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University of Alaska Coastal Marine Institute

IN COOPERATION

Minerals Management Service

University of Alaska

State of Alaska

Annual Report

Federal Fiscal Year 2000

SUBMITTED BY

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Director

University of Alaska Coastal Marine Institute

TO

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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, with the first full funding cycle beginning late in (federal) fiscal year 1994. CMI is pleased to present this 2000 Annual Report, our seventh annual report. Of the 17 research projects covered, four have been completed and principal investigators are preparing their final reports. Only abstracts and study products are included for these projects. Abstracts for the three proposals funded in FY2000 are in the New Projects section.

The Minerals Management Service 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 that 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 (e.g., 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 & 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 & 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. Scientific 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 & 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 potential environmental effects of resource development activities in arctic and subarctic environments.

Initial guidelines given to prospective researchers identified Cook Inlet and Shelikof Strait, as well as the Beaufort and Chukchi seas, as areas of chief 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 in Cook Inlet and Shelikof Strait remains.

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 publicized and sent to researchers at the University of Alaska and to various state agencies, and to relevant profit and non-profit corporations. 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 report their findings at the CMI's annual research review, 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 problems other than 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, and potential economic and social impacts as well.

Kachemak Bay Experimental and Monitoring Studies: Recruitment, Succession, and Recovery in Seasonally Disturbed Rocky-Intertidal Habitat

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Task Order 11982

Abstract

The purpose of this study was to establish a multi-year sampling program in rocky-intertidal assemblages of outer Kachemak Bay and to assess recruitment and successional patterns leading to recovery of selected intertidal species and the intertidal community after seasonal disturbances. The specific objectives were to:

1. *Determine whether the season in which a disturbance takes place affects recovery rates or succession processes.*
2. *Quantify inter- and intra-annual abundance patterns for major species.*
3. *Determine the effect of wave exposure on community structure and response to seasonal disturbances.*

The study was initiated in response to questions raised during injury assessment studies following the Exxon Valdez *oil spill [Highsmith et al. 1994]. Several organisms showed increased numbers or percent cover in oiled compared to unoiled rocky-intertidal habitat. Data were not available to determine if these increases were correlated with the time of year that space had become available, due either to the oil or to subsequent clean-up activities, and thus reflecting timing of reproduction or recruitment for some species but not others. The responses of the various invertebrates and algae to the oil spill differed by species, tidal height, region, habitat, and wave exposure as reflected by increases, decreases, or no change to abundance, biomass, or percent cover. Rates of recovery, or convergence with control sites, also differed among the numerous taxa and depended upon the above variables. Another question raised was whether there were inherent differences between oiled and control sites, based on the prevailing currents that carried oil to the impacted sites. A lack of pre-spill intertidal data necessitated the comparison of oiled shorelines to unoiled control beaches for all of the intertidal injury and restoration studies [Gilfillan et al. 1993; Houghton et al. 1993; Highsmith et al. 1994]. With data for the major space-occupying species, Highsmith et al. [1994] used the multi-dimensional scaling (MDS) method to evaluate recovery of invertebrate and algal communities on rocky substrates. Their results showed that site exposure to waves explained the ordinations and the oiling category did not. Kachemak Bay rocky-*

intertidal communities have been generally surveyed and have some similarities to lower-latitude west coast communities that have been more intensively studied. However, extrapolation of the lower-latitude results to southcentral Alaska is not appropriate, as certain key intertidal species are not present or occur in very low abundances in Kachemak Bay. In Alaska, physical extremes such as temperature and photoperiod are greater and many species are at their northern geographical limit. In fact, some of the major community-structuring species in the Pacific Northwest do not occur in the Kachemak Bay intertidal, e.g. Mytilus californianus, *or are in such low densities, e.g.* Pisaster ochraceus, *that they have little role in community dynamics. Studies in lower-latitude west coast areas have shown effects of season on population dynamics and recovery rates after disturbances in rocky intertidal habitat [Kinnetic Laboratories, Inc. 1992; Minerals Management Service 1995; Kim and DeWreede 1996]. In Alaska, seasonal effects may be a primary factor in determining recovery rates. Generally, information on inter- and intra-annual variability in Alaskan intertidal communities is lacking. The final report for this project contains results from a study in outer Kachemak Bay to provide multi-year data on rocky-intertidal assemblages and to assess recovery and successional patterns after seasonal disturbances.*

In this study, experimental disturbances in different seasons and over a range of wave exposures were used to assess recruitment and succession patterns during recovery in rocky-intertidal habitat sites. To simulate seasonal environmental disturbances, quadrats at three tidal heights at eight sites were cleared of all invertebrates and algae during March, July and October 1994, and March 1995. These dates were selected to provide potential settlement sites (bare rock) for organisms that recruit in different seasons. Undisturbed control quadrats were also established to provide data on inter- and intra-annual variability of dominant invertebrates and algae and for comparative statistical analyses of degree of recovery of disturbed plots. The eight study sites were selected to represent a range of wave exposures from highly-sheltered to frequently-impacted. Sites were surveyed, quadrats established and cleared, and subsequently monitored for organism abundance and/or percent cover. Sampling dates were July 1995, October 1995, June 1996 and September 1996. Data were analyzed using two main approaches. First, dominant or key invertebrates and algae were analyzed across time using repeated-measure ANOVAs to assess the effects of site and disturbance date. To assess recovery of the intertidal community, a multivariate technique, multi-dimensional scaling (MDS), was used. This method plots multi-species, multi-sample data sets on a two-dimensional graph such that the rank ordering of the sample distances agrees with the rank order of distances from a dissimilarity matrix. The ordination gives a visual representation of the similarity or dissimilarity of species composition between samples [Clark and Warwick 1994]. Ordination gradients were then used to evaluate the importance of environmental variables in recovery dynamics from the disturbance.

This study showed that time of disturbance relative to seasonal reproductive events of major space-occupying species affected the time required for recovery. Summer and fall disturbances took longer to recover from than spring disturbances because the latter occurred just prior to the peak of barnacle larval settlement. Therefore, early barnacle recruitment appears to be a critical element in recovery rates. Although this three-year study provides a data and knowledge base for continued work, this project was not long enough for all end-points to be reached. A primary recommendation is that long-term, i.e. 5–10 years, monitoring of experimentally disturbed sites is needed in Kachemak Bay in order to fully understand the specific events and time-course of recovery from seasonal disturbances.

In control quadrats, the community remained relatively stable throughout the study, although some intra-annual variability was detected due to life histories, such as in annual algae. The acorn barnacles Semibalanus balanoides *and* Balanus glandula *were the first to colonize the disturbed quadrats in the high- (1.5 meters of vertical drop [MVD] below mean higher high water) and mid- (2.5 MVD) intertidal zones, often with > 80% cover. Adult percent cover of these species remained above control quadrat levels at the end of the study, suggesting stability had not yet been achieved. The dominant alga in the mid- to upper-intertidal,* Fucus gardneri, *colonized disturbed plots only after the above barnacle species* *were established and had not returned to control levels at the end of the study except in quadrats that had 2.5 years to recover. A similar scenario occurred for the dominant algal and barnacle species in the low-intertidal (3.5 MVD). Recruitment of the kelp* Alaria fistulosa *followed recruitment by the barnacle* S. cariosus, *and neither had recovered to control levels by the end of the study. The blue mussel* M. trossulus, *which also appears to recruit in large numbers only after barnacles have become established, had not recovered by the end of the study and the data indicate that much longer than 2.5 years may be required for recovery at wave-exposed sites. Generally, recovery rates within quadrats scraped on different dates were driven by the seasonal timing of barnacle recruitment relative to the date of scraping (bare rock substrate availability).*

Multi-dimensional scaling showed 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. Quadrats scraped in July and October 1994 showed slower recovery rates than quadrats scraped in March 1994 or 1995. The dissimilarity of scraped quadrats compared to control quadrats was reduced between July 1995 and September 1996, suggesting community recovery was in progress but just not complete after 2.5 years. Although there were recruitment differences for some species between protected and exposed sites, wave-exposure as a matrix variable did not account for community-level differences in recovery.

Study Products

Kachemak Bay Algal Voucher Collection: stored at the University of Alaska Fairbanks Kasitsna Bay Laboratory.

Incorporation of the study sites from this CMI study into the NOAA HAZMAT intertidal program: "Epibiota sampling in Kachemak Bay", staffed/funded by Gary Shigenaka, NOAA HAZMAT and by Susan Saupe, Cook Inlet Regional Citizens Advisory Council.

Saupe, S.M., and R.C. Highsmith. 1995. Recruitment and succession after disturbances to the intertidal zone in outer Kachemak Bay, Alaska. Oral presentation at the University of Alaska Coastal Marine Institute Annual Research Review, February 1995, Fairbanks.

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Minerals Management Service. 1996. Mussel recovery and species dynamics at four California intertidal sites, 1992 data report. Prepared in association with Kinnetic Laboratories, Inc. for the U.S. Department of the Interior, Minerals Management Service, Pacific OCS Region. Contract No. PC 94-1. OCS Study MMS 96-0009.

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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Task Orders 14195 & 15167

Abstract

This was a two-year study (1997–99) of historical changes in concentrations of selected heavy metals in sediments of the Beaufort Sea nearshore, arctic Alaska—from Harrison Bay to the Canning River delta. The research involved the metals Fe, Mn, Cu, Cr, Ni, V, Pb, Zn, Cd, As and Ba in sediment mud fractions (< 62 μm), and concentrations in gross sediments of total Hg (THg) and methyl Hg (MeHg), saturated hydrocarbons (normal and isoprenoid alkanes, triterpenoids and steranes) and polycyclic aromatic hydrocarbons (PAHs). The primary purpose of the study was to ascertain if there were any significant increases in concentrations of the trace metals and hydrocarbons subsequent to the recent development of petroleum-related industrial activities. An additional purpose was to gain an understanding of the sources of hydrocarbons accumulated in the sediments in view of ongoing, as well as proposed, oil and gas developments in the region.

Time-series comparisons of mean concentrations of trace elements in muddy sediments of the Beaufort Sea nearshore, at approximately 10-year intervals (1977, 1986 and 1997), show significantly increased concentrations in V in 1986 and 1997 from the initial concentration measured in 1977, and in Ba from 1986 to 1997 accompanied by no changes in other elements. However, these findings are not reflected in the stratigraphic variations of the elements in two cores examined. The stratigraphy demonstrates a net significant decrease up-core in MeHg, Zn, Cd, and Pb accompanied by no significant change in concentrations of the other elements. The reasons for the increased concentrations in V and Ba are unknown, but petroleum-related activities are suspect. Despite increased concentrations in V and Ba detected during the past 30 years, the levels of these and other elements are below or comparable to those in unpolluted marine sediments.

Correlation coefficient analysis suggests that V, Cu, Ni, Zn, As and Mn are primarily chelated (with ligand formation) with organic matter, whereas some of the V is also adsorbed on the clays. Cluster analysis of the elemental data indicates the presence of two major station groups that are discriminated by differences in MeHg contents. These differences could have evolved from several factors, such as regional variations in natural terrestrial or industrial inputs of Hg, the methylation process, sediment granulometry, or all three.

The molecular markers investigated in the sediments are of mixed marine and terrigenous origin. Generally, the resolved n-*alkanes are less and the total PAHs more than those found by others in the same region a decade ago. The PAH assemblage in the surface sediments is different from that found in Prudhoe Bay crude oil but is very similar to that observed in coastal peat and North Slope fluvial sediments. The triterpenoid and sterane profiles reinforce the biogenic rather than the petrogenic origin of major portions of the hydrocarbon. Only in isolated cases is a petroleum signature documented by the presence of thermally mature hopanes and steranes in small amounts. The fingerprint of triterpanes/steranes rather than some internal ratio parameters in the current samples helps to clearly distinguish biogenic inputs from petrogenic sources. The composition of triterpenoids/steranes should serve as an important diagnostic tool in future monitoring studies that follow subtle changes in hydrocarbon inputs to the study region, especially from oil-related activities.*

In summary, the environment of the study area has remained clean as far as heavy metals and hydrocarbons are concerned in spite of the recent oil-related industrial activities. Results of our investigations should serve as a baseline for future monitoring of heavy metal and hydrocarbon contaminations within the study area.

Study Products

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Naidu, A.S., L.W. Cooper, B.P. Finney, R.W. MacDonald, C. Alexander and I.P. Semiletov. 2000. Organic carbon isotope ratios ($\delta^{13}C$) of Arctic Amerasian continental shelf sediments. Int. J. Earth Sci. In press.

(This paper was also presented as a poster display by Dr. Naidu at the NSF-sponsored workshop, “Arctic Coastal Dynamics”, held at the Woods Hole Oceanographic Institution, October 1999.)

Naidu, A.S., J.J. Goering and J.J. Kelley. 1998. Time-series monitoring of trace elements in nearshore sediments of the Alaskan Beaufort Sea. Proc.1998 ASLO/ESA Annual Meeting, St. Louis. p. A-63.

Naidu, A.S., J.J. Goering and J.J. Kelley. 1999. Three-decadal time-series monitoring of trace elements in nearshore sediments, Alaskan Beaufort Sea, p. 11 (abstract). *In* Proceedings Seventh MMS Information Transfer Meeting. Alaska OCS Region, Minerals Management Service, January 1999, Anchorage. (http://www.mms.gov/Alaska/ess/itm/itm99/itm.htm)

Naidu, A.S., J.J. Goering and J.J. Kelley. 1999. Historical changes in trace metals and hydrocarbon contaminants on the inner shelf, Beaufort Sea: prior and subsequent to the petroleum-related industrial development. University of Alaska Coastal Marine Institute Annual Research Review, February 1999, Fairbanks.

A set of 35-mm slides showing sampling tasks in the field was also submitted to the CMI office at the University of Alaska Fairbanks.

An Economic Assessment of the Marine Sport Fisheries for Halibut, and Chinook and Coho Salmon in Lower Cook Inlet

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Task Order 14196

Abstract

The Cook Inlet Planning Area includes and abuts productive commercial, subsistence, and sport fishing grounds. Outer Continental Shelf minerals exploration, development and production activities could affect the productivity of these fisheries, the quality of recreation opportunities, and the demand for tourism-related services. The marine sport fisheries of Cook Inlet are the focus of a large recreation based economic sector that provides non-monetary benefits to participants and monetary benefits to tourism-related businesses. This study and a companion study, Lee et al. [1999], develop a predictive model of participation rate changes that can be linked to a regional input–output model to estimate net benefits to sport fishers and the regional economic impact of marine sportfishing on the Kenai Peninsula economy.

The probability that a typical sport fisher would take a halibut or salmon sportfishing trip in lower Cook Inlet is modeled as a random utility function of the expected trip cost and catch (species, size, number). The model, estimated using a binary probit estimation technique, allows for declining marginal utility as well as the interactions between salmon and halibut sportfishing catches. The model is used to predict changes in participation given changes in expected catch that may result from changes in mean catch that could arise from changes in biomass (abundance) or changes in catch limits. The estimated probability of taking a trip is transformed into a prediction of changes in total sportfishing effort.

Net benefits to sport fishers are measured by compensating variations, the amount of money that could be added to the price of the trip until the sport fisher would be indifferent to taking the trip. Consequently, compensating variation is a measure of the consumer surplus from sportfishing and changes in the total compensating variation are measures of changes in consumer surplus. The total compensating variation is the product of the estimated mean compensating variation per day ($87.82) and the number of sportfishing days. Reductions in expected catch reduce the compensating variation in two ways. First,

the marginal participant will drop out of the fishery as the expected benefits (in terms of catch) decrease, thereby decreasing the total net benefits of the sportfishing. Second, the net benefit of taking a trip is also reduced for those who continue to participate because the average trip produces less net benefit when the catch rate declines.

In contrast to net benefits, which are a measure of economic efficiency, economic impact is a measure of the distribution of economic activity. Changes in sportfishing effort affect regional economies by altering primary and secondary expenditure patterns. For example, if fishing effort were to diminish, fishing-related expenditures would also decline. However, estimates of these changes must account for the possibility that some individuals might engage in other Kenai Peninsula recreation activities as substitutes for the foregone sportfishing days. The Cook Inlet Region Marine Sportfishing Economic Assessment simulation model accounts for these substitution effects and declining marginal utility and allows estimation of the economic impact of lower Cook Inlet sportfishing for halibut and salmon under varying conditions of stock abundance and harvest limitations [Hamel et al. 2000].

Five examples of changes to sportfishing trip attributes are examined: two increases (10% and 20%) and three decreases (–10%, –20%, and –30%) from the baseline (1997) mean catch per fishing trip. The five scenarios reflect changes in expected harvests that might result from natural stock dynamic processes; changes in allocation shares between commercial, subsistence, and sport fishers; changes in catch limits; or population, regulatory, or economic and behavioral responses to environmental damage that might result from accidents associated with minerals exploration, development, production, or transportation.

The results indicate, for example, that for a 10% decrease in expected salmon and halibut catch, net benefits to sport fishers will decrease by 29%. The concomitant decrease in participation can be expected to result in a decrease of direct, indirect, and induced output expenditures in the Kenai Peninsula region, a reduction in personal income, and a loss of jobs.

Our study uses Alaska Department of Fish and Game estimates of total days fished in Kenai Peninsula Area saltwater sport fisheries to expand participation rate estimates into estimates of regional economic impacts. As a result of an internal review conducted in late 1999, ADF&G determined that computer programs used to process data from the statewide harvest survey contained errors that altered some anglers' reported catch and harvest. In addition, when generating estimates for angler-days fished and household trips the computer programs did not properly account for anglers who did not respond to the survey, resulting in an upward bias in estimated days-fished for 1995 through 1997. We did not become aware of these problems with ADF&G's estimates of days-fished until early in September 2000. ADF&G expects to release revised harvest and effort estimates later this fall. While the revisions affect our estimates of overall participation and impacts, they do not affect our coefficient estimates or the statistical significance of those coefficients. We will revise the total participation, compensating variation, and regional economic impacts using the revised ADF&G estimate of total days fished when that estimate is finalized.

Study Products

Publications

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Herrmann, M., S.T. Lee, K.R. Criddle and C. Hamel. Survey results for sport caught halibut and salmon in Lower Cook Inlet. Working paper.

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

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Task Order 15160

Abstract

As demands for additional commercial fisheries opportunities increase, forage species may be sought after by industry. We are examining the role of forage species as a part of the food energy requirements of the sockeye salmon, and looking at the potential impacts that nearshore development in relation to oil exploration leases may have on the prey species of the salmon—hence the coupling of this research with the Minerals Management Service. The 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 1998, a majority of sockeye salmon sampled from Kodiak migration pathways of sockeye were shown to be feeding until late July when feeding was reduced, confirming earlier published findings. Both time and area effects on feeding prevalence and dietary content were found to be significant. Feeding levels for the population gradually diminish rather than abruptly ceasing prior to the fish entering into fresh water. Dominant prey of sockeye salmon were Pagurus *crab larvae, Pacific sandlance (*Ammodytes hexapterus*), and a pteropod,* Limacina helicina.

Study Products

Quarterly reports starting July 1998.

Annual reports for 1998–1999, 1999–2000.

Annual presentations to CMI TSC on 23 February 1999 and 9 March 2000.

35-mm slides from annual presentation have been submitted.

Field and laboratory data: Data has been recorded on forms especially developed for this project. Copies will be submitted to the ADF&G repository at the completion of this project.

Correction Factor for Ringed Seal Surveys in Northern Alaska

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Task Order 15162

Abstract

The transition from occupying subnivean lairs to basking on the surface by ringed seals was studied from April to June in 1999 and 2000 in order to develop a correction factor for aerial surveys. Eight and ten ringed seals were live-captured in 1999 and 2000, respectively, and their use of lairs and basking sites was monitored by radio telemetry. The distribution of the tagged seals was relatively stable between winter and spring as only one seal in two years moved beyond our detection range and did not return. The transition period, defined as the period during which the majority (75%) of the tagged seals began basking, was longer in 2000 (24 days) than it was in 1999 (7 days). The midpoint of the transition period, the day by which 50% of the tagged seals began basking, was 31 May in both years. Only once each year was a lair used subsequent to each seal's first basking event. Changes in the number of seals counted during ground-based, visual surveys of seals resting on the ice corresponded to changes in the number of radio-tagged seals basking. Tagged seals spent approximately 20% of the time out of the water before basking began and approximately 30% of the time out of the water after basking began. The transition from lair use to basking appeared related to measurable characteristics of the snow.

Introduction

Ringed seals are an important resource for Native people of northern and western Alaska, and they are an important ecological component of the northern marine ecosystem [McLaren 1958a, b; Stirling and Smith 1977; Huntington 1992]. Shore-fast ice is important as a breeding habitat for ringed seals, and they maintain breathing holes through the ice by abrading it with their claws. The holes become snow-covered in the fall or early winter, and the seals continue to breathe at the ice surface but under the snow [Smith and Stirling 1975]. Where the snow drifts to depths greater than 20 cm above breathing holes, the seals may excavate snow caves (lairs). Lairs provide protected sites for seals to rest, give birth, and nurse their young. Throughout the winter and early spring, seals occupy lairs exclusively when out of the water. In late spring, however, seals lie on top of the ice and snow (bask) next to breathing holes after the snow cover collapses or is removed by the seals.

In the Beaufort Sea, during winter and early spring, the oil industry uses shore-fast ice as a platform for seismic surveys, ice roads, ice islands, and gravel island construction. Those activities affect the use of shore-fast ice habitat by ringed seals [Burns and Kelly 1982; Kelly et al. 1986, 1988; Burns and Frost 1988; Richardson et al. 1995]. Aerial surveys of ringed seals on the ice have been used to estimate population size [Stirling et al. 1977; Kingsley et al. 1985] and their distribution and density, particularly with reference to industrial activities [Burns and Harbo 1972; Burns et al. 1981; Burns and Kelly 1982; Frost and Lowry 1988, 1998, 1999; Frost et al. 1988, 1997; Richardson and Williams 2000]. Temporal and spatial comparisons of seal densities have assumed that the proportion of seals not seen is effectively constant both within and among years. During aerial surveys, some seals are not visible because they are under the ice, and others are not visible because they are in subnivean lairs. Estimates of the proportion of seals not seen are needed for estimating absolute population size and to compare densities over time or among areas.

Aerial surveys have been designed to reduce, or control for, the influence of weather on the proportion of seals visible. For example, strong winds are thought to decrease the number of seals basking; therefore, surveys are not conducted at wind speeds in excess of 37 km/hr [Kingsley et al. 1985; Frost et al. 1988; 1997; Frost and Lowry 1988, 1998, 1999]. Meteorological data used to decide if the weather conditions for a survey are met, however, have been taken from terrestrial sites (typically airports) some distance from the sea ice environment and may not be an appropriate surrogate for conditions experienced by seals. Furthermore, the weather guidelines were determined based on aerial observations and, therefore, data limited to a narrow range of weather conditions.

We tested the assumption that the proportion of seals visible remains constant by radio-tracking ringed seals before, during, and after the conventional aerial survey period. We determined the proportions of seals visible during the transition from resting in lairs to resting in the open, and we investigated the influence of weather on those proportions.

Methods

The study area extends seaward from Prudhoe Bay (70° 22.0′N 148° 22.0′W) to just beyond Reindeer Island (70° 29.1′N 148° 21.4′W) in the east and is adjacent to the Northstar oil development area. Shore-fast ice covers the area from October to July in most years. Water depths are mostly less than 9 m with a maximum of 15 m. Snowfall (measured at Prudhoe Bay) averages between 75 and 100 cm per year. Most of the snow falls before January and is redistributed by winds to form drifts at irregularities in the ice surface (e.g., pressure ridges) and areas of shallow snow overlying relatively flat ice.

We located ringed seal lairs and breathing holes using trained dogs [Kelly and Quakenbush 1987]. We captured seals in nets that pursed below them when they entered breathing holes [Kelly 1996]. We glued VHF radio transmitters (164–166 MHz) to the seals' hair and subsequently monitored their locations and the amount of time they spent out of the water [Kelly and Quakenbush 1990]. We monitored radio signals hourly using a telemetry receiver with an 8-element Yagi antenna on a 35-ft high tower. We rotated the antenna through 360° while monitoring and recorded the direction from which each signal was received. Each time a seal came out of the water, as indicated by the presence of its radio signal, we attempted to determine whether it was in or outside of a lair by determining the signal location with a hand-held directional antenna and viewing the area with binoculars.

