000	1.01	0.553	0.816	1.385	1.462
7B-SS-4 F2	7B	5	8.966	13.333	0.000	5.849	1.29	0.673	0.962	1.679	2.267
7C-SS-P F2	7C	5	2.889	10.500	5.000	18.333	1.37	0.552	1.462	2.143	1.529
7D-SS-P F2	7D	5	2.900	10.000	10.822	6.744	1.58	0.733	1.638	2.043	1.519
7E-SS-P F2	7E	5	3.023	8.696	25.000	12.000	2.09	0.799	1.846	2.650	1.944
7G-SS-P F2	7G	5	2.913	17.391	10.000	9.189	2.57	1.288	2.537	3.167	2.214
8A-SS-4 F2	8A	8	5.235	6.333	6.300	1.587	1.37	0.387	0.787	1.789	1.746
8A-SS-3 F2	8A	8	4.583	5.083	6.349	2.833	1.73	0.467	0.891	2.295	2.150
8A-SS-2 F2	8A	8	4.750	4.462	5.125	1.250	1.04	0.417	0.596	1.328	1.195
8B-SS-4 F2	8B	8	3.333	0.000	0.000	0.000	3.35	0.704	1.050	2.200	12.909
8B-SS-2 F2	8B	8	5.000	8.276	12.143	0.000	1.93	0.712	0.950	2.458	2.588
8B-SS-3 F2	8B	8	3.095	9.130	6.071	0.000	1.91	0.696	1.462	2.095	2.118

POLYCYCLIC AROMATIC HYDROCARBONS IN 1989 SURFACE SEDIMENTS (ng/g)

SAMPID	STATION	REGION	C1P/C1C	C2P/C2C	C3P/C3C	C4P/C4C	N/P	C0N/C0P	C1N/C1P	C2N/C2P	C3N/C3P
8C-SS-2 F2	8C	8	2.857	7.442	0.000	25.000	1.34	1.500	1.278	2.188	0.800
8C-SS-4 F2	8C	8	3.188	17.000	0.000	0.000	1.00	0.709	0.773	1.147	1.133
8C-SS-3 F2	8C	8	3.600	18.966	0.000	0.000	0.92	0.917	0.889	1.145	0.425
8D-SS-4 F2	8D	8	3.830	0.000	0.000	0.000	0.99	1.033	0.722	2.083	0.000
8D-SS-3 F2	8D	8	3.889	9.444	0.000	0.000	0.31	1.800	0.929	0.000	0.000
8D-SS-2 F2	8D	8	6.000	11.892	0.000	0.000	1.55	2.680	0.963	1.205	4.476
8E-SS-3 F2	8E	8	2.857	6.000	10.000	3.400	1.37	0.445	1.167	1.778	1.400
8E-SS-2 F2	8E	8	2.743	6.154	10.833	3.085	1.08	0.384	0.958	1.313	1.077
8E-SS-4 F2	8E	8	2.683	6.207	10.769	3.297	1.37	0.375	1.091	1.611	1.500
8F-SS-2 F2	8F	8	5.294	5.775	7.045	5.417	2.51	0.467	0.889	2.244	5.806
8F-SS-4 F2	8F	8	5.342	6.081	5.862	6.800	2.33	0.531	0.897	2.111	5.000
8F-SS-3 F2	8F	8	3.538	0.000	0.000	0.000	1.85	0.248	1.174	1.816	4.615
5(0)-SS-2 F2	5(0)	6	2.882	5.571	10.656	3.947	1.38	0.584	1.327	1.795	1.338
5(0)-SS-3 F2	5(0)	6	3.000	12.105	6.196	8.571	1.52	0.516	1.357	2.029	1.561
5(0)-SS-4	5(0)	6	8.182	7.857	12.923	0.000	1.64	0.560	0.833	1.727	2.738
5(1)-SS-2 F2	5(10)	6	3.235	11.233	3.194	0.000	2.55	0.821	1.582	3.171	5.652
5(10)-SS-P	5(10)	6	6.226	4.200	0.000	0.000	1.54	0.833	1.242	1.881	1.321
5(1)-SS-3 F2	5(10)	6	3.400	10.339	7.692	0.000	3.34	1.187	1.353	3.279	7.250
5(1)-SS-4 F2	5(10)	6	2.917	0.000	0.000	0.000	2.55	0.875	1.393	2.222	7.727
5(5)-SS-3 F2	5(5)	6	2.923	4.000	10.000	4.667	1.90	0.596	1.526	2.500	2.083
5(5)-SS-4	5(5)	6	7.910	8.272	21.667	0.000	1.57	0.733	0.774	1.642	2.885
5(5)-SS-2 F2	5(5)	6	2.867	4.857	15.938	4.783	2.02	0.889	1.535	2.353	1.961
9A-SS-4 F2	9A	7	2.927	0.000	0.000	0.000	1.03	1.271	1.750	1.579	0.000
9A-SS-2 F2	9A	7	3.256	0.000	0.000	0.000	1.30	1.014	1.143	3.200	0.000
9A-SS-3 F2	9A	7	2.955	0.000	0.000	0.000	1.14	1.508	1.308	1.917	0.000
9B-SS-4	9B	7	2.818	55.882	0.000	0.000	0.93	0.662	0.758	1.474	0.918
9B-SS-2	9B	7	0.000	0.000	0.000	0.000	0.60	0.673	0.330	0.721	0.769
9B-SS-3	9B	7	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
9C-SS-4 F2	9C	7	2.357	9.811	6.618	6.667	0.94	0.442	0.939	1.269	0.867
9C-SS-2 F2	9C	7	2.615	11.087	8.036	7.826	1.09	0.512	1.059	1.588	0.867
9C-SS-3 F2	9C	7	2.333	12.115	8.000	5.333	1.07	0.513	1.086	1.270	1.075

All values below instrument
detection limits (ND) are
indicated by blank spaces

POLYCYCLIC AROMATIC HYDROCARBONS IN 1989 SURFACE SEDIMENTS (ng/g)

SAMPID	STATION	REGION	C4N/C4P
1A-SS-P	1A	1	0.632
1B-SS-P	1B	1	0.000
1C-SS-P	1C	1	2.652
1D-SS-P F2	1D	1	3.417
1E-SS-4 F2	1E	1	0.000
1E-SS-2 F2	1E	1	0.000
1E-SS-3 F2	1E	1	0.960
2A-SS-P F2	2A	1	2.095
2B-SS-P F2	2B	1	2.241
2C-SS-P	2C	1	0.000
2D-SS-P	2D	1	1.711
2E-SS-P F2	2E	1	6.186
2F-SS-P F2	2F	1	6.667
3A-SS-P F2	3A	2	2.379
3B-SS-2 F2	3B	2	7.083
3B-SS-3 F2	3B	2	2.417
3B-SS-4 F2	3B	2	1.267
4A-SS-P F2	4A	2	9.630
4B-SS-P3 F2	4B	2	3.718
4C-SS-P F2	4C	2	20.000
5H-SS-P F2	5H	2	0.703
5A-SS-3	5A	3	1.556
5A-SS-2	5A	3	1.313
5A-SS-4	5A	3	0.000
5B-SS-P	5B	3	0.000
5D-SS-P F2	5D	3	1.289
5E-SS-P F2	5E	3	2.579
5F-SS-P F2	5F	3	2.813
5G-SS-P	5G	3	0.000
6A-SS-P	6A	4	0.000
6B-SS-P-2	6B	4	0.177
6C-SS-P-2	6C	4	0.000
6D-SS-4 F2	6D	4	2.652
6D-SS-3 F2	6D	4	2.818
6D-SS-2 F2	6D	4	4.545
6F-SS-P	6F	4	0.000
6G-SS-P	6G	4	4.571
7A-SS-P	7A	5	2.000
7B-SS-3 F2	7B	5	1.486
7B-SS-2 F2	7B	5	1.413
7B-SS-4 F2	7B	5	2.548
7C-SS-P F2	7C	5	1.000
7D-SS-P F2	7D	5	2.207
7E-SS-P F2	7E	5	10.000
7G-SS-P F2	7G	5	5.294
8A-SS-4 F2	8A	8	7.600
8A-SS-3 F2	8A	8	11.373
8A-SS-2 F2	8A	8	6.000
8B-SS-4 F2	8B	8	0.000
8B-SS-2 F2	8B	8	5.098
8B-SS-3 F2	8B	8	0.000

POLYCYCLIC AROMATIC HYDROCARBONS IN 1989 SURFACE SEDIMENTS (ng/g)

