Coastal Marine Institute

University of Alaska

Annual Report No. 16

Calendar Year 2009

BOEMRE 2010-049

Submitted by
Michael Castellini
Director
University of Alaska Coastal Marine Institute

to

U.S. Department of the Interior
Minerals Management Service
Alaska OCS Region
Anchorage, Alaska

November 2010

Minerals Management Service
Department of the Interior

and the

School of Fisheries & Ocean Sciences

University of Alaska Fairbanks

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Contents

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 2009 Annual Report, our sixteenth annual report. We are currently working under MMS Cooperative Agreement M03PC00003.

The Minerals Management Service administers the outer continental shelf (OCS) natural gas, oil, and marine minerals program overseeing 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 activites?

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. CMI is administered by the University of Alaska Fairbanks School of Fisheries and Ocean Sciences. 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:

- Scientific studies for better understanding marine, coastal, or human environments affected or potentially affected by offshore oil & gas or other mineral exploration and extraction on the outer continental shelf;

- Modeling studies of environmental, social, economic, or cultural processes related to OCS oil & gas activities in order to improve scientific predictive capabilities;

- Experimental studies for better understanding of environmental processes or the causes and effects of OCS activities;

- 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 & gas and marine minerals resources; and

- Synthesis studies of scientific environmental or socioeconomic information relevant to the OCS oil & gas program. Projects funded through CMI are directed toward providing information which can be used by MMS and the state for management decisions specifically relevant to MMS mission responsibilites.

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.

The proposal process is initiated each summer with a request for proposals to addressing one or more of the Framework Issues. This request is publicized and sent to researchers at the University of Alaska, to various state agencies, and to relevant profit and non-profit corporations. The proposals are reviewed both externally and by MMS internally. The CMI technical steering committee then decides which proposals should be recommended to MMS for 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 at UAF. 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.

On-Going Studies:

Idealized Process Model Studies of Circulation in the Landfast Ice Zone of the Alaskan Beaufort Sea

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Abstract

A combination of simple analytic models and idealized process numerical models help to understand how the presence of landfast ice and the frictional coupling of the ice to the ocean control mean, subtidal currents under landfast ice. The analytic model is based on Csanady's vertically averaged transport equation model, the "arrested topographic wave" (ATW). Similar to the ATW, the arrested landfast ice topographic wave model (the ALW) is used to describe the effects of friction (in this case both bottom and a surface friction due to landfast ice) on an along-shore pressure gradient and how along-shore winds interact with landfast ice. Since the analytic model is necessarily simplified, results are intended as a first order description of the effects of landfast ice on mean shelf circulation.

In simulations where an inflow, a mound of water prescribed at the western boundary, drives circulation along a coast, process numerical models show differences from the analytical model that are primarily due to the offshore boundary condition; numerical models include a surface stress curl across the landfast ice edge whereas analytic models necessarily employ a simple boundary condition on transport at the ice edge. Numerical results show that the ice edge is an important vorticity term that causes the inflow to hug the coast much as Coriolis and bottom slope do.

For steady winds offshore of the ice edge, analytic and numerical models show good agreement. Further numerical experiments show that along-shore changes in the ice ocean drag coefficient and along-shore changes in ice coverage lead to time dependant flow (vorticity waves trapped at the coast) and along-shore pressure gradients that lead to significant flows near the coast (in the absence of along-shore variations in the winds).

Numerical experiments of river discharge beneath a landfast ice cover show that the ice cover significantly increases the distance off-shore that the surface advected buoyant plume moves compared to the equivalent ice-free case. Overall, numerical and analytic results show that flow beneath landfast ice is sensitive to along- and cross-shore changes in the frictional coupling of the ice to the ocean.

In addition to these results, three manuscripts are in various stages of preparation (two are in the final stages of editing) and we anticipate completing this project (including the final report) by the end of 2010.

Results

From the vertically averaged, steady state momentum equations under the long wave, we construct a vorticity equation that describes the effect of a sloping bottom, bottom stress, Coriolis and under ice stress on an along-shore sea level slope beneath an immobile landfast ice cover

$$\frac{\partial \eta}{\partial x} = \frac{1}{fs}\frac{\partial}{\partial y}\left(\left(r_{ice}+r_b\right)\frac{\partial \eta}{\partial y}\right) = \underbrace{\frac{\left(r_{ice}+r_b\right)}{fs}\frac{\partial^2 \eta}{\partial y^2}}_{\text{Term 1}} + \underbrace{\frac{1}{fs}\frac{\partial\left(r_{ice}+r_b\right)}{\partial y}\frac{\partial \eta}{\partial y}}_{\text{Term 2}} \tag{0.1}$$

The left side of equation (0.1) is the along-shore sea level slope. It varies in part due to vortex stretching associated with the product of the Coriolis parameter (f) and bottom slope (s). The terms r_{ice} and r_b are the linear ice ocean drag coefficient and bottom drag coefficient, respectively. Expanding the partial derivative in the middle of Equation (0.1) leads to the two terms on the far right. The first term, term 1, is the ATW-like term with the diffusion coefficient (Csanady 1978), which may vary in both x and y, being the sum of the under ice and bottom drag coefficients divided by fs. As in the ATW, diffusion is proportional to the cross-shore divergence of the along-shore geostrophic velocity (a vortex contraction term). In our analysis we will set r_b, constant but allow r_{ice} to vary with x and y. Hence underice friction can cause along- and cross-shore variation in the cross-shore divergence of the along-shore geostrophic transport. The second term, term 2, on the right hand side is the cross-shore gradient in ice friction multiplied by the along-shore geostrophic transport. It behaves like the advection term in an advective-diffusive differential equation and results in vortex contraction. The advective-like velocity is thus the gradient in ice ocean drag divided by fs. For our setting we take the gradient in the ice ocean drag coefficient, $\partial\left(r_{ice}+r_b\right)/\partial y$, to be positive since the Alaskan Beaufort landfast ice cover is generally smoother near shore and rougher due to increased ridging farther offshore (Tucker et al. 1979). In our crude model this effect is represented as smaller r_{ice} nearshore and an increase in r_{ice} moving offshore. Observational evidence suggests that this parameterization is not unrealistic although there are other considerations discussed later that may be important as well (Shirasawa 1986, McPhee 1990). The ALW vorticity balance requires that an increase in diffusion or advection be balanced by an increase in along-shore sea level slope. The analytical solution to equation (0.1) for an inflow through the western boundary is shown in Figure 1 for various parameters associated with the ice. The coast is along the bottom boundary and depth increases linearly (s=0.75 m/km) with distance offshore.

Figure **2** shows the equivalent numerical solution for comparison to panel A of Figure 1. The figure shows that the ice edge stress curl included in the numerical results causes the flow to hug the shore (at large distances from the western boundary) more than the analytic solution predicts.

For winds offshore of the northern, seaward, ice edge equation (0.1) can be solved by specifying the sea level at the ice edge as the boundary condition at the ice edge. Such a solution is shown in Figure 3. Figure 4 is the equivalent numerical solution where a 7 m/s wind is blown offshore of the ice edge from east to west. The analytic and numerical solutions are very similar indicating that the simple vorticity equation captures the essential physics. With no along-shore variations in the ice ocean drag or wind, the cross-shore sea level slope is the same everywhere (and hence there are no along-shore changes in velocity). When along-shore changes in the ice ocean drag coefficient are introduced it is no longer possible to solve equation (0.1) analytically but numerical simulations are possible. The solution for a sinusoidally varying ice ocean drag coefficient is shown in Figure 5 for the same forcing as shown in Figure 4. The figure shows that along-shore variations in the ice ocean drag lead to significant along-shore sea level slopes and hence to along-shore flow. Figure 6 shows that along-shore changes in ice coverage lead to significant along-shore currents beneath landfast ice as well. In addition to the mean response shown in Figure 6, there is time dependant response as well that takes the form of topographically trapped waves that travel from east to west (shown in Figure 7).

Experiments that include river discharge are shown in Figure 8 and Figure 9. Figure 8 includes an ice cover (covering inshore of the 20 m isobath) whereas Figure 9 does not. The river is specified as 50 km wide (East to West) and has a time varying discharge (mimicking the Alaskan North Slope rivers). The effect of the ice cover is to spread the discharge further offshore and further up the coast (in the Kelvin wave sense, further to the West) than in the ice free case.

Conclusions

Idealized analytical and numerical experiments clearly demonstrate the effect of a landfast ice cover on typical shelf forcing mechanisms including winds, buoyancy and along-shore pressure gradients. All of these forcing mechanisms are sensitive to the magnitude of the ice ocean drag coefficient and to along- and cross-shore variability of the ice ocean drag coefficient. We anticipate submitting a final report for this project by the end of 2010.

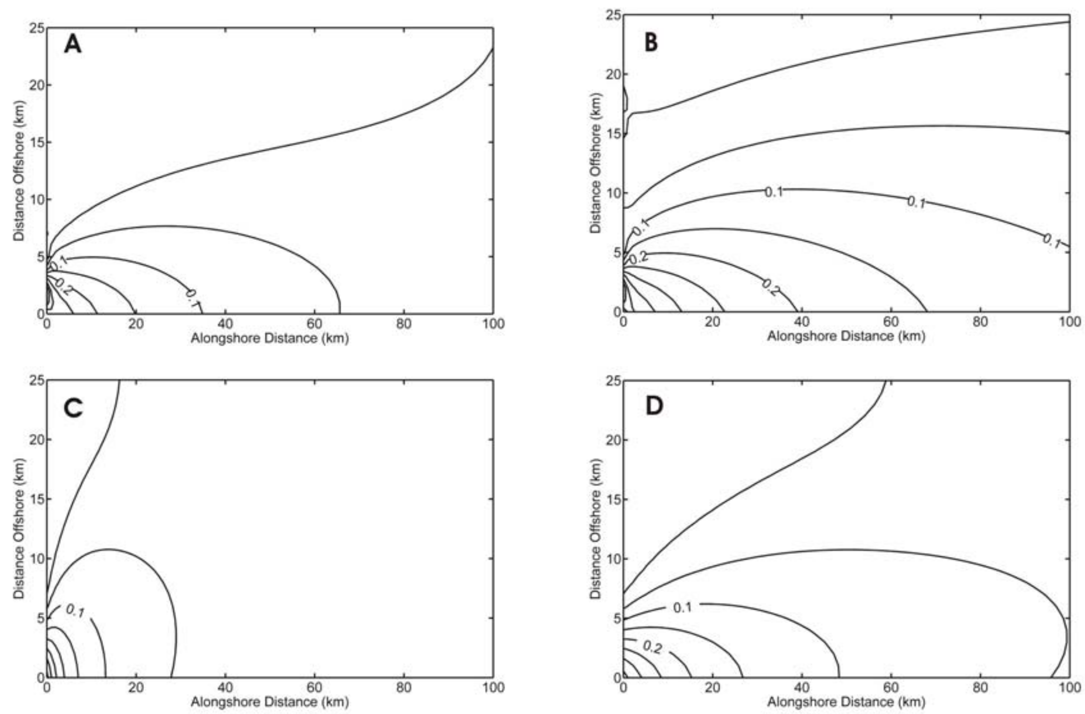

Figure 1. Contours of sea level (m) as predicted by equation (0.1). Contour interval is .5 m. Panel A: solution for a 26 km wide ice cover. Panel B: The solution for a 60 km wide ice cover. Panels C and D: The solution for several different values of the cross-shore gradient of the ice ocean drag coefficient.

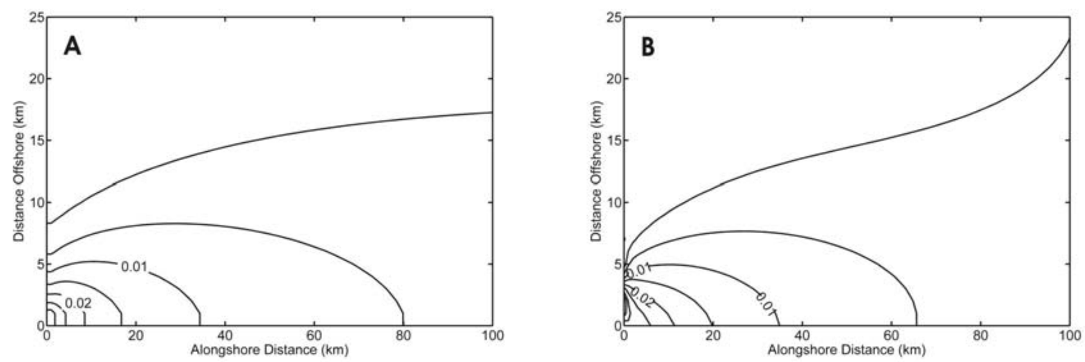

Figure 2. Panel A: Sea level contours (m) from a numerical simulation forced by an inflow at the western boundary. The ice extends from the coast to the 25 km offshore. Panel B: For comparison, the analytical solution shown in Figure 1 panel A for the same ice parameters as the numerical solution shown in panel A.