We measured air temperatures inside and outside of lairs using thermistors and Hobo temperature loggers (Onset Computer Corporation). Occupation of lairs by seals was indicated by abrupt temperature changes in the lairs [Kelly et al. 1986; Smith 1987; Kelly 1988; Kelly and Quakenbush 1990; Kingsley et al. 1990]. Ground-based surveys of seals resting on the ice (outside of lairs) were conducted daily from 29 May–10 June 2000. An observer using 10 x 40 binoculars counted seals within the area visible from the roof of the Seawater Treatment Facility at the end of West Dock. Surveys were conducted at about 16:00 Alaska daylight time each day. We operated a meteorological station on the ice within the study area from 21 April to 8 June 2000. Air temperature, snow temperature (from ice surface to snow surface at 5 cm intervals), wind speed, and wind direction were recorded every 30 minutes using a Campbell Scientific CR10 data logger and SM192 storage module and an R.M. Young 05103 wind monitor. By examining changes in distribution of liquid water in the snow pack, in snow depth, in the size and morphology of snow grains, and in the overall snow landscape we monitored the transformation of the snow pack during snowmelt.

Results

Within the study area, we located 103 seal holes in 1999 and 113 in 2000. In both years, the ratio of breathing holes to lairs was approximately 1:1. Lairs were in use prior to an initial survey in early December and some were in use until at least 11 June 2000. We captured and radio-tagged eight seals in 1999 and ten seals in 2000; three seals were captured more than once.

The majority of seals used more than one lair and up to four different lairs (Table 1). The only seal not tracked to a lair (EL00) had been basking prior to capture. Radio-tagged seals used from 1–3 basking holes and, in 2000, one seal (LA00) was never found outside of a lair. Similarly, one seal (SP99) was still resting exclusively in lairs when we left the ice on 10 June 1999. We did not receive a signal from one seal (SL00) after 15 May. On several occasions after that date, however, LGL Alaska Research Associates received that seal's signal while flying in the vicinity of the Northstar oil development.

Table 1. Ringed seals captured and telemetrically monitored in 1999 and 2000.

Capture date	Seal ID	Sex	Minimum age	No. lairs used	Date of 1st basking	No. basking sites used
6 May 99	RI99	M	6	3	30 May 99	1
6 May 99	SW99	F	6	1	21 May 99	1
13 May 99	MA99	F	7	1	28 May 99	2
14 May 99	VR99	F	6	2	29 May 99	1
15 May 99	SM99	M	7	4	3 June 99	1
21 May 99	SP99	F	6	4	—	0
23 May 99	CH99	F	5	1	3 June 99	1
24 May 99	OR99	F	5	1	2 June 99	2
25 April 00	CS00	M	7	3	17 May 00	2
27 April 00	LM00	M	6	2	10 June 00	1
30 April 00	CC00	M	6	2	24 May 00	3
1 May 00	SL00	M	7	1	—	–
2 May 00	RA00	F	6	2	31 May 00	1
3 May 00	EL00	M	5	0	—	2
6 May 00	PU00	M	7	3	5 June 00	1
6 May 00	OC00	F	4	4	3 June 00	2
17 May 00	LA00	F	5	2	>4 June 00	0
18 May 00	IS00	M	7	1	—	1

We revisited six holes where seals were captured in 2000 five or more days after the capture, and all six holes showed evidence of continued use by seals. One seal (RA00) began basking at the same site where she had been captured one month earlier. Another seal (EL00) continued to bask at his capture site within 5 days of being captured there. Two different seals were captured at the same hole 7 days apart. As in 1999, tagged seals (with the above exception noted) remained in the study area.

We successfully monitored the transition from using lairs to basking in both 1999 and 2000 (Figure 1). For the purposes of this report, we define the "transition period" to be the period during which the majority of the tagged seals (75%) began basking. Specifically, this period commenced the day the second seal began basking and ended when only a single tagged seal continued to occupy a lair. Only once each year did a seal use a lair subsequent to its first basking event. The transition period lasted 7 days (28 May to 3 June) in 1999 and 24 days (17 May to 10 June) in 2000. In both years, 50% of the tagged seals had begun basking by about 31 May. In addition to the shift from using lairs to basking, the amount of time each day spent out of the water increased subsequent to the transition from about 20% to about 30% in both years.

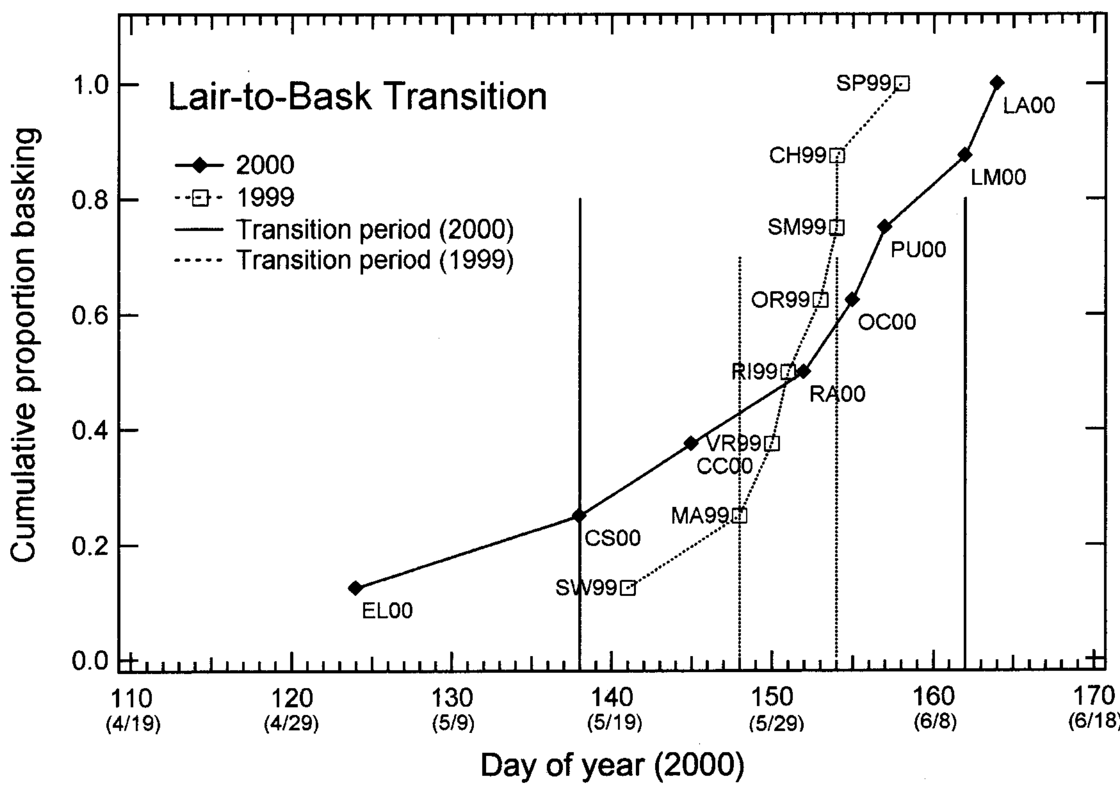

Figure 1. The cumulative proportion of tagged seals basking is plotted as a function of day of year. The transition periods for each year are delineated and seal identifiers are included. The dates provided are for 2000 (a leap year); add one day to obtain dates for 1999.

The trend observed in our ground-based, visual surveys was similar to that obtained from monitoring the tagged seals (Figure 2), suggesting that the behavior of the tagged seals was representative of the population in the study area. The transition period from lair use to basking occurred as the temperature at the snow–ice interface warmed from –5 to 0°C. The end of the transition period in both years closely corresponded to the day when the temperature near the snow–ice interface reached 0°C and the snow became water saturated.

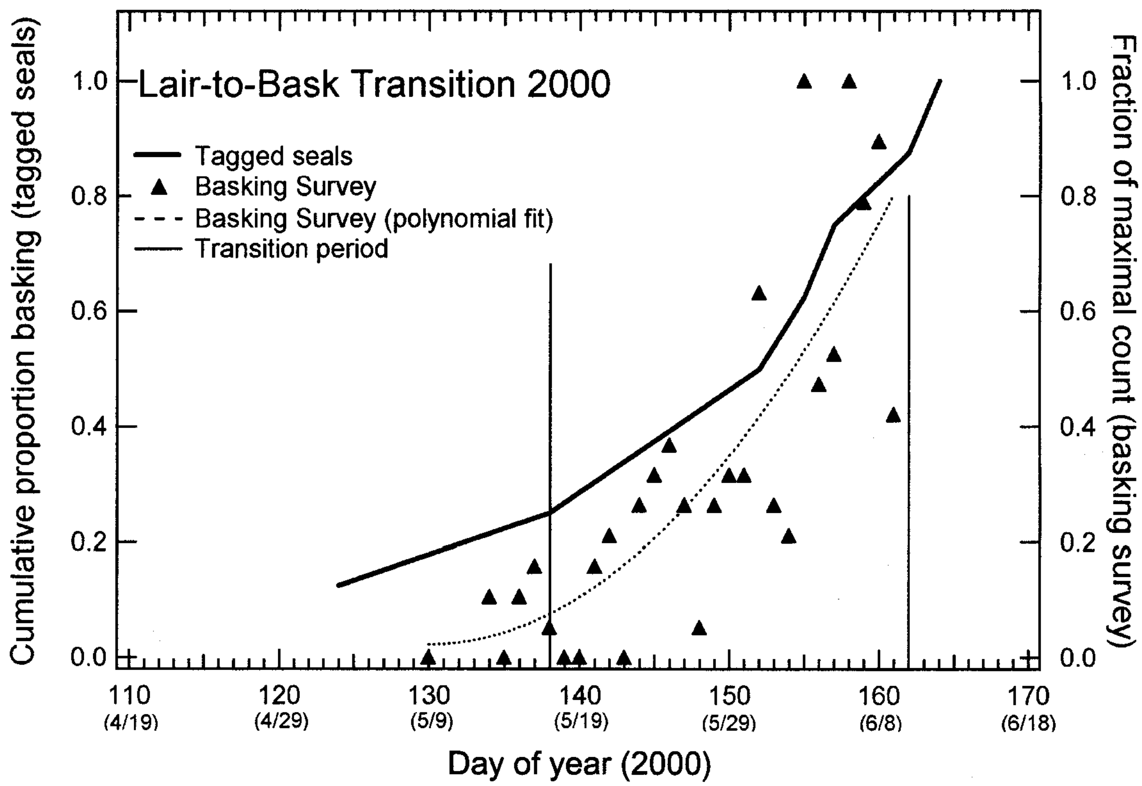

Figure 2. Visual counts of basking seals are plotted along with the cumulative proportion basking (Figure 1). The trend observed in our ground-based surveys was similar to that obtained from monitoring the tagged seals.

Proportions of the aerial survey time period (10:00–16:00) that tagged seals spent using lairs and basking are plotted for the transition period in 1999 (Figure 3). Trends in the basking and lair use proportions are fit with polynomial curves. These curves show that the time spent basking increased from 0% to about 40% as lair use decreased from about 15% to 0%.

We monitored the temperature in twelve lairs in 1999 and twelve lairs in 2000 for periods ranging from 5–47 days. Distinct diurnal patterns were observed in ambient air temperatures, but temperatures inside lairs were stable, as they were heated by the thermally constant seawater and insulated from atmospheric temperatures by their snow cover. When a seal entered the lair, its body heat produced a marked increase in lair temperature; when the seal left the lair, the temperature dropped quickly (Figure 4 [Figure 1 from the 1999 CMI Annual Report]). Temperature records showed that some lairs were in use until at least 11 June 2000.

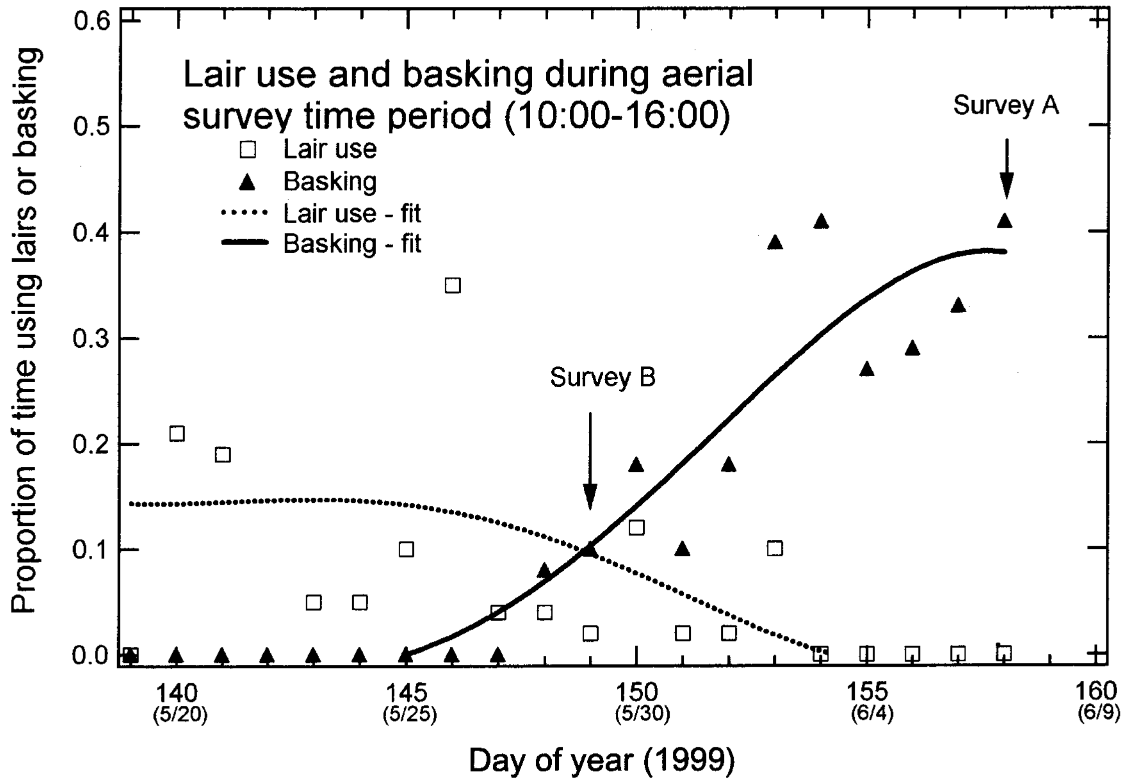

Figure 3. Proportions of the aerial survey time period spent using lairs and basking are plotted for the transition period in 1999. Averages are fit with polynomial curves to help illustrate the trends in lair use and basking. Surveys A and B refer to hypothetical surveys flown at different stages of the transition period.

Meteorological and snow data are not presented here but will be used to determine the influence of weather parameters (wind, temperature, cloud cover) on the proportion of seals basking.

Discussion

Seasonal changes in proportions of time spent basking affect the interpretation of aerial survey data. For example, surveys flown on 6 June 1999 (Survey A in Figure 3) would count, on average, 40% of the population; however, surveys flown on 29 May 1999 (Survey B in Figure 3) would count, on average, 12% of the population. Inter-annual variability in the duration and timing of the transition period (Figure 1) further complicates between-year interpretations of aerial survey data.

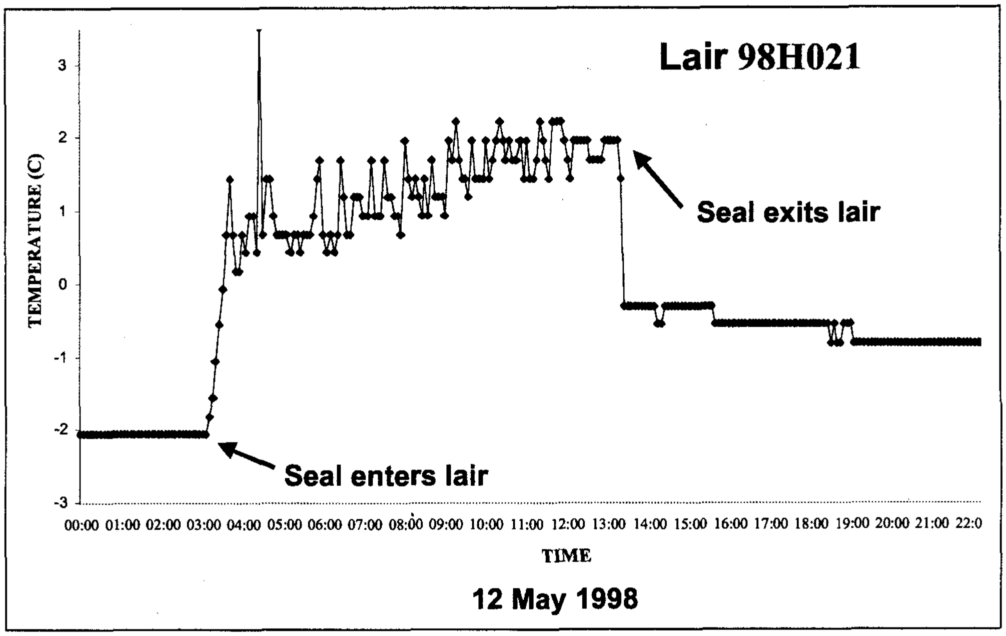

Figure 4. Temperature record of a ringed seal haul out inside a lair found in the Beaufort Sea in 1998.

Previous investigations have found inconsistent relationships between the density of visible ringed seals and air temperature, wind speed, and cloud cover [Kingsley et al. 1985; Stirling et al. 1977; Burns and Harbo 1972; Burns and Kelly 1982; Frost et al. 1988]. We found that the temperature of the snow pack (which integrates air temperature, wind speed, and cloud cover) appears to be a good predictor of when seals are visible. We observed a longer transition period in 2000 (24 days) than in 1999 (7 days), but the periods were centered on nearly the same date. In both years, the transition periods corresponded to changes in the temperature of the snow near the snow–ice interface. Most of the radio-tagged seals were basking as the temperature of the snow reached 0°C.

It may be possible to use historical records of snow conditions to estimate the transition period for previous years and to correct past surveys for the proportion of ringed seals not visible. Records of snow temperature on the ice are lacking, but it may be possible to use snow temperature records from the tundra as a proxy.

We discovered that the transition from dry, insulating snow to wet conductive, snow is visible in Ku-band radar backscatter signatures. In collaboration with S.V. Nghiem at the Jet Propulsion Laboratory in California, we obtained Ku-band backscatter images of our study area in spring 2000 and were able to correlate the transition of radio-tagged seals from lair use to basking with the changes in the radar backscatter. The use of the Ku-band radar data as an early indicator of snowmelt conditions and as a means to determine (remotely and in real time) when to fly aerial surveys of ringed seals is worthy of further investigation.

Acknowledgements

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Study Products

Two reports on the progress of this project have been delivered in spoken presentations this year. On 8 March 2000, Brendan Kelly spoke to the Coastal Marine Institute on developing a "Correction factor for ringed seal surveys in Northern Alaska" in Fairbanks and on 27 July 2000, Oriana Harding presented a seminar on "Activity patterns of ringed seals" to the National Science Foundation Research Experience for Undergraduates Symposium in Juneau.

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

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The Canadian and Japanese partners are providing in-kind (matching) support to this project through shiptime (Japan and Canada) and instrumented moorings (Japan).

Task Order 15163

Abstract

This program has collected hourly time series of ocean velocity, temperature, and salinity properties from moored instruments deployed along the outer shelf and slope of the Alaskan Beaufort Sea for a period of one year. The 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 (heat, salt, nutrients, etc.), contaminants, and pollutants. The region is also an important migratory corridor for marine mammals, particularly bowhead whales that feed here during part of the year. Previous measurements showed that the near surface flow here (< ~50 m depth), 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, for measurements here will capture the integrated effects of the circumpolar forcing which we believe force the undercurrent.

Background and Framework Issues

Flow along the Alaskan Beaufort Sea shelf is influenced by the flow along the adjoining slope and shelfbreak. That flow field is complicated and consists of a surface (upper 50 m), westward flow and a subsurface, eastward flow. The surface flow is wind-driven and forced by the prevailing northeasterly wind field. It is the southern limb of the clockwise Beaufort Sea Gyre. The kinematic properties (vertical and horizontal motion scales, speeds, transports, and temporal and spatial scales of variability) are poorly described. The dynamics of the subsurface flow (also know as the Beaufort Undercurrent, Aagaard [1989]) are not understood but include a number of influences: both the local and far-field alongshore winds, inflows from the continental shelves bordering the Arctic Ocean to the west of the Beaufort Sea, and inflows from the Atlantic and Pacific oceans.

We believe that regional (Beaufort Sea shelf) oil spill trajectory models will need to include the influence of the circulation along the shelfbreak and slope in order to correctly assess the fate and transport of contaminants into the local marine environment. Our observations will guide model development and evaluation.

Objectives

The overall purpose of this program is to provide a kinematical and, where possible, dynamical description of the circulation, thermohaline structure, and cross-shelf transport along the Beaufort Sea shelfbreak and slope. To achieve this goal the field and data analysis portion of the program is designed to address the following questions and objectives:

1. What is the mean transport over the outer shelf and slope and what are the cross-shore and vertical scales of the mean flow field?

2. What are the magnitudes of transport variability and what are the dominant temporal and spatial scales associated with this variability?

3. What is the relation between variations in temperature and salinity and variations in the flow field at time scales from the synoptic to the seasonal? Are changes in the baroclinic flow consistent with changes in the cross-shore density structure?

4. What are the cross-shore fluxes of heat, salt, and momentum? Do these appear to be related to instabilities (eddy generation mechanisms) of the alongshore flow?

5. How are these variations related to changes in the surface wind field?

6. Compare the results obtained from the proposed field program with those collected in 1987/88 by Aagaard et al. [1989] to determine whether recent large changes in the Arctic Ocean are also reflected in conditions in the Beaufort Sea.

7. Combine this data set with other measurements recently acquired from around the Arctic Ocean to provide an updated synthesis that relates the Beaufort Sea to the large-scale circulation of the Arctic Ocean.

Methods

We are completing the field program, which has included the deployment of six instrumented moorings at the locations listed in Table 1 and shown in Figure 1. Mooring deployments (fall 1998) and recoveries (fall 1999) were conducted from the CCGS *Sir Wilfred Laurier*. Figure 2 shows the vessel and Figure 3 shows a portion of the mooring deployment operation on the well deck. All of the moorings were recovered in fall 1999 except for B4. The acoustic releases did not appear to be responding when we attempted recovery. However, persistently bad weather (high winds, freezing spray) limited the amount of effort that could be expended in the search for this mooring to only a few hours. The program was extended for an additional year so that a more intensive effort could be applied to recovering this mooring. The CCGS *Sir Wilfred Laurier* is now (September 2000) in the Beaufort Sea searching for this mooring. We will be analyzing these data in conjunction with the surface wind field computed from sea level pressure fields prepared by the European Center for Medium Range Weather Forecasting (ECMWF). We have obtained these pressure fields from the National Oceanic and Atmospheric Administration's National Center for Atmospheric Research (NOAA, NCAR).

Table 1. 1998 Beaufort Sea mooring deployments.

Mooring ID	Isobath (m)	Current Meter Depth (m) RCM = Default; F = FSI	T/C Depth (m) (M-Cats at 60 m; S-Cats elsewhere)	Latitude (N)	Longitude (W)
MAIN ARRAY					
B1-98	80	50, 70	none	70° 54.30′	146° 41.15′
BF-S-98 (JAMSTEC)	500	50, 90, 180, 240, 400 (S4+CT)	60, 90, 120, 150, 180, 210, 240	70° 56.94′	146° 35.48′
B3-98	1200	50, 150, 250, 400, 900	60, 125, 200, 300	71° 00.78′	146° 36.58′
B4-98	1700	50, 250, 500, 800 (F), 1200	60, 125, 200, 300	71° 07.46′	146° 31.27′
B5a-98	1000	50, 250, 500, 1000 (F), 1500	60, 125, 200, 300	70° 35.62′	139° 57.54′
WESTERN MOORING (JAMSTEC)					
BF-K-98	120	60, 65 (600 kHz ADCP), 95, 108, 115	none	71° 23.00′	152° 04.72′

Ancillary Programs

This mooring program complements two additional programs being undertaken simultaneously by the principal investigators. The first is sponsored by the Office of Naval Research (ONR) and is an investigation of the circulation and thermohaline structure of the Chukchi–Beaufort continental slope. It employed the unique sampling capabilities of a U.S. Navy nuclear submarine (SSN *Hawkbill*) operating beneath the ice pack. The sampling included underway measurements of temperature and salinity at a depth of ~130 m from a sail-mounted CTD and submarine-launched expendable CTDs (SSXCTD). Such data are helping to determine the decorrelation length scale of the along-slope density field, the magnitude and structure of the alongshore baroclinic pressure gradient, and along-slope variations in the cross-slope baroclinic pressure gradient. These measurements are directly related to the scales of cross-slope exchanges and forcing mechanisms for the eastward-flowing undercurrent. The second program, sponsored by NOAA, supported moorings in Bering Strait. The purpose of this program is to monitor transport and water mass variations in Bering Strait. Since the flow through the strait eventually feeds the flows along the Beaufort slope, these data are relevant to this CMI program. The strait measurement program results in a nearly 10-year-long time series of direct transport measurements in Bering Strait. This time series will allow us to discuss the data from the Beaufort slope mooring program in the context of interannual and seasonal variability of the flow through Bering Strait.