SAMPID	STATION	REGION	C4N/C4P
8C-SS-2 F2	8C	8	1.286
8C-SS-4 F2	8C	8	2.000
8C-SS-3 F2	8C	8	2.059
8D-SS-4 F2	8D	8	0.000
8D-SS-3 F2	8D	8	0.000
8D-SS-2 F2	8D	8	0.000
8E-SS-3 F2	8E	8	3.235
8E-SS-2 F2	8E	8	2.828
8E-SS-4 F2	8E	8	4.333
8F-SS-2 F2	8F	8	4.154
8F-SS-4 F2	8F	8	4.000
8F-SS-3 F2	8F	8	4.265
5(0)-SS-2 F2	5(0)	6	2.867
5(0)-SS-3 F2	5(0)	6	2.556
5(0)-SS-4	5(0)	6	2.788
5(1)-SS-2 F2	5(10)	6	4.783
5(10)-SS-P	5(10)	6	0.000
5(1)-SS-3 F2	5(10)	6	3.421
5(1)-SS-4 F2	5(10)	6	2.600
5(5)-SS-3 F2	5(5)	6	3.429
5(5)-SS-4	5(5)	6	1.875
5(5)-SS-2 F2	5(5)	6	7.364
9A-SS-4 F2	9A	7	0.000
9A-SS-2 F2	9A	7	0.000
9A-SS-3 F2	9A	7	0.000
9B-SS-4	9B	7	0.795
9B-SS-2	9B	7	0.000
9B-SS-3	9B	7	0.000
9C-SS-4 F2	9C	7	1.350
9C-SS-2 F2	9C	7	1.722
9C-SS-3 F2	9C	7	1.875

All values below instrument detection limits (ND) are indicated by blank spaces

TRACE METALS IN 1989 SURFACE SEDIMENTS (ug/g)

sample#	station	region	Cd	Pb	Ba	Cr	Cu	V	Zn
1A-SS-P	1A	1	0.11	12.5	640	95	29.7	148	108
1B-SS-P	1B	1	0.11	11.5	675	96	23.2	167	110
1C-SS-P	1C	1	0.07	11.6	755	98	27.4	200	116
1D-SS-P	1D	1	0.14	23.2	860	94	22.9	114	103
1E-SS-2	1E	1	0.09	12.7	540	69	19.6	92	83
1E-SS-3	1E	1	0.09	12	523	70	19.4	80	77
1E-SS-4	1E	1	0.18	19.8	566	80	18.6	91	79
2A-SS-P	2A	1	0.26	19.5	732	106	38.1	196	131
2B-SS-P	2B	1	0.13	12.6	585	86	19.8	164	99
2C-SS-P	2C	1	0.12	15.6	765	96	25.2	203	116
2D-SS-P	2D	1	0.28	10.2	575	83	24.6	158	117
2E-SS-P	2E	1	0.25	11.9	635	117	18.6	142	102
2F-SS-P	2F	1	0.15	7.2	505	90	18.4	127	96
3A-SS-P	3A	2	0.17	11.4	587	80	22.6	149	103
3B-SS-2	3B	2	0.13	10.9	560	81	16.7	138	85
3B-SS-3	3B	2	0.13	10.17	580	80.3	19.3	132.7	90
3B-SS-4	3B	2	0.11	9.0	590	77	18.4	132	89
4A-SS-P	4A	2	0.14	5.9	585	81	22.2	142	111
4B-SS-P3	4B	2	0.17	5.8	635	86	23.3	153	123
4C-SS-P	4C	2	0.12	12.2	670	97	24.8	191	122
5G-SS-P	5G	2	0.16	11.9	690	104	24.1	177	108
5H-SS-P	5H	2	0.10	6.6	580	82	22.7	147	102
5A-SS-2	5A	3	0.11	7.8	625	88	23.9	153	112
5A-SS-3	5A	3	0.22	11.6	642	87.3	22.5	150	103
5A-SS-4	5A	3	0.17	10.8	587	89	23.7	165	107
5B-SS-P	5B	3	0.14	15.3	778	94	27.5	221	134
5D-SS-P F2	5D	3	0.27	10.2	653	89	22.5	153	110
5E-SS-P F2	5E	3	0.16	15.8	700	102	26.9	221	120
5F-SS-P F2	5F	3	0.10	3.9	530	88	14.3	106	90
6A-SS-P	6A	4	0.19	11.4	568	91	25.8	174	111
6B-SS-P-2	6B	4	0.20	17.1	790	102	30.8	185	119
6C-SS-P-2	6C	4	0.15	14.4	660	108	28.5	219	122
6D-SS-2 F2	6D	4	0.12	16.1	760	125	29.5	229	130
6D-SS-3 F2	6D	4	0.12	16.2	780	123	29.2	220	131
6D-SS-4 F2	6D	4	0.10	18.2	725	117	30.3	228	129
6F-SS-P	6F	4	0.10	12.2	650	115	27.0	187	113
6G-SS-P	6G	4	0.13	9.6	555	102	23.7	154	107
7A-SS-P	7A	5	0.06	10.6	1100	219	18.4	145	100
7B-SS-2 F2	7B	5	0.09	11.1	765	162	21.5	170	105
7B-SS-3 F2	7B	5	0.08	11.1	1112	170	20.5	169	103
7B-SS-4 F2	7B	5	0.10	9.6	841	155	19.4	147	97
7C-SS-P F2	7C	5	0.19	14.9	625	97	23.2	168	107
7D-SS-P F2	7D	5	0.19	13.8	675	103	21.6	163	107
7E-SS-P F2	7E	5	0.10	7.7	650	105	21.1	142	101
7G-SS-P F2	7G	5	0.20	11.1	1082	185	17.4	136	92
5(0)-SS-2 F2	5(0)	6	0.21	8.3	555	88	25.0	150	114

TRACE METALS IN 1989 SURFACE SEDIMENTS (ug/g)

sample#	station	region	Cd	Pb	Ba	Cr	Cu	V	Zn
5(0)-SS-3 F2	5(0)	6	0.29	9.4	608	88	24.5	146	109
5(0)-SS-4 F2	5(0)	6	0.24	6.8	635	89	24.9	149	112
5(1)-SS-2 F2	5(1)	6	0.26	11.5	651	97	22.8	167	112
5(1)-SS-3 F2	5(1)	6	0.27	11.4	635	97	24.1	178	111
5(1)-SS-4 F2	5(1)	6	0.12	7.9	567	95	23.9	160	117
5(10)-SS-P	5(1)	6	0.19	10.5	585	84	21.5	168	105
5(5)-SS-2 F2	5(5)	6	0.12	7.6	624	91	25	158	112
5(5)-SS-3 F2	5(5)	6	0.21	9.6	635	89	24.6	172	112
5(5)-SS-4 F2	5(5)	6	0.11	7.5	553	91	24.3	153	111
8A-SS-2	8A	6	0.13	4.1	576	87	22.0	131	104
8A-SS-3	8A	6	0.15	4.5	582	90	23.6	144	107
8A-SS-4	8A	6	0.16	6.6	665	87	24.8	149	114
8B-SS-2	8B	6	0.22	10.4	642	93	24.5	152	116
8B-SS-3	8B	6	0.22	9.6	659	91	23.8	148	116
8B-SS-4	8B	6	0.22	10.6	715	98	24.3	160	122
8C-SS-2	8C	6	0.16	4.8	309	67	17.7	111	117
8C-SS-3	8C	6	0.13	7.7	588	93	18.9	130	118
8C-SS-4	8C	6	0.15	10.0	577	99	19.3	111	128
8D-SS-2	8D	6	0.15	12.4	685	98	23.1	159	131
8D-SS-3	8D	6	0.17	7.8	700	93	22.8	148	122
8D-SS-4	8D	6	0.19	8.1	649	93	23.5	142	123
8E-SS-2	8E	6	0.23	8.6	590	87	26.6	158	118
8E-SS-3	8E	6	0.23	8.8	595	90	25.3	158	122
8E-SS-4	8E	6	0.15	9.1	610	87	25.2	148	110
8F-SS-2	8F	6	0.22	13.5	565	86	25.8	136	120
8F-SS-3	8F	6	0.18	7.7	607	89	25.8	157	116
8F-SS-4	8F	6	0.16	6.9	575	87	25.4	161	125
9A-SS-2	9A	7	0.15	14.4	659	75	23.6	132	109
9A-SS-3	9A	7	0.17	12.6	703	87	23.3	126	114
9A-SS-4	9A	7	0.22	24.4	699	92	25.1	150	110
9B-SS-2	9B	7	0.09	12.3	725	95	24.1	174	111
9B-SS-3	9B	7	0.07	14.1	695	96	22.9	180	101
9B-SS-4	9B	7	0.22	19.8	713	88	22.6	170	107
9C-SS-2	9C	7	0.09	12.4	795	94	26.7	169	108
9C-SS-3	9C	7	0.11	10.3	675	88	24.5	148	102
9C-SS-4	9C	7	0.10	12.7	735	88	24.4	175	104

APPENDIX II

Concentrations of Saturated Hydrocarbons, Polycyclic Aromatic Hydrocarbons, and Metals in Beaufort Sea Tissue from 1989

BEAUFORT SEA TISSUE DATA, 1989 - SATURATED HYDROCARBONS (ug/g wet weight)

