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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 2003 Annual Report, our tenth annual report and the first one under MMS Cooperative Agreement 0102CA85294. Of the 23 research projects covered, eight have been completed and final reports are now in various stages of review. Abstracts are included for all but one of these (Kelly, Quakenbush & Taras [TO 15162], Terschak, Henrichs & Shaw [TO 15170], Duesterloh & Shirley [TO 15171], Winker & Rocque [TO 15173], Braddock, Gannon & Rasley [TO 15175], Smith & Lee [TO 15177] and Suydam, Lowry & Frost [TO 15179]). Wang & Jin [TO 15178] submitted their final report after their annual report had been edited and the complete text for it is included here. Four of the 23 projects were funded in FY2003 and are in the New Projects section. Three on-going projects received supplemental funding; two are outlined in the New Projects section (Naidu & Kelley [TO 15181] and Okkonen & Saupe [TO 85243]) and the new focus is described in the annual report of the third (Quakenbush & Suydam [TO 85241]).

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 for better understanding marine, coastal, or human environments affected or potentially affected by offshore oil and gas or other mineral exploration and extraction on the outer continental shelf;
2. Modeling studies of environmental, social, economic, or cultural processes related to OCS gas and oil activities in order to improve scientific predictive capabilities;
3. Experimental studies for better understanding of environmental processes or the causes and effects of OCS activities;
4. Projects which design or establish mechanisms or protocols for sharing of data or scientific information regarding marine or coastal resources or human activities to support prudent management of oil and gas and marine mineral resources; and
5. Synthesis studies of scientific environmental or socioeconomic information relevant to the OCS gas and oil program.

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.

Correction Factor for Ringed Seal Surveys in Northern Alaska

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Task Order 15162

Abstract

The proportion of radio-tagged ringed seals visible on the ice surface from April to June in 1999 (n = 8) and 2000 (n = 10) was used to estimate correction factors for aerial surveys. The transition period, defined as the period during which the majority (75%) of the tagged seals began resting outside of lairs, 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 resting in the open, was 31 May in both years. Only once each year was a lair used subsequent to each seal's first appearance outside of a lair. 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 appearing outside of lairs and approximately 30% of the time out of the water after they began to abandon lairs. The transition from lair use to resting in the open appeared related to measurable characteristics of the snow.

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 ship time (Japan and Canada) and instrumented moorings (Japan).

Task Order 15163

Abstract

This program 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 (< ~50 m depth) here, and over the inner shelf, is westward and forced by the winds. However, flow reversals are common and often a result of upwelling of the undercurrent. Further, the pressure field responsible for the undercurrent must influence the dynamics of the inner shelf. The undercurrent originates in the eastern Arctic as a result of inflow through Fram Strait and is fed by outflows from the Eurasian shelf seas and the Chukchi Sea. Hence it is circumpolar in extent and carries with it a variety of water masses. The flow could thus transport pollutants from these regions to the Alaskan shelf. The 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 Goals

This program 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 (< ~50m depth) here, and over the inner shelf, is westward and forced by the winds. However, flow reversals are common and often a result of upwelling of the undercurrent. Further, the pressure field responsible for the undercurrent must influence the dynamics of the inner shelf. The undercurrent originates in the eastern Arctic as a result of inflow through Fram Strait and is fed by outflows from the Eurasian shelf seas and the Chukchi Sea. Hence it is circumpolar in extent and carries with it a variety of water masses. The flow 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.

Results

Since the beginning of the project we have found that the shelfbreak flow (water depths between 80 and 120 m) differs considerably from the flow field over the slope (150–250 m). The shelfbreak flow is eastward year round and shows little indication of varying seasonally. This observation is surprising insofar as there are strong seasonal variations in the outflow from Bering Strait and the Chukchi Sea (minimum in winter and maximum in fall) and in the wind field (maximum westward winds in winter and minimum wind stress in summer). The shelfbreak flow is also coherent over alongshelf spatial scales of at least 200 km, with much of this variability apparently forced by fluctuations in the wind. In contrast, the deeper flow along the slope is incoherent with current fluctuations on the shelfbreak, with the winds, and over alongslope spatial scales of about 200 km. Moreover, there is an apparently large seasonal variation in the slope flow, with maximum eastward flow in winter and weak flow in summer. The results suggest that the dynamics underlying the flows along the shelfbreak and slope are different. We are presently attempting to understand how these differences are dynamically maintained.

Study Products

Some of these data were presented at an MMS sponsored workshop on Physical Oceanography Study Recommendations for the Beaufort Sea (held in Fairbanks, Alaska, February 2003) and some will be presented at the Arctic Shelf–Basin Interactions meeting to be held in Cadiz Spain in November 2003.

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

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Task Order 15170

Abstract

Sediments are major reservoirs of persistent petroleum contamination in marine environments. Petroleum hydrocarbons associate with the sediment organic matter, of which humic acids are an important constituent. This study examined the role that humic acids and their structures play in the kinetics and mechanisms of polycyclic aromatic hydrocarbon (PAH) interactions with sediments. Natural humic acids, with a wide range of properties, were isolated from Alaska coastal marine sediments. Melanoidins were synthesized and used as humic acid analogs. The humic acids were characterized by elemental and isotopic analyses, Fourier transform infrared spectroscopy, and cross-polarized magic angle spinning ^{13}C nuclear magnetic resonance spectroscopy. The humic acids were coated onto a standard montmorillonite clay, and the adsorption and desorption of phenanthrene was measured using a radiotracer.

Adsorption required about one week to reach steady state, indicative of slow diffusion of PAH within the humic acid. The composition of the humic acids had a greater effect on phenanthrene adsorption than their concentrations on the clay. Organic carbon normalized adsorption partition coefficients were closely correlated with the sum of amide and carboxylic carbons, a measure of the polarity of the humic acids, but were independent of initial phenanthrene concentration, indicating that the binding sites were unlimited and uniform in strength. This explains the fact that the initial adsorbed concentration of phenanthrene had no effect on subsequent phenanthrene adsorption.

Desorption of phenanthrene was not related to any of the humic acid structural characteristics measured. The initial desorption rate was linearly related to the initial adsorbed concentration, as expected for a diffusive process, and was negatively correlated with the carbon content of the humic acid coated clay. Under most conditions, desorption was complete after one to seven days; there was little evidence for irreversible adsorption.

Because of the substantial variability of adsorption and desorption behavior with organic matter characteristics, interactions of aromatic hydrocarbons with marine sediments cannot be predicted based on total organic matter concentration alone. Information on aspects of organic matter composition is needed in order to make accurate predictions.

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

Copepods may provide a significant pathway for the concentration and transfer of polyaromatic compounds (PAC) to higher trophic level consumers. PAC dissolved from weathered crude oil are more persistent in the environment and have much higher toxicity than the lighter, more volatile fractions of crude oil. Because of their polarity, PAC tend to accumulate in bio-lipids. Subarctic copepod species can contain up to 80% of their body dry weight in lipids and have a high surface area to volume ratio. Thus, PAC accumulation is rapid and bioaccumulation factors are in the order of 500–8000, depending upon species and lipid content. While direct toxic effects of oil on copepods have been reported in the order of 10 mg L^{-1}*, toxicity increases substantially in the presence of natural ultraviolet (UV) radiation. Phototoxic effects on the copepods* Calanus marshallae *and* Metridia okhotensis *were observed at concentrations of* ~2 $\mu g\ L^{-1}$ *total dissolved PAC followed by 4–8 hours of exposure to ambient daylight. Responses included mortality, immobilization and discoloration of lipid sacs. Further experiments were conducted to test the interaction effects of various concentrations of PAC dissolved from weathered Alaska North Slope crude oil and subsequent exposure to sunlight with and without the UVB component for the copepods* Neocalanus flemingeri *and* N. plumchrus. *Phototoxicity was found to be a linear function of the product of light intensity and PAC concentration. High natural variability in egg production rates precluded significant results of the toxicity of oil to copepod reproduction. This work has shown that copepods could potentially provide a mechanism for the concentration of dissolved PAC from the water and its transfer into pelagic and benthic food chains.*

Seabird Samples as Resources for Marine Environmental Assessment

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Task Order 15173

Abstract

Archived specimens of seabirds are playing critical roles in many studies contrasting changes in time and space in genetics, stable isotopes, and contaminants. Seabirds are excellent marine bioindicators, representing multiple trophic levels but being especially rich at higher levels. Preserving and archiving multiple sample types from these animals caters to an increasingly broad variety of researchers. By preserving these samples, we enable present and future analyses for questions ranging from changes in contaminant levels, to the nature of populations and genetic stocks in affected areas, to other issues related to outer continental shelf (OCS) activities. Having the samples to address retrospective and geographic comparative analyses is important for studying the rates and characteristics of natural and anthropogenic changes.

This project focused on an increasing interest in and need for samples of preserved marine bird specimens, particularly for genetic, contaminant, and stable isotope studies. Having material available for such studies is critical, particularly material from representative time periods and geographic areas. Requests for samples of several different types have made it clear that demand exceeds supply and that low rates of specimen influx were not meeting this demand, particularly in the documentation of the present. By supporting a graduate assistantship to process marine bird specimens, this project stimulated such sample preservation and made it less geographically and taxonomically haphazard than in the past. During this project, 872 seabirds were prepared and archived as skin and/or skeleton, and tissue samples in the University of Alaska Museum. This was 45% more than forecast when the project began. A snowballing effect has occurred, both in the deposition of more specimens and in the level of interest in this new material. Equally important has been the graduate training opportunity that this funding provided. This support served as a platform from which Deborah Rocque completed her doctoral degree. Thirteen visitors to the collection have used seabird specimens for their research, and ten loans were made to researchers worldwide studying Alaska seabirds. In sum, the project has been very successful. This success will be built upon as we continue to preserve and archive seabirds and as researchers continue to capitalize on this important and growing research resource.

Petroleum Hydrocarbon Degrading Microbial Communities in Beaufort–Chukchi Sea Sediments

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Task Order 15175

Abstract

Despite large-scale development on the North Slope, no recent studies examining arctic marine sediment microbial communities and their ability to metabolize petroleum compounds have been published. Microbial populations are of interest since biodegradation of petroleum hydrocarbons is a major removal mechanism of these compounds from the environment. We conducted a survey (near Barrow and near Prudhoe Bay) of marine sediment microbial populations to determine what microorganisms are present and what their metabolic capability is for degradation of model petroleum hydrocarbons. We also examined the effect of sediment on bioavailability of a polycyclic aromatic hydrocarbon (phenanthrene) to hydrocarbon degrading bacteria. In our survey we found high total numbers of microorganisms (about 10^{10} cells g^{-1} dry wt sediment). Interestingly the total numbers were higher than have been reported for more temperate locations such as Prince William Sound. Most probable numbers of culturable phenanthrene and hexadecane degraders were fairly high (about 10^4 cells g^{-1} dry wt sediment each) and numbers were significantly higher near Prudhoe Bay than offshore Barrow. Culturable crude oil degraders were also significantly greater offshore Prudhoe Bay than Barrow. There was no evidence that these differences are due to anthropogenic contaminants. Mineralization potentials were low for both hexadecane and phenanthrene at both geographic locations, indicating that microbial populations are not acclimated to readily use these compounds. Despite the low organic carbon content of these sediments ($\leq 1.5\%$), substantial adsorption to particles occurred and adsorption was rapid. Unexpectedly, the presence of sediment in bioavailability assays had no effect or enhanced mineralization of phenanthrene, even when sediment was aged with phenanthrene for up to two months before adding microorganisms. Overall, biodegradation will likely be a slow removal mechanism of contaminants from the arctic marine environment but adsorption to sediments may not contribute substantially to persistence of these compounds in the environment.

Alaska Sea Ice Atlas

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Task Order 15177

Abstract

A GIS-based atlas of sea ice conditions in the territorial waters of Alaska is in the final stages of preparation. It updates previously printed ice atlases and provides risk analysis information for engineers and resource managers. The Alaska Sea Ice Atlas includes a comprehensive collection of georeferenced digital historical data on Alaska sea ice and other environmental factors that bear directly on ice processes and conditions. Historical ice reports of the U.S. National Ice Center form the foundation of the database of ice conditions. This information is supplemented by ice and related climatological data from the U.S. National Weather Service and other archives. Areas of uniform ice concentration, stage, and form are portrayed as polygons and superimposed on a 5-km-square grid. Grid cell statistics over the period of record for each week of the calendar year include distribution parameters, reported extremes, combined probabilities of concentration and stage, and related atmospheric variables. Hindcast wind stress divergence is applied as an analog of ice compression and ridge formation. These statistics allow derivation of a navigability index for assessing difficulties in navigating ice-covered waters in various classes of vessels. The preliminary version of the Alaska Sea Ice Atlas is accessible via a customized implementation of GIS tools at the public website http://holmes-iv.engr.uaa.alaska.edu. The final version is scheduled for public access in March 2003.

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

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Task Order 15178

Abstract

A nested coupled ice–ocean model was developed and validated during the first two years of the project. In the third year we focused on oil spill modeling. Using station wind data and simulated surface current, sea ice velocity and ice concentration from the coupled ice–ocean model, we conducted a series of simulations of oil spills released on different dates with and without sea ice cover. The results show significant seasonal and interannual variability of the oil spill trajectory under simulated ice conditions. Sea ice cover can affect oil spill trajectory by reducing wind effects on sea surface current, sea ice flow and oil spill velocity. Ice flows dominate oil spill movement in the winter months, and wind has a greater effect during the summer.

Introduction

The Beaufort Sea is located off the north coast of Alaska and is a part of the Arctic Ocean. It draws much attention from researchers engaged in oil exploration and climate research. Hydrography of the Beaufort Sea shows that a coastal current exists along its shelf. Affected by local wind, heat flux and salt flux, the circulation in the Beaufort Sea is also driven by several current systems, such as inflow of North Pacific water from the Bering Strait, the Beaufort Gyre in the Canada Basin, and the intrusion of intermediate water of North Atlantic origin. Eddy activities are important features of circulation in the Beaufort Sea [Manley and Hunkins 1985]. Chu et al. [1999] classify the thermohaline structure into four types of features.

The abundant natural resources and complex ocean conditions in the Beaufort Sea can be studied using ocean modeling as a tool to provide information to decision makers. The complexity of the Beaufort Sea current system has led us to develop a fine-grid Beaufort Sea model nested into a basin-scale model of the pan-Arctic–North Atlantic Ocean [Jin et al. 2001; Wang et al. 2002b; Wang et al. 2003d]. Because the Beaufort Sea is a perennially ice-covered area except along the coastal region, which is open for a short period of time from summer to fall, ice growth/decay and movements are important factors in the heat budget and hydrodynamics. A coupled ice–ocean model is the basic tool for studying the ice and ocean features. Here we implement a nowcast/forecast sea ice–ocean–oil spill system in the Beaufort Sea in order to assess possible consequences of hypothetical oil spill episodes and impacts on the environment.

The sea ice–ocean–oil spill model system consists of two parts: a 3-D coupled ice–ocean model and an oil spill trajectory model. Most of the existing ice–ocean models are large-scale climate models with 50-km resolution and are not eddy resolving, such as Hedstrom's [1994]. Other idealized ice–ocean models cannot produce realistic ocean conditions for oil spill predictions. While ice motion and eddy activities are important to oil spill predictions, we proposed to develop a fine-resolution (eddy resolving) coupled ice–ocean model nested into a similar, but large-scale coupled ice–ocean model covering the entire Arctic Ocean and North Atlantic Ocean to 40 °N. With this fine-resolution coupled ice–ocean model, we are able to predict oil spill trajectories under the composite effects of sea ice flow, ocean current, wind and turbulent dispersion.

This project was funded by the Coastal Marine Institute/Minerals Management Service from May 2000 to May 2003. During the first year (May 2000 to April 2001), a coupled ice–ocean model for the Beaufort Sea was devised [Wang et al. 2002a]. This model has a 3.4-km horizontal resolution and is nested in a similar model covering the pan-Arctic–North Atlantic Ocean with a 27.5-km horizontal resolution. Some preliminary results on circulation and the thermohaline structure were also included. During the second year of the project (May 2001 to May 2002), the model was validated with available observations [Wang et al. 2003b]. During the third year of the project (May 2002 to May 2003), an oil spill trajectory model was formulated and seasonal and interannual variabilities of the oil spill trajectory were examined with and without ice cover. Thus, this project has built an infrastructure for the ice–ocean–oil spill model, which is ready for further applications, such as: establishing a nowcast/forecast system, and adding land-fast ice and tidal information.

Modeling Oil Spill Trajectory

The coupled sea ice–ocean model and its validation have been described in previous annual reports [Wang et al. 2002a, 2003b, 2003c). The domain and bathymetry for the coarse pan-Arctic–North Atlantic Ocean model and nested fine-resolution coupled ice–ocean model in the Beaufort Sea are shown in Figure 1. In this report, we introduce the oil spill trajectory model and a series of numerical experiments conducted using the model.

Oil spill trajectory model with sea ice

Oil spill is a major environmental risk of offshore oil exploration and production. Since we do not know when, where, or how an oil spill will happen, a numerical oil spill trajectory model is an important way to assess the impact on the environment under various potential oil spill scenarios.

We developed a subgrid scale turbulent dispersion model that includes surface wind drift, sea ice concentration, sea ice flow and surface current predicted from the circulation model, and used it to predict the surface trajectory of a passive particle, based on a previous model that did not consider sea ice impact [Wang 1999, 2001]. Furthermore, this model can capture wintertime Arctic halocline ventilation along the Beaufort–Chukchi coast, probably induced by oceanic upwelling that is driven by the anticyclonic Beaufort Gyre, as shown below. The Lagrangian motion of a particle in a two-dimensional plane in the presence of a mean flow (u, v), a turbulent velocity (u', v') and surface wind (W_x, W_y) is described with the following equations:

$$\frac{dx}{dt} = u_{oil} = u + u' + \alpha b W_x$$

$$\frac{dy}{dt} = v_{oil} = v + v' + \alpha b W_y$$

where x and y are the particle trajectory coordinates at time t after the particle is released at a location (x_0, y_0) at time (t_0). α is the wind factor of 0.025 in our model (typically between 0.02 and 0.03). b is the ice factor $b = 1 - C_{ice}$ for normal cases and implies that the oil will adhere to ice and move only with ice. $b = 1$ represents an open water condition, and C_{ice} is ice concentration. The turbulent velocity (u', v') is the complex and inherent motion that occurs at spatial and temporal scales much smaller than the predominant scales of the coastal current and the wind drift surface current. This velocity is calculated by a random number generator obeying a Gaussian-distribution with a mean of zero and variance of unity. The turbulent velocity has only statistical meaning in contrast to the deterministic large-scale mean flow and wind driven flow. The random flight model can be described as follows:

$$du' = -\frac{1}{T} u' dt + K^{1/2} dw$$

where T is the turbulent decorrelation time, $K = 2\sigma^2/T$ is the turbulent diffusion coefficient, σ is the variance of turbulence, and dw is the stochastic kick received by the particle. More details on this random flight statistic approach and its applications to atmospheric and oceanic pollution dispersion can be found in Thomson [1987], Dutkiewicz et al. [1993], and Wang [1999, 2001].

The surface current (u, v) can be chosen as sea surface current in open water, ice flow in full ice-cover, or a combination of both. One special case is the occurrence of an oil spill on land-fast ice, which is common along the Beaufort Sea coast in winter. Then, the oil spill would stay with the ice and prediction is much easier as long as the fast ice does not break up before the oil can be removed. Actually, fast ice needs a higher resolution model than our present one to resolve both horizontally and vertically, which is what we plan to do in the next phase. Therefore, the predictions in this study only consider oil spills on moving ice or water. In a case in which the ice concentration is between 0 and 1, the oil could be on water or ice, or under ice. The model cannot predict if an oil particle is on water or stuck on or under ice. We assume that the oil spill particles spread evenly in space, so the portion of particles stuck with ice is proportional to ice concentration, and the surface current driving the oil spill can be expressed statically as the combination of sea surface velocity (u_{water}, v_{water}), and ice velocity (u_{ice}, v_{ice}) weighed by ice concentration (C_{ice}):

$$u = u_{water} \times (1 - C_{ice}) + u_{ice} \times C_{ice}$$

$$v = v_{water} \times (1 - C_{ice}) + v_{ice} \times C_{ice}$$

Sea surface current and ice velocity fields are very similar, especially at high ice concentration conditions such as in April, when the simulation shows that both have similar anticyclonic circulation along the slope (Figure 2).

Observed wind data

The oil spill model is driven by observed meteorological data from stations operated by MMS along the Beaufort Sea coast to provide more realistic results. Five stations have been operating from January 2001 to the present (Figure 3). The longitude ranges from 149°39′W to 147°W (see Table 1). The meteorological stations collect wind speed, wind direction, barometric pressure, relative humidity, solar radiation, and air temperature. Data collection at four of the meteorological stations began on 1 January 2001. The fifth station at Cottle Island was added to the study on 21 August 2002. Data collection at all five stations will likely continue through October 2004.

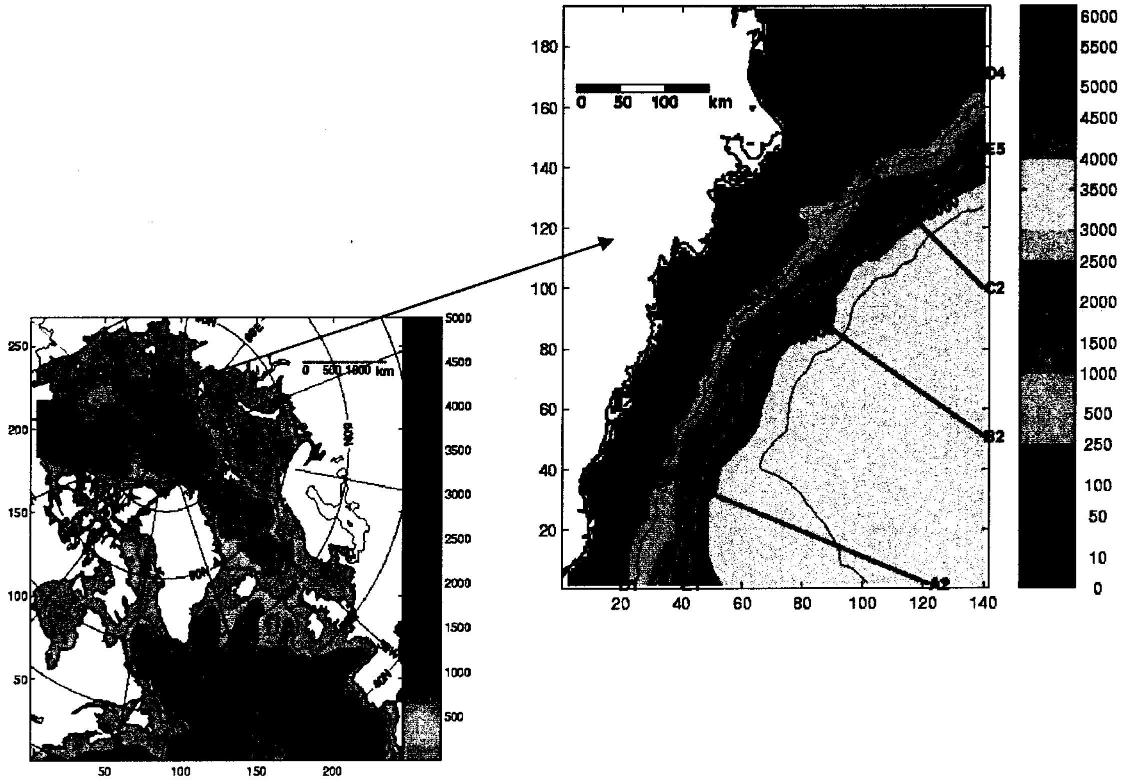

Figure 1. The domain, bathymetry and grid system for the coarse (left) and nested fine-resolution (right) coupled ice-ocean model in the Beaufort Sea. The location of transects A, B, C, D, and E are shown.

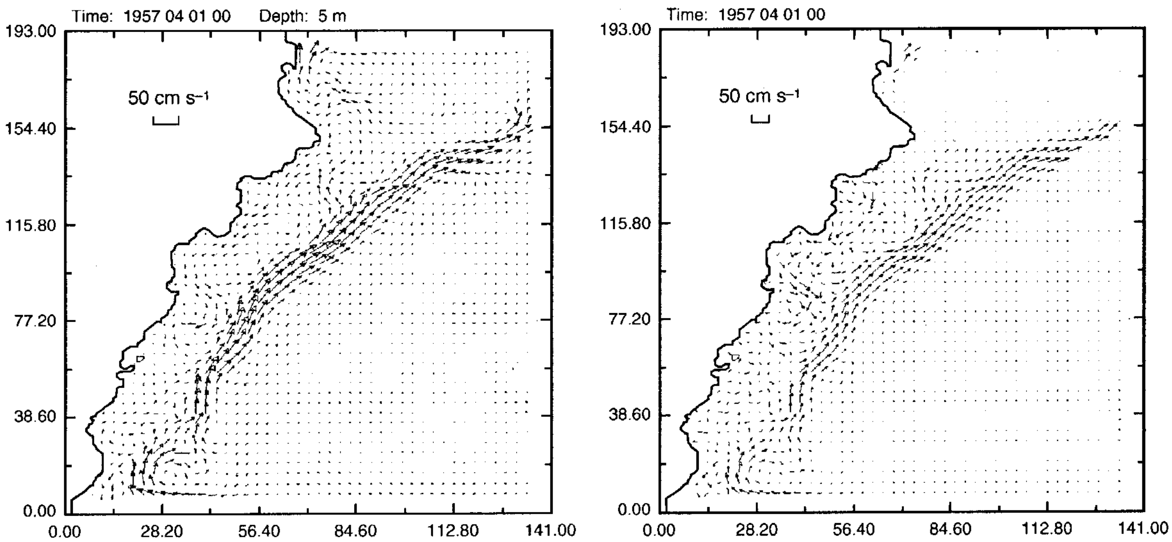

Figure 2. Simulated sea surface current (left) and ice velocity (right) for the Beaufort Sea in April. The x- and y-axis units are the model grid size (3.4 km).

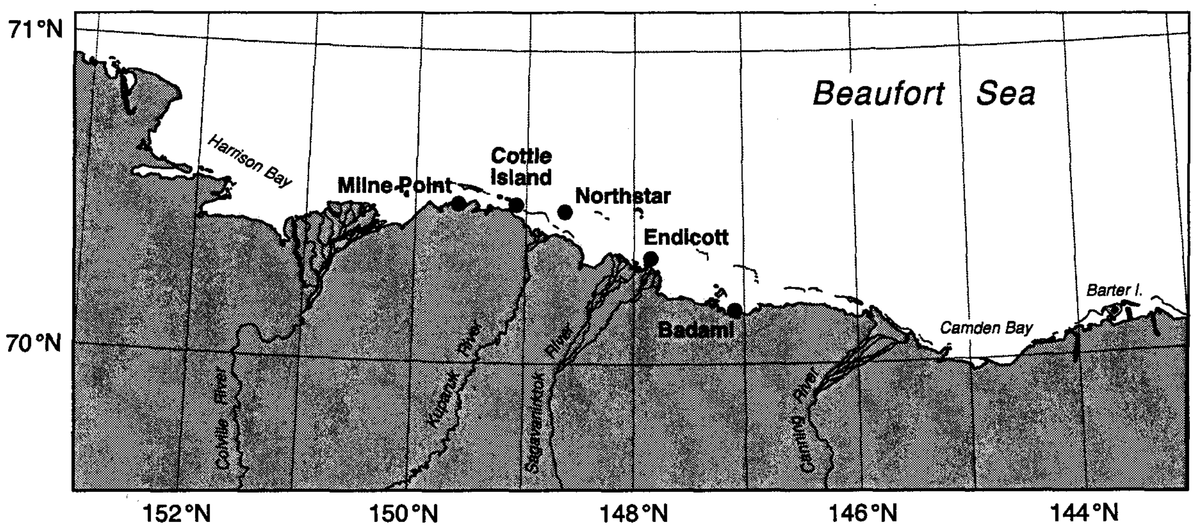

Figure 3. Map showing locations of MMS-operated meteorological stations along the Beaufort Sea coast.

Table 1. Geographic locations and starting dates for the MMS-operated meteorological stations.

Station Name	Latitude °N	Longitude °W	Start of Operation
Badami	70° 08.171′	147° 00.522′	1 January 2001
Endicott	70° 19.370′	147° 51.895′	1 January 2001
Milne Point	70° 30.402′	149° 39.725′	1 January 2001
Northstar	70° 29.428′	148° 41.901′	1 January 2001
Cottle Island	70° 29.920′	149° 05.571′	21 August 2002

The wind speed and direction among the five stations are highly correlated, as they are located within a range of 100 miles and are not affected by mountains (see wind rose and wind speed figures in the reports at http://www.resdat.com/mms). We selected offshore of Endicott station as the oil spill location and used its wind data to drive the oil spill model because more complete data and fewer technical problems have been reported for this station during its operation. The wind data discussed in the remainder of this report refers to Endicott station for 2001 and 2002.

Hourly wind speed and wind rose of Endicott in 2001 is shown in Figure 4. The annual mean wind speed is 4.7 m s^{-1} and the maximum speed is 23.7 m s^{-1}. The dominant wind direction is NEE. The wind direction shows little seasonal change from January to September (Figure 5), with dominant wind NEE, except October to December, when both NEE and SWW winds are dominant.

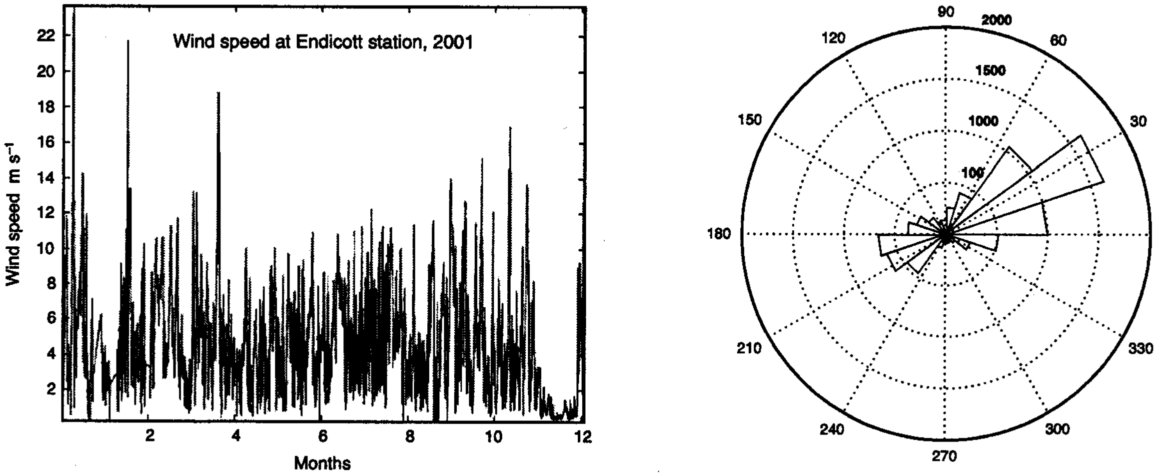

Figure 4. Hourly wind speed (left), and wind rose (right) for Endicott station, 2001. The vertical column of figures on the wind rose indicates numbers of data points.

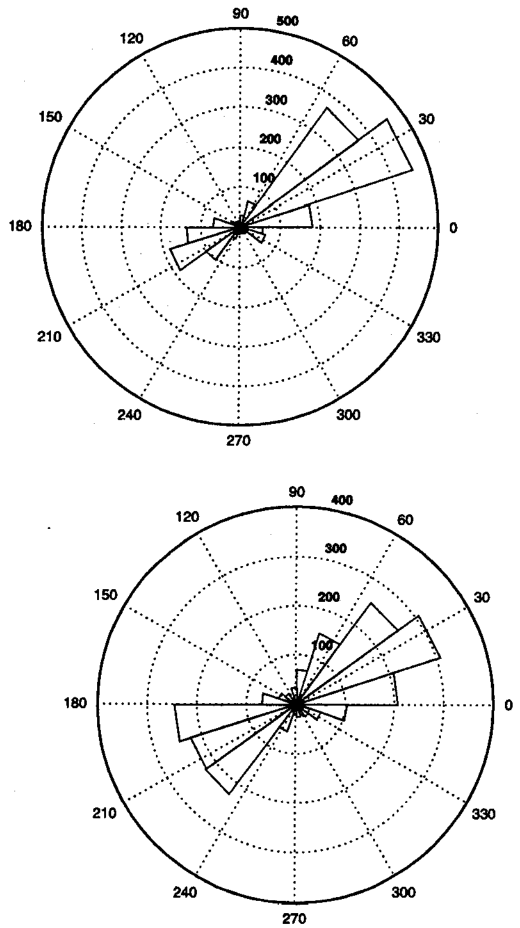

Figure 5. Wind rose of January to March (upper left), April to June (upper right), July to September (lower left), and October to December (lower right) for Endicott station, 2001. The vertical columns of figures indicate numbers of data points.

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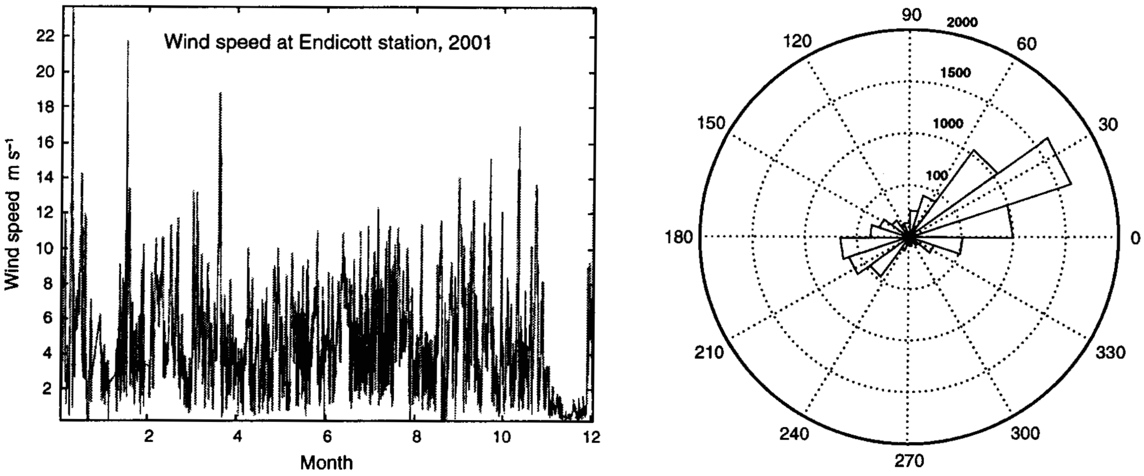

Figure 4. Hourly wind speed (left), and wind rose (right) for Endicott station, 2001. The vertical column of figures on the wind rose indicates numbers of data points.