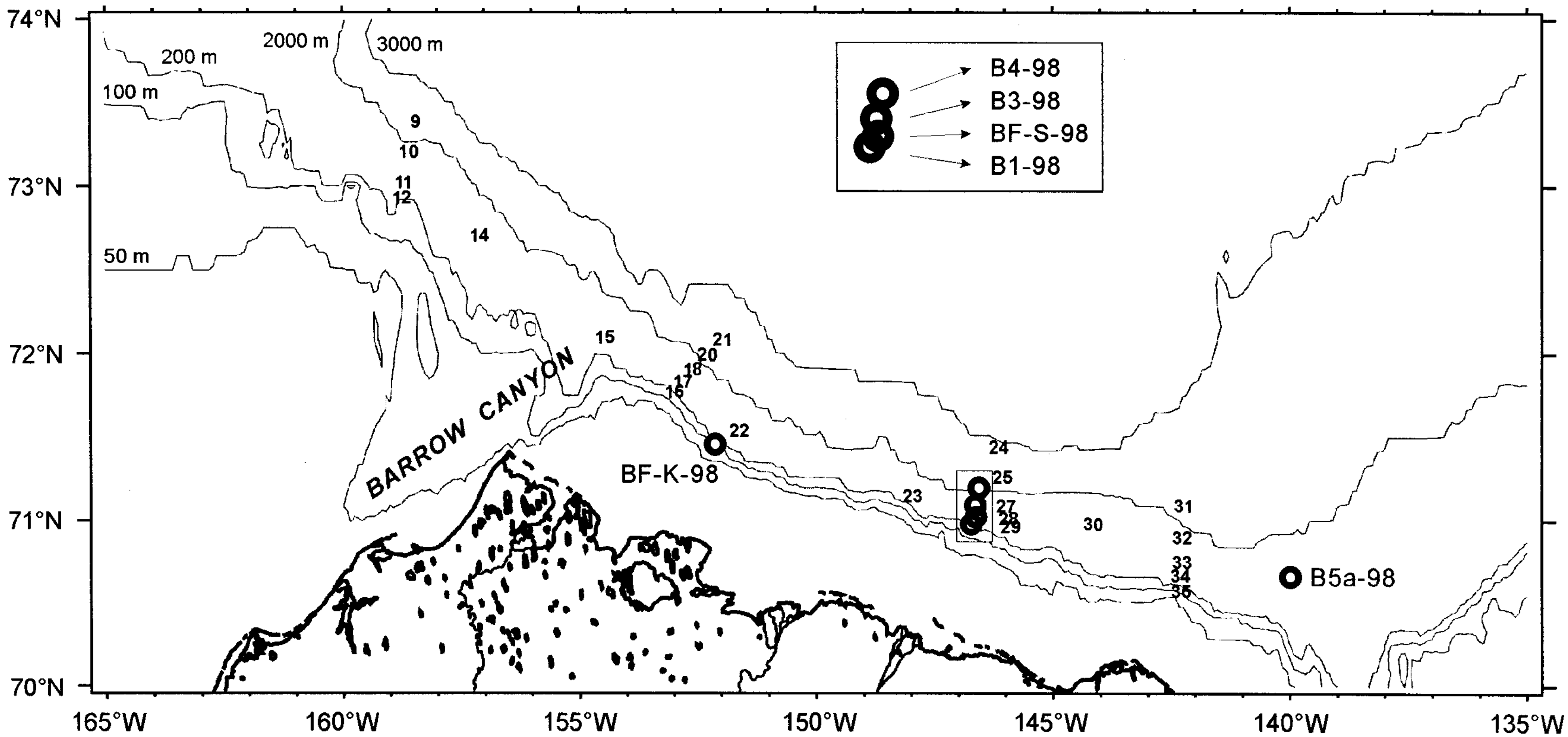

Figure 1. Bathymetric map of the Alaskan Beaufort Sea region showing locations of the moorings listed in Table 1. The numbered locations indicate positions where submarine launched expendable conductivity–temperature–depth probes (SSXCTDs) were launched from the SSN *Hawkbill* in April 1999.

Figure 2. The *Sir Wilfred Laurier*, the Canadian Coast Guard icebreaker that supported the mooring operations during this program.

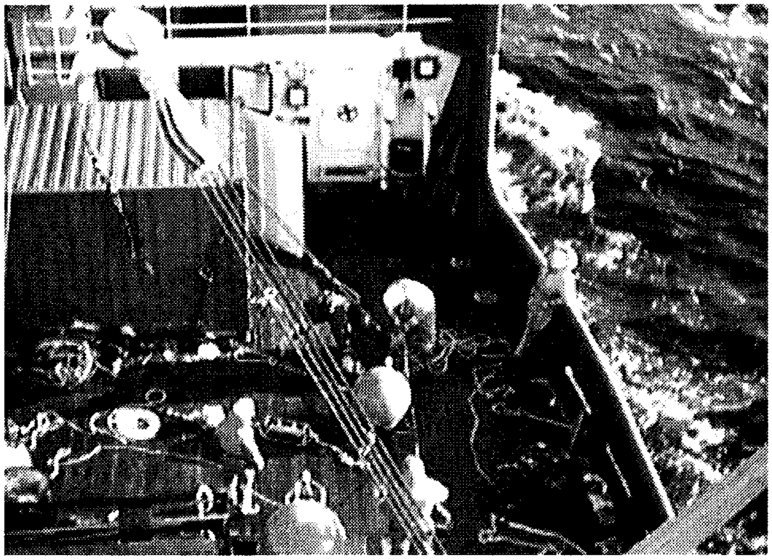

Figure 3. Deployment of one of the Beaufort Sea moorings from the well-deck of the *Sir Wilfred Laurier.*

Preliminary Results

We briefly outline two results that illustrate the data we have gathered. Figure 4 shows time series of the north–south (V), east–west (U), temperature, and salinity from mooring B398 at the 150-m depth. The data have been smoothed with a 3-day running mean to focus on the low-frequency features. Note that most of the flow is in the east–west component, indicating that it approximately parallels the local isobaths. The along-slope flow varies throughout the year, being weak and variable from July through October 1998, strongly eastward from November 1998 through March 1999, and weak but generally westward from May through September 1999. By contrast, the north–south velocity component is comparatively weak, suggesting that there is little onshore–offshore flow. Temperature and salinity variations are closely correlated throughout the record indicating water masses from within and below the Arctic Ocean's halocline. Indeed, over most of the record the temperature range is between −0.4 and 0.2°C and the salinities are between 34.5 and 34.8. These water mass characteristics are those of Atlantic Ocean waters that entered the Arctic Ocean through Fram Strait and flowed counter-clockwise around this basin.

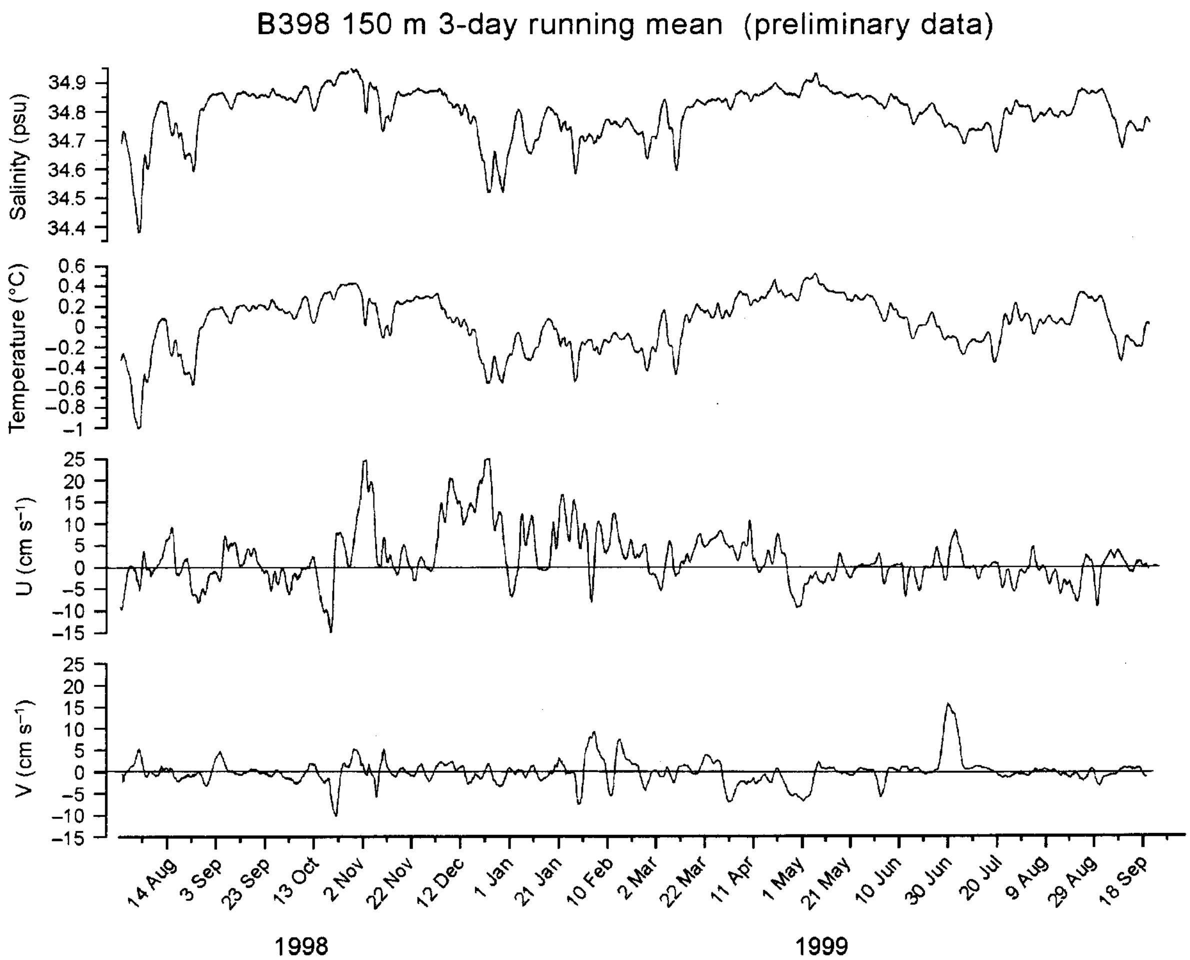

Figure 4. From top to bottom are time series of the salinity, temperature, east–west (U), and north–south (V) velocity components from mooring B398 at the 150-m depth. Each time series was smoothed with a 3-day running mean to highlight longer period fluctuations.

Figure 5 shows the along-shore dynamic height obtained from the SSXCTDs collected by the SSN *Hawkbill* in April 1999. These data show a trough in the dynamic height at about 150° W (longitude 210). The dynamic height slopes upward to the east and west of the trough. The structure of the along-slope dynamic height field (in conjunction with the cross-shore dynamic height which is not shown) implies a flow with eastward velocity shear (eastward velocities increase and westward velocities decrease with decreasing depth) to the west of 150° W and westward velocity shear (westward velocities increase and eastward velocities decrease with decreasing depth) to the west of 150° W. The dynamic height picture is consistent with the velocity time series from Figure 5 that shows that the eastward flow at the 150-m depth decreased from early winter 1998–99 to April 1999. The joint analyses of these data are ongoing.

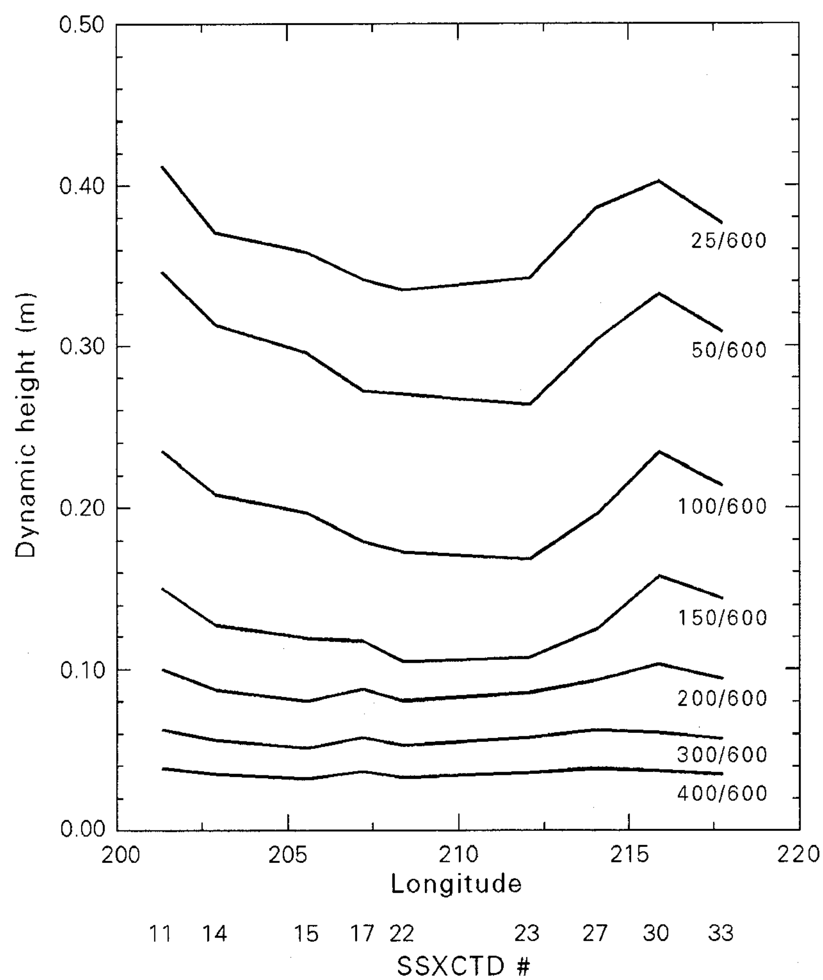

Figure 5. The variation in dynamic height at selected depths (and all referenced to 600 db) from west to east along the Beaufort Sea slope in April 1999.

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

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Task Order 15164

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. Between 1 July 1999 and 30 June 2000, the AFTC accessioned tissues from 822 marine mammals. This was more than double the number of marine mammal specimens acquired in typical recent years and reflects an exceptionally large accession of walrus samples. Frozen tissue loans (n = 12) representing 128 individual animals have been made to ongoing research projects. Database development has expanded onto a highly professional system and is being integrated across all of the Museum's biological collections. The AFTC has played a signal role in attracting National Science Foundation support for the Museum's Arctic Archival Observatory.

Introduction

Long-term monitoring of biological change in marine ecosystems dictates long-term accumulation of data. Because it is difficult to predict which data will be important, or even what methods may be available, accumulation of well-documented specimens is crucial to assessing change. This mandates permanent, cooperative archives with appropriate protocols for sharing specimens and associated data, such as the Alaska Frozen Tissue Collection (AFTC).

For the past year, CMI has provided a coordinator for the AFTC in the form of a graduate student assistantship dedicated to recruiting and processing marine animals from subsistence hunting. CMI has also provided auxiliary support for supplies and travel, and the Museum has matched this funding with a state-funded student assistantship that was initially created from earlier CMI support. The objectives of this project were to (1) expand the marine sector of the AFTC, (2) establish an online catalog of the AFTC, and (3) commit the university to long-term support of the AFTC subsistence coordinator.

This project and earlier CMI support have made the AFTC into the primary regional archive for frozen zoological samples. For at least two reasons, this is a substantial contribution to the scientific infrastructure:

1. Improved methods for extracting data from DNA sequences, stable isotope signatures, and trace element concentrations are making the historical archives found in museums crucial to the study of long-term ecological change. Older specimens in collections are becoming important for interpreting past environments (baseline conditions). Material now being archived will serve such functions better in the future. Ultracold storage of biological tissues preserves a broad suite of biochemical characteristics and is an efficient means of preserving specimens for such studies.

2. The AFTC facilitates cost-effective use of specimens. Many assessment and inventory projects generate important sampling opportunities, frequently at tremendous expense. Such projects are usually short term because of funding limitations and in the past few have gathered or archived specimens. Now, through extensive cooperative efforts, the AFTC is becoming a long-term, specimen-based record of the biotic environment of the North Pacific and Arctic oceans. Unique and important material is being made available to the general scientific community in perpetuity, and AFTC specimens are being used extensively in ongoing research. The value of CMI support will be realized as future investigations call for, or are designed around, the use of archived samples.

Molecular analyses (e.g., DNA sequences) are now basic to defining and managing natural populations. These techniques are providing insight into social systems [Karl and Bowen 1999], effective population size, lineage divergence [O'Corry-Crowe et al. 1998; Avise 1994] and the effects of inbreeding and outbreeding depression [O'Brien et al. 1985; Ralls et al. 1988]. DNA sequencing has eclipsed much of the stock-delimiting work formerly done by electrophoresis of allelic proteins [Moritz 1994; Brooks et al. 1992]. Improvements in sequencing technology are yielding more data per sample at lower costs and streamlining the processing of larger sample sizes. This work relies on cryogenically archived specimens.

Frozen tissue collections are also important in studies of epidemiology in wild populations. Crises such as the distemper epidemic in North Atlantic gray and harbor seals (see Dickson [1988] for an early review) suggest that we should be building a baseline of tissue samples for Alaskan marine organisms. Blood samples archived in the AFTC were used to screen for seal (phocine) distemper subsequent to the epidemic in the North Sea. Hundreds of AFTC samples have been used in three projects screening for hantavirus and babesiosis in Alaska rodents. Epidemic diseases of wildlife can only be understood when the baseline levels of infection are known. Good baseline data require material collected over many years.

Both frozen samples and samples from standard dry museum specimens are being used to examine carbon and other stable isotope signatures in several marine species (Don Schell, University of Alaska Fairbanks, Institute of Marine Science [UAF/IMS]; James Burton, University of Wisconsin; Merav Ben-David, UAF Institute of Arctic Biology). These are powerful new methods for tracking biologically important elements through ecosystems.

Frozen tissues can also be used as indicators of environmental toxicity [McBee and Bickham 1990], particularly when high trophic level organisms are archived. Samples from older, dry museum specimens have been particularly significant because they often represent pre-disturbance, baseline conditions. Temporal changes in environmental mercury, over a span of decades, are currently being examined in the annual growth segments of bowhead (*Balaena mysticetus*) baleen archived in the Mammal Collection.

In order to provide tissues for research such as this, the AFTC must continue to develop and maintain a broad coverage of Alaskan marine organisms. This can only be done by coordinating the efforts of potential collectors, and by maintaining easy access for the research community.

Collection Growth

Approximately 4,900 mammal specimens were added to the collection and about 17% of these were marine mammals. Table 1 outlines the major marine mammal accessions.

Table 1. Major marine mammal accessions.

SPECIES	NUMBER	NUMBER
Bowhead	3	Sheffield (ADF&G)
Hair seals (various)	80	Sheffield (ADF&G)
Belukha	1	Mahoney (NMFS)
Harbor seal	106	Jemison (ADF&G)
Harbor seal	23	Vanek (ADF&G)
Spotted seal	2	Mahoney (NMFS)
Spotted seal	5	Sheffield (ADF&G)
Bearded seal	2	Mahoney (NMFS)
Polar bear	15	Evans (USGS)
Ice seals	24	Dehn (North Slope Borough)
Walrus	506	Hills (USGS)
Northern fur seal	2	Springer (UAF/IMS)
Steller sea lion	17	Springer (UAF/IMS)
Sea otter	14	Raum-Suryan (ADF&G)
Sea otter	22	Lensink (USFWS)
TOTAL	822	

A single accession of 506 walrus tissue samples accounts for most of this increment and puts the year's growth well above what would have otherwise been a typical healthy year's increase in marine mammal holdings. Marine Mammal Management at the U.S. Geological Survey (USGS) transferred the walrus samples to the AFTC. Sue Hills collected the samples in 1992 during a USA/Russia pinniped research cruise in the Bering Sea. This accession will certainly form the basis for several studies over the next few years. The USGS Marine Mammals Management program may initiate a study of population structure of North Pacific walrus this year.

Other important accessions included a total of 129 harbor seals coming to us from Alaska Department of Fish and Game (ADF&G) biologists through a co-management agreement between the Alaska Native Harbor Seal Commission and the National Marine Fisheries Service (NMFS). Additional samples of historic interest were acquired, including skulls, teeth, claws, jaws, a fetus, and bacula from 80 phocid seals collected by ADF&G from 1967 to 1985. The U.S. Fish and Wildlife Service (USFWS) provided nineteen sea otter skulls, some collected in the 1960s by the noted zoologist, Karl Kenyon. Calvin Lensink (USFWS, retired) donated 22 sea otter skulls with bacula.

Collection Use

A dozen loans involving marine mammal material acquired with CMI support were conducted:

- Donald Siniff of the University of Minnesota requested two more blood samples from Antarctic Weddell seals collected in 1991for paternity analyses (at Curtis Strobeck's lab, University of Alberta) in order to complete a pedigree of the White Island population and test genetic distances and population subdivision in the McMurdo Sound region. These investigators have indicated that they will archive samples from two decades of work on Weddell seals in the AFTC.
- Don Schell's laboratory used frozen tissues from twelve western arctic bowhead whales in a study to determine the importance of the eastern part of the Alaskan Beaufort Sea as a spring feeding area.
- Peter Boveng of the National Marine Mammal Lab received teeth from 45 harbor seals for age analysis. The ages are being used in an age class and capture study that is necessary for effective harbor seal management.
- Alan Springer at UAF/IMS received teeth from twelve sea lions for age analysis.
- Michael Castellini and Heather Harmon of the Alaska SeaLife Center and UAF/IMS received pituitary and pineal glands from six Steller sea lions and one fur seal. These glands will be used in reproductive hormone analysis. Little is known about their reproductive endocrinology, and evidence suggests that their reproductive rates may have decreased over the past several decades.
- Forty-seven blubber samples from harbor seals were loaned to Sara Iverson at Dalhousie University, Nova Scotia. These samples will be used in an ongoing study screening blubber samples for contaminants.
- Tissue samples from 21 harbor seals were sent to Greg O'Corry-Crowe (NMFS Southwest Fisheries Center, La Jolla) for ongoing analyses of the genetic structure of the Alaska populations.
- Six seal skeletons were loaned to National Park Service (NPS) archeologist Becky Saleeby (NPS Anchorage) for use in a course on faunal analysis of archeological middens.
- Tissue samples from 28 sea otters were sent to Klaus Koepfli in Robert Wayne's laboratory at UCLA for a study of geographic population structure of the entire species.
- Educational donations of a belukha skull were made to Kate Wynne of the UAF Marine Advisory Program at Kodiak and of a sea otter skull to Kay Furman of the Staatliches Museum für Naturkunde, Oldenburg, Germany. A polar bear skull was loaned to Brendan Kelly (University of Alaska Southeast) for a student project on bear craniology.

Computerization and Information Technology

Database development for the AFTC is now intertwined with the larger initiative of bringing all of the Museum's biological collections into the comprehensive database of the new Arctic Archival Observatory (AAO). The Museum has received funding from the National Science Foundation (NSF) to develop the AAO as a first part of NSF's National Ecological Observatory Network (NEON). A key part of this project is to create a web-based, georeferenced database of a wide variety of ecological samples. Conceptual development has been catalyzed by ongoing CMI support.

Since 1996, the AFTC has had a summary database of its holdings on the world wide web. This site also allows users to interrogate a summary of the Museum's Mammal Collection that provides information on all AFTC samples and conventional museum specimens. It is an excellent overview of our holdings and, increasingly, requests for tissues are explicit, indicating that the requestor is already familiar with our holdings.

We are now engaged in implementing a far more sophisticated system on an enterprise-caliber platform. The 110-table database is running in Oracle software on a dedicated Sun Microsystems server. The database architecture and the development environment for user and client interfaces are identical to those at the University of California's (Berkeley) Museum of Vertebrate Zoology (http://elib.cs.berkeley.edu/mvz). MVZ's programmer, John Wieczorek, is in the final stages of migrating mammal records into the system, and the AAO's full-time programmer, Dorothy Corbett, is now working with him on expanding the model and developing interfaces for our other biological collections.

Students

John Chythlook and Amy Runck, both of whom were supported by CMI-funded graduate research assistantships in the AFTC, defended their M.S. theses this spring. John is now working in fisheries management with ADF&G and Amy is continuing with AFTC under NSF support.