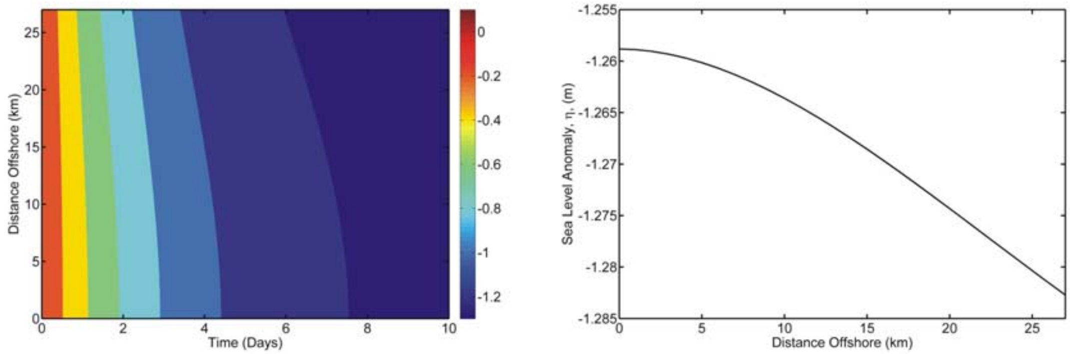

Figure 3. Left Panel: Sea level anomaly, η (m), versus time, from the analytic solution to (0.1) for sea level specified at the ice edge (26 km offshore). Right Panel: Sea level anomaly (m) between the coast and the ice edge from the analytic solution at day 10.

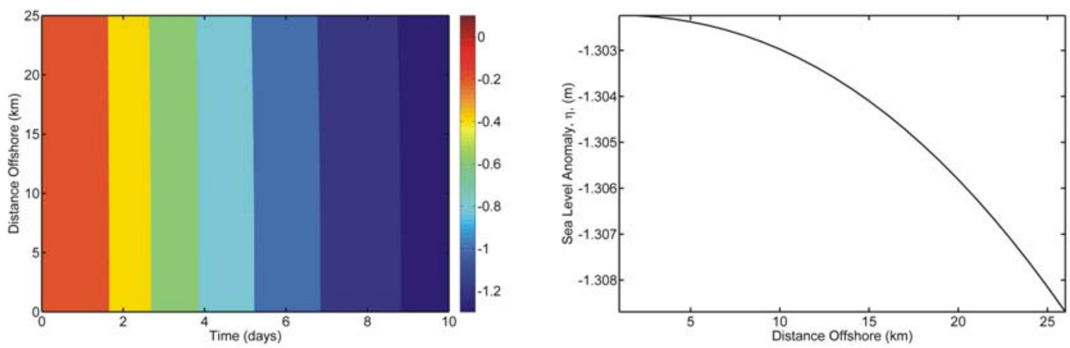

Figure 4. Left Panel: The progression of the cross-shore distribution of the sea surface anomaly, η, (m) through time beneath a landfast ice cover for comparison to the analytic prediction shown in Figure 3. Ice covers the area inshore of the 20 m isobath (25 km offshore). The ice ocean drag coefficient is the same as in the previous figure. The forcing is an upwelling windstress (-7.01 m/s) offshore of the ice edge. Right Panel: The cross-shore sea level slope beneath the ice edge after ten days. Note the difference in y-scale in the right hand panel versus the y-scale in the previous figures.

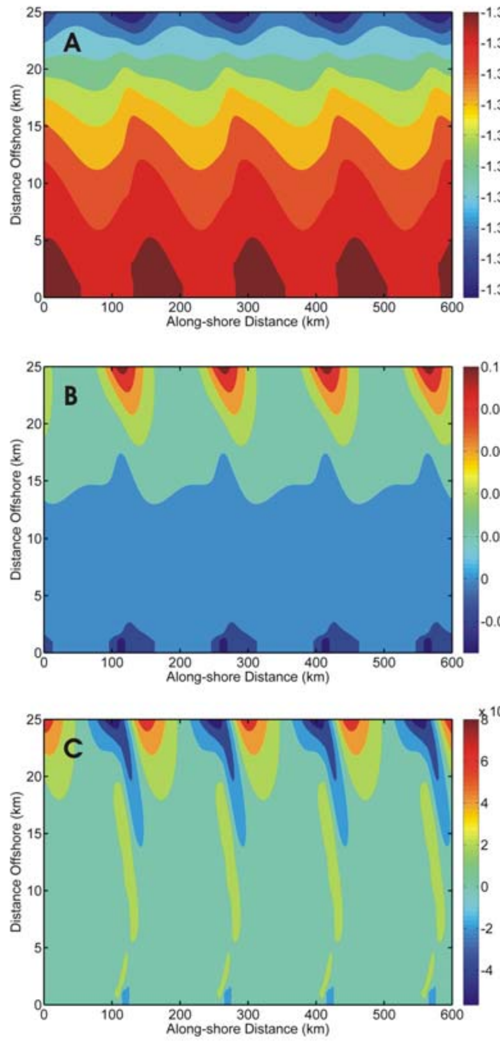

Figure 5. (A) Sea level (m) beneath a landfast ice cover with along-shore variations in the ice ocean drag coefficient, $\left(r_{ice}+r_b\right)=\left[C_0+C_1\sin\left(mx\right)\right]10^{-2}$, *$C_0=10^{-2}$*, *$C_1=10^{-2}$*, *$m=\pi/75$ km*. (B) Vertically averaged along-shore velocity (m/s). Positive velocities are directed to the east. (C) Vertically averaged cross-shore velocities (m/s). Positive velocities are directed to the north.

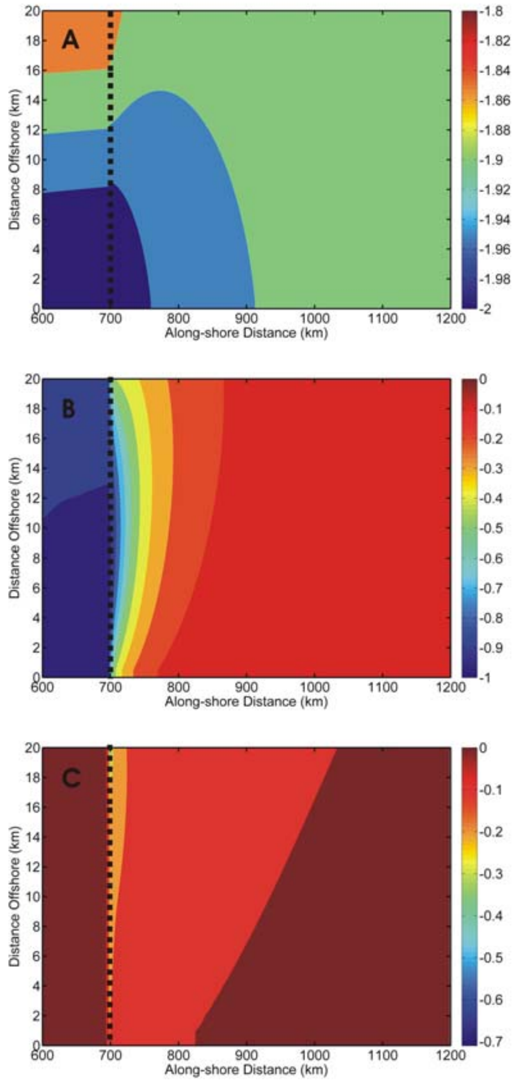

Figure 6. (A) Sea level (m). The ice edge is marked by the dashed line at 700 km. There is ice to the east of the dashed line and open water to the west and offshore of the area shown. (B) Vertically averaged along-shore velocity (m/s). (C) Vertically averaged cross-shore velocity m/s. The forcing is a -7.01 m/s wind stress everywhere there is no ice.

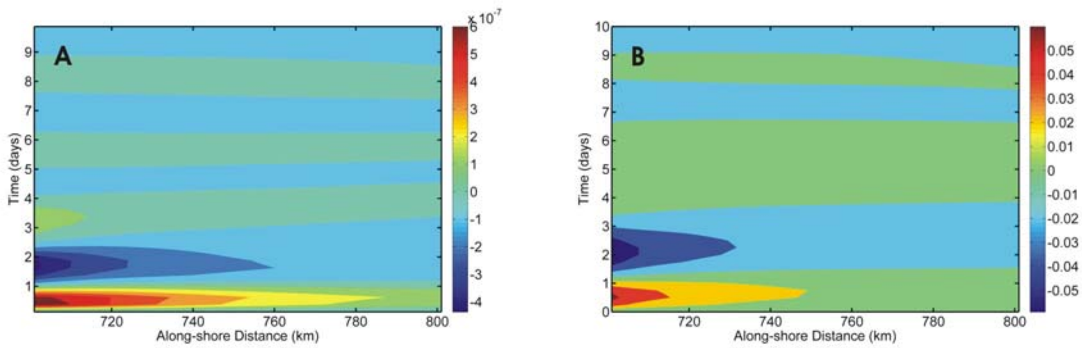

Figure 7. (A) The fluctuating along-shore pressure gradient (m s^{-2}) at the coast. Time in days is on the y axis. The x axis is along-shore distance. (B) The vertically averaged along-shore velocity (m/s) resulting from the fluctuation along-shore sea level slope associated with the propagating vorticity waves.

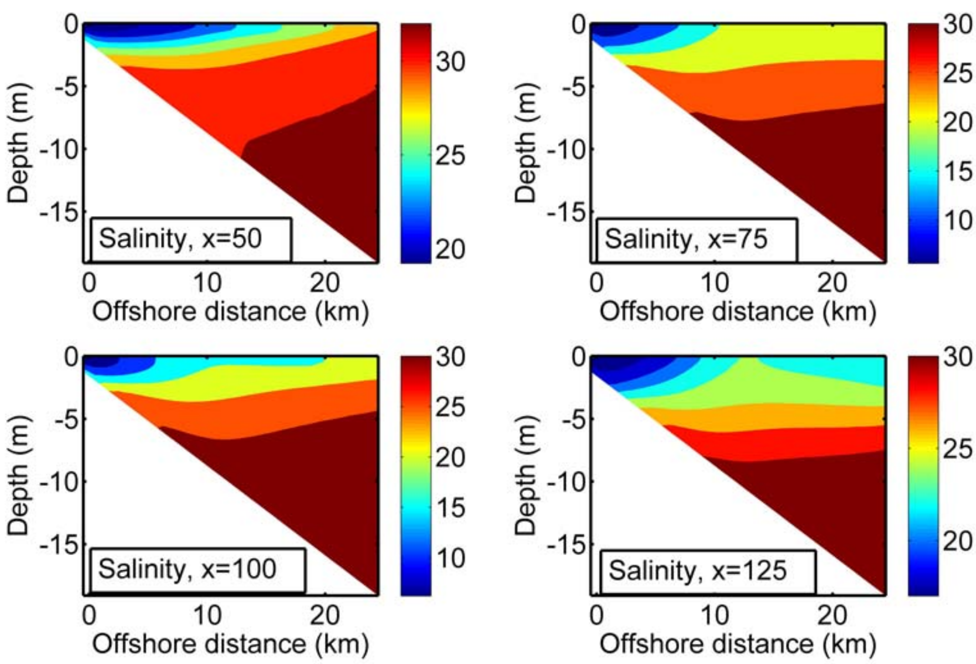

Figure 8. Salinity field resulting from a river inflow specified between an along-shore distance of x=75 and x =125 km (the width of the river is chosen to resemble the Colville River). There is no wind stress. Landfast ice, a surface stress, covers the area inshore of the 20 m isobath.