LABSAMP	SPECIES	nC10	nC11	nC12	nC13	1380	nC14	1470	nC15	nC16	1650	nC17	pristane	nC18
1A/B/E-AN-1-1	Anonyx	0.014	0.010	0.021	0.012	0.0073	0.024	0.0085	0.11	0.019		0.18	0.86	0.03
1A/B/E-AN-1-2	Anonyx	0.011	0.013	0.025	0.012	0.0058	0.028	0.0091	0.12	0.022	0.0091	0.18	0.87	0.019
1A/B/E-AN-1-3	Anonyx	0.021	0.0091	0.024	0.012	0.006	0.035	0.0095	0.12	0.021	0.0048	0.17	0.86	0.018
2D-AN-1-1	Anonyx	0.020	0.0072	0.017	0.0093	0.006	0.019	0.0061	0.037	0.0035		0.022	1.2	0.0055
2D-AN-1-2	Anonyx	0.021	0.011	0.012	0.0048	0.0055	0.0097	0.0097	0.048	0.0048		0.02	1.1	0.0043
2D-AN-1-3	Anonyx	0.023	0.0031	0.014	0.031	0.0081	0.020	0.0097	0.049	0.011	0.0038	0.033	1.2	0.0061
4B-AN-1-1	Anonyx	0.044	0.008	0.014	0.011	0.006	0.023	0.0093	0.15	0.015		0.11	4.2	0.017
4B-AN-1-2	Anonyx	0.02	0.01	0.015	0.0086	0.01	0.019	0.013	0.14	0.016		0.12	4.2	0.021
4B-AN-1-3	Anonyx	0.016	0.0087	0.013	0.011	0.0054	0.023	0.0089	0.14	0.02		0.12	4.2	0.021
5H-AN-1-1	Anonyx		0.0039	0.015	0.0072	0.0082	0.019	0.017	0.12	0.023	0.0062	0.12	6.1	0.022
5H-AN-1-2	Anonyx	0.036	0.014	0.028	0.015	0.011	0.026	0.016	0.14	0.024	0.0069	0.12	6.0	0.018
5B-AN-1-1	Anonyx	0.015	0.011	0.0067	0.016	0.0077	0.017	0.0047	0.014	0.0027		0.017	0.54	0.0035
5B-AN-1-2	Anonyx	0.033	0.0088	0.01	0.0081		0.021	0.024	0.021	0.02		0.017	0.57	0.0044
5B-AN-1-3	Anonyx	0.041	0.011	0.013	0.015		0.015	0.0038	0.018	0.0069	0.029	0.010	0.56	0.0041
6D-AN-1-1	Anonyx		0.012	0.028	0.012	0.0058	0.026	0.0097	0.093	0.022	0.0045	0.083	1.5	0.026
6D-AN-1-2	Anonyx	0.014	0.012	0.024	0.011	0.004	0.023	0.0097	0.071	0.017	0.014	0.071	1.2	0.0089
6D-AN-1-3	Anonyx	0.020	0.012	0.025	0.011	0.0064	0.028	0.016	0.087	0.022	0.0076	0.082	1.3	0.033
7E-AN-1-1	Anonyx	0.011	0.020	0.024	0.012	0.0028	0.026	0.0093	0.095	0.028		0.2	1.4	0.035
7E-AN-1-2	Anonyx	0.012	0.013	0.025	0.014	0.0037	0.048	0.016	0.086	0.024	0.0068	0.19	1.4	0.024
7E-AN-1-3	Anonyx	0.019	0.0097	0.022	0.0097	0.0044	0.021	0.010	0.075	0.016	0.0046	0.17	1.2	0.016
1A-AS-1-1	Astarte	0.053	0.02	0.11	0.027	0.011	0.11		0.05	0.072	0.02	0.054	0.03	0.026
1B-AS-1-1	Astarte	0.021	0.025	0.043	0.014		0.038	0.013	0.017	0.022	0.018	0.032	0.019	0.016
1B-AS-1-2	Astarte	0.024	0.026	0.063	0.013	0.0088	0.038		0.023	0.024	0.013	0.057	0.026	0.028
1B-AS-1-3	Astarte	0.042	0.012	0.041	0.016	0.0091	0.034	0.0097	0.022	0.02	0.0096	0.023	0.0076	0.019
3A-AS-1-1	Astarte	0.038	0.026	0.071	0.016	0.0078	0.048	0.013	0.02	0.026	0.018	0.037	0.032	0.023
3A-AS-1-2	Astarte	0.065	0.04	0.082	0.016		0.069	0.037	0.037	0.055	0.076	0.056	0.037	0.031
3A-AS-1-3	Astarte	0.04	0.024	0.067	0.0095	0.009	0.051	0.008	0.021	0.036	0.0053	0.023	0.013	0.015
6D-AS-1-1	Astarte	0.048	0.4	0.03	0.0059		0.02	0.0082	0.017	0.0093		0.028	0.024	0.016
6D-AS-1-2	Astarte	0.033	0.11	0.041	0.015		0.021	0.015	0.0083	0.005		0.014	0.015	0.012
6D-AS-1-3	Astarte	0.043	0.23	0.027	0.0091		0.019	0.0069	0.0097	0.01		0.012	0.02	0.0084
5H-AS-1-1	Astarte	0.053	0.028	0.056	0.027	0.0094	0.057	0.012	0.027	0.04	0.0092	0.031	0.029	0.016
5H-AS-1-2	Astarte	0.026	0.012	0.054	0.016	0.0075	0.039	0.0077	0.018	0.018	0.0076	0.029	0.018	0.012
5H-AS-1-3	Astarte	0.083	0.011	0.076	0.012	0.011	0.051	0.0057	0.015	0.044	0.012	0.029	0.022	0.022
5(1)-AS-1-1	Astarte	0.063	0.028	0.13	0.028		0.098	0.014	0.029	0.039	0.029	0.042	0.022	0.035
5(1)-AS-1-2	Astarte	0.052	0.0063	0.067	0.0094		0.076		0.033	0.027	0.01	0.04	0.02	0.049
5(1)-AS-1-3	Astarte	0.032	0.024	0.047	0.013		0.045		0.031	0.021	0.0082	0.026	0.0081	0.025
5F-CY-1-1	Cyrtodaria	0.063	0.4	0.029	0.0078		0.031		0.018	0.017	0.0084	0.036	0.014	0.017
5F-CY-1-2	Cyrtodaria	0.05	0.46	0.027	0.0096		0.021	0.0034	0.023	0.015		0.026	0.0087	0.017
5F-CY-1-3	Cyrtodaria	0.024	0.42	0.03	0.018	0.0028	0.02		0.019	0.013	0.016	0.027	0.0077	0.013
6G-CY-1-1	Cyrtodaria	0.03	0.39	0.022	0.0091	0.003	0.019	0.0077	0.013	0.013		0.035	0.022	0.013
6G-CY-1-2	Cyrtodaria	0.039	0.4	0.029	0.022		0.036	0.0071	0.017	0.015	0.0038	0.038	0.022	0.019
6G-CY-1-3	Cyrtodaria	0.031	0.26	0.024	0.013	0.0012	0.031	0.010	0.0092	0.011	0.007	0.024	0.016	0.017
6D-MA-1-1	Macoma	0.061	0.015	0.033	0.014	0.013	0.023	0.025	0.018	0.01		0.011	0.15	0.011
9B-MA-1-1	Macoma	0.031	0.22	0.018	0.022	0.0054	0.023	0.0082	0.063	0.011	0.0025	0.016	0.046	0.011
9B-PO-1-1	Portlandia	0.025	0.039	0.027	0.014		0.032	0.013	0.034	0.0055		0.011	0.029	0.011
1A-PO-1-1	Portlandia	0.025	0.17	0.022	0.0095		0.019	0.0066	0.013	0.016		0.03	0.022	0.016

BEAUFORT SEA TISSUE DATA, 1989 - SATURATED HYDROCARBONS (ug/g wet weight)