Conclusions

The Alaska Frozen Tissue Collection has continued to expand its holdings and its utility. Development of the collection database is accelerating rapidly and allowing the University of Alaska Museum to apply information technology to collection documentation and management. Web access is allowing a wide clientele to access and expand this resource. CMI support has built the AFTC into a widely used and internationally recognized scientific resource and was integral to the creation of the Arctic Archival Observatory.

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Beaufort Sea Nearshore Under-Ice Currents: Science Analysis and Logistics

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Task Order 15169

Abstract

We are measuring and will analyze currents in the landfast (nearshore) ice zone of the Beaufort Sea in the vicinity of Prudhoe Bay, Alaska. Our objective is to quantify the circulation variability in this region where current measurements are largely lacking during the freeze-up, ice-covered, and ice melt seasons. This information is deemed critical for designing oil spill response protocols for offshore drilling operations in the Northstar and Liberty fields. The data will also be useful in evaluating regional numerical circulation models that would be used for oil spill trajectory predictions. Although these are the principal reasons for undertaking this study the data is expected to have broader scientific applications to other Arctic shelves. For example, current energy is expected to be low beneath the landfast ice zone, implying little vertical mixing. Low vertical mixing has potentially important implications on the formation of fronts and the circulation structure on the inner shelf. These data will enable us to better understand mixing processes on the innermost portion of Arctic shelves.

Background and Relevance to Framework Issues

Liberty and Northstar oil prospects are on-line for development in the near future, with construction activities beginning at Northstar in 2000. There is considerable concern these actions might impact nearshore biota. The Minerals Management Service (MMS) Alaska Outer Continental Shelf Region is requiring integrated studies of key issues, including long-term impacts on benthic/kelp communities and other sensitive resources.

Understanding the under-ice currents is a necessary precursor to estimating potential effects of oil spills on sensitive resources in the landfast ice zone, and in particular at the Liberty project. The one prior study of under-ice currents supported by MMS [reported by Matthews 1981] was made within Stefansson Sound (Figure 1). His measurements indicated that under-ice oil spills can move off-site and risk nearshore resources. This risk cannot be evaluated with the standard MMS oil risk analysis based on regional circulation. Another important question is whether the under-ice currents could transport suspended sediments from the development area to the nearby Boulder Patch and endanger kelp during the critical under-ice growth period.

Under-ice current speed and direction are important because currents of 10–20 cm/s will move spilled oil along the underside of the ice. Matthews [1981] found that average currents under landfast ice appeared to be related to brine drainage and peak currents to wind-forced, negative surges. He did not measure currents directly under the ice, but estimated these from mass-balance considerations. Under-ice currents averaged 6 cm/s and had a maximum onshore speed of 37 cm/s. We caution that the model assumptions might not be correct, but if they are, these speeds imply onshore displacements of approximately 3 and 20 nautical miles/day. Alongshore currents appeared to have similar magnitudes. Actual currents might be swifter if the water column is stratified. Note that we expect wind-forced currents to dominate in this region as tidal currents are only about 2 cm/s [Kowalik and Proshutinsky 1994].

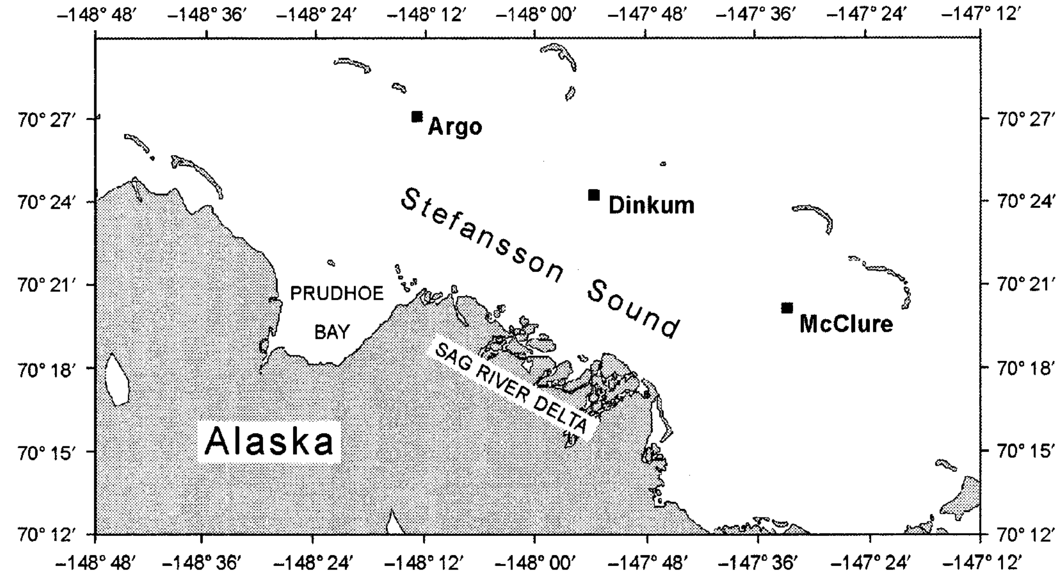

Figure 1. Regional map showing location of current meter moorings.

Matthews' [1981] measurements, made from mid-November 1978 through February 1979, were obtained within Stefansson Sound, a shallow lagoon bounded offshore by barrier islands. We anticipate that the lagoon circulation is less energetic than the flow offshore of the barrier islands. In this regard, his measurements are probably more applicable to the Liberty development than to Northstar. Moreover, his measurements did not include the early fall period of vigorous ice growth and the developing landfast ice cover. We expect under-ice currents to be swifter during this period, as the ice is still mobile and therefore effective in transmitting the momentum from the winds to the underlying ocean. We expect that until the landfast ice cover is established, the drag of the ice over the ocean will form a frictional boundary layer (e.g., very large vertical gradients in ocean velocity) in the surface layer. Finally, his measurements did not include the effects of river runoff, which increases rapidly in early summer when fast ice is still present. The river plume will spread under the ice, likely forming strong vertical velocity gradients with maximum speeds near the bottom of the ice.

Landfast ice is an immobile lid that inhibits the flux of wind energy into the water column. *A priori* we expect that portion of the inner shelf covered by landfast ice to be relatively quiescent. This zone typically lies shoreward of the 20 m isobath [Reimnitz 1978]. In summer this region receives a large influx of river water with much of the discharge flowing under the landfast ice. Whether this freshwater mixes with ambient shelfwater, and if it does, how this mixing evolves, is crucial in the seasonal evolution of the shelf circulation [Chapman and Lentz 1994; Yankofsky and Chapman 1997; Weingartner et al. 1999].

Goal and Objectives

The goal and objectives of this project are to provide direct measurement of winter under-ice currents in the vicinity of the Liberty and Northstar projects to help MMS and the Alaska Department of Environmental Conservation (ADEC) evaluate oil-spill and sedimentation risk to the nearshore Beaufort Sea, including the Boulder Patch and other local resources. The specific objectives are to:

1. Deploy three instrumented moorings in the vicinity of the Liberty and Northstar projects for a period of one year. The moorings will collect velocity, temperature, salinity, and transmissivity data at hourly intervals. Transmissivity is a proxy for the suspended sediment load in the water column.

2. Quantify the variability of the current meter and local wind records and their relationship to each other.

3. Determine the vertical structure of the currents throughout the water column and how this structure changes with the development of the landfast ice through winter and in summer when the ice melts and rivers flood the inner shelf.

Results

This project commenced in May 1999 with the purchase of the instrumentation. From June through July 1999 mobilization for the fieldwork took place at the University of Alaska Fairbanks Institute of Marine Science's Seward Marine Center (Seward, Alaska). During this time the instruments arrived from the manufacturer, the mooring frames were built and the equipment was prepared for shipment to Prudhoe Bay.

Three instrumented mooring frames were deployed in the Prudhoe Bay vicinity in August 1999. Figure 1 shows a map of the region, including the three deployment sites (Argo, Dinkum, McClure). The specifics of these moorings are given in the accompanying table (Table 1); Figure 2 shows a frame (fabricated from fiberglass angle stock) and the instruments installed on it. The instruments were configured to collect current, temperature, salinity, turbidity, and subsurface pressure at hourly intervals. They are to be recovered in August–September 2000. (Recovery operations were underway during the preparation of this annual report.) The instruments were deployed from MMS vessel "1273".

Each mooring also includes an Edgetech AMTR200 Release/Transducer that sends and receives acoustic signals when remotely interrogated. These instruments will be used during recovery operations to locate the moorings. The release mechanism is hooked to a float that will rise to the surface and that trails a line to the mooring frame. Retrieval of the mooring would begin by hooking onto the float and then hauling the line. Each mooring also includes a 27 kHz pinger as a backup for recovery. The pinger allows divers to locate the mooring should the release or floats fail or visibility be obstructed. Figure 3 gives an idea of the frame dimensions in comparison to the 6-ft tall Dr. Okkonen. The ADCP (yellow plastic cover) is mounted in the top and center of the frame. The instrument is installed on gimbals so that the ADCP transducers point straight up even if the frame is tilted while resting on the seabed.

BP, Inc. provided matching support through logistics and lodging. Funds for the purchase of the equipment used in this program were provided by the Alaska Department of Environmental Conservation.

Table 1. Mooring specifics.

Mooring Name	Latitude (N)	Longitude (W)	Time deployed (GMT, 1999)	Bottom Depth	Instrumentation
Argo	70° 27.177′	148° 12.722′	13 Aug: 1821	8.4 m (27.7 ft)	1200 kHz ADCP[1], Microcat with pressure sensor[2]
Dinkum	70° 24.352′	147° 53.656′	14 Aug: 1837	6.8 m (22.4 ft)	1200 kHz ADCP[1], Seacat with transmissometer[3],
McClure	70° 20.204′	147° 32.701′	14 Aug: 2007	6.7 m (22.2 ft)	1200 kHz ADCP[1], Seacat with transmissometer[3]

[1]1200 kHz ADCP is an Acoustic Doppler Current Profiler which measures velocity every 0.5 m throughout the water column including to within ~ 0.5 m beneath the ice. These instruments transmit sound at a 1200 kHz and then measure the Doppler shift of the backscattered signal. The ADCPs depend upon scatterers (density discontinuities, zooplankton, flocculated material) suspended in the water column. Internal software reconstructs the current profile throughout the water column at a high vertical and temporal resolution. The instruments are also capable of measuring ice displacement as a function of time. This feature will be particularly valuable during fall freeze-up and spring break-up when the landfast ice is mobile. The data will provide us with information on the difference in velocities between the bottom of the ice and the near-surface portion of the water column.

[2]Microcats measure temperature, salinity and water pressure.

[3]Seacats are similar to the Microcats but also measure transmissivity (turbidity).

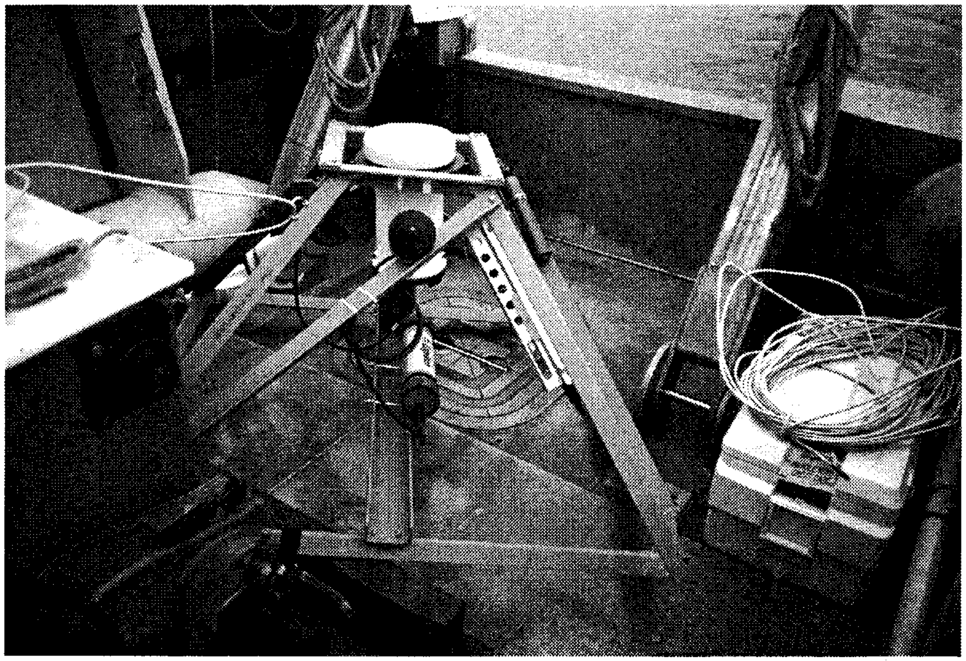

Figure 2. Close up of mooring frame with instrument package.

Figure 3. Frame dimensions in comparison to the 6-ft tall Dr. Okkonen.

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Kinetics and Mechanisms of Slow PAH Desorption from Lower Cook Inlet and Beaufort Sea Sediments

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Abstract

Adsorption and desorption of a polycyclic aromatic hydrocarbon, phenanthrene, by marine sediment and synthetic humic substances is being investigated. The objective is to better understand the phenomenon of slow or incomplete desorption of aromatic hydrocarbons from sediments, and thus to better predict the fate of such contaminants in the marine environment. Experiments completed so far are consistent with previous work, showing strong adsorption by a synthetic humic substance. Phenanthrene partition coefficients do not vary with concentration and adsorption is only partly reversible for reaction times up to two weeks. Initial results suggest that the rates of both adsorption and desorption are influenced by a slow diffusion process.

Introduction

Marine sediments are important reservoirs for many organic contaminants, including polycyclic aromatic hydrocarbons (PAH), which can be derived from petroleum, combustion, and other sources. PAH are of particular concern because many molecules in this class are highly toxic and degrade slowly in the marine environment. PAH can persist in contaminated sediments for at least 20 years after an oil spill [Teal et al. 1992] due, in part, to a strong association between the sediment particles [Means et al. 1980] and the decrease in biodegradability associated with this adsorption [Guerin and Boyd 1992; Braddock and Richter 1998].

Because hydrocarbons have very low solubilities in both freshwater and seawater [Shaw 1989], they tend to partition into other organic phases. One important organic phase is the naturally occurring organic matter that is a part of the marine sediments. The adsorption of hydrophobic compounds by sediments and soils is positively correlated with their organic matter content [Means et al. 1980; Schwarzenbach and Westall 1981; Shaw and Terschak 1998]. Sorption of aromatic hydrocarbons is positively correlated with the nonpolar-to-polar functional group ratio [Garbarini and Lion 1986; Rutherford et al. 1992] and the proportion of the organic structure that is composed of aromatic rings (aromaticity) [Gauthier et al. 1987].

Aromatic hydrocarbons are strongly adsorbed by marine sediments, and adsorption is not rapidly, completely reversible, indicating that this process probably affects PAH retention by contaminated sediments [Brusseau et al. 1991; Hatzinger and Alexander 1995]. In particular, the final report of a CMI-funded project "A study of the adsorption of aromatic hydrocarbons by marine sediments"

[Henrichs et al. 1997], reported that lower Cook Inlet sediments strongly adsorbed phenanthrene, naphthalene, and benzene, and that this adsorption was not completely reversible. Since desorption was carried out for a maximum of three days and using water:particle concentration ratios equal to those used in adsorption experiments, they recognized that adsorption could be reversible under more favorable conditions. For example, Means [1995] found that pyrene adsorption by sediments was reversible, but employed an experimental procedure which would allow even slow desorption of strongly adsorbed hydrocarbons to proceed to completion. The results of Henrichs et al. [1997] were most consistent with the apparently irreversible adsorption being due to diffusion of the hydrocarbons into a 3-dimensional organic structure; reversal of this process would be slow. Although adsorption of aromatic hydrocarbons at several types of sites (with varying partition coefficients) on the particle surface did not explain the observations as well, this remained a possibility.

In another, related CMI-funded project, "Interaction between marine humic acids and polycyclic aromatic hydrocarbons in Lower Cook Inlet and Port Valdez" [Shaw and Terschak 1998], the interactions of PAH with humic acid were investigated. Humic acids are defined as the fraction of organic material isolated from natural waters, soils, and sediments that is soluble in aqueous base but insoluble in aqueous acid [Parsons 1988]. Humic acids are thought to play a central role in the sorption of PAH to soils, with aromaticity being an important quality. Chin et al. [1994] showed that the humic acid–PAH association appears to result from weak dipole interactions between aromatic rings of the PAH and those of humic acids, particularly the aromatic structures derived from lignins of woody terrigenous plants.

Shaw and Terschak [1998] showed that humic substances were strong adsorbers of phenanthrene, consistent with an important role of sediment organic matter in governing aromatic hydrocarbon adsorption. There was marked variation in the adsorptive properties of humics from different sediments that did not support their main hypothesis that aromaticity is positively correlated with PAH adsorption. However, the data did show that phenanthrene was adsorbed less by humic substances extracted from sediment that contained higher concentrations of PAH (or total aromatic hydrocarbons, TARO). One interpretation of this result is that a limited number of strong phenanthrene adsorption sites were present, and were already occupied in the more contaminated sediments, leading to inhibition of further adsorption.

The current project is further investigating the apparently irreversible aromatic hydrocarbon adsorption that was found in Henrichs et al. [1997]. Longer reaction times are being used and studies are employing organic matter extracted from sediments, to better determine the adsorptive properties of sediment humic substances by eliminating variability associated with other sediment constituents. The current project is also investigating the possibility that humic substances from sediments with greater levels of PAH contamination adsorb less phenanthrene because sites that strongly bind PAH are already occupied. This aspect of the work is using laboratory synthesized humic acids, initially free of hydrocarbon contamination.

Methods

All glassware and foil used were cleaned of hydrocarbons or other organic matter by heating to ≥450°C in a muffle furnace. Materials that could not be heated were cleaned with chromic acid. Intertidal sediment samples were collected from the upper section of Jakolof Bay (lower Cook Inlet) during an extreme low tide, –5.9 ft below mean lower low water. Collection was done using a metal implement to remove the upper 1 cm of mud (the oxic layer). This mud was stored frozen in 8-oz glass jars with foil-lined lids.

Synthetic humic acids were made via reaction of glucose and bovine casein [Yamamoto and Ishiwatari 1989]. Glucose was dissolved in 100 mL of a buffer solution (50% 0.1 M KH_2PO_4 / 30% 0.1 M NaOH / 20% glass distilled H_2O). Likewise, casein was dissolved in a separate flask. The two solutions were then mixed together and allowed to reflux for 24 hr. The mixture was allowed to cool and then was centrifuged to remove the insoluble part of the reaction products.

Humic acids were isolated from both the natural sediments and the synthesis reaction mixture using the method outlined by Anderson and Schoenau [1993]. Acid (150 mL of 0.5 M HCl) was mixed with 30 g wet sediment for 10 min to remove debris and acid-volatile inorganic forms of C, N, P, and S. The sample was then centrifuged for 20 min at 5000 rpm. Next, the sediment was washed twice with 150 mL double-distilled water and centrifuged again as above. Then 150 mL of freshly prepared 0.5 M NaOH was added to the sediments or to the supernatant from the humic synthesis reaction. The headspace was flushed with ultra-high purity nitrogen (UHP-N_2) gas to minimize oxidation of the humic and fulvic acids. The sample was then shaken for 20 hr and centrifuged at 5000 rpm for 20 min. The supernatant was decanted into a tared centrifuge bottle and the humic acids were precipitated by the slow addition of about 23 mL of 6 M HCl, until a pH of 1.5 was obtained. The mixture was allowed to stand for 15 min and was then centrifuged for 30 min at 5000 rpm. After centrifugation, the fulvic acid supernatant was discarded and the precipitated humic acid portion was lyophilized at –85°C for 24 hr. The resulting dry humic acid was weighed and stored in a glass vial until needed. The humic acids were characterized by a battery of spectroscopic and chemical analyses, including total organic content, Fourier transform infrared spectroscopy, ultra-violet–visible light spectroscopy, isotopic analyses ($\delta^{13}C$ and $\delta^{15}N$), and cross-polarized magic angle spinning ^{13}C nuclear magnetic resonance spectroscopy.

A standard montmorillonite (A.P.I. #26, 49 E 2600 from Clay Spur, WY) was used as the solid phase to which the isolated humic acids were bound to simulate a marine sediment. The clay was ground for 2 min using a shatterbox equipped with carbide rings and pucks. The resulting powder was passed through a 270-mesh sieve using a Rotap shaker. Organic matter associated with the clay was removed by treating with 30% hydrogen peroxide until no evolution of CO_2 gas was observed. The clay was then centrifuged at 5000 rpm for 30 min, washed with organic-free water, and centrifuged again.

In order to coat the clay, a lyophilized humic acid was dissolved in organic-free water brought to pH = 10 with sodium hydroxide. Once dissolved, the humic acid solution was added to the washed clay and allowed to mix for 24 hr. The suspension was transferred to a centrifuge bottle containing the crystallized salts resulting from the evaporation of an equal amount of artificial seawater and mixed for 48 hr. The suspension was then centrifuged at 5000 rpm for 30 min and the supernatant discarded. After flushing the headspace with UHP-N_2 gas, the humic coated clay was stored in a refrigerator.

Sorption experiments began by weighing 0.1 g of wet, humic-coated clay into 2-dram vials whose caps were lined with Teflon. Five milliliters of artificial seawater solutions containing either phenanthrene or radiolabeled phenanthrene at several concentrations (50, 300, or 700 μg/L) were added to the vials. A 15-second agitation on a vortex mixer thoroughly mixed the clay and solution. The vials were then placed on a table shaker. After sorption for 1 h, 1 d, 3 d, 7 d, or 14 d the vials were centrifuged at 5000 rpm for 30 min and a 1.0-mL aliquot of each of the radiolabeled reaction solutions was removed and scintillation counted. The remaining supernatant, including that from all vials containing phenanthrene without radiolabel, was discarded and fresh phenanthrene solution was added to begin the desorption. Desorption was carried out for 1 d, 3 d, 7 d, 14 d, 30 d, 60 d, or 90 d. Phenanthrene solution (300 μg/L) without radiolabel was added to vials that previously contained radiolabeled phenanthrene, and radiolabeled phenanthrene (also 300 μg/L) was added to vials that previously contained phenanthrene without radiolabel. The vials were vortex mixed as above and returned to the table shaker. At the given desorption times, a group of vials was centrifuged as above and a 1.0-mL aliquot was taken from each supernatant and scintillation counted.

Results and Discussion

Adsorption of phenanthrene by a synthetic humic acid

Figure 1 shows the variation with reaction time of phenanthrene adsorption to synthetic humic acid coated on montmorillonite. Although the partition coefficients on the synthetic humic-coated clay are lower than those on natural sediments, the new results are similar in several ways to the findings reported by Henrichs et al. [1997]. In particular, much of the phenanthrene adsorption occurred within 1 hr, and adsorption was only slightly greater for a reaction time of 3 d relative to 1 d. No clear increase in adsorption was seen at the longer reaction times (7 and 14 d), which were not done in the earlier study. Rapid adsorption reactions (such as ion exchange) that occur at the particle surface are typically complete within minutes in well-mixed systems [Stumm 1992], indicating that phenanthrene adsorption is slowed by factors not affecting such simple cases. Similar to the Henrichs et al. [1997] study, there was no apparent effect of phenanthrene concentration on adsorption for reaction times ≥1 d. Partition coefficients at the three concentrations did range over a factor of two for the 1-hr reaction time, but this is attributable to experimental variability, since small differences in the execution of the experiment, e.g., mixing of the clay and solution, have more effect at short reaction times. Constant partition coefficients with concentration, consistent with the Henrichs et al. [1997] study, indicate that all adsorption sites have similar partition coefficients for phenanthrene and that availability of adsorption sites does not limit adsorption in the concentration range used.

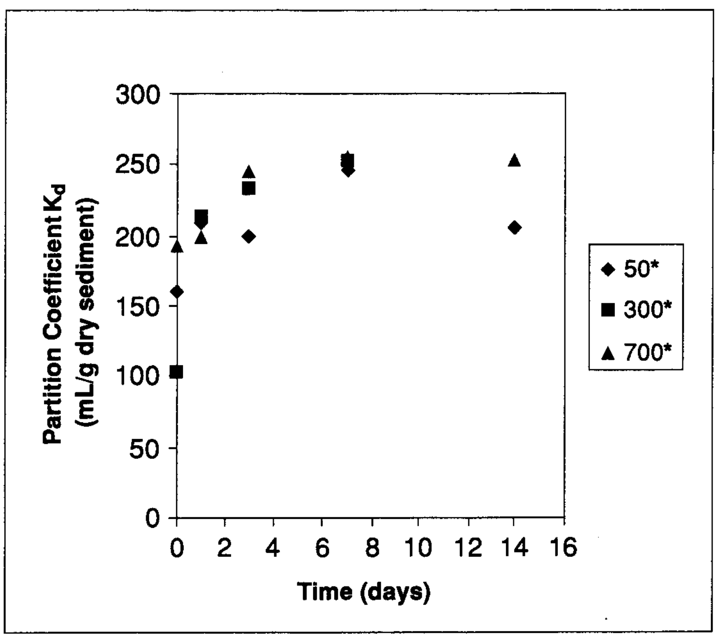

Figure 1. Partition coefficients for phenanthrene adsorption onto a clay coated with synthetic humic acid. *Phenanthrene concentrations in µg/L.