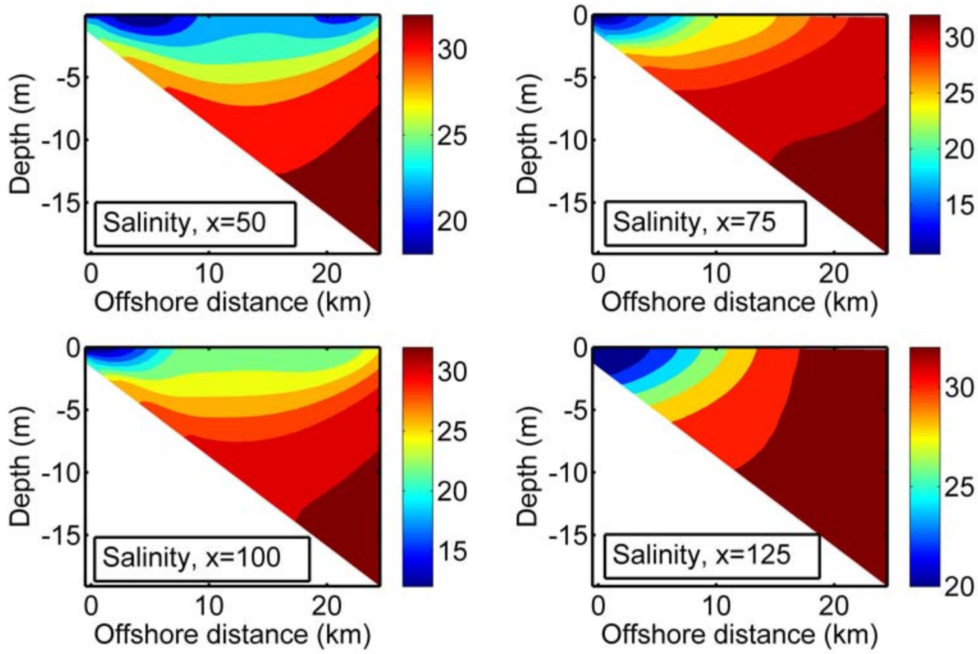

Figure 9. Salinity for comparison to Figure 8. Every thing is the same as in Figure 8 except there is no landfast ice.

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Current and Historic Distribution and Ecology of Demersal Fishes in the Chukchi Sea Planning Area

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Abstract

This project documents the distribution and abundance of demersal fishes within and adjacent to the MMS Chukchi Sea Lease Sale 193 area based on new field collections and review of both archived specimens and historical scientific catch data. We have completed examination of archived specimens collected 1959–1992. We are still developing and populating an electronic database for MMS, i.e., the Chukchi Demersal Fish Database. This database will contain data from scientific collections of demersal fishes within the lease area and ecological information associated with those catches. The purpose for developing this database is to facilitate analysis of historical vs. current fish collections. That will allow ecosystem changes to be detected and effects of changes in fish abundance and species composition to be differentiated between those caused by climate change versus oil and gas development. Developing the database has taken much more time than anticipated because many of the data were not in an easy-to-use format. Furthermore, compiling the correct data for incorporation in the database has been more difficult than expected. Unexpected problems have been encountered in all aspects of this database. These problems include, but are not limited to, difficulties locating data that we know were collected, discrepancies between contract or study reports and data that were located, discrepancies between fish collections located in museums and those reported or data located. Difficulties compiling the historic database delayed synthesis of data.

Introduction

Assessment of fish in the northeastern Chukchi Sea is particularly important in light of the lack of current knowledge and the potential for changes to the ecosystem with changing climate and anthropogenic use of the region, e.g., oil and gas exploration, fisheries, and vessel use of the area. It is important to assess the fish resources of the northeastern Chukchi Sea, i.e., before oil and gas exploration and possible commercial fishing, and prior to these factors having any effect on variability of fish populations.

Prior to this project, information on fishes in the Chukchi Sea has been limited to a few historical surveys conducted 1959–1992 (Table 1) many of which were not readily accessible in electronic format. Knowledge of both historical and current status of fish populations is necessary to identify vulnerable fish species, life stages, and essential habitat. This gap in fish and ecosystem data can be attributed to several reasons. Logistics and sampling in this remote arctic region are particularly expensive, and traditional fish surveys can only be accomplished during the ice-free summer season. The Chukchi Sea is outside the range of the NOAA Alaska Fishery Science Center regular fish trawl surveys, there has been no notable effort for commercial fishing in the eastern Chukchi Sea, and subsistence fishing is limited to large fishes for human consumption that are taken closer to shore than the Lease Sale 193 area. The North Pacific Fisheries Management Council adopted, and the Secretary of Commerce approved, an Arctic Fishery Management Plan (FMP) that prohibits new commercial fishing in US Chukchi Sea waters. The FMP closes the Arctic Management Area to commercial fishing so that unregulated fishing does not occur until information improves in order that fishing can be conducted sustainably and with due concern for other ecosystem components (NPFMC 2009; http://www.fakr.noaa.gov/npfmc/current_issues/Arctic/arctic.htm).

Currently the niche of benthic consumers in the Arctic, including the Chukchi Sea, is filled by seabirds and marine mammals (Grebmeier et al. 2006). However, with decreasing sea ice in the Chukchi Sea, demersal fishes moving northward from the eastern Bering Sea might usurp the place of birds and mammals as benthic consumers. Until recently, the northern Bering Sea has been a benthic-dominated ecosystem, i.e., very similar to that of the Chukchi Sea. With Arctic warming (ACIA 2004), the composition of marine fish and benthic communities is expected to change. Observed changes in distribution and abundance of walleye pollock *Theragra chalcogramma* and Arctic cod *Boreogadus saida*, in response to changes in sea ice cover and subsurface temperatures, provide insight as to how Arctic climate change affects marine ecosystems (Wyllie-Echeverria and Wooster 1998). The northern Bering Sea is now shifting from a shallow, ice-dominated system in which bottom-dwelling fishes prevail to one more dominated by pelagic fishes (Grebmeier et al. 2006). We can only speculate whether similar changes are occurring in the Chukchi Sea, as there is a paucity of information about fishes in this area.

The accurate characterization of fish presence and abundance in the northeastern Chukchi Sea requires a current evaluation of previous collections from the region. Fish are the least well studied component of the arctic vertebrate fauna (Mecklenburg et al. 2008), with great confusion existing over species identities, and therefore, our understanding of species diversity and distributions. The fishes of the Alaskan arctic, including the Chukchi Sea, are especially poorly known, because few ichthyological and fisheries investigations have been conducted there compared to other Arctic seas. Alaskan arctic fish species’ identifications are often different from their original designations (e.g., Mecklenburg et al 2002, Love et al 2005, Mecklenburg et al. 2006). Taxonomic problems exist with previous identifications of both common and less common species. Therefore, this led to complications with compiling databases.

Historic (1959–1992) scientific collections of demersal fishes in the northeastern Chukchi Sea needed to be located, proofed and combined with more recent (2004–2008) collections in an electronic database that we developed, i.e., the Chukchi Demersal Fish Database. This database includes demersal fish presence, and where data are available, also includes quantity and biomass of fishes and environmental data associated with the fish catches. We established a baseline of small demersal fishes from fieldwork in 2007 and 2008 that extends the RUSALCA collections made in 2004 (Norcross et al. 2009). Our synthesis of scientific information, which was delayed because of issues establishing the database, will provide a better understanding of marine fishes that could potentially be affected by offshore oil and gas exploration in the Chukchi Sea. This project provides historic and contemporary analysis of fishes in the Chukchi Sea to support oil, gas, and mineral resource management, thereby providing a basis for post-sale monitoring of fishes in the Chukchi Sea.

Relevance to CMI Framework Issues

1. Provide better understanding of fishes in the marine environment that could potentially be affected by offshore oil and gas exploration in the Chukchi Sea;

2. Establish mechanisms for sharing data and information that are in support of oil, gas, and mineral resource management;

3. Synthesize scientific information that is relevant to fish habitat and distribution in the Chukchi MMS Program Area.

Research Objectives and Hypotheses and Summary of Progress to Date

1. *Completed (2008):* Collect fishes and document species presence, abundance, distribution, geographic range, species diversity and assemblages, and habitat parameters (Framework Issue 1). Reported in 2008 annual report.

2. *Completed (2009):* Determine physical and oceanographic features (water masses) characteristics that define demersal fish habitat (Framework Issues 1 & 3). Bottom water masses were determined for cruises in 1990, 1991 and 1992 as for cruises in 2004, 2007 and 2008.

3. *Ongoing:* Determine physical characteristics that define juvenile and adult fish communities and compare among collection periods and with historic collections (Framework Issues 1 & 3).

4. *Completed (2008):* Correct the identification of historical archived fish specimens for accurate comparison with the proposed collections in the Chukchi Sea Planning Area (Framework Issues 1 & 3). Reported in 2008 annual report.

5. *Ongoing:* Synthesize historic distribution patterns of fish species in and near the Chukchi Sea Lease Sale 193 area, and compare with 2007–2008 *Oshoro-Maru* collections (Framework Issues 1 & 3). Patterns for Oshoro-Maru 1990, 1991 and 1992 and Barber et al. 1989 and 1990 do not show any patterns. We are examining new ways of analyzing these data, and will also include the recent 2004 RUSALCA and 2007 Oscar Dyson collections.

6. *Ongoing:* Incorporate both historic and current scientific fish collection data from the northeast Chukchi Sea into electronic format suitable for incorporation into the MMS database (Framework Issue 2). Acquiring, proofing, and formatting data to fit in the database structure that was agreed upon with MMS was the major focus of this project in 2009.

7. *Future:* Provide a basis for post-sale monitoring of fishes in the Chukchi Sea (Framework Issues 1 & 3). Our final product with provide a basis for post-sale monitoring.

Study Area

The primary study area of this project is the Chukchi Sea Lease Sale 193 area that is under exploration for oil and gas development (Figure 1). Data from past (1959–1992) and present (2004–2008) scientific collections of demersal fishes within Lease Sale 193 are included in our study, and we also report catches to the south, west and north of this area to give added perspective of fish distribution patterns in the northeastern Chukchi Sea that could affect, or be affected by, fishes within the Lease Sale area. Data within the Lease Sale area are as complete as archived specimens and data records allow. Data we provide from outside the Lease Sale area were collected during cruises that entered the Lease Sale area, with one exception. We provide data from the RUSALCA 2004 cruise in the Russian and US areas of the Chukchi Sea, including sites near Lease Sale 193, where we sampled with the same gear and methods as during 2007–2008.

Understanding fish distribution in the Chukchi Lease Sale 193 in northeastern Chukchi Sea requires knowledge of circulation of water upstream (i.e., northern Bering Sea), within the area of concern, and downstream (i.e., Arctic Ocean and Beaufort Sea). Chukchi Sea Lease Sale 193 area may be impacted by four distinct surface water masses (Danielson and Weingartner in Johnson 2003; Figure 2). The cooler Aleutian North Slope – Bering Slope – Anadyr Waters (ANS-BS-AW), relatively warm and salty Bering Shelf Water (BSW) and warm, dilute Alaska Coastal Water (ACW) flow northward through the Bering Strait. The ANS-BS-AW flows mainly to the west of the Lease Sale 193, and may influence the western and northern areas of Lease Sale 193. The BSW flows north and east across Lease Sale 193, while the ACW generally flows inshore of the Lease Sale 193. Influences from the north include cold, fresh Atlantic Water flowing across the northern edge of Lease Sale 193.