LABSAMP	SPECIES	phytane	nC19	nC20	nC21	nC22	nC23	nC24	nC25	nC26	nC27	nC28	nC29	nC30
1A/B/E-AN-1-1	Anonyx	0.0071	0.025	0.021	0.044	0.11	0.11	0.15	0.16	0.19	0.14	0.13	0.12	0.090
1A/B/E-AN-1-2	Anonyx	0.0077	0.033	0.021	0.039	0.071	0.098	0.1	0.13	0.15	0.12	0.12	0.1	0.086
1A/B/E-AN-1-3	Anonyx		0.033	0.016	0.027	0.038	0.050	0.066	0.052	0.064	0.038	0.034	0.032	0.034
2D-AN-1-1	Anonyx	0.0000	0.0039	0.0027	0.015	0.017	0.034	0.020	0.029	0.016	0.019	0.0093	0.011	0.0083
2D-AN-1-2	Anonyx	0.0077	0.0058	0.0061	0.016	0.026	0.053	0.034	0.045	0.022	0.024	0.015	0.012	0.021
2D-AN-1-3	Anonyx	0.0063	0.0075	0.0038	0.016	0.025	0.050	0.032	0.050	0.029	0.031	0.023	0.020	0.014
4B-AN-1-1	Anonyx	0.000	0.023	0.022	0.024	0.031	0.044	0.037	0.040	0.018	0.017	0.014	0.018	0.024
4B-AN-1-2	Anonyx	0.0087	0.021	0.014	0.023	0.033	0.06	0.048	0.052	0.037	0.041	0.027	0.027	0.019
4B-AN-1-3	Anonyx	0.0051	0.022	0.015	0.043	0.066	0.09	0.091	0.11	0.086	0.084	0.064	0.062	0.042
5H-AN-1-1	Anonyx	0.015	0.024	0.026	0.046	0.084	0.098	0.14	0.16	0.16	0.13	0.12	0.10	0.099
5H-AN-1-2	Anonyx	0.000	0.027	0.019	0.025	0.05	0.051	0.081	0.070	0.093	0.064	0.052	0.052	0.048
5B-AN-1-1	Anonyx	0.006	0.0066	0.014	0.052	0.099	0.15	0.19	0.24	0.25	0.27	0.23	0.21	0.15
5B-AN-1-2	Anonyx	0		0.0074	0.016	0.03	0.038	0.027	0.018	0.012	0.0098	0.014	0.0091	0.01
5B-AN-1-3	Anonyx	0.0053	0.0053	0.014	0.013	0.022	0.033	0.022	0.019	0.015	0.019	0.0082	0.015	0.009
6D-AN-1-1	Anonyx	0.000	0.022	0.019	0.037	0.063	0.078	0.06	0.078	0.092	0.063	0.058	0.052	0.058
6D-AN-1-2	Anonyx	0.0082	0.0077	0.014	0.022	0.031	0.041	0.036	0.036	0.039	0.018	0.014	0.016	0.018
6D-AN-1-3	Anonyx	0.015	0.011	0.020	0.041	0.081	0.11	0.14	0.15	0.17	0.15	0.13	0.12	0.096
7E-AN-1-1	Anonyx	0.015	0.029	0.021	0.055	0.076	0.15	0.13	0.13	0.12	0.11	0.084	0.099	0.073
7E-AN-1-2	Anonyx	0.018	0.047	0.047	0.16	0.27	0.47	0.55	0.63	0.65	0.62	0.54	0.5	0.39
7E-AN-1-3	Anonyx	0.0078	0.03	0.021	0.052	0.078	0.14	0.084	0.11	0.094	0.083	0.062	0.060	0.048
1A-AS-1-1	Astarte	0.035	0.021	0.036	0.051	0.059	0.058	0.067	0.088	0.062	0.059	0.04	0.056	0.046
1B-AS-1-1	Astarte	0.021	0.028	0.027	0.063	0.11	0.17	0.2	0.24	0.24	0.25	0.21	0.2	0.14
1B-AS-1-2	Astarte	0.030	0.035	0.059	0.2	0.36	0.54	0.66	0.81	0.83	0.84	0.73	0.69	0.47
1B-AS-1-3	Astarte	0.0084	0.0064	0.019	0.025	0.043	0.056	0.049	0.058	0.053	0.056	0.042	0.046	0.035
3A-AS-1-1	Astarte	0.016	0.018	0.032	0.037	0.055	0.059	0.056	0.054	0.058	0.048	0.035	0.04	0.033
3A-AS-1-2	Astarte	0.021	0.033	0.076	0.13	0.23	0.29	0.36	0.43	0.4	0.42	0.34	0.31	0.23
3A-AS-1-3	Astarte	0.0083	0.018	0.028	0.028	0.049	0.056	0.058	0.076	0.05	0.045	0.048	0.08	0.031
6D-AS-1-1	Astarte	0.013	0.013	0.029	0.09	0.14	0.22	0.25	0.3	0.3	0.31	0.26	0.24	0.16
6D-AS-1-2	Astarte	0.022	0.01	0.025	0.061	0.11	0.17	0.21	0.25	0.25	0.25	0.22	0.2	0.16
6D-AS-1-3	Astarte		0.013	0.02	0.054	0.1	0.16	0.18	0.2	0.18	0.18	0.15	0.14	0.1
5H-AS-1-1	Astarte		0.037	0.042	0.098	0.17	0.24	0.27	0.3	0.29	0.33	0.28	0.24	0.18
5H-AS-1-2	Astarte	0.011	0.021	0.019	0.024	0.028	0.049	0.03	0.046	0.04	0.024	0.015	0.027	0.025
5H-AS-1-3	Astarte	0.014	0.029	0.033	0.056	0.071	0.11	0.11	0.11	0.12	0.09	0.076	0.069	0.05
5(1)-AS-1-1	Astarte	0.015	0.041	0.046	0.049	0.071	0.082	0.11	0.074	0.064	0.049	0.055	0.055	0.075
5(1)-AS-1-2	Astarte	0.024	0.033	0.045	0.091	0.14	0.21	0.27	0.3	0.29	0.3	0.26	0.24	0.18
5(1)-AS-1-3	Astarte		0.01	0.023	0.039	0.071	0.11	0.12	0.13	0.14	0.13	0.11	0.1	0.073
5F-CY-1-1	Cyrtodaria	0.0095	0.021	0.022	0.06	0.076	0.12	0.15	0.16	0.14	0.17	0.13	0.13	0.082
5F-CY-1-2	Cyrtodaria		0.016	0.024	0.067	0.11	0.18	0.19	0.26	0.25	0.29	0.22	0.23	0.16
5F-CY-1-3	Cyrtodaria	0.018	0.014	0.022	0.048	0.068	0.097	0.074	0.092	0.069	0.091	0.057	0.071	0.035
6G-CY-1-1	Cyrtodaria	0.011	0.014	0.024	0.053	0.075	0.13	0.12	0.17	0.14	0.17	0.12	0.14	0.096
6G-CY-1-2	Cyrtodaria	0.0061	0.027	0.033	0.096	0.17	0.29	0.34	0.45	0.43	0.47	0.37	0.37	0.25
6G-CY-1-3	Cyrtodaria	0.016	0.015	0.019	0.059	0.086	0.15	0.15	0.21	0.19	0.22	0.16	0.18	0.11
6D-MA-1-1	Macoma	0.012	0.016	0.012	0.042	0.067	0.12	0.12	0.18	0.17	0.23	0.17	0.23	0.15
9B-MA-1-1	Macoma		0.011	0.014	0.031	0.043	0.067	0.066	0.1	0.066	0.097	0.054	0.086	0.037
9B-PO-1-1	Portlandia		0.018	0.019	0.049	0.076	0.11	0.1	0.14	0.11	0.16	0.084	0.13	0.069
1A-PO-1-1	Portlandia	0.026	0.016	0.027	0.088	0.18	0.32	0.38	0.49	0.46	0.56	0.41	0.46	0.29

BEAUFORT SEA TISSUE DATA, 1989 - SATURATED HYDROCARBONS (ug/g wet weight)