In order to investigate the hypothesis that previous aromatic hydrocarbon adsorption affects subsequent adsorption, phenanthrene was adsorbed to the clay coated with synthetically prepared humic acid. After this "primary sorption", phenanthrene adsorption from a fresh, radiolabeled phenanthrene solution was measured ("secondary sorption"). Figure 2 shows typical secondary sorption (1 to 14 d reaction times) on a humic-coated clay, for which primary sorption of phenanthrene had been carried out over a 3-d reaction time. In all cases, it appears that secondary sorption is less than primary sorption for short reaction times (1 to 3 d), but at longer times the partition coefficients approach the values for primary sorption. The difference between the values for primary sorption and secondary sorption after a 1-d reaction time grow larger as the reaction time for primary sorption increases (Figure 3). However, as the secondary sorption times become longer, primary sorption reaction time has little effect and the quantity of secondary sorption is near that for primary sorption (Figure 4).

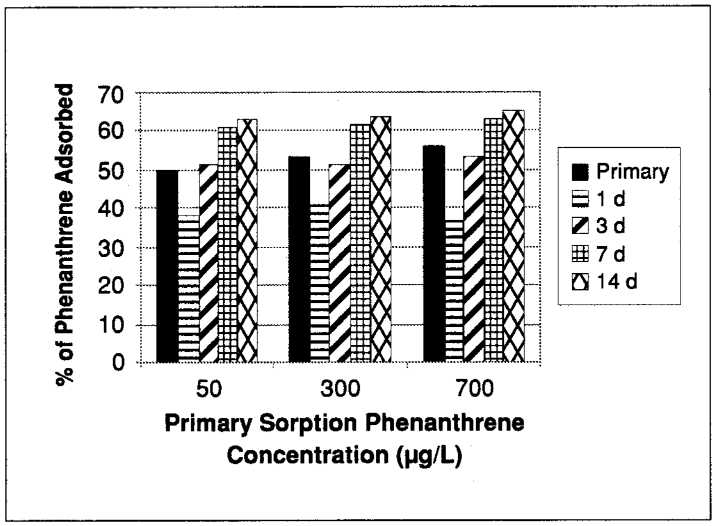

Figure 2. Secondary sorption after three days of primary sorption from solutions containing 50, 300, or 700 µg/L phenanthrene.

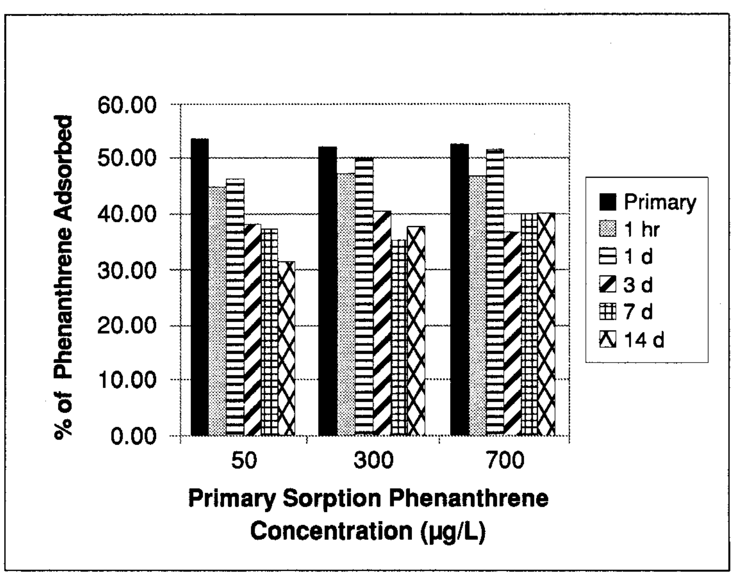

Figure 3. Effect of primary sorption times on secondary sorption at a one day reaction time.

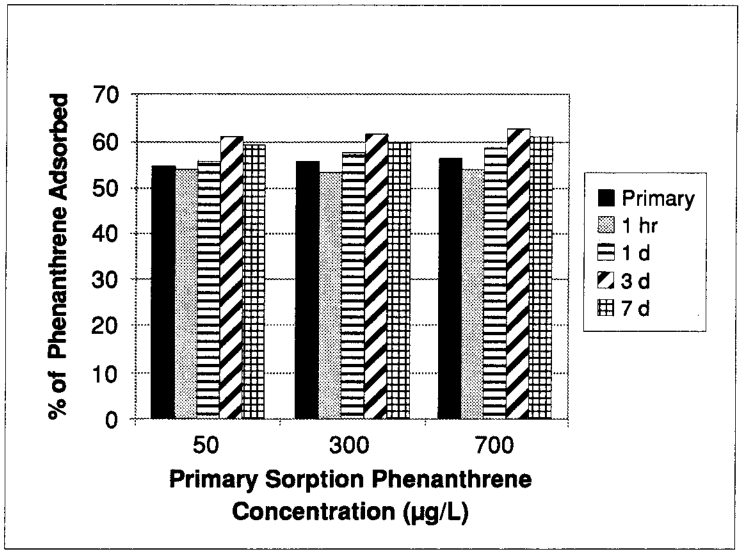

Figure 4. Effect of primary sorption times on secondary sorption at a seven day reaction time.

The results of the adsorption experiments are consistent with one of our hypotheses on the mechanism of phenanthrene adsorption. There appear to be binding sites, probably on or near the surface of the organic coating, where phenanthrene adsorption and desorption are rapid. However, there are additional sites where both adsorption and desorption are slower. A plausible explanation is that some phenanthrene diffuses slowly into small water-filled volumes within the three-dimensional organic matrix, or moves to sites within the organic coating via a slow process of surface diffusion. During the secondary sorption reaction, the slow diffusion limits the rate at which new phenanthrene exchanges with that sorbed during the primary sorption step. The diffusion rate during the secondary sorption should decrease with increasing primary phenanthrene adsorption, because the concentration gradient into the organic matter coating would decrease.

Desorption of phenanthrene from a synthetic humic acid

The reverse processes were examined by measuring the percent of an adsorbed phenanthrene that dissolved when the clay was recovered and resuspended in a fresh, 300 µg/L phenanthrene solution. An expected desorption value was calculated based on the assumption that sorption was completely reversible at a given reaction time, and that all adsorption sites had the same phenanthrene partition coefficient. Deviations from the expected value indicate that the desorption reaction was slow relative to the reaction time, there was more than one type of binding site for phenanthrene on the particle surface, or there was another deviation from the idealized adsorption process.

Figure 5 shows typical desorption data for reaction times ranging from 1 to 14 d, and the corresponding expected value calculated for idealized adsorption. For this example the adsorption reaction time was 1 hr. Unexpectedly, longer desorption times decreased the total amount of phenanthrene desorbed. In all but two cases, the values are consistently below the idealized prediction. There are several possible interpretations of the results, which will be better discriminated when all of the planned experiments are completed. On first examination, the results seem inconsistent with the adsorption results described above. Based on the adsorption experiments it was expected that desorption would increase with time and approach the idealized values, as adsorbed phenanthrene slowly diffused out of the organic matter, but instead desorption decreased with increasing desorption time. However, the desorption results could be due to the same slow diffusion processes that seem to explain the adsorption data. The initial adsorption reaction probably was incomplete, since in this example the adsorption reaction time was only one hour. In this case, the desorption results would reflect continued diffusion and adsorption of phenanthrene on new sites within the organic coating, as well as desorption of some of the adsorbed phenanthrene. An additional possibility is that adsorption sites that bind phenanthrene more strongly than most exist within the humic acid coating and are relatively inaccessible, so that adsorption at these sites is very slow. (These sites are not on the clay mineral surface because separate experiments have shown only weak adsorption to the clay.) Although the concentration vs. adsorption data (Figure 1) do not indicate the presence of more than one type of adsorption site, desorption data are much more sensitive indicators [Ding 1998]. Another possibility is that there is a gradual conformational change in the humic coating, associated either with the phenanthrene adsorption itself or with prolonged suspension in aqueous solution, that changes either partition coefficients, accessibility of adsorption sites, or both.

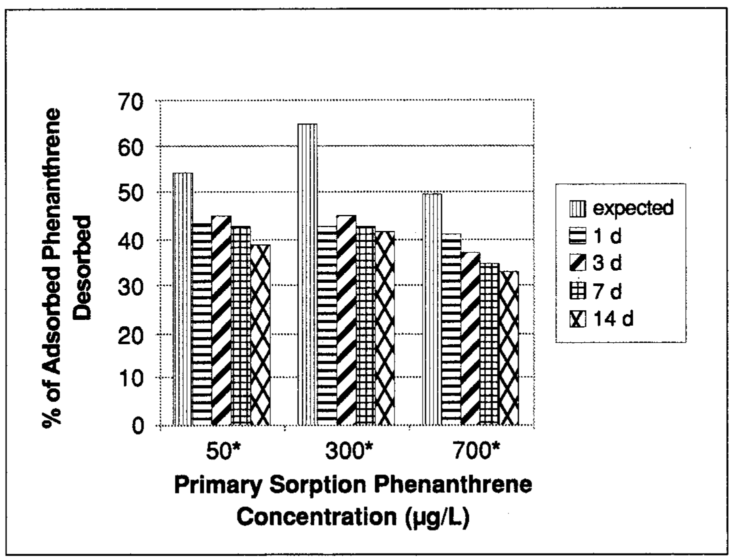

Figure 5. Effect of time on desorption, after primary sorption with a one hour reaction time. *Phenanthrene concentration in primary sorption step.

Preliminary Conclusions

The results obtained so far are consistent with the interpretation that phenanthrene adsorption and desorption are slow processes because of slow diffusion of phenanthrene in the organic matter coating clay particles used in the experiments. The results help to further explain observations of Henrichs et al. [1997] and Shaw and Terschak [1998]. In particular, the partly irreversible adsorption Henrichs et al. [1997] observed in relatively short experiments can be thus explained, but our new results suggest that complete desorption, if it occurs at all, will require many weeks. The new results are also consistent with Shaw and Terschak's [1998] observations that humic substances from sediments with high PAH initially adsorb less phenanthrene, but suggest that this is a short-term effect that disappears if exposure times are longer than a few days.

Future Work

This project will conclude in June 2001. The current experiment, which provided data for this report, will continue in order to provide longer desorption times (30, 60, and 90 d). Also, adsorption and desorption properties of additional synthetic humic acids, with varying aromaticity, will be studied. The synthetic humic acids will be compared to those extracted from natural sediments from lower Cook Inlet, Port Valdez, and the Beaufort Sea.

Study Products

Terschak, J.A. 1999. Humic acids & hydrocarbons: CMI déjà vu? Oral presentation at the MMS office in Anchorage, October 1999.

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An Experimental Approach to Investigate Seasonal Differences in the Role of Zooplankton in the Distribution of Hydrocarbons

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Task Order 15171

Abstract

This project investigates the role of zooplankton in distributing oil components and the effects of hydrocarbons on copepod reproduction. Copepods are thought to contribute to the distribution of oil components in three ways: 1) through the food chain, 2) through sedimentation of oil-laden feces, and 3) through incorporation of hydrocarbons in reproductive tissue and delayed release of eggs. Due to their seasonally high abundance, the copepods Neocalanus *spp. and* Pseudocalanus *spp. are important prey for various fish and birds. The production of fecal pellets and pseudofeces by these species enhances sedimentation rates of ingested material, possibly including polyaromatic hydrocarbons (PAH) from oil. Sedimented organic matter is consumed by benthic suspension and detritus feeders and PAH may enter benthic food chains by this pathway. Finally, due to their lipophilic properties, PAH adhere to storage lipids, which are mostly diverted into egg material. This distribution pathway may result in a reintroduction of PAH into the surface food chain in the subsequent season, when copepod larvae ascend.*

Oil exposure experiments with the copepods Neocalanus *spp. and* Pseudocalanus *spp. and with the pteropod* Limacina helicina *and the euphausiids* Thysanoessa *spp. will be conducted. Lipid samples will be analyzed for the ratio of triglycerides, phospholipids and wax esters. Due to the lipophilic properties of PAH, a positive correlation between total lipid content and PAH uptake is expected. Establishment of a correlation coefficient between total lipid content and PAH uptake will make estimates of the PAH load of predominant plankton on the basis of abundance data and their lipid profile possible.*

Objectives and Progress

Zooplankton are collected with a 16-ft skiff, using a hand-drawn ring net to a maximum depth of 120 m. Twelve daytime and three nighttime sampling trips were made in Auke Bay and adjacent waters between mid May and August 2000. Due to a general shortage of *Neocalanus* spp. in the area, the calanoid copepod *Calanus marshallae* was substituted in the experiments. Along with *Metridia* spp., *Calanus marshallae* represents the second largest copepod biomass in Prince William Sound after *Neocalanus* spp. Euphausiids were not encountered during day sampling with zooplankton nets. At night, predominantly subadult stages of *Thysanoessa raschi* were collected and one experiment was conducted with these specimens. No specimens of the pteropod *Limacina helicina* were encountered in the area. Early attempts to sort *Pseudocalanus* spp. females for experiments were unsuccessful due to low numbers of the species in the samples. However, *Pseudocalanus* spp. females have their peak abundance between July and October and efforts are currently concentrated on this species.

Development of a successful and reproducible experimental design for oil exposure experiments with zooplankton is a major objective of this project. Substantial progress has been made in this regard. Generators were developed that consist of glass tubes filled with oiled glass beads. Effluent PAH concentration can be estimated from the volume of the glass beads, their surface area, the film thickness of the oil on the beads and the flow rate. Five kilograms of glass beads were treated with weathered North Slope crude, dried and frozen to assure a uniform oil source for all subsequent experiments. A peristaltic pump was purchased to ensure stable flow rates. Experiments have been conducted with the following objectives:

a) to show variability between columns at start of the experiment;

b) to show if and how the concentration of the test water decreases over the extent of the experiment;

c) to show whether saturation of copepods and euphausiids is achieved;

d) to determine the exposure time required to reach equilibrium in tissue; and

e) to ensure the sample size is adequate (15–20 *Calanus marshallae*).

Water and tissue samples were extracted at the National Marine Fisheries Service Auke Bay Laboratory and were frozen for gas chromatographic and PAH analyses to be conducted this October.

Although no exact data have been collected on the concentration of the PAH effluent of the columns to this date, some evidence of the functionality was provided by two experiments on the combined toxicity of PAH exposure and ultra-violet light. While a 24-hr PAH exposure alone did not impact vitality or behavior of copepods, and UV exposure alone had little effect, the combination of both PAH and UV exposure resulted in noticeable impairment to mobility. These preliminary experiments strongly suggest that PAH dosing is in the sublethal range and that PAH are acquired in copepod tissue during a 24-hr exposure.

To address the lipid composition of forage plankton and its seasonal variability, and the significance of lipid content and composition for the accumulation of hydrocarbons in body tissue, a sample was collected and frozen immediately after each sampling. These samples have been stored at –80°C for later processing and analysis. Mean total lipid content per individual will then be related to the mean PAH content of the exposed specimens from the same sampling event.

The effects of previous oiling on egg production and hatching rates of copepods are to be tested in culture experiments. A feasibility study was conducted in August 1999, in which females of *Pseudocalanus* spp. were cultured in culture wells over four days and their egg production was monitored. Production rates of these unoiled copepods were less than reported in the literature. Several factors may have affected production: varying temperatures in the cultures, insufficient food supply, or decline of production rates in the late season. However, the goal of the study was to test the methods for further experiments with oiled and unoiled females. Stable temperatures can be assured in future experiments.

Further, *Neocalanus* spp. females and fifth stage copepodites (CV) were cultured. While survival of CV was poor, some females survived in culture for more then three months, developed gonads and extruded eggs, which hatched in culture.

Between June and August 2000 similar experiments were conducted with *Calanus marshallae*. Twenty-four unoiled females were cultured and monitored for egg production and survival rates for more then five weeks. Egg production varied between 0 and 80 eggs per female, averaging 27. Nineteen females (79%) spawned in culture, all laying one or two clutches of eggs before they stopped spawning. Copepods were not fed in the cultures.

In mid July, 11 females were included in a 24-hr oil exposure experiment at low PAH dosage. Eleven control specimens were kept in culture at about 7°C. Subsequently, egg production and mortality were monitored. The large individual differences in production rates did not allow for evaluation of productivity differences in this experiment. Only two of the oiled and four of the control specimens spawned. No difference in egg vitality was observed in this experiment. However, after 19 days in culture, oiled females had significantly higher mortality rates then control females (Figure 1). This could be a delayed effect of the oil exposure when lipid reserves are utilized and PAH that were stored in the lipids were metabolized. However, these observations need further careful investigation, because of a temperature difference between the exposure flasks and the reference cultures during the time of exposure.

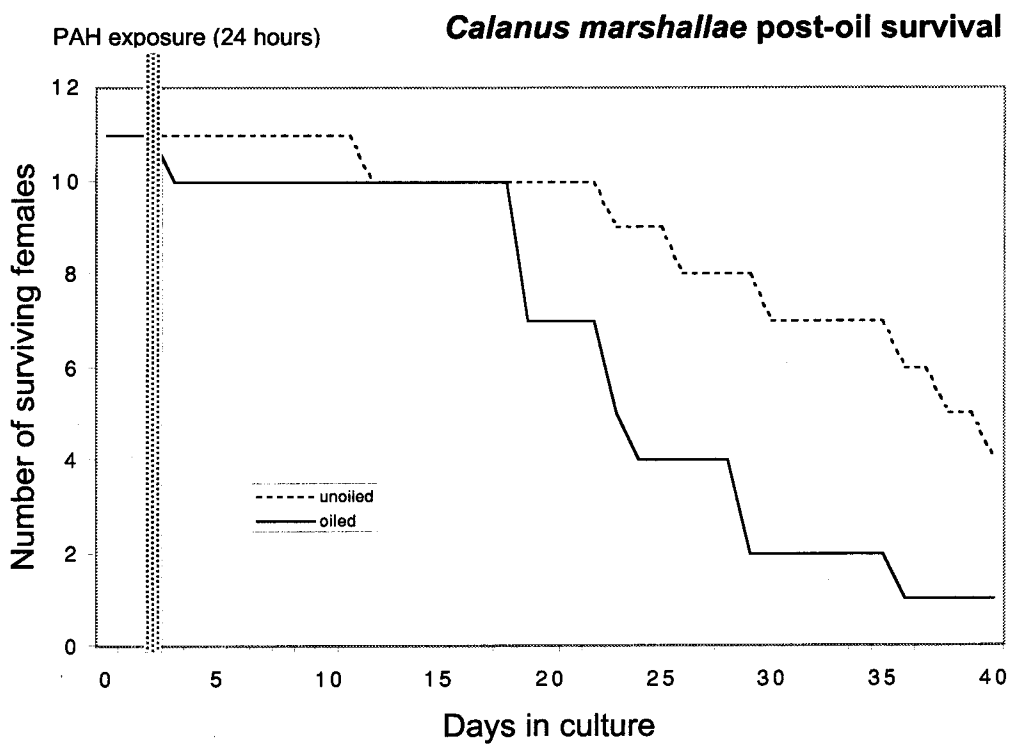

Figure 1. Survival of female *Calanus marshallae* following 24-hr oil exposure.

Experiments to collect fecal material from oiled and unoiled copepods require high abundances of test species and a concentrated sampling effort, because many specimens are needed to produce an adequate sample size for analysis. The low abundances of zooplankton precluded experiments which would test PAH concentrations in fecal pellets.

Study Products

1. Duesterloh S., and T. Shirley. 2000. An experimental approach to investigate seasonal differences in the role of zooplankton in the distribution of hydrocarbons. Oral report of research progress at the University of Alaska Coastal Marine Institute Annual Research Review, March 2000, Fairbanks.
2. Duesterloh, S. 2000. An experimental approach to investigate seasonal differences in the role of dominant zooplankton in the distribution of hydrocarbons. Oral presentation at Juneau Student Chapter of the American Fisheries Society Symposium, April 2000, Juneau, AK.
3. Shirley, T.C. 2000. An experimental approach to investigate seasonal differences in the role of zooplankton in the distribution of hydrocarbons. Seminar summarizing research progress at Minerals Management Service office, March 2000, Anchorage.
4. An article for Onchorhynchus, the newsletter of the Alaska Chapter of the American Fisheries Society, was submitted in June 2000, but has not yet been published.

Seabird Samples as Resources for Marine Environmental Assessment

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Task Order 15173

Abstract

If analyses contrasting places or events in time are to continue to be used to monitor stability or change in the environment among biological systems, archival samples of these biological systems must be routinely preserved. Birds are excellent environmental indicators, and can be thought of as small biological filters sampling various aspects of marine ecosystems. In preserving samples of these 'filters' we enable present and future analyses to determine such diverse questions as changes in contaminant levels, causes for population changes, nature of the genetic stocks affected, and other issues related to Outer Continental Shelf (OCS) activities. These analyses grow more important each day as we attempt to determine the rate and characteristics of natural and anthropogenic changes.

Marine birds are an important component of the higher marine trophic levels, making them desirable to a broad array of researchers. Demands by researchers for seabird specimens for analyses of contaminants, stable isotopes, genetics, and morphology have recently exceeded available holdings, making it clear that the pitifully low influx of such specimens must change if research of this nature is to continue. By supporting a graduate assistantship to process marine bird specimens, this project is making such sample preservation both active and less geographically and taxonomically haphazard than in the past. In the first year of this project, more than 220 seabirds have been prepared and archived as skin, skeleton, and tissue samples in the University of Alaska Museum (UAM). Two important research projects have been supported, and visiting researchers have also been using this material.

Introduction

The birds of Alaska that depend on marine environments comprise a complex array of more than 100 species occupying three trophic levels. These birds are a major component of Alaska's marine ecosystems and are vulnerable to both natural and anthropogenic changes (e.g., Outer Continental Shelf activities). This is a particularly sensitive group of marine organisms because they are protected by international treaties with such countries as Russia, Japan, Canada, and Mexico. Also, many are a source of food for humans. Birds have long served our society as environmental indicators, and specimens representing baseline conditions have been crucial for documenting both natural and anthropogenic changes.
Perhaps the most widely recognized example of this was the use of historic museum egg collections to demonstrate the effects of increased concentrations of DDT on the reproduction of birds occupying higher trophic levels (e.g., Peregrine Falcons, *Falco peregrinus*).

The ability to process, archive, and retrieve biological samples in support of environmental research has become an increasingly important function of natural history museums. But with limited resources to apply to broad taxonomic, geographic, and scientific demands, museums do well to cover even a few areas well. Because many of the researchers making sample requests to the University of Alaska Museum are engaged in studies directly relevant to the Framework Issues of interest to the Minerals Management Service (MMS), this project was proposed as a partnership with MMS, through CMI, whereby marine bird samples are actively brought in and preserved for this research community. Requests for Alaska marine bird samples vary widely, from studies of temporal contrasts of contaminant levels and stable isotope ratios, to comparative systematic studies of population and species-level genetics and morphology, to synoptic studies for the identification of archaeological material. This collection, though limited in its holdings, provides these researchers with a substantial percentage of the samples pertinent to their questions. It is clear that this science could be substantially strengthened if more samples were available, and this project was developed to meet this objective through the establishment of a half-time graduate assistantship to focus on processing marine bird samples.

This project is separate from other sample preservation projects and fills a major gap in present sample archiving efforts. It complements existing projects and addresses an obvious weakness in the preservation of samples of higher marine organisms. Our objectives are to preserve and make available to the research community a substantially increased number of marine and coastal bird samples from Alaska for studies ranging from contaminants and stable isotopes to genetics and morphology. It is clear that this is not occurring anywhere at levels sufficient to meet the needs of this research community, and that the UA Museum is in a unique position to effectively address this need. In pursuing this goal we make possible the testing of numerous hypotheses, particularly those addressing environmental changes from events such as contaminations and other OCS activities impacting Alaska's marine environments.

Our goal of maximizing the usefulness of each individual bird to the scientific community leads us to preserve, when possible, a combination skin/skeleton prep, two tissue samples, and stomach contents from every bird. We use no chemicals in the preparation process, except when a specimen is particularly fatty; in these cases the fat remaining after fleshing the skin is often removed with a solvent (e.g., mineral spirits). Skin and skeleton preparations are archival in quality, and are expected to last for centuries. Tissue samples are placed in two, 2-mL plastic cryovials and archived at –80°C in the Alaska Frozen Tissue Collection (AFTC). Stomach contents are preserved in isopropyl alcohol.

