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University of Alaska Coastal Marine Institute

In Cooperation:
Minerals Management Service
University of Alaska
State of Alaska

Annual Report
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Submitted by
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To:
U. S. Department of the Interior
Minerals Management Service
Alaska OCS Region
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Introduction

The University of Alaska Coastal Marine Institute (CMI) was created by a cooperative agreement between the University of Alaska and the Minerals Management Service (MMS) in June 1993 and the first full funding cycle began late in (federal) fiscal year 1994. CMI is pleased to present this 1998 Annual Report, our fifth annual report. Of the ten research projects included in this Annual Report, eight are scheduled to end this federal fiscal year or in the first quarter of the next one. Only abstracts and study products for those projects are included here because principal investigators are preparing their final reports, which will be available soon. Five additional research projects were begun this year. Abstracts for these projects are included in the section titled New Projects.

MMS administers the outer continental shelf (OCS) natural gas, oil, and marine minerals program in which it oversees the safe and environmentally sound leasing, exploration, and production of these resources within our nation's offshore areas. The Environmental Studies Program (ESP) was formally directed in 1978, under Section 20 of the OCS Lands Act Amendments, to provide information in support of the decisions involved in the planning, leasing, and management of exploration, development, and production activities. The research agenda is driven by the identification of specific issues, concerns, or data gaps by federal decision-makers and the state and local governments who participate in the process. ESP research focuses on the following broad issues associated with development of OCS gas, oil, and minerals:

> What are the fates and effects of potential OCS-related pollutants (e.g., oil, noise, drilling muds and cuttings, products of fuel combustion) in the marine and coastal environment and the atmosphere?
>
> What biological resources (such as fish populations) exist and which resources are at risk? What is the nature and extent of the risk? What measures must be taken to allow extraction to take place?
>
> How do OCS activities affect people in terms of jobs and the economy? What are the direct and indirect effects on local culture? What are the psychological effects of the proposed OCS activities?

Because MMS and individual states have distinct but complementary roles in the decision-making process, reliable scientific information is needed by MMS, the state, and localities potentially affected by OCS operations. In light of this, MMS has developed a locally managed CMI program. Under this program, MMS takes advantage of highly qualified, scientific expertise at local levels in order to:

1) Collect and disseminate environmental information needed for OCS oil and gas and marine minerals decisions;
2) Address local and regional OCS-related environmental and resource issues of mutual interest; and
3) Strengthen the partnership between MMS and the state in addressing OCS oil and gas and marine minerals information needs.

CMI is administered by the University of Alaska Fairbanks School of Fisheries and Ocean Sciences to address some of these mutual concerns and share the cost of research. Alaska was selected as the location for this CMI because it contains some of the major potential offshore oil and gas producing areas in the United States. The University of Alaska Fairbanks is uniquely suited to participate by virtue of its flagship status within the state and its nationally recognized marine and coastal expertise relevant to the broad range of OCS program information needs. In addition, MMS and the University of Alaska have worked cooperatively on ESP studies for many years. Research projects funded by CMI are required to have at least one active University of Alaska investigator. Cooperative research between the University of Alaska and state agency scientists is encouraged.

Framework Issues were developed during the formation of CMI to identify and bracket the concerns to be addressed:

1) Studies to improve understanding of the affected marine, coastal, or human environment;
2) Modeling studies of environmental, social, and economic processes in order to improve predictive capabilities and define information needs;
3) Experimental studies to improve understanding of environmental processes and/or the causes and effects of OCS activities;
4) Projects which design or establish mechanisms or protocols for the sharing of data or information regarding marine or coastal resources or human activities to support prudent management of oil and gas and marine mineral resources; and
5) Synthesis studies of background information.

Projects funded through CMI are directed towards providing information which can be used by MMS and the state for management decisions specifically relevant to MMS mission responsibilities. Projects must be pertinent to either the OCS oil and gas program or the marine minerals mining program. They should provide useful information for program management or for the scientific understanding of the potential environmental effects of resource development activities in arctic and subarctic environments.

Initial guidelines given to prospective researchers identified the Cook Inlet and Shelikof Strait areas as well as the Beaufort and Chukchi seas as areas of primary concern to MMS and the state. Primary emphasis has subsequently shifted to the Beaufort Sea, and to the Chukchi Sea as it relates to the Beaufort Sea. However, a strong interest remains with Cook Inlet and Shelikof Strait.

The proposal process is initiated each summer with a request for letters of intent to address one or more of the Framework Issues. This request is sent to researchers at the University of Alaska and to various state agencies. The CMI technical steering committee then decides which of the proposed letters of intent should be developed into proposals for more detailed evaluation and possible funding.

Successful investigators are strongly encouraged to publish their results in peer-reviewed journals as well as to present them at national meetings. In addition, investigators present their findings at the CMI's annual research review meeting, held at UAF in February. Some investigators present information directly to the public and MMS staff in seminars.

Alaskans benefit from the examination and increased understanding of those processes unique to Alaskan OCS and coastal waters because this enhanced understanding can be applied to other problems besides oil, gas, and mineral extraction, such as subsistence fisheries and northern shipping.

Many of the CMI-funded projects address some combination of issues related to fisheries, biomonitoring, physical oceanography, and the fates of oil. The ultimate intent of CMI-related research is to identify the ways in which OCS-related activities may affect our environment. Even though work funded to date is primarily related to the physical world, the intent of CMI is to also include studies of the potential economic and social impacts as well.

The CMI project reports have been placed in alphabetic order by lead author. Abstracts for new projects and an overall funding summary follow the reports.

An Economic Assessment of the Marine Sport Fisheries in Lower Cook Inlet

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Abstract

The marine sport fisheries of lower Cook Inlet are the focus of a large and growing recreation-based economic sector. Sport fisheries produce non-monetary benefits to participants and monetary benefits to tourism-related businesses. Activities associated with OCS exploration, development and production could affect the quality of recreation opportunities and the demand for tourism-related services. This study develops a regional input–output model to measure the monetary impact of marine sport fisheries on the Kenai Peninsula economy.

Introduction

The commercial and sport fisheries of lower Cook Inlet both contribute to the economic well being of residents of the Kenai Peninsula, Alaska, and the nation (Figure 1). The Alaska Department of Fish and Game (ADF&G) estimates that statewide annual direct expenditures in the marine and freshwater sport fisheries total about $30 million. Commercial salmon (*Oncorhynchus sp.*) catches from Cook Inlet totaled $25.8 million in 1995. Commercial catches of Pacific halibut (*Hippoglossus stenolepis*) from the Gulf of Alaska were 21.4 million pounds in 1995. Sport catches of halibut from the same region exceeded 4.7 million pounds. In this analysis, we focus on the marine sport fisheries for Pacific halibut and chinook salmon (*O. tshawytscha*). The marine salmon sport fishery is both a substitute and a compliment for the sport halibut fishery. Consequently, models that attempt to assess the economic value and impact of one while ignoring the other will produce biased estimates.

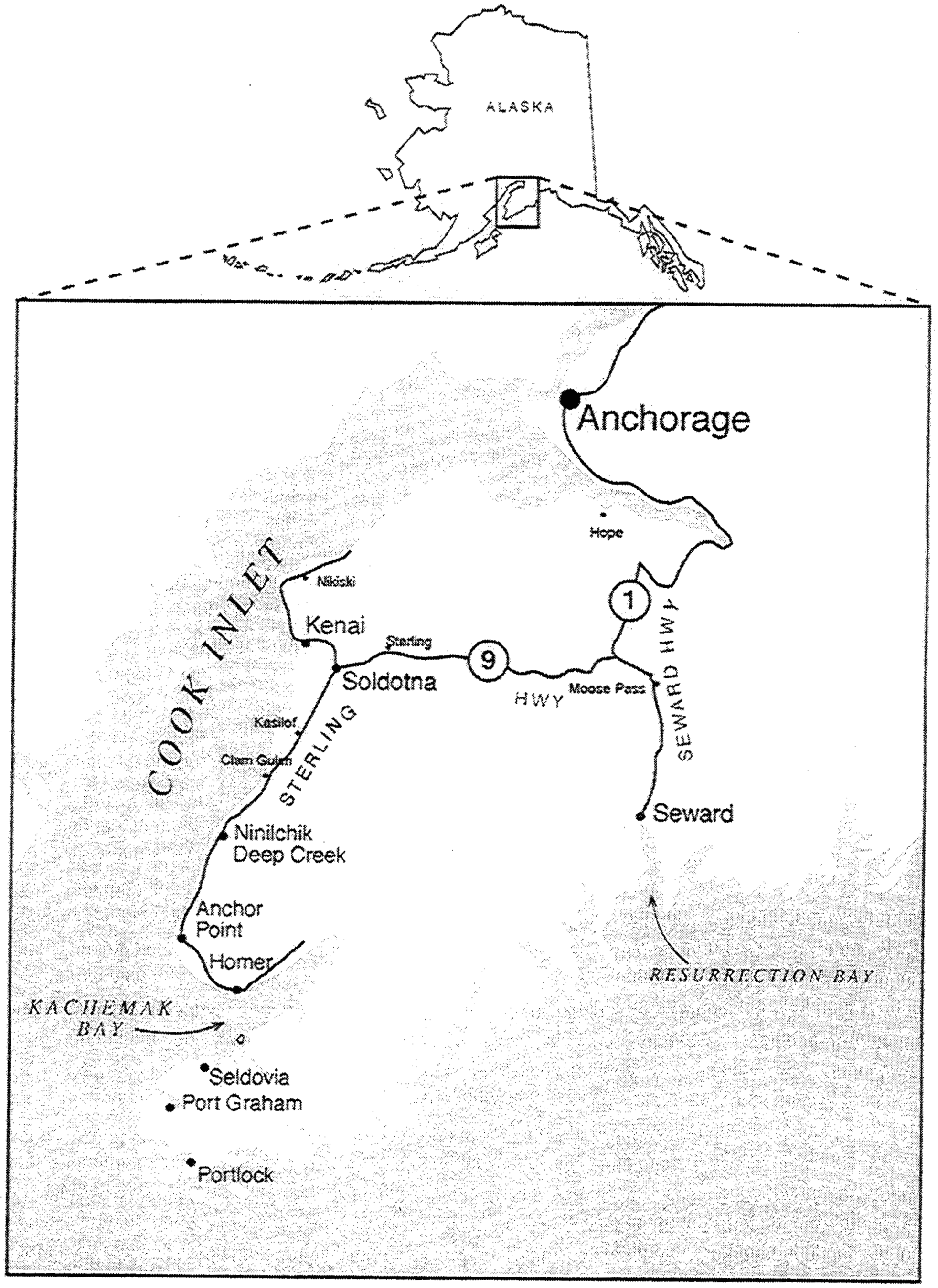

Figure 1. Location of the study area.

There are three components to a comprehensive evaluation of marine sport fisheries: (1) estimation of angler net benefits; (2) estimation of charter/guide operation profits; and (3), assessment of the economic impacts generated by (1) and (2).

Charter/guide operations are seasonal commercial enterprises whose revenues come from anglers and whose costs include such things as fuel, bait, fishing gear, wages, insurance, depreciation, repairs, licenses and fees, etc. Although guide/charter operators may have selected their profession based in part on 'lifestyle' considerations, freedom to enter and exit the industry ensures that profitability will have an important role in determining who will stay in business. Assessing the profitability of commercial operations involves the straightforward application of economic statistical and optimization techniques and relies largely on observable market transactions. While the information generated from economic models of the profitability of charter/guide operations can serve as an input to models of the economic impact of recreational fishing, they do not provide estimates of those impacts.

Anglers fish because the recreational benefits that they anticipate from fishing and associated activities exceed the costs they expect to incur. While assessment of the net non-market benefits that accrue to anglers is difficult, several estimation techniques have been widely accepted. Benefits that accrue to anglers differ from profits that accrue to charter/guide operators because the charter/guide fees are costs to the angler and revenues to the guide/charter operator.

Impact analysis estimates the direct, indirect, and induced effects on output (production), income and employment by industry and aggregated industries. Direct effects are production changes associated with immediate final demand changes. Indirect effects are those associated with changes in inputs to the production process. Induced effects are those caused by changes in household spending patterns due to changes in household income generated by direct and indirect effects.

Most economic activities generate secondary impacts (indirect effects). That is, when goods or services are purchased, the seller in turn purchases goods and services. Secondary impacts are generated whether the initial activity involves commerce or recreation. However, different activities generate different impacts. Moreover, the impact of alternative activities depends on the scale considered. It is traditional to examine economic impacts at local, regional, and national scales. Our focus on the Kenai Peninsula dictates a regionally based impact assessment.

Input-Output (I/O) is the most widely applied tool for assessing regional economic impacts.

I/O models are applied economic tools used to analyze the interdependence of economic factors in a regional economy (Miller and Blair, 1985). The I/O framework is based on identifying sectors of regional economies as defined by a sector's usage of inputs in the production process and the subsequent distribution of a sector's output throughout the economy. Relationships are measured by dollar values of exchanges of goods and services among different regional economic sectors, through imports or exports from other regions, and final demand by households, government entities, and other economic actors. The annual dollar values of these exchanges represent the database used in constructing the I/O model (Figure 2).

Figure 2. Simplified Input-Output Transactions Table (Richardson, 1972)

To		Purchasing Sectors					Local Final Demand				Total Gross Outputs
From		1	...	j	...	n	Households	Private Investment	Government	Exports	
Producing Sectors	1	X_{11}	...	X_{1j}	...	X_{11}	C_1	I_1	G_1	E_1	X_1
		...		...		...	...	...	...	...	...
	i	X_{i1}	...	Xij	...	X_{ij}	C_i	I_i	G_i	E_I	X_i
		...		...		...	...	...	...	...	...
	n	X_{n1}	...	X_{nj}	...	$X_{n,j}$	C_n	I_n	G_n	E_n	X_n
Labor		L_1	...	L_j	...	L_n	L_C	L_I	L_G	L_E	L
Other Value Added		V_1	...	V_j	...	V_n	V_C	V_I	V_G	V_E	V
Imports		M_1	...	M_j	...	M_n	M_C	M_I	M_G		M
Total Gross Outlay		X_1	...	X_j	...	X_n	C	I	G	E	X

I/O models have been used extensively outside of Alaska for impact analysis of development and government policy changes. I/O models in other states have described resource issues such as forestry (Summers and Birss, 1991), regional impacts of federal grazing policies (Geier and Holland, 1991), community development strategies (Geier et al., 1994), and the impact of federal land use decisions on regional economies (Fawson and Criddle, 1994). I/O models have also been employed to model the Alaska statewide economy (Logsdon et al., 1977, Weddelton, 1986).