The ACC flows rapidly northward along the east side of the Bering Strait and is recognizable as the warm, dilute ACW along the east side of the Chukchi Sea and into the Arctic Ocean. The ACW is isolated from the rest of the Chukchi Sea by a well-defined front ~50 km from the Alaskan coast that extends northward from Bering Strait to the Lisburne Peninsula. The BSW, a mixture of Bering Sea and Gulf of Anadyr waters, also flows northward through Bering Strait and is found on the west side of this front. The front, which extends to the bottom, appears annually in the northeastern Chukchi Sea. Although the exact position can vary with winds, its mean position is based on bathymetry, i.e., where the bottom depth is equal to the mean depth of the mixed layer. Resident Chukchi Water (RCW) is derived from the upper layers of the Arctic Ocean or from shelf water left from the previous winter (Gillespie et al. 1997; Weingartner 1997). This water mass is found offshore in the northern Chukchi Sea. The RCW is separated from ACW in the northeastern Chukchi Sea by a semi-permanent front that extends to the bottom ~70–71° N (Weingartner 1997). The Siberian Coastal Current (SCC) flows southeastward from the East Siberian Sea and enters the Chukchi Sea through Long Strait, inshore of Wrangell Island (Weingartner 1997; Weingartner et al. 1999). A broad front separates the cold, dilute Siberian Coastal Water (SCW) from the warmer, saltier BSW. The SCC continues its southward flow and converges with northward flow through the Bering Strait. It is usually deflected on the Chukchi shelf, but occasionally northerly wind events force the SCC to flow south through Bering Strait. In the western Chukchi Sea, surface-advected fronts form more often than bottom-advected fronts. These hydrographic features, some of which are permanent while others are transient, are expected to have significant biological implications (Weingartner et al. 1999).

Methods

Ongoing Tasks – Objectives 2–3 & 5–7

Progress continues on the remaining project Objectives 2 and 3. Data now are available from 2007–2008 collections, i.e., fish, temperature, salinity, etc. We used CTD data to determine the characteristics of physical and oceanographic features (water masses) that define demersal fish habitat, following methods in Norcross et al. (2009), i.e., standard potential density plots and cluster analysis. Physical data such as bottom temperature, bottom salinity, depth, and substrate still need to be assessed for their importance in defining species complexes (communities), and to be compared between present (2004–2008) and past (1959–1992) timeframes (Objectives 2 & 3, Framework Issues 1 & 3).

Progress was made on Objective 3, but the objective is not yet completed. Two sets of past cruises used the same gear in more than one year, so interannual comparison can be made within those cruises (*Oshoro-Maru* cruises in 1991 and 1992, and *Ocean Hope* / Barber cruises in 1990 and 1991). Patterns of fish distribution within these time frames can be compared to our more recent data from 2004–2008 (Norcross et al. 2009, Norcross and Holladay unpublished.) However, as collecting gear differed among the three collection sets, fish presence can be compared among them but fish abundance is not directly comparable.

We continue to identify and incorporate historic and current scientific fish collection data from the northeast Chukchi Sea (Table 1) into electronic format suitable for incorporation into the Chukchi Demersal Fish Database (Objective 6, Framework Issue 2). This has involved searches for published data in peer-reviewed literature, gray literature, and the internet. Unpublished data has been sought from colleagues and institutional databases such as NOAA's RACEBASE groundfish resource database and the University of Alaska Fairbanks' IMS database. Many data were not available electronically and have been keyed into a database from paper reports and publications. An important part of the Chukchi Demersal Fish Database is the incorporation of C.W. Mecklenburg's review of archived specimens from the northeastern Chukchi Sea, which confirms or revises historical identifications and recommends the level of taxonomic precision to use in analysis. For example, identification of eelpouts and sculpins has been problematic at times, thus of our analyses over multiple data sets, such as taxonomic diversity and evenness, we will use the family or genus rather than species level of precision. Based on this review of archived specimens, this project can now provide an accurate analysis of historical distribution of fishes, including a determination of which historical records should be considered by species, and which should be considered at a less specific taxonomic level, i.e., genus or family. Format of the Chukchi Demersal Fish Database will follow the general design of an MMS funded analysis of fish abundance in the Colville River, Alaska (Prichard et al. 2007), and will also contain summary tables detailing fish abundance and biomass together with environmental data such as bottom temperature, salinity, depth, and substrate.

Because there was a delay completing the Chukchi Demersal Fish Database, we could not yet begin to synthesize historic distribution patterns of fish species in and near the Chukchi Lease Sale 193, and compare with 2007–2008 collections (Objective 5, Framework Issues 1 & 3). These analyses will provide a basis for post-sale monitoring of fishes in the Chukchi Sea (Objective 7, Framework Issues 1 & 3)

Results

To accomplish Objective 2, bottom water masses were determined for four historic and four more recent cruises where bottom temperature and salinity were available. Historic cruises included collections from the F/V *Ocean Hope* in 1990 and T/S *Oshoro-Maru* in 1990, 1991 and 1992. Recent cruises included R/V *Khromov* in 2004 (reported by Norcross et al. 2009), T/S *Oshoro-Maru* in 2007 and 2008, and R/V *Oscar Dyson* in 2007 (Figures 3, 4, 5, 6, 7, 8, and 9). Not all water masses were found in each of the six cruises. Though there appeared to be two water masses in August 2007 (OS180), the differences were not significant; whereas there were four significantly different water masses in July 2008 (OS190). Intra- and interannual differences in water masses were apparent.

Progress made on Objectives 3 and 4 consisted of comparisons of fish communities among periods with historic collections. Unfortunately fish (CPUE) community distributions from *Oshoro-Maru's* 1990, 1991 and 1992 collections and those of Barber in 1989 and 1990 do not show any explanatory patterns (Figure 10). The characteristic that best defined the distribution among the historic data was the cruise itself. Likewise fish community distributions for NOAA Ship *John Cobb* in 1959 and the *Glacier* in 1977 (Figure 11) were defined by the place and time sampling occurred. We are examining new ways of analyzing these data.

Objective 6, to incorporate both historic and current scientific fish collection data from the northeast Chukchi Sea into electronic format suitable for incorporation into the MMS database, was the major focus of this project in 2009. Acquiring, proofing and reformatting the data to fit in the database structure that was agreed upon with MMS were more labor intensive than anticipated. Unexpected problems have been encountered in all aspects of this database. These problems include, but are not limited to, difficulties locating data that we know were collected, discrepancies between contract or study reports and electronic records, and discrepancies between voucher fish specimens and reported data. A specific example of a problem is that the 1989, 1990 and 1991 Oshoro-Maru cruises do not have salinity data that can be readily incorporated in the database. Based on our (Norcross et al. 2009) and Barber's et al. (1997) research, salinity is an important environmental factor determining fish assemblages in the northeast Chukchi Sea. Temperature and salinity are associated with an Oshoro-Maru station name (e.g., OS91162), and temperature and fish data are associated with a trawl number (e.g., OST9103). The station name and trawl number are not associated. The temperature data were recorded with two different instruments and are different. It was necessary to use latitude and longitude to detect which environmental data were associated with a trawl catch, i.e., a time-consuming but important task.

Difficulties compiling the historic database delayed synthesis of data.

Discussion

We found intra- and interannual differences in water masses. This is not surprising because temperature and salinity values vary over space and time. One reason for the variability may be that even when samples were taken at the same time frame, e.g., *Oshoro-Maru* in July 1990, 1991 and 1992 (Figures 4-6), the location of the sample sites varied. Water masses change from nearshore to offshore and south to north (e.g., see Figure 3).

Fishes community analysis reveals patterns connected to time and location of collection. This is most apparent with data collected 18 years apart, i.e., 1959 and 1977 (Figure 11). Our analysis defined only one fish community within each of the two cruises. More communities were statistically defined for collections in 1989–1992 (Figure 10), but careful examination revealed the patterns to be closely linked to collection location, which was not consistent among cruises.

Due to relatively primitive knowledge of the fishes, existing publications unavoidably include significant misidentifications, omissions, and mistakes. Advances in taxonomic knowledge and methods of identification have allowed the correction of these problems through re-examination of voucher specimens. Incorporation into the Chukchi Demersal Fish Database of fish catch data from a variety of sources, and recommendation of a level of taxonomic precision for long-term analysis, will aid detection and understanding of changes in demersal fish communities.

Preliminary conclusions

There are intra-and interannual differences in water mass distributions in the northeast Chukchi Sea.

Fishes tend to cluster by time and location of sample collection.

Table 1. Scientific collections of demersal fishes in the northeastern Chukchi Sea. *Fished in midwater and bottom.

Year	Fishing dates	Headrope & net type	Mesh size of net & liner	Presence	Abundance	Vessel Cruise / Researcher	Citation
1959	6 – 30 Aug	21.6 m otter trawl	90 & 38 mm	x	x	John N. Cobb cruise 43 / D. Alverson	Alverson and Wilimovsky 1966, RACEBASE 2008
1970	25 Sep – 17 Oct	3 m beam trawl	38 mm	x	-	Glacier WEBSEC-70 / J. Quast (1 site)	Quast 1972
1973	Jul – Sep	5 m otter trawl	25 & 6 mm	x	-	Alpha Helix AH-1973 / J. Morrow	C.W. Mecklenburg, pers. comm.
1977	2 Aug – 3 Sept	5 & 6 m otter trawls	32 & 6 mm	x	x	Glacier-1977 / K. Frost	Frost et al. 1978, Frost and Lowry 1983
1989	3 – 9 Sep	6.1 m try net	5 mm	x	x	Alpha Helix HX130 / W. Barber	Barber et al. 1994
1990	26 Jul – 1 Aug	43 m otter trawl	90 mm & no liner	x	x	Oshoro-Maru OS33	Hokkaido University 1991
1990	16 Aug – 16 Sep	25.2 m; 83-112 trawl	90 & 33 mm	x	3 spp.	Ocean Hope-1990 / W. Barber	Barber et al. 1994, 1997
1991	25 – 31 Jul	43 m otter trawl	90 mm & no liner	x	x	Oshoro-Maru OS38	Hokkaido University 1992; Barber et al. 1994
	16 Aug – 16 Sep	25.2 m; 83-112 trawl	90 & 33 mm	x	3 spp.	Ocean Hope-1991 / W. Barber	Barber et al. 1994, 1997
1992	25 – 31 Jul	43 m otter trawl	90 & 45 mm	x	x	Oshoro-Maru OS44	Hokkaido University 1993; Barber et al. 1994
	2 – 27 Jul 13 – 18 Aug 28 Sep	4.9 m try net	5 mm	-	-	Responder / W. Barber	Data are referred to in Barber et al. 1994, but have not been located
2004	10 – 22 Aug	4.5 m; 3 m beam trawl	7 & 4 mm	x	x	Khromov RUSALCA-04 / B. Norcross	Norcross et al. 2009
	10 – 22 Aug	7.1 m otter trawl	37 mm & no liner	x	o	Khromov RUSALCA-04 / C. Mecklenburg	Mecklenburg et al. 2007
2007	5 – 12 Aug	4.5 m; 3 m beam trawl	7 & 4 mm	x	x	Oshoro-Maru OS180 / B. Norcross	Norcross et al., unpublished
	5 – 12 Aug	43 m otter trawl	90 & 45 mm	o	o	Oshoro-Maru OS180 / M. Yabe	unpublished
	4 – 16 Sep	4.5 m; 3 m beam trawl	7 & 4 mm	x	x	Oscar Dyson OD0710 / B. Norcross	Norcross et al., unpublished
2008	7 – 17 Jul	4.5 m; 3 m beam trawl	7 & 4 mm	x	x	Oshoro-Maru OS190 / B. Norcross	Norcross et al., unpublished
	7 – 17 Jul	43 m otter trawl	90 & 45 mm	o	MW & BT*	Oshoro-Maru OS190 / M. Yabe	unpublished