LABSAMP	SPECIES	nC31	nC32	nC33	nC34	PHC	LALK	TALK	Tot PHC/ Sum Alk	Iso/Alk	LALK/TALK
1A/B/E-AN-1-1	Anonyx	0.068	0.047	0.034	0.025	5.7	0.47	1.90	3.0	2.1	0.25
1A/B/E-AN-1-2	Anonyx	0.068	0.056	0.035	0.033	6	0.48	1.71	3.5	2.1	0.29
1A/B/E-AN-1-3	Anonyx	0.039	0.011	0.0072	0.0084	4.9	0.47	0.99	5.0	2.1	0.49
2D-AN-1-1	Anonyx	0.0032	0.004			1.9	0.15	0.34	5.7	8.7	0.44
2D-AN-1-2	Anonyx	0.0083	0.0046	0.0092	0.003	2.1	0.15	0.44	4.8	8.3	0.33
2D-AN-1-3	Anonyx	0.011	0.0055			2.4	0.20	0.52	4.7	6.7	0.40
4B-AN-1-1	Anonyx	0.0089				5.8	0.44	0.72	8.1	10.7	0.61
4B-AN-1-2	Anonyx	0.014	0.0084	0.0093	0.0077	5.8	0.40	0.82	7.2	11.4	0.50
4B-AN-1-3	Anonyx	0.035	0.028	0.018	0.011	6.3	0.41	1.24	5.1	11.3	0.33
5H-AN-1-1	Anonyx	0.066	0.049	0.041	0.027	12	0.38	1.72	7.0	18.6	0.22
5H-AN-1-2	Anonyx	0.049	0.020	0.020	0.011	10	0.47	1.17	8.7	14.3	0.40
5B-AN-1-1	Anonyx	0.12	0.089	0.065	0.040	4.4	0.12	2.27	1.9	5.5	0.05
5B-AN-1-2	Anonyx	0.0063	0.0054			1.6	0.15	0.35	4.6	4.1	0.44
5B-AN-1-3	Anonyx	0.011	0.0061		0.0073	1.8	0.15	0.36	5.1	4.5	0.43
6D-AN-1-1	Anonyx	0.036	0.022	0.019	0.055	6.1	0.34	1.13	5.5	5.0	0.31
6D-AN-1-2	Anonyx	0.017	0.0046			4.5	0.27	0.58	8.0	5.0	0.48
6D-AN-1-3	Anonyx	0.076	0.051	0.05	0.028	7	0.35	1.75	4.0	4.3	0.20
7E-AN-1-1	Anonyx	0.054	0.036	0.031	0.018	6.1	0.51	1.67	3.7	3.1	0.30
7E-AN-1-2	Anonyx	0.32	0.23	0.17	0.12	12	0.53	6.17	1.9	3.3	0.09
7E-AN-1-3	Anonyx	0.041	0.021	0.020	0.012	5.3	0.41	1.33	4.0	3.4	0.31
1A-AS-1-1	Astarte	0.035	0.014	0.028	0.025	4	0.58	1.36	3.2	0.2	0.46
1B-AS-1-1	Astarte	0.12	0.091	0.068	0.048	4.9	0.28	2.45	2.0	0.3	0.12
1B-AS-1-2	Astarte	0.41	0.32	0.26	0.18	17	0.39	7.73	2.2	0.3	0.05
1B-AS-1-3	Astarte	0.028	0.018	0.016	0.016	2.4	0.25	0.82	3.0	0.2	0.32
3A-AS-1-1	Astarte	0.029	0.016	0.024	0.016	3.3	0.36	0.96	3.6	0.3	0.39
3A-AS-1-2	Astarte	0.2	0.13	0.094	0.13	8	0.56	4.30	1.9	0.4	0.13
3A-AS-1-3	Astarte	0.03	0.036	0.027	0.035	3.3	0.33	1.02	3.4	0.2	0.34
6D-AS-1-1	Astarte	0.15	0.12	0.079	0.047	6.9	0.62	2.91	2.1	0.1	0.19
6D-AS-1-2	Astarte	0.13	0.09	0.062	0.053	4.8	0.29	2.44	1.9	0.2	0.12
6D-AS-1-3	Astarte	0.095	0.062	0.047	0.036	4.3	0.40	1.88	2.1	0.1	0.19
5H-AS-1-1	Astarte	0.16	0.13	0.082	0.12	26	0.41	3.33	7.9	0.2	0.13
5H-AS-1-2	Astarte	0.02	0.012	0.012	0.015	2.1	0.26	0.67	3.3	0.2	0.42
5H-AS-1-3	Astarte	0.055	0.042	0.023	0.019	3.6	0.41	1.47	2.6	0.2	0.29
5(1)-AS-1-1	Astarte	0.019	0.031	0.015	0.02	3.9	0.58	1.45	2.9	0.2	0.43
5(1)-AS-1-2	Astarte	0.15	0.13	0.076	0.068	6.2	0.44	3.20	2.0	0.2	0.14
5(1)-AS-1-3	Astarte	0.059	0.043	0.048	0.026	2.7	0.30	1.52	1.8	0.1	0.20
5F-CY-1-1	Cyrtodaria	0.087	0.047	0.044	0.028	3.5	0.66	1.71	1.7	0.1	0.32
5F-CY-1-2	Cyrtodaria	0.15	0.092	0.077	0.049	4.7	0.69	2.58	1.6	0.0	0.23
5F-CY-1-3	Cyrtodaria	0.053	0.021	0.024	0.02	2.4	0.62	1.05	1.7	0.1	0.43
6G-CY-1-1	Cyrtodaria	0.095	0.046	0.045	0.032	3.6	0.58	1.65	1.8	0.1	0.29
6G-CY-1-2	Cyrtodaria	0.23	0.17	0.12	0.072	6.6	0.68	4.13	1.5	0.1	0.15
6G-CY-1-3	Cyrtodaria	0.11	0.058	0.051	0.029	3.5	0.45	1.99	1.6	0.1	0.20
6D-MA-1-1	Macoma	0.19	0.13	0.13	0.091	4.1	0.22	2.26	1.8	1.0	0.10
9B-MA-1-1	Macoma	0.053	0.022	0.021	0.011	2.2	0.44	0.99	1.8	0.1	0.37
9B-PO-1-1	Portlandia	0.083	0.03	0.036	0.011	3.1	0.24	1.41	2.2	0.2	0.17
1A-PO-1-1	Portlandia	0.3	0.19	0.16	0.1	6.9	0.36	4.60	1.5	0.2	0.08

BEAUFORT SEA TISSUE DATA, 1989 - SATURATED HYDROCARBONS (ug/g wet weight)

LABSAMP	SPECIES	PRIS/PHT		OEPI
1A/B/E-AN-1-1	Anonyx	121		0.96
1A/B/E-AN-1-2	Anonyx	113		0.94
1A/B/E-AN-1-3	Anonyx		ND	0.84
2D-AN-1-1	Anonyx		ND	1.38
2D-AN-1-2	Anonyx	142.86		0.99
2D-AN-1-3	Anonyx	196		1.14
4B-AN-1-1	Anonyx		ND	1.01
4B-AN-1-2	Anonyx	483		1.24
4B-AN-1-3	Anonyx	820		1.14
5H-AN-1-1	Anonyx	401		0.92
5H-AN-1-2	Anonyx		ND	0.95
5B-AN-1-1	Anonyx	90		1.10
5B-AN-1-2	Anonyx		ND	0.76
5B-AN-1-3	Anonyx	105.58		1.69
6D-AN-1-1	Anonyx		ND	0.87
6D-AN-1-2	Anonyx	150		0.80
6D-AN-1-3	Anonyx	90		1.06
7E-AN-1-1	Anonyx	91		1.16
7E-AN-1-2	Anonyx	79		1.06
7E-AN-1-3	Anonyx	153		1.07
1A-AS-1-1	Astarte	0.9		1.22
1B-AS-1-1	Astarte	0.90		1.13
1B-AS-1-2	Astarte	0.87		1.11
1B-AS-1-3	Astarte	0.90		1.19
3A-AS-1-1	Astarte	2.00		1.09
3A-AS-1-2	Astarte	1.76		1.11
3A-AS-1-3	Astarte	1.57		1.41
6D-AS-1-1	Astarte	1.85		1.12
6D-AS-1-2	Astarte	0.68		1.06
6D-AS-1-3	Astarte		ND	1.10
5H-AS-1-1	Astarte		ND	1.11
5H-AS-1-2	Astarte	1.64		1.07
5H-AS-1-3	Astarte	1.57		0.99
5(1)-AS-1-1	Astarte	1.47		0.84
5(1)-AS-1-2	Astarte	0.83		1.09
5(1)-AS-1-3	Astarte	ERR		1.06
5F-CY-1-1	Cyrtodaria	1.5		1.24
5F-CY-1-2	Cyrtodaria	ERR		1.22
5F-CY-1-3	Cyrtodaria	0.43		1.49
6G-CY-1-1	Cyrtodaria	2.00		1.30
6G-CY-1-2	Cyrtodaria	3.61		1.18
6G-CY-1-3	Cyrtodaria	0.97		1.29
6D-MA-1-1	Macoma	13		1.39
9B-MA-1-1	Macoma		ND	1.73
9B-PO-1-1	Portlandia		ND	1.67
1A-PO-1-1	Portlandia	0.85		1.30

POLYCYCLIC AROMATIC HYDROCARBONS IN 1989 TISSUES (ng/g wet weight)