Methods

We selected IMPLAN, developed by the U.S. Forest Service (Olson et al., 1993) and the most commonly used I/O model, as a base for our model. Regional and specialized I/O models can be derived from IMPLAN through adjusting the national level data to fit the economic composition and estimated trade balance for a specific region.

The IMPLAN database includes 21 economic and demographic variables for 528 industrial sectors for all counties (and boroughs) of the US. The database is largely built from employment and income data sets including County Business Patterns, ES 202, and the Regional Economic Information System. In cases where there are disclosure problems, IMPLAN uses national averages as estimates for income and employment. The IMPLAN database is recognized as the best source of US secondary regional economic data. Nevertheless, although the national level data is regularly updated, the regional data is updated infrequently. Moreover, regions may have unique economic sectors or linkages that are not well represented in the basic IMPLAN model. Consequently, it is important to update, regionalize, and groundtruth the model before relying on it to predict regional economic impacts. In Alaska, with small numbers of firms (frequent disclosure problems), and a rapidly evolving and heavily resource-dependent economy, it is particularly essential that the transaction coefficients be thoroughly updated and carefully groundtruthed with local data and expert knowledge.

The Recreational Economic Impact Model (REIM) (William Jensen Consulting, 1997) is a programming module that provides specialized treatment of the economic activities generated by recreational fishing by disaggregating IMPLAN sectors which comprise assemblages of recreational sectors. REIM uses IMPLAN-generated response coefficients and secondary regional economic data as inputs in model formulation. The secondary model data are augmented with primary data for the target industries (e.g., sport/charter industry) supplied by primary data collection. REIM, through its I/O framework, explicitly accounts for linkages in regional coastal economies among various economic sectors according to production and consumption patterns.

Results/Progress

The IMPLAN database and model have been modified to portray more accurately economic activities within the Kenai Peninsula region, and to trace secondary and higher level impacts. A series of focus group meetings and conversations were held in communities on the Kenai Peninsula, in conjunction with discussions with civic and industry leaders. Particular attention was paid to the types of data that could affect the Regional Purchase Coefficients used to allocate consumption expenditures between local goods consumption and imported goods. Following verification and groundtruthing of the Kenai Peninsula I/O model, the IMPLAN and REIM model coefficients and linkages were updated. Recreational fishing was also disaggregated from commercial fishing and from other recreational activities.

Individual sport fishing activities are accommodated differently from direct income-generating activities such as guiding, harvesting, and processing. The characteristics of sport fishing necessitate that these recreational activities be accounted for by expenditure patterns in retail and service sectors, rather than treated as an identifiable economic sector. REIM allocates recreational expenditures among these sectors.

The sport fishing expenditure data to be used in REIM will be provided as a side-product of our Sea Grant–funded survey of sport fishers. (Based on results of the first and second mailings, we anticipate an overall response rate in excess of 60%.) The operating cost data required for modeling charter operations are reported in NPFMC (1997) and were modified in the groundtruthing process.

Discussion

Our work to date has been largely preparatory. We are now poised to begin using the models to explore the effects of changes in sport fishing opportunity on angler net benefits and the ultimate impact of those changes on the regional economy through the evaluation of various scenarios. The regional economic impacts of these scenarios will be explored by representing the effects of the contingent behavior of anglers in the I/O model.

Preliminary Conclusions

It is too early to draw conclusions from this study.

Student Involvement

Students working on this project are Chuck Hamel, MS student, supported by CMI, Mike Orr, an undergraduate whose time (5-8 hours per week for the 1997-98 academic year) was donated to the project, and Isaac Wedin, an MS student supported by Alaska Sea Grant.

Acknowledgements

We are grateful for information provided by the Seward and Homer Chambers of Commerce, Becky Hultberg and Craig Layman (Kenai Peninsula Borough Economic Development District), Sheri Hobbs (City of Homer), Tim Evers (Deep Creek Charter Association), Frank Libal (Anchor Point Charter Association), Robert Ward (Homer Charter Association), Karl Kircher (Kenai Peninsula Fishermen's Association), Theo Matthews (United Cook Inlet Drifters Associations), Nancy and John Hillstrand (Alaska Custom Seafoods), Doug Coughenower (Alaska Sea Grant Marine Advisory Program)

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The Alaskan Frozen Tissue Collection and Associated Electronic Database: A Resource for Marine Biotechnology

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Abstract

The Alaska Frozen Tissue Collection (AFTC) is the primary regional archive for frozen zoological samples and a major contributor to biotechnology studies of the North Pacific and Arctic oceans. It has become the world's third largest frozen tissue collection for wild mammals. In addition to expanding the scope of the collection by recruiting contributions of marine mammal, bird, fish, and invertebrate specimens from throughout the North Pacific and Arctic oceans, a collection of approximately 5,000 seals was incorporated. These specimens span three decades of field work by the Alaska Department of Fish and Game, and include samples from throughout Alaska's waters. This is the largest collection of western Arctic and North Pacific seals worldwide.

Between 1 July 1995 and 30 June 1998, the AFTC accessioned tissues from 945 marine mammals representing 26 species, as well as fish and marine invertebrate samples. Frozen tissue loans (n = 28) representing 375 individual animals have been made to ongoing research projects. Other investigators have visited the collection to study marine specimens. Cooperative agreements have been developed or continued with individual collectors and organizations, including the National Marine Fisheries Service, the U. S. Fish and Wildlife Service, the North Slope Borough, the Alaska Marine Mammal Tissue Archival Project (AMMTAP), and an ongoing Alaska Department of Fish and Game subsistence

Study Products

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Kachemak Bay Experimental and Monitoring Studies

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Abstract

This study in lower Kachemak Bay, Alaska, was designed to obtain baseline data on abundance and distribution of intertidal invertebrates and algae and to gather information throughout the year on community-structuring mechanisms such as recruitment and succession. Specific objectives were 1) to gain an understanding of the seasonal and interannual relationships among intertidal invertebrates and plants 2) to assess community relationships when recovering from seasonal disturbances in the form of cleared substrate, and 3) to determine the role of wave exposure in differences found in the first two objectives. Quadrats in rocky intertidal habitat on eight sites were cleared of all invertebrates and algae during four visits in 1994 and 1995.

Control, or uncleared, quadrats were also established to provide community assemblages for determining recovery on each site. The dates for creating the quadrats were selected to provide substrate for organisms that recruit in different seasons. The quadrats were subsequently monitored for organism abundance and percent cover. The acorn barnacles, Semibalanus balanoides *and* Balanus glandula *first colonized the quadrats in the high and middle tidal zones, often with > 80% cover.* Fucus gardneri *colonized the plots only after barnacles were established. The recovery rates of quadrats scraped on different dates were driven by the timing of barnacle recruitment relative to the timing of bare substrate availability.*

Recovery of the dominant algae in the low intertidal zone, Alaria flocossa, *was dependent on recruitment of the thatched barnacle,* S. cariosis. *Bray-Curtis dissimilarity matrices were calculated on community level data to compare recovery rates of scraped quadrats among sites, quadrat scrape dates, and data collection dates. Multi-dimensional scaling (MDS) ordination plots of the dissimilarity data show that scraped quadrats had not fully converged with control quadrats by the last sampling date, 30 months after the first set of quadrats were scraped in March 1994.*

Recovery rates varied by the season that quadrats were scraped, with quadrats scraped *in July and October 1994 showing slower recovery rates than quadrats scraped in March 1994 or 1995. MDS ordinations indicate that the extent of recovery on disturbed quadrats compared to control quadrats varied among sites. Differences in wave-exposures on the sites do not account for the differences found for recovery.*

Study Products:

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Historical Changes in Trace Metals and Hydrocarbons in the Inner Shelf Sediments, Beaufort Sea: Prior and Subsequent to Petroleum-Related Industrial Developments

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Abstract

The project objective is to the assess historical changes in concentrations of selected trace metals (Cu, Cr, Ni, V, Pb, Zn,Cd, Ba, As and methyl Hg) and normal, branched and cyclic (tricyclic di- and pentacyclic tri-terpenoid) hydrocarbons and polynuclear aromatic hydrocarbons (PAH), in nearshore sediments of the Beaufort Sea extending from Harrison Bay to the Canning Delta. The goal is to ascertain if there are have been any significant increases in concentrations of trace metals and hydrocarbons during the past century, and especially subsequent to the recent development of petroleum-related activities.

To date, 33 mud fractions separated from triplicate surficial sediment samples from 11 stations (out of the 63 collected from 21 stations in September 1997) and 21 stratigraphic sections from two ^{210}*Pb-based dated cores were analyzed for the 10 trace metals. The granulometry, carbonate, and total organic matter (TOM) were also analyzed on the above samples. The hydrocarbon analyses on 21 gross sediments are partially complete, with only n-alkane values available to date. Time-series comparisons among data from 1977, 1986, and 1997, based on the trace metal mean concentrations in muddy sediments of the nearshore Beaufort Sea, show significanly increased concentrations in V in 1986 and 1997, and in Ba from 1986 to 1997. However, these findings are not reflected in the stratigraphic analysis. The specific mechanism and source of the enhanced concentrations of the two contaminants are unknown.*

Correlation coefficient analysis indicates that all elements except Cr, Cd and Hg are *bound in the clays and organic matter. The higher MeHg concentrations in basal sections of two cores are probably related to the increased methylation of Hg in anoxic sediment layers. Our study shows no higher concentrations of Me-Hg in sediments from the Prudhoe Bay region, in the vicinity of which, notably higher Hg was reported in snow samples. The sediment metal levels are generally similar to those in unpolluted regions.*

The concentrations of n-alkanes in sediments of this study are comparable to values reported by earlier workers from the nearshore Beaufort Sea in 1982 and 1992. The n-alkanes generally show a bimodal distribution typical of a mixture of marine autochthonous and terrestrial allochthonous inputs.

Introduction

In recent years, considerable attention has been given to assessing the state of the arctic environment, especially in relation to the presence and biological effects of anthropogenic contaminants (AMAP, 1997). The earlier conception that the high arctic region of Alaska, which lies far away from major industries, has remained pristine is no longer valid, as attested to by increasing levels of industrial contaminants there (Snyder-Conn et al., 1997; Naidu et al., 1998 and references therein). Since the discovery of oil in 1968 the North Slope region of Alaska has been subjected to large-scale petroleum-related industrial activities. The impacts of these activities, especially relating to contaminants, are not well known. This report provides highlights of investigations conducted during the past year on the concentrations of a suite of trace metals and hydrocarbons in sediment samples collected from the nearshore region of the Beaufort Sea located off the North Slope of Alaska.

Methods

Sample Collection

In September 1997, triplicate surficial sediment samples from 21 stations (n = 63) and sediment core samples from two stations were collected, using a Kynar-coated Van veen grab sampler and gravity/Haps corer respectively, from the nearshore of the Alaskan Beaufort Sea, located within the Colville-Canning Delta region (Figure 1; Table 1). Immediately after collection, each of the samples was further processed onboard. For the surficial sediment sample, the upper 2-cm oxidized layer was sectioned from the top of the grab and core sampler, using a Teflon-coated (for trace metal) and stainless-steel (for hydrocarbon) knife. The core samples were further sectioned at 1-cm intervals. Each of the samples thus collected was placed in EPA-approved I-CAM glass jars and kept frozen until analyzed. Selected samples from the above suite were shipped for analysis, under contract, to Frontier Geosciences, Seattle, for analysis of trace metals and to Dr. Indira Venkatesan (UCLA) for analysis of hydrocarbons. Additionally, splits of the original grab samples were retained for analyses of granulometry, CO_3, and total organic matter (TOM) at the IMS/UAF laboratory, while portions of the core sections were also sent to D. M. Baskaran (Texas A and M) for ^{210}Pb and ^{137}Cs analyses for estimating sediment accumulation rates.

Laboratory Analyses

During the past year a selected number of samples have been processed for the trace metal and hydrocarbon analyses. For trace metals, granulometry, carbonate, and total organic matter (TOM) analyses, 33 mud fractions separated from triplicate surficial sediment samples from 11 stations (out of the 63 collected from 21 stations) were selected. The metal analyses were also performed on 21 stratigraphic sections separated from two cores. For hydrocarbon analyses, 21 gross sediments representing triplicate samples from seven out of the 21 stations, were selected.

Copper, Cr, Ni.V, Zn , Pb, Ba, and Cd were analyzed in the mud fraction (<63 micron) of surficial and core sediment samples, using an ICP/MS, Model Perkin-Elmer Elan 6000 unit. The methods for the separation of the mud fraction from the gross sediment, its acid dissolution and the subsequent analyses of the above elements, including analytical precision, accuracy, and MDL, are outlined in Medlin et al. (1969), Boehm et al.(1990), and Crecelius et al. (1991). The analyses of methyl Hg (Me-Hg) and As were on gross sediments. Me-Hg analysis was performed on sediment alkaline leachates, using a cold vapor atomic fluorescence detector following cryogenic GC separation (Bloom, 1989). Arsenic was determined by Excalibur automated hydride generation atomic fluorescence spectrometry. Prior to taking up the analysis, Frontier Geosciences participated successfully in the NOAA/11 intercomparison exercise, arranged through Dr. Naidu (as required of this MMS/CMI project) and conducted by the NOAA/ORCA-National Research Council of Canada.

The analyses of the hydrocarbons (aliphatic and polycyclic aromatic hydrocarbons) were on gross sediments, following the method outlined in Venkatesan (1994). After solvent extraction and separation into individual compounds, GC using a flame ionization detector quantified alkanes. Tricyclic di- and pentacyclic tri-terpenoids and a suite of 30 PAHs (routinely analyzed by NOAA/NS&T) were measured by GC mass spectrometry.

The analyses of ^{210}Pb and ^{137}Cs of the sediment core sections, which are related to the establishment of geochronology, were by high resolution alpha and gamma spectrometry, following the methods outlined in Weiss and Naidu (1986) and Baskaran and Naidu (1995, and references therein). Analysis of the sediment granulometry was by the sieve-pipette method (Folk, 1968), whereas CO_3 and TOM were analyzed by sequential loss in weight by ignition at 500° C and 1000° C, respectively (Dean, 1974).

Standard statistical analyses were conducted to assess time-series changes in mean concentrations of trace metals during the past 30 years at ten-year intervals. Additionally, correlation coefficients were calculated to determine interelement and element-granulometry-carbonate-TOM relationships.

Results

The results of the Frontier Geosciences participation in the NOAA/11 interlaboratory comparision exercise relating to trace metal analyses was rated as good to excellent (data are on file). To date, 33 mud fractions separated from triplicate sediment samples from 11 out of the total 21 stations, as well as 21 stratigraphic sections from two cores were analyzed for trace metals, whereas the analyses of hydrocarbons on 21 gross sediment samples from seven stations have been partially completed (refer to Table 1 for sample station locations). Additionally, the analyses of the granulometry, carbonate, and TOM on the 33 mud fractions were completed.