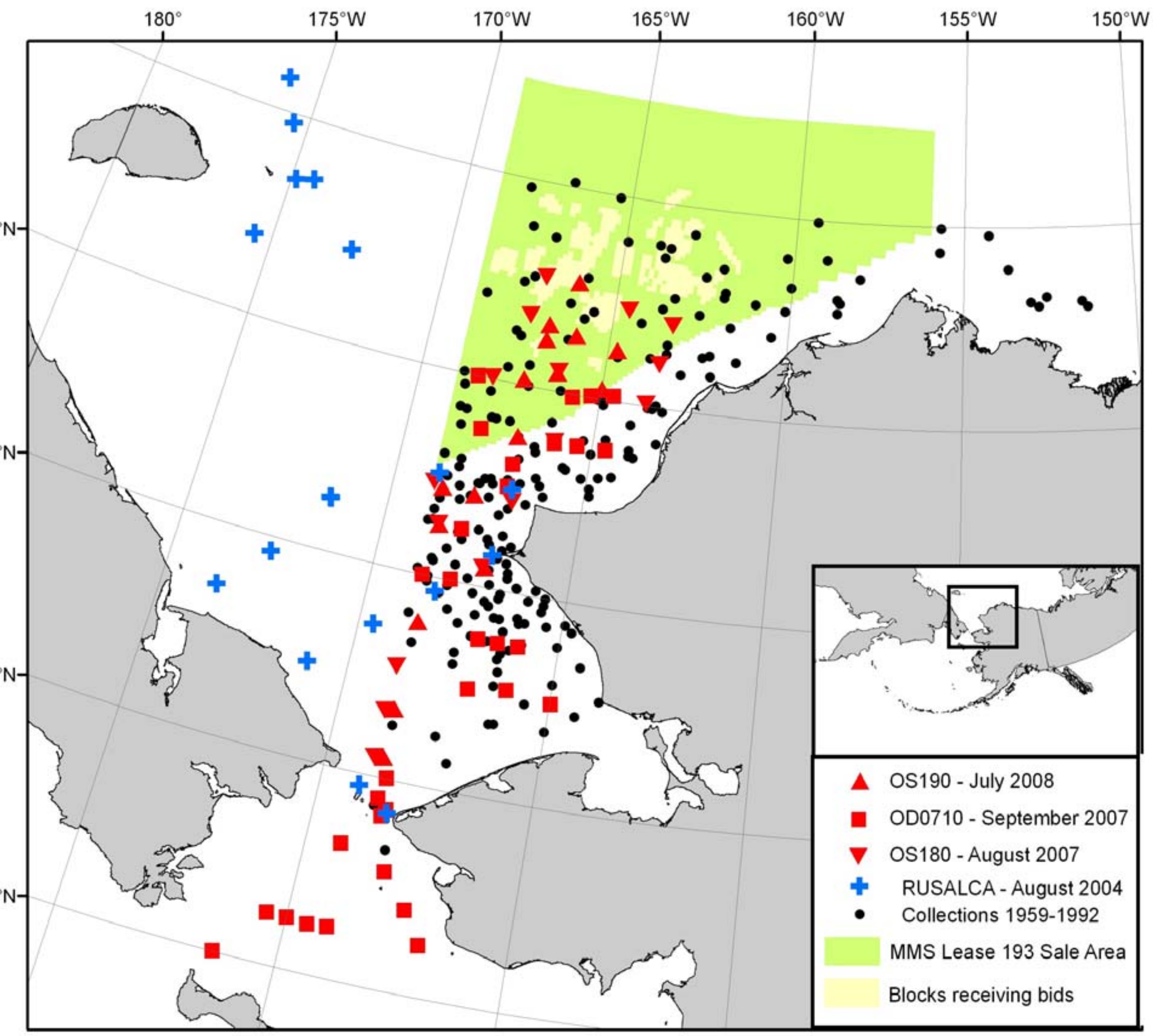

Figure 1. Chukchi Lease Sale 193. Sites with demersal fishing data for inclusion in the MMS Alaskan Fisheries Database. All scientific collections during 1959–1992 and 2007–2008 with sites in the lease area are included. RUSALCA 2004 data are included because of their proximity to the lease area.

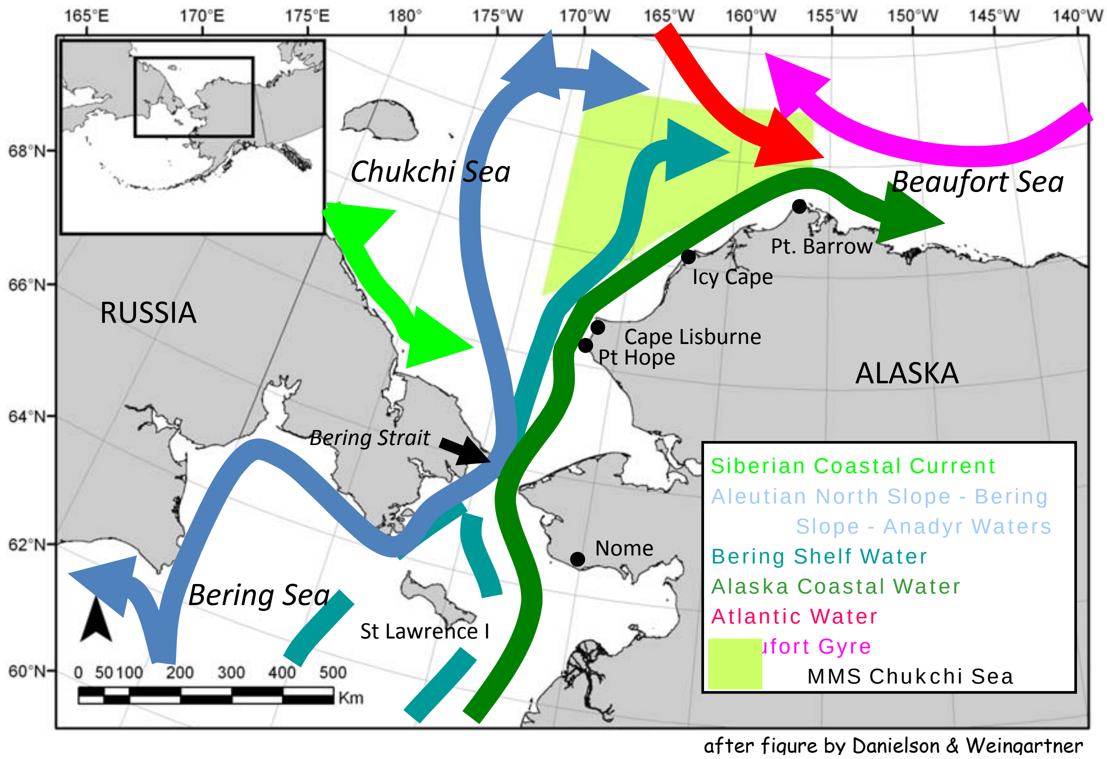

Figure 2. Directions of water transport in the Chukchi and adjacent seas (after Danielson and Weingartner in Johnson 2003).

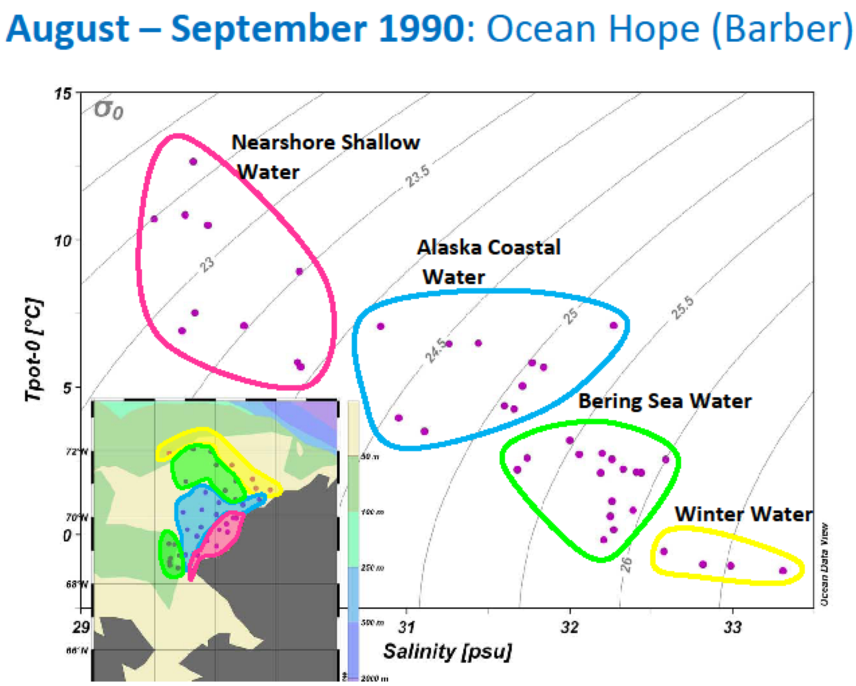

Figure 3. Standard potential density and water mass distributions plot for August-September 1990, Barber et al. cruise.

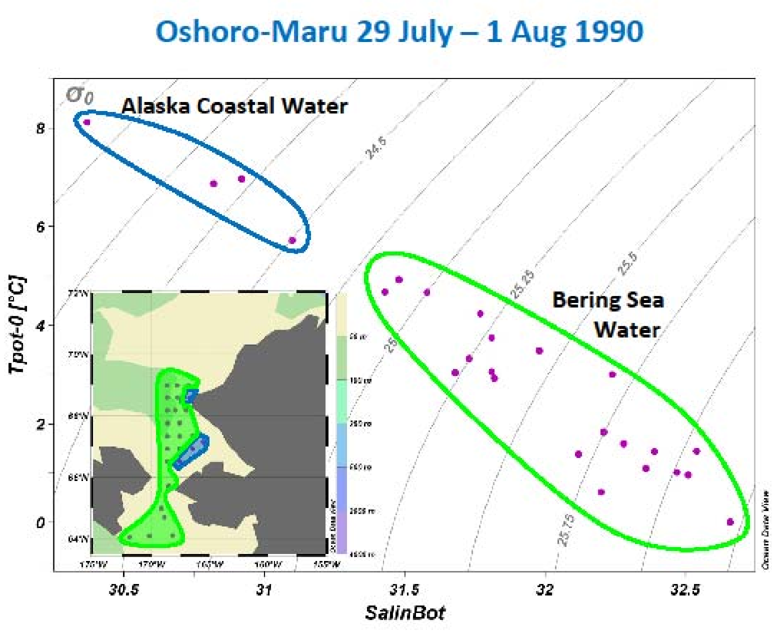

Figure 4. Standard potential density and water mass distributions plot for July-August 1990, T/S *Oshoro-Maru* cruise.

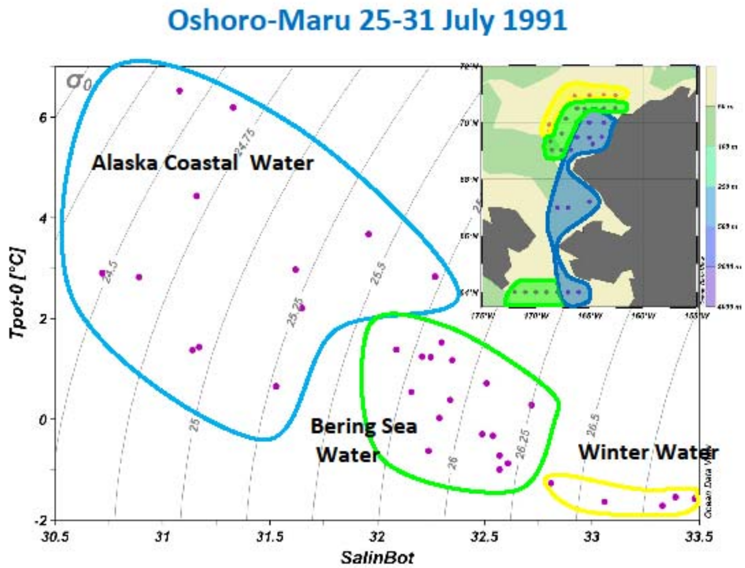

Figure 5. Standard potential density and water mass distributions plot for July 1991, T/S *Oshoro-Maru* cruise.

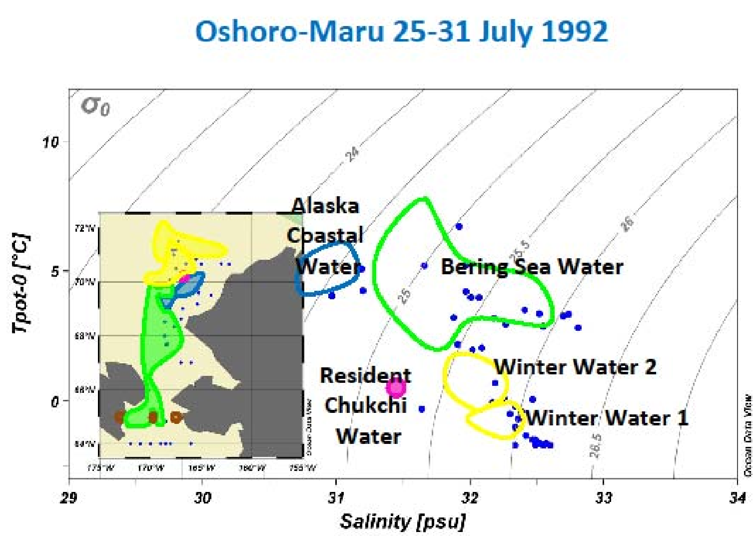

Figure 6. Standard potential density and water mass distributions plot for July 1992, T/S *Oshoro-Maru* cruise.