Results

With notification of funding approval during summer 1999, the graduate assistantship that this project supports was widely advertised. The response was very good, and Deborah Rocque was selected to join UAF as a Ph.D. student in the fall of 1999. Deb received a Master's degree at the University of Connecticut, where she gained experience studying contaminants in birds. This is therefore a particularly appropriate match to the position. Deb had not prepared bird specimens before arriving here, but during this first year she has become a proficient preparator and has thus far prepared excellent series of seabird specimens. Becoming proficient as a preparator takes considerable time and skill, and both ornithology collections manager Dan Gibson and I have been impressed with how quickly and how well Deb has mastered the processes involved.

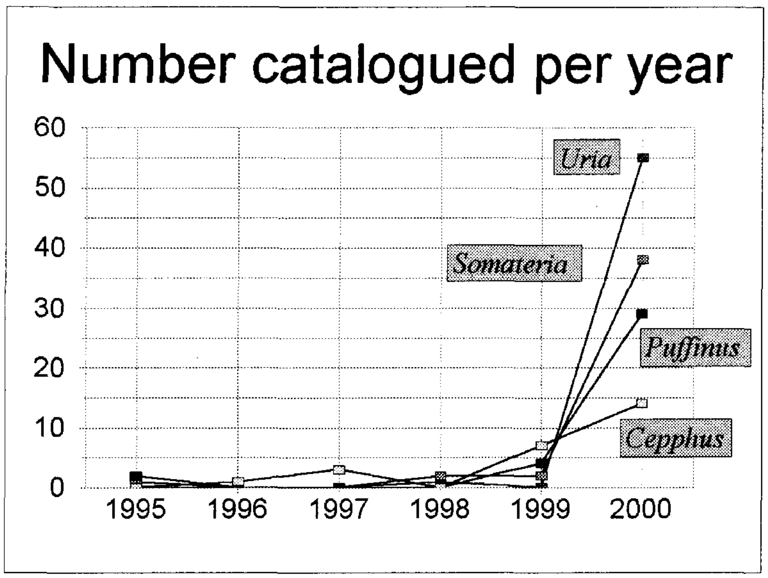
More than 220 specimens were prepared during this first year, representing a diverse array of seabird genera, including: *Fratercula*, *Clangula, Somateria, Gavia, Phalaropus, Melanitta, Histrionicus, Cepphus, Stercorarius, Uria, Rissa, Puffinus, Aethia, Brachyramphus,* and *Larus*. Key localities represented are Barrow, the Chukchi Sea, Cook Inlet, and scattered localities around the Bering Sea.

Dan Gibson and I are in the process of cataloguing those birds prepared so far, and we are rearranging the entire collection to make room in proper taxonomic sequence for continued additions of seabirds.

We are still communicating with AMMTAP (Alaska Marine Mammal Tissue Archival Project) regarding sampling protocols and the possibilities of depositing samples with them. Their avian efforts are still restricted to eggs so far, but we have agreed to serve as an archival repository for the eggshells that their sampling generates.

Collection Growth

The graph below shows what an immediate impact this project is having on samples of key seabird genera in the UAM bird collection. It is equally important to realize that these samples, representing unique points in time and geographic space, are not being replicated elsewhere.



Collection Use

Two loans of seabird samples that occurred this year go straight to the heart of the purpose behind this project. One was for Vicki Friesen's (Queen's University, Ontario) genetics study comparing Prince William Sound seabird populations with Aleutian populations unaffected by the *Exxon Valdez* Oil Spill. This request demonstrated the importance of having comparative material available from outside of areas affected (or potentially affected) by petroleum development. Some of these birds were processed specifically to meet this request. Another loan made was to George Divoky for a retrospective study of mercury loads as reflected in feathers (Arctic Ocean). Another loan of seabird samples for stable isotope analyses was made, and we received two independent visits from researchers to work with UAM eider specimens.

Discussion

Having the ability to process seabirds and notifying people that we'd like to receive birds from them has begun to create a good snowball effect: we have a lot of seabirds coming in. In the forthcoming year we anticipate receiving enough birds from the Arctic Ocean, Cook Inlet, and the Chukchi Sea to saturate our preparation abilities. Everything is in accordance with the proposed timeline and the project is going well.

Acknowledgments

We are grateful to all biologists who obtain dead seabirds, label and freeze them, then deposit them with the University of Alaska Museum. Particularly important on this project thus far have been the efforts of Robert Suydam, Alan Springer, Jeff Williams, Vernon Byrd, John Piatt, Shannon Fitzgerald, and Paula Cullenberg. This work is conducted under a series of permits from the U.S. Fish and Wildlife Service, CITES (Convention on the International Trade in Endangered Species of Wild Fauna and Flora), the Alaska Department of Fish and Game, and U.S. Department of Agriculture Animal and Plant Health Inspection Service (USDA-APHIS). We thank permitting officers for their continued facilitation of permits and related matters.

Beaufort and Chukchi Sea Seasonal Variability for Two Arctic Climate States

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Task Order 15174

Abstract

Arctic navigation, oil and gas exploration, and arctic pollutant transport depend on arctic environmental conditions. Existing atlases, manuals and reference books contain multiyear mean environmental variables and their multiyear mean seasonal variability; however, uncertainties sometimes result from the existing atlases because they do not take climate change and climate variability into account. Our project work is motivated by the recent finding of two regimes (or two climate states) of arctic atmosphere–ice–ocean circulation described by Proshutinsky and Johnson [1997]. Based on our recent work, we expect that seasonal variations in ice concentration, ice thickness, and ice drift; ocean currents, ocean temperature, and salinity; horizontal and vertical heat fluxes; atmospheric pressure, wind speed, cloudiness, and precipitation; river discharge; and permafrost temperatures are different for cyclonic and anticyclonic arctic climate states. The major goal of this research is to document the atmospheric, ice, oceanic and terrestrial signals showing seasonal variability of environmental parameters during cyclonic and anticyclonic climate states in the Beaufort and Chukchi seas. During the first year of the research we analyzed observational data to document seasonal variability of the Beaufort and Chukchi seas, including environmental characteristics for the cyclonic and anticyclonic arctic climate regimes.

Introduction/Background

The Proshutinsky and Johnson [1997] results indicate that wind-driven motion in the Arctic alternates between anticyclonic (ACCR) and cyclonic (CCR) circulation with each regime persisting for 5–7 years (the period is 10–15 years), based on analysis of modeled sea level and ice motion. Anticyclonic wind-driven motion in the Arctic and in the Beaufort Sea appeared during 1946–1952, 1958–1962, 1972–1979, 1984–1988 and 1998–present; cyclonic motion appeared during 1953–1957, 1963–1971, 1980–1983, and 1989–1997. Shifts from one regime to another are forced by changes in the location and intensity of the Icelandic Low and the Siberian High. These transformations from one regime to another can be defined as climate shifts in the Arctic Ocean and occur quite rapidly. In very general terms, for the traditional and historically well-known anticyclonic circulation, high atmospheric pressure prevails over the Arctic Ocean during anticyclonic ice and surface water motion in the Arctic Basin. The arctic atmosphere is termed "cold and dry" and the Arctic Ocean is termed "cold and salty". In the cyclonic climate regime, low atmospheric pressure prevails over the Arctic, and surface ice and water motion are cyclonic. The arctic atmosphere is termed "warm and moist" and the ocean is termed "warm and fresh". For each regime these terms describe general conditions in ice concentration, salinity, and ocean–atmosphere heat flux, which are expected to be highly variable over the Beaufort and Chukchi seas. The two regimes of arctic climate explain the significant basin-scale changes in temperature, salinity and circulation that have been recently observed, and are a major influence on both past and present variability of ice and ocean conditions. The existence of these two regimes of circulation provides the foundation and motivation for the research proposed here. We believe that the fundamental changes in Arctic Ocean circulation and arctic climate [e.g., Quadfasel 1991; Rudels et al. 1994; Steele and Boyd 1998; Smith 1998; Tanaka et al. 1995; Walsh et al. 1996; Zhang et al. 1998] may account for the inferred changes based on recent Arctic Ocean measurements that led Carmack and Aagaard [1996] to conclude that "remarkable new observations call for a revised conceptual model of the Arctic Ocean, and a re-thinking of theory and process parameterization." The two-climate regime theory may help explain some of these problems related to observed variability in the Arctic Ocean, and the different conclusions among scientists who have analyzed hydrography data, water circulation, ice thickness and ice motion, and other parameters. Analyses of regional sea ice anomalies have been linked to the cyclonic circulation regime dominant in recent years [Serreze et al. 1995; Maslanik and Dunn 1998; Maslanik et al. 1998]. However, existing atlases of environmental parameters and reference books do not describe this climate variability.

Hypotheses/Objectives

Hypothesis:

The two climate states, anticyclonic and cyclonic, dominate interannual variations in environmental parameters. Preliminary results reveal significant differences among atmosphere, ice, and ocean processes during the anticyclonic and cyclonic regimes in the Arctic Ocean and particularly in the Beaufort and Chukchi seas. Figure 1 shows seasonal variability of some of these parameters and demonstrates the expected range of their differences in terms of magnitude and direction between two climate regimes. Based on existing data and results of numerical experiments, we conclude that during the anticyclonic circulation regime the prevailing processes lead to increases in atmospheric pressure in the Arctic, in ice concentration and ice thickness, river runoff, and surface water salinity, as well as to decreases in air temperature, wind speed, number of storms, precipitation, permafrost temperatures, coastal sea level, and surface water temperature. As a result of the dynamic–thermodynamic processes we expect that the rate of land–shelf and shelf–basin interactions (transport of ice, fresh water, sediments, pollutants) will be lower than usual during the anticyclonic circulation regime.

During the cyclonic circulation regime the prevailing processes lead to increased air and water temperatures, wind speed, number of storms, open water period, and heights of wind waves, and to decreases in ice thickness and ice concentration, river runoff, atmospheric pressure, and water salinity. These processes will enhance the magnitude and rate of land–shelf and shelf–basin interactions. Cross-shelf transport of sediments and contaminants will be promoted and sediments and contaminants will be flushed out of the coastal regions and shelves.

This project has several broad objectives:

- Do a quality control of the existing data and analyze temporal and spatial variability of the environmental fields at seasonal and interannual time scales. These fields will be analyzed using standard statistical methods, time series analysis, and empirical orthogonal function (EOF) analysis.
- Average existing data for the periods of cyclonic and anticyclonic regimes of circulation. The averaged fields will then be used for analysis of differences in ice drift and water circulation between the two regimes.

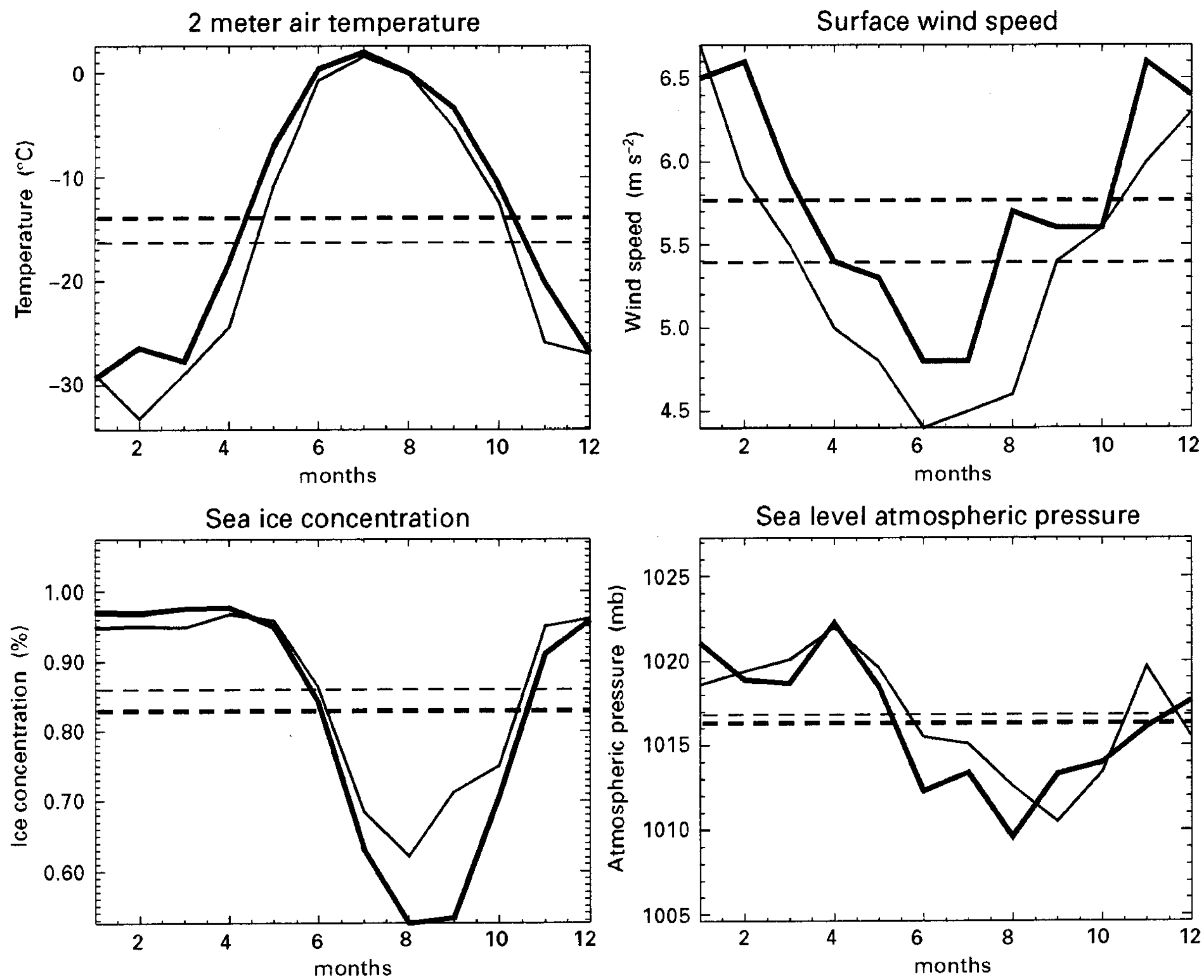

Figure 1. Atmospheric parameters for the cyclonic (thick lines) and anticyclonic (thin lines) climate states.

Results/Progress

Data collection/processing

During the reporting period we have been working on data collection and partial analyses of the existing information. Monthly mean sea level atmospheric pressure (SLP) fields were reconstructed for the period 1899–1998. Sea ice concentration satellite derived data (1978–1996) and the Arctic and Antarctic Research Institute *AARI 10-Day Arctic Ocean EASE-Grid Sea Ice Observations* (1953–1990) were obtained from the Earth Observing System Data and Information System, National Snow and Ice Data Center (EOSDIS, NSIDC) Distributed Active Archive Center, at the University of Colorado at Boulder. We obtained some water temperature and salinity data from the *Joint U.S.–Russian Atlas of the Arctic Ocean* [1997]. In this atlas, water temperature and salinity are gridded and averaged in time for the periods 1950–1959, 1960–1969, 1970–1979 and 1980–1989. These atmospheric, ice and oceanic data were analyzed and re-processed for the purposes of our project (interpolation into the Beaufort and Chukchi seas model grid, analyses of seasonal variability for the anticyclonic and cyclonic climate states).

We obtained water temperature and salinity data from *The Polar Science Center Hydrographic Climatology* (PHC) [Steele and Morley 1999], a global physical oceanographic atlas found at the University of Washington web site: http://psc.apl.washington.edu/Climatology.html. We simulated ice drift and water circulation to analyze ice and water trajectories during years with the cyclonic and anticyclonic circulation regimes.

Seasonal cycle of the atmosphere

Observational data form the basis for this section. Assuming that the sea level atmospheric pressure (SLP), winds, surface air temperature (SAT), precipitation, and cloudiness are different for the CCR and ACCR, we have averaged them separately over years with either the cyclonic or anticyclonic regimes. Resulting seasonal cycles of the atmospheric parameters are discussed below.

Seasonal variability of SLP for the two circulation regimes are presented in Figure 1 (lower right). A center of high SLP is located over the Beaufort Sea during the mean ACCR year, except in August and September (not shown). Anticyclonic winds prevail from October through July. In August and September the atmospheric circulation becomes cyclonic. When the CCR dominates in the Arctic, the Icelandic Low is intensified and a tongue of low SLP propagates to the north (not shown). From June through September the center of low pressure is located in the vicinity of the North Pole, where it generates cyclonic winds. Even in October and December the isobars have a cyclonic curvature in the central Arctic. The center of high SLP is well developed over the Beaufort Sea in January, April and November only. Detailed analysis of the SLP during ACCR and CCR years is presented in Johnson et al. [1999]. During the ACCR the SLP is higher overall than during the CCR everywhere in the Arctic. In August the SLP is lower by about 4 hPa during the CCR, compared with the ACCR. Figure 1 (upper right) shows the seasonal variability of geostrophic winds: in general, wind speed is higher for CCR, especially in summer, than for ACCR.

Air temperature and cyclonic activity

The daily SAT (2 meter) data used in this analysis are derived from buoys, manned drift stations, and all available land stations [Martin and Munoz 1997; Rigor et al. 1997]. The seasonal variability of SAT is presented in Figure 1 (upper left). The mean ACCR winter is colder than the mean CCR winter everywhere in the Arctic. The SAT difference between mean ACCR and CCR years tends to decrease from regions adjacent to the North Atlantic toward the Pacific Ocean, reaching its minimum in the Beaufort Sea. The maximum temperature difference of 9°C is in March in the central arctic region. The ACCR and CCR SAT in summer are practically equal. Arctic warming during the CCR is related to advection of heat from the North Atlantic due to atmospheric circulation. According to Proshutinsky and

Johnson [1997], the 1990s were CCR years. Enhanced cyclonic activity may cause increased cloudiness associated with a warmer arctic winter during the CCR compared with the ACCR.

Arctic ice seasonal cycles

Our investigations of the relationships between large-scale atmospheric circulation indices and ice severity in the Beaufort/Chukchi region take advantage of a variety of data sets and model results. Using historical data augmented by remotely-sensed products, the variability of late-summer ice extent in the Alaskan sector of the Arctic Ocean is seen to be quite variable over the past 45 years (Figure 2). The unusually large reductions in ice cover in the late 1990s are also apparent, including the record minimum ice extent in the Beaufort/Chukchi region in 1998. Comparison of this time series to the series of the intensity of cyclonic/anticyclonic circulation in the Arctic Basin does not suggest any significant, direct correlation. However if we average ice concentration for the years with the cyclonic and anticyclonic circulation regimes (see Figure 1, lower left), one can see that the ice concentration generally decreases during the cyclonic circulation regime and increases during the anticyclonic regime (in summer, of course).

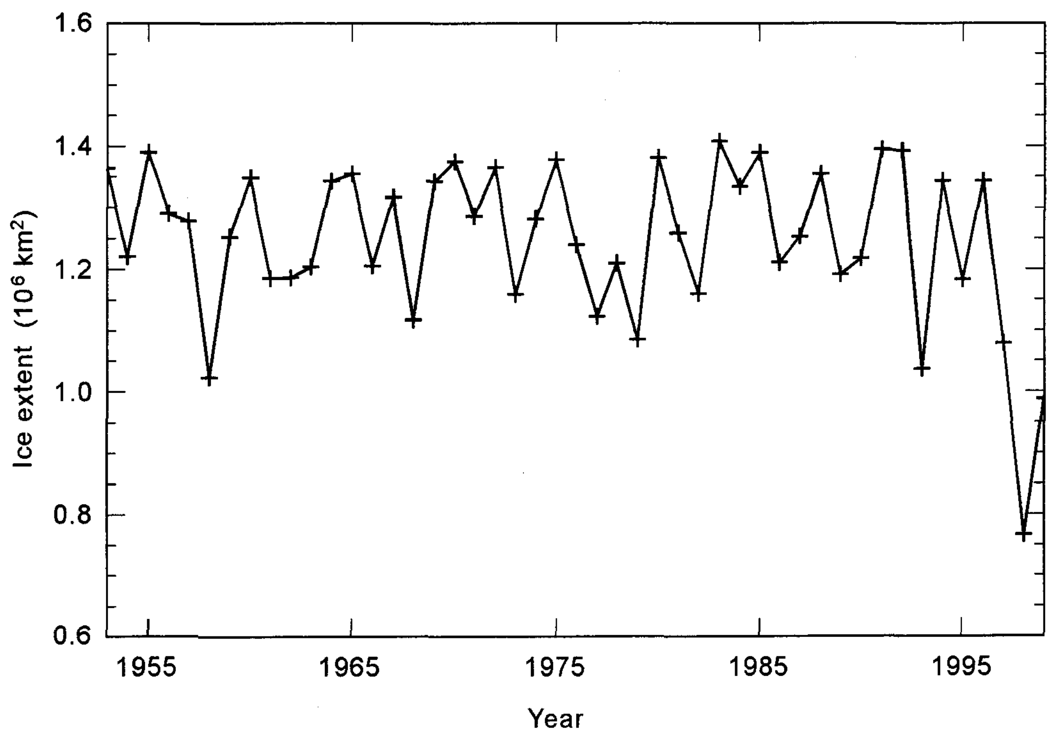

Figure 2. Sea ice extent at the end of September in the Beaufort/Chukchi region for 1953–1999. Note that the two years with lowest ice extent were 1998 and 1999. See Maslanik et al. [1999] for a description of region and data sets used.

Figures 3 and 4 depict mean ice motion and mean multiyear ice concentration during cyclonic and anticyclonic years, respectively. The data shown were obtained from SMMR and SSM/I satellite data spanning the period from 1979–1997, and represent averages of monthly means for the years indicated in the figures. The mean ice motion captures the basic circulation patterns associated with cyclonic and anticyclonic atmospheric conditions. Ice drift during cyclonic years (Figure 4) shows a weakened Beaufort Gyre, with the center of the gyre shifted to the east. As a consequence, ice flows into the central Arctic and Transpolar Drift Stream from the Siberian Arctic. The western boundary of the gyre transports ice more northward in the Chukchi Sea than during anticyclonic years, with a decreased southward flow in the eastern portion of the gyre. The effects of these differences in drift patterns between cyclonic and anticyclonic years are consistent with the differences seen in multiyear ice concentration and extent in the figures. During anticyclonic years, the concentration of multiyear ice is increased in the eastern portion of the Beaufort Sea, with higher concentrations extending farther southward into the southern Beaufort and Chukchi seas. During cyclonic years, the northward transport in the western side of the Beaufort Gyre may be contributing to the reduction in southward extent of the multiyear ice in the Chukchi Sea. From our analyses of National Ice Center ice charts for these and other years, the passive microwave-derived estimates of the extent of the multiyear icepack appear reasonable. Our work to date suggests that the late-winter multiyear ice extent may provide a useful indicator of the potential for ice retreat during the following summer [Maslanik et al. 1999]. Multiyear ice extents in spring 1997, 1998, and 1999, for example, correspond reasonably well to the subsequent ice edge limit at the end of the melt season. The time series of end-of-summer ice extent in the western Arctic (Figure 3) indicates that the large reduction in multiyear ice extent that followed the record melt-back year of 1998 was followed by another season of well-below-normal ice extent in 1999. In 1999, the summer ice pack was relatively diffuse, with a reduced ice concentration over large areas. The potential existed for reductions in ice extent similar to or exceeding that of 1998. However, unlike 1998, southerly winds did not develop to drift this weakened, diffuse ice pack further northward.

We plan to continue investigation of these relationships between atmospheric circulation, ice drift, and ice pack characteristics to determine the degree to which the types of relationships discussed above may provide an improved ability to predict the likelihood of heavy vs. light ice conditions in the Beaufort and Chukchi seas. In addition, we intend to consider whether basic changes in ice conditions, such as a general thinning of the ice pack, could lead to different responses by the ice–atmosphere system. For example, winter 1998 was mainly a period of anticyclonic atmospheric circulation, yet multiyear ice extent was well below normal in winter, followed by record ice reductions in summer. Thus, continued work is needed to assess how basic circulation modes interact with more localized atmospheric patterns and underlying ice conditions.