Table 2 shows the concentrations of the 10 trace metals analyzed, the granulometry, carbonate, and TOM concentrations in the triplicate mud samples, and the mean values corresponding to each of the 21 stations. The stratigraphic variations of the metal concentrations in the two core samples are shown in Table 3. It is clear that there are wide regional disparities in the "within station" variations in all the parameters within the study area. Table 4 shows the time-series comparisons (at approximately 10-year intervals for the past 30 years) of the mean concentrations of selected metals in muds for the study area. It is shown that there has been a significant increase in the concentrations of V in 1986 and 1977 from 1977 and an increase in the mean concentration in Ba from at least 1986 to 1997. However, these variations are not clearly demonstrated in the stratigraphic analyses of the metals in both the cores (Table 3). The only stratigraphic change that is well illustrated is in the concentrations of Me-Hg, with a broad pattern of progressive increase down the two cores (Table 3; Figure 2).

Table 5 provides results of the correlation coefficient analysis for chemical and physical parameters on muds from the study area. It is shown that all the metal concentrations except those of Me-Hg, Ba and Cd have strong positive correlations with each other as well as with the clay and TOM contents. A negative correlation of Me-Hg with As, clay, TOM and carbonate contents is also shown. There is a lack of variance of Ba with the granulometry and carbonate.

Table 6 shows a comparison of the mean concentrations of a group of elements in muddy sediments (from this study) with those of selected shelf regions from the circumarctic. Generally, the mean concentration of all metals in the study area is either lower than or comparable to those in other shelf regions.

The hydrocarbon analyses have been partially completed. Twenty-one surface sediments have been extracted with organic solvents and processed for compound class separation by column chromatography. The saturated hydrocarbon fractions have been analyzed by GC. Results of the alkane analyses are presented in Table 7. The triplicates from the same site (3A, 4A, 5F, and 6B) showed internally consistent results. The maximum variation in the data among the triplicates at three sites (2F, 4A, and WPB) was between factors of 1.5 to 2.

Discussion

The analyses of trace metals and hydrocarbons in triplicate samples from the same station provide an idea on the "within station" variability that is to be expected in the above analytes within the study area. The results show that for some stations there is significant variability in trace metals, and the poor precision for those stations can be attributed to the intersample differences in the silt and clay contents within a station. However, the hydrocarbon analyses on triplicate samples from the same station are reasonably homogenous within the general area of sampling.

As mentioned earlier, an increase in the mean concentrations in V in mud has been identified in 1986 and 1997 samples compared with those from 1977, whereas the mean concentration of Ba is significantly higher in 1997 relative to 1977 and 1987 samples. The reasons for these time-series changes are not known, but it is tempting to link the increasing V and Ba in post-1977 samples to possible petroleum-related industrial activities within the study area. For example, Vanadium is a common constituent of crude oil and Ba is associated with barytes that are used in drilling fluids. However, the exact source, mode, and mechanics of transport and deposition of the two contaminants into the sediments of the nearshore Beaufort Sea are yet to be resolved. In this context, it is of interest to note that snow samples collected at Prudhoe Bay, an area of industrialization, showed relatively higher concentrations in many trace elements including V and Ba compared with several other sites along the North Slope coast (Snyder-Conn et al., 1997).

The preliminary results of the past year provide some insight into the geochemical partitioning of the trace metals. The strong covariances of V, Cr, Cu, Ni, Zn, As, and Pb with the mud TOM % and all of these elements, except Ba and Cr, with the mud clay % (Table 5) presumably reflect the strong role of organic chelation and/or clay adsorption in the binding of the above metals in mud. It is suggested that the net progressive increased concentrations of Me-Hg identified down the two cores (Figure 4) are most likely a result of a corresponding increase in the Hg methylation process in anoxic sediments.

The finding of increased levels of the toxic Me-Hg in sediment 3 cm below the sea bottom could have some potential environmental implications within the study area, particularly if the Me-Hg levels increase significantly in the future because of higher anthropogenic input. It is possible that some of the subsurface Me-Hg could be mobilized into the overlying water consequent to resuspension of bottom sediment by any of the several natural or anthropogenic processes (i.e., ice gouging, storm-induced currents, dredging). Any Me-Hg thus mobilized during the early freeze-up period could be encapsulated in sea ice. If a large flux of Me-Hg concentrated in sea ice were to be released suddenly into the water during the spring breakup, some of it could be sequestered by primary producers and ultimately passed on to the food-chain, with possible deleterious effect.

The comparison of the mean concentrations of a suite of trace metals in muddy sediments of the study area with those of other circumarctic shelves (Table 6), generally indicates that the levels of metals in the Beaufort Sea, nearshore, are relatively low and are comparable with unpolluted marine regions, a view consistent with that recently reported by Naidu et al. (1998).

The resolved n-alkanes display concentrations (Table 7) comparable to values previously reported from the general region and relatively higher than the other Alaskan coastal areas (Venkatesan and Kaplan, 1982; Steinhauer and Boehm, 1992). The n-alkanes in the sediments generally show a bimodal distribution typical of a mixture of marine autochthonous and terrestrial allochthonous inputs. The maximum at C-17 reflects algal inputs. The dominant maximum at C-27 and occasionally at C-29 and the odd/even ratios ranging from 2.8 to 4.3 are due to inputs from terrigenous detritus (plant wax components) which is to be expected from the nearshore locations of the sample stations. For example, the several fluvial systems and the large erosional rates (1-10 m/year) of the peat-infested coast, could contribute significantly terrigenous sediments to the Beaufort Sea nearshore.

Sediments from stations 2F, 3A and 4A contain n-alkanes and other related parameters (Table 7) comparable to those reported earlier for the same stations by Steinhauer and Boehm (1992). Likewise, stations 5F and 6B contain n-alkanes significantly lower than those reported for the same stations by the above authors. Similar data for comparison from sites SL and WPB, representing samples from Simpson Lagoon and Western Prudhoe Bay, respectively, are not currently available. All these comparisons indicate that during the past seven years, the levels of n-alkanes in sediments from the study area have remained essentially unchanged.

Preliminary Conclusions

Comparison of the time-series data on the mean concentrations of trace metals on the muddy fraction of sediments and n-alkanes on gross sediments from this study in 1997 with those reported for the past 30 years (at about 10-year intervals for the Alaskan Beaufort Sea nearshore) suggests no significant change in all the analytes with the exception of V and Ba in the mud. There is a significant increase in V from 1977 to 1986 and 1997, and in Ba from at least 1986 to 1997. However, these elevated values for the two metals are within concentration ranges reported for unpolluted marine regions. Presumably, most of the metals are either adsorbed on clays and/or chelated with organic particles. The only noticeable stratigraphic change is in the concentration of Me-Hg ,which progressively increases down the core. This trend most likely reflects increased methylation of Hg in anoxic sediment.

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Students

Rion Schmidt and Ricardo Lopez, two Alaska Native undergraduate student interns, and Liying Zhao, Ph. D. student, were involved in various aspects of the project work, including assistance in sampling in the field and laboratory analysis. Liying Zhao, however, is no longer associated with this project as of May 1998, as sufficient matching funds were not available to support her full stipend in the second year (Phase II) study.

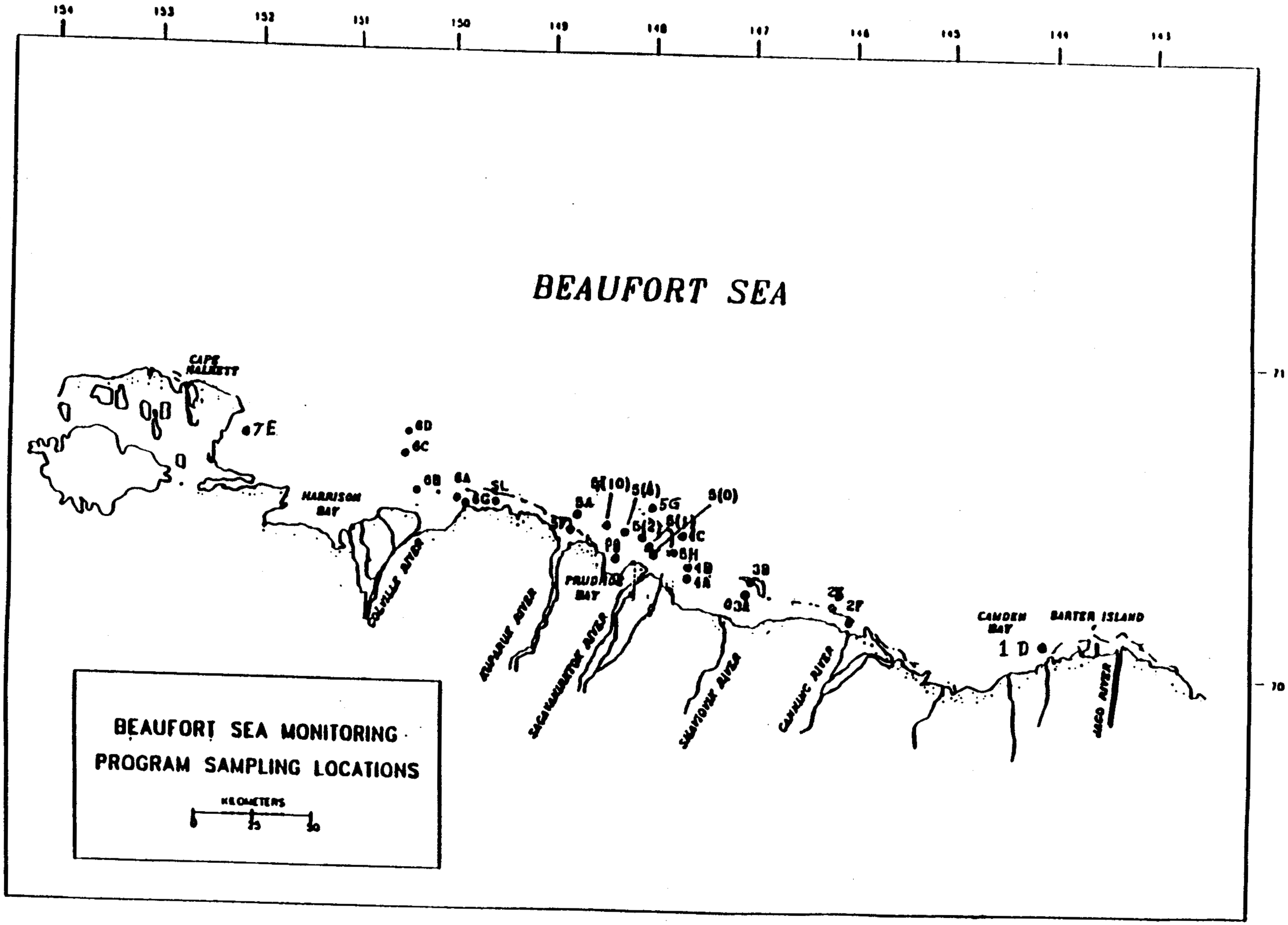

Figure 1. Locations of sediment samples in the nearshore region of the Beaufort Sea.

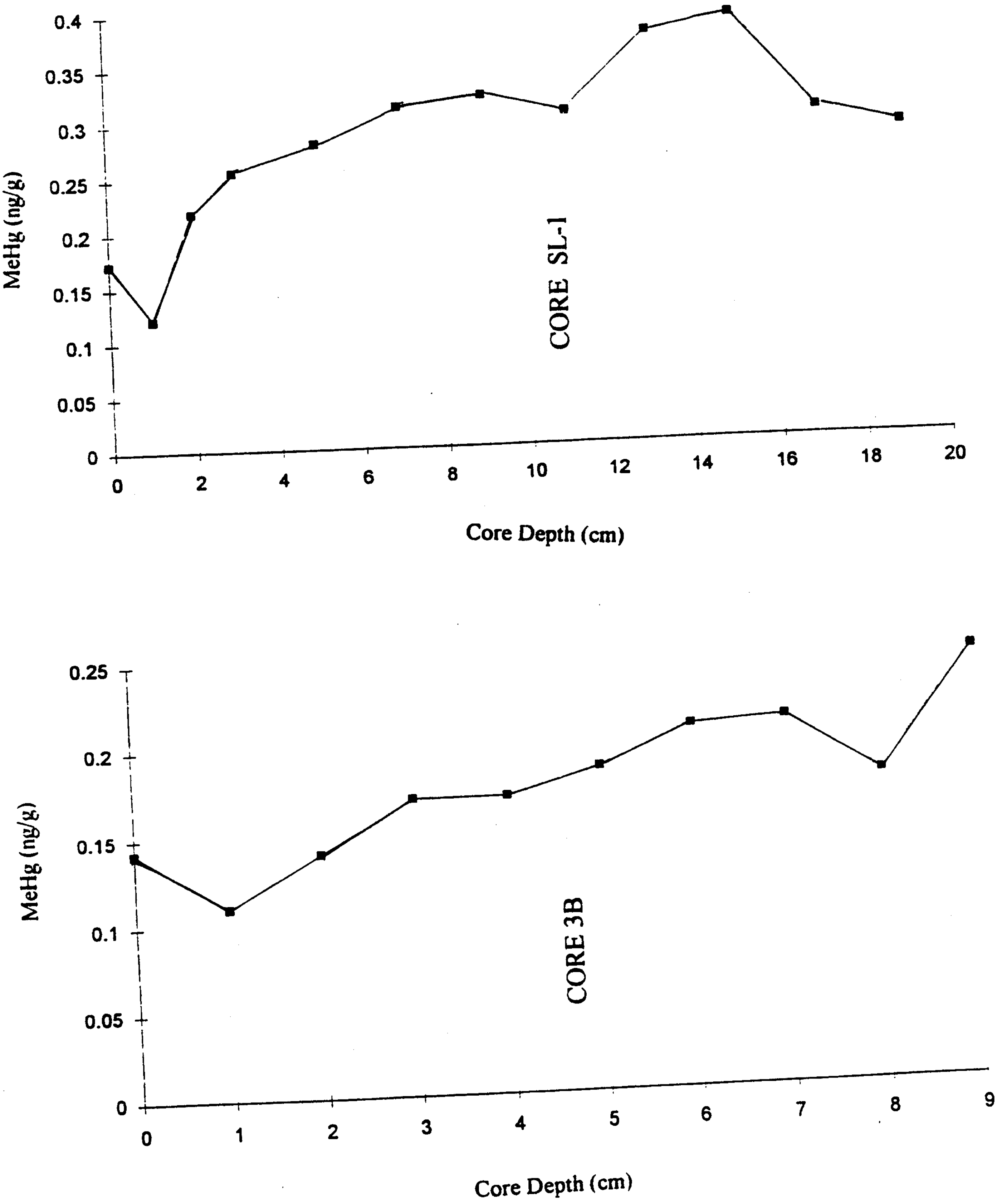

Figure 2. Stratigraphic variations in the concentrations of Me-Hg in two core samples.