SAMPID	Species	Station	C0N	C1N	C2N	C3N	C4N	ACEY	ACE	BIP	C0F	C1F	C2F	C3F	C0D
1A-AS-1-1 F2	Astarte	1A	15							6.9				36	
1A-PO-1-1 F2	Portlandia	1A	12	9.4	9.3					3.7		4.8	40	49	
1A/B/E-AN-1-1	Anonyx	1A/B/E	15								12				
1A/B/E-AN-1-1	Anonyx	1A/B/E	15							3.3					
1A/B/E-AN-1-2	Anonyx	1A/B/E	23							3.4					
1A/B/E-AN-1-2	Anonyx	1A/B/E	20								8.8				
1A/B/E-AN-1-3	Anonyx	1A/B/E	17	3.5	4.5					4.1					
1A/B/E-AN-1-3	Anonyx	1A/B/E	14								8.1				
1B-AS-1-1 F2	Astarte	1B	12							5.8					
1B-AS-1-2 F2	Astarte	1B	13							5.6					
1B-AS-1-3 F2	Astarte	1B	13							4.4					
2D-AN-1-1	Anonyx	2D	6.6	2.2											
2D-AN-1-2	Anonyx	2D	9.9	2.6	7.3										
2D-AN-1-3	Anonyx	2D	9.4	2.7						2.4					
2D-AN-1-3	Anonyx	2D	12												
3A-AS-1-1 F2	Astarte	3A	12	5.3	31					5.5					
3A-AS-1-2 F2	Astarte	3A	770							1300					
3A-AS-1-3 F2	Astarte	3A	13		21					3.5					
4B-AN-1-1	Anonyx	4B	14					2,3	3.1	2.4					
4B-AN-1-2	Anonyx	4B	9.3	3.2						2.3					
4B-AN-1-3	Anonyx	4B	9.7	3											
5(1)-AS-1-1 F2	Astarte	5(1)	11							5.6			87	54	
5(1)-AS-1-2 F2	Astarte	5(1)	11							4.2				67	
5(1)-AS-1-3 F2	Astarte	5(1)	11	11						6.2	2.9				3.6
5B-AN-1-1	Anonyx	5B	8.2	3.9											
5B-AN-1-2	Anonyx	5B	15	5											
5B-AN-1-3	Anonyx	5B	14	5.3											
5F-CY-1-1 F2	Cyrtodaria	5F	12	13						5.1			70	58	
5F-CY-1-2 F2	Cyrtodaria	5F	14							6					
5F-CY-1-3 F2	Cyrtodaria	5F	21							7.3					
5H-AN-1-1	Anonyx	5H	45					7.6							
5H-AN-1-1 F2	Anonyx	5H	46					7.8	8.2	5.4	7.9				
5H-AN-1-2 F2	Anonyx	5H	19							4.6					
5H-AS-1-1 F2	Astarte	5H	22							4.6					
5H-AS-1-2 F2	Astarte	5H	8.6							3.1					
5H-AS-1-3 F2	Astarte	5H	11							4.1					
6D-AN-1-1	Anonyx	6D	19								8.6				
6D-AN-1-1 F2	Anonyx	6D	20							3.9					
6D-AN-1-2	Anonyx	6D	32					9.5							
6D-AN-1-2 F2	Anonyx	6D	31					9	8.9	2.8	8.6				
6D-AN-1-3	Anonyx	6D	21								7.2				
6D-AN-1-3 F2	Anonyx	6D	17	3.9						3.2					
6D-AS-1-1 F2	Astarte	6D	15		12					5.5	17	5.3	76	47	
6D-AS-1-2 F2	Astarte	6D	16												
6D-AS-1-3 F2	Astarte	6D	19					5.7	7	6.8					

VALUES BELOW INSTRUMENTAL DETECTION LIMITS (ND) ARE INDICATED BY BLANK SPACES.

POLYCYCLIC AROMATIC HYDROCARBONS IN 1989 TISSUES (ng/g wet weight)

SAMPID	Species	Station	C0N	C1N	C2N	C3N	C4N	ACEY	ACE	BIP	C0F	C1F	C2F	C3F	C0D
6D-MA-1-1	Macoma	6D	17	4.9	19					2.1					
6G-CY-1-1	Cyrtodaria	6G	12	11						3.6	19				
6G-CY-1-2	Cyrtodaria	6G	26	13						8.2					
6G-CY-1-3	Cyrtodaria	6G	13	7.6						4	16				
7E-AN-1-1	Anonyx	7E	17								13				
7E-AN-1-1 F2	Anonyx	7E	19								6				
7E-AN-1-2	Anonyx	7E	22								15				
7E-AN-1-2 F2	Anonyx	7E	20												
7E-AN-1-3	Anonyx	7E	14								7.5				
7E-AN-1-3 F2	Anonyx	7E	13												
9B-MA-1-1 F2	Macoma	9B	11					4.6	6.8	3.8	4.4				
9B-PO-1-1	Portlandia	9B													

VALUES BELOW INSTRUMENTAL DETECTION LIMITS (ND) ARE INDICATED BY BLANK SPACES.

POLYCYCLIC AROMATIC HYDROCARBONS IN 1989 TISSUES (ng/g wet weight)

SAMPID	Species	Station	C1D	C2D	C3D	C0P	C0A	C1P/A	C2P/A	C3P/A	C4P/A	FLUANT	PYR	C1F/P	BAA	C0C
1A-AS-1-1 F2	Astarte	1A				5.7										
1A-PO-1-1 F2	Portlandia	1A				5.4	5.2		6.2	12	45	2.6	4.8		1.6	1.3
1A/B/E-AN-1-1	Anonyx	1A/B/E														
1A/B/E-AN-1-1	Anonyx	1A/B/E				2.1										
1A/B/E-AN-1-2	Anonyx	1A/B/E														
1A/B/E-AN-1-2	Anonyx	1A/B/E														
1A/B/E-AN-1-3	Anonyx	1A/B/E				2.1										
1A/B/E-AN-1-3	Anonyx	1A/B/E														
1B-AS-1-1 F2	Astarte	1B				2.8							1.8			0.86
1B-AS-1-2 F2	Astarte	1B				3										
1B-AS-1-3 F2	Astarte	1B				3.6										
2D-AN-1-1	Anonyx	2D				2.1										
2D-AN-1-2	Anonyx	2D				2.5										
2D-AN-1-3	Anonyx	2D														
2D-AN-1-3	Anonyx	2D														
3A-AS-1-1 F2	Astarte	3A				3.1										
3A-AS-1-2 F2	Astarte	3A				1900										
3A-AS-1-3 F2	Astarte	3A				3										
4B-AN-1-1	Anonyx	4B				7	2.9					3.2	3.4		4.1	4.2
4B-AN-1-2	Anonyx	4B				2.8										
4B-AN-1-3	Anonyx	4B				2.4										
5(1)-AS-1-1 F2	Astarte	5(1)				4.5										
5(1)-AS-1-2 F2	Astarte	5(1)				4.2							2.1			
5(1)-AS-1-3 F2	Astarte	5(1)				7.2	2.9	14	6.3			3.5	3.1	3.1	6.4	7.5
5B-AN-1-1	Anonyx	5B				0.77	2.5									
5B-AN-1-2	Anonyx	5B				6.9	2.8					4	3			
5B-AN-1-3	Anonyx	5B				2.8										
5F-CY-1-1 F2	Cyrtodaria	5F				4.3				5	15	1.8				1.3
5F-CY-1-2 F2	Cyrtodaria	5F				4.6						1.4				
5F-CY-1-3 F2	Cyrtodaria	5F				5						1.4				1.5
5H-AN-1-1	Anonyx	5H														
5H-AN-1-1 F2	Anonyx	5H				4.7										
5H-AN-1-2 F2	Anonyx	5H				3.1										
5H-AS-1-1 F2	Astarte	5H				3.9										
5H-AS-1-2 F2	Astarte	5H				3										
5H-AS-1-3 F2	Astarte	5H				4.1										
6D-AN-1-1	Anonyx	6D														
6D-AN-1-1 F2	Anonyx	6D				2.2										
6D-AN-1-2	Anonyx	6D														
6D-AN-1-2 F2	Anonyx	6D				5.9										
6D-AN-1-3	Anonyx	6D														
6D-AN-1-3 F2	Anonyx	6D				2.1										
6D-AS-1-1 F2	Astarte	6D				4.2										
6D-AS-1-2 F2	Astarte	6D				4.7										0.79
6D-AS-1-3 F2	Astarte	6D				13	6					11	10		6	6.4

VALUES BELOW INSTRUMENTAL DETECTION LIMITS (ND) ARE INDICATED BY BLANK SPACES.

POLYCYCLIC AROMATIC HYDROCARBONS IN 1989 TISSUES (ng/g wet weight)

SAMPID	Species	Station	C1D	C2D	C3D	C0P	C0A	C1P/A	C2P/A	C3P/A	C4P/A	FLUANT	PYR	C1F/P	BAA	C0C
6D-MA-1-1	Macoma	6D				1.2	5.4					0.88	1.3			
6G-CY-1-1	Cyrtodaria	6G				4.7		12	5.8			1.8	1.1	7.6	0.68	3
6G-CY-1-2	Cyrtodaria	6G				6.1		17	27	32	32	3.5	6			2.2
6G-CY-1-3	Cyrtodaria	6G				4.3		9.5	20	4.8		1.6	1.3	8.1	0.35	2.8
7E-AN-1-1	Anonyx	7E														
7E-AN-1-1 F2	Anonyx	7E				8.8	3.6					6.4	7		11	11
7E-AN-1-2	Anonyx	7E														
7E-AN-1-2 F2	Anonyx	7E				2.5										
7E-AN-1-3	Anonyx	7E														
7E-AN-1-3 F2	Anonyx	7E				2.2										
9B-MA-1-1 F2	Macoma	9B				10	5.9					4.9	7.4			1.2
9B-PO-1-1	Portlandia	9B														

VALUES BELOW INSTRUMENTAL DETECTION LIMITS (ND) ARE INDICATED BY BLANK SPACES.