Acknowledgements

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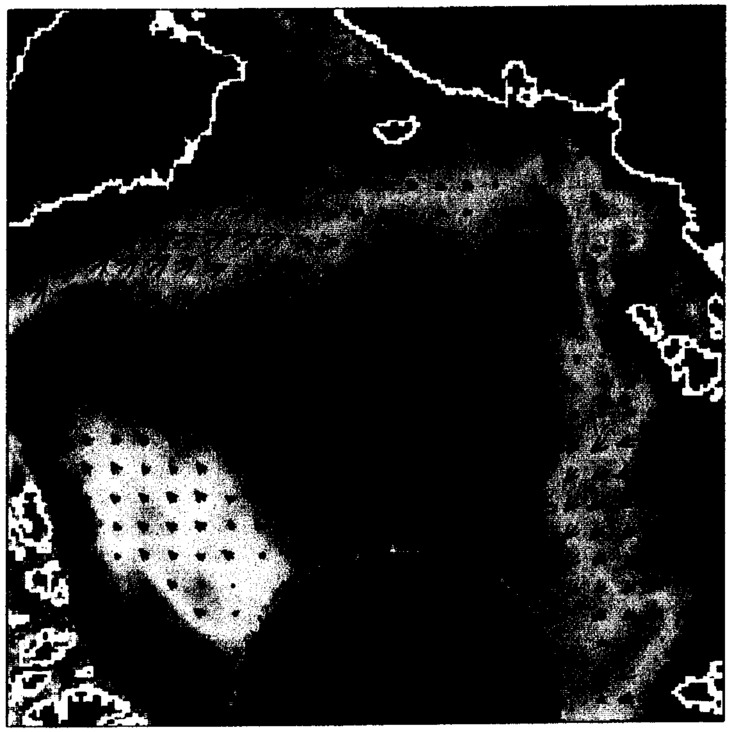
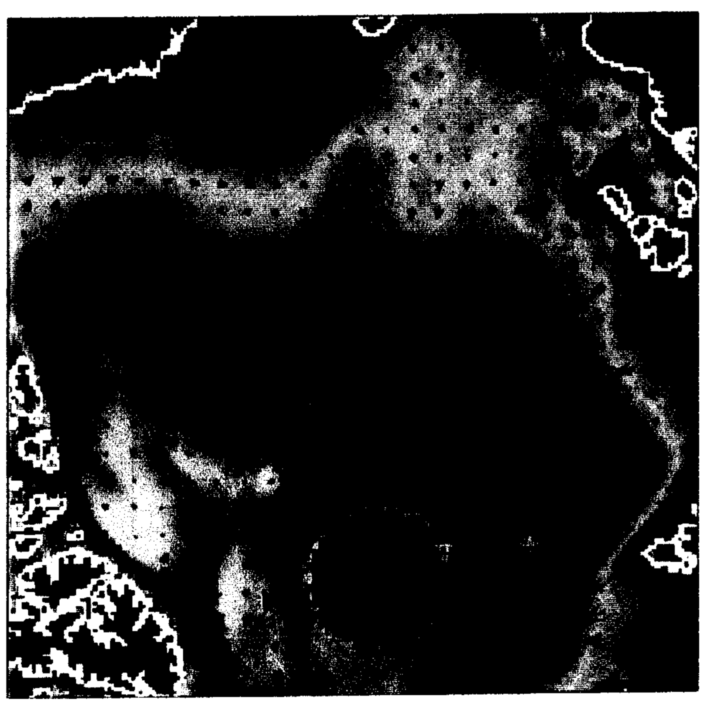


Years 1979, 1980, 1981, 1983, 1984

Figure 3. Mean ice motion during anticyclonic years (December–March).



Years 1985, 1986, 1988, 1989, 1990, 1991, 1993, 1995, 1996, 1997

Figure 4. Mean ice motion during cyclonic years (December–March).

Study Products

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Petroleum Hydrocarbon Degrading Microbial Communities in Beaufort Sea Sediments

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Abstract

Despite large-scale development on the North Slope, no recent studies examining Alaskan arctic marine sediment microbial communities and their ability to metabolize petroleum compounds have been published. Microbial degradation of spilled petroleum hydrocarbons is a major mechanism of removal of these compounds from the environment. In this study we initiated a survey of marine sediment microbial populations in the Arctic Ocean to determine what microorganisms are present and what their metabolic capability is for degradation of various petroleum hydrocarbons. We also began a series of laboratory studies to examine the bioavailability of the polycyclic aromatic hydrocarbon, phenanthrene, to microorganisms in the presence of sediments collected near Barrow, Alaska. In our survey we found high total numbers of microorganisms in the sediments examined (approximately 10^9 cells/g dry wt sediment). Only about 10^6 of these organisms were culturable in a marine heterotroph medium. Most probable numbers of culturable phenanthrene and hexadecane degraders were fairly high, ~ 10^4/g dry wt sediment each. Mineralization potentials were low for both hexadecane and phenanthrene. Despite the low organic carbon content of these sediments ($\leq 1.5\%$), substantial adsorption to particles occurred; adsorption was rapid. Laboratory bioavailability studies using these same sediments are ongoing. The results of this study will be useful in predicting the fate of spilled petroleum hydrocarbons in the Arctic Ocean.

Introduction

The response to recent lease sales in the Beaufort Sea suggests that Beaufort Sea offshore oil development projects will be increasing in number and frequency over the upcoming decade. Increased offshore oil and gas production can lead to both chronic and acute additions of petroleum hydrocarbons to the arctic marine environment. One important unanswered question in this context is: "What is the long-term fate of petroleum hydrocarbons spilled in the Arctic Ocean?"

Following the *Exxon Valdez* oil spill (EVOS), the most recent high-latitude large oil spill for which published studies are available, the fate of EVOS oil was determined from the most complete and accurate mass balance of any oil spill [Wolfe et al. 1994]. The most significant term in the mass balance was approximately 50% of the spilled oil that biodegraded either in situ on shorelines or in the water column. It is apparent that the microbial component was the most important of the mechanisms determining the long-term fate of EVOS oil in Prince William Sound (PWS). As noted by Sugai et al. [1997], prediction of hydrocarbon persistence following a spill requires systematic ecosystem-level studies of the abiotic and biotic factors influencing biodegradation. Among these many factors are nutrient availability, oxygen tension, presence of fine-grained sediments, and presence of an acclimated community of hydrocarbon-metabolizing microbes [Leahy and Colwell 1990].

In contrast to the many EVOS-generated studies of oil impact and fate, relatively little information is available regarding the potential fate or persistence of oil spilled in the Beaufort Sea. The marine environment of the Beaufort Sea is quite different from that in PWS, so data from the EVOS studies should be extrapolated to the Beaufort Sea environment with caution. Microbial studies conducted in the 1970s and 1980s [Atlas et al. 1978; Haines and Atlas 1982] found that hydrocarbon-degrading microbes generally increased following oil contamination, but petroleum hydrocarbons were degraded very slowly. In general, following initial abiotic losses from their experimental systems, biodegradation of oil was limited and did not significantly alter the chemical composition of the residual oil. The authors found that oil is degraded in arctic sediments very slowly; biodegradation was only detectable after a full year of exposure of oil to the sediments. They pointed to several factors limiting biodegradation. These included limited populations of hydrocarbon-metabolizing microbes, localized high concentrations of hydrocarbons, low temperatures, unfavorable C:N and C:P ratios, low oxygen tensions and limited circulation of interstitial waters in fine-grained sediments. They also noted that abiotic weathering of the oil was also slow, with "limited loss of low molecular weight aliphatic and aromatic hydrocarbons during 2 years' exposure."

Despite large-scale development on the North Slope, no recent studies examining Alaskan arctic marine sediment microbial communities and their ability to metabolize petroleum compounds have been published. In year one we conducted a survey of Arctic Ocean offshore sediments near Barrow, Alaska, and evaluated the sediment microbial communities for their ability to metabolize petroleum hydrocarbons. In addition, laboratory acclimation studies using field sediment were used to estimate the adaptability to hydrocarbon metabolism of extant microbial communities. Sediment samples collected were also split and archived cryogenically for potential later analysis of microbial community structure by DNA or phospholipid fatty acid analysis. Samples were also collected for laboratory-based studies on the effects of sediment sorption on bioavailability of petroleum hydrocarbons. These latter studies are designed to assess the effects of Arctic Ocean sediments on biodegradability of petroleum fractions known to be toxic (e.g., phenanthrene or other polynuclear aromatic hydrocarbons).

Methods and Materials

In the first year of this project we focused our efforts on sediments collected near Barrow, Alaska. Sampling occurred 24–25 July 1999. Samples were collected in Elson Lagoon, offshore the former Naval Arctic Research Laboratory (NARL), and offshore the town site of Barrow (see Table 1 for specific locations). At each sampling location five sites were selected and at each site triplicate grabs were taken for a total of 45 sediments collected. From each grab, sediment samples were collected with a disinfected metal spoon. Each replicate sample was placed into sterile containers and kept cold until processing. Additionally a 15-mL cryovial was filled from each grab sample to be frozen and preserved to have available for genetic or fatty acid analysis at a later date. Samples for microbial analysis were chilled until being returned to the laboratory in Fairbanks. Cryovials were frozen (–20°C) as soon as possible (within ~4 hr of collection) and stored frozen until returned to Fairbanks, at which point they were transferred to an ultracold freezer (–80°C). The unfrozen sediments were then analyzed for existing hydrocarbon degradation potential as well as hydrocarbon degradation acclimatization potential.

Table 1. Sampling locations for this study were Elson Lagoon (E), offshore the former Naval Arctic Research Laboratory (NARL; N), and offshore Barrow (B). Three grabs were collected at each of five sampling sites at each location. Latitudes and longitudes were recorded from a handheld GPS unit once at the Elson Lagoon sampling sites and each time a grab was taken at the offshore NARL and Barrow sites.

Sampling Location	Latitude	Longitude	Approximate Depth (m)
E 1	71° 20.035′ N	156° 33.584′ W	1.8
E 2	71° 19.176′ N	156° 32.473′ W	2
E 3	71° 17.529′ N	156° 24.707′ W	3–4
E 4	71° 22.824′ N	156° 26.775′ W	3
E 5	71° 21.176′ N	156° 30.889′ W	2–3
N 1-1	71° 20.000′ N	156° 42.878′ W	10
N 1-2	71° 19.957′ N	156° 42.973′ W	
N 1-3	71° 19.942′ N	156° 42.986′ W	
N 2-1	71° 20.025′ N	156° 42.356′ W	8
N 2-2	71° 19.944′ N	156° 42.523′ W	
N 2-3	71° 20.006′ N	156° 42.689′ W	
N 3-1	71° 19.976′ N	156° 41.519′ W	6
N 3-2	71° 19.986′ N	156° 41.572′ W	
N 3-3	71° 19.986′ N	156° 41.572′ W	
N 4-1	71° 19.880′ N	156° 40.975′ W	5
N 4-2	71° 19.871′ N	156° 41.009′ W	
N 4-3	71° 19.863′ N	156° 41.031′ W	
N 5-1	71° 19.811′ N	156° 40.606′ W	5
N 5-2	71° 19.811′ N	156° 40.634′ W	
N 5-3	71° 19.808′ N	156° 40.634′ W	
B 1-1	71° 18.109′ N	156° 46.089′ W	3
B 1-2	71° 18.110′ N	156° 46.084′ W	
B 1-3	71° 18.111′ N	156° 46.074′ W	
B 2-1	71° 18.175′ N	156° 46.494′ W	4
B 2-2	71° 18.174′ N	156° 46.502′ W	
B 2-3	71° 18.174′ N	156° 46.502′ W	
B 3-1	71° 18.305′ N	156° 47.042′ W	7
B 3-2	71° 18.279′ N	156° 47.164′ W	
B 3-3	71° 18.274′ N	156° 47.162′ W	
B 4-1	71° 18.067′ N	156° 47.419′ W	7
B 4-2	71° 18.067′ N	156° 47.419′ W	
B 4-3	71° 18.067′ N	156° 47.420′ W	
B 5-1	71° 18.260′ N	156° 47.992′ W	14
B 5-2	71° 18.118′ N	156° 47.880′ W	10
B 5-3	71° 18.102′ N	156° 47.904′ W	14

Microbial population and activity assays to determine the existing potential of the sediments were initiated within two days after returning to Fairbanks. Analyses included estimates of total, heterotrophic, crude oil emulsifying, and substrate-specific degrader microbial populations, and assays for metabolic activity. Data derived from these assays was pooled (i.e., six values for each assay from each sampling site) to generate mean and standard error estimates. In addition, some samples were analyzed for total carbon content at the UAF Mass Spectrometer Facility and others were analyzed for particle size composition at the University of Washington Analytical Services Laboratory (see Table 2).

Table 2. Particle size analysis and percent carbon content of selected Arctic Ocean sediment samples.

Sampling Location	%C	Size Class (%)			
		rock > 2 mm	sand 2–0.05 mm	silt 0.05–0.002 mm	clay < 0.002 mm
Elson Lagoon					
Site 1	0.088, 0.093	x	92.5	1.25	6.25
Site 2		x	55.0	20.75	16.25
Site 3		x	54.0	10.0	36.0
Site 4		x	3.75	43.75	52.5
Site 5		x	46.25	27.5	26.25
Offshore NARL					
Site 1		x	14.0	54.0	32.0
Site 2	1.59, 1.50	x	26.0	52.0	22.0
Site 3		x	74.0	10.0	16.0
Site 4		x	93.75	2.50	3.75
Site 5		x	96.25	2.50	1.25
Offshore Barrow					
Site 1	0.044, 0.044	9.22	79.36	2.27	9.07
Site 2		x	86.2	5.05	8.75
Site 3*		x, x, x	83.75, 70.0, 58.0	3.75, 10.0, 20.0	12.5, 20.0, 22.0
Site 4		22.6	26.3	18.6	32.5
Site 5		x	50.0	24.0	26.0

*Five samples (grabs) were collected at each site. Only one sample was analyzed for particle size except at Barrow Site 3 where three different samples were analyzed to assess variability at a given site.

Microbial population analyses included most-probable-number assays (MPNs) for crude oil emulsifiers [Brown and Braddock 1990], marine heterotrophs [Lindstrom et al. 1991], substrate specific assays for phenanthrene and hexadecane [Braddock and McCarthy 1996; Wrenn and Venosa 1996; Braddock and Catterall 1999], and total microscopic direct counts of marine microbes [Braddock et al. 1990]. Activities, as well as numbers, of specific types of hydrocarbon degraders were assessed using a technique for extracting kinetic data from the cultures set up for enumeration [Lindstrom et al. 1998]. Selected samples were also spiked with ^{14}C-labeled hydrocarbons in microcosms. To prepare each microcosm, 10 mL of a 1:10 sediment slurry in a mineral salts medium (Bushnell Haas; Atlas [1993]) was added to a previously sterilized, 40-mL septum vial (I-Chem Research, Hayward, CA). After the microcosms were constructed, 50 µL of a 2-g/L solution (in acetone) of radiolabeled hydrocarbon was added by syringe to each vial through the septum. The resulting initial concentration of added hydrocarbon was then 100 µg per vial (10 µg/mL culture broth; radioactivity ca. 50,000 dpm). Substrates used (Sigma Chemical Co., St. Louis, MO) included the alkane hexadecane (1-^{14}C-labeled), and the polynuclear aromatic hydrocarbon (PAH) phenanthrene (9-^{14}C-labeled). Each treatment was replicated five-fold, and killed controls were used to check for abiotic $^{14}CO_2$ evolution. Vials were incubated at 8°C for 96 hours, killed by adding NaOH to stop respiration, and assayed for $^{14}CO_2$ from hydrocarbon mineralization [Brown et al. 1991].

To begin to understand the acclimation potential of the microbial population and to understand the effect of the presence of particles on biodegradation, enrichment flasks were set up, as well as abiotic microcosms, to assess the adsorptive properties of the sediments collected. An additional set of experiments in the presence of hydrocarbon degrading populations (bioavailability experiments) is ongoing and will not be reported here.

Phenanthene solutions for adsorption experiments were prepared using [9-^{14}C]phenanthrene (10.0 mCi/mmole, 98% purity; Sigma) dissolved in spectranalyzed acetone (99.7% pure; Fisher). Fifty microliters (ca. 50,000 dpm) of a stock solution was injected into 10 mL of the appropriate sediment slurry to yield final phenanthrene concentrations of approximately 1.25, 2.50, 3.75, or 5.0 ng phenanthrene/mL slurry (the solubility of phenanthrene is ~ 1.0 µg/mL in pure water at 25°C; [Shaw 1989]).The chemical extractability of sorbed phenanthrene was determined for each sediment slurry concentration (1, 2%). Microbial activity was inhibited by autoclaving. Samples were spiked with 50 µL of the appropriate [9-^{14}C]phenanthrene stock solution to yield final concentrations as indicated for each experiment. Triplicate vials of each sediment and phenanthrene concentration were incubated as indicated depending on the experiment. No aging (0 day) samples were extracted as soon as practical after spiking the samples. All glassware was washed, combusted and autoclaved before use. To extract the phenanthrene from the samples, the vials were first centrifuged at approximately 3000 × g for 1 min after which 2.5 mL of the supernatant was removed. This fraction is indicated as the aqueous phase phenanthrene concentration.

Results and Discussion

Particle size analysis indicated variability in samples in the distribution of sand, silt or clay (Table 2). In the three samples analyzed for organic carbon content, all were very low (~ 1.5% or less).

Direct counts of microorganisms in sediments collected at all sampling locations indicate healthy populations (~ 10^9 cells/g dry wt sediment) of microorganisms present in surface sediment from Elson Lagoon and offshore Barrow and NARL (Figure 1). These numbers are consistent with total direct counts on average of 2×10^9 cells/g dry wt sediment reported by Kaneko et al. [1978] for the Beaufort Sea. The cultivatable marine heterotrophs were lower (on average about three orders of magnitude lower) than direct counts. These numbers are also consistent with Kaneko et al. [1978], who found approximately 10^5 heterotrophic microorganisms/g dry wt sediment. Phenanthrene and hexadecane degraders were between 10^3 and 10^4 cells/g dry wt sediment. Even after a long incubation period for the sheen screen plates (crude oil degraders) we found little to no activity present for any sediment (data not shown).

While populations of microorganisms are present in these Arctic Ocean sediments, their ability to readily degrade petroleum hydrocarbons appears to be limited. The 96-well plate kinetic data were hampered by very slow growth rates of phenanthrene and hexadecane degraders. In addition, mineralization potentials for phenanthrene and hexadecane were uniformly low (Table 3). These sediments universally showed higher potential for mineralization of the linear alkane, hexadecane, than the polycyclic aromatic hydrocarbon, phenanthrene. A further indicator of low activity is that our efforts to enrich for a consortium that degrades both hexadecane and phenanthrene have thus far had limited success. We are continuing our efforts to find an isolate or consortium appropriate for the bioavailability experiments.

To begin to understand the adsorptive properties of these Arctic Ocean sediments we initiated a series of isotherm assays (Figure 2). NARL sediment most rapidly adsorbed phenanthrene, a result consistent with the somewhat higher organic carbon content measured for this sediment (Table 2). Aging generally led to increased partitioning into the sediment fraction. The adsorption isotherms were used to calculate partition coefficients (Kp) under various experimental conditions (Table 4). The NARL sediment was clearly the most adsorptive of the three sediments examined.

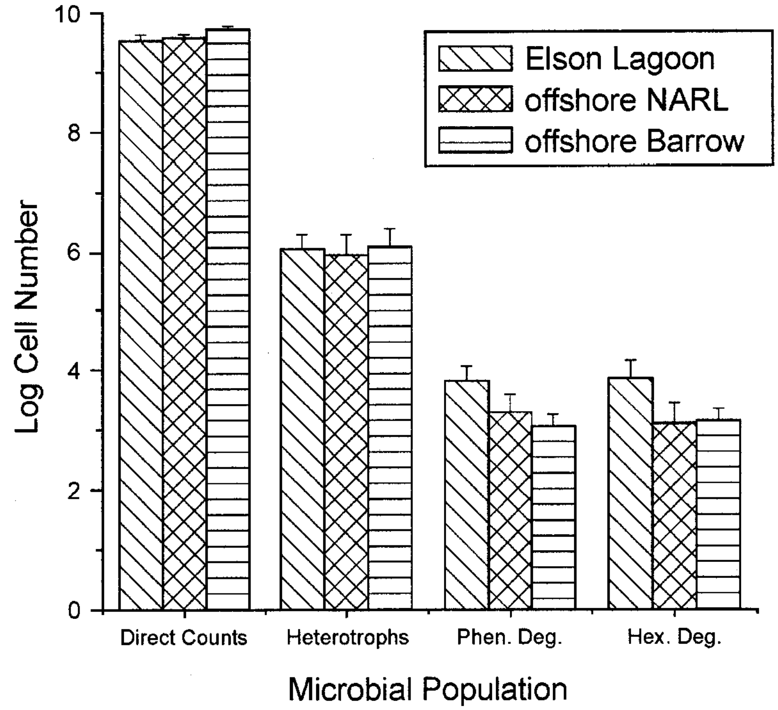

Figure 1. Microscopic direct counts and most probable numbers of heterotrophs, phenanthrene degraders, and hexadecane degraders from sediments collected near Barrow, Alaska in July 1999. Data represent the mean of 15 sediments from each sampling location (five sites per location and three grabs per site) ± one standard error.

Table 3. Mineralization potentials of Arctic Ocean sediments collected August 1999. Values shown are the mean (± SE) of five replicate microcosms.

Sampling Location	**Mineralization Potential (ng substrate mineralized/g dry wt sediment)**	
	Hexadecane	Phenanthrene
Elson Lagoon		
Site 1	46 ± 4	12 ± 1
Site 2	90 ± 5	21 ± 2
Site 3	56 ± 2	15 ± 2
Site 4	127 ± 6	30 ± 4
Offshore NARL		
Site 1	100 ± 15	15 ± 2
Site 2	86 ± 5	15 ± 3
Site 3	62 ± 7	13 ± 1
Site 4	59 ± 4	19 ± 1
Offshore Barrow		
Site 1	57 ± 2	12 ± 1
Site 2	38 ± 4	7 ± 1
Site 3	35 ± 4	11 ± 1
Site 4	134 ± 4	39 ± 2
Site 5	51 ± 4	18 ± 2

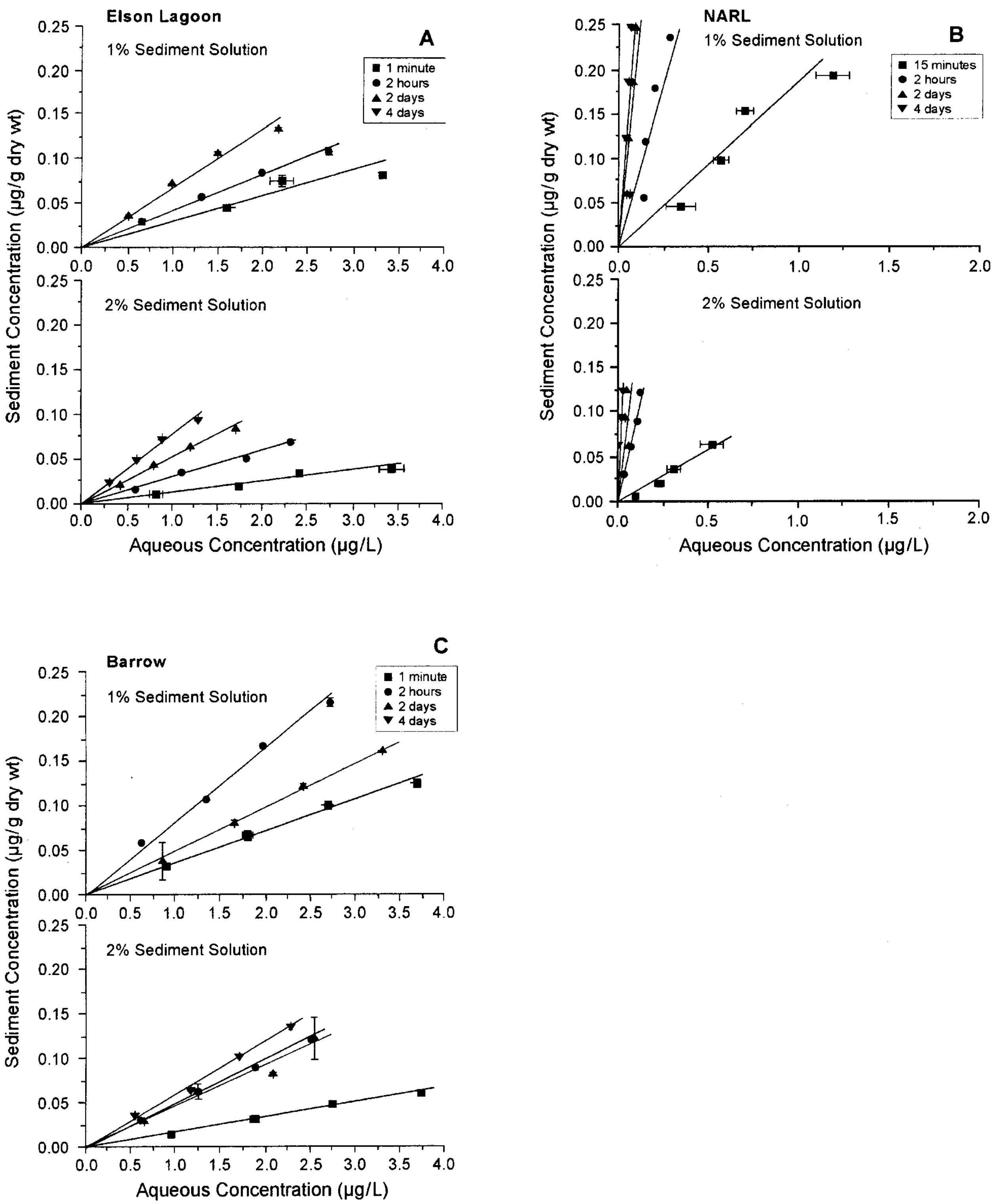

Figure 2. Phenanthrene in solution versus phenanthrene associated with sediment particles after various reaction times for sediments collected near Barrow, Alaska in July 1999. Experiments were conducted in microcosms with either 1 or 2% sediment slurries. Data points are the mean of triplicates ± one standard error.