Table 1. Station locations and water depths for sediment samples in Beaufort Sea nearshore, and samples selected for analysis in 1997-98 study (Phase I) and those proposed for analysis in 1998-99 (Phase II) study.

STATION	LATITUDE	LONGITUDE	DEPTH (m)	PHASE I	PHASE II
2E	70°12.8′	146°11.6′	7.4	*	**
2F	70°10.3′	146°02.0′	1.9	***	
3A	70°17.0′	147°05.5′	6.2	***	
3B[a]	70°17.9′	147°02.3′	4.2	*	**
4A	70°18.5′	147°40.2′	4.5	***	
5A	70°29.7′	148°46.0′	11.4		*
5F	70°26.5′	148°49.6′	1.5	***	
5(1)	70°25.0′	148°03.5′	5.8	*	**
5(2)	70°25.4′	148°07.2′	5.8		*
5(5)	70°26.1′	148°18.1′	6.7	*	
5(10)	70°27.3′	148°30.1′	8.2	*	**
6A	70°32.1′	149°57.6′	3.6		***
6B	70°33.4′	150°24.6′	5.5	***	
6C	70°40.3′	150°32.1′	16.1	*	**
6D	70°44.9′	150°28.5′	18.4		*
6G	70°31.3′	149°53.9′	2.1		*
SL[a]	70°32.6′	149°38.9′	2.4	***	
WPB	70°20.6′	148°23.2′	2.5	***	
7E	70°43.6′	152°04.4′	3.3		*
5G	70°29.3′	144°05.4′	9.3		*
1D	70°05.7′	148°02.6′	6.0		***

NOTE:

*	Trace-metal analysis
**	Hydrocarbon analysis
***	Trace metal and hydrocarbon analyses
[a]	Sediment core stations

Table 2. Concentration of trace metals, granulometry, carbonate and total organic matter (TOM) in the mud fraction of sediments.

Station	Organic C%	Carbonate%	Silt %	Clay%	Hg(ng/g)	V(ug/g)	Cr(ug/g)	Cu(ug/g)	Ni(ug/g)	Zn(ug/g)	As(ug/g)	Cd(ug/g)	Pb(ug/g)	Ba(ug/g)
6C	7.35	2.38	5.68	94.32	0.074	168.00	90.60	42.30	52.10	115.70	17.90	0.198	18.00	716.50
	8.6	4.64	12.10	87.90	0.015	140.10	78.00	33.80	39.90	104.60	25.90	0.191	16.90	629.20
	7.44	2.79	6.12	93.88	0.063	165.50	87.10	39.80	50.00	115.80	14.50	0.175	17.50	695.70
Mean	7.80	3.27	7.97	92.03	0.05	157.87	85.23	38.63	47.33	112.03	19.43	0.19	17.47	680.47
c.v %	8.94	36.82	45.02	3.90	61.92	9.78	7.63	11.31	13.78	5.75	30.12	6.27	3.15	6.70
6B	5.7	9.95	49.42	50.58	0.024	96.40	63.30	19.50	31.50	74.90	11.00	0.18	9.00	612.60
	6.38	8.77	100.00	0.00	0.013	92.00	70.40	18.70	27.90	80.50	10.70	0.213	9.10	609.90
	7.66	8.51	65.07	34.93	0.02	95.40	63.00	21.10	29.10	88.20	11.90	0.195	9.70	661.80
Mean	6.58	9.08	71.50	28.50	0.02	94.60	65.57	19.77	29.50	81.20	11.20	0.20	9.27	628.10
c.v. %	15.12	8.45	36.22	90.85	29.30	2.44	6.39	6.18	6.21	8.22	5.58	8.43	4.09	4.65
SL	5.37	7.13	17.54	82.46	0.172	115.40	73.60	27.70	35.10	100.20	9.80	0.212	12.60	545.20
	5.78	8.14	80.02	19.98	0.121	112.50	53.70	27.00	35.70	88.50	10.90	0.282	11.20	280.10
	3.56	10.14	72.66	27.34	0.218	92.50	43.40	19.60	30.20	75.40	9.30	0.246	9.00	466.20
Mean	4.90	8.47	56.74	43.26	0.17	106.80	56.90	24.77	33.67	88.03	10.00	0.25	10.93	430.50
c.v. %	24.09	18.09	60.18	78.93	28.49	11.67	26.98	18.12	8.96	14.09	8.19	14.19	16.60	31.62
5F	4.95	8.99	77.68	22.32	0.115	100.90	62.30	24.50	32.50	96.50	10.00	0.259	9.90	421.60
	5.2	9.08	80.86	19.14	0.095	97.40	48.80	21.80	30.70	82.40	9.90	0.249	9.00	482.40
	5.7	9.54	81.04	18.96	0.101	108.80	67.80	26.90	33.60	99.20	11.20	0.344	11.70	528.30
Mean	5.28	9.20	79.86	20.14	0.10	102.37	59.63	24.40	32.27	92.70	10.37	0.28	10.20	477.43
c.v. %	7.23	3.21	2.37	9.38	9.90	5.70	16.39	10.46	4.54	9.73	6.98	18.38	13.48	11.21
5(10)	6.41	13.12	32.77	67.23	0.013	110.50	59.20	24.40	29.00	85.30	15.80	0.26	12.40	526.40
	7.91	11.22	38.06	61.94	0.023	90.30	49.30	19.60	23.70	79.10	12.90	0.286	9.30	489.40
	6.7	11.91	54.16	45.84	0.024	102.80	61.30	23.30	25.30	86.90	16.80	0.24	13.40	535.20
Mean	7.01	12.08	41.66	58.34	0.02	101.20	56.60	22.43	26.00	83.77	15.17	0.26	11.70	517.00
c.v. %	11.36	7.96	26.74	19.10	30.41	10.07	11.32	11.21	10.46	4.92	13.36	8.80	18.27	4.70

Station	Organic C%	Carbonate%	Silt %	Clay%	Hg(ng/g)	V(ug/g)	Cr(ug/g)	Cu(ug/g)	Ni(ug/g)	Zn(ug/g)	As(ug/g)	Cd(ug/g)	Pb(ug/g)	Ba(ug/g)
WPB	8.84	10.2	70.75	29.25	0.057	121.60	91.70	28.90	42.20	111.10	13.80	0.337	12.60	662.50
	6.52	11.4	71.22	28.78	0.044	118.70	83.10	30.20	38.40	113.30	12.50	0.369	12.80	684.30
	8.78	8.3	75.62	24.38	0.092	132.30	87.60	32.20	40.30	116.60	14.40	0.29	14.90	543.60
Mean	8.05	9.97	72.53	27.47	0.06	124.20	87.47	30.43	40.30	113.67	13.57	0.33	13.43	630.13
c.v. %	16.44	15.68	3.70	9.78	38.59	5.77	4.92	5.46	4.71	2.44	7.16	11.97	9.48	12.02
5(5)	5.26	9.98	70.16	29.84	0.008	107.30	48.10	23.70	29.80	78.00	13.00	0.206	11.50	393.40
	5.24	11.13	69.33	30.67	0.041	110.00	52.50	23.90	30.00	82.90	13.60	0.222	12.30	545.50
	5.55	9.02	63.71	36.29	0.043	119.40	69.00	29.20	33.00	97.90	15.10	0.239	14.10	600.00
Mean	5.35	10.04	67.73	32.27	0.03	112.23	56.53	25.60	30.93	86.27	13.90	0.22	12.63	512.97
c.v. %	3.24	10.52	5.18	10.87	64.09	5.66	19.49	12.18	5.79	12.02	7.78	7.42	10.54	20.87
5(1)	8.47	12.01	18.65	81.35	0.001	168.20	77.00	39.20	37.80	147.00	45.00	0.378	40.50	584.70
	8.18	12.36	4.02	95.98	-0.001	136.60	61.30	30.10	33.50	104.00	26.10	0.253	21.90	536.30
			0.00	100.00	0.012	120.20	59.90	30.00	29.20	102.00	25.70	0.287	21.80	550.10
Mean	8.33	12.19	7.56	92.44	0.00	141.67	66.07	33.10	33.50	117.67	32.27	0.31	28.07	557.03
c.v. %	2.46	2.03	129.89	10.62	175.00	17.22	14.37	15.96	12.84	21.61	34.18	21.12	38.36	4.48
4A	8.9	7.27	38.37	61.63	0.033	139.50	68.20	40.20	47.70	123.20	16.10	0.407	16.60	676.50
	6.57	8.7	40.40	59.60	0.044	100.40	41.90	25.80	34.30	76.50	9.90	0.52	9.60	702.30
Mean	7.74	7.99	39.39	60.62	0.04	119.95	55.05	33.00	41.00	99.85	13.00	0.46	13.10	689.40
c.v %	21.30	12.66	3.64	2.37	20.20	23.05	33.78	30.86	23.11	33.07	33.72	17.24	37.78	2.65
3A	6.05	8.02	74.98	25.02	0.115	117.40	52.80	26.40	30.70	82.50	12.40	0.2	12.20	851.70
	4.75	8.64	73.34	26.66	0.099	114.40	54.70	25.60	30.40	81.50	14.90	0.231	13.00	602.20
	5.98	7.77	75.71	24.29	0.137	107.70	52.10	25.10	28.50	75.60	13.90	0.234	12.30	567.60
Mean	5.59	8.14	74.68	25.32	0.12	113.17	53.20	25.70	29.87	79.87	13.73	0.22	12.50	673.83
c.v %	13.07	5.50	1.63	4.79	16.31	4.39	2.53	2.55	3.99	4.67	9.16	8.49	3.49	23.00

Station	Organic C%	Carbonate%	Silt %	Clay%	Hg(ng/g)	V(ug/g)	Cr(ug/g)	Cu(ug/g)	Ni(ug/g)	Zn(ug/g)	As(ug/g)	Cd(ug/g)	Pb(ug/g)	Ba(ug/g)
3B	6.21	7.22	66.75	33.25	0.246	122.20	55.10	28.90	34.60	106.50	9.90	0.277	14.00	539.40
	6.69	6.85	74.90	25.10	0.177	98.80	48.30	23.50	28.60	76.30	9.60	0.278	11.60	545.70
	7.48	6.45	67.71	32.29	0.21	126.90	56.50	29.80	34.00	89.40	12.00	0.298	14.60	540.30
Mean	6.79	6.84	69.79	30.21	0.21	115.97	53.30	27.40	32.40	90.73	10.50	0.28	13.40	541.80
c.v %	9.44	5.63	6.38	14.74	16.36	12.98	8.23	12.44	10.20	16.69	12.45	4.17	11.85	0.63
2E	7	8.82	64.28	35.72	0.02	125.60	80.50	30.00	32.80	101.10	16.70	0.277	15.10	662.50
	9.13	9.02	44.72	55.28	0.028	109.00	50.10	23.50	30.60	77.30	13.80	0.219	10.50	592.90
	7.91	8.74	53.81	46.19	0.026	87.30	57.10	24.20	25.70	76.20	11.60	0.215	9.80	519.30
Mean	8.01	8.86	54.27	45.73	0.02	107.30	62.57	25.90	29.70	84.87	14.03	0.24	11.80	591.57
c.v %	13.34	1.63	18.04	21.40	16.88	17.90	25.45	13.78	12.24	16.58	18.23	14.64	24.40	12.11
2F			70.39	29.61	0.121	104.00	46.30	31.00	32.70	94.20	12.00	0.345	11.30	487.00
			74.67	25.33	0.143	115.00	67.30	29.80	31.50	102.90	14.30	0.294	13.50	508.10
			77.66	22.34	0.184	81.10	47.70	19.90	23.00	74.00	9.40	0.278	9.00	438.70
Mean			74.24	25.76	0.15	100.03	53.77	26.90	29.07	90.37	11.90	0.31	11.27	477.93
c.v %			4.92	14.18	21.41	17.29	21.84	22.65	18.19	16.41	20.60	11.45	19.97	7.44

Table 3. Stratigraphic variations in the concentrations of trace metals.

CORE 3B	MMHg	Trace Metals, ug/g (ppm) Dry Weight (Silt/Clay) Basis								
	ng/g (wet)	V	Cr	Cu	Ni	Zn	As	Cd	Pb	Ba
3B-0-1	0.246	122.2	55.1	28.9	34.6	106.5	9.9	0.277	14.0	539.4
3B-2-2	0.177	98.8	48.3	23.5	28.6	76.3	9.6	0.278	11.6	545.7
3B-3-3	0.210	126.9	56.5	29.8	34.0	89.4	12.0	0.298	14.6	540.3
3B-4-4	0.207	117.5	59.2	28.1	32.7	85.8	11.2	0.286	13.3	546.8
3B-5-5	0.185	100.0	48.6	22.7	29.0	85.1	10.1	0.249	11.4	499.0
3B-6-6	0.170	106.6	49.0	24.6	29.8	77.9	10.7	0.236	11.7	540.9
3B-7-7	0.170	110.4	45.9	25.3	31.2	79.6	10.6	0.186	11.4	529.5
3B-8-8	0.140	103.2	47.6	23.3	29.1	74.1	11.2	0.242	11.1	535.3
3B-9-9	0.110	98.7	47.3	22.6	27.7	75.6	11.7	0.231	11.2	547.4

CORE SL

SL-01	0.172	115.4	73.6	27.7	35.1	100.2	9.8	0.212	12.6	545.2
SL-02	0.121	112.5	53.7	27.0	35.7	88.5	10.9	0.282	11.2	280.1
SL-03	0.218	92.5	43.4	19.6	30.2	75.4	9.3	0.246	9.0	466.2
SL-04	0.256	97.8	44.7	21.7	33.3	81.7	7.8	0.213	11.6	487.9
SL-06	0.281	102.1	52.5	22.1	33.9	82.4	8.8	0.213	10.2	443.5
SL-08	0.312	95.2	44.9	22.4	34.3	81.5	8.5	0.200	9.7	464.6
SL-10	0.321	101.3	45.1	24.6	35.1	84.2	8.7	0.220	10.7	502.5
SL-12	0.304	88.1	41.6	20.6	31.4	71.4	7.6	0.191	9.0	482.1
SL-14	0.375	106.9	47.8	25.6	37.0	88.2	8.3	0.235	10.5	451.4
SL-16	0.388	98.0	49.7	23.0	33.6	84.9	9.1	0.289	10.6	470.8
SL-18	0.300	103.0	47.1	24.1	36.3	84.6	8.2	0.228	9.6	435.9
SL-20	0.285	107.0	52.9	24.1	36.6	85.8	8.3	0.209	10.9	494.8

Table 4. Time-series changes in the mean concentrations of trace metals.