POLYCYCLIC AROMATIC HYDROCARBONS IN 1989 TISSUES (ng/g wet weight)

SAMPID	Species	Station	C1C	C2C	C3C	C4C	BBF	BKF	BEP	BAP	PER	INDPYR	DAHA	BGHIP
1A-AS-1-1 F2	Astarte	1A								16				
1A-PO-1-1 F2	Portlandia	1A							9.2	11	5			
1A/B/E-AN-1-1	Anonyx	1A/B/E												
1A/B/E-AN-1-1	Anonyx	1A/B/E												
1A/B/E-AN-1-2	Anonyx	1A/B/E							5.7					
1A/B/E-AN-1-2	Anonyx	1A/B/E												
1A/B/E-AN-1-3	Anonyx	1A/B/E							6					
1A/B/E-AN-1-3	Anonyx	1A/B/E												
1B-AS-1-1 F2	Astarte	1B	13				3.2	3	0.63		6.8		4.3	
1B-AS-1-2 F2	Astarte	1B	3.4								0.85			
1B-AS-1-3 F2	Astarte	1B												
2D-AN-1-1	Anonyx	2D							5.1					
2D-AN-1-2	Anonyx	2D		110	25				6.7					
2D-AN-1-3	Anonyx	2D												
2D-AN-1-3	Anonyx	2D												
3A-AS-1-1 F2	Astarte	3A	1.5											
3A-AS-1-2 F2	Astarte	3A					580							
3A-AS-1-3 F2	Astarte	3A								11				
4B-AN-1-1	Anonyx	4B							9.6					
4B-AN-1-2	Anonyx	4B							7					
4B-AN-1-3	Anonyx	4B							4.8					
5(1)-AS-1-1 F2	Astarte	5(1)		230	13					14				
5(1)-AS-1-2 F2	Astarte	5(1)								12				
5(1)-AS-1-3 F2	Astarte	5(1)					6.8	7.7	7	8.6	8.8	4.6	6.0	6.0
5B-AN-1-1	Anonyx	5B							5.1					
5B-AN-1-2	Anonyx	5B					4.5	4.3	13			5.1		4.1
5B-AN-1-3	Anonyx	5B		84					6.5					
5F-CY-1-1 F2	Cyrtodaria	5F								9.4	4.2			
5F-CY-1-2 F2	Cyrtodaria	5F								7.8	4.2			
5F-CY-1-3 F2	Cyrtodaria	5F								9.3	4.1			
5H-AN-1-1	Anonyx	5H												
5H-AN-1-1 F2	Anonyx	5H							6.7					
5H-AN-1-2 F2	Anonyx	5H							5.8					
5H-AS-1-1 F2	Astarte	5H		180										
5H-AS-1-2 F2	Astarte	5H	2.2							8				
5H-AS-1-3 F2	Astarte	5H								11				
6D-AN-1-1	Anonyx	6D												
6D-AN-1-1 F2	Anonyx	6D							5.2					
6D-AN-1-2	Anonyx	6D												
6D-AN-1-2 F2	Anonyx	6D							5.2					
6D-AN-1-3	Anonyx	6D												
6D-AN-1-3 F2	Anonyx	6D							5					
6D-AS-1-1 F2	Astarte	6D								8.7	0.93			
6D-AS-1-2 F2	Astarte	6D								11	1.1			
6D-AS-1-3 F2	Astarte	6D								11	1.5			

VALUES BELOW INSTRUMENTAL DETECTION LIMITS (ND) ARE INDICATED BY BLANK SPACES.

POLYCYCLIC AROMATIC HYDROCARBONS IN 1989 TISSUES (ng/g wet weight)

SAMPID	Species	Station	C1C	C2C	C3C	C4C	BBF	BKF	BEP	BAP	PER	INDPYR	DAHA	BGHIP
6D-MA-1-1	Macoma	6D								12	3.3			
6G-CY-1-1	Cyrtodaria	6G					1.6				7.6			0.45
6G-CY-1-2	Cyrtodaria	6G									7.3			0.44
6G-CY-1-3	Cyrtodaria	6G	5.2				1				6.5			
7E-AN-1-1	Anonyx	7E												
7E-AN-1-1 F2	Anonyx	7E					13	7.4		25				
7E-AN-1-2	Anonyx	7E												
7E-AN-1-2 F2	Anonyx	7E							5.3					
7E-AN-1-3	Anonyx	7E												
7E-AN-1-3 F2	Anonyx	7E							5.2					
9B-MA-1-1 F2	Macoma	9B								8.6				
9B-PO-1-1	Portlandia	9B												

VALUES BELOW INSTRUMENTAL DETECTION LIMITS (ND) ARE INDICATED BY BLANK SPACES.

BEAUFORT SEA TISSUE DATA, 1989 - METALS
ALL VALUES ARE ON WET WEIGHT BASIS.

Sample	Fe %	Ba ppm	Cd ppm	Cr ppm	Cu ppm	Pb ppm	V ppm	Zn ppm
1A-AS-1-M-1	0.025	2.1	3.50	0.29	2.1	0.07	0.59	16.9
1A-PO-1-M-1	0.102	10.2	1.05	1.58	3.1	0.43	2.45	28.2
1B-AS-1-M-1	0.011	2.8	4.99	0.22	1.9	0.27	0.35	12.5
1B-AS-1-M-2	0.021	3.4	5.62	0.37	1.8	0.16	0.73	17.6
1B-AS-1-M-3	0.023	2.1	5.68	0.34	2.1	0.16	0.79	15.5
1A/B/E-AN-1-M-1	0.009	7.8	0.88	0.16	24.3	0.09	0.92	33.9
1A/B/E-AN-1-M-2	0.008	7.8	0.88	0.17	26.6	0.09	0.84	34.1
1A/B/E-AN-1-M-3	0.006	5.0	1.03	0.22	20.4	0.13	0.61	29.2
2D-AN-1-M-1	0.007	11.4	0.38	0.18	40.2	0.04	1.41	33.2
2D-AN-1-M-2	0.007	7.3	0.25	0.25	25.3	0.11	0.75	22.6
2D-AN-1-M-3	0.006	8.0	0.29	0.27	27.0	0.11	1.01	23.8
3A-AS-1-M-1	0.032	4.2	0.78	0.28	3.5	0.07	0.76	18.0
3A-AS-1-M-2	0.016	3.6	0.86	0.24	2.9	0.10	0.47	17.6
3A-AS-1-M-3	0.015	4.2	0.73	0.21	2.8	0.03	0.41	16.0
4B-AN-1-M-1	0.005	11.2	0.53	0.17	41.4	0.06	0.64	33.0
4B-AN-1-M-2	0.003	9.2	0.33	0.20	28.3	0.11	0.56	22.4
4B-AN-1-M-3	0.005	11.4	0.41	0.16	41.4	0.07	0.83	31.8
5B-AN-1-M-1	0.002	3.4	0.47	0.10	11.4	0.08	0.28	33.6
5F-CY-1-M-1	0.043	4.9	0.40	0.62	3.8	0.08	2.74	16.2
5F-CY-1-M-2	0.043	5.4	0.35	0.46	4.1	0.17	1.00	14.8
5F-CY-1-M-3	0.041	6.0	0.34	0.75	4.1	0.10	1.13	16.7
5H-AS-1-M-1	0.025	10.5	1.23	0.38	3.1	0.04	0.72	15.5
5H-AS-1-M-2	0.014	2.0	1.03	0.27	2.4	0.07	0.37	13.5
5H-AS-1-M-3	0.006	4.3	1.25	0.13	2.6	0.07	0.26	13.3
5H-AN-1-M-1	0.009	13.8	0.40	0.29	21.7	0.12	0.99	29.0
5(1)-AS-1-M-1	0.018	2.1	0.80	0.29	4.1	0.16	0.54	17.4
5(1)-AS-1-M-2	0.018	2.5	1.01	0.32	3.5	0.06	0.64	17.0
5(1)-AS-1-M-3	0.024	3.2	0.86	0.41	3.7	0.10	0.77	17.1
6D-AS-1-M-1	0.033	8.2	2.33	0.52	4.8	0.09	1.17	17.1
6D-AS-1-M-2	0.024	7.2	3.57	0.35	4.4	0.13	0.75	18.4
6D-AS-1-M-3	0.046	6.3	2.34	0.60	5.2	0.09	1.26	19.1
6D-MA-1-M-1	0.118	16.0	1.24	1.76	5.6	0.20	3.73	40.9
6G-CY-1-M-1	0.070	9.3	0.94	0.79	5.0	0.21	1.81	18.7
6G-CY-1-M-2	0.044	6.3	0.66	0.54	4.0	0.11	1.23	15.4
6G-CY-1-M-3	0.052	8.9	0.92	0.67	4.9	0.12	1.54	18.4
6A/D/G-AN-1-M-1	0.008	6.6	0.54	0.22	23.6	0.09	0.90	5.6
6A/D/G-AN-1-M-2	0.007	6.1	0.70	0.19	23.1	0.09	0.69	6.4
6A/D/G-AN-1-M-3	0.010	9.1	0.53	0.28	34.4	0.08	1.18	7.3
7E-AN-1-M-1	0.017	30.6	0.20	0.54	30.0	0.06	1.41	23.8
7E-AN-1-M-2	0.004	13.2	0.24	0.33	22.4	0.14	0.54	18.2
7E-AN-1-M-3	0.014	20.3	0.18	0.43	27.2	0.16	0.83	21.3
9B-MA-1-M-1	0.095	13.7	0.22	1.56	3.0	0.24	2.94	17.3
9B-PO-1-M-1	0.099	14.7	1.30	1.49	4.0	0.25	2.76	30.6

REFERENCES

Boehm, P.D., E. Crecelius, J.M. Neff, C.E. Tuckfield, and M. Steinhauer. 1987. Final Report on Beaufort Sea Monitoring Program: Analysis of Trace Metals and Hydrocarbons from Outer Continental Shelf (OCS) Activities. Submitted to the Minerals Management Service, Alaska OCS Region, Anchorage, AK.