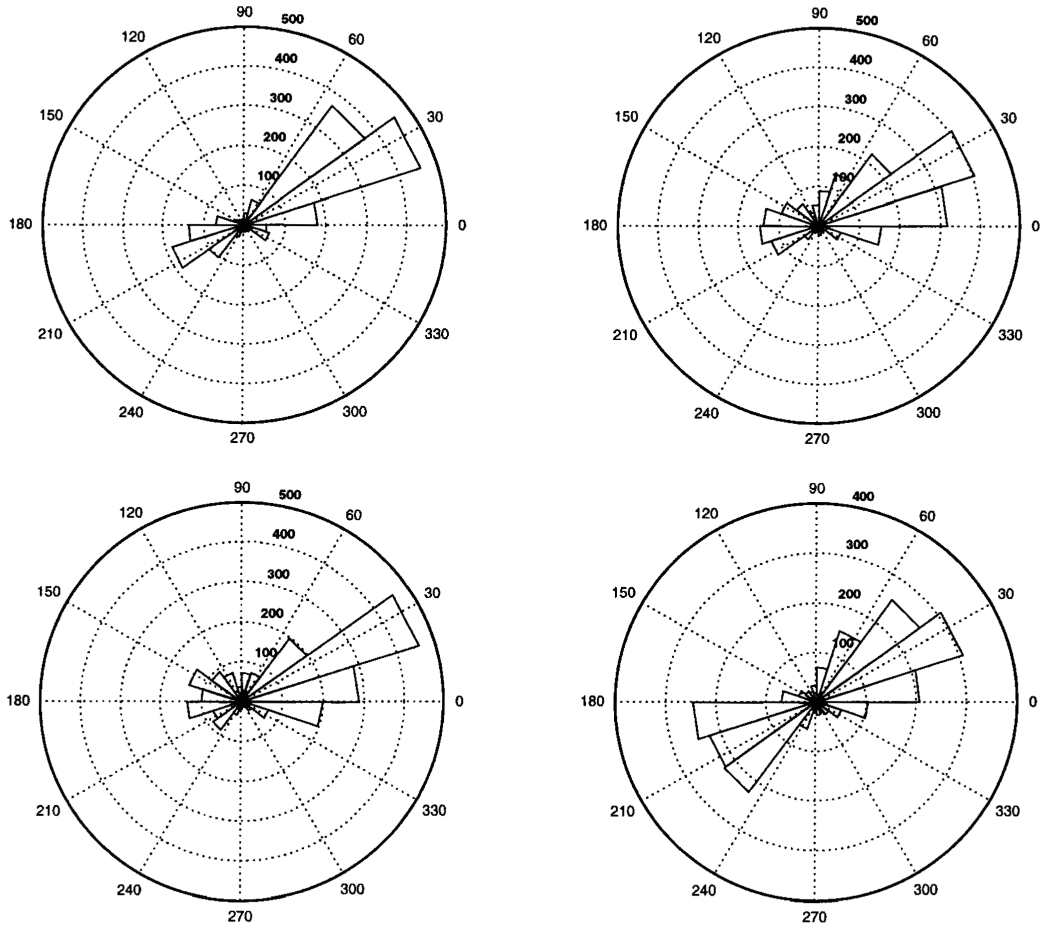

Figure 5. Wind rose of January to March (upper left), April to June (upper right), July to September (lower left), and October to December (lower right) for Endicott station, 2001. The vertical columns of figures indicate numbers of data points.

Analysis of oil spill simulation results

Oil spill simulation results with or without ice

In order to illustrate the seasonal changes of potential oil spill trajectories and the impacts of different ice conditions on oil spill trajectories, we conducted oil spill simulations starting in different months and compared the results with the same time period but without ice ($C_{ice}=0$). For all the cases, the oil spill tracers were released evenly for three days from the starting day and the simulation lasted for one month. The model was designed to release any amount of tracers within any time period, as defined by the user.

The oil trajectories of the control run with ice (using simulated ice velocity and ice concentration) are shown in Figure 6, and the comparative cases without ice in Figure 7. We used the 2001 wind data from Endicott station in these two numerical experiments. The red star near Prudhoe is the release point. The oil spill tracers are illustrated with different colors indicating the number of days from the starting date as shown in the legends within the figures.

January 2001. Under simulated ice conditions, the oil moved slowly eastward and remained on the shelf for the first 17 days and then split: some continued its slow eastward movement, while some moved into the slope current and followed it, traveling quickly towards the west from day 21 to 29. Because the Beaufort Sea was almost fully ice covered in January, the comparative case without ice showed large differences—the oil spill was restrained near shore by the dominant NEE wind (Figure 7).

April 2001. Ice was at its thickest. Under ice conditions, the oil moved slowly eastward on the shelf for the first 17 days, but after day 17 the oil tracers split: Some of them continued eastward on the shelf and others spread into the slope region and moved westward following the slope current. The comparative case without ice also showed that the oil spill was restrained near shore by the dominant NEE wind, as in January.

July 2001. The oil drifted eastward along the coast with the coastal current. Because the ice along the Beaufort Sea coast had already melted, there was no difference between the ice and no-ice results.

August 2001. As open water areas further widened offshore, oil spill tracers were spread by the surface turbulent current and transported westward by wind and the slope current. The tracers in the slope current region on day 13 were driven toward shore by wind, as is seen from the tracer locations on day 17 to day 29. Because the ice concentration in the offshore and slope regions where the oil spill tracers traveled was still not zero, the two simulations varied, especially from day 17 to 29, when tracers for the no-ice example were pushed closer to shore and the west coast of Barrow (see Figure 7d) than they were in the case of the simulated ice conditions (see Figure 6d). The comparative simulation in August is different from those in the other months because the oil spill was driven by the combination of wind and surface current along with the no-ice conditions. Although the wind rose is very similar from January to September, the simulated surface current is different, because in the coupled ice–ocean model, the wind-driven westward surface current prevails in August, while the eastward Beaufort Sea coastal current dominates in the ice-covered months, since wind is blocked by ice cover.

October 2001. The ice formation on the sea surface restrained the oil spill to the shelf region. In the no-ice condition, the oil spill moved farther offshore in October than January and April, because October to December both the NEE and SEW wind were dominant, instead of a NEE wind as in the other months (Figure 5).

November 2001. Ice cover formed on the sea surface. The ice movement brought the oil spill offshore into the slope current on day 21, then the oil turned westward and drifted along the slope. In the no-ice condition, the oil spill trajectory was quite different: The oil moved farther offshore than in October, which was also due to a more frequent SWW wind in November.

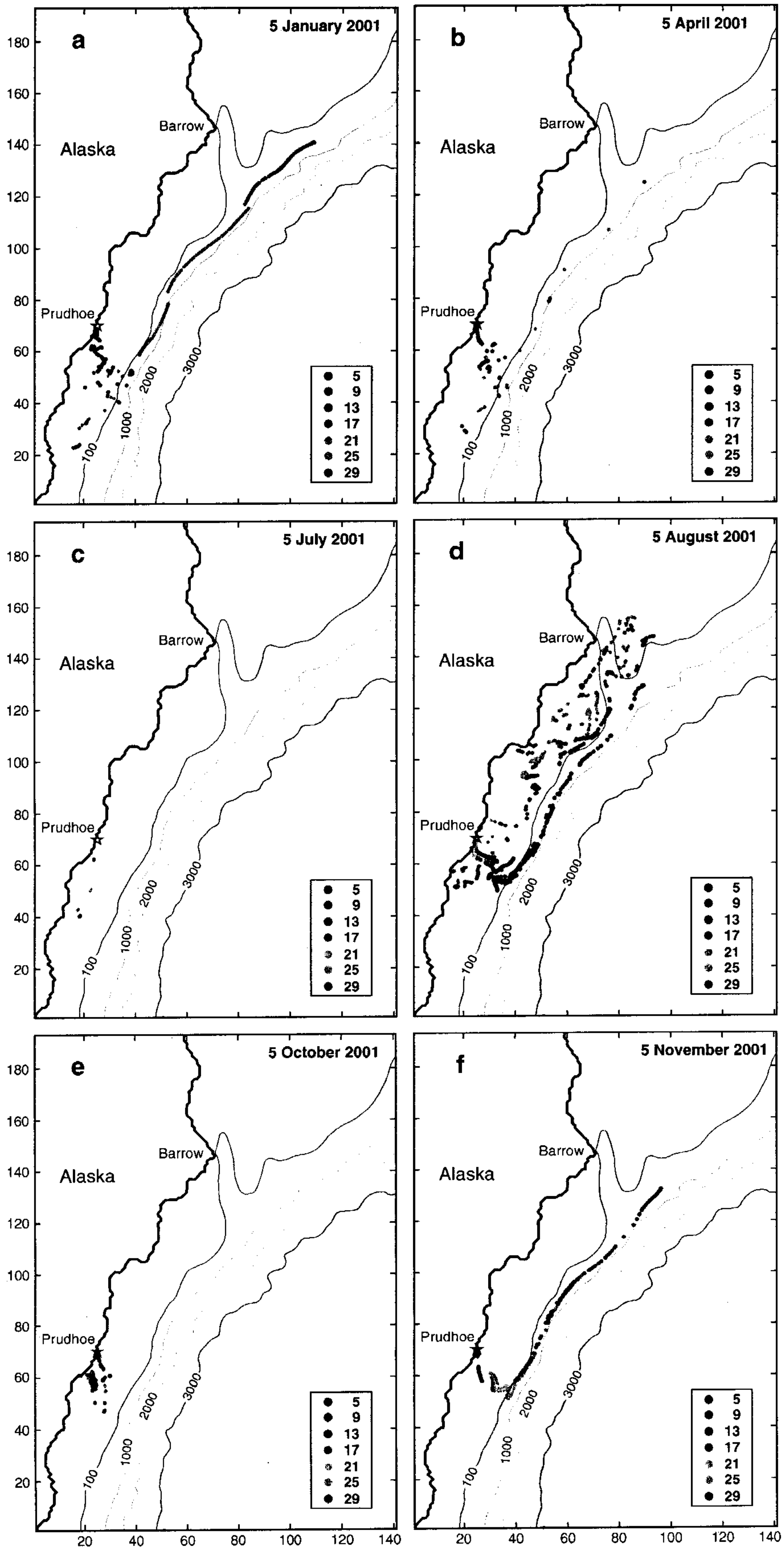

Figure 6. Oil spill trajectory following simulated release on: a) 5 January, b) 5 April, c) 5 July, d) 5 August, e) 5 October, and f) 5 November 2001. The legend indicates number of days from the release date. The x- and y-axis units are the model grid size (3.4 km).

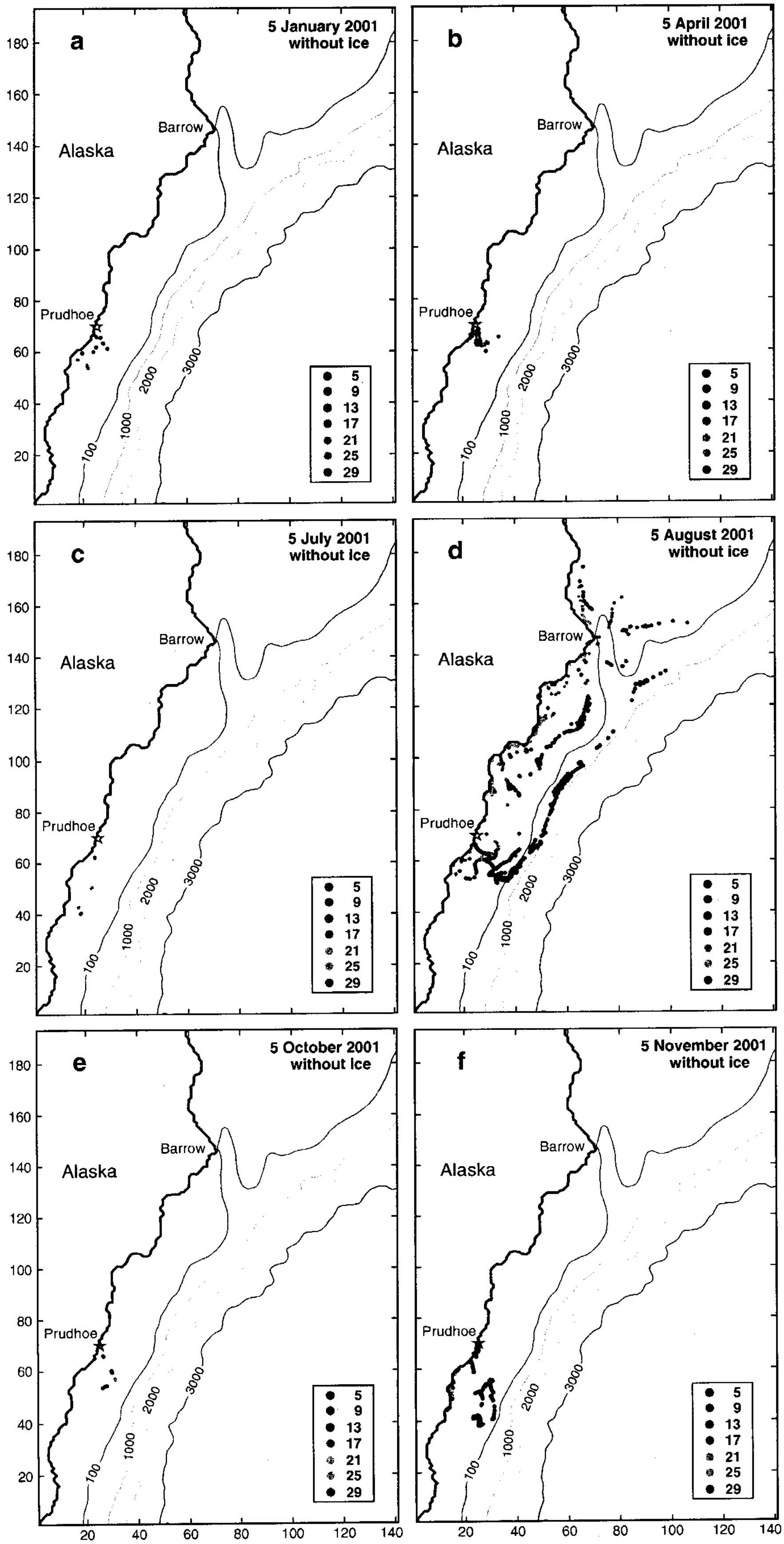

Figure 7. Same as Figure 6 except that the sea ice flow was not considered in the simulation. Oil spill trajectory following simulated release on:
a) 5 January,
b) 5 April,
c) 5 July,
d) 5 August,
e) 5 October, and
f) 5 November 2001.
The legend indicates number of days from the release date. The x- and y-axis units are the model grid size (3.4 km).

Interannual differences in oil spill simulation results

Using the same ocean and ice velocity fields and the 2002 wind data at Endicott station, the same sets of numerical experiments with ice were conducted to investigate the interannual differences of oil spill trajectories by comparing with the results using 2001 wind forcing. Figure 8 displays the same simulations as Figure 6 but for 2002. The winter months of January and April are very similar for the two years; small differences can be seen for July and November; and large differences can be seen for the two months, August and October, due to open water conditions.

Since we used the same ocean and ice velocity fields, but different wind data for 2001 and 2002, the above results demonstrated that in the winter months ice flow dominated the oil spill motion, but in summer, wind effects were also important. With less sea ice concentration, wind would have a more direct impact on the oil spill drift, as the wind effect is weighted by an ice concentration coefficient in the oil spill drift model. That explains the gradually increasing differences from winter to summer. Actually, wind affects ice velocity in the coupled ice–ocean model; therefore, if we use different wind data to drive the coupled ice–ocean model, we would also see interannual differences of oil trajectories in winter.

Notes on Oil Spill Modeling in the Beaufort Sea

When the simulation results are used for actual oil spill accidents, the following should be noted:

1. The simulated oil spill cases in this study are based on assumed oil spill location, time, and amount of oil spilled, and they might not cover all the potential scenarios.
2. Any human-related removal of an oil spill are not included or considered in the model. If those efforts take place within the first two weeks, while the oil spill is still on the shelf and not widely spread, then the actual oil spill impact will be largely reduced and confined to limited regions.
3. Tidal current is not included in this study. In the Beaufort Sea, tidal current is only significant in the shallow coast regions, in the order of 5 cm s^{-1}, similar to that of the stable eastward Beaufort Sea coastal current. When the oil spill movement is considered in the time scale of less than a tide cycle, the tide current is important, while in multi-day to one-month time scales, only the tide-induced residual current is significant, which is one order smaller (0.5 cm s^{-1}) than tide current (5 cm s^{-1}). Therefore, the simulation results in this study represent the major components of oil spill movements on several days to one-month time scales.

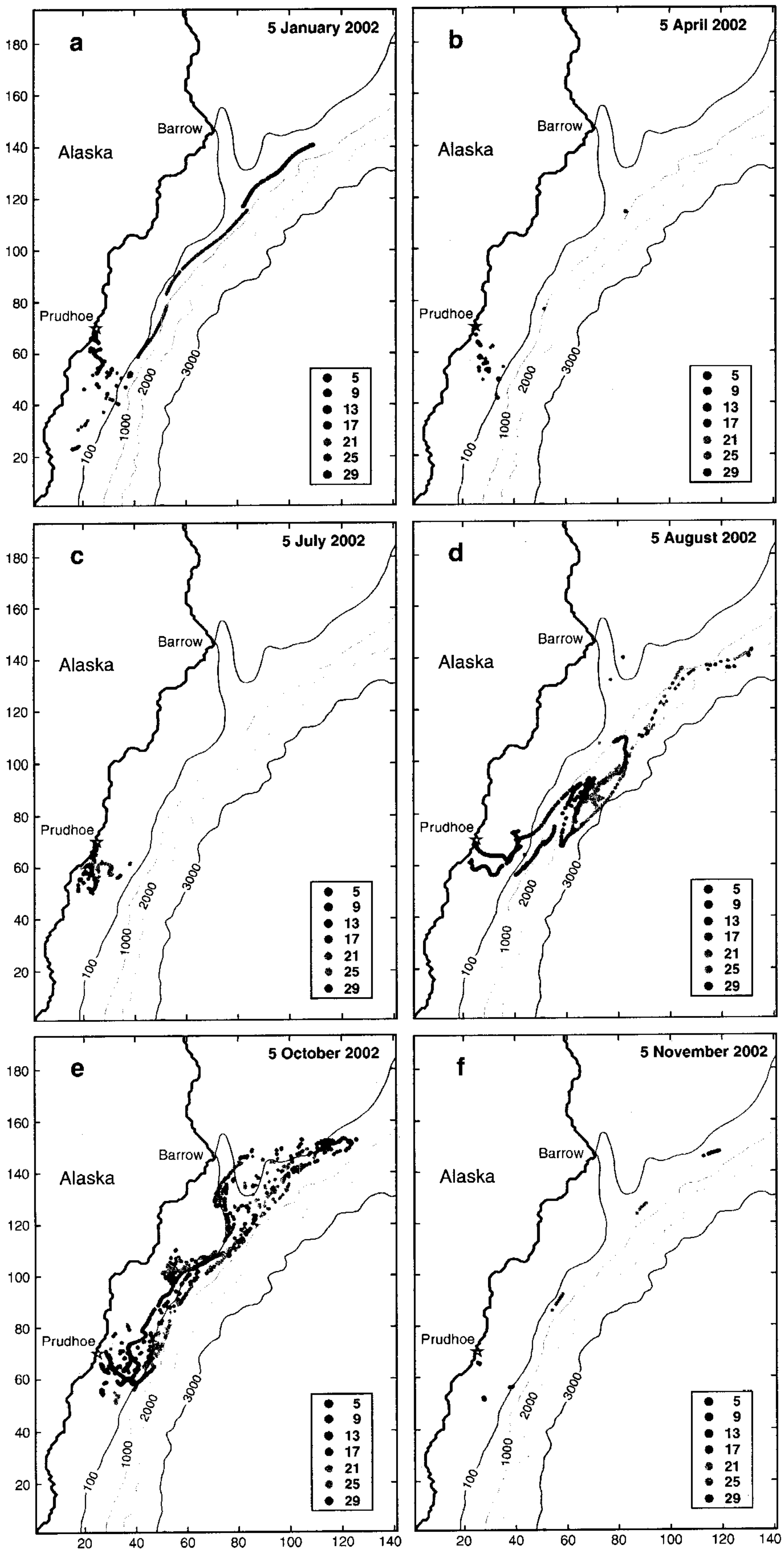

Figure 8. Same as Figure 6 except for 2002. Oil spill trajectory following simulated release on:
a) 5 January,
b) 5 April,
c) 5 July,
d) 5 August,
e) 5 October, and
f) 5 November 2001.
The legend indicates number of days from the release date. The x- and y-axis units are the model grid size (3.4 km).

Summary

Using station wind data and simulated surface current, ice velocity and ice concentration from the coupled ice–ocean model, we conducted a series of simulations of oil spills starting on different dates and with different ice-cover conditions.

The results showed significant seasonal and interannual variations in the oil spill trajectory under simulated ice conditions. During the ice-covered months, the oil spill tracers first moved eastward or northeastward offshore. In January of both 2001 and 2002, the tracers split on day 17, some moving eastward slowly along the coast and some moving into the slope current and drifting towards the west from day 21 to 29. In April and November of both 2001 and 2002, some of the tracers that moved into the slope current were driven westward by the slope current and never returned to the Alaska coast. In July of both 2001 and 2002, the tracers were confined on the shelf (day 1 to 29). In August, a broad open water condition enabled the tracers to spread widely over the shelf and move westwards driven by a dominant NEE wind and the slope current. The oil spill reached the coastline from Prudhoe to Barrow in August of 2001 but not in August of 2002. An oil spill was constrained to the coast east of Prudhoe in October of 2001, but met the slope current and moved westward along the shelf break in October of 2002.

Ice cover can affect oil spill trajectory by reducing wind effects on sea surface current, sea ice flow and oil spill drift. Sea ice flow dominates the oil spill movement in the winter months, and wind has a larger effect on oil spill movement in the summer.

Acknowledgements

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References

Chu, P.C., Q. Wang and R.H. Bourke. 1999. A geometric model for the Beaufort/Chukchi Sea thermohaline structure. J. Atmos. Ocean. Tech. 16(6):613–632.

Dutkiewicz, S., A. Griffa and D.B. Olson. 1993. Particle diffusion in a meandering jet. J. Geophys. Res. 98(C9):16487–16500.

Hedstrom, K.S. 1994. Technical manual for a coupled sea-ice/ocean circulation model (version 1). OCS Study MMS 94-0020, USDOI, MMS, Alaska OCS Region. 117 p.

Jin, M., J. Wang, F.J. Saucier and M. Ikeda. 2001. General circulation and transport in the pan Arctic and North Atlantic Ocean, p. 182–185. *In* 6th Conf. Polar Meteorology and Oceanography, San Diego. American Meteorological Society.

Manley, T.O., and K. Hunkins. 1985. Mesoscale eddies of the Arctic Ocean. J. Geophys. Res. 90:4911–4930.

Thomson, D.J. 1987. Criteria for selection of stochastic models of particle trajectories in turbulent flow. J. Fluid Mech. 180:529–556.

Wang, J. 1999. A nowcast/forecast system for coastal ocean circulation. International Arctic Research Center–Frontier Research System for Global Change. IARC/Frontier Tech. Rep. No. 99-1. University of Alaska Fairbanks. 97 p.

Wang J. 2001. A nowcast/forecast system for coastal ocean circulation using simple nudging data assimilation. J. Atmos. Ocean. Tech. 18(6):1037–1047.

Wang, J., M. Ikeda and F.J. Saucier. 2003a. A theoretical, two-layer, reduced-gravity model for descending dense water flow on continental slopes. J. Geophys. Res. 108(C5). 10.1029/2000JC000517.

Wang, J., M. Jin, M. Ikeda, K. Shimada and J. Takahashi. 2003b. A nowcast/forecast model for the Beaufort Sea ice–ocean–oil spill system (NFM-BSIOS), p. 21–33. *In* University of Alaska Coastal Marine Institute Annual Report No. 9. OCS Study MMS 2003-003, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region.

Wang, J., R. Kwok, F.J. Saucier, J. Hutchings, M. Ikeda, W. Hibler III, J. Haapala, M.D. Coon, H.E.M. Meier, H. Eicken, N. Tanaka, R. Prentki and W. Johnson. 2003c. Working toward improved small-scale sea ice–ocean modeling in the Arctic seas. EOS 84(34):325, 329–330 [26 Aug 03].

Wang, J., Q. Liu and M. Jin. 2002a. A nowcast/forecast model for the Beaufort Sea ice–ocean–oil spill system (NFM-BSIOS), p. 80–94. *In* University of Alaska Coastal Marine Institute Annual Report No. 8. OCS Study MMS 2002-001, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region.

Wang, J., Q. Liu and M. Jin. 2002b. A User's Guide for a Coupled Ice–Ocean Model (CIOM) in the Pan-Arctic and North Atlantic Oceans. International Arctic Research Center–Frontier Research System for Global Change, Tech. Rep. 02-01, 65 p.

Wang, J., Q. Liu, M. Jin, M. Ikeda and F. Saucier. 2003d. A coupled ice–ocean model in the pan-Arctic and the northern North Atlantic Ocean: Simulation of seasonal cycles (Submitted to J. Oceanogr.).

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

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Task Order 15179

Abstract

*At least five stocks of beluga whales (*Delphinapterus leucas*) occur in Alaska. One of these, the eastern Chukchi Sea stock, is most commonly seen in coastal waters near Kasegaluk Lagoon in northwestern Alaska during June and July. Despite their status under the Marine Mammal Protection Act and their importance to many Alaska Native hunters for subsistence, relatively little is known about the movements and seasonal distribution of these whales during the rest of the year. During 1998–2002 we instrumented 23 belugas with satellite-linked depth recorders, including 12 adult males, 4 immature males, 2 adult females and 5 immature females. The recorders provided location information for an average of 67 (range 5–154) days. Saddle mount tags averaged 52 days, spider mounts 68 days and side mounts 81 days, although there was no statistical difference in longevity among attachment types. Animals moved north and east into the northern Chukchi and western Beaufort Seas after capture. During July–September movement patterns differed by age and/or sex. All belugas that moved north of 75 °N in the Beaufort Sea and Arctic Ocean were males. Adult males tended to use deeper water and to remain there for most of the summer. Five of 9 adult males tagged from all-male groups early in their northward migration traveled through 90% pack ice cover to reach 79–80 °N by late July/early August. Adult males captured from groups that included adult females also moved into deep water, but apparently for shorter periods of time. In all years adult and immature females remained at or near the shelf break throughout summer and early fall. Immature males moved farther north than immature females, but not as far north as adult males, based on our small sample size. Belugas of all ages and both sexes were most often found in water deeper than 200 m along and beyond the continental shelf break. They rarely used the inshore waters within the outer continental shelf lease sale area of the Beaufort Sea. Heavy ice apparently did not inhibit the movements of large adult males in summer, since they traveled through and were often located in >90% ice cover. Only 3 tagged belugas transmitted data after October. Those animals migrated south through Bering Strait into the northern Bering Sea north of St. Lawrence Island.*

Timing and Re-Interpretation of Ringed Seal Surveys

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Task Order 15180

Abstract

*We recorded weather data and the proportion of radio-tagged ringed seals (*Phoca hispida*) visible on the ice surface in the Alaskan Beaufort Sea from April to June 2003. Fifteen ringed seals were live captured, and we monitored their use of lairs and basking sites by radio telemetry. The proportion of seals visible on the surface of the ice was highly variable both within a day and as the spring season progressed. The first tagged seal began basking on the surface of the ice on 28 April; however, lairs were not completely abandoned until 30 May. The proportion of tagged seals visible on the surface of the ice increased rapidly from 14 May to 30 May, reaching 100% on 8 June. The recapture of two individuals previously tagged in 2002 suggests a high degree of inter-annual site fidelity.*

Introduction

Ringed seals spend most of the year hidden from view either resting in snow caves (lairs) excavated above breathing holes in the ice, or swimming in the ocean [e.g., Chapskii 1940; McLaren 1958; Smith and Stirling 1975; Smith 1987; Kelly and Quakenbush 1990]. Each spring, as the snow melts, seals abandon their lairs and rest on the surface of the ice next to uncovered breathing holes. Adult seals are molting then, and regeneration of the epidermis requires that they bask in the sun to elevate skin temperatures [Feltz and Fay 1966; King 1983]. Surveys of ringed seals have been concentrated during the annual molt in late May and early June when an unknown proportion of the population is visible on the surface of the ice [Kelly 1988]. Spatial and temporal comparisons of animal densities from aerial survey data typically rest on the assumption that the proportion of animals visible is constant from survey to survey [Caughley 1977; Drummer 1999].

We are testing the implicit assumptions of aerial surveys and investigating how the proportion of visible seals changes over time and between years. We used VHF radio telemetry to determine where and when ringed seals are concealed under the ice, concealed in subnivean lairs, or visible on top of the snow and ice April–June 2001–2003. We also are determining the weather and snow conditions that influence the abandonment of subnivean lairs and the subsequent relationships between environmental variables and the availability of seals for counting. We will then apply that information in a reanalysis of historical survey data for ringed seals in the Alaskan Beaufort Sea.

Methods

In April–June 2003, we monitored the use of subnivean lairs by ringed seals in the Alaskan Beaufort Sea 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).

We located subnivean breathing holes and lairs using dogs trained to indicate sources of ringed seal odor [Smith and Stirling 1975; Kelly and Quakenbush 1987], and we marked those sites with numbered wooden stakes and recorded the locations with a global positioning system.

We used pursing nets to capture seals when they entered breathing holes [Kelly 1996]. Two VHF radio transmitters (Advanced Telemetry Systems, Models MM170 and MM420) were attached to each seal, one glued to the hair on the dorsum and the second attached to a hind flipper. The flipper transmitter allowed data collection to continue after the seal had molted its hair (and its dorsal transmitter) in early June.

We monitored radio signals hourly from stations equipped with 8-element Yagi antennas on a 10-m high mast and within 5 km of the seal capture sites. 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 determined its location using a mobile receiver and hand-held directional antenna array. The directional antenna array consisted of two H-antennas communicating with the acoustic receiver by way of a null combiner. Thus, the bearing from the array to a transmitter was indicated by a deep null surrounded by high amplitude signals. Typically, five or more bearings (approximately ± 3°) from points surrounding a tagged seal were obtained and it's position read as the intersection of those bearings. Once the position was determined, we recorded whether each seal was concealed within a lair or visible on the snow surface.

To verify that the behavior of tagged seals was representative of the behavior of the overall population, we counted all seals visible on the ice daily (approximately 16:00 Alaska Daylight Time) in May 2003. We used binoculars (Leica 10 × 42) to make the counts from the roof of a building about 62 m above the ice at the southern edge of the study area.

We recorded air temperature, snow temperature (from ice surface to snow surface at 5 cm intervals), wind speed, and wind direction within the study area every 30 minutes from 7 April to 3 June 2003. Air temperature and snow temperature were measured by HOBO data loggers (Onset Computer Corporation). The wind speed and wind direction were measured by a wind monitor (R.M. Young) and stored on a CR10 data logger (Campbell Scientific).

Results

The trained dogs located 58 breathing holes and 38 lairs in 2003. An additional 4 breathing holes and 11 lairs were located by tracking radio-tagged seals. We set nets in breathing holes 51 times and captured 15 seals 16 times (1 recaptured).

Fifteen seals were radio-tagged and monitored hourly from 28 April to 19 June. Individual seals used a maximum of 4 lairs and 3 basking sites (Table 1). Two seals (SH02 and WW02) that had been tagged and tracked in 2002 were recaptured in 2003. Both seals retained the flipper-mounted radio tag (one still broadcasting) applied in 2002, and both were recaptured less than 2 km from their 2002 capture sites. Furthermore, the size and configuration of their home ranges were similar across years, although each seal's range appeared to be shifted north by about 1 km in 2003 (Figure 1).

The earliest observation of a tagged seal basking on the surface of the ice was on 28 April. Lairs were not completely abandoned, however, until 30 May (Figure 2). The proportion of tagged seals visible on the surface of the ice increased rapidly from 14 May to 30 May, reaching 100% on 8 June.

Table 1. Ringed seals captured and telemetrically monitored in the Alaskan Beaufort Sea in 2003.

Capture date	Seal ID	Sex	Minimum age	No. Lairs used	Date of 1st basking	No. basking sites used
9 Apr 03	YK03	M	9	4	2 Jun 03	1
13 Apr 03	KA03	F	6	3	1 Jun 03	1
16 Apr 03	SU03	F	6	2	18 May 03	1
18 Apr 03	SQ03	F	9	1	18 May 03	2
22 Apr 03	VI03	F	7	4	28 May 03	1
23 Apr 03	SH02	F	8	4	14 May 03	1
23 Apr 03	SE03	M	6	3	21 May 03	2
25 Apr 03	JW03	M	8	1	18 May 03	1
26 Apr 03	TE03	M	6	3	28 Apr 03	2
26 Apr 03	TA03	F	7	2	16 May 03	3
29 Apr 03	PF03	F	7	1	14 May 03	3
5 May 03	MO03	M	8	3	–	2
7 May 03	WW02	M	6	2	14 May 03	3
10 May 03	GR03	F	7	1	18 May 03	1
10 May 03	FI03	F	6	1	31 May 03	1

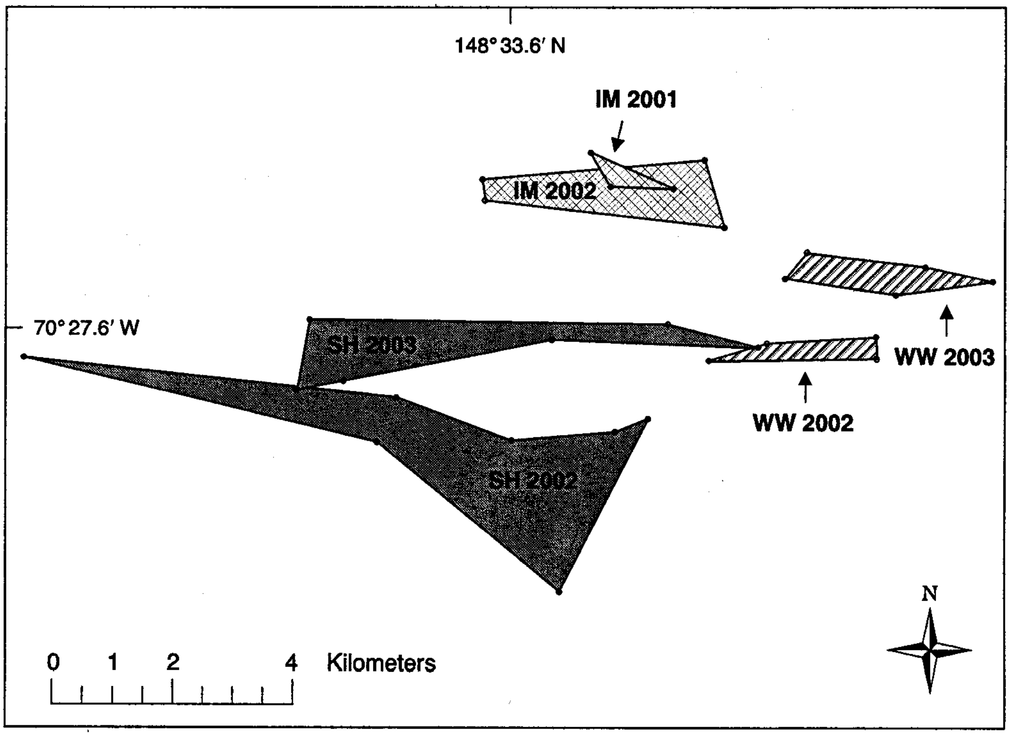

Figure 1. Home ranges of two adult males (IM and WW) and one adult female (SH) ringed seal captured and telemetrically tracked in multiple years.

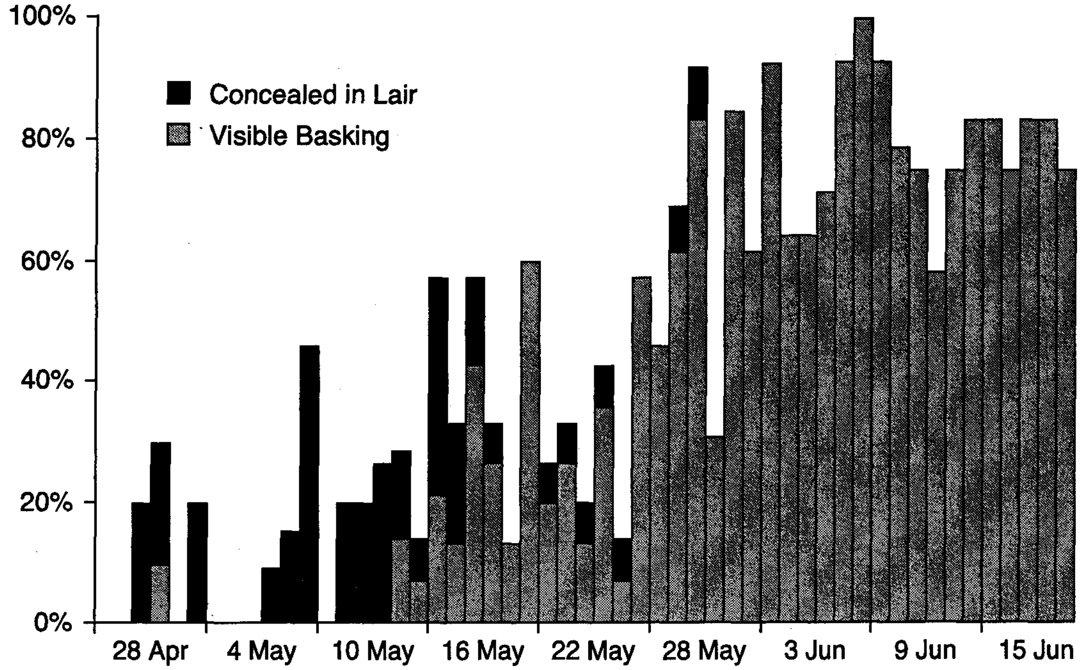

Figure 2. Proportion of radio-tagged ringed seals out of the water (at 3:00 pm) and concealed in their lairs or visible basking on the surface of the ice in 2003.