(Concentrations of MeHg in ng/g; other elements in ug/g)

YEAR	Cu	Cr	Ni	Zn	V	Pb	Cd	Ba	As	MeHg
1977										
N=12										
X	21	60	30	94	**87**					
SD	4	5	2	10	3					
CV%	19	8	7	11	3					
1985-86										
N=13										
X	24	78		93	**115**	15	0.19	**347**		
SD	4	10		13	17	4	0.06	77		
CV%	17	13		14	15	27	32	22		
1997										
N=36										
X	27	64	33	94	**115**	14	0.27	**579**	15	0.066
SD	6	14	7	18	22	6	0.07	94	7	0.055
CV%	22	22	21	19	19	43	26	16	47	83

Table 5. Correlation coefficients for chemical and physical parameters of muds from the Beaufort Sea nearshore, north Arctic Alaska. (n=34; only significant correlations at p<.05000 are shown)

	Organic C%	*Carbonate*	*Silt %*	*Clay%*	*Hg*	*V*	*Cr*	*Cu*	*Ni*	*Zn*	*As*	*Cd*	*Pb*	*Ba*
Organic C%	1.00													
Carbonate%	-0.13	1.00												
Silt %	-0.45	0.22	1.00											
Clay%	0.45	-0.22	-1.00	1.00										
Hg(ng/g)	-0.43	-0.34	0.39	-0.39	1.00									
V(ug/g)	0.44	-0.43	-0.60	0.60	-0.17	1.00								
Cr(ug/g)	0.45	-0.29	-0.30	0.30	-0.29	0.67	1.00							
Cu(ug/g)	0.48	-0.49	-0.54	0.54	-0.11	0.93	0.63	1.00						
Ni(ug/g)	0.37	-0.59	-0.41	0.41	-0.06	0.83	0.70	0.86	1.00					
Zn(ug/g)	0.48	-0.16	-0.43	0.43	-0.16	0.84	0.75	0.86	0.74	1.00				
As(ug/g)	0.46	0.17	-0.60	0.60	-0.47	0.65	0.34	0.54	0.24	0.63	1.00			
Cd(ug/g)	0.20	0.25	0.05	-0.05	0.03	0.05	-0.06	0.23	0.15	0.30	0.11	1.00		
Pb(ug/g)	0.41	0.03	-0.57	0.57	-0.27	0.77	0.41	0.69	0.39	0.77	0.94	0.19	1.00	
Ba(ug/g)	0.34	-0.30	-0.27	0.27	-0.27	0.40	0.43	0.37	0.42	0.27	0.16	0.04	0.18	1.00

Table 6. Mean concentrations of trace metals in muddy sediments of the study area compared with those in muds from selected circum-arctic shelf regions (Naidu, 1982; Sweeney, 1984; Crecelius et al., 1991; Naidu et al., 1998, Loring et al., 1995; Loring and Asmund, 1996; Nolting et al., 1996).

Shelf	n	Fe	Mn	OC	Cu	Cr	Co	Ni	Zn	V	Pb	Cd
Chukchi Sea[a]	12	3.46	295	0.75	22	82	26	27	79	116		
	SD	0.64	37	0.44	6	21	5	6	18	30		
Beaufort Sea[b]	23	3.36	410	0.83	33	89	89	47	98	152		
	SD	1.12	174	0.20	9	14	14	11	18	26		
Beaufort Sea[c]	13				24	78			93	115	15	0.19
	SD				4	10			13	17	4	0.06
Beaufort Sea[d]	36				27	64		33	94	115	14	0.27
(This study)	SD				6	14		7	18	22	6	0.07
Pechora Sea[e]	40				21	110		43	84	175		
	SD				2	15		9	9	46		
Kara Sea[e]	36				20	110		42		147		
	SD				6	25		10		27		
Svalbard[e]	15					153		50	107	248		
	SD					5		1	3	11		
E. Greenland[e]	10				50	117		62	92	167	19	0.11
	SD				36	37		27	16	64	7	0.05
W. Greenland[f]	22				49	163		82	77	129	18	0.15
	SD				40	154		96	19	70	8	0.16
W. Baffin Bay[e]	12				29	63		22	61	91		
	SD				8	19		9	14	32		
Laptev Sea[g]	11	4.06	206		16			28	98		18	0.06
	SD	1.00	175		4			7	22		3	0.02

Table 7. Results of the n-alkane analysis on gross sediments from the study area.

Sample ID	2F1	2F2	2F3	3A1	3A2	3A3 Lost
Surrogate Recovery%						
Deu C14	47.19	48.38	53.18	52.79	43.57	
Deu C24	59.95	64.14	65.91	60.10	43.53	
Deu C36	59.95	60.37	60.62	55.47	41.81	
n-alkane (ng/g)						
n-C10	18.80	19.50	33.08	32.22	13.19	
n-C11	30.19	31.17	52.45	48.38	29.16	
n-C12	29.92	34.17	65.64	56.30	45.59	
n-C13	38.69	56.32	84.19	73.82	68.43	
n-C14	36.34	38.69	64.96	67.03	46.17	
n-C15	43.13	46.05	70.58	83.03	61.17	
n-C16	35.46	34.92	54.54	57.20	43.19	
n-C17	44.83	45.63	75.04	87.32	66.38	
pr	28.87	28.45	48.59	51.90	39.51	
n-C18	32.61	32.20	53.36	55.98	42.50	
ph	12.86	13.25	22.49	24.62	19.85	
n-C19	41.74	41.37	73.05	79.08	60.84	
n-C20	37.37	36.40	63.70	70.32	53.05	
n-C21	64.43	62.79	127.86	146.05	109.90	
n-C22	51.51	49.43	80.02	110.67	82.86	
n-C23	112.35	107.58	243.68	264.01	196.11	
n-C24	49.56	46.98	95.80	105.54	78.00	
n-C25	136.97	129.29	336.42	346.79	261.40	
n-C26	38.05	37.50	78.23	81.97	60.74	
n-C27	230.47	212.77	553.20	559.22	418.12	
n-C28	35.27	26.78	58.14	60.84	45.56	
n-C29	202.39	181.58	191.66	510.17	376.81	
n-C30	22.64	21.29	45.59	47.96	34.68	
n-C31	160.24	150.57	165.81	427.85	311.98	
n-C32	13.28	12.55	26.18	32.33	23.66	
n-C33	46.91	43.97	91.95	133.98	90.04	
n-C34	4.54	3.65	6.88	7.59	5.63	
n-C35	9.29	1.22	14.48	21.65	14.85	
n-C36	3.03	nd	0.92	3.02	2.71	
Total n-alkanes	1570.00	1504.38	2807.40	3570.32	2642.73	
C12-C19	302.71	329.36	541.35	559.76	434.28	
C20-C33	1201.44	1119.48	2158.25	2897.70	2142.91	
Pr/Ph	2.25	2.15	2.16	2.11	1.99	
Odd/Even*	3.38	3.39	3.43	4.18	4.16	

* Summed from nC15-nC34

Sample ID	4A1	4A2	4A3	5F1	5F2	5F3
Surrogate Recovery%						
Deu C14	64.43	57.77	50.46	48.40	42.84	49.98
Deu C24	83.36	73.83	67.12	55.21	53.28	59.60
Deu C36	83.89	77.08	55.20	55.92	50.77	60.57
n-alkane (ng/g)						
n-C10	86.19	27.26	76.94	17.70	17.08	18.36
n-C11	105.53	42.40	107.66	26.19	25.33	29.79
n-C12	124.23	47.80	119.86	28.34	25.87	31.43
n-C13	168.67	64.65	152.21	32.24	30.28	39.01
n-C14	140.83	57.38	118.21	31.53	30.03	38.60
n-C15	158.40	69.90	137.22	34.82	34.04	41.33
n-C16	116.45	52.14	95.99	26.57	25.66	31.25
n-C17	139.37	111.04	112.76	41.90	40.23	46.40
pr	79.65	40.43	69.80	20.04	20.19	24.27
n-C18	103.60	47.60	86.83	29.31	27.82	32.65
ph	34.54	17.85	29.76	9.65	9.63	11.30
n-C19	122.95	58.77	104.42	50.41	45.61	50.19
n-C20	109.02	51.96	94.40	40.38	35.66	39.95
n-C21	172.96	87.13	150.31	110.66	99.61	102.80
n-C22	143.30	70.80	124.91	81.79	82.54	77.20
n-C23	269.55	139.88	226.36	14.33	218.17	2·7.97
n-C24	129.88	65.04	113.82	80.96	90.59	78.23
n-C25	283.08	153.59	243.47	267.88	266.90	266.39
n-C26	93.60	61.28	90.39	60.38	75.81	58.74
n-C27	162.63	234.33	380.31	419.23	363.43	354.29
n-C28	87.49	36.27	68.54	39.95	65.29	47.04
n-C29	53.24	241.94	453.89	327.36	285.56	280.51
n-C30	52.60	26.88	48.04	31.50	42.72	28.72
n-C31	67.43	211.39	429.66	275.13	243.63	234.65
n-C32	27.50	15.69	25.22	14.89	21.73	13.28
n-C33	49.02	68.95	142.41	99.71	89.10	88.47
n-C34	10.05	5.92	9.05	5.14	8.41	5.28
n-C35	23.78	16.53	25.31	20.49	20.73	23.00
n-C36	6.55	2.81	nd	2.12	2.86	nd
Total n-alkanes	3007.91	2059.24	3738.19	2210.94	2314.65	2274.53
C12-C19	1074.50	509.18	927.51	275.13	259.52	309.85
C20-C33	1701.30	1455.14	2591.73	1864.17	1980.72	1888.24
Pr/Ph	2.31	2.26	2.35	2.08	2.10	2.15
Odd/Even*	1.69	3.25	3.14	3.99	3.54	4.08

* Summed from nC15-nC34

Sample ID	6B1	6B2	6B3	SL1	SL2	SL3
Surrogate Recovery%						
Deu C14	36.32	31.93	Sur	54.39	51.90	62.05
Deu C24	50.80	48.47	not	50.38	51.14	61.48
Deu C36	53.64	49.03	added	51.63	53.54	61.91
n-alkane (ng/g)						
n-C10	4.55	5.13	4.64	34.56	33.45	28.07
n-C11	8.97	8.82	7.95	55.74	57.32	50.74
n-C12	8.99	7.95	5.68	66.53	63.09	71.68
n-C13	11.02	9.55	7.18	83.84	70.80	88.72
n-C14	11.05	8.63	6.50	59.24	57.52	72.12
n-C15	12.49	10.39	7.85	68.28	71.32	85.68
n-C16	10.67	9.31	7.14	52.13	51.01	66.58
n-C17	13.43	11.95	8.68	71.08	79.27	97.73
pr	7.84	7.20	5.16	37.92	38.91	53.38
n-C18	10.74	9.47	6.90	52.53	52.49	65.78
ph	4.28	3.58	2.50	19.46	20.06	26.54
n-C19	13.80	12.78	8.76	81.37	84.62	88.30
n-C20	11.80	10.75	7.57	60.19	64.36	76.59
n-C21	22.19	21.81	14.35	167.50	178.29	201.66
n-C22	18.01	17.82	11.77	126.38	131.36	152.86
n-C23	46.55	45.00	27.79	5.30	4.86	416.62
n-C24	17.69	17.94	11.34	121.66	123.94	150.85
n-C25	46.87	49.76	28.05	456.93	473.54	569.13
n-C26	13.86	14.25	8.86	94.59	93.82	108.41
n-C27	67.44	66.34	41.01	559.12	656.91	765.88
n-C28	11.25	11.87	6.32	80.21	88.77	100.06
n-C29	57.01	57.00	33.83	445.69	530.11	617.03
n-C30	6.70	6.77	4.09	46.45	53.74	60.50
n-C31	46.37	45.78	26.49	382.57	473.21	520.83
n-C32	1.17	1.81	1.23	21.70	28.57	31.79
n-C33	16.00	15.42	8.86	139.68	205.88	176.88
n-C34	1.70	2.10	1.17	7.50	9.80	9.04
n-C35	4.91	3.41	1.80	46.10	26.90	40.87
n-C36	0.79	1.07	nd	nd	0.68	0.55
Total n-alkanes	494.02	482.91	305.81	3386.86	3765.64	4712.96
C12-C19	92.20	80.04	58.69	534.99	530.12	636.59
C20-C33	380.91	382.34	231.56	2707.98	3107.37	3949.10
Pr/Ph	1.83	2.02	2.06	1.95	1.94	2.01
Odd/Even*	3.28	3.29	3.10	3.58	3.95	4.30

* Summed from
nC15-nC34

Sample ID	WPB1	WPB2	WPB3	P-blk 1	P-blk 2
Surrogate Recovery%					
Deu C14	40.64	42.98	45.22	60.90	57.55
Deu C24	51.85	57.53	54.74	103.08	98.97
Deu C36	53.51	63.61	56.11	104.20	103.14
n-alkane (ng/g)					
n-C10	10.07	8.96	14.39	nd	nd
n-C11	15.94	15.66	22.42	2.44	nd
n-C12	17.31	16.68	25.51	nd	nd
n-C13	23.49	22.78	35.06	nd	nd
n-C14	20.62	21.48	28.29	nd	nd
n-C15	25.34	23.42	34.80	nd	nd
n-C16	18.89	19.20	25.34	nd	nd
n-C17	22.81	23.22	34.14	0.24	nd
pr	10.42	10.46	14.41	nd	nd
n-C18	16.32	16.97	22.85	0.30	nd
ph	6.62	7.98	8.16	nd	nd
n-C19	20.02	19.51	32.77	0.32	nd
n-C20	16.59	16.88	26.45	0.52	0.17
n-C21	26.85	27.13	55.90	0.81	0.27
n-C22	21.88	22.23	42.57	1.18	0.48
n-C23	43.34	43.35	104.53	2.29	0.94
n-C24	20.50	20.97	40.91	1.31	0.68
n-C25	46.59	45.83	108.60	2.13	0.91
n-C26	15.78	16.51	31.51	1.01	0.43
n-C27	72.68	72.01	164.44	2.40	1.07
n-C28	10.91	11.41	20.24	0.81	0.35
n-C29	58.99	60.89	133.70	1.60	0.98
n-C30	8.27	8.02	16.16	0.63	0.21
n-C31	47.03	47.83	53.94	1.21	0.48
n-C32	1.33	1.85	3.62	0.57	0.20
n-C33	15.23	17.00	34.29	0.52	0.15
n-C34	2.75	1.39	3.55	0.30	nd
n-C35	4.44	1.50	7.74	nd	nd
n-C36	1.59	1.50	1.77	nd	nd
Total n-alkanes	605.57	604.18	1125.47		
C12-C19	164.80	163.27	238.75		
C20-C33	405.98	411.90	836.85		
Pr/Ph	1.57	1.31	1.77		
Odd/Even*	2.84	2.81	3.25		

* Summed from
nC15-nC34

Physical-Biological Numerical Modeling on Alaskan Arctic Shelves

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Abstract

The Arctic shelves north of the Bering Strait and north coastal Alaska are regions of important benthic and marine mammal resources, and are areas that will be impacted by offshore oil, gas, and mining operations. These shelves are also regions of seasonal sea ice cover that is mobile and restless. Physical (including ice), biological, and chemical oceanographic conditions in both summer and winter are such that several types of both natural and man-derived "particles" (e.g., primary production or phytoplankton, detritus, petroleum, mining, radionuclides, etc.) may interact, aggregate, and ultimately be transported deeper into the ocean, into the Arctic halocline, onto the shelf bottoms, and into the benthic and marine mammal ecosystems.