Boehm, P.D. and A.G. Requejo. 1986. Overview of the Recent Hydrocarbon. Measurements from Atlantic and Gulf Coast Outer Continental Shelf Environments. Est. Cstl. Shelf Sci. 23:29-58

Boehm, P.D., E. Crecelius, W. Steinhauer, M. Steinhauer, and C. Tuckerfield. 1986. Beaufort Sea Monitoring Program: Analysis of Trace Materials and Hydrocarbons from Outer Continental Shelf (OCS) Activities. Second Annual Report to Minerals Management Service, Alaska OCS Region, Contract No. 14-12-0001-30163, 238pp.

Boehm, P.D., J.E. Barak, D.L. Fiest and A. Elskus. 1982. A chemical investigation of the transport and fate of petroleum hydrocarbons in littoral and benthic environments: The TSESIS oil spill. Marine Environmental research 6:157-188.

Broad, A.C. 1979. Environmental Assessment of Selected Habitats in the Beaufort and Chukchi Littoral System. Pages 361-544 In: Environmental Assessment of the Alaskan Continental Shelf. Annual Reports of Principal Investigators for the Year ending March, 1979. Volume III: Receptors-Fish, Littoral Benthos. U.S. Department of Commerce NOAA-OCSESP, Boulder, CO.

Brown, D.W., L.S. Ramos, J.J. Friedman, and W.D. Macleod. 1979. Analysis of trace levels of petroleum hydrocarbons in marine sediments using a solvent/slurry extraction procedure. Pages 161-167 In: Trace Organic Analysis: A New Frontier in Analytical Chemistry. National Bureau of Standards Special Publication 519. Washington, D.C.

Craig, J.D., K.W. Sherwood, and P.P. Johnson. 1985. Geologic Report for the Beaufort Sea Planning Area, Alaska: Regional Geology, Petroleum Geology, Environmental Geology. Anchorage, AK: USDOI, MMS, Alaska OCS Region, December 1985, 192 pp.

Crecelius, E.A., Trefrey, J.H., Steinhauer, M.S., and Boehm P.D. 1990. Trace Metals in Sediment from the Inner Continental Shelf of the western Beaufort Sea. Environmental Geology 1990 in press.

Dames and Moore. 1984. Proceedings of the Beaufort Sea Monitoring Workshop, sponsored by the National Oceanic and Atmospheric Administration and the Minerals Management Service, September 1983.

Folk, R.L. 1980. Petrology of Sedimentary Rock. Hemphil Publishing. Austin, TX. 182 p.

Froelich, P.N. 1980. Analysis of organic carbon in marine sediments. Limnol. Oceanog. 25:564-572.

Hachmeister, L.E. and J.B. Vinelli. 1984. Environmental Characterization and Biological Use of Lagoons in the Eastern Beaufort Sea, Chapter 7, Physical Oceanography, J.C. Trueet, ed. Final Report of Principal Investigators, Vol. 24, October 1984, Outer Continental Shelf Environmental Assessment Program, RU 632. Anchorage, AK: USDOC, NOAA, OCSEAP. Prepared by Science Applications, Inc. 13400B Northrup Way #36, Bellevue, WA 98005.

Holme, N.A. and I.A. McIntrye, Eds. 1971. Methods for the Study of Marine Benthos. Blackwell Scientific Publications, Oxford.

Horner, R.A. and G.C. Schrader. 1984. Beaufort Sea Plankton Studies: Winter-Spring Studies in Stefansson Sound and off Norwal Island, November 1978 - June 1980. U.S. Department of Commerce, NOAA-OCSEAP Final Report 25:193-325.

Kaplan, I.R. and M.I. Venkatesan. 1981. Characterization of Organic Matter in Sediments from Gulf of Alaska, Bering and Beaufort Seas. Final Report to U.S. Department of Commerce NOAA-OCSEAP, Juneau, AK.

Naidu, A.S., M.D. Sweeney and L. Klein. 1981. Aspects of Size Distributions, Clay Mineralogy, and Geochemistry of Sediments in the Beaufort Sea and Adjacent Deltas, North Arctic Alaska: Synthesis Report. In: Environmental Assessment of the Alaska Continental Shelf. Annual Reports of Principal Investigators for the Year Ending March, 1981. Volume V. U.S. Department of Commerce, NOAA and U.S. Department of the Interior, BLM, Anchorage, AK.

Neff, J.M. and J.W. Anderson. 1981. Response of Marine Animals to Petroleum and Specific Petroleum Hydrocarbons. Applied Science Publishers Ltd., London. 176 pp.

Schell, D.M., D.M. Parrish and P.J. Ziemann. 1984. Primary Production, Nutrient Dynamics and Trophic Energies. In: J.C. Truett, Ed., Environmental Characterization and Biological Use of Lagoons in the Eastern Beaufort Sea. U.S. Department of Commerce, NOAA-OCSEAP Final Report 24:433-467.

Seifert, W.K., J.M. Moldowan and R.W. Jones. 1979. Application of Biological Marker Chemistry to Petroleum Exploration. 10th World Petroleum Congress. Bucharest. 425-438 pp.

Sharma, G.D. 1983. Fate of Drilling Discharge and Solids Disposal in the Beaufort Sea and Diapir Field. In: Testimony of the Alaska Oil and Gas Association on Draft General NPDES Permits for Beaufort Sea. Report submitted to the U.S. Environmental Protection Agency, Region X.

Shaw, D.G., D.J. McIntosh and E.R. Smith. 1979. Arene and Alkane Hydrocarbons in Nearshore Beaufort Sea Sediments. Estuarine and Coastal Marine Science 9:435-439.

Standard Alaska Production Company Anchorage, Alaska. 1988 Annual Report. Endicott Development NPDES Monitoring Program - Drilling Effluent Plume Monitoring Above-Ice Drilling Effluent Disposal Monitoring Sediment Quality Monitoring Benthic Macroinvertebrate Studies. Permit No. AK-003866-1.

Steinhauer, M.S., and P.D. Boehm. 1990. The Composition and Distribution of Saturated and Aromatic Hydrocarbons in Nearshore Sediments, River Sediments and Coastal Peat of the Alaskan Beaufort Sea: Implications for Marine Monitoring Studies. Mar. Env. Res. (submitted)

U.S. Department of Interior, Minerals Management Service. 1990. Beaufort Sea Planning Area Oil and Gas Lease Sale 124. Draft Environmental Impact Statement. Volume I & II.

U.S. Department of Interior, Minerals Management Service. 1987. Alaska Outer Continental Shelf Beaufort Sea Sale 97. Final Environmental Impact Statement. Volume I & II.

U.S. Environmental Protection Agency, Region X, Seattle, Washington. 1988. Ocean Discharge Criteria Evaluation for Beaufort Sea OCS Oil and Gas Lease Offering 97.

U.S. Environmental Protection Agency, 40 CFR 136. October 26, 1984. Guidelines Establishing Test Procedures for the Analysis of Pollutants

Under the Clean Water Act; Final Rule and Interim Final Rule. Federal Register Vol. 49 No.209, 198 pp.

U.S. Environmental Protection Agency, 1986. Test Methods for Evaluating Solid Waste. Volume 1A: Laboratory Manual Physical/Chemical Methods. Office of Solid Waste and Emergency Response, Washington D.C.

Warner, J.S. 1976. Determination of Aliphatic and Aromatic Hydrocarbons in Marine Organisms. Anal. Chem. 48:578-583.

Venkatesan, M.I. and I.R. Kaplan. 1982. Distribution and Transport of Hydrocarbons in Surface Sediments of the Alaskan Outer Continental Shelf. Geochim. Cosmochim. Acta 46:2135-2149.