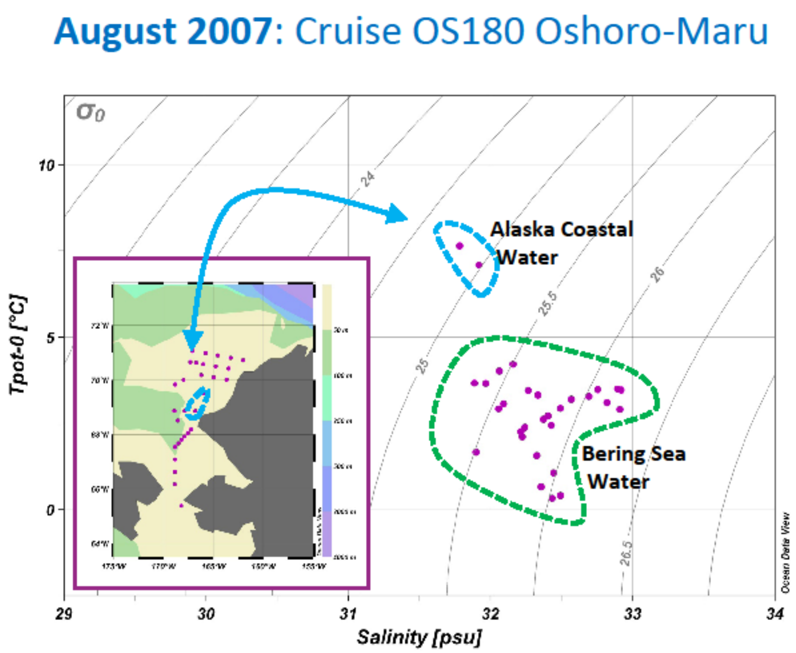

Figure 7. Standard potential density and water mass distributions plot for August 2007, T/S *Oshoro-Maru* cruise.

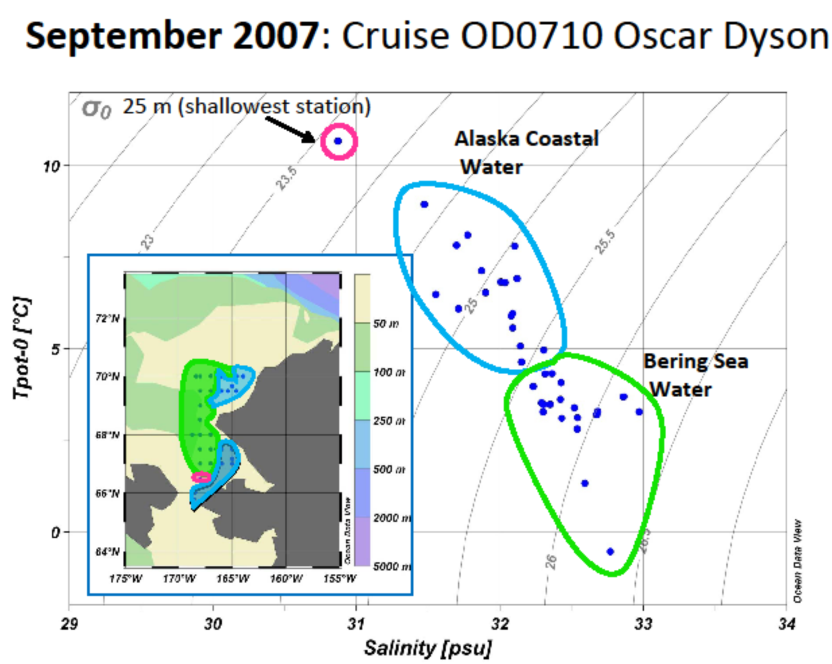

Figure 8. Standard potential density and water mass distributions plot for September 2007, R/V *Oscar Dyson* cruise.

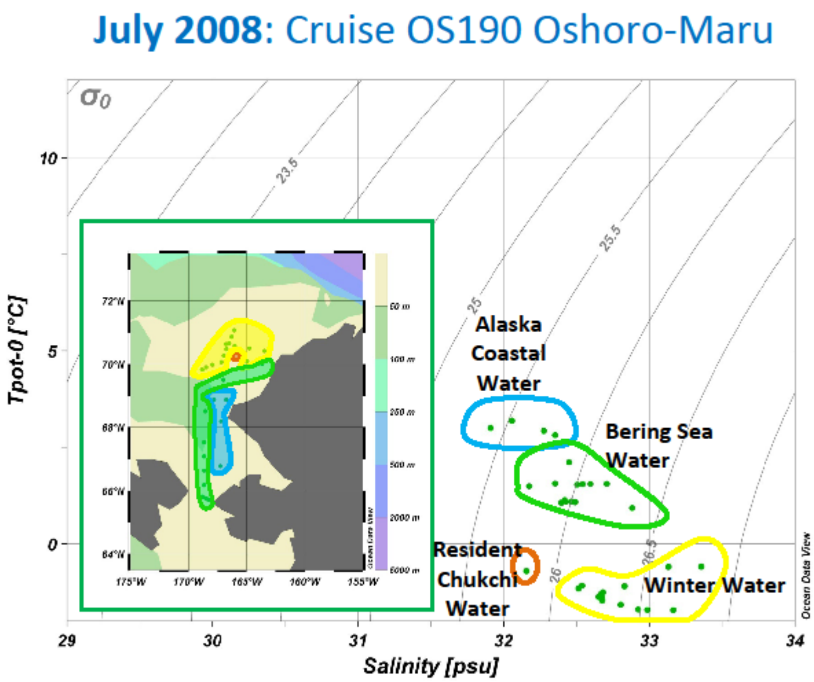

Figure 9. Standard potential density and water mass distributions plot for July 2008, T/S *Oshoro-Maru* cruise.

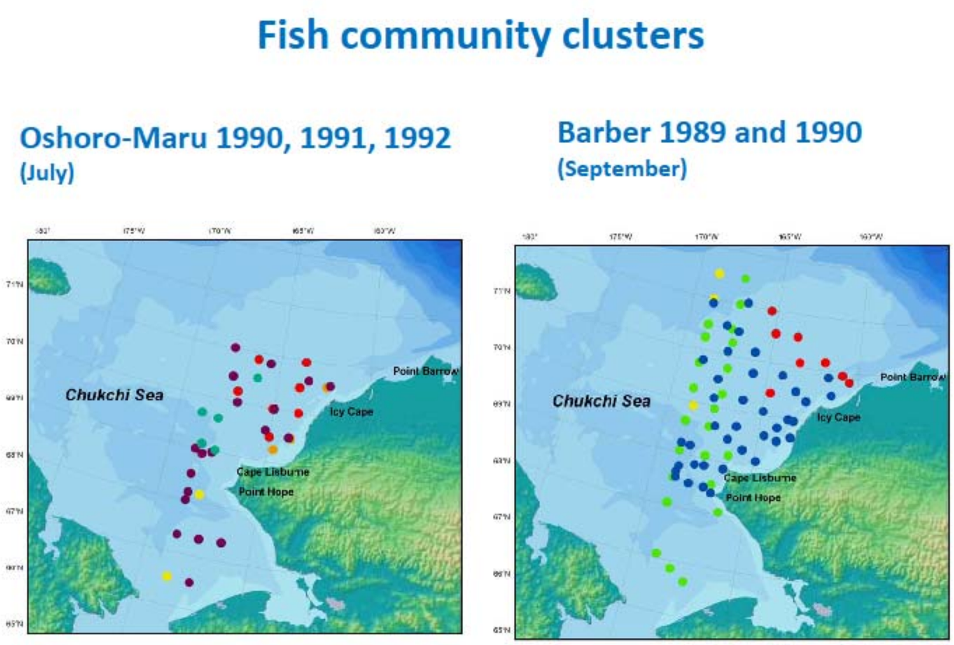

Figure 10. Fish community clusters for R/V *Oshoro-Maru* cruises 1990, 1991 and 1992 and Barber et al cruises 1989 and 1990.

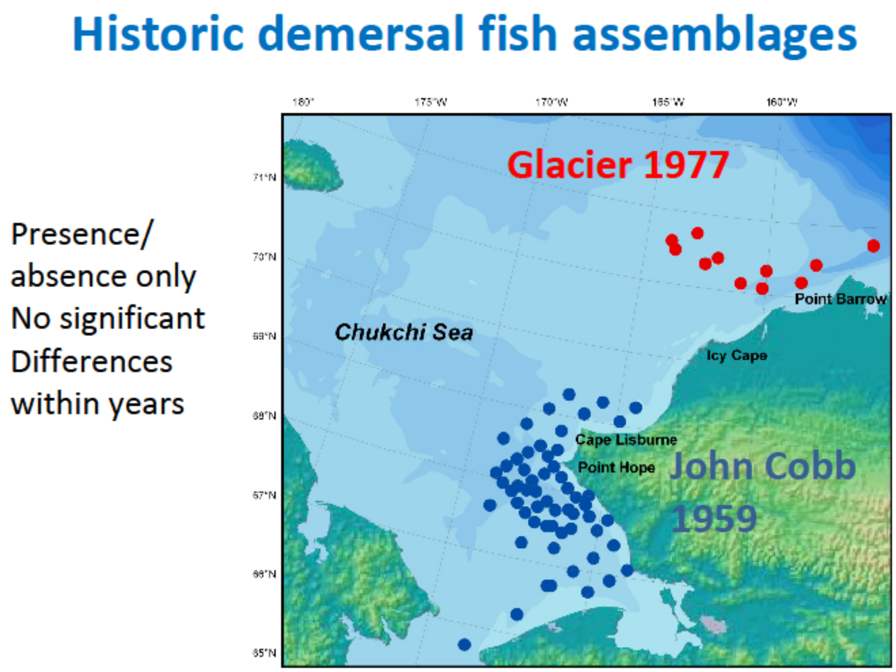

Figure 11. Fish community clusters for R/V *John Cobb* cruise 1959 and F/V *Glacier* cruise 1977.

Presentations

Norcross, B.L and B.A. Holladay. Demersal fish of the Chukchi Sea. Fisheries Department, University of Alaska Fairbanks, Juneau, AK on 23 October 2009.

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Study Products

Bluhm, B.A., K. Iken, S. Mincks Hardy, B.I. Sirenko and B.A. Holladay. 2009. Community structure of epibenthic megafauna in the Chukchi Sea. Aquatic Biology Vol. 7: 269–293. doi: 10.3354/ab00198.

Acknowledgements

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Recovery in a High Arctic Kelp Community

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Abstract

The overarching goal of this project is to acquire a better understanding of how sessile communities recover after disturbances in the Boulder Patch, a high arctic kelp community. Specifically this research will determine 1) timing of natural recruitment on to hard substrates, 2) effect of grazers to timing of recruitment, 3) effect of sedimentation to timing of recruitment, and 4) rate of vegetative re-growth of various sessile organism groups. High arctic kelp communities in Prudhoe Bay are considered sensitive habitats and have the potential of being impacted by oil and gas activities. One such kelp community located adjacent to BP leased lands is the Boulder Patch. It is known that if sessile organisms are killed or removed in the Boulder Patch, the recovery of the sessile community is very slow. What is unknown is exactly how slow recruitment is, the reasons for this slow recruitment, and how communities naturally recover from disturbances. This project is determining the timing of natural recruitment over an eight year time period by monitoring rocks that were cleared in 2002 (project will end in 2010). To determine grazer impacts, cleared rocks that were placed into cages in 2002 are being monitored. To determine sedimentation impacts on initial recruitment, sediments are being excluded from settling plates that were placed into the field in 2007. To determine the rate of vegetative re-growth, clearings that were established in 2007 are being monitored for regrowth of specific sessile organism groups. All combined, this study is improving our understanding of recovery and recruitment of high arctic rocky systems.