In this study, we numerically model the generation, flux, and fate of the natural primary production phytoplankton particles, and their interaction with each other and with physical processes. A cross-sectional, multi-layered, time-dependent, finite-difference numerical model composed of physical, biological, and sea ice submodels was applied to the region off the north coast of Alaska. The air-ice-ocean interaction was numerically simulated using physical forcing of winds as well as heating and cooling of the ocean to melt or make ice. The modeling simultaneously simulated physical interaction with both primary production and the aggregation of phytoplankton. Available hydrographic, satellite etc. data were used for initial and boundary conditions and for verification.

Four sets of experiments were conducted: 1) Simulation of aggregation of primary production particles or chlorophyll. The aggregation modeling was used in the rest of the modeling. 2) Ice edge melt experiments with and without ice melt; with and without

deep stratification. 3) Coastal upwelling with a mobile ice cover with and without winds; with and without ice cover. 4) Experiments simulating deep convection from brine rejection after wind-driven preconditioning with and without density as a function of pressure, and with and without deeper stratification.

At least two main pathways or processes for this flux are brine rejection from ice formation in fall and winter, and primary production blooms in spring and summer. The modeling appears to reasonably portray some of the complex physical and biological mesoscale processes and their interaction in Arctic waters. These processes included particle aggregation and flux through the water column as forced by ice-edge meltwater stratification, coastal upwelling in ice infested waters, and by wind forcing that clears ice off the ocean followed by freezing conditions that generate ice leading to brine rejection and vertical convection. Some of the vertical convection experiments are really not verifiable yet as data do not exist on vertical flux due to convection. By running controlled experiments and simulations in which physical, biological, nutrient chemical, and ice conditions were carefully forced and varied, progress was made in understanding how the processes work in nature. Reasonable agreement has been obtained in comparisons of model results with existing data, suggesting insight was gained into these poorly understood air-ice-ocean processes of the Arctic.

Study Products

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Defining Habitats for Juvenile Groundfishes in Southcentral Alaska, with Emphasis on Flatfishes

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Abstract

*Seasonal and interannual abundance and distribution of juvenile groundfishes were addressed through studies in Chiniak Bay, Kodiak Island, and Kachemak Bay, lower Cook Inlet. Sampling three times a year over two years (1994–1996) in Kachemak Bay provided insight into short-term interannual variability and seasonal variability. Physical habitat parameters of the two most abundant flatfishes in Kachemak Bay, flathead sole (*Hippoglossoides elassodon*) and rock sole (*Pleuronectes bilineatus*), were quantified in a location separate from Kodiak Island. August sampling was conducted for six years (1991–1996) in Chiniak Bay. The first four years included location and definition of nursery grounds of juvenile flatfishes and provided the background necessaryfor designing and testing new sampling designs for abundance estimation. During 1995–1996, we used stepwise sampling strategies designed to increase the precision of abundance estimates. The interannual variability of the four most abundant flatfishes in Chiniak Bay: flathead sole, Pacific halibut (*Hippoglossus stenolepis*), yellowfin sole (*Pleuronectes asper*) and rock sole, was assessed over six years. For the two periods that Kachemak and Chiniak Bays were sampled simultaneously (August 1995 and August 1996), the groundfish community composition, distribution, and abundance were compared. Depth was the most important factor related to distribution and abundance of groundfishes in these two locations. The taxonomic compositions of benthic invertebrates and flatfish diets were contrasted at one site in Kachemak Bay.*

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Relationship of Diet to Habitat Preferences of Juvenile Flatfishes, Phase I

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Introduction

Nursery habitats and abundance of juvenile flathead sole and rock sole in Kachemak Bay, lower Cook Inlet, Alaska were established during the a previous research project which collected the fish for this study (Abookire, 1997; Abookire and Norcross, 1998; Norcross et al., 1998). Depth and substrate were found to define nursery areas. Preferred year-round nurseries of flathead sole are 40–80 m and >50% mud, preferred summer nurseries of rock sole are 10–30 m deep and >90% sand.

This project is in many ways similar to research we conducted on diets of juvenile flatfishes collected near Kodiak Island, Alaska (Holladay and Norcross, 1995a; 1995b). Diets of Kodiak flatfishes, including flathead sole and rock sole, were examined and described relative to parameters of depth, substrate, and bay (Holladay and Norcross, 1995b). Flathead sole and rock sole consumed mainly crustacean taxa. In particular, mysids, cumaceans, and gammarid amphipods were sometimes consumed by both fishes within a location, depth increment or substrate type. Few flathead sole and rock sole were collected concurrently at the same site near Kodiak Island; this is also the case for Kachemak Bay (Abookire, 1997). Diets of flathead sole near Kodiak were different for age-0 versus age-1 fish (Holladay and Norcross, 1995b).

The primary Phase I objectives for the current study were 1) to investigate the feeding differences of a subsample of 80 flathead sole seasonally and at physically distinct sites in Kachemak Bay, 2) to use a balanced subsample design to determine whether season (winter, spring, and summer), depth preference (shallower than preferred, preferred, deeper than preferred), or substrate preference (preferred grain size and larger than preferred) have a statistically significant effect on diet of predators, 3) to determine the power of statistical analyses, and 4) to estimate the sample size necessary to bring the power of the statistical tests to an appropriate level (e.g., $\alpha > 0.20$ and $\beta < 0.80$). A secondary objective was 5) to analyze the diets of 80 flathead sole by fish size.

Methods and Results

Fishes and benthos were collected during winter (February 1996), spring (May 1995 and May 1996), and summer (September 1994, August 1995, and August 1996) (Abookire, 1997). Fishes were captured via 3.05 m plumb staff beam trawl, with 7 mm mesh and 4 mm codend. Flathead sole and rock sole of lengths <200 mm were packaged and frozen by species, station, and cruise, with up to 10 fish of various sizes frozen together from each site. Only flathead sole were examined during Phase I. Benthos was collected via a 0.06 m^3 ponar sediment grab, preserved in an initial solution of buffered 10% formalin, and preserved in a final solution of 50% isopropyl alcohol containing rose bengal biological stain.

During Phase I laboratory analysis, stations were randomly selected within the habitat category under consideration, and within each station, up to 10 flathead sole were randomly selected and stomach contents were examined without regard to fish size. Fish were defrosted gradually in order to maintain condition. The stomach contents of 140 flathead sole <200 mm total length were examined during Phase I (Table 1). Seventy-five percent of the examined fish stomachs that were collected during winter were empty, compared with 52% during spring and 24% during summer.

Each fish was examined for evidence of regurgitation. Fish that had regurgitated would have been omitted from further analysis, but there was no evidence of regurgitation in any of the fish examined in Phase I. Fish total length (mm) and weight (1.0 mg) were measured before the stomach was excised at the esophagus and pyloric caecum. Stomach fullness was recorded, and prey taxa within the stomachs were identified to the lowest practical taxon, counted, preserved in 50% isopropyl alcohol, and weighed (0.1 mg). For each prey taxon, whole individuals and heads were counted; all fragments within a single predator that could be assigned to a taxon received a count of one individual regardless of the number of fragments. Where taxa were of negligible weight per individual (<0.1 mg), the prey biomass data set was completed using average weights of animals present in the zooplankton of Prince William Sound, Alaska, e.g., polychaete larvae, copepods, and juvenile mysids (Chris Stark, IMS/SFOS, pers. comm.). During preliminary analyses, prey taxa were considered separately at the most specific taxonomic level and at a more general level (e.g., class or order). Subsequent analyses considered prey only at the general level.

Eighty fish containing prey were analyzed further; hereafter those 80 fish are termed 'predators'. Ten predators were examined from the winter collection (regardless of depth or substrate), 10 predators were examined from spring collections (regardless of depth or substrate), and 60 predators were examined from summer collections (10 predators within each of 6 substrate/depth combinations). During Phase I, 46% of prey individuals were identifiable to species or genus, 26% were identifiable to the level of family, and 26% were identifiable to the level of order or class. Each predator sampled in Phase I consumed only a few prey taxa, amounting to 2.0 ± 1.15 prey taxa per predator for the specific taxonomic level, and 2.4 ± 1.67 prey taxa per predator for the general level. A summary of the counts of individuals identified of each prey taxon indicated flathead sole ate taxa within the taxonomic classes Foraminifera, Polychaeta, Bivalvia, and Crustacea. The greatest variety of taxa was from the class Crustacea, particularly from the Copepoda, Gammaridea, and Euphausiacea. We emphasize these counts do not represent the amount of food (soft tissue biomass) provided by the prey taxa.

Two factors created difficulties with identification of prey to species. The primary factor was that many of the prey were juveniles, with very small appendages that could not be seen while using a dissecting scope. Juvenile prey could be allocated into general taxonomic groups (e.g., class, family), but further examination was beyond the scope of this project's funding and time allocation. The second obstacle to precise identification was that prey were generally in an advanced state of digestion, with much of the soft tissue already digested. While it was sometimes still possible to identify crustaceans based on chitinous exoskeletons, identification of those samples was much more difficult than when the prey was whole and in good condition.

Weights of prey taxa were measured. However, in many cases the prey weights poorly represented the amount of food (soft tissue) provided to the predator. Weights of whole prey may overestimate of the food value provided by animals with heavy shells (e.g., foraminiferans, bivalves, gastropods). This error is very difficult to account for, thus many feeding studies suggest caution when considering the proportional biomass of these prey taxa.

An error we view with greater concern is that the state of prey digestion was not consistent among predators; some samples appeared to be in good shape, but many were at an advanced state of digestion. For Phase I preliminary analyses, we used measured weights of prey >0.1 mg and average zooplankton weights of taxa (Chris Stark, IMS/SFOS, pers. comm.) where individuals <0.1 mg. The imprecision of using an average biomass to represent the weight of larger prey taxa increases with the size of the individual prey. For example, using an average weight for all Pandalid shrimps would be inappropriate since shrimp weight may change by a factor of 100 depending on size of the shrimp. We considered developing length/weight regressions for prey taxa during Phase II, to try to minimize this type of error. We determined it would not be appropriate to attempt this for polychaetes and mollusks, since the polychaetes eaten were generally not whole, and mollusk soft tissue weights are much less than shell weights. However, length/weight relationships would be appropriate for crustaceans, which comprised the majority of the prey consumed by flathead sole. Crustaceans have a chitinous exoskeleton, and thus we would not expect crustaceans to shrink appreciably while in the stomach, although that is sometimes the case for prey eaten by larger animals. Lengths could be measured of Phase I and Phase II crustacean prey taxa, and length/weight regressions could be created using three possible data sources available at IMS/SFOS/UAF. A length/weight regression on 10–20 specimens in each prey taxon, of similar size to those eaten by flathead sole or rock sole, should be sufficient. We estimated our best source of animals for length/weight regressions would be the benthos samples collected concurrently with the fishes used in this project. A subsample of 11 (of a total of approximately 200) benthos samples was sorted to gather information for use in length/weight regressions of prey taxa. Only 6 individual crustaceans of taxa consumed by flathead sole were found in those 11 benthic samples. We determined that gathering data to produce length/weight relationships for crustacean taxa (e.g., via this method) would require too much time to be completed during the time-frame of Phases I and II of this project.

We performed the following preliminary analyses based on prey biomass. Data transformations and statistical tests were done with Statistica software (StatSoft, 1995), with the exception of power analyses, which was done with SigmaStat software (Jandal Scientific, 1994). Square-root and natural log transformed biomass data were used to produce Bray-Curtis dissimilarity matrices. Each Bray-Curtis dissimilarity matrix was processed via non-metric multidimensional scaling (NMDS) to produce two-dimensional axes then used as variables for further analysis. The transformation of biomass data via square-root transformations was compared with *ln*+1 transformations to determine which transformation resulted in lower stress of NMDS results. The square root transformed data provided only slightly better results using NMDS. Statistical tests were performed on NMDS results to test for significant differences between diets of predators collected on different habitats, where habitat is defined as the particular season, depth or substrate type where the fish was captured. One-way analysis of variance (ANOVA) tested for differences of flathead sole diets over 3 seasons (winter, spring, and summer), 3 depths (<40 m, 40–80 m, and >80 m), and 3 fish sizes (small, medium, and large). A t-test tested the statistical difference between diets in 2 substrate categories (>50% mud and <50% mud).

Preliminary analyses led us to determine the Phase I data set was inappropriate for the statistical tests originally proposed, i.e., NMDS, principal components analysis (PCA), ANOVA, and t-test. For reasons explained previously, the accuracy and precision of the prey biomass data upon which these tests were based were questionable. Each flathead sole sampled in Phase I consumed only one or a few prey taxa, yielding data matrices of predator by prey which were comprised of only a few non-zero data points per predator. The data matrix of predator by prey contained so few non-zero data (i.e., the data were sparse) that calculation of an ecologically meaningful similarity matrix was not possible and non-metric multidimensional scaling was not able to produce meaningful results. Principal components analysis was not applicable to these data due to technical constraints, i.e., PCA requires a data set to contain more variables (columns) than cases (rows). Generally in the Phase I data set, there were fewer prey species identified (the variables) than predators examined (the cases), and therefore PCA was not used. The sparseness of the data set also precluded comparisons between habitat categories based on means (e.g., ANOVA) or ranks (e.g., non-parametric ANOVA) for the different prey categories for the methods proposed.

Subsequent to the preliminary statistical analysis, the Phase I data were converted to presence/absence data and a logistic model was applied. Presence/absence data consisted of the counts of times a prey taxon was present (≥ 1 was identified) or absent within a predator stomach. Logistic analyses used the procedure CATMOD in SAS (SAS Institute, 1989; Stokes et al., 1995), which accepts categorical explanatory variables, and provides results analogous to performing an ANOVA comparison using linear regression and dummy variables. CATMOD compares the counts of a prey taxon among habitats, where total counts for the taxon are >4 for each habitat. This choice is extremely liberal for χ^2 tests but was made due to the exploratory nature of this preliminary analysis. One requirement for valid χ^2 tests is that most of the cells in the data set contain counts ≥ 5 (i.e., 5 or more predators consumed the prey taxon within the habitat). This requirement was not met for many of the prey taxa, and therefore, the results cannot be taken to be exact since the χ^2 statistic may only be an approximation. Additionally, in a number of cases, zero values occurred. Statistically, it is acceptable to add a constant (e.g., 0.5) to the zero values. However, the preliminary comparisons presented here were run without the addition of a constant to the data.