Discussion

Site fidelity

In 2003, the 15 seals we captured included 2 of the 16 seals that we had tagged and tracked in 2002. Together with a recapture in 2002 of a seal tagged in 2001, these observations suggest a previously unknown and unexpectedly high degree of inter-annual site fidelity among adult ringed seals.

The site fidelity suggested by these data has important implications for our understanding of ringed seal ecology and the seals' exposure and responses to industrial activities. Given that the topography of the ice varies from year to year, we suspect that benthic features may provide important cues to seals relocating under ice home ranges. Benthic feeding is likely to be important in shallow areas such as the near shore Beaufort Sea of Alaska, and site fidelity among ringed seals in the region may reflect predictable heterogeneity in benthic prey.

Inter-annual site fidelity also has implications for understanding the effects of industrial activities in the ringed seal's shorefast ice habitat. Currently, ice-road construction is not regulated until late winter on the assumption of negligible impact to seals prior to their establishment of under-ice home ranges. In fact, we do not know when the under-ice home ranges are established, and inter-annual site fidelity would suggest that it is possible to impact seals by excluding them from critical sites used from year to year. On the other hand, it may be that inter-annual site fidelity affords more opportunity for habituation to long-term industrial activities such as offshore production wells.

Proportion of seals visible

We have demonstrated that the proportion of ringed seal populations available to be counted during aerial surveys is dramatically affected by the timing of the surveys, both within a day and as the spring season progresses [Kelly et al. 2000, 2002]. We have also shown that the proportion of seals visible is highly variable between years [Kelly et al. 2003].

Covariate modeling

Inconsistent relationships between the density of visible ringed seals and air temperature, wind speed, and cloud cover have been reported [Burns and Harbo 1972; Stirling et al. 1977; Burns and Kelly 1982; Kingsley et al. 1985; Frost et al. 1988]. We are exploring the use of temperature of the snow pack (which integrates air temperature, wind speed, and cloud cover) and spaceborne Ku-band scatterometer data to predict when lair abandonment is complete. From 2000 to 2002, in conjunction with the Jet Propulsion Laboratory, we found that spaceborne Ku-band scatterometer data were sensitive to snow deterioration and remotely indicated the timing of lair abandonment. We are continuing to test the utility of scatterometer data and are currently modeling the effects of environmental covariates on the proportion of seals visible. The model will then be used in a reanalysis of previous ringed seal surveys in the Beaufort Sea.

Acknowledgements

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Study Products

Presentations on this project were delivered in several venues in 2003. On 19 February 2003, Brendan Kelly spoke to the Coastal Marine Institute in Fairbanks and on 11 March 2003, Oriana Harding spoke to the Minerals Management Service Information Transfer Meeting in Anchorage. On 28 March 2003, Brendan Kelly presented on this project to a National Academy of Sciences panel assisting the North Pacific Marine Research Board in developing a research plan. On 24 April 2003, Brendan Kelly presented an overview of this project to the Minerals Management Service Scientific Committee Meeting in Anchorage (session on "ITM Highlights"). Finally, Ned Conway presented "Snowpack Cold Content as a Predictor of Lair Abandonment by Ringed Seals" and Kyndall Hildebrandt presented "Influence of Predation on Habitat Selection by Ringed Seals" on 4 August 2003 at the Research Experiences for Undergraduates Student Seminar.

References

Burns, J.J., and S.J. Harbo. 1972. An aerial census of ringed seals, northern coast of Alaska. Arctic 25:279–290.

Burns, J.J., and B.P. Kelly. 1982. Studies of ringed seals in the Alaskan Beaufort Sea during winter: impacts of seismic exploration. Unpublished Annual Report, OCSEAP Research Unit 232, to U.S. Dept. Comm., NOAA, Off. Mar. Pollut. Assess., Juneau, Alaska. 57 p.

Caughley, G. 1977. Sampling in aerial survey. J. Wildl. Manage. 41:606–615.

Chapskii, K.K. 1940. The ringed seal of western seas of the Soviet Arctic (The morphological characteristic, biology and hunting production). Tr. Vses. Arkt. Inst. (Leningrad) 145:1–72. (Transl. from Russian by Fish. Res. Bd. Can., 1971, Transl. Ser. 1665, 147p.)

Drummer, T.D. 1999. Planning abundance estimation surveys when detectability is <1.0, p. 67–73. *In* G.W. Garner, S.C. Amstrup, J.L. Laake, B.F.J. Manly, L.L. McDonald and D.G. Robertson [eds.], Marine Mammal Survey and Assessment Methods. A.A. Balkema, Rotterdam.

Feltz, E.T., and F.H. Fay. 1966. Thermal requirements in vitro of epidermal cells from seals. Cryobiology 3:261–264.

Frost, K.J., L.F. Lowry, J.R. Gilbert and J.J. Burns. 1988. Ringed seal monitoring: Relationships of distribution and abundance to habitat attributes and industrial activities. Final Report, OCSEAP Research Unit 667, to U.S. Dept. Comm., NOAA, Natl. Ocean Serv., Ocean Assess. Div., Alaska Office, Anchorage. 101 p.

Kelly, B.P. 1988. Ringed seal, p. 59–75. *In* J.W. Lentfer [ed.], Selected Marine Mammals of Alaska: Species Accounts with Research and Management Recommendations. Marine Mammal Commission, Washington, D.C.

Kelly, B.P. 1996. Live capture of ringed seals in ice-covered waters. J. Wildl. Manage. 60:678–684.

Kelly, B.P., and L.T. Quakenbush. 1987. Trained dogs and wild seals. Whalewatcher, J. Amer. Cetacean Soc. 21:8–11.

Kelly, B.P., and L.T. Quakenbush. 1990. Spatiotemporal use of lairs by ringed seals (*Phoca hispida*). Can. J. Zool. 68:2503–2512.

Kelly, B.P., O.R. Harding and M. Kunnasranta. 2003. Timing and re-interpretation of ringed seal surveys, p. 45–50. *In* University of Alaska Coastal Marine Institute Annual Report No. 9. OCS Study MMS 2003-003, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region.

Kelly, B.P., L.T. Quakenbush and B.D. Taras. 2000. Correction factor for ringed seal surveys in northern Alaska, p. 14–23. *In* University of Alaska Coastal Marine Institute Annual Report No. 7. OCS Study MMS 2000-070, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region.

Kelly, B.P., L.T. Quakenbush and B.D. Taras. 2002. Correction factor for ringed seal surveys in northern Alaska, p. 3–15. *In* University of Alaska Coastal Marine Institute Annual Report No. 8. OCS Study MMS 2002-001, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region.

King, J.E. 1983. Seals of the world, 2nd Ed. Comstock Publishing Associates, Ithaca, New York. 240 p.

Kingsley, M.C.S., I. Stirling and W. Calvert. 1985. The distribution and abundance of seals in the Canadian High Arctic, 1980–82. Can. J. Fish. Aquat. Sci. 42:1189–1210.

McLaren, I.A. 1958. The biology of the ringed seal seals (*Phoca hispida* Schreber) in the eastern Canadian Arctic. Fish. Res. Bd. Can. Ms. Rep. (Biology) 653. 146 p.

Smith, T.G. 1987. The ringed seal, *Phoca hispida*, of the Canadian western Arctic. Can. Bull. Fish. Aquat. Sci. 216. Ottawa. 81 p.

Smith, T.G., and I. Stirling. 1975. The breeding habitat of the ringed seal (*Phoca hispida*): The birth lair and associated structures. Can. J. Zool. 53:1297–1305.

Stirling, I., W.R. Archibald and D. DeMaster. 1977. Distribution and abundance of seals in the eastern Beaufort Sea. J. Fish. Res. Bd. Can. 34:976–988.

Importance of the Alaskan Beaufort Sea to King Eiders (*Somateria spectabilis*)

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Abstract

During the molt migration (early July–August) and fall migration (mid-August–October), king eiders move west along the Beaufort Sea coast to areas in the Chukchi and Bering seas, but information on distance offshore and the frequency and location of potential staging areas is lacking. This study was begun to better understand use (timing, location, duration) of nearshore (barrier island to the mainland coast) and offshore (seaward of the barrier islands) habitats of the Beaufort Sea by migrating, staging, and molting adult king eiders. We trapped 12 pre-breeding king eiders (3 females and 9 males) in 2003 using mist nets and decoys at the Kuparuk oil field on the Arctic Coastal Plain of Alaska. An experienced veterinarian surgically implanted satellite transmitters into the body cavity of each eider. The satellite platform transmitting terminal (PTT) transmitters send location information via satellites every 48 hours during late summer and fall migration. This report includes late summer location data from the 12 eiders transmittered in 2003 and molt, winter, and summer location data of 21 king eiders implanted with satellite transmitters during the 2002 field season. Fourteen of the 2002 transmittered eiders were still sending location data as of 31 July 2003. Areas the 2002 eiders used for molting included the Chukotka Peninsula, the Kamchatka Peninsula, St. Lawrence Island, Kuskokwim Bay, the Alaska Peninsula, and the Beaufort Sea. These results are comparable to those of Dickson et al. [2000]. Winter locations were along the Kamchatka Peninsula, the Chukotka Peninsula, the Alaska Peninsula, Kvichak Bay, Chirikof Island, and the Kenai Peninsula. All 2002 females still transmitting returned to the Kuparuk study site during the 2003 breeding season. Males went to Canada, the North Slope of Alaska, and Russia during the 2003 breeding season. As of 31 July 2003, most 2002 and 2003 males were heading south on molt migration, while most females remained in the Beaufort Sea.

Introduction

King eiders (*Somateria spectabilis*) migrate east along the Beaufort Sea during spring (May–June) to arctic nesting areas in Russia, Alaska and Canada. During the molt migration (early July–August) and fall migration (mid-August–October), eiders move west along the Beaufort Sea coast to areas in the Chukchi and Bering seas; however, some adult male king eiders molt in the Beaufort Sea. Although the timing and route of the offshore spring migration is likely determined by the availability of open water in the pack ice, information on distance offshore and the frequency and location of potential staging areas is lacking. Little is known about the migration corridor and staging and molting areas of non-breeders. This study was begun to better understand use (timing, location, duration) of nearshore (barrier island to the mainland coast) and offshore (seaward of the barrier islands) habitats of the Beaufort Sea by migrating, staging, and molting adult king eiders. Because eiders congregate in large, dense flocks during migration and molt, they may be particularly vulnerable to an offshore oil spill in the Beaufort Sea. An apparent decline in the western Canadian and eastern Alaskan populations of king eiders has increased concern for this species [Suydam et al. 2000]. This study will identify when, where, and how long adult king eiders use the Beaufort Sea; consequently, results may be overlapped with trajectories from modeled oil spills to better assess impacts from permitted or planned oil and gas developments.

Objectives

1. Document movements and locations of spring, summer and fall migrating adult king eiders (successful and unsuccessful breeders) marked on breeding areas in Kuparuk, Alaska;
2. Describe potential staging areas used during spring and fall migration;
3. Determine if adult female king eiders (successful and unsuccessful breeders) molt in the Beaufort Sea prior to fall migration to overwintering areas; and
4. Based on satellite imagery, describe sea ice and open water conditions of the nearshore and offshore of the Beaufort Sea relative to observed locations of satellite transmitter implanted king eiders.

Study Area

The study was conducted in the Kuparuk oil field on the Arctic Coastal Plain of Alaska between the Colville and Kuparuk rivers. ConocoPhillips Alaska, Inc. leases this area for oil development from the State of Alaska. The terrain is characterized by numerous thaw lakes, ponds and basins. Wetland community types include wet sedge (*Carex* spp.) meadows, moist sedge–dwarf shrub (*Salix* spp.) meadows, and emergent *Carex* spp. and *Arctophila fulva* on the margins of lakes and ponds [Anderson et al. 1999]. Figure 1 shows the locations of the study area and sites mentioned in the report.

Methods

We arrived at the study site on 10 June 2003 and began trapping eiders on 11 June. King eiders were captured using mist net arrays set up in ponds with relatively large concentrations of eiders. Once captured, the eiders were placed in a secure, dark kennel and transported to an indoor facility equipped for surgery. A veterinarian (Cheryl Scott, DVM) and one assistant surgically implanted a 35-g satellite platform transmitting terminal (PTT) transmitter into the abdominal cavity of each eider following the techniques described in our previous annual report [Powell et al. 2003]. We weighed each eider while in captivity, took tarsus and culmen measurements, and fitted it with a U.S. Fish and Wildlife Service (USFWS) band. The birds were held until fully awake and recovered from anesthesia (usually about two to three hours), and then released near the area where they were captured.

Figure 1. Locations of study area and place names mentioned in the report.

The 35-g PTTs used in this study have an expected battery life of 800 hours. To obtain the greatest number of locations during periods of active migration, the transmitters were programmed to have four different duty cycles. They transmit for six hours every 48 hours for the first four months (June through September) to increase the likelihood of collecting location data in the Beaufort Sea during molt migration. The transmitters then transmit for six hours every 84 hours for three months (October through December), every 168 hours for three months (January through March) and every 84 hours until the end of the battery life. The battery is projected to last about one year.

Migration was defined as an individual remaining in an area less than one week with sequential locations indicating movement in a single direction [Petersen et al. 1999]. Assuming king and spectacled eiders have a similar behavior during molt, a bird was considered molting if it remained within a restricted area and moved less than 1.5 km hr^{-1}. Staging birds were identified from clusters of locations from several birds or a bird remaining in an area for at least 10 days [Petersen et al. 1999]. Location data were filtered for accuracy using PC-SAS Argos Filter V5.0 (Dave Douglas, U.S. Geological Survey/Alaska Science Center). The filtering program removes implausible locations based on location redundancy and tracking paths. Locations were then plotted using ArcView GIS.

Results

When we arrived at the field site on 10 June 2003, most of the ponds in the study area were still partially frozen over and some snow remained on the ground. We trapped eiders at two wetland locations that proved to be successful trapping areas the previous summer. Three female and nine male pre-breeding king eiders were captured and implanted with satellite transmitters between 11 and 19 June. One of the three female king eiders showed obvious signs of egg development when captured. There were no complications during the surgeries and all of the birds appeared healthy when released.

This report includes location data from 1 September 2002 through 31 July 2003 for the 21 king eiders transmittered in 2002 and from capture date through 31 July 2003 for the 12 king eiders transmittered in 2003. Of the 21 transmitters deployed in king eiders in 2002, five (four females, one male) transmitters have stopped transmitting and two birds (one male, one female) are presumed dead based on temperature sensor data from the transmitter (Table 1). All 12 king eiders implanted during the 2003 field season were alive and transmitting as of 31 July 2003. The results and analysis of location data presented here are preliminary and may be subject to change at a later date based on new information received.

2002 satellite transmitter birds

Males ($n = 10$) staged 7–17 days (mean = 10) in the Beaufort Sea prior to fall molt migration at a mean distance from shore of 17 ± 6 km (SD) and a mean water depth of 11 ± 7 m, $n = 94$ location data points. Females ($n = 11$) staged 9–32 days (mean = 20) in the Beaufort Sea prior to molt migration at a mean distance from shore of 14 ± 3 km and a mean water depth of 8 ± 5 m, $n = 174$ location data points. Males reached molting areas along the Chukotka Peninsula and Kamchatka Peninsula, Russia and St. Lawrence Island and Kuskokwim Bay, Alaska from 22 July through 12 August. Females reached molting areas along the Chukotka Peninsula and Kamchatka Peninsula, Russia and St. Lawrence Island, the Arctic Coastal Plain and the Alaska Peninsula, Alaska from 11 August through 18 September (Table 1, Figure 2).

Table 1. September 2002 through July 2003 molting, wintering, summering and current locations of 33 king eiders fitted with satellite transmitters at Kuparuk, Alaska.

ID	PTT #	Sex	Transmitter Status	Molt Location	Wintering Location	Summer Location	Last Location Received and Date
KNG01	33933	F	Failed	NA	NA	NA	9/29/02
KNG02	33934	F	Indicated bird dead	Cape Chaplin, Chukotka Peninsula, Russia	NA	NA	Cape Chaplin, Chukotka Peninsula, Russia 11/25/02
KNG03	33935	F	Alive	Alaska Peninsula	Alaska Peninsula	Kuparuk, AK	Beaufort Sea, AK 7/30/03
KNG04	33936	M	Alive	Cape Chaplin, Chukotka Peninsula, Russia	Chukotka Peninsula, Russia	Beaufort Sea off coast of Canada	Pt. Lay, AK Chukchi Sea 7/31/03
KNG05	33937	F	Failed	Kvichak Bay, AK	Kenai Peninsula, AK	NA	5/01/03
KNG06	33938	F	Failed	NA	NA	NA	9/21/02
KNG07	33939	M	Alive	Kuskokwim Bay, AK	Kvichak Bay, AK	Banks Island, Canada	Beaufort Sea, AK 7/29/03
KNG08	33940	M	Alive	Anadyr Bay, Chukotka Peninsula, Russia	Kvichak Bay & Alaska Peninsula	Beaufort Sea off coast of Canada	Icy Cape, AK Chukchi Sea 7/31/03
KNG09	33941	F	Alive	Alaska Peninsula	Kvichak Bay & Alaska Peninsula	Kuparuk, AK	Beaufort Sea, AK 7/28/03
KNG10	33942	M	Alive	Kamchatka Peninsula, Russia	Kamchatka Peninsula, Russia	Inland Russia	Cape Barykova, Russia 7/31/03
KNG11	33943	M	Indicated bird dead	Karagin Bay, Kamchatka Peninsula, Russia	Kamchatka Peninsula, Russia	NA	Chukotka Peninsula, Russia 4/24/03
KNG12	33944	F	Alive	Karagin Bay, Kamchatka Peninsula, Russia	Karagin Bay, Kamchatka Peninsula, Russia	Kuparuk, AK	Beaufort Sea, AK 7/23/03
KNG13	33945	F	Alive	Anadyr Bay, Chukotka Peninsula, Russia	Chirikof Island, AK	Kuparuk, AK	Beaufort Sea, AK 7/31/03
KNG14	33946	F	Alive	Cape Nygchigen, Chukotka Peninsula, Russia	Cape Chukotka, Chukotka Peninsula, Russia	Kuparuk, AK	Beaufort Sea, AK 7/27/03
KNG15	33947	M	Alive	St. Lawrence Island, AK	Togiak Bay, AK	Inland Russia	Chukchi Sea 7/22/03
KNG16	33948	M	Alive	Karagin Bay, Kamchatka Peninsula, Russia	Kamchatka Peninsula, Russia	South of Barrow, AK	Chukotka Peninsula, Russia 7/30/03
KNG17	33949	F	Alive	St. Lawrence Island, AK	Alaska Peninsula	Kuparuk, AK	Beaufort Sea, AK 7/29/03
KNG18	33950	M	Failed	Mechigmen Bay, Chukotka Peninsula, Russia	Chirikof Island & Kvichak Bay, AK	Beaufort Sea off coast of Canada	Beaufort Sea, Canada 6/11/03
KNG19	33952	M	Alive	St. Lawrence Island, AK	Alaska Peninsula & Togiak Bay	Kuparuk, AK	St. Lawrence Island, AK
KNG20	33953	M	Alive	Anadyr Bay, Chukotka Peninsula, Russia	Meynypil'gyno, Russia	Cape Bathurst, Canada	Icy Cape, AK 7/30/03
KNG21	33954	F	Failed	Cape Chukotka, Chukotka Peninsula, Russia	Cape Chaplin, Chukotka Peninsula, Russia	NA	Pt. Lay, AK 5/17/03

Table 1. continued

ID	PTT #	Sex	Transmitter Status	Molt Location	Wintering Location	Summer Location	Last Location Received and Date
KNG22	40898	M	Alive	NA	NA	Kuparuk, AK	Pt. Lay, AK 7/30/03
KNG23	40899	M	Alive	NA	NA	Kuparuk, AK	Anadyr Bay, Chukotka Peninsula, Russia 7/31/03
KNG24	40900	F	Alive	NA	NA	Kuparuk, AK	Kuparuk, AK 7/30/03
KNG25	40901	M	Alive	NA	NA	Kuparuk, AK	Kuskokwim Bay, AK 7/30/03
KNG26	40902	M	Alive	NA	NA	Kuparuk, AK	Beaufort Sea, AK 7/31/03
KNG27	40903	F	Alive	NA	NA	Kuparuk, AK	Beaufort Sea, AK 7/31/03
KNG28	40904	M	Alive	NA	NA	Kuparuk, AK	Icy Cape, AK 7/30/03
KNG29	40905	M	Alive	NA	NA	Kuparuk, AK	Arakamchechen Island, Chukotka Peninsula, Russia 7/31/03
KNG30	40906	F	Alive	NA	NA	Kuparuk, AK	Beaufort Sea, AK 7/30/03
KNG31	40907	M	Alive	NA	NA	Kuparuk, AK	Anadyr Bay, Chukotka Peninsula, Russia 7/30/03
KNG32	40908	M	Alive	NA	NA	Kuparuk, AK	Anadyr Bay, Chukotka Peninsula, Russia 7/30/03
KNG33	40909	M	Alive	NA	NA	Kuparuk, AK	Pt. Lay, AK 7/28/03

Wintering locations for males included areas along the Chukotka Peninsula, Kamchatka Peninsula, and Meynypil'gyno, Russia and Kvichak Bay, the Alaska Peninsula, Chirikof Island, and Togiak Bay, Alaska. Wintering locations for females included areas along Karagin Bay and the Chukotka Peninsula, Russia and the Kenai Peninsula, Kvichak Bay, Chirikof Island, and the Alaska Peninsula, Alaska (Table 1, Figure 3).

The six 2002 females still transmitting returned to the Kuparuk study site during the summer of 2003. Of the nine 2002 males still transmitting, one returned to Kuparuk, one spent some time south of Barrow, three stayed offshore of Canada near Cape Bathurst, two spent time onshore in Canada and two went onshore in Russia (Table 1, Figure 4).

As of 31 July 2003, all six females still transmitting were in the Beaufort Sea, while most the eight males still transmitting were beginning molt migrations south. One male remained in the Beaufort, while four males were off the coast of Alaska in the Chukchi Sea, one was at St. Lawrence Island, Alaska, and two were in the Bering Sea off the coast of Russia (Table 1, Figure 5).

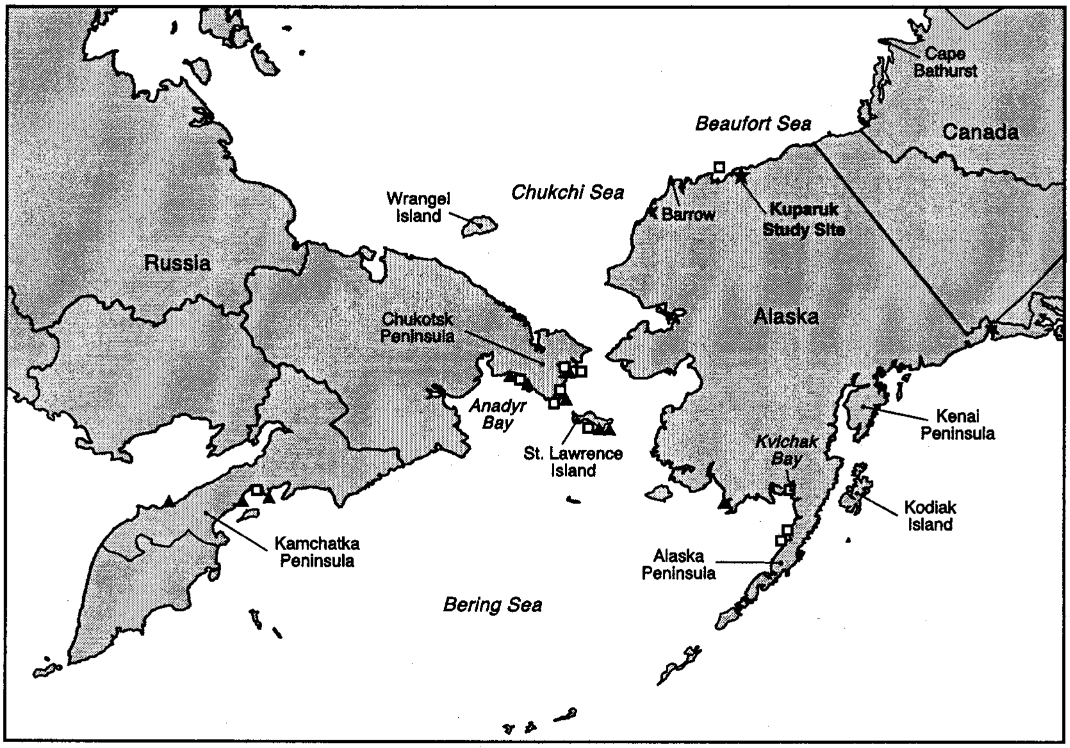

Figure 2. Molting locations of male (▲) and female (□) king eiders fitted with satellite transmitters at Kuparuk, Alaska in 2002.

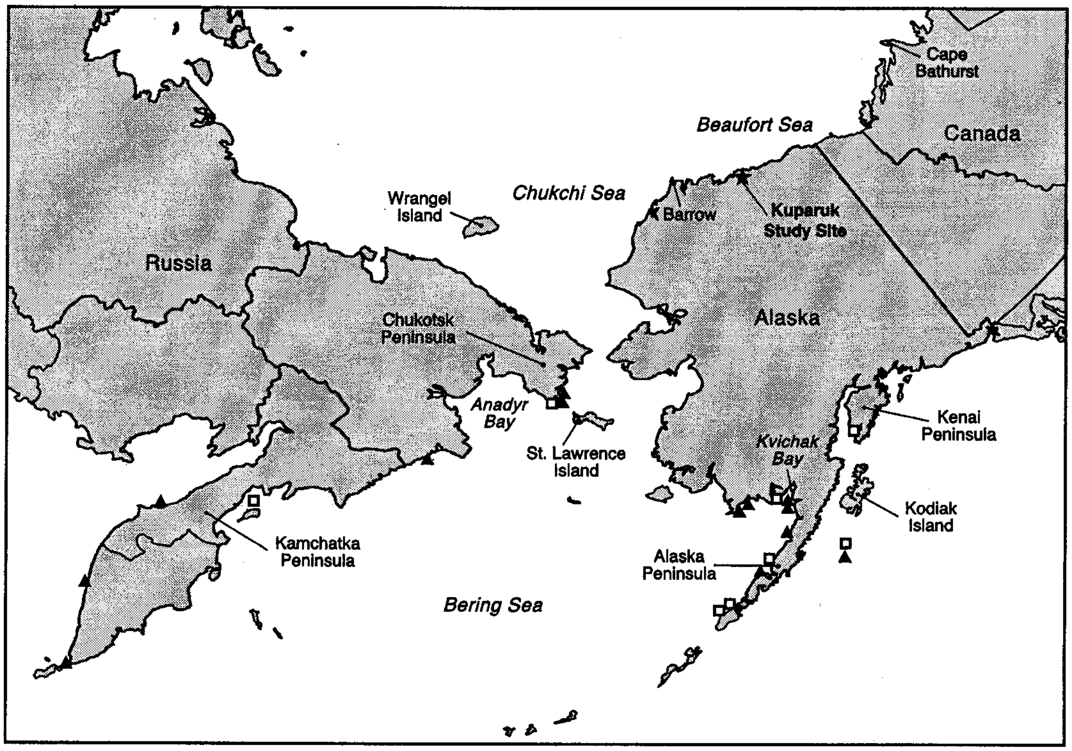

Figure 3. Wintering locations of male (▲) and female (□) king eiders fitted with satellite transmitters at Kuparuk, Alaska in 2002.

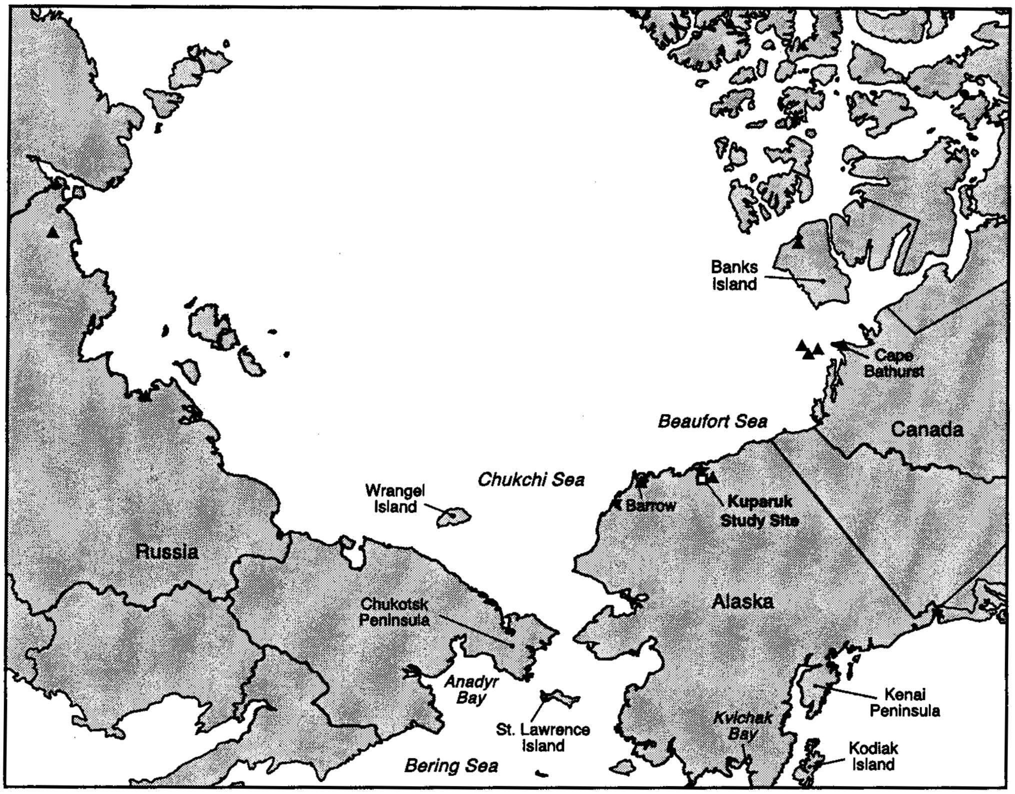

Figure 4. Summer breeding location of male (▲) and female (□) king eiders fitted with satellite transmitters at Kuparuk, Alaska in 2002. All females returned to Kuparuk and are indicated by a single marker.

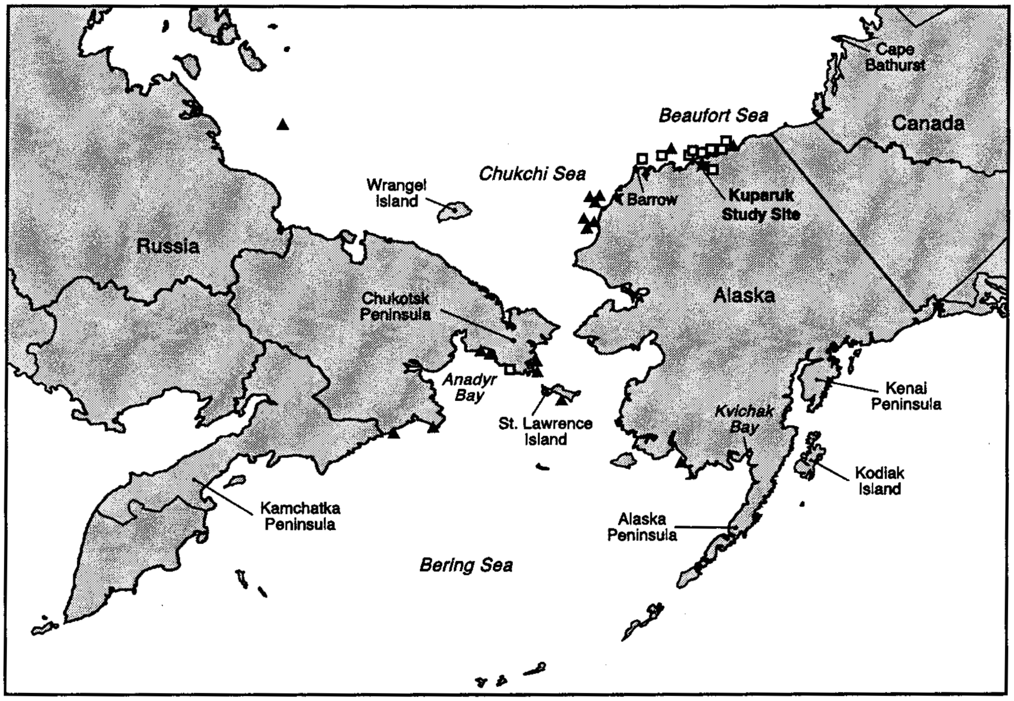

Figure 5. Location of 28 male (▲) and female (□) satellite tagged king eiders the last week of July 2003.

2003 Satellite transmitter birds

Two females left the study area between 15–18 July and were still staging in the Beaufort Sea on 31 July (Table 2, Figure 5). On 26 June, one of these females was found on a nest with two eggs. This nest was later depredated. One female remained inland on the study site on 31 July, and it is possible that this female may be with a brood. Males left the study area between 21 June and 1 July. All of the transmittered males left the Beaufort Sea by 28 July (Table 2). On 31 July, four of the males were off the coast of Russia in the Bering Sea, one was off the coast of Alaska in the Bering Sea, three were in the Chukchi Sea, and one was still in the Beaufort Sea (Table 1, Figure 5).

Table 2. Timing in the Beaufort Sea for 12 king eiders fitted with satellite transmitters at Kuparuk, Alaska in June 2003.

ID	PTT #	Sex	Left Study Area	Left Beaufort Sea
KNG22	40898	M	6/27/03	7/19/03
KNG23	40899	M	7/01/03	7/18/03
KNG24	40900	F		
KNG25	40901	M	6/26/03	7/09/03
KNG26	40902	M	6/26/03	7/28/03
KNG27	40903	F	7/18/03	
KNG28	40904	M	6/22/03	7/22/03
KNG29	40905	M	6/22/03	6/26/03
KNG30	40906	F	7/15/03	
KNG31	40907	M	6/30/03	7/18/03
KNG32	40908	M	6/21/03	7/17/03
KNG33	40909	M	6/30/03	7/22/03

Discussion

Late break up and severe wind and weather conditions on Alaska's North Slope during spring 2003 prevented easy capture of large numbers of king eiders. The severe weather in combination with the restricted period of time that the veterinarian was available to perform surgeries prevented us from capturing our proposed sample of 39 king eiders.

Molting areas for king eiders implanted at Kuparuk in 2002 are similar to those found for eiders implanted at Victoria Island (n = 16) and Prudhoe Bay (n = 9), 1997–1999 [Dickson et al. 2000]. Data on wintering locations of king eiders is limited. Dickson et al. [2000] had a limited sample of king eiders (n = 9) with satellite transmitters that were transmitting location data into December. Their information suggested that similar to eiders breeding at Kuparuk, eiders breeding at Victoria Island and Prudhoe Bay wintered along the Kamchatka Peninsula, the Chukotka Peninsula, the Alaska Peninsula, and Kodiak Island. Ours is the first account of satellite transmitters in king eiders lasting into the next breeding season. Females transmittered in 2002 returning to Kuparuk for the 2003 breeding season suggests some fidelity to nesting areas.

Future Plans

We will continue to collect and map location information as it becomes available. Location data will be analyzed to detect staging, molting and wintering areas. We will also begin to overlay bathymetric and ice coverage maps to evaluate the impacts of these factors on migration paths. The remaining transmitters will be deployed summer 2004. Logistics for summer 2004 fieldwork will begin spring 2004.