Table 4. Partition coefficients (Kp) for phenanthrene in experiments using 1 or 2% sediment slurries.

Sampling Location	**Reaction Time**	**Kp (mL/g)**	
		1% Sediment	2% Sediment
Elson Lagoon	1 minute	26.7	11.9
	2 hours	40.1	28.5
	2 days	64.2	50.3
	4 days	ND	74.7
Offshore NARL	15 minutes	170	231
	2 hours	774	825
	2 days	2130	1610
	4 days	2410	4590
Offshore Barrow	1 minute	35.5	16.8
	2 hours	81.4	48.1
	2 days	49.2	45.0
	4 days	ND	58.9

ND = no data as experiment was not performed under those conditions.

These results indicate that sediment microbial populations have not changed appreciably since 1976. High numbers of microorganisms exist in these sediments, many of which were culturable with either hexadecane or phenanthrene supplied as a sole carbon source. However, mineralization potentials were low relative to other sites (e.g., Prince William Sound Alaska [Braddock et al. 1990]) indicating that the population may only slowly acclimate to biodegradation of these hydrocarbon substrates. Adsorption isotherm experiments with the polycyclic aromatic hydrocarbon, phenanthrene, indicate rapid and extensive adsorption. The three sediments examined in these experiments did show differences in their adsorptive properties. This is likely due in part to differences in organic carbon content and to other unidentified differences among the sediments. Bioavailability experiments are ongoing with these sediments. In addition we have recently collected approximately 30 samples from offshore Prudhoe Bay and will use these sediments to continue our survey to characterize the sediment microbial community in the Arctic Ocean.

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Regional Economic Impact Analysis of Subsistence Bowhead Whaling: Accounting for Non-Market Activities on Alaska's North Slope

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Task Order 15176

Abstract

A fresh look at subsistence economies is needed. This project addresses the use of comprehensive economic methodologies to depict non-formal subsistence sectors prevalent in rural Alaska economies. These methodologies will be applied to subsistence bowhead whaling off the north coast of Alaska, specifically in the Beaufort Sea. A projected result is the provision of an important baseline assessment for communities with mixed subsistence and cash economies. Subsistence activities, whaling in particular, are difficult for contemporary researchers to evaluate or to quantify in a format understandable by western social scientists. What makes this even more difficult is the respected reluctance, for cultural reasons, of those participating in subsistence activities to express the importance of these activities in modern economic or value-based terms. Working in partnership with the Alaska Eskimo Whaling Commission, the North Slope Borough Department of Wildlife Management and the Barrow, Kaktovik, and Nuiqsut communities will ensure accurate and reliable information and ownership of the information by community members.

Introduction

Subsistence whaling for beluga and bowhead whales has been a part of the culture of the Inupiat people in the Bering Strait region, along the Siberian and Alaskan shores of the Chukchi Sea, the Beaufort Sea, and at other locations for centuries. It is a part of the subsistence way of life [Brower and Opie 1996; Hepa and Brower 1997]. The present harvest of both species is currently limited to nine whaling villages in northwest Alaska. Harvest is regulated by quotas imposed by the International Whaling Commission (IWC) and allocated, monitored, and enforced by the Alaska Eskimo Whaling Commission (AEWC) .

The AEWC was formed to deal with crises in the hunt of the bowhead whale in the late 1970s. A lack of information about the population and need for the bowhead is regarded as the cause of the restrictive harvest quota by the IWC. The bowhead is important to the Inupiat. Millions of dollars were spent to determine population and village needs. The North Slope Borough (NSB) Department of Wildlife Management devoted most of its efforts until the mid 1990s to help resolve bowhead whale related issues [Brower and Opie 1996; Hepa and Brower 1997]. Thus, the residents of the NSB, by furnishing better information, were able to protect their use of the bowhead whale resource.

This study concentrates on the impact of oil and gas activity on the mixed economy of subsistence bowhead whaling on the northern coast of Alaska. Beluga whales are also hunted but the bowhead is the most important [Braund 1993]. The communities of Barrow, Kaktovik, and Nuiqsut are the most impacted by oil and gas exploration and extraction activities. Barrow is the largest of the three communities and is located the farthest west (250 miles) from Prudhoe Bay. Kaktovik and Nuiqsut are on the coast of the Beaufort Sea; the Beaufort and the Chukchi seas bound Barrow. The three community economies receive revenue from property taxes on businesses related to oil and gas production located in and around Prudhoe Bay. This revenue helps to support both the subsistence and cash inputs to the community by residents.

The Inupiat's knowledge and view of the world is changing, along with their expectations. Rapid modernization of rural/village communities has occurred in recent years [Worl 1986; Pedersen et al. 1999]. These "improvements" from past conditions have changed lifestyles. The changes require a cash outlay for capital improvements and operating expenses for schools, health facilities, sanitation, and water supplies. Capital outlays for amenities that enhance subsistence pursuits and the new quality of life are escalating [Geier 1993; Wheeler 1992]. Concomitant with these changes is the often lack of capital/cash in communities with limited economic opportunity. This lack of opportunity to participate in the cash economy can affect participation in subsistence hunting, fishing, and gathering.

Subsistence whaling is a significant socio-cultural focus in arctic coastal communities. It not only reinforces the extended family structure, since most whaling crews tend to be formed along family lines, but also helps to reinforce and maintain intercommunity bonds through sharing of subsistence harvests and cultural activities [Stoker and Krupnik 1993; Freeman 1993]. Although subsistence whaling is important in the cash economy because of the goods and services purchased, it is of much greater cultural importance to all whaling villages and to the Inupiat community as a whole.

It is difficult for those in contemporary society outside the Inupiat community to comprehend the importance of subsistence whaling in Inupiat communities. Therefore subsistence activities, whaling in particular, are difficult for contemporary researchers to evaluate or to quantify in a format understandable in modern culture. What makes this even more difficult is the respected reluctance, for cultural reasons, of those participating in subsistence activities to express the importance of these activities in modern economic or value-based terms.

The proximity of the Prudhoe Bay oil fields to Barrow, Kaktovik, and Nuiqsut is important for a number of reasons; the obvious is economic. However, of greater import to subsistence bowhead whaling is the risk of onshore and offshore disturbances on the north coast of Alaska, whether they are oil related or related to some other natural or human-caused event. These disturbances can be long-term and on-going, not necessarily catistrophic—associated with a single event. The northern coastal waters of Alaska are a part of the migratory path of the bowhead whale. Petroleum-related development companies and others associated with potential contaminants go to great lengths to prevent disasters.

Should disaster occur, subsistence whaling could cease or, at the least, quotas would be affected. An example of the disturbance of subsistence resources occurred in the infamous Prince William Sound *Exxon Valdez* oil spill in 1989 [Jorgenson 1993, 1994]. Affected communities sought remuneration for their losses, which included subsistence resources and access to those resources. Outsiders who did not have science-based information generated by the affected communities determined the monetary value of the losses. Their valuations were at best "guesstimates".

There are no quantitative economic methodologies used in Alaska that account for the total spectrum of non-cash value of subsistence products, processes, and activities. The best approaches consider only replacement value of the products and processes. They do not account for the cultural value of subsistence activities nor the time spent on indirectly related tasks and events. In addition, they do not take into consideration long-term events that might cause bowheads to move farther offshore, leading to a greater risk and cost to those who hunt the whales.

Current methodologies used to describe subsistence activities do not do so with rigorous economic theory [Kruse 1983a,b; Jorgensen 1984a,b, 1985; Wolfe 1984]. One recent study uses a time allocation model with secondary data. It demonstrated significance with relation to ethnicity, reciprocity, labor supply, and subsistence activity using econometric models [Kerkvliet and Nebesky 1997].

It is essential that residents of Barrow, Kaktovik, and Nuiqsut be able to document and provide a representative economic model of their important subsistence resource, the bowhead whale. According to a number of federal legislative acts, economic impact statements must be provided in order to determine the level of compensation due in the event of environmental disasters. Examples of such acts that are relevant to potential disasters in coastal communities include the Oil Pollution Act of 1990, the Federal Water Pollution Act of 1948, the Comprehensive Environmental Resource Compensation and Liability Act (CERCLA) of 1980, and the National Environmental Policy Act of 1969 (NEPA).

The underlying premise for our proposed research is founded on the thesis that natural resource management decisions are best made in collaborative atmospheres, i.e., in the context of local community preferences. Community preferences are a set of descriptors that consider the quality of environmental resources. These descriptors are associated with particular environmental media—namely, air, water or terrestrial habitat. The rural communities of Alaska are rich in cultural diversity and socioeconomic characteristics. Their use of environmental resources is commonly allocated outside a structured market system. The duality of commercial and subsistence resource use makes standard economic analysis difficult because of the combination of market and non-market economic activities.

To examine market and non-market activities of rural communities in Alaska, we are using a multi-faceted approach. This entails non-market valuation techniques in combination with traditional regional input–output analysis. We are combining methodologies to capture the values of traditional lifestyles in the metric used for standard economic analysis.

Methods

Three specific methods will be used to determine the economic impact of disturbance on subsistence bowhead whaling in the Inupiat communities of Barrow, Nuiqsut, and Kaktovik and describe the economic value of the bowhead whale to the Inupiat community.

METHOD 1. Nutritional importance of the bowhead

The nutritional value of the bowhead whale is important to the Inupiat. We will determine what nutritional components in the diet would be missing in the absence of the bowhead. This differs from the replacement cost method that substitutes foods available in traditional western markets for the bowhead.

METHOD 2. Cash flow in the community

Input–output models typically depict the flow of money in and out of a community or region. We will be using IMPLAN economic modeling software to characterize the movement of money, including employment, in the market economy (boats, motors, food, gas, etc.) in Barrow, Kaktovik, and Nuiqsut.

METHOD 3. Non-market economic model

This is the part of the study that is the most controversial, and is causing the most concern for the NSB and AEWC. Consequently, a large part of the effort by project managers has been put into reviewing different economic methodologies and survey techniques to determine the most appropriate way to proceed with this very challenging and ultimately most important part of the project. As a result, the approach that will be used has changed from the original proposal.

Value integration surveys (VIS) appears to be a promising technique that has been used successfully in areas with small populations having strongly held beliefs. It blends well with sociological and anthropological survey techniques and is gaining acceptance in the economic community. The methodology utilizes small discussion groups to gain insight into an acceptable way to view the value of the bowhead whale should populations become scarce or, in the worst case scenario, eliminated. It offers promise to be able to address the question of insurance compensation as hunters face higher risk to obtain a whale either because of scarcity or because of a movement of the whale population away from current hunting grounds.

Results/Progress

The regional economic impact analysis of subsistence bowhead whaling has three phases. The first must be completed prior to beginning the remaining two. We have completed all but the last objective of Phase I: obtain letters of support from appropriate community leaders.

PHASE I Obtain approval of the Barrow, Kaktovik, and Nuiqsut community

- Prepare background material for presentation to community leaders and discussion with the community.
- Meet with community leaders (AEWC, NSB and Barrow, Kaktovik, and Nuiqsut community leaders) with assistance from the Department of Wildlife of the NSB to develop a strategy for presentation of the project.
- Discuss and present the project and steps to complete the project in lay terms to the Barrow, Kaktovik, and Nuiqsut whaling communities. If possible, the presentation will be made in Barrow. If not, it can be repeated in Kaktovik and Nuiqsut.
- Obtain letters of support from appropriate community leaders.

Prepare background material for presentation to community leaders and discussion with the community

After discussions with the AEWC, the AEWC legal council, and the NSB, we concentrated our compilation of secondary information on Minerals Management Service publications relevant to social, cultural, and economic impacts on bowhead whaling that occurred prior to and following the ban on bowhead whaling by the IWC.

Additional information regarding historical whaling harvests was collected during the International Institute of Fisheries Economics and Trade (IIFET) conference in Corvallis, Oregon, 16–20 July 2000. During a "Subsistence Whaling" session chaired by Mark Herrmann, invited speakers Thomas Albert, Chief Scientist, North Slope Borough; Tom Mexsis Happynook, World Council of Whalers; Sandra Osawa, Upstream Productions; Bill Aron, Affiliate Professor, College of Ocean and Fishery Sciences, University of Washington; and Milton Freeman, Canadian Circumpolar Institute (CCI), University of Alberta addressed current socioeconomic issues with respect to indigenous whale harvests, resource use perspectives, and the historical effects of past regulatory actions on indigenous populations, including whaling records. A panel discussion of culture, value and perspectives on indigenous whale harvests followed.

A literature search is continuing on current and past bowhead whale research, as well as on non-market economic methodologies and survey methods.

Meet with community leaders (AEWC, NSB and Barrow, Kaktovik, and Nuiqsut community leaders) with assistance from the Department of Wildlife of the NSB to develop a strategy for presentation of the project

On 29 and 30 March 2000 we attended a whaling meeting in Barrow between the NSB, AEWC, MMS, scientists, and interested community members. Discussions with the NSB and AEWC resulted in an action plan that would allow us to complete the regional economic impact analysis of subsistence bowhead whaling. A new work plan that will accommodate additional social and cultural components requested by the NSB and AEWC is underway.

On 11 August 2000 the project team met with two prominent non-market economists—John Loomis, professor of resource economics at Colorado State University, and Joe Cooper, USDA Economic Research Service, Resource Economics Division, Washington DC—to discuss economic methodologies appropriate for this project. As a result, we are strongly considering using value integration surveys, a technique that has been useful in surveys of small populations with strongly held beliefs. This methodology would provide a more manageable data collection effort over the more extensive surveys previously proposed. Concurrent with the evaluation is a comprehensive literature review for VIS, multi-attribute utility (MAUT), and decision analysis techniques used to clarify the values of individuals as part of small-group negotiation processes. The application of these methodologies will enhance the project, making it much more proactive and inclusive.

Discuss and present the project reported here and steps to complete the project in lay terms to the Barrow, Kaktovik, and Nuiqsut whaling communities

This step will be completed after the new work plan is finalized. We will addresses quantification of the social, cultural and economic impacts and potential economic mitigation measures that may be appropriate in the face of continuing and possible catastrophic impacts on the bowhead whale and subsistence bowhead whaling. This plan to present the regional economic impact analysis of subsistence bowhead whaling has been accepted by MMS, AEWC, NSB, and researchers associated with the work plan. The request for proposals has been released by MMS so work can proceed. For this step of the project, the VIS, MAUT and decision analysis techniques will be necessary.

The remaining two phases of the project will be completed following the receipt of letters of support. These two phases are:

PHASE II Update the IMPLAN database to accurately reflect the Barrow, Kaktovik, and Nuiqsut cash economies

PHASE III Use value integration surveys, multi-attribute utility and decision analysis techniques to construct a non-market economic model

Discussion

Our work to date has been largely preparatory under Phase I of the project. The timeline has been delayed due to late approval of funding, and because of requests by the NSB and AEWC for a broader focus. Any work beyond the quantification of the social, cultural, and economic impacts of oil and gas development and exploration on North Slope Alaskan Eskimo subsistence communities will be pending acceptance f the work plan to complete this task. Progress has been frustrated by the need to obtain additional resources necessary to accommodate the project expansion. MMS has approved funding and has released a request for proposals for the socio-cultural component of the work. Timelines will not be set until the selection of a research team for the completion of this component.

Acknowledgements

We are grateful for information provided by the North Slope Borough Department of Wildlife and Chief Scientist Tom Albert; the Alaska Eskimo Whaling Commission and Director Maggie Ahmoak; the Mayor of the North Slope Borough, George Ahmoak; and those from the Barrow, Nuiqsut, and Kaktovik communities who so graciously spoke to us about their culture, their communities, the importance of bowhead whaling and the impact of off-shore oil and gas activities on the North Slope of Alaska.

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New Projects

Three 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.

Alaska Sea Ice Atlas

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Task Order 15177

Abstract

University of Alaska and Cold Regions Research and Engineering Laboratory (CRREL) specialists propose to prepare an updated GIS-based Alaska Sea Ice Atlas with a view toward risk assessment for navigation and mineral developments. Undergraduate and graduate geomatics and engineering students will be integrally involved in the development. This project responds to the "Updated Ice Atlas" objective of the MMS Alaska Environmental Studies Program, Annual Studies Plan, FY 2000–2001. All ice-covered federal Outer Continental Shelf and coastal waters of Alaska will be mapped. National Weather Service (NWS) ice reports for the Beaufort, Chukchi, and Bering seas will be scanned, geographically registered, and rectified to a standard map projection. Areas of uniform ice concentration, stage, and form will be traced as polygons for superposition on a 5-km-square grid. Ice data archived by the U.S. National Ice Center (NIC) will be treated similarly. Ice information from other sources, such as the Canadian Ice Service, will be applied to fill in gaps and to verify NWS and NIC data. Equivalent information for Cook Inlet, Alaska, currently being prepared under separate contract, will be included. Verbal history will be collected through interviews of long-time residents of the Alaska coast and applied to verify measured data and statistics. The GIS database will allow users to view a statistical average over a broad area, a time series of conditions at a point, or an individual historical ice report. Meteorological data related to ice growth, behavior, deformation, and decay will be retrieved from agency archives and incorporated in the GIS database. Parameters to be incorporated include air temperature, freezing and thawing degree-days, sea surface temperature, and wind speed and direction. Historic isobaric maps will be applied to hindcast surface winds and wind stress divergence over ice as an index of ice compression, the primary cause of ridge formation. A chapter will portray multi-year cycles of arctic climate. Final products will include an executable GIS on CD-ROM and on the world wide web.

A Nowcast/Forecast Model for the Beaufort Sea Ice–Ocean–Oil Spill System (NFM-BSIOS)

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Task Order 15178

Abstract

Numerical weather forecasts have long been accepted as a part of our daily life. However, numerical ocean prediction has been slow in developing. As societal use of the sea increases, ocean prediction systems are becoming necessary.

This project will establish a prediction model for the Beaufort Sea ice–ocean–oil spill system (BSIOS), which will serve as a future operational nowcast/forecast system for the oil industry in the region. One of the products provided by BSIOS will be prediction of oil spill trajectories in response to an oil spill event and from pre-oil-spill stochastic modeling, which can be used to access the possible consequence of hypothetical spill trajectories.

BSIOS consists of two parts: a 3-D coupled ice-ocean model (CIOM) and a 2-D trajectory model. CIOM is automatically run to predict ice–ocean variables for up to two days under forcing of lateral inflow/outflow provided by a large-scale Arctic CIOM that is being established at IARC (International Arctic Research Center) and the predicted surface winds that are automatically transferred (by ftp) from a file server at NCEP (National Center for Environmental Prediction). The winds from the mesoscale Eta model (called NCEP-Eta model winds) are utilized. Then the trajectory model is run to predict the path due to: (1) the ice-circulation model predicted ice/ocean surface currents, (2) wind drift due to the predicted Eta winds, and (3) turbulent dispersion based on a random flight (Markov process) model. The predicted surface trajectories can be used to estimate the physical transport of oil spills, although the physical and chemical fate of spills is not included in the present model.

NFM-BSIOS will automatically run on a daily basis on a platform at IARC/Institute of Marine Science (IMS) to forecast and deliver the products to managers, regulators, and industry users interested in the region. This model will be maintained at IARC/IMS after the three-year setup.

Satellite Tracking of Eastern Chukchi Sea Beluga Whales in the Beaufort Sea and Arctic Ocean

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Task Order 15179

Abstract

Beluga whales occur in northern and western Alaska and are important for subsistence to many Alaska Native hunters. Despite this importance and protection of belugas under the Marine Mammal Protection Act, relatively little is known about the movements and distribution of belugas in Alaska. Much information is available from when belugas inhabit coastal waters during the summer but little is known about them during the rest of the year. Satellite tagging provides a means to determine beluga distribution and movements outside of summering areas. Recent satellite tagging studies of belugas in the eastern Chukchi Sea revealed that these animals spent a good portion of the summer in the Beaufort Sea and the Arctic Ocean north of the Beaufort Sea. Only a few belugas have been tagged to date in the Chukchi Sea, and most of those were large males. It is unknown whether the females and smaller males also regularly move into the Beaufort Sea, although initial results indicate that some of them do. Oil and gas exploration and development have the potential to negatively impact the eastern Chukchi Sea stock of beluga whales. We propose to capture and attach satellite tags to female and small male belugas to determine their distribution and movements during the summer and early fall. These data will provide a means to evaluate the potential impacts of offshore oil and gas developments in the Beaufort Sea.

Funding Summary

Student Support

The cooperative agreement that formed the University of Alaska Coastal Marine Institute 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		
2 Ph.D. students	$ 23,000	$ 9,200
7 M.S. students	67,000	37,400
Source Total	$ 90,000	$ 46,600
Fiscal Year 95		
4 Ph.D. students	59,600	12,800
7 M.S. students	115,400	57,200
Source Total	$ 175,000	$ 70,000
Fiscal Year 96		
1 Ph.D. student	4,000	0
10 M.S. students	133,000	31,800
Source Total	$ 137,000	$ 31,800
Fiscal Year 97		
1 Ph.D. student	0	21,500
4 M.S. students	76,700	0
1 undeclared/undergrad	3,900	0
Source Total	$ 80,600	$ 21,500
Fiscal Year 98		
2 Ph.D. students	27,240	0
1 M.S. student	10,560	0
2 undeclared/undergrad	2,610	0
Source Total	$ 40,410	$ 0
Fiscal Year 99		
4 Ph.D. students	26,318	28,710
4 M.S. students	32,419	15,444
2 undeclared/undergrad	0	8,244
Source Total	$ 58,737	$ 52,398
Fiscal Year 00		
1 Ph.D. student	7,630	8,305
1 undergrad	0	15,826
Source Total	$ 7,630	$ 24,131
Total to Date	$ 589,377	$ 246,429

Total CMI Funding

The total MMS funding available for funding CMI projects through federal fiscal year 2000 is approximately $6.7 million. Since all CMI-funded projects require a one-to-one match with non-federal monies, project commitments through fiscal year 2000 have totaled approximately $13.4 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 fund matching participants demonstrates the breadth of support for CMI-funded programs:

- Afognak Native Corporation
- Alaska Beluga Whale Committee
- Alaska Department of Environmental Conservation (ADEC)
- Alaska Department of Fish and Game (ADF&G)
- Alaska Department of Transportation and Public Facilities
- Alaska Science and Technology Foundation
- Alyeska Pipeline Service Company
- Ben A. Thomas Logging Camp
- British Petroleum Exploration
- Cominco Alaska, Inc.
- Cook Inlet Regional Citizens Advisory Council
- Department of Fisheries and Oceans Canada
- Japanese Marine Science and Technology Center (JAMSTEC)
- Kodiak Island Borough
- North Slope Borough
- Oil Spill Recovery Institute
- Prince William Sound Aquaculture Corporation
- University of Alaska Anchorage
- University of Alaska Fairbanks
    - College of Science, Engineering and Mathematics
    - Institute of Arctic Biology
    - Institute of Marine Science
    - International Arctic Research Center
    - School of Agriculture and Land Resources Management
    - School of Fisheries and Ocean Sciences
    - School of Management
    - University of Alaska Museum
    - Wadati Fund
    - Water Research Center
- University of Alaska Natural Resources Fund
- University of Northern Iowa

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, the Office of Naval Research, the National Aeronautics and Space Administration, the National Oceanographic and Atmospheric Administration including the National Marine Fisheries Service, and the Alaska Sea Grant College Program.

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 may be obtained from CMI until supplies are exhausted. Reports marked with an asterisk are no longer available in hard copy from CMI.

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The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Royalty Management Program** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principals of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.