Power analyses were proposed to determine sample size necessary to achieve statistically valid results using biomass data. The power analyses we envisioned are standard for parametric tests, but not for the χ^2 tests the data required. Power analyses for these χ^2 tests require simulations based on choosing hypothetical values for individual cell probabilities (Agresti, 1990). Since there were a number of comparisons where the criterion of a count of ≥ 5 was not met, we do not feel comfortable using the observed data to choose the hypothetical values on which to base power calculations. Simulations to approximate the power of these tests would have been more appropriate if the criterion of counts ≥ 5 had been met, as we would have a more accurate understanding of the relative frequencies of prey in stomachs.

A number of comparisons of prey could not be made due to zero values. Some of these prey items were consumed in low frequencies in all habitats (e.g., Ostracoda and Isopoda), and may represent less preferred items. In other cases, such as that of Polychaeta in the seasonal comparison, a larger sample size would probably result in sufficient data in all cells.

The 30 predators randomly selected for seasonal diet examination had consumed prey from 11 of the 13 taxa eaten by the 80 fish examined in the entire Phase I study. The predators selected for seasonal analysis had not consumed foraminiferans or crabs. The sparseness of the data created difficulty in making statistically-based conclusions on seasonal dietary differences. Only Copepoda and Gammaridae had enough numbers in each cell to allow calculation of χ^2, and no difference was determined for these two prey taxa. However, as these cells all contained <5, we cannot place much confidence in these results. All other prey taxa had zero values for the taxon during at least one season. Using the small sample size of 10 predators for each of 3 seasons, it was not possible to determine if these zeros were valid, i.e., the prey taxon was actually not eaten in certain seasons, or if they were an artifact of the small sample size. For example, Mysidacea had filled cells in summer and winter but a zero value in spring; this may or may not indicate mysids are not consumed in spring.

Unlike the seasonal data, there are fewer zero values in the depth analysis, thus allowing statistical comparisons of 8 prey taxa. Of these comparison only 2 (Mysidacea, $\chi^2=0.15$, $p=0.926$ and shrimp, $\chi^2=8.36$, $p=0.015$) satisfy the criteria of 5 or more observations per cell. Based on these results, we conclude that flathead sole consumed mysids equally at all depth strata, but that shrimp were consumed in higher quantities at depth >80 m. At a lower significance level ($\alpha=0.10$), Gammaridae were consumed more where depth <40 m, though we expect the χ^2 and probability values associated with Gammaridae may change with a larger N of fish examined, since one cell contains <5 observations. There may be a pattern of fewer polychaetes eaten at depth <40 m. The χ^2 value (4.26) for polychaetes is marginally probable ($p=0.119$), but is compromised by the value of 1 in depth <40m. The non-significant results for Bivalvia, Copepoda, Crab, and Euphausiacea may likely be valid, although as all taxa have cells with <5 observations, a larger N is needed for statistically defensible results.

Comparisons of diets by substrate were based on a larger number of samples and thus have fewer zero cells (N=5) than season (N=14) or depth (N=8) comparisons. Of the seven statistical comparisons that could be made, only Copepoda was significant (χ^2=3.75, p=0.053). This result must be viewed with caution as one cell contained <5 observations. Shrimp had an adequate number of observations per cell and yielded marginal results (χ^2=1.74, p=0.187). With a larger N, these results could become more conclusive. Comparisons of four other prey taxa (polychaetes, mysids, gammarid amphipods, euphausiaceans) which had sufficient observations per cell showed no statistical differences in prey consumed over the two substrate categories. Counts of predators which consumed bivalves over the two substrate categories did not appear significantly different, although one cell had <5 observations.

Fish examined during Phase I were limited to flathead sole <200 mm total length. The actual size range of the 80 predators used to analyze diet by season, depth or substrate was 28–165 mm total length. For analysis of diet by fish size, predators were divided into three approximately equal groups of 26–27 fish. These groups of small, medium, and large flathead sole approximated the lengths of age-0, age-1, and age-≥2 flathead sole reported by Abookire (1997).

Comparisons of diet by size of fish contained seven zero values: unfortunately the distribution of these zero values across prey taxa allowed only six χ^2 calculations. Two prey taxa (Copepoda and shrimp) are significantly different (α=0.05) among fish of different sizes, though both taxa contain one cell with <5 observations and thus must be viewed with caution. Mysidacea yielded marginal results, though it has adequate numbers in each cell (χ^2=3.69, p=0.158). Gammaridae and Polychaeta are not significantly different, although cells are filled adequately. Bivalvia are not significantly different, and one cell had <5 observations.

Valuable descriptive information on feeding versus habitat can be gathered from the Phase I data, but the sample size (N=80 predators) is very small for a diet study. There is sufficient statistical evidence from the few data collected during Phase I to indicate that flathead sole diets vary among the habitats examined. However, our confidence in these statistical tests would be much higher if the data fit the statistical requirement that all cell counts are ≥5.

Recommendations for Further Study

Although Phase I analysis has clarified that a data set of flathead sole diets cannot be examined using the statistical methods (NMDS, PCA, ANOVA, and t-test) described in the proposal for this project (Second Amendment, dated 4 September 1997), this does not preclude those analyses being appropriate for rock sole diets. Based on the diets of rock sole around Kodiak (Holladay and Norcross, 1995b), we expect the Kachemak Bay data set of rock sole diets to be less sparse than that of flathead sole diets. Prior to laboratory analysis of rock sole stomach contents, it is not possible to evaluate whether rock sole diets will be sufficiently robust to examine via the methods proposed. Logistic analyses as were used on Phase I data will be applied to both flathead sole and rock sole data from the combined Phases I and II, and if the rock sole data set is sufficiently robust, additional tests will be applied (e.g., NMDS, PCA, ANOVA, and t-test). Similarity indices will be calculated between diets of each pair of categories within a habitat parameter (e.g., for each species, diet similarity will be computed for winter vs. spring, winter vs. summer, and spring vs. summer).

The logistic model applied to Phase I data uses a χ^2 statistic to assess goodness of fit of the data to the model. One of the accepted constraints of a χ^2 statistic is that most cells of the data matrix should have a count of 5 or more. The failure of many of the Phase I comparisons to converge is most likely due to the failure of the data to meet this requirement. Extrapolation of Phase I data suggests that at least 40 but less than 100 predators within each habitat category would be necessary to achieve counts of ≥ 5 in each important prey taxon. We propose to maintain a balanced sample design, by examining a minimum of 40 additional flathead sole predators in each of three seasons (regardless of depth or substrate), 30 additional flathead sole in each of three depth categories, and 20 additional flathead sole within each of two substrate categories. This design provides for examination of flathead sole: at least 50 predators per season, 50 predators per depth (during summer), and 50 predators per substrate (during summer). Because of remaining sample distribution among habitat parameters, this is likely to amount to examining 200 additional flathead sole predators. We propose to initially examine 30 rock sole within each of 3 seasons, each of 3 depth ranges (within summer), and each of 2 substrate ranges (within summer). Based on our previous diet analysis of rock sole and flathead sole near Kodiak Island (Holladay and Norcross, 1995b), we expect the predator by prey data matrix for rock sole diets to be more robust than that for flathead sole, and therefore we think it likely that the logistic model we applied to Phase I flathead sole data will require fewer samples for rock sole diets than are necessary for the flathead sole prey data matrix. After these initial samples of rock sole are examined, we will determine whether the count ≥ 5 criterion is met within each category, and if necessary and fish are available, additional rock sole will be examined to meet the criterion. Based on budget and time constraints, we estimate we will need to limit the number of predators examined of each species to a maximum of 50 per habitat category. We estimate that sufficient numbers of fish are available to provide for the proposed Phase II laboratory analyses of flathead sole and rock sole. Because fishes were subsampled in the field and an unknown number of fishes will have empty stomachs, we cannot guarantee any number of predators within a habitat category.

As in Phase I, rather than confine the subsample of available specimens by size increment of fish, we will disregard fish size during sample selection. After completing laboratory analyses, we will evaluate the diets of each species based on fish size, using 3–4 fish size categories with a balanced N of predators among the categories.

We propose to continue identifying and counting prey as in Phase I, but to omit measuring prey biomass during Phase II. If prey biomass data collected during Phase I had provided a better representation of the amount of food provided the predator, the use of prey biomass as the index of diet would allow stronger statistical analyses than would be appropriate with other measures of diet (e.g., presence/absence of prey, number of prey consumed). However, we estimated critical errors in the prey biomass data collected in Phase I, and therefore we propose limiting Phase II to analyses that can be performed on prey count data.

Identification of prey to a specific taxonomic level allows calculations of a meaningful similarity index (e.g., Bray-Curtis dissimilarity) between diets in different habitat categories or between two species occupying the same site. In the expanded study, we plan to use the most specific prey identifications practical for laboratory analysis to calculate similarity indices between diets in different habitats. Similarity indices can be an extremely useful descriptive tool to help relate statistical analyses to the biological relevance of dietary differences. Similarity indices were not presented in this preliminary report because we could not draw valid comparisons based on the small sample sizes examined during Phase I.

We expect the combined Phase I and Phase II data to provide results that will advance scientific understanding of the ecosystem in Cook Inlet and Alaska. Analysis of seasonal diet has not been published for Alaskan flatfishes of the sizes we will examine. The distribution and abundance of juvenile flathead sole and rock sole in Kachemak Bay have been thoroughly examined with respect to season, depth, and substrate (Abookire, 1997; Abookire and Norcross, 1998; Norcross et al., 1998). This project will add a critical biological component that may help explain the variation in the abundance and distribution of these species that is not accounted for by season or physical parameters.

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Subsistence Economies and North Slope Oil Development

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Abstract

This is a study of the mixed, subsistence-cash economies of Nuiqsut and Kaktovik, two Inupiat villages located near areas that are impacted by petroleum exploration and development on the North Slope. In order to assess the continuity and change in subsistence and wage employment activities of households, we analyze comprehensive quantitative data sets on subsistence production and distribution and employment by households, collected over the past decade. The analysis tested for relationships between short-term changes in subsistence and other employment patterns in response to conditions in the natural, social, and economic environments. Additional materials were collected through key respondent interviews in Nuiqsut and Kaktovik to augment and help interpret the statistical findings. We provide information to assess the potential impacts of petroleum development on the subsistence and wage employment activities of households.

Study products:

Pedersen, S., R. Caulfield and R. Wolfe.1998. Subsistence Economies and North Slope Oil Development. CMI annual research review, Fairbanks, February.

Pedersen, S., R. Caulfield and R. Wolfe.1998. Subsistence Economies and North Slope Oil Development. Seminar at MMS offices, Anchorage.

Wind Field Representations and Their Effect on Shelf Circulation Models: A Case Study in the Chukchi Sea

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Abstract

Arctic pollutant transport models use forcing by winds estimated from atmospheric forecasts of the surface pressure field. There are uncertainties inherent in these forecast pressure fields that lead to errors in the surface winds and the circulation models dependent upon these winds. We investigate the differences among three nominally identical wind field representations derived from surface atmospheric pressure fields prepared by:

1) the European Center for Medium Weather Range Forecasting (ECMWF),

2) the U.S. Navy's Fleet Numerical Oceanography Center (FNOC), and

3) the National Center for Atmospheric Research.

We analyzed:

1) wind and surface atmospheric pressure data from the National Weather Service (Barrow and Kotzebue, Alaska, offices) to examine differences between observed and estimated winds;

2) ice-drifting buoy data from the International Arctic Buoy Program to examine differences between observed and interpolated surface atmospheric pressure, and to examine differences between observed and simulated ice drift;

3) the differences in shelf circulation as predicted by barotropic shelf circulation models (2D and 3D) when forced by these three wind fields

This study demonstrates that the ECMWF sea level atmospheric pressure data with a spatial resolution of 1.125 degree and a temporary resolution of 6 hours can be recommended as a source for wind forcing data. The FNOC atmospheric pressure fields with a spatial resolution of 2.5 degrees and a temporal resolution of 6 hours can be

recommended as well, in the absence of ECMWF data. NCAR data with a spatial resolution of about 350 km and a temporal resolution of 12 hours can be successfully used for climatological simulations.

Study products:

Proshutinsky, A. (presented by T. Weingartner). 1998. Wind field representations and their effect on shelf circulation models: A case study in the Chukchi Sea. CMI annual research review, Fairbanks, February.

Proshutinsky, A. 1998. Wind field representations and their effect on shelf circulation models: A case study in the Chukchi Sea. Seminar at MMS offices, Anchorage, March.

Proshutinsky, T., A. Proshutinsky and T. Weingartner. 1998. Numerical modeling of seasonal and interannual variability of the Chukchi Sea circulation. Poster OS51-A4 at AGU Spring Meeting, May 26-29. Boston,MA. Abstract published as a supplement to EOS, April 28, 1998, p. S183.

Interaction between Marine Humic Matter and Polycyclic Aromatic Hydrocarbons in Lower Cook Inlet and Port Valdez, Alaska

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Abstract

Humic acid is a major component of naturally occurring organic matter; it interacts strongly with organic pollutants including polycyclic aromatic hydrocarbons (PAH), a class of organic pollutants present in petroleum and associated with significant long-term environmental and human health problems. The chemical associations resulting from the interaction between humic acid and PAH influence the fate and effects of PAH which are of great concern in coastal regions such as Cook Inlet, Alaska, where petroleum production and transportation coexist with renewable resources and environmental values. Better understanding of biogeochemical processes that influence the degradation and bioavailability of petroleum can lead to improvements in environmental management for such systems.

This project investigated the interaction of PAH and marine humic acid from sediments of Lower Cook Inlet and Port Valdez, Alaska, in an attempt to understand how and to what extent the molecular character of humic acid from these sediments influences their ability to adsorb PAH. Geochemical characterization of sediments and humic acids from the study area showed that their chemical composition is non-uniform, probably reflecting differences in both source materials and post-depositional alterations. This result indicates that the measured concentrations of PAH are largely unrelated to the properties of the humic acid from the same sediments. It is more likely that the amounts of PAH to which the sediments are exposed control observed concentrations. Experiments which measured the ability of humic acid extracted from these sediments to adsorb phenanthrene showed marked differences among sediments. Humic acid from subtidal sediments showed a greater tendency to adsorb phenanthrene than did humic acid from intertidal sediments.