Introduction and 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, Debenham 2005, Konar and Iken 2005, Aumack et al. 2007, Konar 2007). 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 1986, Debenham 2005). Approximately 148 animal taxa and 10 algal species cover nearly all exposed substrate at densities approaching 18,441 individuals/m^2 with an average biomass of 283 g/m^2 (Dunton and Schonberg 2000). 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 temperate marine systems, boulder fields are very dynamic because of physical disturbance (Sousa 1979, 1980, vanTamelen 1987). When a boulder is overturned, the sessile community can be killed in whole or part by a combination of grazing, anoxia, low light levels, or mechanical damage caused by crushing or abrasion (Sousa 1980). Studies in temperate systems have shown that algal communities can recover to previous densities within one year of denuding (Foster 1975, Bertness et al. 2004, Milazzo et al. 2004). Many studies on coralline algal recruitment have shown that although their growth is remarkably slow, they will settle and grow to a visible size in a few months (Adey and Vasser 1975, Matsuda 1989, Konar and Foster 1992). In contrast to temperate systems, recruitment in high Arctic systems appears to be much slower (Dunton et al 1982). A recolonization experiment in the Boulder Patch demonstrated that recovery of denuded areas is slow with 50% of the substrate still being bare three years after an initial disturbance (Dunton et al. 1982). Another recolonization experiment in the Boulder Patch, which began in 2002, also demonstrated and reinforced the idea that this community is very slow to recover from disturbances (Konar 2007). In this latter study, less than 5% of the substrate was recolonized four years after clearing. The reason why recruitment is so slow in the Boulder Patch remains unknown.

Questions/Objectives/Hypotheses

To further our understanding of Boulder Patch recruitment and recovery dynamics the following objectives and hypotheses are being examined:

Objective 1: *Determine the timing of natural recruitment on to hard substrates.*

H1) Recruitment is slow and episodic in the Boulder Patch.

Objective 2: *Determine the effect that grazers have on the timing of recruitment.*

H2) Grazers slow the initial recruitment of sessile organisms.

Objective 3: *What effect does sedimentation have to the timing of recruitment?*

H3) Sedimentation slows initial recruitment of sessile organisms.

Objective 4: *What is the rate of vegetative re-growth of various sessile organism groups?*

H4) Community recovery via vegetative re-growth is the primary means of recovery from disturbances while recovery via recruitment events plays only a minor role.

Study Area

This study was primarily conducted at site DS-11, which is within the Boulder Patch in Stefansson Sound, Beaufort Sea (Figure 1). A satellite site also was established at L1 to examine spatial differences in vegetative re-growth at different boulder patches within the overall Boulder Patch area. The overall study area is in 6-7 m water depth and contains numerous cobbles and boulders that provide substrate for several invertebrate and macroalgal species. At the time of this study, foliose algae covered approximately 24.5±3.6 s.e. of the substrate at DS-11 and the primary herbivores encountered were the chitons *Amicula* spp. (6.4±2.1 s.e. per $0.25m^2$) and *Ischnochiton* sp (12.8± 2.09 s.e. per $0.25m^2$). Seastars and the gastropod *Margarites* sp. were also occasionally seen at the study sites.

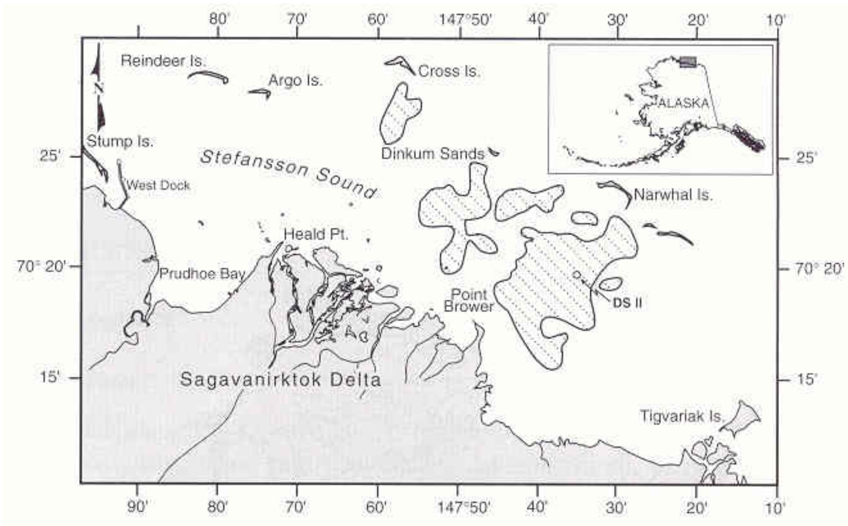

Figure 1. Chart of Boulder Patch showing Dive Site 11 (DS-11) within Stefansson Sound. Hatched polygons are areas with high boulder/cobble density. From Dunton and Schonberg 2000.

Experimental Methods

Objective 1: Determine the timing of natural recruitment on to hard substrates.

To address this objective, 18 boulders (approximately 30-40 cm in diameter and 10-20 cm tall) from DS-11 were brought to the surface and cleared of all sessile organisms. Boulders were left in the air for five days to kill any remaining seed bank and then replaced into one of three areas within DS-11. Six uncleared boulders also were marked in each of the three areas within DS-11. These cleared and uncleared boulders have been monitored yearly since August 2002.

Objective 2: Determine the effect that grazers have on the timing of recruitment

For this objective, 36 additional boulders from DS-11 were brought to the surface and cleared of all sessile organisms. These boulders also were left in air for five days to kill any remaining seed bank and then assigned to one of two treatments: 1) caged, and 2) cage controls. Cages were 45 cm on a side, 30 cm tall, with a 1 cm mesh size and constructed of stainless steel mesh coated with a non-toxic antifouling compound (copper paint) to inhibit sessile invertebrate and algal growth (Figure 2). Cage controls (cages with holes cut into them so that grazers had access to the boulders) controlled for artifacts produced by the cages themselves (Figure 3). Six replicates of each treatment were randomly placed *in situ* at one of three areas within DS-11 in August 2002 and have been monitored yearly.

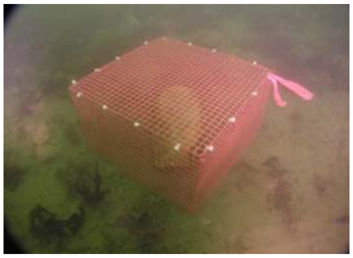

Figure 2. Caged rock *in situ*

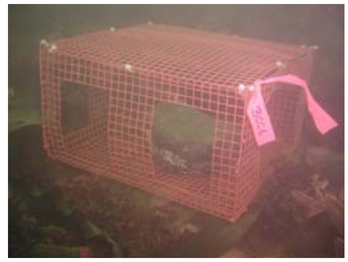

Figure 3. Cage control *in situ*

Objective 3: What effect does sedimentation have to the timing of recruitment?

For this objective, six settlement plates were placed in three areas within DS-11, totaling 18 plates. Plates were approximately 20cm on each side, 3mm thick, and were placed approximately 10cm above the substrate (Figure 4). Both sides of the plates were made rough by scrubbing with sand paper to facilitate settlement. Plates were monitored for recruitment of sessile organisms on the underside of the plates where no sediments accumulate and on the surface, where sediments do accumulate. This is a common technique used to ascertain recruitment while eliminating sedimentation effects (Irving and Connell 2002). Plates were placed *in situ* in 2007 and are being monitored yearly.

Figure 4. Settlement plate at DS-11.

Objective 4: What is the rate of vegetative re-growth of various sessile organism groups?

For this objective, various rocks had 4cm x 4cm clearings made on them at three different areas within DS-11 and L-1 (Figure 5). In each area, six boulders had clearings centered in an encrusting coralline patch and six were in a foliose red algal patch. In DS-11, there were an additional 12 clearing within an encrusting sponge patch (six each in two different morphological sponge types). Sponges were not found at L-1 so clearings could not be done there. Each organism patch extended at least 2cm beyond the cleared area to ensure enough material for re-growth. These cleared areas are being monitored for vegetative re-growth using digital photography. Re-growth of the organisms on the photographs is being compared using SigmaScan. Each year, the percentage of re-growth is being determined.

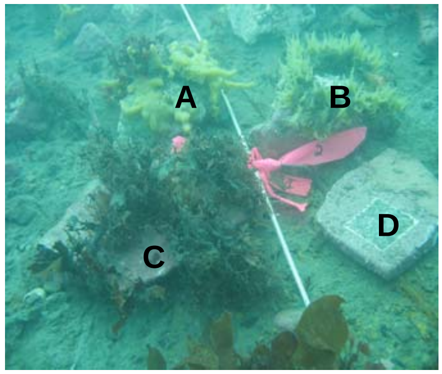

Figure 5. One set of cleared rocks at DS-11. A and B are sponge clearings. C is within a red algal clump and D is within an encrusting coralline.

Preliminary Results

Objective 1: Determine the timing of natural recruitment on to hard substrates.

Of the 18 cleared boulders that were tagged in 2002 to monitor natural variation in the system, only five were found this year. These boulders are getting harder to find each year, primarily because of ice that has scoured the study area in the last four years. Although the sample size is now relatively small, it can be seen that the epilithic community that is not disturbed by iceberg scour is fairly stable (Figure 6). Percent cover of bare rock and total invertebrates was very low, as seen in earlier years. Although increases in corallines and decreases in total foliose algae have been noted, particularly in 2008, this could be an artifact due to the very small sample size that also was surveyed in 2008 (n=6).

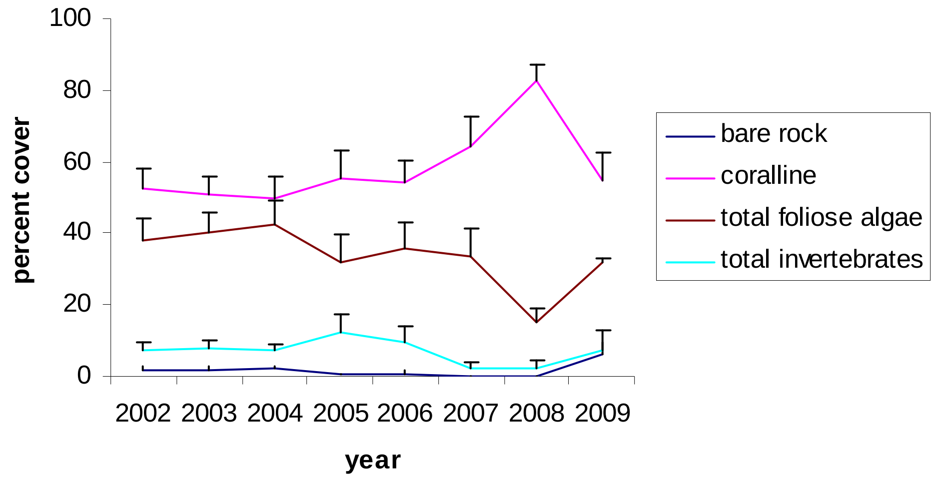

Figure 6. Mean percent cover (±1 s.e.) of bare rock, corallines, total foliose algae, and total invertebrates on uncleared control boulder from 2002 to 2009.

Boulders that were cleared and left out in the field showed little recruitment over the years. In fact, it was not until 2005 that the very first invertebrates were seen (Figure 7). It should be noted that in both 2008 and 2009, very few of these treatments were found (n=2 in 2008 and n=1 in 2009). Once again, the icebergs that went through this area have made it very difficult to determine which rocks are out treatment rocks.

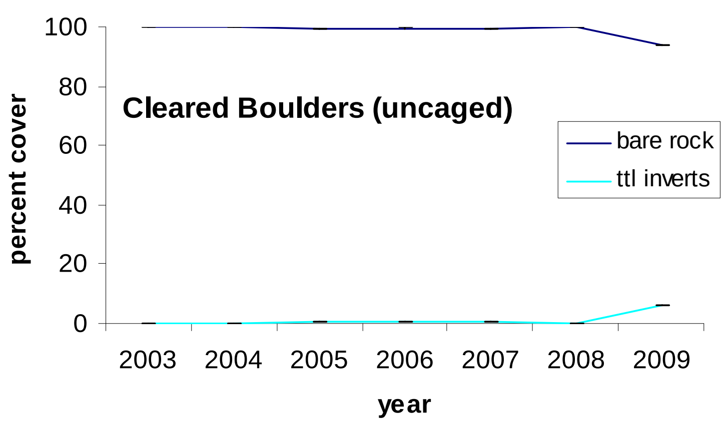

Figure 7. Mean percent cover (±1 s.e.) of bare rock and total invertebrates on uncleared control boulder from 2002 to 2009.