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References

Anderson B.A., C.B. Johnson, B.A. Cooper, L.N. Smith and A.A. Stickney. 1999. Habitat associations of nesting spectacled eiders on the Arctic Coastal Plain of Alaska, p. 27–32. *In* R.I. Goudie, M.R. Peterson and G.J. Robertson [eds.], Behavior and Ecology of Sea Ducks. Can Wildl. Ser. Occas. Pap. 100.

Dickson, D.L., R.S. Suydam and G. Balogh. 2000. Tracking the movements of king eiders from nesting grounds at Prudhoe Bay, Alaska to their molting and wintering areas using satellite telemetry. Canadian Wildlife Service 1999/2000 Progress Report.

Korschgen, C.E., K.P. Kenow, A. Gendron-Fitzpatrick, W.L. Green and F.J. Dein. 1996. Implanting intra-abdominal radiotransmitters with external whip antennas in ducks. J. Wildl. Manage. 60:132–137.

Petersen, M.R., W.W. Larned and D.C. Douglas. 1999. At-sea distribution of spectacled eiders: A 120-year-old mystery resolved. Auk 116:1009–1020.

Powell, A.N., E.A. Rexstad, E.J. Taylor and L.M. Phillips. 2003. Importance of the Alaskan Beaufort Sea to king eiders (*Somateria spectabilis*), p. 57–62. *In* University of Alaska Coastal Marine Institute Annual Report No. 9. OCS Study MMS 2003-003, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region.

Suydam, R.S., D.L. Dickson, J.B. Fadely and L.T. Quakenbush. 2000. Population declines of king and common eiders of the Beaufort Sea. Condor 102:219–222.

Population Structure of Common Eiders Nesting on Coastal Barrier Islands Adjacent to Oil Facilities in the Beaufort Sea

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Task Order 85239

Abstract

Recent expansion of oil and gas development into the nearshore waters of the Beaufort Sea, Alaska, may pose a risk to the thousands of sea ducks and other marine birds that use this area every summer. Common Eiders are particularly vulnerable because they nest almost exclusively on barrier islands that are vulnerable to direct and indirect effects of oil and gas development. Several of the larger nesting colonies of this species are located near current and proposed oil development sites. Observational data of banded birds suggest these colonies may be discrete and demographically independent management units. If such population structuring exists, an accidental oil spill could destroy a portion of the Common Eider population (e.g., nesting island), and prevent recolonization of the island after the spill. Unfortunately, the observational data available are quite limited and difficult to collect. During this project we will use three classes of molecular genetic markers that differ in their mode of inheritance (i.e., traits are inherited from both parents, from the male parent, or from the female parent) to document the level of population structuring among Common Eiders breeding on coastal barrier islands of the Beaufort Sea. To achieve this goal, we will also compare Common Eiders from the central Beaufort Sea to Common Eiders sampled broadly throughout their range in North America. This information will enable us to test the discreteness of different genetic stocks inhabiting the Beaufort Sea region, assess the potential dangers to the Common Eider population from oil spills, and identify impediments offshore oil and gas development might pose to their recovery.

This is a report of the first two summer field seasons and preliminary laboratory results.

Field Work

During the 2002 and 2003 field seasons, we expanded our sampling efforts to include feathers from nest bowls and egg shell membranes from depredated and abandoned nests. Combined with the previous year's efforts, we were able to collect blood samples from 199 female Common Eiders nesting on the barrier islands along with 300+ feather and 20 egg shell membrane samples. Since an arctic fox depredated most of the nests in the western region in 2002 and 2003, feather samples will comprise a major component of our sample size on each of the islands located in the western region of our study site (Figure 1).

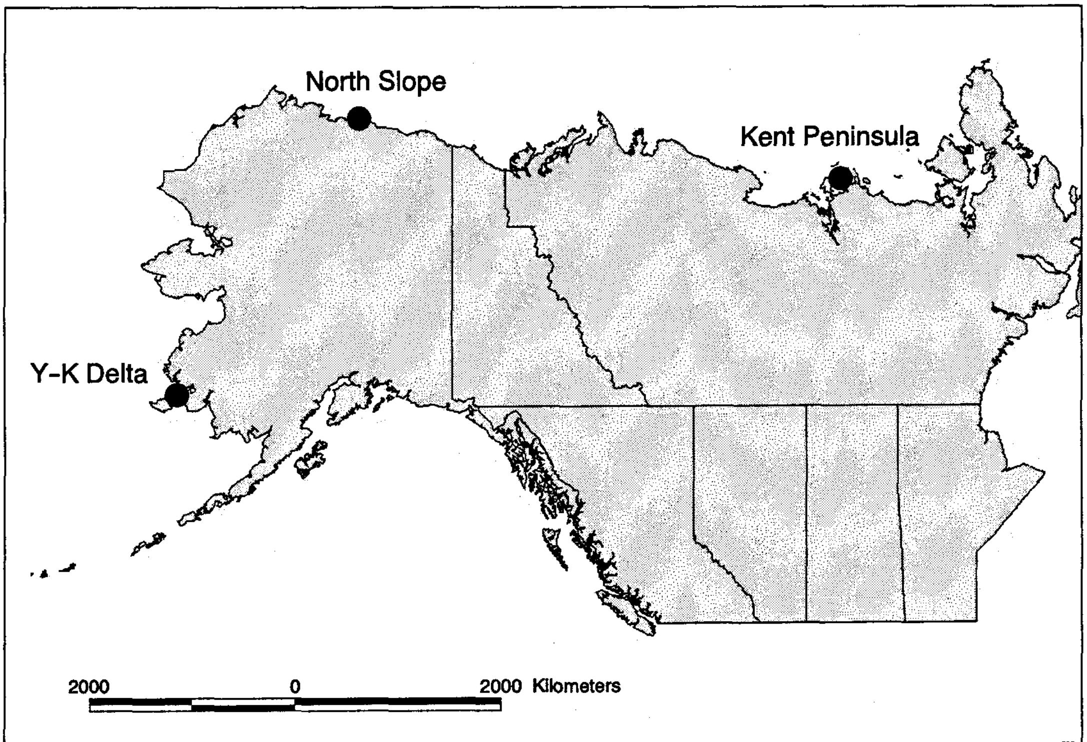

Figure 1. Location of sites sampled for Common Eiders breeding on the Kent Peninsula, Canada; North Slope (Beaufort Sea), Alaska; and Yukon–Kuskokwim Delta, Alaska.

Laboratory Analysis and Results

In the laboratory, 56 microsatellite loci were screened using 12 individuals from two populations. Thirty-four loci were variable in Common Eiders (Table 1). In the remaining 22 loci, there was either no variation or no PCR (polymerase chain reaction) product was produced (Table 1). Optimization has begun on 20–30 variable loci in order to form PCR multiplexes, to increase efficiency of data collection. Ultimately, we hope to have nine multiplexes for 20–30 loci to assess population subdivision across the barrier islands in the Beaufort Sea. By using an increased number of microsatellite loci we will achieve individual identification with a low probability of using the same individual of our feather samples across years. At the conclusion of last summer, a total of 90 individuals from three populations were genotyped at five loci. With this data, we plan to assess levels of population subdivision occurring throughout the Kent Peninsula, Canada; North Slope, Alaska; and the Yukon–Kuskokwim River Delta, Alaska (Y–K Delta), in addition to determining gene flow of female Common Eiders across sampled barrier islands in the Beaufort Sea. Preliminary data were analyzed in FSTAT [Goudet 1995, 2001], GENEPOP [Raymond and Rousset 1995], and *structure* [Pritchard et al. 2000] genetic data analysis programs. There were no significant deviations from Hardy–Weinberg equilibrium across or within populations. All loci were in Hardy–Weinberg equilibrium except for one locus in the Y-K Delta population. Mean observed heterozygosity per locus ranged from 52.5% to 65.0% for each population. The overall F_{ST} (0.017) was not significantly greater than zero, suggesting no population subdivision (Table 2). However, there were significant differences between pairwise F_{ST} values between the Kent Peninsula and Y-K Delta populations and the Beaufort Sea and Y-K Delta populations (Table 3). Population models generated in *structure* support a two-population system among sampled sites, consistent with the pairwise F_{ST} results.

Table 1. Microsatellite loci screened for variability in Common Eiders using 12 individuals from two populations and number of alleles observed (nv = no variability, np = no PCR product).

Microsatellite Loci	Number of Alleles Observed	Microsatellite Loci	Number of Alleles Observed
2AB	nv	BCA8	2
5AB	np	BCA9	nv
6AB	np	BCA10	nv
4AC	2	BCA11	4
Aalμ1 (WFG54)	4	CRG	nv
Aph02	3	Hhi2	2
Aph04	nv	Hhi3	2
Aph05	nv	Hhi5	4
Aph08	2	Sfiμ1 (C7)	3
Aph13	3	Sfiμ2	nv
Aph15	4	Sfiμ3 (1B8)	4
Aph16	3	Sfiμ4 (1D8)	3
Aph17	7	Sfiμ5 (WFG2)	4
Aph18	2	Sfiμ6	3
Aph19	nv	Sfiμ7 (WFG8)	np
Aph20	3	Sfiμ9	4
Aph21	np	Sfiμ10	7
Aph22	nv	Sfiμ11	4
Aph23	6	Smo01	3
Aph24	2	Smo04	8
Aph25	nv	Smo06	4
BCA1	2	Smo07	2
BCA2	np	Smo08	3
BCA3	np	Smo09	nv
BCA4	nv	Smo10	4
BCA5	np	Smo11	nv
BCA6	3	Smo12	2
BCA7	np	Smo13	nv

One hundred and six individuals—10 from the Kent Peninsula, 52 from the North Slope, and 44 from the Y-K Delta—were sequenced for 550 base pairs of the mtDNA control region. Two haplotype groups are present in these sequences and frequencies of individuals from each locality differ between the two groups (Figure 2). Individuals from the North Slope are predominately represented in the upper haplotype group and individuals from the Y–K Delta are predominately represented in the lower haplotype group. There are currently not enough samples from individuals from the Kent Peninsula to determine which haplotype group represents these individuals.

Table 2. Weir and Cockerham [1984] estimation of F-statistics for five microsatellite DNA loci.

Locus	F_{IT}	F_{ST}	F_{IS}
WFG54	–0.026	0.114	–0.158
Sfiμ9	–0.023	–0.009	–0.014
1B8	–0.092	–0.004	–0.088
BCA11	–0.007	0.002	–0.009
Sfiμ11	–0.058	0.014	–0.073
Overall Loci	–0.042	0.017	–0.061
95% C.I.	–0.070, –0.019	–0.006, 0.064	–0.110, –0.024

Table 3. Pairwise F_{ST} values and p-values for each population pair after 3000 permutations.

Populations	F_{ST}	p-value*
Kent Peninsula & Beaufort Sea	–0.013	0.9673
Kent Peninsula & Y–K Delta	0.033	0.0007
Beaufort Sea & Y–K Delta	0.032	0.0010

*Adjusted p-value significance level after multiple comparisons is 0.017.

Eighty-eight individuals—10 from the Kent Peninsula, 33 from the North Slope, and 45 from the Y–K Delta—were also sequenced for the lamin A nuclear gene intron, non-coded portion of a nuclear gene. Like mtDNA, two allele groups are also present, but neither appears to be associated with a particular locality (Figure 3). However, the two allele groups may reflect the same historical process that resulted in the two haplotype groups observed in mtDNA. In other words, the existence of two allele (nuclear DNA) and two haplotype (mtDNA) groups suggests that Common Eiders historically were subdivided. However, shared alleles and haplotypes between localities suggest that recent gene flow via female and male dispersal has occurred. Moreover, differences observed between the more structured maternally (mtDNA) inherited markers and the less structured bi-parentally (nuclear DNA) inherited markers suggest that female Common Eiders are exhibiting philopatry whereas males are more dispersive.

In addition, all individuals collected prior to this past field season have been sequenced for 550 base pairs of the mitochondrial DNA control region and the lamin A intron. No new structuring was formed with the additional sequences, which is consistent with above findings. Further nuclear gene introns have been probed for variability and structuring in Common Eiders: ADAR-2I, BF7, CHD-W, Cmos, GADPH, Hemoglobin-α chain, OD7, and Rag1.

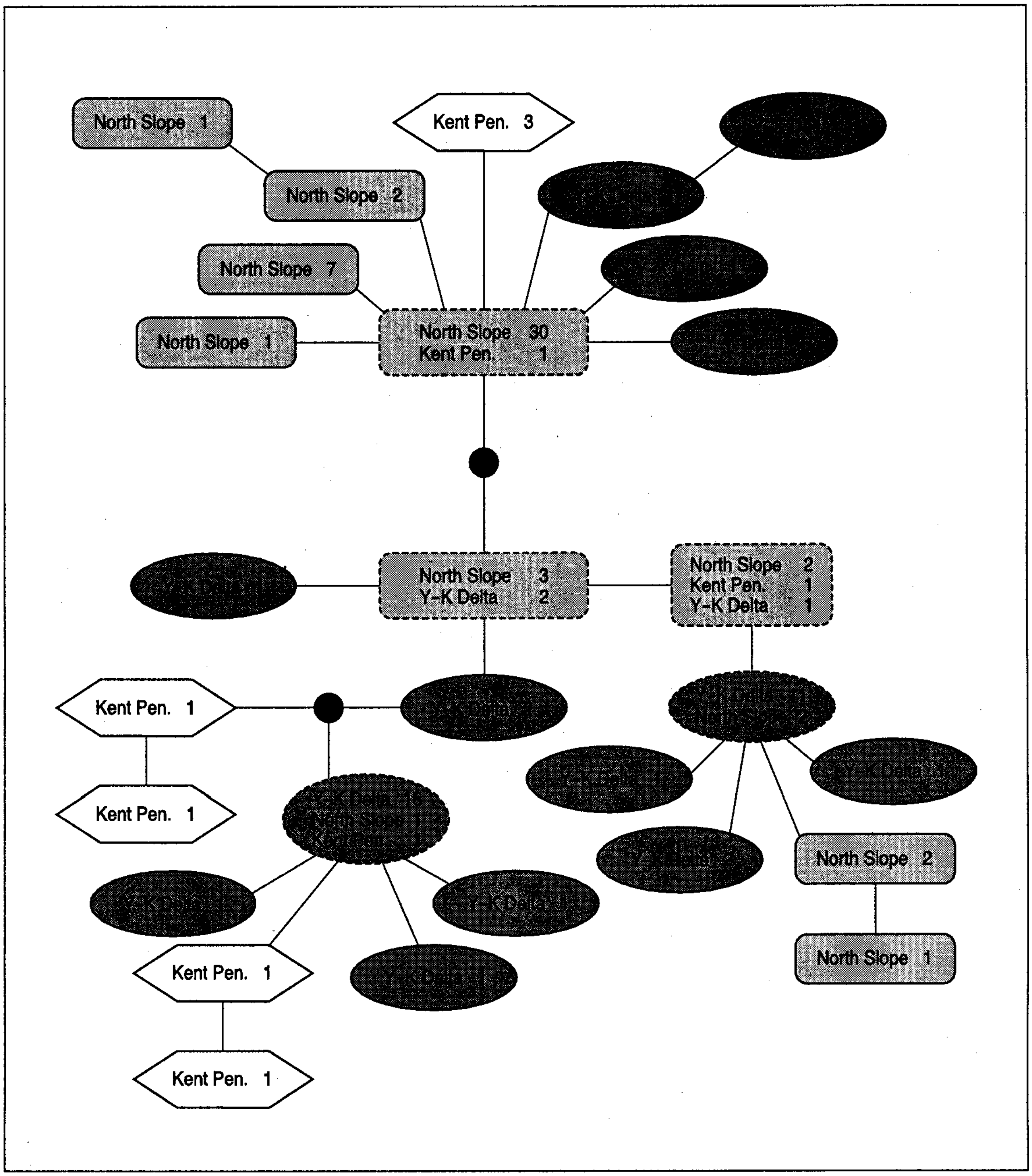

Figure 2. Mitochondrial DNA cluster diagram of 550 base pairs of control region sequence data from 106 individuals (10 from the Kent Peninsula, 52 from the North Slope, and 44 from the Y-K Delta). Hexagons with solid lines represent haplotypes from the Kent Peninsula, rectangles with solid lines represent haplotypes from the North Slope, ovals with solid lines represent haplotypes from the Y-K Delta. A black circle represents a haplotype not represented in our data set but part of the evolutionary history of the resulting haplotype. Dashed lines indicate a haplotype with individuals from multiple localities. Number of individuals and locality of individuals with that haplotype are indicated within the shape.

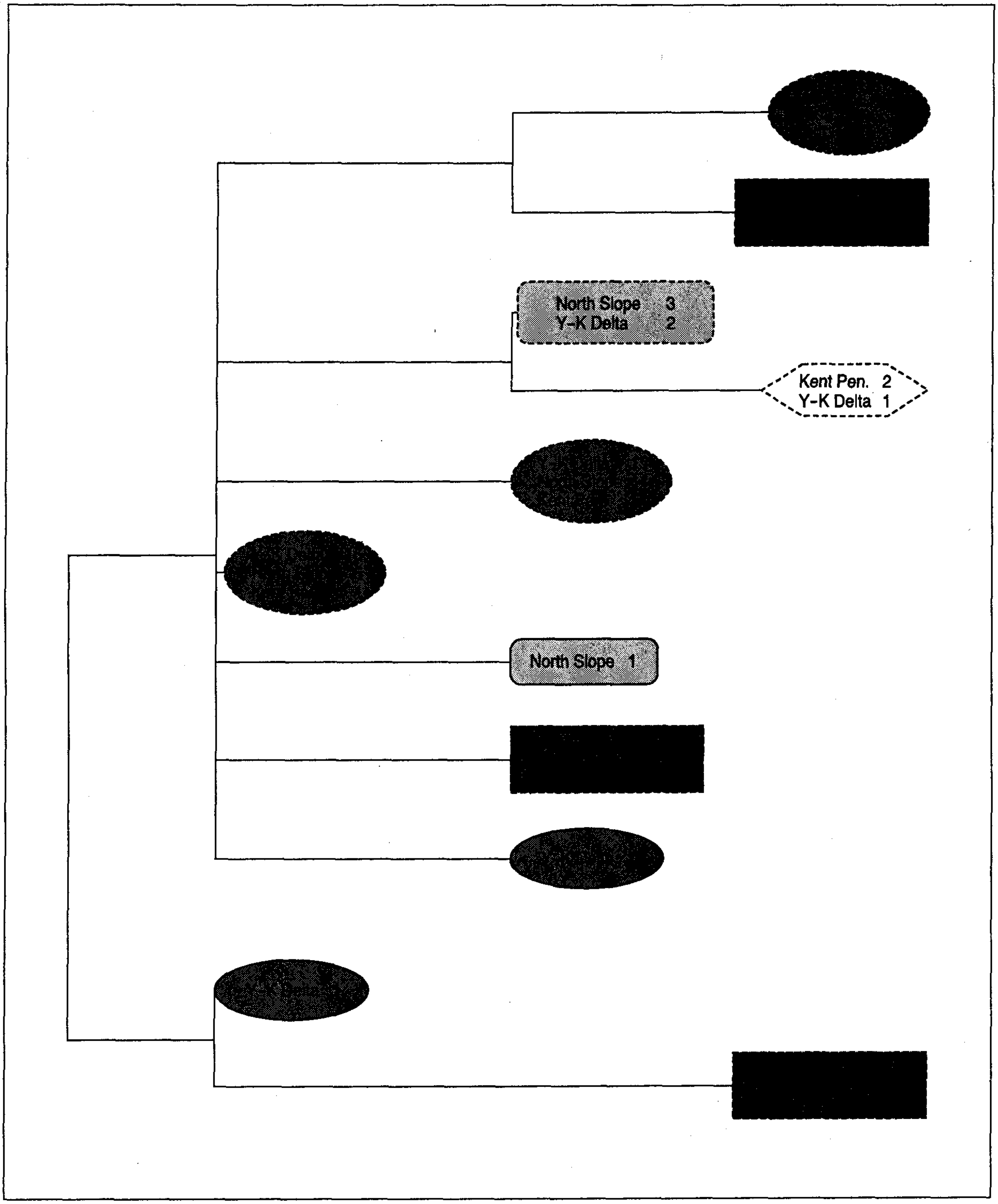

Figure 3. Lamin A nuclear gene intron phylogram of sequence data from 88 individuals (10 from the Kent Peninsula, 33 from the North Slope, and 45 from the Y-K Delta). Hexagons with solid lines represent alleles from the Kent Peninsula, rectangles with solid lines represent alleles from the North Slope, and ovals with solid lines represent alleles from the Y-K Delta. Dashed lines indicate an allele with individuals with from multiple localities. Number of individuals and locality of individuals with that allele are indicated within the shape.

Acknowledgements

Additional funding through an Angus Gavin Migratory Bird Research Fund mini-grant and a University of Alaska Fairbanks EPSCoR (Environmental Program to Stimulate Competitive Research) graduate student fellowship and collaborations with Lynne Dickson, Paul Flint, and colleagues of Kim Scribner, have enabled us to expand this project to include additional facets, including: assessing the degree population structure across breeding areas on the Yukon–Kuskokwim River Delta, assessing the levels of gene flow occurring throughout the sub-species range in Alaska and Canada, and examining population structure within Common Eiders in a phylogeographic context across their circumpolar distribution.

References

Goudet, J. 1995. FSTAT (version 1.2): A computer program to calculate F-statistics. J. Heredity 86:485–486.

Goudet, J. 2001. FSTAT, a program to estimate and test gene diversities and fixation indices (version 2.9.3). Available from http://www.unil.ch/izea/softwares/fstat.html. Updated from Goudet [1995].

Pritchard, J. K., M. Stephens and P. Donnelly. 2000. Inference of population structure using multilocus genotype data. Genetics 155:945–959.

Raymond, M. and F. Rousset. 1995. GENEPOP (version 1.2): Population genetics software for exact tests and ecumenicism. J. Heredity 86:248–249.

Weir, B.S., and C.C. Cockerham. 1984. Estimating F-statistics for the analysis of population structure. Evolution 38:1358–1370.

Breeding Biology and Habitat Use of King Eiders on the Coastal Plain of Northern Alaska

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Abstract

*Little is known about the breeding biology of king eiders (*Somateria spectabilis*), partly because they typically nest in remote areas in low densities. The western North American population of king eiders declined by more than 50% between 1979 and 1996 for unknown reasons. Additionally, NPR-A (National Petroleum Reserve–Alaska) is being leased for oil and gas exploration and may potentially be developed. Within the northeast planning area of NPR-A is the highest known density of nesting king eiders on the North Slope of Alaska. During the summers of 2002 and 2003 we studied king eiders in an area to the southeast of Teshekpuk Lake and in the Kuparuk oil field on the North Slope to evaluate the potential impacts of development and to provide information on their basic breeding biology and habitat use. We are examining and comparing timing of nesting, clutch size, reproductive success, and habitat use between a relatively undisturbed site at Teshekpuk Lake and an area with considerable human activity at Kuparuk. This report summarizes the results of the second field season of data collection.*

Objectives

- Document the timing of nest initiation of king eiders
- Document timing of arrival and departure of male king eiders
- Document nest success and apparent causes of failure
- Document nest site characteristics
- Compare data collected from above objectives between Teshekpuk Lake and the Kuparuk oil field
- Document rate and direction of movement of broods

Study Areas

This study has two main sites on the North Slope of Alaska: Teshekpuk Lake and the Kuparuk oil field. The Teshekpuk Lake study site is 10 km inland from the southeast shore of the lake and has experienced very little human impact. The Kuparuk study site is an area on the Arctic Coastal Plain between the Colville and Kuparuk rivers leased by ConocoPhillips Alaska, Inc. for oil development. Both areas are characterized by numerous thaw lakes, ponds and basins. Wetland community types include wet sedge (*Carex* spp.) meadows, moist sedge–dwarf shrub (*Salix* spp.) meadows, and emergent *Carex* spp. and *Arctophila fulva* on the margins of the lakes and ponds [Anderson et al. 1999]. Some wetlands at Kuparuk have been intersected by roads and/or created with the development of gravel pits.

Methods

Accessible areas around Teshekpuk Lake and Kuparuk were searched for pre-nesting and nesting king eiders during the summers of 2002 and 2003. At Teshekpuk we also recorded numbers of male and female king eiders observed each day. We marked nests with a tongue depressor placed 1 m from the nest in vegetation so as to be concealed from potential nest predators. We measured length and width, and weighed and candled each egg to determine incubation stage. Latitude and longitude were recorded for each king eider nest using a hand-held GPS unit. Habitat within 50 m of each nest was classified as to type using Bergman's classification system [1977]. Vegetation types and frequency were recorded for all king eider nests and for random locations within the two study areas. Additionally, we recorded island size, distance to the mainland and depth of the water if the nest occurred on an island.

Data loggers (HOBO Temp) were placed in randomly selected nests at Teshekpuk ($n = 10$) and Kuparuk ($n = 8$) in both 2002 and 2003 to determine nest attendance and abandonment; they were set to record every two minutes and were downloaded every ten days. Blown chicken eggs, dyed an olive green and glued to a spike, were used to hold the temperature probes. This anchored the probe in the nest and allowed for a quick response to any change in temperature, since the probe had only an eggshell between it and the incubating female.

King eiders typically incubate for 22–24 days and all nests were monitored twice weekly during this period. Hatch success was determined by the presence of eggshells with detached membranes [Girard 1939] or the presence of ducklings. If there were eggshells with no membranes or if the entire egg was absent, the nest was considered depredated. Nesting success was defined as the percentage of all nests initiated in which at least one egg hatched. We attempted to determine cause of failure for nests that did not succeed.

This year we trapped and fit female king eiders (Teshekpuk $n = 7$, Kuparuk $n = 12$) with VHF transmitters to follow broods after hatch. The females were trapped late in incubation using a drop net or a bow net and the transmitter was glued on the back of the hen between the wings. The transmitter was designed to fall off before fall migration. We took morphometric measurements and each bird was fitted with a U.S. Fish and Wildlife Service leg band. Radioed hens were tracked by foot, boat and air at Teshekpuk and by vehicle, foot and air at Kuparuk.

Results

Teshekpuk

Upon arrival at the Teshekpuk study site on 11 June 2003, we found an equal ratio of males to females; this balance continued until 25 June. No males were seen in the study area after 8 July (Figure 1). Initiation of incubation ranged from 11 June to 4 July, with most females beginning incubation around 23 June (Figure 2).

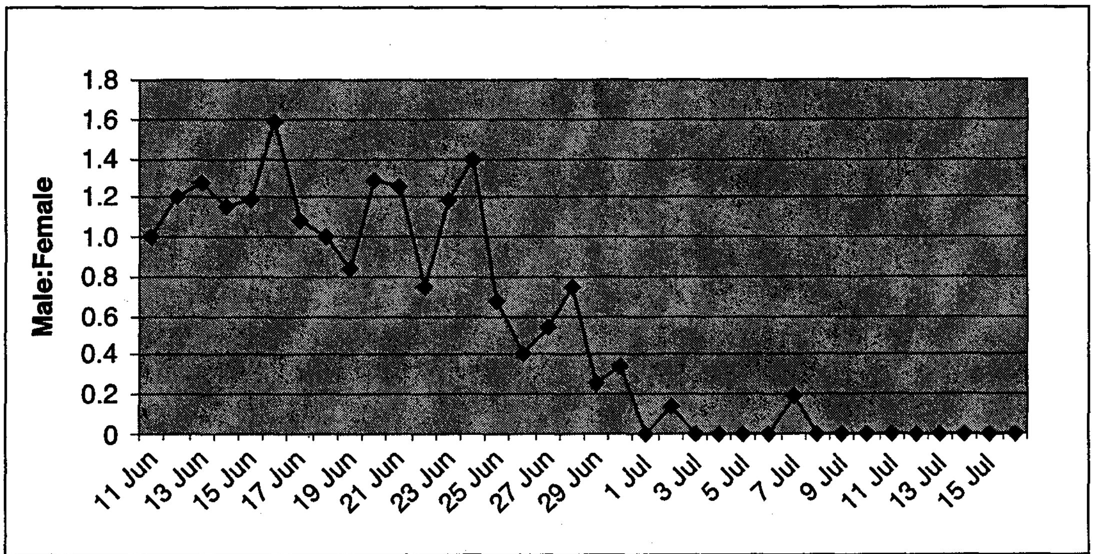

Figure 1. The change in the sex ratio of king eiders observed at Teshekpuk Lake in June and July 2003.

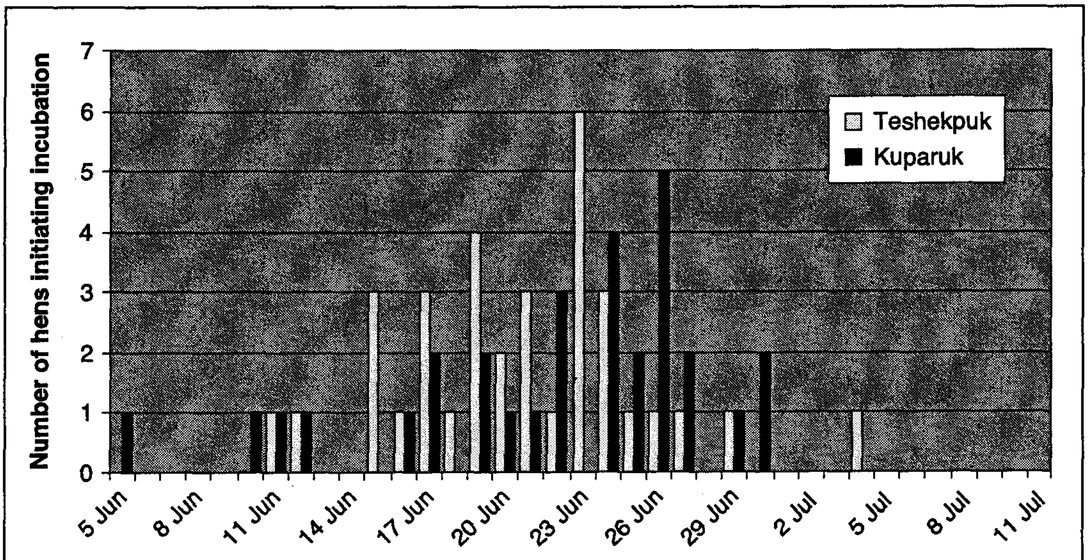

Figure 2. Initiation of incubation by female king eiders at Teshekpuk Lake and the Kuparuk oil field, 2003.

We found 40 active king eider nests in the study area at Teshekpuk Lake. We also found seven nests post depredation that were likely king eider nests. However, because spectacled eider (*Somateria fischeri*) nests look very similar to those of king eiders, and we may have misidentified these nests, they were not included in estimates of apparent nest success. We did not find every nest within our study area; several unexpected broods were seen. Apparent nesting success was 17.5% in 2003; however four of the hens that we trapped late in incubation subsequently failed, perhaps caused by handling. King eider nests at Teshekpuk hatched between 9 and 17 July. Mean clutch size was 4.18 ± 0.15 (SE, n = 33). Egg length was 65.4 ± 0.23 mm (n = 145), width 43.8 ± 0.14 mm and mass of fresh eggs 65.1 ± 1.14 g (n = 41). In general, nests at Teshekpuk occurred in low marshy areas or on islands and not on the barren, dry ridges. 52.5% of nests found (n = 40) occurred on islands; however, all but one of the seven successful nests occurred on islands (85.7%).

Kuparuk

Arrival and departure dates of king eiders were not recorded at Kuparuk. Initiation of incubation ranged from 5 June to 30 June, with most females beginning incubation around the 25 June (Figure 2). The period of time in which hens began incubating is similar between Kuparuk and Teshekpuk; however the peak is a few days later at Kuparuk.

We found 39 active nests at Kuparuk and 14 more nests were found post depredation. Apparent nest success was 35.1% (n = 37). King eider nests at Kuparuk hatched between 8 and 25 July. Mean clutch size was 3.97 ± 0.17 (SD, n = 34). Egg length was 66.3 ± 0.28 mm (n = 80), width 43.6 ± 0.12 mm (n = 79) and mass of fresh eggs was 76.2 ± 0.58 g (n = 54). 51.3% of nests found (n = 39) occurred on islands.

Brood rearing

Eight hens were trapped at Teshekpuk during the last week of incubation (5–15 July 2003) and radio transmitters were attached subcutaneously. Of the hens trapped, only three successfully hatched eggs. Two of the hens with broods were followed for over a week before they traveled too far away to be located on foot. Both broods remained in marshes within 1 km of their nest site for around a week. One brood appeared to be heading north before it was lost, while the other did not have a clear direction of movement. Both of these hens still had ducklings when they where last located. The third hen disappeared right after hatch with her brood.

It is possible that we caused four nests to fail due to trapping activity. We left the nest area immediately after releasing the hen, assuming she would return more rapidly if no people were in the area. One of the hens was observed on the nest after trapping but it is unknown whether the other four hens returned to their nests prior to depredation or not. Disregarding trapping, there was very high depredation late in incubation that was not related to anthropogenic causes.

Twelve hens were trapped and had transmitters attached at Kuparuk (3–20 July). Nine of these hens successfully hatched ducklings and seven broods were followed. Direction and distance traveled by these broods has not yet been analyzed; however there does not appear to be a clear pattern among broods. One female lost her entire brood before being located and another hen disappeared soon after hatch. Two hens raised at least one duckling to 20 days. The remaining five hens with broods lost all their ducklings within ten days of hatch.

Future Data Analysis

Program MARK will be used to estimate nest success (± SE) and to test for site-, year-, and island/mainland-specific differences in nest survival and to investigate the importance of three spatial covariates (distance to the nearest conspecific nest, distance to the nearest larid nest, and distance to the mainland) and habitat covariates on daily nest survival rates [White and Burnham 1999; Dinsmore et al. 2002]. We will investigate any effects of nesting associations between king eiders and nearby nesting larids, both within and between the two sites. Direction and movement of broods at both Kuparuk and Teshekpuk will be further analyzed. The data from the HOBO temperature recorders will be analyzed for incubation constancy.

We intend to use landcover databases (National Petroleum Reserve–Alaska landcover inventory database of the Bureau of Land Management and Ducks Unlimited, and the Beechey Point landcover inventory database of the U.S. Army Cold Regions Engineering and Research Laboratory) and the random sites to investigate distribution and availability of habitats within the study areas and thus determine if selection of particular habitats has occurred and how the study sites compare.

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References

Anderson B.A., C.B. Johnson, B.A. Cooper, L.N. Smith and A.A. Stickney. 1999. Habitat associations of nesting spectacled eiders on the Arctic Coastal Plain of Alaska, p. 27–32. *In* R.I. Goudie, M.R. Peterson and G.J. Robertson [eds.], Behavior and Ecology of Sea Ducks. Can Wildl. Ser. Occas. Pap. 100.

Bergman, R.D., R.L. Howard, K.F. Abraham and M.F. Weller. 1977. Water birds and their wetland resources in relation to oil development at Storkersen Point, Alaska. U.S. Fish and Wildl. Serv. Resour. Publ. 29, Washington D.C. 38 p.

Girard, G.L. 1939. Life history of the shoveler. Trans. N. Am. Wildl. Conf. 4:364–371.

Dinsmore, S.J., G.C. White and F.L. Knopf. 2002. Advanced techniques for modeling avian nest survival. Ecology 83:3476–3488.

White, G.C., and K.P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study 46 Suppl.:120–138.

King and Common Eider Migrations Past Point Barrow

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Abstract

*King (*Somateria spectabilis*) and common eiders (*S. mollissima v-nigra*) are important resources for Native people of northern Alaska and Canada. Both species pass Point Barrow, Alaska twice annually —during their northward migration in the spring and their southward migration in the fall. In 1996, we conducted spring and fall counts and compared our results with standardized data from other counts. The results indicated that both populations had declined by approximately 50% between 1976 and 1996. We are repeating the fall migration counts (July–October 2002 and 2003) and the spring counts (May 2003 and 2004) in order to update the population trends and gather information on the behavior of eiders during migration to provide a context for the behavior of individual eiders instrumented with satellite transmitters (CMI Project: Importance of the Alaskan Beaufort Sea to King Eiders [*Somateria spectabilis*]). The counts will also determine if the age composition of eiders migrating during late fall can be used as an index to annual productivity.*

Introduction

King (*Somateria spectabilis*) and common eiders (*S. mollissima v-nigra*) wintering in the Bering Sea and north Pacific Ocean migrate north to nesting areas in Russia, Alaska, and Canada. Most of the eiders nesting in Alaska and Canada pass by Point Barrow, Alaska when entering and leaving the Beaufort Sea. At Point Barrow the migration transits very close to shore and the spring passage can be spectacular. Woodby and Divoky [1982] estimated 113,000 eiders passed in 30 minutes in the spring of 1976. Murdoch [1885], Bailey [1948], Brueggeman [1980], and others have commented on the spring passage of eiders, but the magnitude of the spring migration has been estimated only on a few occasions [Woodby and Divoky 1982; Suydam et al. 1997, 2000a]. By standardizing the analysis of spring migration counts conducted at Barrow in 1953 [Thompson and Person 1963], 1970 [Johnson 1971], 1976 [Woodby and Divoky 1982], 1987, 1994 [Suydam et al. 1997], and 1996 [Suydam et al. 2000a, b] we determined that the king eider population appeared to remain stable between 1953 and 1976, but declined by 53% between 1976 and 1996 [Suydam et al. 2000a]. The common eider population declined by 56% during the same time period [Suydam et al. 2000a].