Based on this study and the CMI-sponsored studies of J. F. Braddock and S. M. Henrichs, it appears likely that humic acid is involved in the adsorption of PAH in sediments of Lower Cook Inlet and Port Valdez, Alaska. The variability of adsorption and its implications for corresponding variability in bioavailability suggest that management tools (e.g., ecotoxicological models) that depend on a single value for adsorption of PAH by marine sediments should be used with caution.

Study Products

Shaw, D. G. 1995. Interaction between marine humic matter and polycyclic aromatic hydrocarbons in Lower Cook Inlet and Port Valdez, Alaska. Abstract for the U.S. Department of the Interior, Minerals Management Service, Alaska OCS Region, Anchorage, Alaska, 1 p.

Shaw, D. G. 1998. Interaction between marine humic matter and polycyclic aromatic hydrocarbons in Lower Cook Inlet and Port Valdez, Alaska. Oral presentation to MMS Anchorage office, 28 October.

Shaw, D. G. and J. Terschak. 1996. Interaction Between Marine Humic Matter and Polycyclic Aromatic Hydrocarbons in Lower Cook Inlet and Port Valdez, Alaska. Annual Report for the U.S. Department of the Interior, Minerals Management Service, Alaska OCS Region, Anchorage, Alaska, 8 pp.

Shaw, D. G. and J. Terschak. 1997. Interaction Between Marine Humic Matter and Polycyclic Aromatic Hydrocarbons in Lower Cook Inlet and Port Valdez, Alaska. Annual Report for the U.S. Department of the Interior, Minerals Management Service, Alaska OCS Region, Anchorage, Alaska, 16 pp.

Shaw, D. G. and J. Terschak. 1998. Interaction between marine humic matter and polycyclic aromatic hydrocarbons in Lower Cook Inlet and Port Valdez, Alaska. Poster presentation to the Cook Inlet Symposium, Anchorage, Alaska, 30 October.

Shaw, D. G. and J. Terschak. 1998. Interaction Between Marine Humic Matter and Polycyclic Aromatic Hydrocarbons in Lower Cook Inlet and Port Valdez, Alaska. Final Report for the U.S. Department of the Interior, Minerals Management Service, Alaska OCS Region, Anchorage, Alaska. 27 pp.

Terschak, J. 1998. Interaction Between Marine Humic Matter and Polycyclic Aromatic Hydrocarbons in Lower Cook Inlet and Port Valdez, Alaska. Thesis, in preparation, University of Alaska Fairbanks.

New Projects

Five new projects are being funded this federal fiscal year along with the ongoing projects reported above. Abstracts are presented here to show the full range of work being supported by the University of Alaska Coastal Marine Institute.

The Alaskan Frozen Tissue Collection and Associated Electronic Database: A Resource for Marine Biotechnology

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Abstract

With prior CMI support, the Alaska Frozen Tissue Collection (AFTC) has become the primary regional archive for frozen zoological samples and a major contributor to biotechnology studies of the North Pacific and Arctic oceans. It is now the world's third largest frozen tissue collection for wild mammals. The increasingly powerful tools of biotechnology and the in creasing need to monitor perturbation of the environment are accelerating both collection growth and usage. We are acquiring new material from statewide sources and loaning more material than ever worldwide.

The AFTC coordinator, a half-time graduate assistantship created with CMI funds, will become a state-funded position this year. Because of the dramatic growth in collection size and usage, the demands on this position are now excessive. The objective of this project is to support the expanding demands on the Collection by creating an additional position of AFTC Subsistence Coordinator, a graduate assistantship specifically dedicated to handling material from subsistence hunting of marine mammals.

This renewed support from CMI will do three things 1) continue to expand the scope of the collection by recruiting contributions of marine mammal, bird, fish, and invertebrate specimens from Cook Inlet, Shelikof Strait, and the Beaufort and Chukchi seas, especially those from subsistence hunters of marine mammals;2) allow development of our methods of tracking specimen usage and the scientific results of this usage; and 3)secure the new position of AFTC Subsistence Coordinator as a second permanent state-funded position, thus insuring a broad, long-term, systematic record of marine populations in Alaska.

Correction Factor for Ringed Seal Surveys in Northern Alaska

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Abstract

The utility of aerial surveys to monitor trends in the distribution and density of ringed seals in the Alaskan Beaufort Sea has been severely limited by unknown year-to-year variation in numbers of seals visible to aerial observers. The haulout behavior and movement patterns of ringed seals will be quantitatively related to aerial surveys sponsored by the Minerals Management Service (in cooperation with the Alaska Department of Fish and Game), the National Marine Fisheries Service, and the oil and gas industry. In conjunction with surveys by the National Marine Fisheries Service in the Beaufort Sea in 1999 and 2000, we propose to conduct on-ice studies using radio telemetry and direct observations to determine seal behavior relative to the sex, age, reproductive status, and stage of molt of individuals as well as weather, ice conditions, and predation threat. A correction factor for the proportion of the population that is not visible, and therefore not counted during aerial surveys, and a coefficient of variation of that correction factor, will be calculated.

Sediments, Beaufort Sea: Prior and Subsequent to Petroleum-Related Industrial Developments — Phase II

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Abstract

This is a continuation of a previous study (see this volume. The additional funding will allow analysis of additional samples of sediments from the nearshore area of the Alaskan Beaufort Sea.

Feeding Ecology of Maturing Sockeye Salmon (*Oncorhynchus nerka*) in Nearshore Waters of the Kodiak Archipelago

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Abstract

The Kodiak commercial salmon fishing area (average sockeye harvest of 4.5 million fish, worth 27.5 million dollars annually since 1991) is comprised of Alaska statute waters. An array of research efforts has focused on the feeding ecology of juvenile sockeye salmon in freshwater and immature sockeye salmon in offshore Gulf of Alaska waters. However, we see a lack of research concerning the age at which mature sockeye salmon cease feeding within freshwater or marine environments, and regarding the feeding ecology of maturing fish in nearshore areas.

As demands for additional commercial fisheries opportunities increase, forage species may be sought after by industry. It is imperative that biologists examine the role of forage species as a part of the food energy requirements of the present target species. Also important is understanding the potential impacts nearshore development may have on these prey species – hence the coupling of this research with the Minerals management Service. They North Shelikof Strait oil and gas lease area is known to be both a migration corridor and a foraging area for Kodiak's Pacific salmon.

During 1994, a majority (63%) of sockeye salmon sampled from Kodiak waters were shown to be feeding while in late July incidence of feeding was sharply reduced (24%). Both time and area effects on feeding prevalence and dietary content were found to be significant. We propose conducting an intensive study of feeding prevalence and dietary content of sockeye salmon harvested from five Kodiak Archipelago locations.

Circulation, Thermohaline Structure, and Cross-Shelf Transport in the Alaskan Beaufort Sea

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Abstract

I propose to obtain time-series measurements of current and water properties from moored instruments deployed along the outer shelf and slope of the Alaskan Beaufort Sea for a period of one year. My goals are to: 1) quantify the vertical and cross-shore spatial and temporal scales of variability in the circulation and the density (thermohaline) field in this region, and 2) estimate the transport within the eastward flowing subsurface undercurrent. The flow and the density structure on the outer shelf and slope affect the cross-shelf transfer of momentum, water properties (hear, salt, nutrients, etc.), contaminants, and pollutants. The region is also an important migratory corridor for marine mammals, particularly bowhead whales, which feed there during part of the year. On average, the near-surface flow (<~50 m depth) here, and over the inner shelf, is westward and forced by the winds. However, flow reversals are common and often a result of upwelling of the undercurrent. Further, the pressure field responsible for the undercurrent must influence the dynamics of the inner shelf. The undercurrent originates in the eastern Arctic as a result of inflow through Fram Strait and is fed by outflows from the Eurasian shelf seas. Hence it is circumpolar in its extent and in its water properties. It could thus transport pollutants from these regions to the Alaskan shelf. The proposed observations will provide information crucial in guiding model development and evaluating the performance of pollution transport models. The study site is practical (from the resource manager's perspective and for logistical reasons), and optimal from a scientific perspective because measurements here will capture the integrated effects of the circumpolar forcing which we believe accelerate the undercurrent.

Funding Summary

Student Support

The cooperative agreement that formed the University of Alaska Coastal Marine Institute (CMI) stressed the need to support education as well as research. The following student support information is summarized from proposals and may not accurately reflect actual expenditures:

	Funds from MMS	Match from other sources
Fiscal Year 94		
7 Master Students	$ 67,000	$ 37,400
2 Doctoral Students	23,000	9,200
Source Totals	$ 90,000	$ 46,600
Fiscal Year 95		
7 Master Students	$ 115,400	$ 57,200
4 Doctoral Students	59,600	12,800
Source Totals	$ 175,000	$ 70,000
Fiscal Year 96		
10 Master Students	$ 133,000	$ 31,800
1 Doctoral Student	4,000	0
Source Totals	$ 137,000	$ 31,800
Fiscal Year 97		
4 Master Students	$ 76,700	0
1 Doctoral Student	0	$ 21,500
Undeclared or Undergrad	3,900	0
Source Totals	$ 80,600	$ 21,500
Fiscal Year 98		
1 Master Students	$ 10,560	$ 0
2 Doctoral Student	27,240	0
2 Undeclared or Undergrad	2,610	0
Source Totals	$ 40,410	$ 0
Totals to date	$ 523,010	$ 169,900

These figures show a strong commitment to graduate student education by MMS through CMI. Approximately 13% of the funding provided by MMS has gone directly to support students involved in coastal and OCS-related research in Alaska.

Total CMI Funding

The total MMS funding available for funding CMI projects through federal fiscal year 1998 is approximately $5 million. Since all CMI-funded projects require a one-to-one match with non-federal monies, project commitments through fiscal year 1998 have totaled approximately $10 million.

Sources of Matching Funds

Matching for CMI-funded projects has come from a wide variety of sources. Identifying and verifying match remains a major administrative challenge in the development of CMI proposals. In general, match has been available to those investigators who expend the necessary extra effort to locate and secure the support. The following partial list of matching support participants demonstrates the breadth of support for CMI-funded programs:

Afognak Native Corporation
Alaska Department of Fish and Game (ADF&G)
Alyeska Pipeline Service Company
Ben A. Thomas Logging Camp
British Petroleum Exploration (BPX)
College of Natural Sciences, University of Alaska Fairbanks (UAF)
Institute of Arctic Biology, UAF
Institute of Marine Science, UAF
Japanese Marine Science and Technology Center (JAMSTEC)
Kodiak Island Borough
North Slope Borough
UAF Equipment Fund
University of Alaska Museum, UAF
University of Northern Iowa
Water Research Center, UAF

Some of the CMI-funded projects are closely related to other federally funded projects which cannot be considered as match but nevertheless augment and expand the value of a CMI project. Related projects have been funded by the National Science Foundation (NSF), the Office of Naval Research (ONR), the National Aeronautics and Space Administration (NASA), the National Marine Fisheries Service (NMFS), the National Oceanographic and Atmospheric Administration (NOAA), and Alaska Sea Grant.

A positive relationship has been fostered between MMS, the University of Alaska, and the State of Alaska since the formation of CMI. Residents of Alaska, as well as the parties to the agreement, benefit from the cooperative research that has been and continues to be funded through CMI.

University of Alaska CMI Publications

These publications are available from the CMI until supplies are exhausted, and will soon be available for downloading or viewing on the World Wide Web. Those marked with an asterisk are no longer available in hard copy from CMI.

* Alexander, V. (dir.). 1995. University of Alaska Coastal Marine Institute **Annual Report No. 1**. University of Alaska Fairbanks..

Alexander, V. (dir.). 1996. University of Alaska Coastal Marine Institute **Annual Report No. 2**, OCS Study MMS 95-0057. University of Alaska Fairbanks. 122 pp.

Alexander, V. (dir.). 1997. University of Alaska Coastal Marine Institute **Annual Report No. 3**, OCS Study MMS 97-0001. University of Alaska Fairbanks. 191 pp.

* Alexander, V. (dir.). 1998. University of Alaska Coastal Marine Institute **Annual Report No. 4**, OCS Study MMS 98-0005. University of Alaska Fairbanks. 81 pp.

Braddock, J. F. 1998. **Microbial Degradation of Aromatic Hydrocarbons in Marine Sediments**. Final Report. OCS Study MMS 97-0041. Coastal Marine Institute, University of Alaska, Fairbanks. 82 pp.

Duffy, L. K., R. T. Bowyer, D. D. Roby and J. B. Faro. 1998**. Intertidal Effects of Pollution: Assessment of Top-trophic Level Predators as Bioindicators.** Final Report. OCS Study MMS 97-0008. Coastal Marine Institute, University of Alaska, Fairbanks. 62 pp.

Henrichs, S. 1997. **A Study of the Adsorption of Aromatic Hydrocarbons by Marine Sediments**. Final Report. OCS Study MMS 97-0002. Coastal Marine Institute, University of Alaska, Fairbanks. 47 pp.

Kline, T. C. and J. J. Goering. 1998. **North Slope Amphidromy Assessment**. Final Report. OCS Study MMS 98-0006. Coastal Marine Institute, University of Alaska, Fairbanks. 25 pp.

Norcross, B. L. 1998. **Defining Habitats for Juvenile groundfishes in Southcentral Alaska. Vol. 1**. Final Report. OCS Study MMS 97-0046. Coastal Marine Institute, University of Alaska, Fairbanks. 131 pp.

* Norcross, B. L. 1998. **Defining Habitats for Juvenile groundfishes in Southcentral Alaska. Vol. 2**. Final Report. OCS Study MMS 97-0046. Coastal Marine Institute, University of Alaska, Fairbanks. 131 pp.

Shaw, D. G. 1998. **Interaction between Marine Humic Matter and Polycyclic Hydrocarbons in Lower Cook Inlet and Port Valdez, Alaska**. Final Report. OCS Study MMS 98-0033. Coastal Marine Institute, University of Alaska, Fairbanks. 27 pp.

Schell, D. M. 1998. **Testing Conceptual Models of Marine Mammal Trophic Dynamics Using Carbon and Nitrogen Stable Isotope Ratios**. Final Report. OCS Study MMS 98-0031. Coastal Marine Institute, University of Alaska, Fairbanks. 137 pp.

Weingartner, T. J. 1998. **Circulation on the North Central Chukchi Sea Shelf.** Final Report. OCS Study MMS 98-0026. Coastal Marine Institute, University of Alaska, Fairbanks. 39 pp.

Weingartner, T. J. and T. Proshutinsky. 1998. **Modeling the Circulation on the Chukchi Sea Shelf.** Final Report. OCS Study MMS 98-0017. Coastal Marine Institute, University of Alaska, Fairbanks. 75 pp.