King and common eiders are an important source of fresh protein after a long winter for local residents of Alaska and Canada [Braund et al. 1993; Fabijan et al. 1997]. Residents of Barrow harvest more king and common eiders than any other species of waterfowl [Fuller and George 1997]. While the reasons for the declines are unknown they are of concern.

It appears from our previous work and the reports of others [Thompson and Person 1963; Johnson 1971; Timson 1976] that the number of eiders returning after the end of August may be indicative of the number of young produced that year. Therefore, we are investigating the age composition of the fall passage from July into October in 2002 and 2003 to explore the use of late migration numbers as an indicator of annual productivity. By collecting detailed fall migration data we will be able to address timing, behavior, molt, and weather conditions related to migration, with the result of a better understanding of the timing and use of the Beaufort Sea marine and coastal environment by king and common eiders. The data will provide information that will aid in predicting the number of eiders using the outer continental shelf area by time of year.

Methods

Summer/fall migration counts in 2002 and 2003 were conducted from land at the base of the Point Barrow spit (71° 21'N, 156° 36'W; Figure 1). One to two observers counted eiders for up to 10 hours per day from 11 July until 15 October in 2002, and in 2003 counts will be conducted from 8 July to 15 October. In October the count becomes limited to 2 hours per day due to decreasing day length.

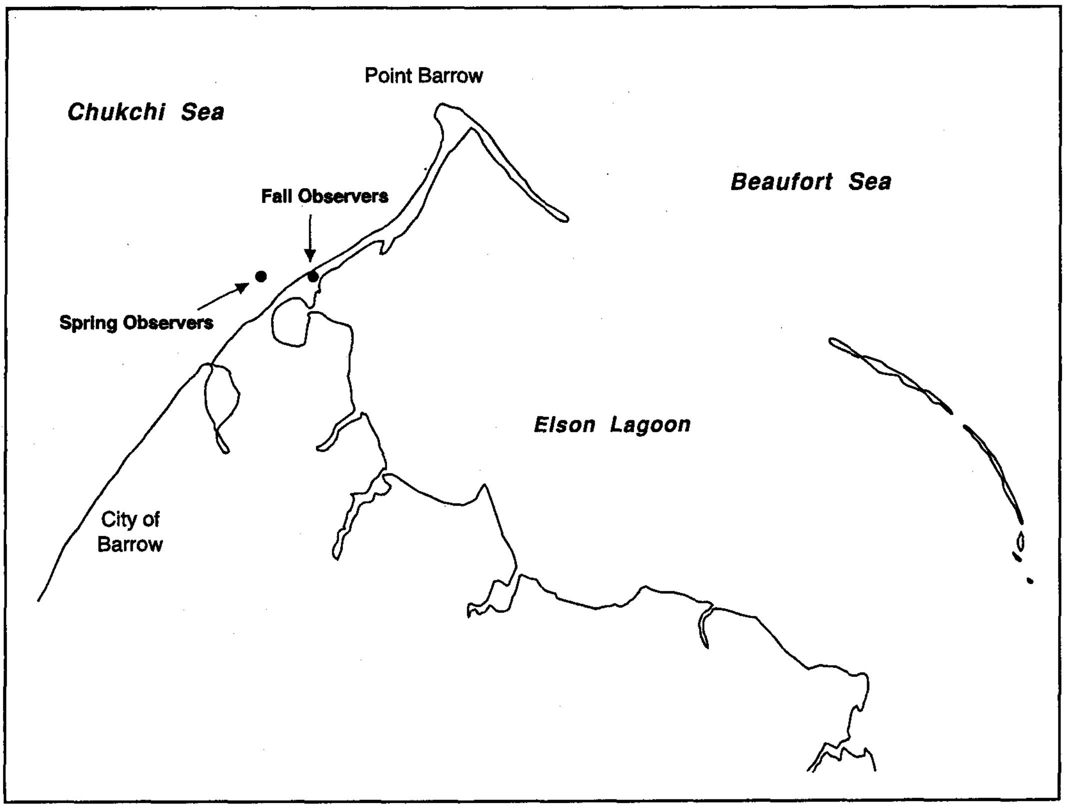

Figure 1. Fall eider migration study area.

For the spring 2003 count, we established an observation site on the shore-fast ice southwest of Point Barrow (71° 21′N, 156° 43′W; Figure 1). The observation site was on a large pressure ridge approximately 20 m high. The distance to nearshore lead ranged from 50 to 1500 m depending upon sea ice conditions. The site allowed a view of eiders migrating along the lead as well as along the beach. Two observers conducted spring counts for 12 hours each day (i.e., 2 hours out of every 4) from 30 April to 2 June 2003.

In each count period, regardless of season, data were collected on weather conditions (temperature, wind speed, wind direction, cloud cover, visibility). For each flock sighted we recorded time, direction of travel, species composition, number in flock, ratio of males to females for each species, and other comments on behavioral observations. Observers were trained on species identification and flock estimation by being paired with an experienced observer. They made independent estimates of the size of each flock. Estimates between trained observers were generally within 10% or less of each other.

We calculated daily projected passage estimates and point estimates for total passage of king and common eiders using methods similar to Suydam et al. [1997]. These estimates include eiders counted but not identified to species, which are divided between king and common eider categories in proportion to the king and common eiders that were identified that day. We assumed a constant movement throughout each 24-hour period. The projected total passage was estimated by summing the daily passage estimates. We also calculated 95% confidence intervals using a procedure for stratified sampling [Thompson 1992] that treated each day as a separate stratum [Suydam et al. 2000b]. Point estimates for two time periods are presented. A point estimate for 11 July to 7 September is a standardized time period which we can compare with counts prior to 1996 [Suydam et al. 2000a]. This shorter time period represents the period prior to when young produced that year have returned. Therefore, it may be a better estimate of the adult breeding population. The 11 July to 15 October time period can be compared with our estimate in 1996 only and includes the eiders produced that year.

Subsistence-harvested eiders, and wounded and lost birds we found, were weighed to the nearest gram using a spring scale; tarsus and culmen length were measured to the nearest millimeter using calipers. Eiders with female type plumage were inspected for age by looking at feather wear and notched tail feathers. Young produced that year would have new feathers and notched ends on their tail feathers [Godin 1960 in Giles 1971].

Results

Summer/Fall 2002

Our preliminary estimate for the passage of king eiders for the early migration period between 11 July and 7 September is 493,248 (95% CI 74,332; Table 1). For the later period (11 July–15 October) our preliminary estimate is 529,271 (95% CI 78,742).

Some king eiders migrated past Point Barrow before we began counting, as indicated by the king eiders implanted with satellite transmitters in the Kuparuk oil field by Powell and Phillips (CMI project: Importance of the Alaskan Beaufort Sea to King Eiders [*Somateria spectabilis*] [hereafter Powell et al. CMI project]; Figure 2). Five of ten male king eiders with transmitters passed by Point Barrow before our count began in 2002. None of the tagged females passed prior to 29 July. The daily estimated passage of king eiders, however, shows low numbers passing until 15 July (Figure 3) and large numbers passing on 27 and 29 July, 19 and 24 August, and 12 September.

Table 1. Preliminary numbers, projected total passage, and 95% confidence interval of king and common eiders seen during two time periods of the summer/fall 2002 migration and preliminary numbers of eiders seen during the spring 2003 migration.

	King Eider	Common Eider	Eider[1]	TOTAL
Early Summer/Fall 2002 [2]				
Number seen[3]	60,177	4,810	114,164	179,151
Projected total passage[4]	493,248	51,622		544,870
95% confidence interval	74,332	21,784		
Late Summer/Fall 2002 [5]				
Number seen[3]	61,881	13,864	134,073	209,818
Projected total passage[4]	529,271	176,109		705,380
95% confidence interval	78,742	42,390		
Spring 2003 [6]				
Number seen[3]	76,420	24,091	99,902	200,413
Projected total passage[4]	In progress	In progress		
95% confidence interval	In progress	In progress		

[1]Unidentified eiders
[2]Early period from 11 July to 7 September (458 hours counted)
[3]Net number of eiders migrating southwest (summer/fall) or northeast (spring)
[4]Sum of daily projected passage estimates
[5]Late period from 11 July to 15 October (650 hours counted)
[6]30 April–2 June (340 hours counted)

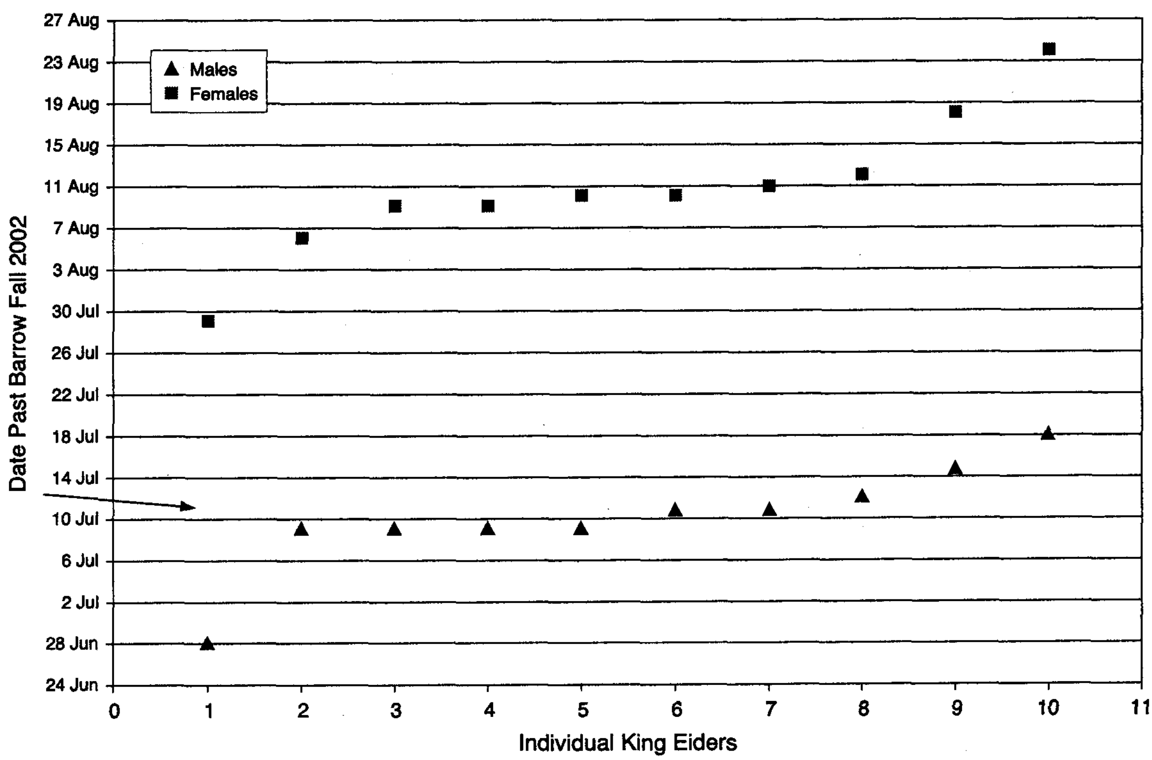

Figure 2. Dates that 10 male and 10 female king eiders with satellite transmitters passed Barrow during summer/fall 2002. Arrow denotes date migration count began (11 July). Data from A. Powell, unpublished.

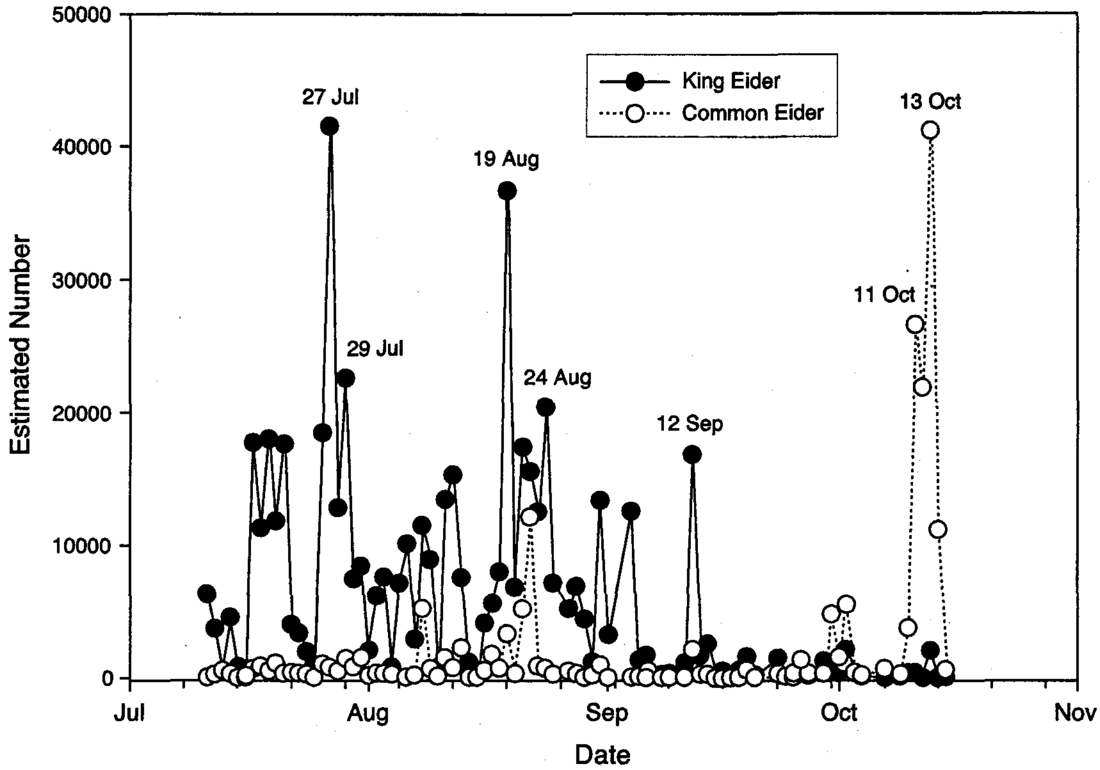

Figure 3. Projected daily passage of king and common eiders during summer/fall 2002 at Point Barrow.

Our preliminary estimate for the passage of common eiders for the early migration period was 51,622 (95% CI 21,784) and 176,109 (95% CI 42,390) for the late period. Only 29% of the estimated total of common eiders passed by before 7 September. The remaining 71% passed by in October, with the largest numbers passing on 11 and 13 October when 26,592 and 41,143 were estimated to pass, respectively. King eiders comprised 82% of all eiders identified and commons made up 18% (Table 1).

Summer/Fall 2003

The summer/fall 2003 count is underway, therefore we have no preliminary numbers to present. When we began counting on 8 July, 3 of 15 (17%) of the male king eiders with satellite transmitters had already left the Beaufort Sea (data from Powell et al. CMI Project; Figure 4). The earliest female left on 2 August 2003 (Figure 4).

We weighed and measured 32 male and 24 female king eiders (Table 2). Preliminary analysis indicates that females weigh significantly more during their eastward migration in May than they do during their westward migration in August (t-test, $p < 0.001$). Mean tarsus and culmen measurements for May and August are not significantly different (t-test, $p = 0.67$ and 0.24, respectively), indicating that the difference in weight was not due to size. The data for males appears more complicated. We have weights for May, July, and August. Although the males apparently weigh least in August and most in May, the birds also appear to be smallest in July. We plan to look at these data in more detail. Young-of-the-year begin to migrate in September and October, therefore those data are currently being collected.

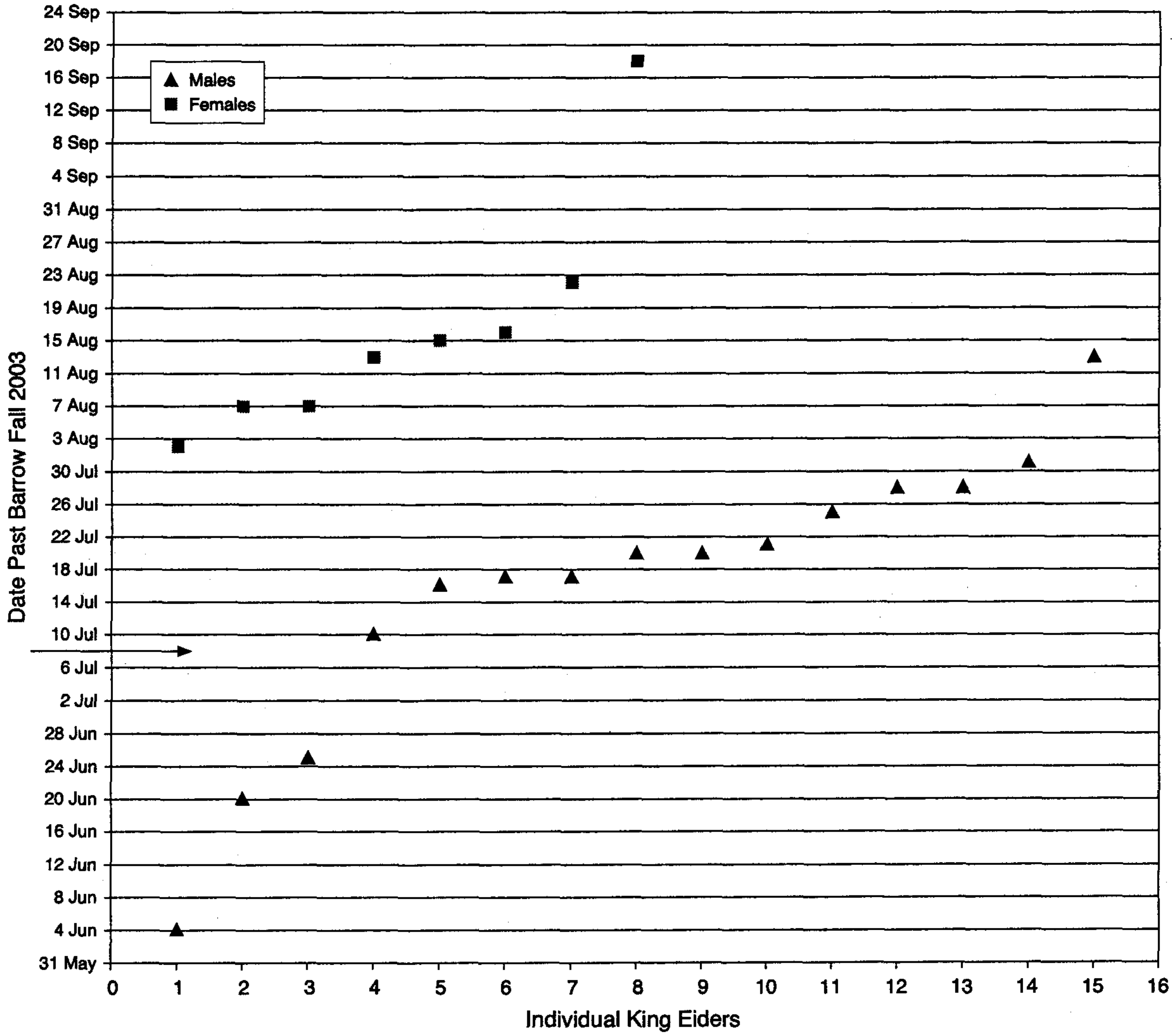

Figure 4. Dates 15 male and 8 female king eiders with satellite transmitters passed Barrow during summer/fall 2003. Arrow denotes date migration count began (8 July). Data from A. Powell, unpublished.

Spring 2003 count

Preliminary projected daily and total passage estimates have not been calculated for spring 2003, but numbers seen include 76,420 king, 24,091 common, and 99,902 unidentified eiders (Table 1). King eiders comprised 76% and commons 24% of all eiders identified. Spring appeared to be several weeks early in 2003 and eiders were seen east of Barrow prior to our start date of 30 April. None of the king eiders with satellite transmitters implanted in 2002 passed by prior to 30 April (Figure 5).

Table 2. Summary statistics for king eiders harvested near Point Barrow May–August 2003.

	Mass (g)	Tarsus (mm)	Culmen (mm)
Males (n = 32)			
Mean	1697	585	284
Standard deviation	203	28	39
Range	1170–2120	541–696	201–375
Females overall (n = 24)			
Mean	1639	581	325
Standard deviation	238	41	26
Range	1175–2050	531–742	228–386
Females May (n = 10)			
Mean	1826.5[1]	585.5	332.7
Standard deviation	242	61	8
Range	1175–2050	531–742	320–347
Females August (n = 14)			
Mean	1505[1]	578	319
Standard deviation	114	17.5	34
Range	1360–1710	546–601	228–386

[1]These means are significantly different from one another (t-test, $p < 0.001$).

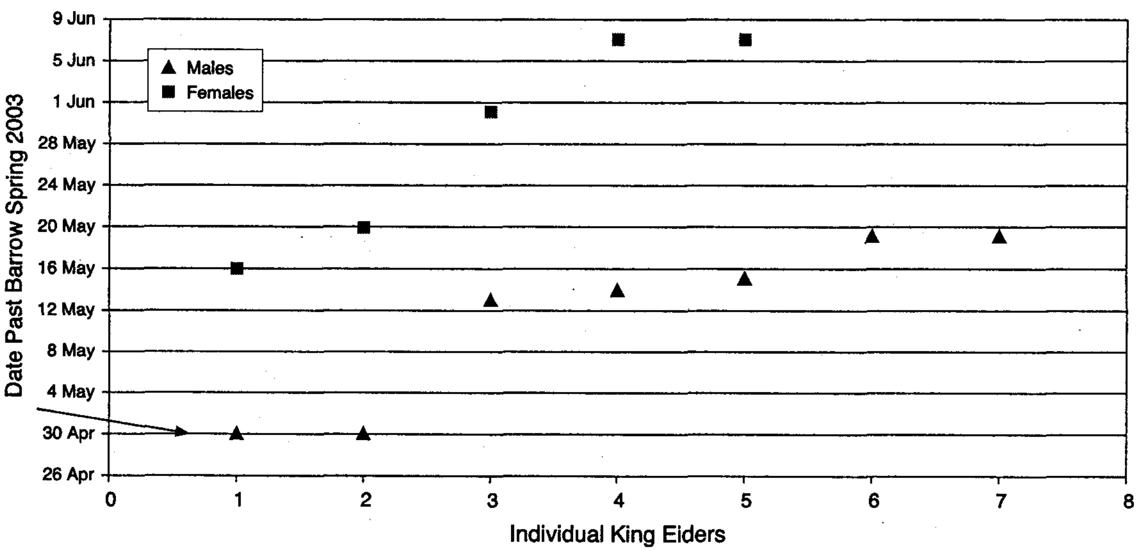

Figure 5. Dates 7 male and 5 female king eiders with satellite transmitters passed Barrow during spring 2003. Arrow denotes date migration count began (30 April). Data from A. Powell, unpublished.

Discussion

When comparing the early 11 July–7 September time period between 2002 and 1996, the total point estimate appears to be higher for king eiders in 2002 (Table 3); however, the total point estimates for the late period (11 July–15 October) do not appear to be significantly different (Table 3). Comparing this early time period among years avoids comparing estimates that include large numbers of young from highly productive years with low numbers in poorly productive years. In 1996, there were large numbers of king eiders passing in September and October; this pattern was not seen in 1994 [Suydam et al. 1997] or in 2002 and may indicate that 1996 was a good reproductive year. Comparing the early time periods may be most appropriate here and may indicate that the king eider population has increased or at least not decreased. We will use the spring 2003 and 2004 and summer/fall 2003 data to better interpret this result.

Although 50% and 17% of the male king eiders fitted with satellite transmitters passed by Point Barrow prior to the beginning of our counts in 2002 and 2003, respectively, we do not think those percentages represent the overall timing of male king eider migration (Figures 2 and 4). The projected daily passage rates for the early season (Figure 3) did not indicate any large numbers of eiders passing until 15 July. The early departure of the male king eiders with implants may have been a reaction to surgery or it may be that males on the western portion of the breeding site nearer to Barrow arrive there early each year.

Table 3. Estimated passage for king and common eiders including 95% confidence intervals for the early (11 July–7 September) and late (11 July–15 October) time periods in 1996 and 2002.

	King Eider	Common Eider
Early Summer/Fall 2002		
Projected total passage[1]	493,248	N/A
95% confidence interval	74,332	N/A
Projected total range[2]	418,916–567,580	N/A
Early Summer/Fall 1996[3]		
Projected total passage[1]	330,248	N/A
95% confidence interval	70,725	N/A
Projected total range[2]	259,493–400,943	N/A
Late Summer/Fall 2002		
Projected total passage[1]	529,271	176,109
95% confidence interval	78,742	42,390
Projected total range[2]	450,667–608,013	133,719–218,499
Late Summer/Fall 1996[3]		
Projected total passage[1]	507,667	111,635
95% confidence interval	84,680	42,440
Projected total range[2]	422,987–592,347	69,195–154,075

[1]Sum of daily projected passage estimates
[2]Upper and lower limits of passage using confidence interval
[3]From Suydam et al. [2000a]

The bulk of the common eider summer/fall migration occurs in October; therefore, we will only compare the late time period estimates. More common eiders were counted in summer/fall 2002 than in 1996 (Table 3); however the estimates overlap. The spring 2003 and 2004 and the summer/fall 2003 estimates will help us evaluate this result.

In our attempts to evaluate annual productivity for eiders breeding east of Barrow, we weighed, measured, and inspected feathers of harvested eiders (Table 2). It appears that few young were produced in 2002 and the timing of their return in 2003 does not occur until after this report is due. We have, however, collected weight data that indicate that females arrive in the Beaufort Sea weighing more than when they leave. These data may offer some insight into the energetics of breeding and migration. We will coordinate with the Powell et al. CMI project to share these data and incorporate the weights they collected of eiders captured on the breeding grounds.

Students

We have amended our project to incorporate a study designed by Michael Knoche, a master's degree student at the University of Alaska Fairbanks. His project proposes to use carbon isotope ratios in feathers collected from king eiders passing Barrow to determine areas used by king eiders during the fall molt when the birds are flightless. Questions of interest include whether molting flocks are large or small and sexually segregated or sexually mixed. Feathers grown in one geographical region will have a signature that reflects that region. Molt is energetically taxing and understanding distribution during molt may provide insight into mortality factors. Thus molting areas are important habitats for king eiders and learning more about them could be helpful for better understanding the species.

Feather sample collection began in May of 2003. We obtained permits from the U.S. Fish and Wildlife Service and the Alaska Department of Fish and Game to collect 60 king eiders during 2003; however, only 17 king eiders were shot for the project and another 237 samples were obtained from subsistence hunters and from birds found dead. Mr. Knoche is preparing for the laboratory analysis phase of his study. In addition to collecting feather samples for his master's project, he worked full time on the migration project in both 2002 and 2003 conducting counts, scheduling counters, and entering and managing the data.

The other student working on our project is Rita Frantz, an undergraduate at Ilisagvik College in Barrow. In addition to counting and measuring eiders she also entered data into a database in preparation for analysis.

Presentations

Michael Knoche gave a presentation for the Barrow Arctic Science Consortium, National Science Foundation, Schoolyard Project on 16 August 2003. The presentation was titled, "The Biology of King Eiders: What can their feathers tell us?" The presentation was given at the Ukpeagvik Iñupiat Corporation Science Center in Barrow and was well attended by local residents and scientists.

Acknowledgements

This project is funded by the University of Alaska Coastal Marine Institute (Minerals Management Service) with logistic support provided by the North Slope Borough, Department of Wildlife Management. We are grateful to Lynne Dickson of the Canadian Wildlife Service for providing support and travel for Andrea Hoover to assist us with counts. The U.S. Fish and Wildlife Service was generous in allowing their employees, Dominic Bachman, Tim Obritschkewitsch, and Nate Pamperin to assist our project. Quaiyaan Aiken, Paula Earp, Quaiyaan Opie, Bruce MacTavish, Rebecca McGuire, Leslie Pierce, and Yumiko Uchiro assisted in the migration counts. Michael Wald found the spring perch, made a trail to get there, and conducted counts. We thank Craig George for helping us get started in the spring and Ben Akootchook for mechanical talent. The subsistence hunters of Barrow helped by allowing us to look at their birds, donating samples, and sharing their knowledge of eiders with us. *Quyanaq*. We also appreciate the data sharing that has occurred with Abby Powell and Laura Phillips and look forward to more in the future.

The migration portion of this project was reviewed and approved by the Institutional Animal Care and Use Committee (IACUC) of the University of Alaska Fairbanks (#02-05). The portion of this study using stable isotopes to identify molting areas of king eiders was also reviewed and approved by the IACUC (#03-15).

References

Bailey, A.M. 1948. Birds of Arctic Alaska. Colorado Museum of Natural History. Pop. Ser. No. 8. 317 p.

Braund, S.R., K. Brewster, L. Moorhead, T.P. Holmes and J.A. Kruse. 1993. North Slope Subsistence Study, Barrow, 1987, 1988, and 1989. Techn. Rep. No. 149, OCS Study, MMS 91-0086. Anchorage.

Brueggeman, J.J. 1980. Coastal occurrence of birds at Point Barrow, Alaska, in spring. Murrelet 61:31–34.

Fabijan, M., R. Brook, D. Kuptana and J.E. Hines. 1997. The subsistence harvest of King and Common eiders in the Inuvialuit Settlement Region, 1988–1994, p. 67–73. *In* D.L. Dickson [ed.], King and Common Eiders of the Western Canadian Arctic. Occ. Pap. No. 94. Can. Wildl. Ser., Ottawa.

Fuller, A.S., and J.C. George. 1997. Evaluation of Subsistence Harvest Data from the North Slope Borough 1993; Census for Eight North Slope Villages: For the Calendar Year 1992. Unpubl. report, North Slope Borough, Department of Wildlife Management, Barrow, Alaska.

Giles, R.H. [ed.]. 1971. Wildlife Management Techniques. The Wildlife Society, Ann Arbor, Michigan. 633 p.

Johnson, L.L. 1971. The migration, harvest and importance of waterfowl at Barrow, Alaska. M.S. thesis. University of Alaska, Fairbanks.

Murdoch, J. 1885. Birds, p. 104–128, *In* P.H. Ray [ed.], Report of the International Polar Expedition to Point Barrow, Alaska. Part 4. Government Printing Office, Washington, D.C.

Suydam, R., L. Quakenbush, M. Johnson, J.C. George and J. Young. 1997. Migration of King and Common eiders past Point Barrow, Alaska, in spring 1987, spring 1994 and fall 1994, p. 21–28. *In* D.L. Dickson [ed.], King and Common Eiders of the western Canadian Arctic. Occ. Pap. No. 94. Can. Wildl. Ser., Ottawa.

Suydam, R.S., D.L. Dickson, J.B. Fadely and L.T. Quakenbush. 2000a. Population declines of king and common eiders of the Beaufort Sea. Condor 102:219–222.

Suydam, R.S., L.T. Quakenbush, D.L. Dickson and T. Obritschkewitsch. 2000b. Migration of King, *Somateria spectabilis*, and Common, *S. mollissima v-nigra*, Eiders past Point Barrow, Alaska, during spring and summer/fall 1996. Can. Field-Naturalist 114:444–452.

Thompson, D.Q. and R.A. Person. 1963. The eider pass at Point Barrow, Alaska. J. Wildl. Mgmt. 27:348–356.

Thompson, S.K. 1992. Sampling. John Wiley & Sons, Inc., New York. 343 p.

Timson, R.S. 1976. Late summer migration at Barrow, Alaska, p. 354-400. *In* Environmental Assessment of the Alaskan Continental Shelf. Principal Investigators' Reports, April–June 1976, Vol. 1. U.S. Dept. Comm., NOAA, Boulder, Colorado.

Woodby, D.A., and G.J. Divoky. 1982. Spring migration of eiders and other waterbirds at Point Barrow, Alaska. Arctic 35:403–410.

Susceptibility of Sea Ice Biota to Disturbances in the Shallow Beaufort Sea. Phase 1: Biological Coupling of Sea Ice with the Pelagic and Benthic Realms

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Abstract

The abundance and diversity of biological communities in sea ice, the water column and the sea floor were studied in nearshore fast-ice-covered waters close to Barrow, Alaska. One of our major objectives was to assess the potential impact of sea ice sediment load on biological productivity and coupling processes. Sampling was conducted in April 2002 and February, April and May/June 2003 with ice corers, water samplers, plankton nets and sediment corers at two locations which differed mainly in terms of sea ice sediment. A strong ice algal bloom was observed in the sediment-free fast ice, reaching a maximum pigment concentration of 330 µg Chl a *L^{-1} in the bottom 10 cm of the ice in May, while the concentration remained below 1 µg Chl* a *L^{-1} in the water column. With the increasing ice algal bloom, the $\delta^{13}C$ isotopic ratio of sea ice particulate organic matter (POM) decreased from initially –25‰ in February to –16‰ in May/June, while no depletion was observed in pelagic POM. The abundance of ice meiofauna increased with the progressing season to a maximum of 276,000 animals m^{-2}, dominated by nematodes and polychaete juveniles. The isotopic ratio of the ice meiofauna followed the enrichment of ice algae with time, indicating feeding on ice produced organic matter; pelagic fauna generally reflected the water column isotopic signature. Abundances of meroplanktic stages of benthic polychaetes in the water column were consistently at least one order of magnitude below densities in the ice, suggesting sea ice as an important habitat for young life stages. The sediment-loaded sea ice showed no indications of spring bloom formation for any of the studied parameters. Our observations demonstrate that disturbances due to increased sediment load within sea ice may cause a reduction of biological activity within the ice, impacting various trophic levels within the sea-ice-based food web.*

Introduction

Sea ice is a crucial habitat in polar areas. Beside its well-known role as a platform for marine mammals and birds, it serves as a habitat for a diverse community of bacteria, protists and metazoa. Sea ice algae contribute significantly to primary production in many parts of the Arctic and, thereby, provide a food source for seasonal or permanent inhabitants of sea ice and the ice–water interface. Through biological coupling processes, the particle production in sea ice also contributes to the growth of benthic invertebrates and fish species like arctic cod—key components of the higher trophic level food web. Our project targets the effects of disturbances, such as increased erosion and turbidity due to climate change and exploration-related construction activities, on the productivity of the sea ice food web and the related biological coupling processes. We hypothesize that de-coupling may lead to reduced biological production in all three realms (sea ice, water column, benthos), and more specifically, to changes in the diversity and abundance of ice meio- and macrofauna, as well as reduced recruitment of benthic invertebrates with meroplanktic ice-associated larvae and juveniles.

Field Sampling, Sample Processing and First Results

Logistics

The field sampling in Barrow, Alaska was successfully completed. Following a pilot field trip in April 2002, three trips were conducted in February, April and May/June 2003 in order to sample late winter, spring and post-spring/ice melt conditions. We received excellent logistical support from the Barrow Arctic Science Consortium (BASC), which provided us with lab space, snow machines, sleds, a power generator and polar bear watch.

Our scientific equipment largely worked well under the harsh Arctic conditions with some exceptions. Low air temperatures in February (–30 °C) and April (–15 °C) caused freezing of sensor tips and plankton nets, which hindered sampling. Sediment sampling was a challenge through the core holes, partly due to sediment characteristics. We tested a hand-held vanVeen grab in February and April 2003 but could not retrieve any quantitative samples. We therefore reverted to our sediment corer despite the associated drawbacks, which we described in the 2002 annual report.

Sampling sites

During each field phase, we collected samples from sea ice, the water column and the sea floor at two fast-ice locations close to BASC (Figure 1). Both sites were about 200 m offshore in a water depth of 5 to 5.6 m and were selected based on differences in the amount of sediment incorporated into the sea ice. The fast ice was sampled in level un-ridged areas. Site 1 (without visible sediment incorporation) was located in the Chukchi Sea just off BASC (71° 20′N, 156° 42′W). The second site was located in the Beaufort Sea (71° 22′N, 156° 24′W), 30 minutes by snow machine from BASC. All equipment was loaded onto two sleds that were towed by the snow machines. The fieldwork is documented on the project's web page: http://www.sfos.uaf.edu/research/seaicebiota/cmi/barrow2002/index.html

Temperature, snow and light

At each location, several physical parameters were measured along with taking samples. Snow thickness was determined at ten locations in a perimeter of 1 m around each site and varied between 3 and 7 cm. Air, snow surface, snow/ice interface and ice temperatures were measured with a traceable thermometer (accuracy of 0.05 °K) (Figure 2a and b). Ice temperature was measured on one ice core per site in 10 to 20 cm intervals over the entire ice thickness. The determined temperature gradients in the ice did not differ between the two sites. The coldest temperatures were encountered in February 2003, with a minimum ice temperature of –25 °C at the ice surface and an air temperature of –30 °C. Ice temperatures in April ranged from –13 °C at the top of the cores to –1.9 °C at the bottom. In late spring (May) temperatures were considerably higher—between –0.2 and –2 °C. Temperature and salinity of the water column were determined with a YSI 85 sensor in 1 m intervals. To ensure accurate depth readings, the sensors were attached to marked fiberglass rods. Freezing of the sensor head due to cold surface temperatures caused a malfunction of the salinity readings in February and April. The temperature profiles of the water column exhibited neither seasonal patterns nor any indication of vertical stratification. Values ranged between –1.4 and –2 °C. Salinity in May/June varied between 30.6 and 31.9 (data not shown).

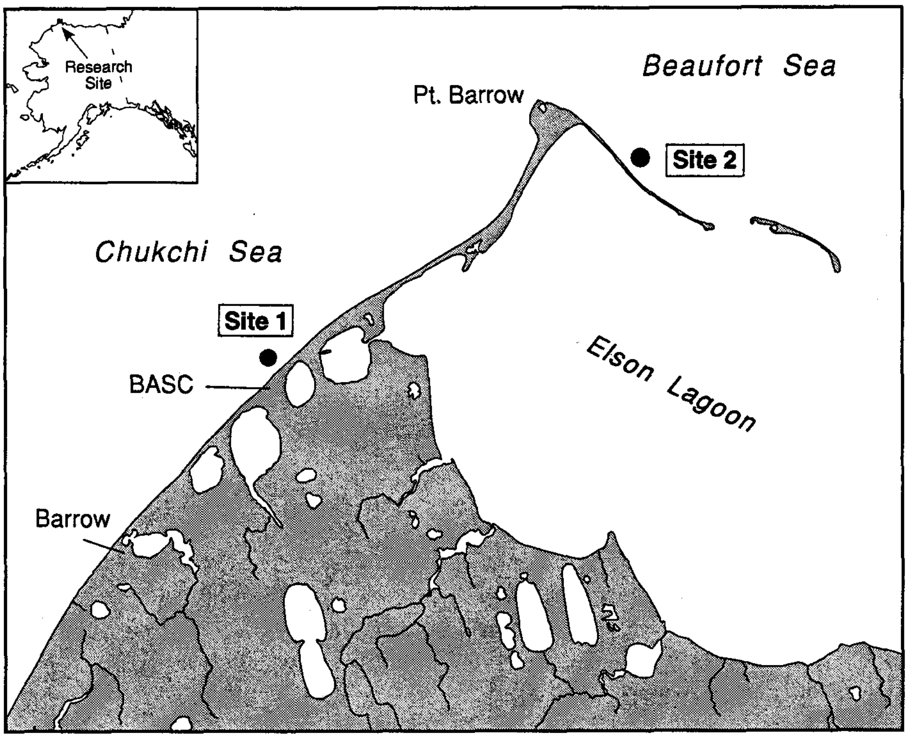

Figure 1. Location of project sampling sites. Site 1: sediment-free ice, Site 2: sediment-loaded ice.

Through the first core hole at each station, the PAR (photosynthetically active radiation) light intensity was measured with a LI-COR underwater 4π sensor in 1 m intervals down to just above the seafloor (Figure 2c and d). A 2π sensor that remained at the ice surface acted as a reference. Light intensities at the 2 m water depth under sediment-loaded sea ice were two orders of magnitude below the sediment-free ice values and never exceeded absolute values of 0.4 $\mu E\ m^{-2}\ s^{-1}$. At the sediment-free site, the relative irradiance levels at the 2 m depth decreased from February to April, probably as a result of algal development.

In May 2003, the spectral composition of the light above and below the sea ice was determined using a fiberoptic radiometer with a resolution of 2 nm (Figure 2e and f). Distinct differences between sea ice with a high sediment load (Beaufort location) versus low sediment load but high ice algal biomass (Chukchi location) are evident (Figure 2e and f): At the Chukchi site, attenuation was highest in the blue and red wave bands, where chlorophyll (Chl) has its absorbance maxima, while the spectral composition at the sediment-laden site did not indicate any preferential absorption in the PAR range (400 to 700 nm).

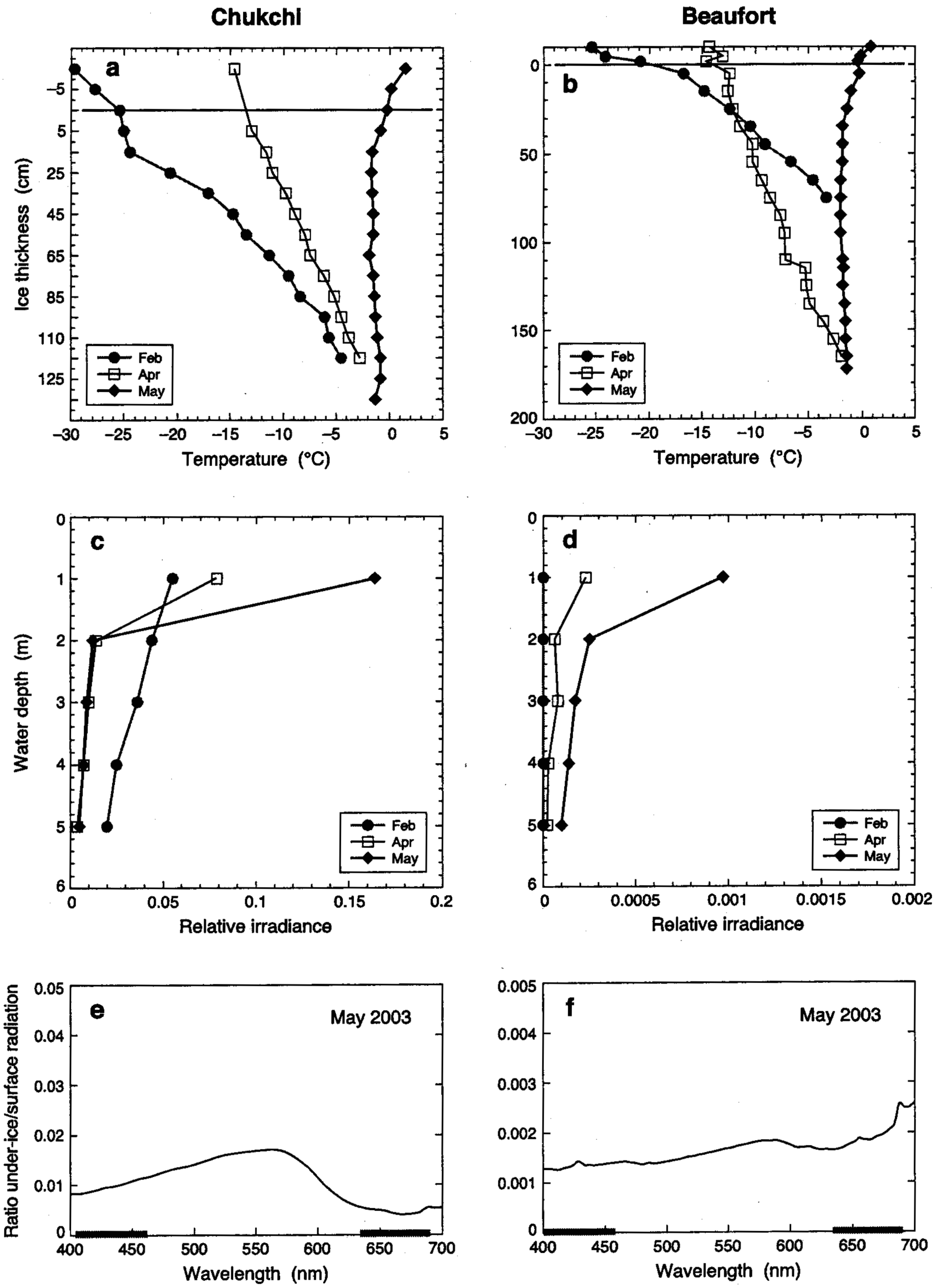

Figure 2. Environmental parameters at two coastal fast-ice sites with no sediment (left) and high sediment load (right) in sea ice cover in 2003. a and b: Sea ice temperatures. Horizontal line indicates top of ice floe; measurements above the line were made in air and snow. c and d: Sub-ice irradiance (ratio 4π/2π sensor) in February, April and May 2003 (note the different scales). e and f: Spectral light composition in May 2003. Thick gray lines along the x-axis indicate ranges of maximum chlorophyll absorption.

Algal pigments, particulate organic carbon (POC) and nitrogen (PON)

A minimum of eight ice cores were taken at each site, comprising four replicates of two core sets (A and B). The total ice thickness was recorded from a minimum of four cores. For further processing we used the bottom 10 cm of the ice cores, as this portion is the region with highest algal and meiofauna abundances.

The bottom sections of set A of the replicates were melted directly in the dark. After complete melt, 50 ml sub-samples were filtered onto Whatman GF/F filters for algal pigment analysis. These filters were rinsed with filtered seawater and subsequently frozen. Another set of 50 ml sub-samples was filtered onto pre-combusted and pre-weighed GF/F filters, rinsed with deionized water and frozen for later determination of stable isotope composition and amount of total inorganic and organic material (seston). One-hundred-milliliter sub-samples were preserved in 0.5% formaldehyde (final concentration) for algal counts. Processing of core set B is described in the next section.

Four replicates of water samples were taken through the core holes from an intermediate water depth (3 m) with a Kemmerer water sampler. For analyses of algal pigments, total organic and inorganic matter and stable isotope composition, about 0.2 to 0.5 L each was filtered on GF/F filters and treated like the ice samples. One-hundred-milliliter sub-samples were likewise preserved for algal counts.

Sediment samples were collected with a benthic corer and frozen for algal pigment, POC and PON analysis (the latter two yet to be done). The total amount of organic material in the sediment was determined by weighing sediment samples before and after burning in a muffle furnace (550 °C for 24 hours).

Algal pigments (chlorophyll and phaeopigments) from all realms were extracted from four replicate samples with 90% acetone for 24 hours in the freezer [Arar and Collins 1992]. For the sediment samples, 15 ml of acetone were added to about 1 g (wet weight) of sediment and chlorophyll was extracted for 24 hours in the freezer [Conde et al. 1999]. After extraction, 7 ml of the acetone were transferred into a borosilicate tube and centrifuged for 20 minutes at 1500 rpm. Pigment concentrations were determined fluorometrically with a Turner Designs fluorometer.

At site 1 (without sediment) algal biomass in the sea ice increased by two orders of magnitude from February to May, with a mean final biomass of 330 ± 42 µg Chl *a* L^{-1} sea ice (Figure 3a). At site 2 (with sediment) pigment concentration increased slightly from 1.9 ± 0.0 µg Chl *a* L^{-1} in February to a mean of 8.3 ± 7.0 µg Chl *a* L^{-1} in May. We did not see any indication of water column algal blooms —phytoplankton biomass levels remained low (<2 µg Chl *a* L^{-1}) throughout the study period. Sediment chlorophyll concentration varied between <0.2 and >1.0 µg Chl *a* g^{-1} DW (dry weight) sediment. Pigment concentrations within the sediment varied considerably between replicates as indicated by the high standard deviations (Figure 3c). This may be due to small-scale patchiness or could be a sampling artifact, as we had difficulty in retrieving consistent sediment layers. No clear seasonal pattern was observable in the sediment Chl *a* concentrations, but the sudden increase in the Chl *a*/phaeopigment ratio from values <1 to 5.2 in May (Figure 3d) points toward direct sedimentation of fresh algal material from the ice to the sediment.

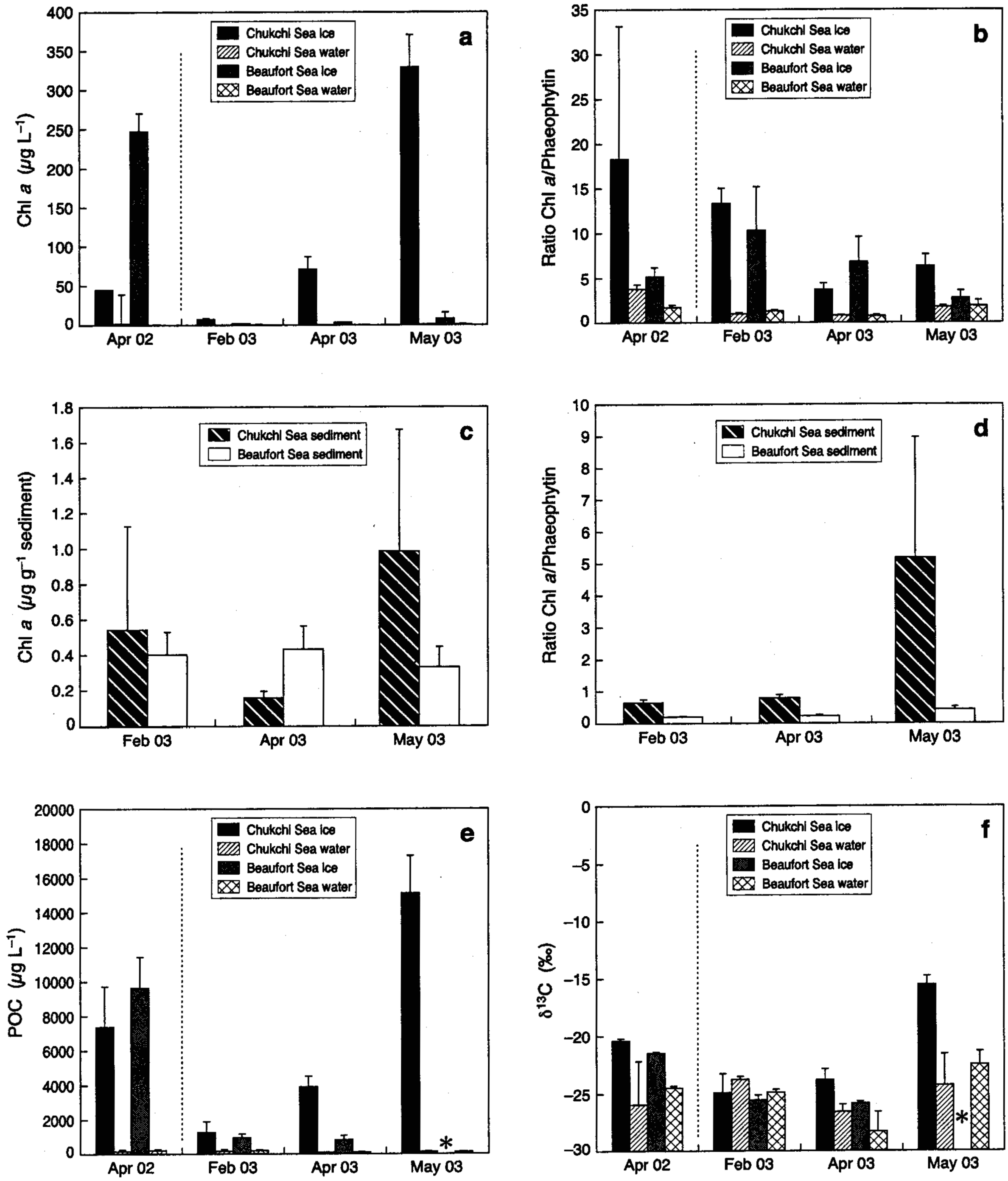

Figure 3. Biological parameters at two coastal fast-ice sites with no sediment (Chukchi site) and high sediment load (Beaufort site) during sea ice cover in 2003. Algal pigment concentrations (a and c) and pigment ratios (chlorophyll *a*/phaeopigments; b and d) in ice, water and sediment. POC and $\delta^{13}C$ (e and f) in sea ice and water samples. * indicates missing data point.

Abundance of metazoan fauna in the sea ice and water samples

The bottom sections of core set B were melted in the dark after addition of 1 L of 0.2 μm filtered seawater to avoid osmotic stress. After complete melt, 100 ml sub-samples were preserved in 0.5% formaldehyde (final concentration) for determination of algal counts (yet to be done). A second set of sub-samples was enriched over 41 μm gauze for ice meiofauna analysis. These samples were life-sorted and individual taxa were filtered onto pre-combusted GF/F filters for stable isotope analysis (see below). Another portion of the meiofauna samples, usually 500 ml, was preserved in 4% formaldehyde for abundance estimates that were performed on a Wild M3 dissecting microscope.

Vertical plankton hauls were taken with 20 μm and 200 μm nets. Four replicates per site and season were sorted either alive or after preservation in formaldehyde (4% final concentration), and specimens were counted by species/taxon using a dissecting microscope. Additional samples, taken with the same nets or a pump, were sorted and prepared for stable isotope analysis.

Sediment samples were collected with a small benthic corer (6 cm diameter). Due to the sandy sediment at the Chukchi site and the difficulty in deploying the corer under harsh conditions, we could not retrieve undisturbed cores suitable for quantitative analysis of the benthic meiofauna. Most of the sediment was washed out of the plexiglass liners while retrieving the core. The sediment retrieved from the corer was collected for qualitative analysis (yet to be done, preserved in formaldehyde [4% final concentration]), stable isotope composition (preserved in 70% ethyl alcohol or frozen), organic content and sediment Chl *a* analysis.

The abundance of meiofauna within the sea ice followed the seasonal trend of the ice algal biomass (Figure 4a and b). Mean total abundances of four replicates increased within the sediment-free ice from initially 18,000 animals m^{-2} sea ice in February to 276,000 individuals m^{-2} in May. In contrast, mean abundances in the sediment-loaded ice remained below 17,000 specimens m^{-2}. Ice meiofauna was dominated by polychaete juveniles and copepod nauplii. High abundances of nematodes in May were related to reproduction events.

At all sampling dates, the zooplankton (Figure 4c and d) was dominated by crustaceans, with larval stages (nauplii) starting to occur in late April (2002) and May (2003). The total abundance of polychaete juveniles in the water column was <700 animals m^{-2} at any of the sampling events and, thus, at least one order of magnitude below sea ice values (maximum of 136,600 animals m^{-2}).

Stable isotope analysis

Samples for stable isotope analysis were dried in a drying oven at 65 °C for 1–2 days and subsequently weighed. All filters were then HCl-fumed in a vacuum chamber for 10–15 hours and dried again. The filters were folded up, put into aluminum cups and delivered to the University of Alaska Fairbanks (UAF) Alaska Stable Isotope Facility where they were run on ThermoFinnigan Delta mass spectrometers for their $\delta^{13}C$ and $\delta^{15}N$ values and total organic carbon (POC) and nitrogen (PON) masses.

The sea ice POC concentrations increased at the sediment-free location by a factor of 12 during the 2003 sampling period (Figure 3e). This reflects both the dramatic increase in chlorophyll concentration and in meiofauna abundance at this site. The samples from the sediment-laden site taken in May 2003 have not been completely analyzed yet, but the April 2003 data suggest that, in agreement with the chlorophyll development, little POC built up in the sediment-loaded ice. Water POC concentrations remained low at both sites throughout the study period. Presumably, pelagic POC concentration increased once the sea ice had melted.

Consistent with studies from other sea ice regions, as biomass increased the $\delta^{13}C$ in the Chukchi sea ice became increasingly enriched from initial values of –25‰ in February 2003 to –16‰ in May/June 2003 (Figure 3f). In contrast, preliminary data suggest that that this trend was not evident in the Beaufort Sea where little ice algal biomass had built up. First insight into $\delta^{13}C$ values of the ice meiofauna implied that the fauna picked up the enriched signal found in the ice algae. This would indicate feeding on ice-derived carbon. The complete analysis of this data set, including analysis of ice and pelagic metazoans and $\delta^{13}N$ measurements, is in progress.

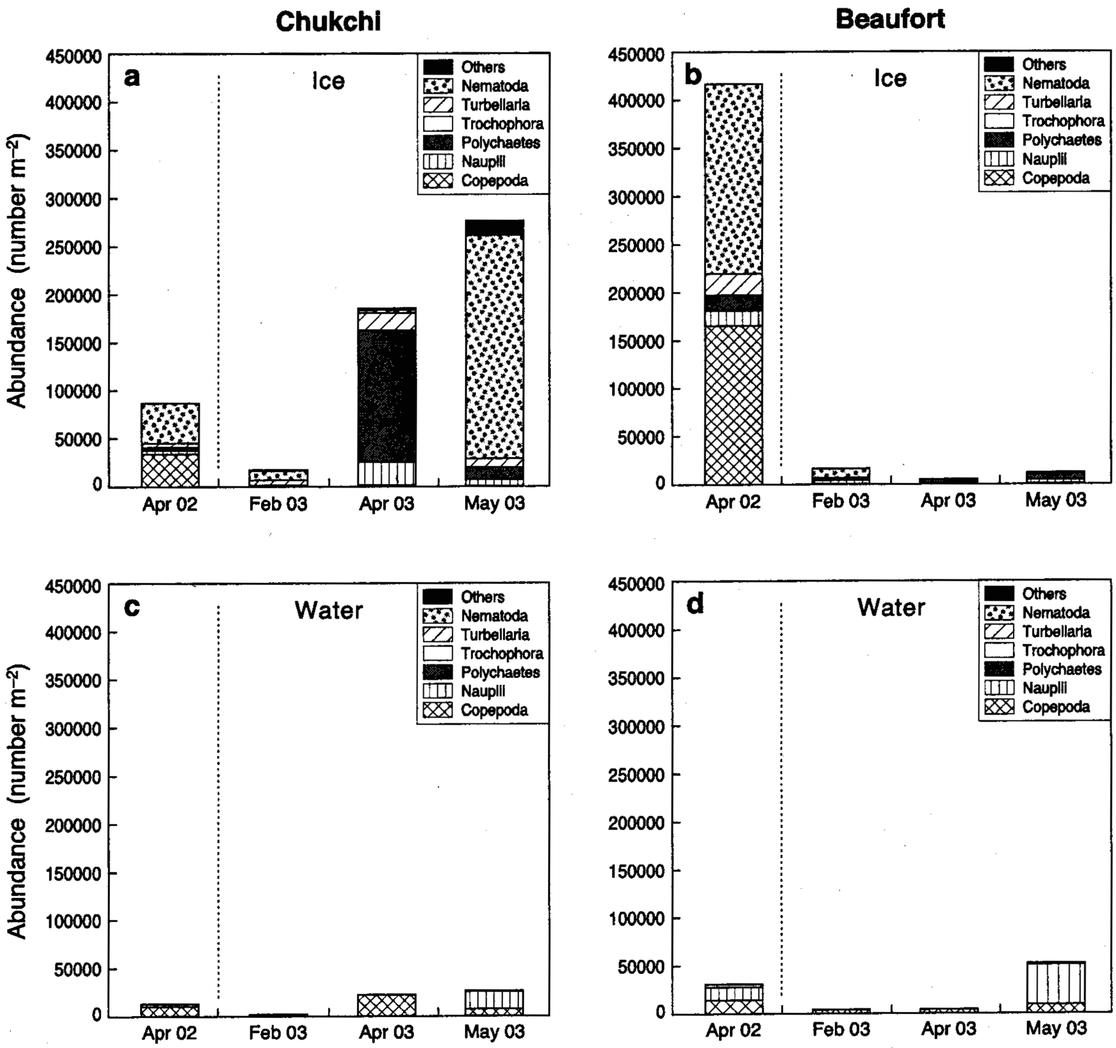

Figure 4. Abundance and composition of metazoans in the sea ice (a and b) and water column (c and d) in April 2002 to May 2003 in and under sediment-free ice (Chukchi) and sediment-loaded ice (Beaufort).

Outreach and Presentations

We established a website presenting our project on the UAF School of Fisheries and Ocean Sciences (SFOS) server which has been accessible since January 2003. In addition, we gave two public lectures in Barrow, entitled "Hidden Life in the Arctic Sea Ice: From Barrow's Shore-Fast Ice to the Central Arctic Ocean" (15 February 2003) and "Explorations under the Pack-Ice of the Arctic Ocean" (31 May 2003). The first public talk was followed by an interview at the local public radio station and an article in Barrow's newspaper, *The Arctic Sounder*.

We also presented first results at the CMI annual review in Fairbanks on 19 February 2003; during the Gordon Research Conference, "Polar Science" in Ventura, California, 16–21 March 2003; and during the SEARCH (Study of Environmental Arctic Change) Open Science Meeting in Seattle, 26–30 October 2003.

Mette Nielson started as a graduate student at SFOS in spring 2003. She has worked and will continue working on part of the collected material. She received CMI funding to participate in the Barrow field phase. During the spring field phase she became familiar with all aspects of the project relevant to field sampling, including the use of ice coring, water column and sediment sampling equipment, as well as driving snow machines and processing samples in the lab. She will use part of the collected material for her master's thesis.

Conclusion

The sampling in Barrow was successfully completed. A set of field data unique to this area was collected and the first analysis substantiates the hypothesis that sea ice is a temporary environment for young stages of benthic and pelagic fauna (e.g., polychaetes and copepods). Secondly, the high amount of sediment and the subsequent reduction of irradiance caused drastically reduced ice algal growth at site 2. This also led to lower abundances of meiofauna within the sea ice at that site. The next months will be used for a) completing the analysis of our collected material, and b) conducting a comprehensive analysis (including statistics) of the data sets.

Acknowledgements

We wish to thank BASC director, Glenn Sheehan, and BASC logistics coordinators, Matt Irinaga and Dave Ramey, as well as their staff, for the excellent logistical support during our stays in Barrow. Hajo Eicken, Geophysical Institute at UAF, and Peter McRoy and Alan Springer, Institute of Marine Science (IMS) at UAF, were very helpful in providing sampling equipment. Thanks are due to Sang Lee, IMS at UAF, and Klaus Meiners, Yale University, for assistance during field sampling. Tim Howe and Norma Haubenstock ran the stable isotope samples at the Alaska Stable Isotope Facility, UAF.

References

Arar, E.J. and G.B. Collins. 1992. In vitro determination of chlorophyll *a* and phaeophytin *a* in marine and freshwater phytoplankton by fluorescence [Method 445.0]. *In* Methods for the Determination of Chemical Substances in Marine and Estuarine Environmental Samples, EPA/600/R-92/121. Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. EPA.

Conde, D., S. Bonilla, L. Aubriot, R. de León and W. Pintos. 1999. Comparison of the areal amount of chlorophyll *a* of planktonic and attached microalgae in a shallow coastal lagoon. Hydrobiologia 408/409:285–291.

Role of Grazers on the Recolonization of Hard-Bottom Communities in the Alaska Beaufort Sea

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Task Order 85244

Abstract

This project is expanding on the recovery work completed by Dunton [1985] to determine the importance of grazing to recolonization rates of sessile organisms at the Boulder Patch. A simple manipulative study was set up last summer (2002) to test the suggestion that invertebrate grazing is associated with the slow recovery of Boulder Patch communities. This summer (2003), the experiment was sampled for the first time. No growth was found on any of the cleared rocks and little difference was seen in the control rocks. It is hoped that another year of sampling will determine if grazing effects exist but have a slow response. A pilot study to test a method to explore sedimentation effects of grazing also was set up this year.

Background

Alaska's Beaufort Sea shelf is typically characterized by silty sands and mud and as having an absence of macroalgal beds and associated organisms [Barnes and Reimnitz 1974]. In 1971, a diverse kelp and invertebrate community was discovered near Prudhoe Bay in Stefansson Sound, Alaska. Since its discovery, the Boulder Patch has been subject to much biological and geological research [Dunton et al. 1982; Dunton and Schell 1987; Dunton and Jodwalis 1988; Dunton 1990; Martin and Gallaway 1994; MMS 1996, 1998; Dunton and Schonberg 2000]. This research stems from a need to protect sensitive biologically-productive regions, while allowing oil exploration in the surrounding areas [Wilson 1979].

The Boulder Patch contains large numbers of cobbles and boulders that provide a substrate for attachment for a diverse assortment of invertebrates and several species of red and brown algae. The predominant alga is the brown *Laminaria solidungula*, which constitutes 90% of the brown algal biomass [Dunton et al. 1982]. This alga is an important food source to many benthic and epibenthic organisms [Dunton and Schell 1987]. Differences in infaunal abundance and biomass between the Boulder Patch and peripheral sediment areas demonstrate the importance of this unique habitat [Dunton and Schonberg 2000]. In the Boulder Patch, algae and epilithic invertebrates cover nearly all exposed substrate, with the exception of recently upturned rocks [Dunton and Schonberg 2000].

Recolonization experiments in the Boulder Patch have shown that recovery of denuded areas is slow [Dunton et al. 1982]. In temperate systems, algal communities can recover to previous densities within one year of denuding [Foster 1975], but in the Boulder Patch, 50% of the substrate was still bare three years after an initial disturbance [Dunton et al. 1982]. One of the primary reasons suggested for the slow recolonization is grazing by invertebrates [Dunton et al. 1982]. Motile herbivorous, omnivorous, and carnivorous invertebrates such as chitons, snails, seastars and polychaetes have been frequently observed in the Boulder Patch [Dunton et al. 1982]. Many studies have shown that grazers can be very important in structuring communities [Johnson et al. 1997; Worm and Chapman 1998; Jenkins et al. 1999; Ojeda and Muñoz 1999; Morton 1999; Wilson et al. 1999; Konar 2000].

To achieve the goal of determining if grazing/predation is associated with the slow recruitment in the Boulder Patch, various comparisons have been set up using exclusion cages, cage controls, and natural rock.

Objective and Hypothesis

Objective:

Determine if grazing is limiting the rate of recruitment of hard substrate communities in the Boulder Patch.

The specific hypothesis is:

H_1 There is no significant difference between recruitment of sessile organisms on bare boulders with and without cages to exclude mobile invertebrates.

Experimental Methods

This experiment was set up last summer (2002). The boulders used in this study were collected from the Boulder Patch (DS-11, Figure 1). Because of the difficulty in removing living material from rocky substrata underwater, all boulders were brought to the surface to be cleared (Figure 2). After five days, the denuded rocks (with and without cages and cage controls) were placed back into the field.

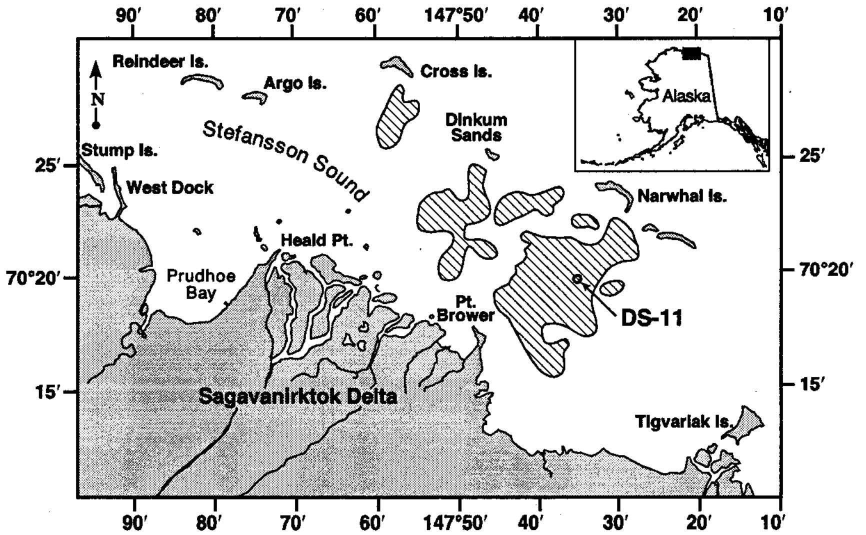

Figure 1. Chart of Boulder Patch showing Dive Site 11 (DS-11).
Hatched sections are areas with high boulder/cobble density.

Six cages were deployed to exclude large mobile invertebrates at each of three locations within DS-11, totaling 18 cages. The cages in this experiment were constructed of stainless steel mesh (Figure 3). All cages were coated with a non-toxic antifouling compound to inhibit growth of sessile invertebrates and algae. Eighteen cage controls were also deployed to control for any artifacts caused by the cages, such as decreased light levels or increased sedimentation. These cage controls were cages that had holes cut into the sides so that invertebrates could easily pass through them (Figure 4).

For comparison, 18 cleared rocks were deployed with no cages to determine natural recruitment. As a control for natural changes in the community during the time period of this experiment, 18 non-cleared boulders were also examined.

Last summer, all rocks (caged and non-caged, cleared and non-cleared) were photographed (Figure 5) and initially sampled for percent cover (dead corallines, rock, algal species, etc.).

Preliminary Results

This summer all rocks except for one uncleared control were re-sampled for percent cover. This uncleared control was not relocated. No change was found in any of the cleared rocks (Figure 6). In fact, the rocks and the cages look like they were placed in the field yesterday. The uncleared controls did change significantly from last year (Figure 6).

Light consideration

This summer, light readings were taken along a depth gradient on three separate occasions. Light levels and visibility were very low on all three days and at two sites (Figure 7).

Sediments in the water column caused this lack of light. These sediments also could be seen on the encrusting organisms and rocks. Since there was no growth on the cleared rocks in this first year and sediments were found on the substrate, a pilot experiment was set up to test a method to eliminate sediments from a settling surface. These surfaces will be examined for growth next year. If growth is found, a proposal will be submitted to examine sedimentary effects.

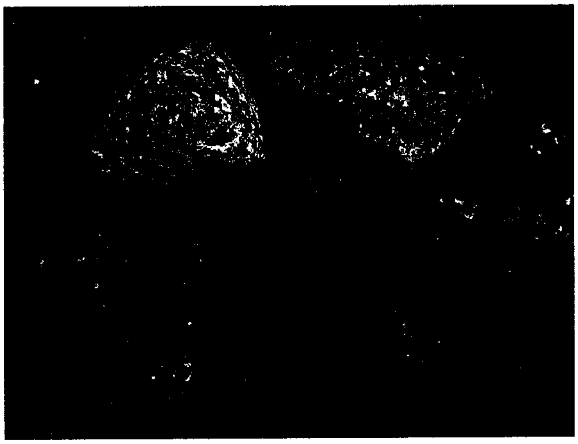

Figure 2. Examples of cleared and non-cleared boulders.

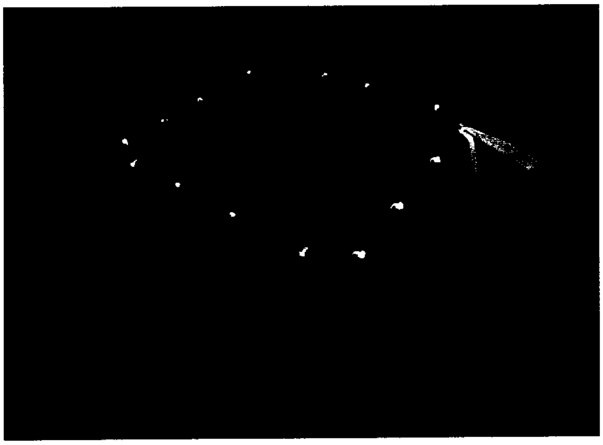

Figure 3. Cage rock in situ.

Figure 4. Cage control in situ.

Figure 5. Example of non-cleared boulder.

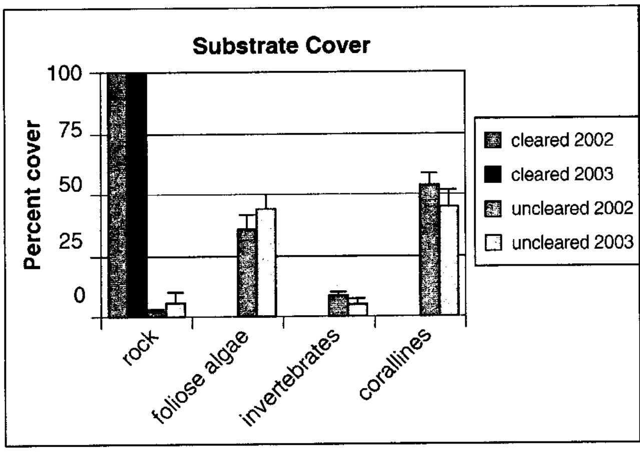

Figure 6. Comparison of substrate cover between cleared and uncleared rocks in 2002 and 2003.

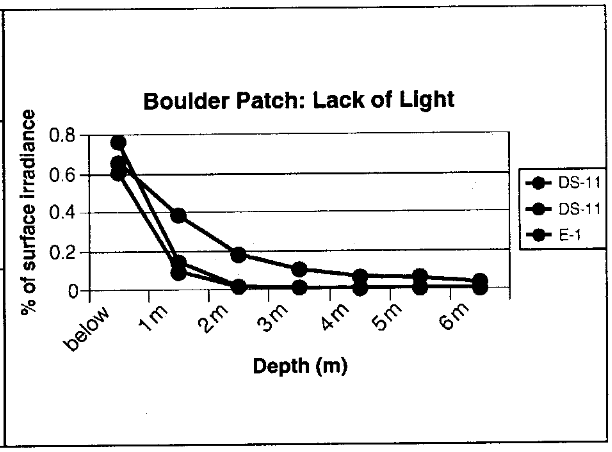

Figure 7. Light readings relative to surface irradiance at two Boulder Patch sites on three different dates.

References

Barnes, P.W., and E. Reimnitz. 1974. Sedimentary processes on arctic shelves off the northern coast of Alaska, p. 439-476. *In* J.C. Reed and J.E. Sater [eds.], The Coast and Shelf of the Beaufort Sea, Arctic Institute of North America, Arlington, VA.

Dunton, K.H. 1985. Trophic dynamics in marine nearshore systems of the Alaskan high arctic. Ph.D. dissertation. University of Alaska Fairbanks.

Dunton, K.H. 1990. Growth and production in *Laminaria solidungula*: Relation to continuous underwater light levels in the Alaskan High Arctic. Mar. Biol. 106:297–304.

Dunton, K.H., and C.M. Jodwalis. 1988. Photosynthetic performance of *Laminaria solidungula* measured *in situ* in the Alaskan High Arctic. Mar. Biol. 98:277–285.

Dunton, K.H., and D.M. Schell. 1987. Dependence of consumers on macroalgal (*Laminaria solidungula*) carbon in an arctic kelp community: $\delta^{13}C$ evidence. Mar. Biol. 93:615–625.

Dunton, K.H., and S.V. Schonberg. 2000. The benthic faunal assemblage of the Boulder Patch kelp community, Chapter 18. *In* The Natural History of an Arctic Oil Field. Academic Press.

Dunton, K.H., E. Reimnitz and S. Schonberg. 1982. An Arctic kelp community in the Alaskan Beaufort Sea. Arctic 35:465–484.

Foster, M.S. 1975. Algal succession in a *Macrocystis pyrifera* forest. Mar. Biol. 32:313–329.

Jenkins, S.R., S.J. Hawkins and T.A. Norton. 1999. Interaction between a fucoid canopy and limpet grazing in structuring a low shore intertidal community. J. Exp. Mar. Biol. Ecol. 233:41–63.

Johnson M.P., M.T. Burrows, R.G. Hartnoll and S.J. Hawkins. 1997. Spatial structure on moderately exposed rocky shores: Patch scales and the interactions between limpets and algae. Mar. Ecol. Prog. Ser. 160:209–215.

Konar, B. 2000. Seasonal inhibitory effects of marine plants on sea urchins: Structuring communities the algal way. Oecologia 125:208–217.

Martin, L.R., and B.J. Gallaway. 1994. The effects of the Endicott Development Project on the Boulder Patch, an Arctic kelp community in Stefansson Sound, Alaska. Arctic 47:54–64.

Minerals Management Service [MMS]. 1996. Beaufort Sea planning area oil and gas lease sale 144. Final Environmental Impact Statement. MMS OCS EIS/EA MMS 96-0012. U.S. Dept. of Interior, MMS, Alaska Outer Continental Shelf Region, Anchorage.

Minerals Management Service [MMS]. 1998. Arctic Kelp Workshop Proceedings, Anchorage, Alaska. T.D. Newbury [ed.], OCS Study MMS 98-0038. U.S. Dept. of Interior, MMS, Alaska Outer Continental Shelf Region, Anchorage.

Morton, B. 1999. Competitive grazers and the predatory whelk *Lepsiella flindersi* (Gastropoda: Muricidae) structure a mussel bed (*Xenostrobus pulex*) on a southwest Australian shore. J. Mollus. Stud. 65:435–452.

Ojeda, F.P., and A.A. Muñoz. 1999. Feeding selectivity of the herbivorous fish *Scartichthys viridis*: effects on macroalgal community structure in a temperate rocky intertidal coastal zone. Mar. Ecol. Prog. Ser. 184:219–229.

Wilson, H.M. 1979. Beaufort Sea high bids top $1 billion. Oil Gas J. 77:26–29.

Wilson, W.G., C.W. Osenberg, R.J. Schmitt and R.M. Nisbet. 1999. Complementary foraging behaviors allow coexistence of two consumers. Ecology 80:2358–2372.

Worm, B., and A.R. Chapman. 1998. Relative effects of elevated gazing pressure and competition from a red algal turf on two post-settlement stages of *Fucus evanescens* C. Ag. J. Exp. Mar. Biol. Ecol. 220:247–268.

Water and Ice Dynamics in Cook Inlet, Alaska

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Task Order 85308

Abstract

In the first year of this project, 15 satellite tracked buoys were purchased and 12 have been released in Cook Inlet since April 2003. Trajectories are predominantly south of the Forelands. One buoy drifted out of Cook Inlet and westward into Shelikof Strait. Grounded buoys were recovered and redeployed. All buoys were drogued at 7.5 m to follow the average water motion in the 5–10 m depth range. Buoy data have been downloaded via the Argos satellite system, transferred to the University of Alaska Fairbanks, and converted to useful values. Buoy trajectories have been plotted, and the velocity and accelerations have been computed.

The bathymetry for Cook Inlet has been assembled and incorporated into a numerical model of the region. M2 tidal forcing has been invoked, and the advance of the tidal currents and the M2 phase and amplitude have been computed. The phase is in general agreement with previous studies. The amplitude varies from a maximum in Turnagain Arm to a minimum in lower Cook Inlet. The tidal residual circulation shows generally southward motion in upper Cook Inlet. Several regions of closed circulation may be possible in the lower inlet. There is qualitative agreement between the model residual circulation and some of the buoy tracks.

Training to make best use of the ENVI software has been completed in a timely fashion. Satellite imagery is now being browsed, and images from 33 dates have been identified for further analysis. Browsing continues for additional, quality images to compare with the buoys and numerical model results.

Introduction

In September 2003, the Coastal Marine Institute (CMI) at the University of Alaska Fairbanks (UAF) School of Fisheries and Ocean Sciences, in partnership with the U.S. Department of the Interior's Minerals Management Service (MMS), began funding this three-year project on water and ice dynamics in Cook Inlet, Alaska. The goals of the project are to improve MMS's environmental assessments and oil spill contingency planning by better understanding the circulation in Cook Inlet, improving Cook Inlet circulation modeling, and validating oil spill trajectory modeling.

To meet these goals, we began investigating the water and ice dynamics in Cook Inlet using satellite tracked drifting buoys, winter satellite imagery, and a high resolution numerical model. Our focus is to identify the temporal and spatial variability of the tide rips through analysis and inter-comparison of the buoy data, satellite data, and the results from the numerical model.

Relevance to specific MMS Framework Issues

MMS Framework Issue 1:
"Studies for better understanding marine, coastal environments affected or potentially affected by offshore oil and gas or other mineral exploration and extraction on the outer continental shelf." — Water and ice dynamics are fundamental for understanding how the marine and coastal environments could be affected by offshore exploration. Our project focuses on understanding the dynamics of Cook Inlet oceanography to provide MMS with a comprehensive regional model, and sets of observations from drifters and the SAR (synthetic aperture radar) satellites.

MMS Framework Issue 2:
"Modeling studies of environmental processes for better predictive capabilities and for defining information needs." — We have assembled a high resolution bathymetry database for use in a high-resolution numerical model (~500 m grid spacing) for the Cook Inlet region in order to understand and predict ice and water dynamics.

Project organization

Mark Johnson, lead principal investigator, drifting buoys
Steve Okkonen, SAR satellite imagery
Andrey Proshutinsky, numerical modeling

Methods

Satellite tracked drifting buoys

Fifteen drifting buoys were built for deployment and use in Cook Inlet, Alaska. Consistent with our CMI/MMS tasks, our goal is to track tidal and sub-tidal motions by having the buoys outfitted with drogues to follow the water at a pre-selected depth range. The buoys are specifically not surface-following or oil-following buoys. Our task to track deeper water motion may be different from previous Cook Inlet studies using surface-following or oil-following buoys. All 15 buoys were delivered on-time to our collaborators at CISPRI (Cook Inlet Spill Prevention Response, Inc.).

Once a buoy is active, data are transmitted to the Argos satellite system. Argos (www.argosinc.com) is a system of satellites for collecting data from relevant platforms located around the world. Because of Cook Inlet's high latitude, Argos satellites pass overhead several times per day. Transmission and communication with the Argos satellite uses the telemetry electronics built into each drifter. At regular intervals, the drifter communicates with the Argos satellite. Data are transmitted to the Argos satellite and re-transmitted to Argos service centers for further processing, and then e-mailed to us approximately a day later. The Argos system has been in use since 1978 and is quite reliable. Fees are paid to Argos based on the total hours of data transmission from all the buoys. We are watching this cost closely to make sure our fee estimates are reasonable and in line with our proposed budget.

The data are redundantly transmitted. With each pass of the satellite, the most recent data are uploaded. If the satellite link remains intact beyond that point, then earlier data are also sent to the satellite. This highly redundant process means that very little data are lost due to transmission failures. A successful transmission, however, may still have errors. Each transmission has a checksum transmitted following each bundle of data sent to the satellite. A percentage (17%) of the transmitted data fail the checksum test and are discarded. Fortunately, because of the highly redundant storage and transmission protocol, almost none of the hourly data have been lost.

The buoys are SVP-type drifters manufactured by Technocean, Inc., in Cape Coral, Florida. Our contact person is Jeff Wingenroth. The buoys have been heavily engineered to track water motion: the surface float has a drag radio about 1/40th of the drogue, which is designed to follow the water. The drifter float is tethered by cable to the drogue. We have selected a drogue depth of 7.5 m, which means that the buoy will best represent the average water motion between 5 and 10 m.

A GPS receiver in the surface float acquires hourly positions, generally at the top of each hour. The GPS position data are accurate to within a few meters, and the GPS time stamp recorded internally to the drifter is accurate to the nearest minute (i.e., no seconds are recorded). In addition to time and position, each buoy records the tension on the drogue (percent), and the battery voltage. These are stored and then transmitted in hexadecimal. We have written code (MATLAB) to convert the Argos hexadecimal data to meaningful numbers. Preliminary analysis of the buoy trajectories and analysis are shown on our website (http://www.ims.uaf.edu/resarch/johnson/cmi).

The internal GPS records the position at the top of each hour. The Argos satellite also acquires the position of the buoy at irregular intervals. However, the GPS data are far more accurate in space (a few meters) compared to the Argos position fixes (tens of meters). In our data processing, we have ignored the Argos position fixes in most cases and used only the GPS position fixes.

Data are e-mailed daily to Mark Johnson and processed at the Institute of Marine Science, University of Alaska by Dr. Johnson using code written in MATLAB. The data include the time, position (latitude and longitude), battery voltage, and a "drogue sensor" which indicates whether the drogue is still intact. Redundant data are deleted, and the hourly positions are used to compute the east–west and north–south velocities, the overall speeds, and accelerations. Obvious errors, based on maximum probable speed and acceleration in Cook Inlet, are deleted. Following this process, the hourly positions are plotted, along with other relevant information.

Modeling of the Cook Inlet tides

During the reporting period (October 2002–September 2003) we have worked on data collection, data preparation for modeling, and modeling itself. Three major data sets were collected, analyzed, and used for modeling and validation of tides in the Cook Inlet model domain:

- Cook Inlet bathymetry,
- Cook Inlet tidal constituents, and
- Boundary conditions for the model domain.

Cook Inlet bathymetry has been constructed using several data sets. They include ETOPO5, ETOPO2 (Earth Topography–5 minute and –2 minute), NOAA (National Oceanic and Atmospheric Administration) data sets, and a proprietary data set produced by Scientific Fisheries Systems, Inc. exclusively for UAF. The last data set consists of randomly spaced bathymetric data points. It is constrained by 58.5° to 61.75 °N latitude and –154.5° to –148.5 °W longitude. All of these data sets were used to prepare a 500-m resolution bathymetry grid. Figure 1 shows contours of this bathymetry for Cook Inlet along with several geographic names.

Our bathymetry data have several sources, and we specifically credit the following groups:

NOAA, National Geophysical Data Center: Hydrographic surveys and marine geophysics tracklines, GEODAS Version 4.0 software. Boulder, Colorado.
http://www.ngdc.noaa.gov/mgg/bathymetry/relief.html

U.S. Geological Survey, USGS Geography: Topographic digital elevation models and digital raster graphics. Reston, Virginia.
http://mapping.usgs.gov

U.S. Army Corps of Engineers – Alaska District: Hydrographic surveys for Homer and Seldovia. Anchorage, Alaska.
http://www.poa.usace.army.mil

Walker and Associates, Inc.: Bathymetric and topographic data for Homer. Seattle, Washington.
http://www.walkermap.com

AeroMap, U.S.: Homer LIDAR (light detection and ranging) grid. Anchorage, Alaska.
http://www.aeromap.com

For our preliminary studies of the Cook Inlet tidal dynamics we used a 2-D barotropic non-linear model with 1-km spatial resolution [Kowalik and Proshutinsky 1993, 1994]. The model domain's maximum depth is 330 meters and a model time step is about 6 seconds. In order to simulate tides in Cook Inlet we have tidal harmonics from the FES95.1 and FES95.2 (Finite Element Solutions) model results that stem from the earlier pure hydrodynamic finite element solution FES94.1 [see Le Provost et al. 1994, 1995]. For more information see
http://www-aviso.cnes.fr:8090/HTML/information/publication/news/news6/leprovost_fr.html

An improved version includes results of data assimilation from Topex/Poseidon altimetry measurements. Harmonic constituents from 11 tidal waves are available along southern and western boundaries of the model domain (see Figure 2 with the simulated M2 tidal amplitude and phase in Cook Inlet).

We analyzed different data sources including tidal constituents for tidal sea level variability and for tidal currents based mainly on NOAA reports [Patchen et al. 1981]. Collection of the Cook Inlet tidal constituents work is not yet completed, and much more information is needed for model validation.

Satellite imagery

Steve Okkonen attended a five-day ENVI (environment for visualizing images) image analysis software training in Anchorage in October 2002. The class introduced general image analysis theory and techniques. The ENVI software will be used to analyze synthetic aperture radar images of sea ice concentration and distribution in Cook Inlet.

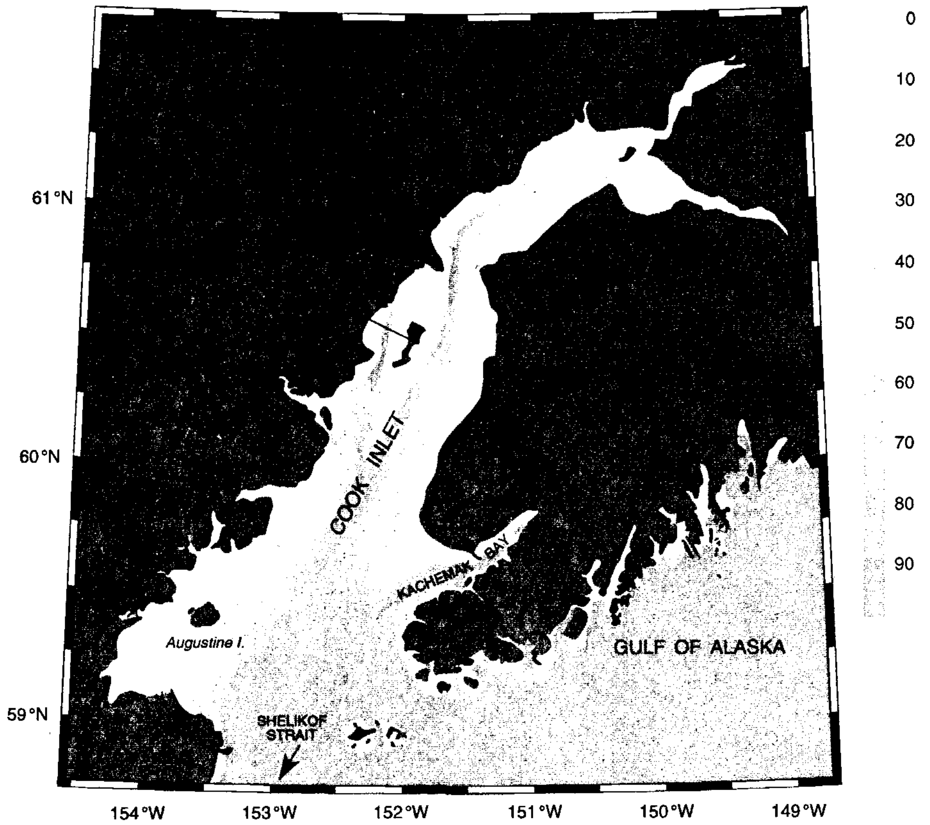


Figure 1. Location map with place names for the Cook Inlet study region.

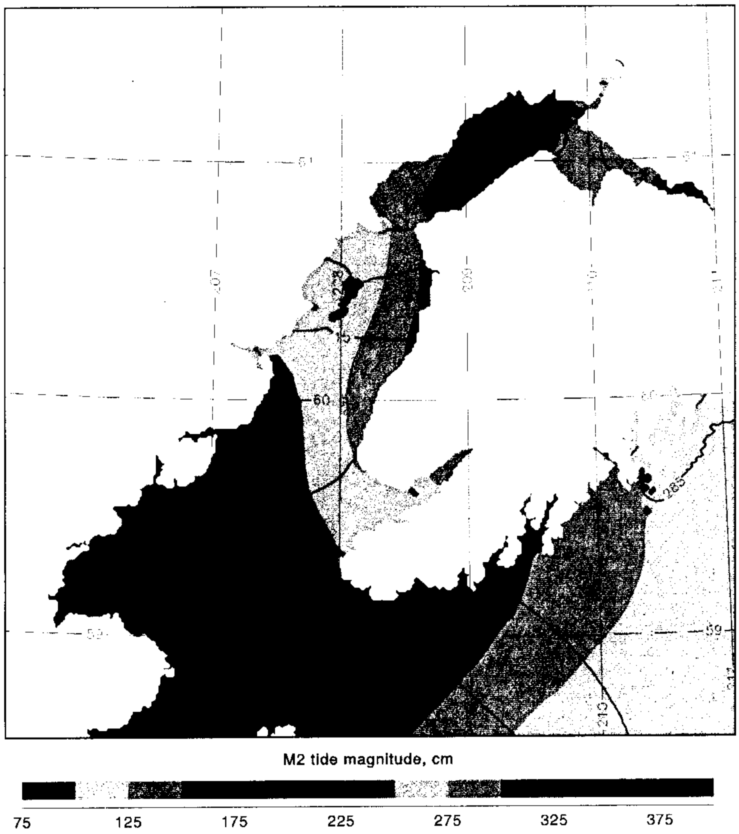


Figure 2. Amplitude (colors) and phase (black thick lines) of M2 tide.

Results

Drifting buoys

Twelve buoys have been released in Cook Inlet as of 16 September 2003. Four buoys were released by CISPRI personnel on 5 April in the middle rip. One failed after about 16 hours, and we speculate that it was damaged by ice still in the inlet at that time. Its last transmission was at 3:30 AM on 6 April.

A second deployment on 21 May released two more buoys. One failed immediately, likely because of a problem with the internal electronics. This assumption is supported by the transmitted GPS position which indicated 90 °N and 0° longitude, rather unusual numbers for Cook Inlet. The manufacturer, Technocean, Inc., has agreed to replace this buoy without charge.

A third deployment of two buoys was on 17 June and a fourth deployment of two buoys ocurred on 5 July. The latest deployment of two buoys was completed on 10 October. All initial deployments were by CISPRI as part of the proposal "match". In general, the buoys are working as expected.

One challenge is the almost unavoidable problem of having a buoy ground in shallow water when currents move it near shore. At present, we have had several buoys ground in Cook Inlet. All grounded buoys have been recovered by citizen volunteers, CISPRI personnel (Steve Russell), Carl Schoch (KBNERR), or Steve Okkonen. The recovered buoys were either re-deployed or transported and stored at our Kasilof, Alaska facility. During or prior to recovery of two of the grounded buoys, their drogues were either cut off or damaged beyond repair. We have ordered replacement drogues (at a cost of $300 each, plus shipping, from Technocean, Inc.). Drogues will be reattached and the buoys re-deployed. We have allowed the recovered buoys to continue to transmit for later error analysis of the stationary position data. All other buoys have continued to transmit and no other failures or assembly problems have appeared.

Three buoy tracks are of particular interest. Figure 3 shows the track of buoy 39912, which was released slightly south of the Forelands. Currents carried the buoy northward for several tidal cycles, but the mean southward flow moved it in loops toward Kalgin Island. From there, it was caught in the middle rip and tracked north and south for two weeks, then moved steadily south to the lower inlet where it looped for nearly a month before grounding. Note that the area of looping motion is consistent with the model results of the M2 residual current.

Buoy 39910 was grounded off Kalgin Island and recovered and re-deployed by Steve Okkonen. Figure 4 shows its track beginning from Kalgin Island along with time series of the buoy's speed and acceleration. The track has been colored so that accelerations are red and deceleration is blue. From this it can be seen how the tides decelerate at the end of the tidal ellipse and then accelerate strongly into the tide. The tidal ellipses are clockwise in motion. Also note from the acceleration time series the modulation over time, with larger amplitudes in mid-June and mid-July and smaller amplitudes, hence weaker accelerations, in between these times.

Similar accelerations are revealed in the buoy motion from 39995 (Figure 5) in lower Cook Inlet. This buoy was deployed in Kachemak Bay and moved southwest out of Cook Inlet. Note the strong modulation in both speed and acceleration as the buoy moves from shallow to deep water.

Figures 6 and 7 show the u-velocity (east–west) and v-velocity (north–south) plus speed and acceleration for buoys 39910 and 3997. In both cases the v-velocity dominates, as expected, with strong tidal periodicity.

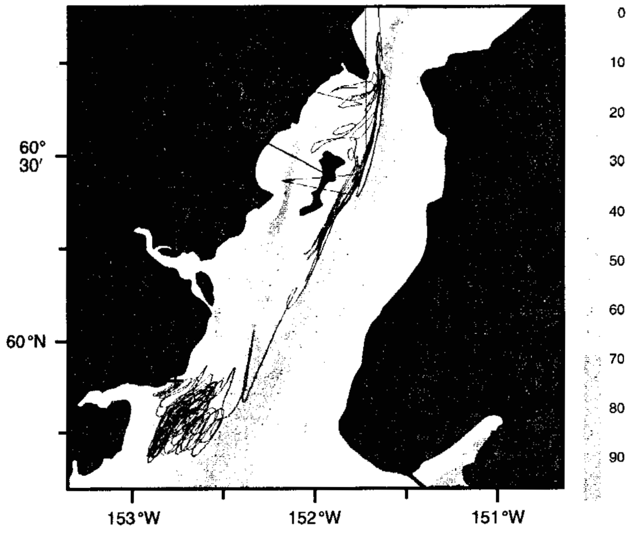
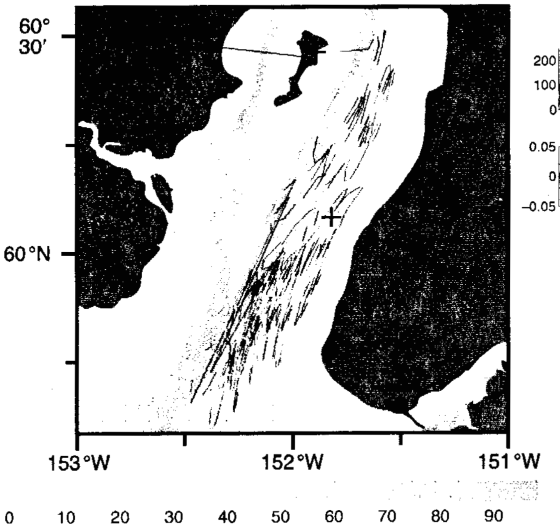


Figure 3. Trajectory for buoy 39912. Green "plus" shows location while on board *Montana* and red "plus" when grounded.



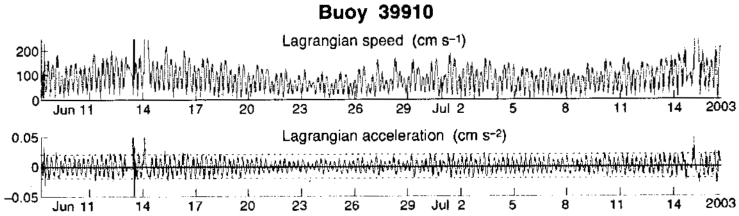


Figure 4. Trajectory for buoy 39910 with speed and acceleration. Track is coded red for acceleration and blue for deceleration. Green "plus" shows location while on board *Montana* and red "plus" when grounded.

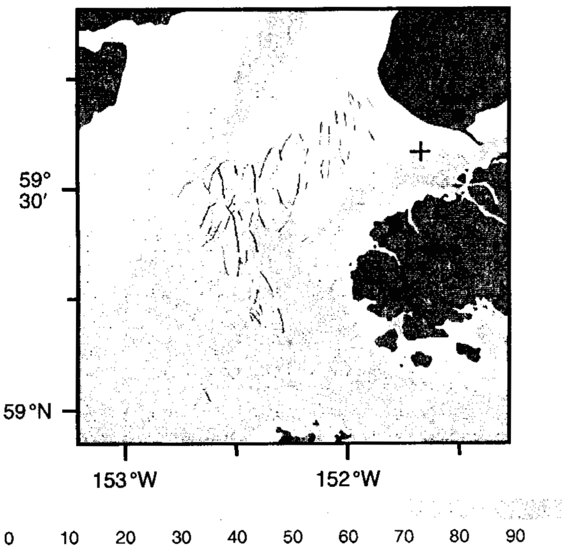


Figure 5. Trajectory for buoy 39995 with speed and acceleration. Track is coded red for acceleration and blue for deceleration. Green "plus" shows location while on board *Montana*.

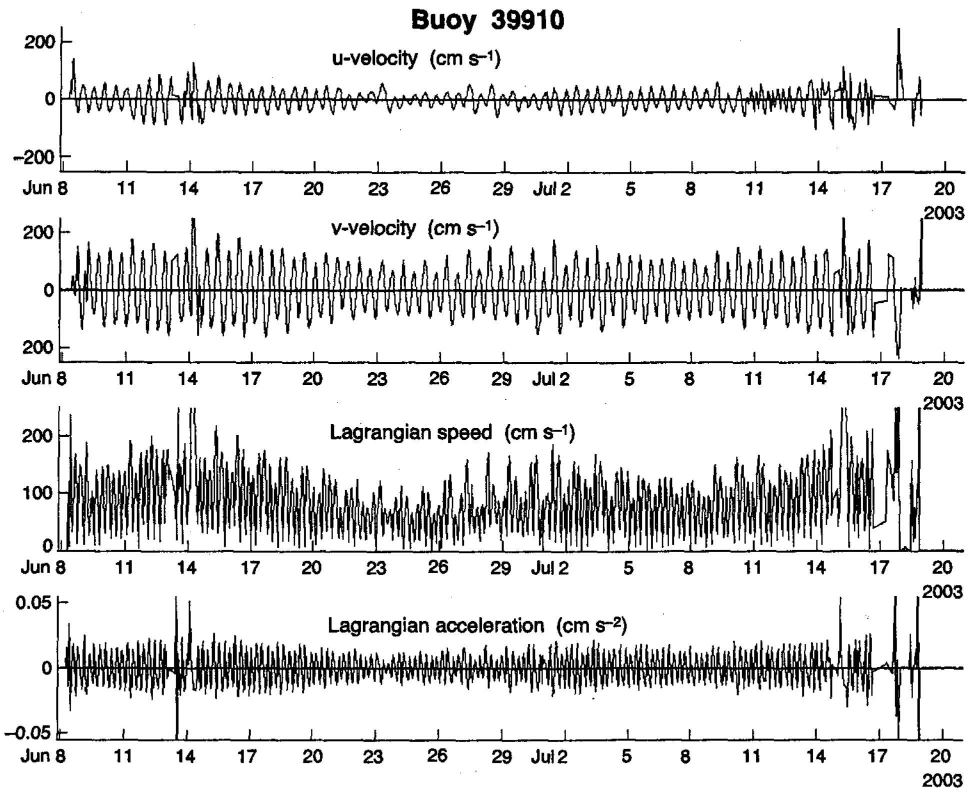


Figure 6. Velocity, speed and acceleration for buoy 39910.

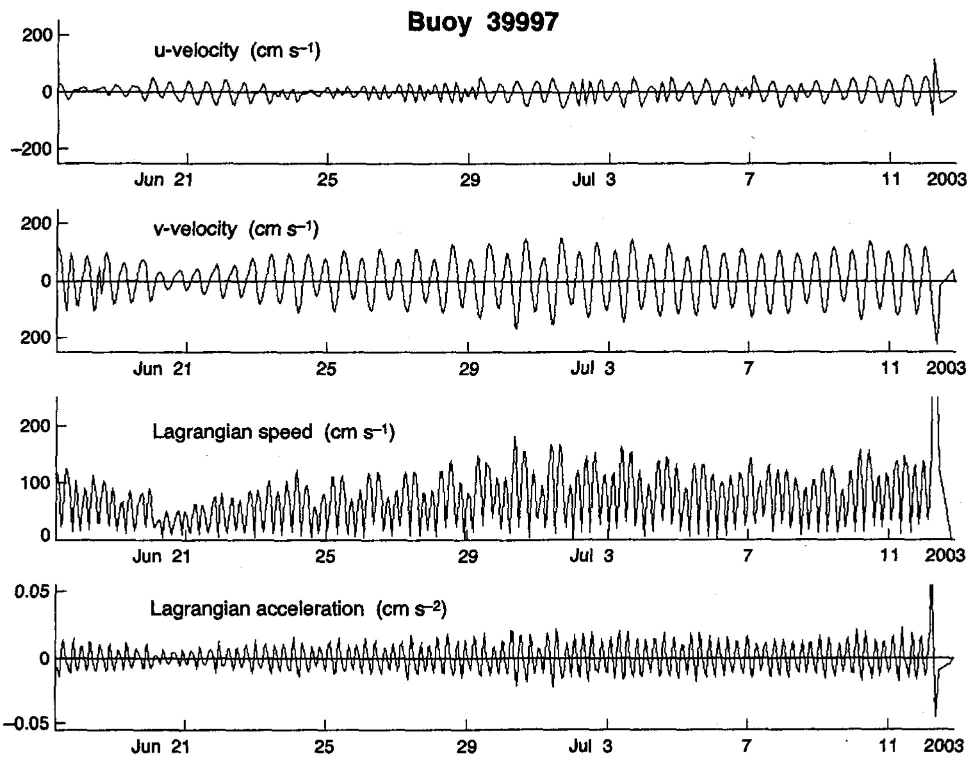


Figure 7. Velocity, speed and acceleration for buoy 39997.

Numerical model

In our first experiments we simulated the four major tidal waves: M2, S2, K1 and O1. Table 1 shows a comparison between M2 tidal amplitudes and phases at three major locations in Cook Inlet (Anchorage, Nikiski and Seldovia).

Table 1. M2 tide simulation results.

Station		Amplitude			Phase		
		Observed cm	Calculated cm	Difference cm	Observed deg	Calculated deg	Difference deg
0001	Anchorage	353.1	288.7	64.4	107.8	108.3	–0.5
0002	Nikiski	251.1	293.1	–42.0	30.9	39.6	–8.7
0003	Seldovia	222.9	264.8	–41.9	324.2	339.2	–15.0

In general, preliminary results are in relatively good agreement with observations. Existing errors relate mainly to uncertainties in the depths of Turnagain Arm. There are limited observations in this area and we are improving this information for our model domain using navigation charts.

The model does not take into account wetting and drying of shallow regions during the tidal cycle, which could be very important in the highly non-linear process of tide propagation in Cook Inlet. However, the wetting and drying problem is not an MMS priority in this work.

There are non-liner interactions among the tidal waves. We hope that when all tidal waves are applied at the model boundary, the model results for each tidal wave will be significantly improved due to inclusion of these non-linier wave interactions.

Figures 8–11 show the evolution of the M2 tidal dynamics during a semidiurnal cycle. Figure 12 shows residual tidal currents generated by this wave. Residual currents are responsible for eddy-like cyclonic (over deep parts of the bathymetry) and anticyclonic (over shallow banks) closed and semi-closed circulations. More detail and higher current speeds are expected when all tides are combined and simulated simultaneously. However, it is interesting that the anticyclonic motion in lower Cook Inlet displayed by buoy 39912 (Figure 3) is in qualitative agreement with the calculated residual currents. Our comparison of model and drifters continues.

Satellite imagery

SAR images from 33 dates for years 2000–2002 have been identified as initial candidates for identification and analyses of frontal features. Analysis of the identified images is beginning.

Figure 13 is a SAR image of the central Cook Inlet region from 25 January 2002. Areas of high backscatter, such as sea ice, appear as red and yellow features. The quasi-linear features east of Kalgin Island are frontal (convergent) zones. This particular image was obtained from the Johns Hopkins Applied Physics Laboratory website (http://www.jhuapl.edu).

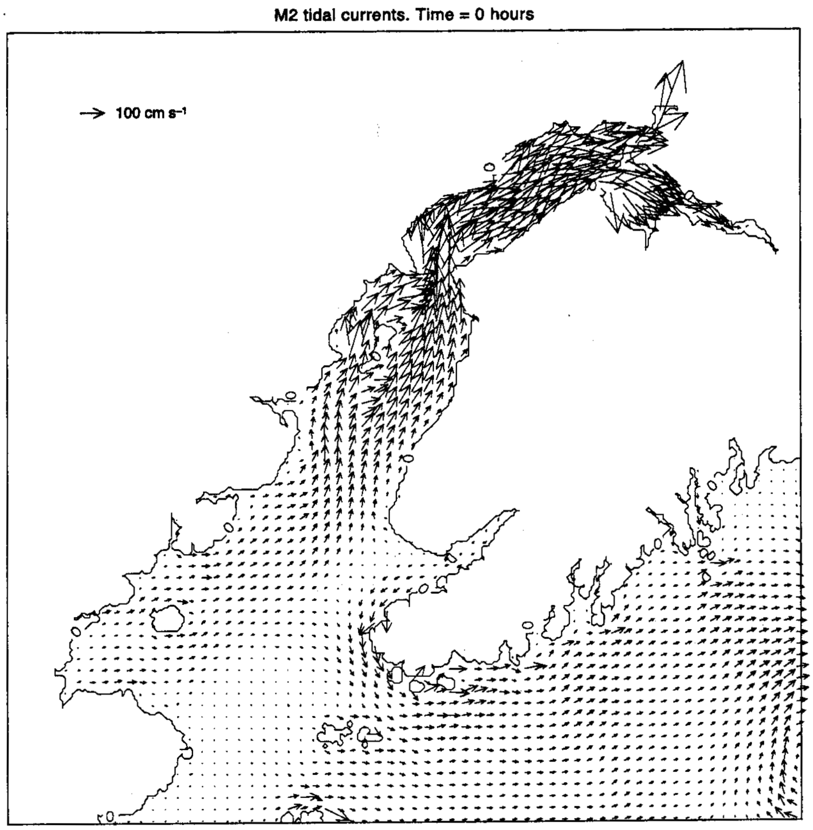


Figure 8. The temporal evolution of the M2 tidal cycle for 0 hours.

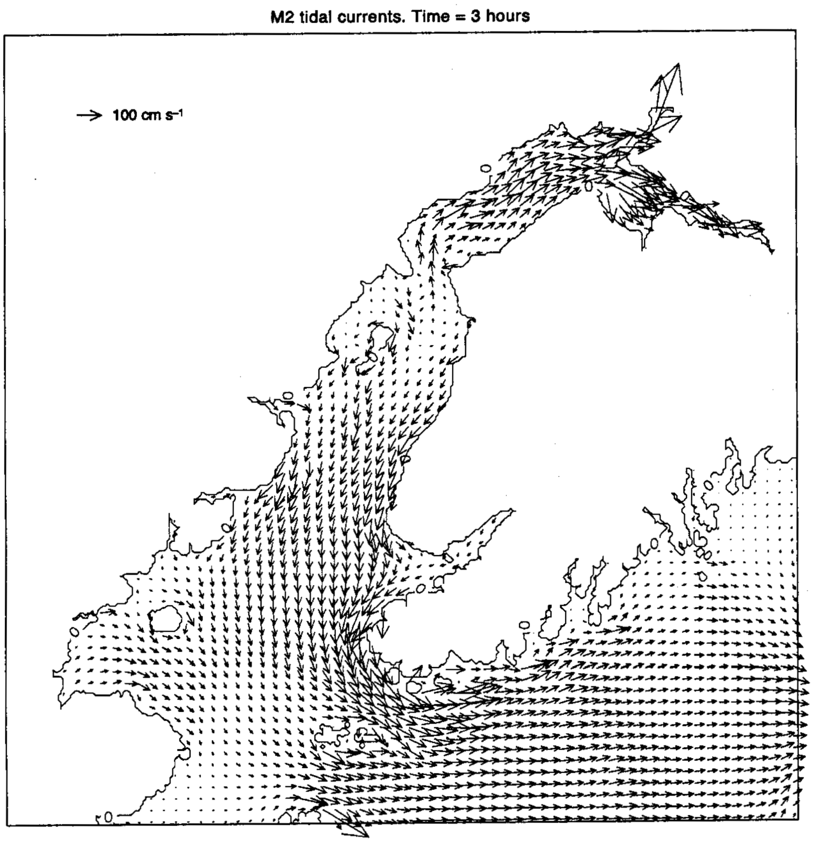


Figure 9. The temporal evolution of the M2 tidal cycle for 3 hours.

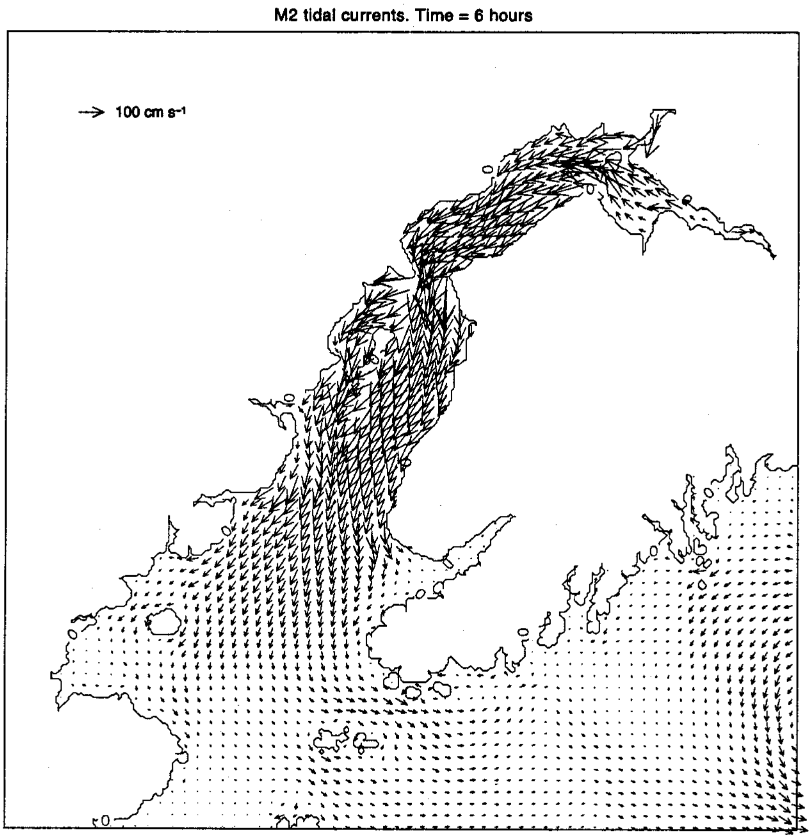


Figure 10. The temporal evolution of the M2 tidal cycle for 6 hours.

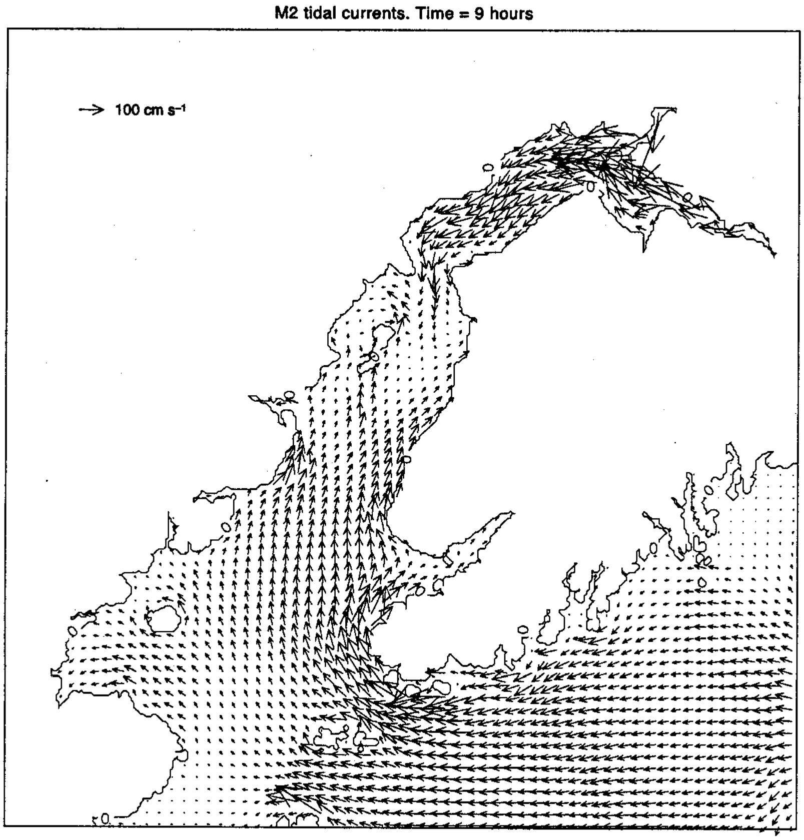


Figure 11. The temporal evolution of the M2 tidal cycle for 9 hours.

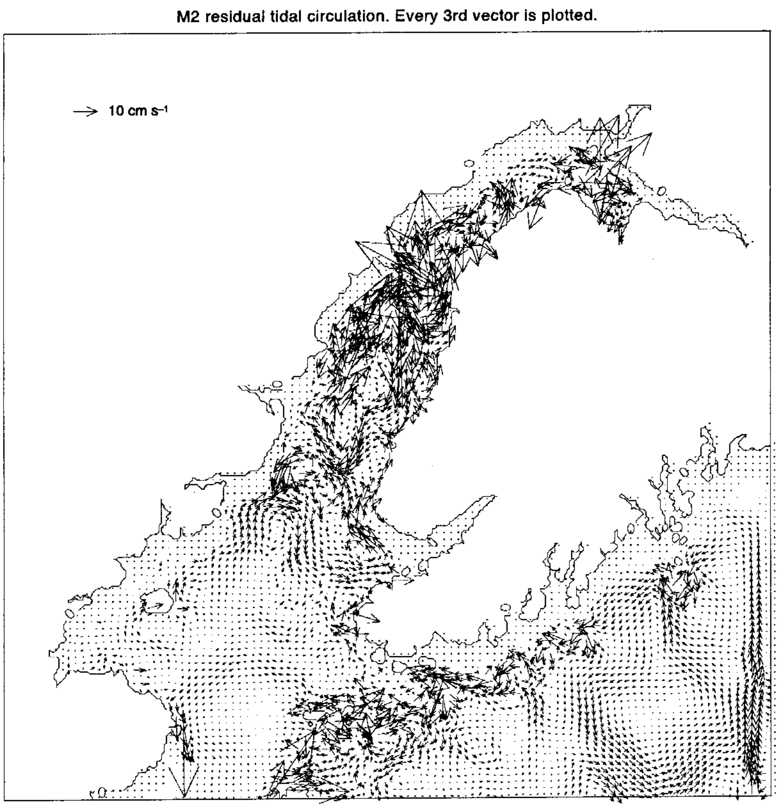


Figure 12. Residual circulation from the M2 tide. The residual is the net circulation over multiple tidal cycles and shows generally southern flow.

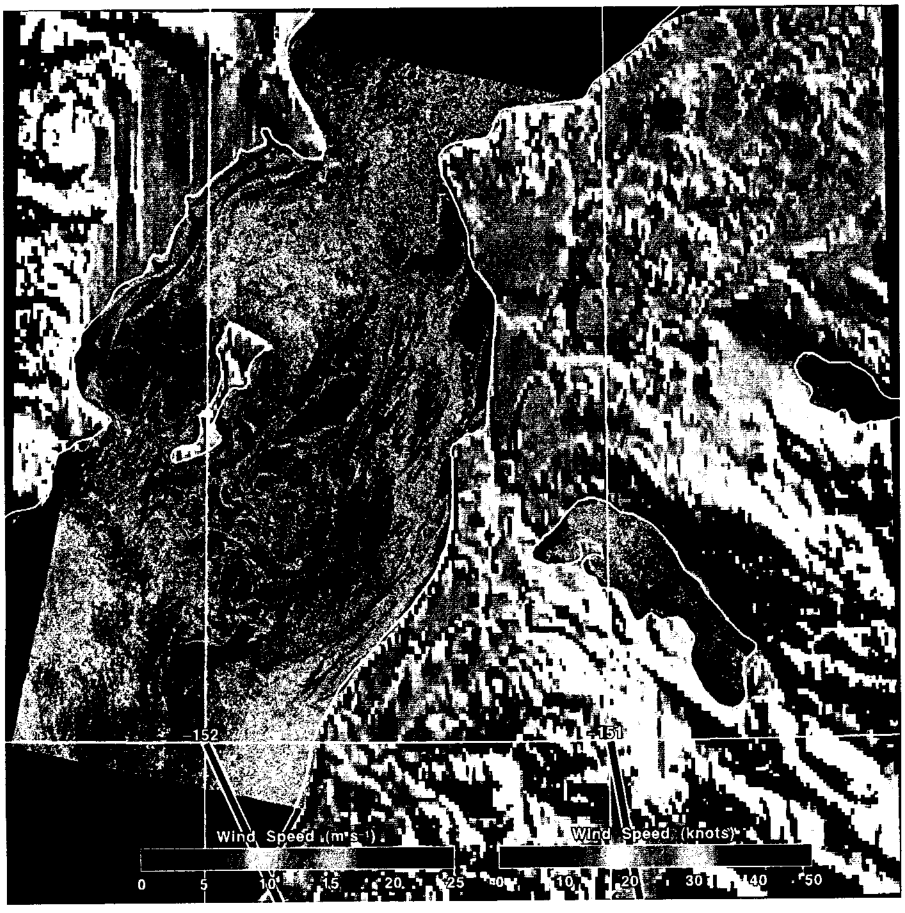


Figure 13. Wind speed over Cook Inlet from satellite data. Note the detailed structure on the eastern side of the inlet, and the high speed winds south of Kalgin Island.

Discussion

Despite the extreme tidal range in Cook Inlet, there are locations around the world with larger tidal ranges. The NOAA/CO-OPS (Center for Operational Oceanographic Products and Services) web page (http://www.co-ops.nos.noaa.gov/faq2.html) lists the fifty locations with the largest tidal ranges, and places Cook Inlet at number twelve. The first six sites listed are all in the Bay of Fundy; followed by Leaf Lake, Ungava Bay, Quebec; Port of Bristol, England; another Bay of Fundy location; then Newport, Bristol Channel, England; and then Sunrise, Turnagain Arm, in Cook Inlet. If one counts all Bay of Fundy tidal locations as one, then the tidal amplitudes in Cook Inlet are number five. It is worth noting that this reflects only locations where tides are actually measured. We report on this because in this first project year, we have had several newspaper articles about this project appear with erroneous statements regarding the magnitude of tides in the Inlet. These articles indicate that Cook Inlet has the second largest tides in the world when, as mentioned above, the tides may be at best, fifth.

In this first year we deployed drifters in Cook Inlet and began analysis of the drifter motions. We are working well with a number of people and agencies to make the drifter program a success. Bathymetry for the numerical model has been obtained, and the early model results are in reasonable agreement with our observations and other results. Satellite images are being browsed and readied for further analysis. We believe that we have met our first year tasks. Our drifter, modeling, and image analysis will continue, with a stronger focus in year two on inter-comparison.

Recommendations

In 1973–1975, NOAA carried out a circulation survey of Cook Inlet. It would be important to repeat such a survey at least partially at mooring locations 25, 5, 4, 3, and 5 [see Patchen et al. 1981], and 57, 58, 59, 60. It is important to compare tidal water current constituents measured 30 years ago with the recent data to quantify changes. All collected data could be digitized and an observational digital data archive created.

We also suggest conducting a set of carefully designed observations of Cook Inlet tides during at least one month in summer 2004. These observations should include 5–7 moorings to measure currents at different levels at the southern boundary of Cook Inlet between Cape Douglas and Cape Elizabeth or between Cape Douglas and Barren Island, and Barren Island and Chugach Island.

Acknowledgements

We wish to thank Cook Inlet Spill Prevention and Response, Inc. (Doug Lentsch, Buzz Rome, Steve Russell) and the Cook Inlet Region Citizens Advisory Council (Sue Saupe) for their ongoing support of this project. We also wish to thank Carl Schoch and Scott Pegau, Kachemak Bay National Estuarine Research Reserve, for ongoing help. Special thanks for helping to recover and redeploy the buoys goes to David Coray, Silver Salmon Creek Lodge; Bob Collins, Ninilchik; Gary Jackinsky, Ninilchik; Ben O'Neal, Homer; Jim Williamson, Kenai; and Erik Lindow, Kenai. Such help is essential to the success of this project. We are interested in hearing from others in the Cook Inlet region wishing to help with this project. Our long-term results depend on this kind of support to deploy the drifters.

References

Kowalik, Z. and A.Yu. Proshutinsky. 1993. Diurnal tides in the Arctic Ocean. J. Geophys. Res. 98(C9):16449–16468.

Kowalik, Z. and A.Y. Proshutinsky. 1994. The Arctic Ocean tides, p. 137–158. *In* O.M. Johannessen, R.D. Muench and J.E. Overland [eds.], The Polar Oceans and Their Role in Shaping the Global Environment. Geophysical Monograph 85, AGU.

Le Provost, C., A.F. Bennett and D.E. Cartwright. 1995. Ocean tides for and from TOPEX/POSEIDON. Science 267:639–642.

Le Provost, C., M.L. Genco, F. Lyard, P. Vincent and P. Canceil. 1994. Tidal spectroscopy of the world ocean tides from a finite element hydrodynamic model. J. Geophys. Res. 99(C12):24777–24798.

Patchen, R.C., J.T. Bruce and M.J. Connolly. 1981. Cook Inlet Circulatory Survey: 1973–75. NOS Oceanographic Circulatory Survey Report No. 4, NOAA, U.S. Department of Commerce, June 1981. 89 p.

New Projects

Four new projects are being funded this federal fiscal year along with the ongoing projects reported above. In addition, three continuing projects have received supplementary funds. Quakenbush & Suydam [TO 85241] include the new focus with their report on p. 41. Amendment abstracts for Naidu & Kelley [TO 15181] and Okkonen & Saupe [TO 85243] are presented here with the new project abstracts.

Archiving of Shelikof Strait Sediment Samples at the University of Alaska Museum

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Task Order 15181

Abstract

In 1997–98, 288 surface sediment samples were collected from lower Cook Inlet and Shelikof Strait as part of a research project on trace elements and hydrocarbons by Arthur D. Little, and funded by the Minerals Management Service. After completion of the project MMS made the residual samples available for supplemental studies or archiving. These sediment samples are very valuable, as they were collected at considerable cost and effort and from an area where few sediment samples are available.

Sathy Naidu, Institute of Marine Science, University of Alaska Fairbanks, is in the process of transferring his sediment samples from marine regions of arctic and subarctic Alaska (collected over the last 33 years) to the Earth Sciences Collection at the University of Alaska Museum (UAM). The goal of the UAM repository is to be the primary marine and freshwater sediment archiving center for the arctic region. This transfer is to take place in spring–summer 2003, and archiving of the samples will be accommodated in the museum repository as part of an effort funded by the National Science Foundation to the museum. This brief proposal requests that the Cook Inlet–Shelikof Strait samples be transferred to Dr. Naidu who, in turn, will arrange for their archiving at UAM. For these samples, Dr. Naidu has been offered walk-in cooler space (maintained at 3.6 °C) with a duplicate refrigeration system. The latter is wired into an alarm system that alerts the university power plant and all curators if there is a power failure. Backup electrical generators are housed next door to the refrigerator. Additionally, all samples will be maintained in a contaminant-free atmosphere. The Cook Inlet–Shelikof Strait sample suite will be integrated into Dr. Naidu's sediment collection, labeled, and arranged systematically for easy retrieval. To ensure proper use of a split of a sample, a potential user will be required to go through the protocol developed by the Museum User's Committee, of which Dr. Naidu is a member. Records (location, coordinates, water depth of collection, available analytical data and their quality) on all samples will eventually be made available on an easily accessible website.

Observations of Hydrography in Central Cook Inlet, Alaska, During Diurnal and Semidiurnal Tidal Cycles

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Task Order 85243

Abstract

The goal of this project is to acquire multiple vertical profiles of temperature, salinity, and transmissivity along a transect crossing central Cook Inlet over a 25-hour period so as to document the evolution of physical oceanographic properties during diurnal and semidiurnal tidal cycles. The results from this project will improve understanding of the relationship between the principal tidal cycles and the density-driven (baroclinic) flow in Cook Inlet. Furthermore, these observations will be available for comparison with and validation of existing and proposed numerical circulation/spill trajectory models.

Foraging Ecology of Common Ravens (*Corvus corax*) on Alaska's Coastal Plain

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Task Order 85294

Abstract

*The impact of avian predators on the North Slope is assumed to be higher in areas with oil development or human habitation due to increased availability of food and nest sites associated with human-made structures. Predator management on Alaska's North Slope is an issue that arises in many contexts. For example, the U.S. Fish and Wildlife Service has attempted to reduce predator access to human food waste in the oilfields and villages through its authorities under the Clean Water Act. Also, the Steller's Eider Recovery Team has recommended killing common ravens (*Corvus corax*) in Barrow to benefit the threatened Steller's eider (*Polysticta stelleri*), and this recommendation has been implemented to a limited extent. Justification for management actions to reduce predator populations or access to anthropogenic resources generally depends on our ability to answer two questions:*

- *To what extent do human activities influence predator distribution and abundance?*
- *What is the documented impact of the predator on other species of management concern?*

*It is clear that common ravens on the North Slope are utilizing anthropogenic resources both as nesting sites and to obtain sufficient food to overwinter on the outer arctic coastal plain. The impact of raven predation on other tundra-nesting birds has not been studied, however. Data on summer diet and raven productivity are needed to assess whether increased raven numbers pose a threat to other species, particularly the threatened spectacled (*Somateria fischeri*) and Steller's eiders. The results will enable agency biologists to evaluate the merits of promoting corrective management actions through permitting processes, as well as endangered species consultations and recovery plans.*

High-Resolution Numerical Modeling of Near-Surface Weather Conditions over Alaska's Cook Inlet and Shelikof Strait

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Task Order 73070

Abstract

Along the north Gulf of Alaska coast, terrain plays an important role in determining local weather. The interaction of terrain with synoptic and mesoscale pressure gradients frequently produces ageostrophic gap and channel winds, often called low-level jets (LLJ) in places like Cook Inlet and Shelikof Strait. These winds may at times be quite strong, with gusts occasionally exceeding 50 m sec^{-1}.

This work proposes to develop an atmospheric modeling capability for the Cook Inlet/Shelikof Strait region of coastal Alaska. The aim is to develop a modeling system that is both fast and efficient enough to act as a nowcast/forecast system and versatile enough to be used for a variety of research purposes. We will use this capability to systematically study low-level jet winds and other wind and precipitation phenomena in Cook Inlet and Shelikof Strait. This work will include: 1) an evaluation of the predictability of LLJ occurrence, strength and duration, with validation of the numerical simulations wherever possible; 2) development and understanding of the underlying mechanisms that drive LLJs in this region; 3) development of a climatology of LLJ occurrence and likelihood in several wind-prone locations; 4) a study of the vertical and thermal structure of wind jets; and 5) a study of the cloud fields and precipitation associated with high wind events in the region.

We intend to use the parallel computing capability being developed at the Alaska Experimental Forecast Facility (AEFF) (at Merrill Field in Anchorage) and the Regional Atmospheric Modeling System to create this modeling capacity. This project fits well within the scope of AEFF's mission of providing Alaska's varied population and constituencies with accurate weather information and guidance.

From the scientific perspective, the ultimate goal is to better understand the phenomena of LLJs. From the modeling perspective, the goal is to develop an automated modeling system that would run daily, using current initialization data that comes to AEFF via a dedicated T1 line from the National Weather Service (NWS) in Alaska. Though the emphasis in this project is on surface winds, still the model produces three-dimensional data sets of winds, pressure and temperature throughout the troposphere and lower stratosphere as a matter of course. Since this would be a real-time effort, graphics derived from model output will be made available on the web, providing public access to high-resolution forecasts. This should be of particular interest to mariners and aviators operating in the Cook Inlet region, and, of course, to NWS weather forecasters as well. The output of the daily summations will also be of use to CMI-supported ocean modeling efforts by providing very high-resolution upper boundary condition wind, temperature and precipitation fields. The gridded model output may also prove useful to other researchers in the region as well.

CODAR in Alaska

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Task Order 74261

Abstract

In this proposal we are requesting funds to operate a high frequency (HF) radar system for measuring surface currents in Cook Inlet, analyze the data, and present the results of the analysis at the MMS-sponsored meeting for HF radar in Alaska in May of 2003. Under separate funding, we are now testing in Cook Inlet, for a limited time in winter–spring 2002–03, two SeaSonde networks built by CODAR Ocean Sensors. These networks will be moved to other locations as specified by the funding of these projects. Based on this work we will be able to demonstrate the utility of such a system for measuring surface currents in Cook Inlet and provide a pathway for migration of this system to regions of interest in the Beaufort Sea.

Trace Metals and Hydrocarbons in Sediments of Beaufort Lagoon, Northeast Arctic Alaska

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Task Order 74464

Abstract

The nearshore region adjacent to Beaufort Lagoon, located on the eastern end of the North Slope coast of Arctic Alaska, is included in an upcoming oil and gas lease sale. There is a concern that anthropogenic contaminants discharged in the region during petroleum exploration and production will accumulate in the lagoon sediments. Beaufort Lagoon consists of three contrasting environments. Two of the sites —Angun Point in the northwest and Nuvagapak Point near a landing strip—have been subjected locally to long-term natural oil seepage and anthropogenic activities relating to an abandoned DEW (Distant Early Warning) Line site, and an active landing strip (including exposure to refined petroleum products), respectively. The remainder of the lagoon presumedly is pristine. It is anticipated that the chemistries of the sediments from these diverse environments will be significantly different and will also be in contrast to sediments that are generally known to have been exposed to more recent (fresh) petroleum spills. Therefore, characterizing the sediment chemistries of the above three environments will have a potential to establish criteria to detect metal and hydrocarbon contamination and distinguish their sources in Beaufort Lagoon. In this context, we propose to analyze sediment samples from the above three environments for concentrations of 13 selected metals (As, Ba, Cd, Cu, Cr, Fe, Hg, Pb, Mn, Ni, Sn, V and Zn) and hydrocarbons (saturated compounds such as normal and isoprenoid alkanes, triterpenoids and steranes, and polycyclic aromatic hydrocarbons). This information will be critical for ecological risk management of the North Slope nearshore in the context of contaminant inputs and sources, and will also provide basic data for our long-term goal of understanding the inorganic and organic geochemistries of Arctic marine sediments.

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	Matching Funds
Fiscal Year 94			
1 Ph.D. student		22,558	9,220
6 M.S. students		65,107	37,411
1 undergrad		4,270	0
	Source Total	$ 91,935	$ 46,631
Fiscal Year 95			
4 Ph.D. students		53,061	9,523
8 M.S. students		90,367	64,380
5 undergrads		4,297	13,933
	Source Total	$147,725	$ 87,836
Fiscal Year 96			
5 Ph.D. students		75,499	8,499
5 M.S. students		80,245	18,661
2 undergrads		4,644	0
	Source Total	$160,388	$ 27,160
Fiscal Year 97			
2 Ph.D. students		37,714	0
2 M.S. students		22,798	0
2 undergrads		2,610	0
	Source Total	$ 63,122	$ 0
Fiscal Year 98			
2 Ph.D. students		17,109	17,109
2 M.S. students		26,012	7,200
2 undergrads		0	2,548
	Source Total	$ 43,121	$ 26,857
Fiscal Year 99			
6 Ph.D. students		66,750	38,073
4 M.S. students		31,650	8,730
4 undergrads		0	10,704
	Source Total	$ 98,400	$ 57,507
Fiscal Year 00			
6 Ph.D. students		61,383	30,551
2 M.S. students		5,868	10,135
7 undergrads		0	21,299
	Source Total	$ 67,251	$ 61,985
Fiscal Year 01			
2 Ph.D. students		19,159	22,019
1 M.S. student		0	5,800
3 undergrads		10,983	5,761
	Source Total	$ 30,142	$ 33,580
Fiscal Year 02			
3 Ph.D. students		48,476	0
5 M.S. students		66,676	7,500
	Source Total	$115,152	$ 7,500
Fiscal Year 03			
2 Ph.D. students		45,032	0
5 M.S. students		79,448	7,500
1 undergrad		1,349	0
	Source Total	$125,829	$ 7,500
	Total to Date	**$943,065**	**$356,556**

Total CMI Funding

The total MMS funding committed to CMI projects through federal fiscal year 2003 is approximately $10 million. Since all CMI-funded projects require a one-to-one match with non-federal monies, total CMI project commitments through fiscal year 2003 have totaled approximately $20 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

BP Amoco

BP Exploration Alaska Inc.

Canadian Wildlife Service

CODAR Ocean Sensors

Cominco Alaska, Inc.

ConocoPhillips Alaska, Inc.

Cook Inlet Regional Citizens Advisory Council

Cook Inlet Spill Prevention & Response, Inc.

Department of Fisheries and Oceans Canada

Frontier Geosciences, Inc.

Japanese Marine Science and Technology Center (JAMSTEC)

Kodiak Island Borough

North Slope Borough

Oil Spill Recovery Institute

Phillips Alaska, Inc.

Prince William Sound Aquaculture Corporation

University of Alaska Anchorage

University of Alaska Fairbanks
- College of Science, Engineering and Mathematics
- Frontier Research System for Global Change, IARC
- Institute of Arctic Biology
- Institute of Marine Science
- International Arctic Research Center (IARC)
- School of Agriculture and Land Resources Management
- School of Fisheries and Ocean Sciences
- School of Management
- School of Mineral Engineering
- University of Alaska Museum
- Wadati Fund
- Water Research Center

University of Alaska Natural Resources Fund

University of Alaska Southeast

University of California, Los Angeles

University of Northern Iowa

University of Texas

Woods Hole Oceanographic Institution

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 or joint projects have been funded by the National Science Foundation, the Office of Naval Research, the National Aeronautics and Space Administration, the U.S. Geological Survey, 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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ALEXANDER, V. (Director). 1995. University of Alaska Coastal Marine Institute **Annual Report No. 1.** University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 16 p.

ALEXANDER, V. (Director). 1996. University of Alaska Coastal Marine Institute **Annual Report No. 2.** OCS Study MMS 95-0057, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 122 p.

ALEXANDER, V. (Director). 1997. University of Alaska Coastal Marine Institute **Annual Report No. 3.** OCS Study MMS 97-0001, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 191 p.

ALEXANDER, V. (Director). 1998. University of Alaska Coastal Marine Institute **Annual Report No. 4.** OCS Study MMS 98-0005, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 81 p.

ALEXANDER, V. (Director). 1998. University of Alaska Coastal Marine Institute **Annual Report No. 5.** OCS Study MMS 98-0062, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 72 p.

ALEXANDER, V. (Director). 2000. University of Alaska Coastal Marine Institute **Annual Report No. 6.** OCS Study MMS 2000-046, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 86 p.

ALEXANDER, V. (Director). 2000. University of Alaska Coastal Marine Institute **Annual Report No. 7.** OCS Study MMS 2000-070, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 92 p.

ALEXANDER, V. (Director). 2002. University of Alaska Coastal Marine Institute **Annual Report No. 8.** OCS Study MMS 2002-001, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 109 p.

ALEXANDER, V. (Director). 2003. University of Alaska Coastal Marine Institute **Annual Report No. 9.** OCS Study MMS 2003-003, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 108 p.

ALEXANDER, V. (Director). 2004. University of Alaska Coastal Marine Institute **Annual Report No. 10.** OCS Study MMS 2004-002, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 119 p.

BRADDOCK, J.F., and Z. RICHTER 1998. **Microbial Degradation of Aromatic Hydrocarbons in Marine Sediments**. Final Report. OCS Study MMS 97-0041, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 82 p.

COOK, J.A., and G.H. JARRELL. 2002. **The Alaska Frozen Tissue Collection: A Resource for Marine Biotechnology, Phase II**. Final Report. OCS Study MMS 2002-027, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 23 p.

COOK, J.A., G.H. JARRELL, A.M. RUNCK and J.R. DEMBOSKI. 1999. **The Alaska Frozen Tissue Collection and Associated Electronic Database: A Resource for Marine Biotechnology**. Final Report. OCS Study MMS 99-0008, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 23 p.

DUFFY, L.K., R.T. BOWYER, D.D. ROBY and J.B. FARO. 1998. **Intertidal Effects of Pollution: Assessment of Top Trophic Level Predators as Bioindicators**. Final Report. OCS Study MMS 97-0008, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 62 p.

HENRICHS, S.M., M. LUOMA and S. SMITH. 1997. **A Study of the Adsorption of Aromatic Hydrocarbons by Marine Sediments**. Final Report. OCS Study MMS 97-0002, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 47 p.

HERRMANN, M., S.T. LEE, C. HAMEL, K.R. CRIDDLE, H.T. GEIER, J.A. GREENBERG and C.E. LEWIS. 2001. **An Economic Assessment of the Sport Fisheries for Halibut, Chinook and Coho Salmon in Lower and Central Cook Inlet**. Final Report. OCS Study MMS 2000-061, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 135 p.

HIGHSMITH, R.C., S.M. SAUPE and A.L. BLANCHARD. 2001. **Kachemak Bay Experimental and Monitoring Studies: Recruitment, Succession, and Recovery in Seasonally Disturbed Rocky-Intertidal Habitat**. Final Report. OCS Study MMS 2001-053, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 66 p.

HOLLADAY, B.A., B.L. NORCROSS and A. BLANCHARD. 1999. **A Limited Investigation into the Relationship of Diet to the Habitat Preferences of Juvenile Flathead Sole**. Final Report. OCS Study MMS 99-0025, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 27 p.

JOHNSON, M.A., and S.R. OKKONEN [eds.]. 2000. **Proceedings Cook Inlet Oceanography Workshop**. November 1999, Kenai, AK. Final Report. OCS Study MMS 2000-043, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 118 p.

KLINE, T.C., JR., and J.J. GOERING. 1998. **North Slope Amphidromy Assessment**. Final Report. OCS Study MMS 98-0006, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 25 p.

NAIDU, A.S., J.J. GOERING, J.J. KELLEY and M.I. VENKATESAN. 2001. **Historical Changes in Trace Metals and Hydrocarbons in the Inner Shelf Sediments, Beaufort Sea: Prior and Subsequent to Petroleum-Related Industrial Developments**. Final Report. OCS Study MMS 2001-061, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 80 p.

NAIDU, A.S., J.J. KELLEY, J.J. GOERING and M.I. VENKATESAN. 2003. **Trace Metals and Hydrocarbons in Sediments of Elson Lagoon (Barrow, Northwest Arctic Alaska) as Related to the Prudhoe Bay Industrial Region.** Final Report. OCS Study MMS 2003-057, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 33 p.

NIEBAUER, H.J. 2000. **Physical–Biological Numerical Modeling on Alaskan Arctic Shelves.** Final Report. OCS Study MMS 2000-041, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 84 p.

*NORCROSS, B.L. 1996. **Recruitment of Juvenile Flatfishes in Alaska: Habitat Preference near Kodiak Island, Vol. I.** Final Report. OCS Study MMS 96-0003, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 118 p.

*NORCROSS, B.L. 1996. **Recruitment of Juvenile Flatfishes in Alaska: Habitat Preference near Kodiak Island, Vol. II.** Final Report, Appendices. OCS Study MMS 96-0003, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 118 p.

NORCROSS, B.L., B.A. HOLLADAY, A.A. ABOOKIRE and S.C. DRESSEL. 1998. **Defining Habitats for Juvenile Groundfishes in Southcentral Alaska, Vol. I.** Final Report. OCS Study MMS 97-0046, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 131 p.

NORCROSS, B.L., B.A. HOLLADAY, A.A. ABOOKIRE and S.C. DRESSEL. 1998. **Defining Habitats for Juvenile Groundfishes in Southcentral Alaska, Vol. II.** Final Report, Appendices. OCS Study MMS 97-0046, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 127 p.

OKKONEN, S.R., and S.S. HOWELL. 2003. **Measurements of Temperature, Salinity and Circulation in Cook Inlet, Alaska.** Final Report. OCS Study MMS 2003-036, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 28 p.

PROSHUTINSKY, A.Y. 2000. **Wind Field Representations and Their Effect on Shelf Circulation Models: A Case Study in the Chukchi Sea.** Final Report. OCS Study MMS 2000-011, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 136 p.

PROSHUTINSKY, A.Y., M.A. JOHNSON, T.O. PROSHUTINSKY and J.A. MASLANIK. 2003. **Beaufort and Chukchi Sea Seasonal Variability for Two Arctic Climate States.** Final Report. OCS Study MMS 2003-024, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 197 p.

SHAW, D.G., and J. TERSCHAK. 1998. **Interaction Between Marine Humic Matter and Polycyclic Aromatic Hydrocarbons in Lower Cook Inlet and Port Valdez, Alaska.** Final Report. OCS Study MMS 98-0033, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 27 p.

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

TYLER, A.V., C.O. SWANTON and B.C. MCINTOSH. 2001. **Feeding Ecology of Maturing Sockeye Salmon (*Oncorhynchus nerka*) in Nearshore Waters of the Kodiak Archipelago.** Final Report. OCS Study MMS 2001-059, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 34 p.

WANG, J. 2003. **Proceedings of a Workshop on Small-Scale Sea-Ice and Ocean Modeling (SIOM) in the Nearshore Beaufort and Chukchi Seas.** Final Report. OCS Study MMS 2003-043, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 56 p.

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

WEINGARTNER, T.J., and S.R. OKKONEN. 2001. **Beaufort Sea Nearshore Under-Ice Currents: Science, Analysis and Logistics.** Final Report. OCS Study MMS 2001-068, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 22 p.

WEINGARTNER, T.J., and T. PROSHUTINSKY. 1998. **Modeling the Circulation on the Chukchi Sea Shelf.** Final Report. OCS Study MMS 98-0017, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region, 75 p.