Objective 2: Determine the effect that grazers have on the timing of recruitment.

For this objective 18 cleared boulders were placed into cages and another 18 boulders were placed into cage controls. Unfortunately the icebergs that have gone through the study site have not been kind to these cages and cage controls. This year, we were only able to relocate 3 of each type of treatment. However, from these data, it does appear that some recruitment is finally occurring (Figure 8).

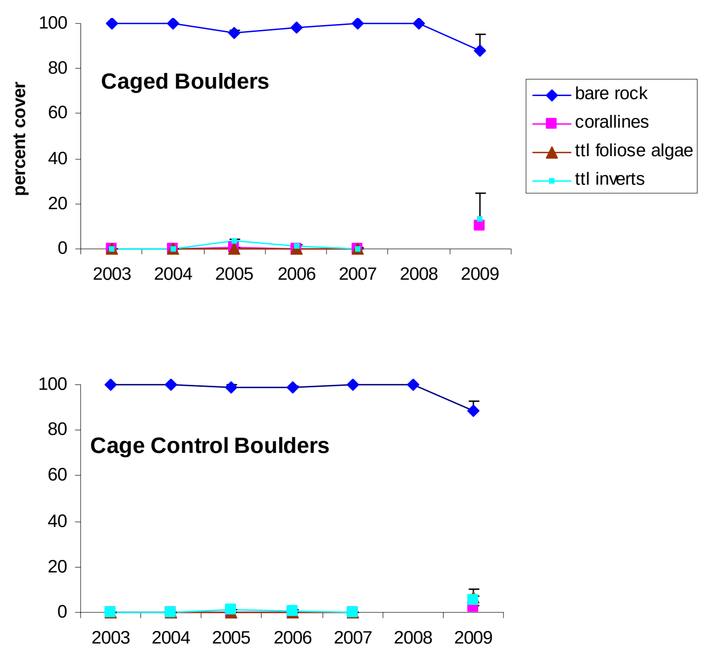

Figure 8. Mean percent cover (±1 s.e.) of bare rock, corallines, total foliose algae, and total invertebrates on cages boulders and cage controlled boulders from 2003 to 2009.

Objective 3: What effect does sedimentation have to the timing of recruitment?

Regrettably the settlement plates were not sampled in 2008 because of limited visibility and limited dive time (we only had approximately 1 dive day this in 2008). This was particularly unfortunate because in 2009 when this objective was to be a high priority, none of the plates could be found. In a similar pilot study (2004-2006), these plates lasted two years so it is unclear what went wrong this year. Some of the bolts used to fasten the plates to the bottom were found, but no plates were found.

Objective 4: What is the rate of vegetative re-growth of various sessile organism groups?

In 2008, six cleared coralline rocks and six cleared sponge rocks were relocated and photographed at DS-11. In addition to these, three cleared coralline rocks were found at L-1. Re-growth was seen on all rocks with the most re-growth occurring on the sponge cleared rocks (Figure 7). The organisms on one of the cleared coralline rocks and one of the cleared sponge rocks were clearly dying. The reason for this mortality is unknown. When these two rocks are excluded from the analyses, re-growth on the corallines and sponges were approximately 20% and 90% respectively (Figure 7). It was expected that more re-growth would occur on the sponge cleared rocks as these are typically the fastest growers, particularly when compared to encrusting coralline algae. Although coralline algae are known to be extremely slow growers, substantial growth was seen over the two year period. Next year, all clearings will be re-photographed and additional growth will be calculated.

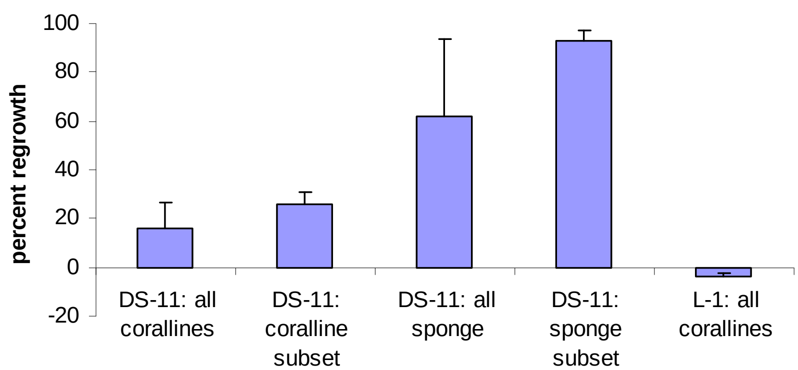

Figure 7. Mean percent re-growth (±1 s.e.) of all DS-11 corallines (n=6), a subset of DS-11 corallines after the one dying coralline was excluded (n=5), DS-11 sponges (n=6), a subset of DS-11 sponges after the one dying sponge was excluded (n=5), and corallines from L-1 (n=3).

Acknowledgements

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Biogeochemical Assessment of the North Aleutian Basin Ecosystem: Current Status and Vulnerability to Climate Change

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Introduction

The overall goal of this project is to gain a better understanding of the carbon biogeochemistry of the Southeastern Bering Sea ecosystem and the controls that regulate the cycling and transformation of carbon and nitrogen in the marine environment. Broadly, the project has the following objectives; (i) quantify upper ocean net ecosystem production, (ii) determine the fate of net community production, (iii) assess the impact of climate variability (i.e. El Niño, Pacific Decal Oscillation, Arctic Oscillation) on carbon biogeochemistry, (iv) determine the extent of ocean acidification in the Eastern Bering Sea and develop long term projections for changes in the pH.

Project Status

Work continued on the project throughout 2009. The year began with the continued analysis of samples collected in the Bering Sea in spring and summer of 2008 (Figure 1). The analysis of approximately 700 samples for dissolved inorganic carbon (DIC), total alkalinity (TA), and total organic carbon (TOC) was completed in February.

As expected, both DIC and TA were tightly correlated with salinity in spring prior to ice melt. Data from summer showed that DIC concentrations had been drawn down considerably in the surface waters as a result of primary production. Using DIC deficits between spring and summer we were able to determine rates of net community production across the Bering Sea shelf. We found that rates of production were higher in the northern shelf. There was also a strong remineralization signature in the bottom waters of the northern shelf that were evident in high DIC concentrations near the bottom. The results are discussed in detail in a paper by Mathis et al., which has recently been accepted in *Biogeosciences*.

The increases in DIC at depth caused an increase in the partial pressure of carbon dioxide (pCO2) in the bottom waters in certain locations and suppressed the saturation states of carbonate minerals. In particular, aragonite was undersaturated over the northern most part of the shelf. These waters could be potentially corrosive to benthic calcifiers in the region including the commercially important crab fishery. Also alarming was the presence of waters undersaturated with respect to aragonite in the inner most stations that were occupied in both spring and summer. The source of these low pH, high pCO2 waters is likely the Yukon and Kuskokwim Rivers, which also contain these biogeochemical signatures. Preliminary discussion of this phenomenon was included in a recent paper by Fabry et al., and will be discussed in greater detail in a paper that will be submitted by Mathis et al. in February of 2010 .

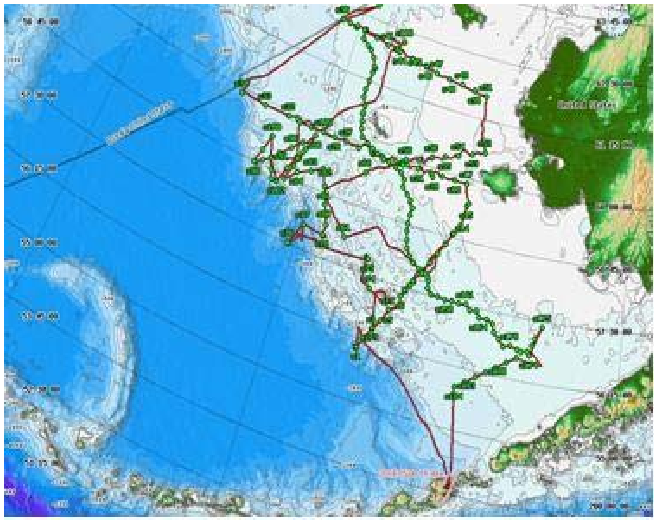

Figure 1: Cruise track and station locations for spring and summer 2008

In 2009, we had the opportunity to participate in two additional cruises along with the planned spring and summer occupations in the Bering Sea. The first of these was conducted simultaneous to the summer BEST cruise on the Japanese vessel *Oshoro Maru.* During this cruise samples were collected in the deep Bering Sea, while samples onboard the USCGC *Healy* were taken over the shelf. These additional data will allow for a better determination of how the deep Bering Sea impacts the carbon biogeochemistry of the shelf. The second additional cruise took place in September of 2009 and was truly a fortunate event. The cruise track was identical to those occupied in spring and summer and provided the opportunity to obtain a late season end member to better constrain the fate of carbon in the ecosystem. However, during the cruise a coccolithophore bloom occurred and we were able to collect samples within the bloom. Since coccolithophores are calcifiers (and are somewhat unusual in the Bering Sea) they can have a major impact on the carbon cycle. By measuring DIC and TA just before and during this bloom we will be able to quantify the rate of calcification for these organisms (something that is rarely possible anywhere in the ocean).

All of these samples were returned to the lab and analysis began in September and is about 70% complete.

Jessica Cross, the PhD student involved in the project continued to make excellent progress and is responsible for much of the project's success. In all, she spent approximately 110 days at sea in 2009 with another 100+ days planned in 2010 (the last official year of fieldwork). She was co-author on the Mathis et al. manuscript and will present this work in an oral presentation at the Ocean Sciences meeting in Portland in February of 2010.

Preparations have begun for the final year of proposed fieldwork (they may be additional opportunities in 2011) in 2010. We will participate in three cruises (spring, summer and fall) this year. Overall, the project is on track and making excellent progress. I anticipate at least four new publications to come out of this work during 2010. We are certainly looking forward to another successful year.

Mapping and Characterization of Recurring Spring Leads and Landfast Ice in the Chukchi and Beaufort Seas

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Introduction

Our project has been submitting monthly progress reports to the MMS Program Officer (Warren Horowitz) as well as quarterly progress reports to CMI. This annual report is a compilation of those reports edited by Andy Mahoney who recently (re)joined the UAF sea ice group as a research assistant professor in February 2010.

Major activities and accomplishments

Analysis of ice distribution and lead patterns

Work started early on this study in anticipation of the contract award, so that data needed for other aspects of the project would be available as soon as possible. To aid our project, the GINA Swathviewer (sv.gina.alaska.edu) tool has been reconfigured to allow more efficient browsing of the large number of scenes (several thousands) that need to be examined for this study.

At the end of 2009 we have examined an AVHRR image of the Chukchi Sea for each day of the winter from 1993 to 2004 to identify clear cloud-free areas for study of ice conditions. This matches the run of images studied for the Beaufort Sea during the earlier MMS project (AK-03-06, MMS-71707). Having identified suitable images, the next step will be review the data manually in more detail to identify repeatable movement patterns that can be interpreted in terms of the interaction of the pack ice with the coasts surrounding the Chukchi Sea. That effort should be completed in the early part of 2010.

We are still developing the workflow of AVHRR data processing, building on the catalog of suitable imagery being assembled. In order to streamline the process, it was decided to migrate programs written for analysis of earlier imagery over into the processing environment at GINA. This migration process and associated programming work is expected to take roughly two months.

Analysis of landfast ice extent

Much of the effort toward the landfast ice analysis section of the project in 2009 went into data mining for RADARSAT ScanSAR Wide Beam imagery. Typically, two frames cover most of the Chukchi Sea portion, but there are often gaps on either side that require an additional frame or two for complete coverage of the study area. It appears that the additional frames are re-occurring and can be automatically identified via database queries. The SAR swaths tend to drift slightly from month to month, so coverage of the study area needs to be manually verified in Google Earth for each potential mosaic prior to placing data orders. In addition, we found that there was not complete overlap between images that were 11 frames apart, as shown the ASF data interface. Instead, we found a separation of 10 frames is required to provide sufficient overlap and so additional frames were ordered to fill the gaps.

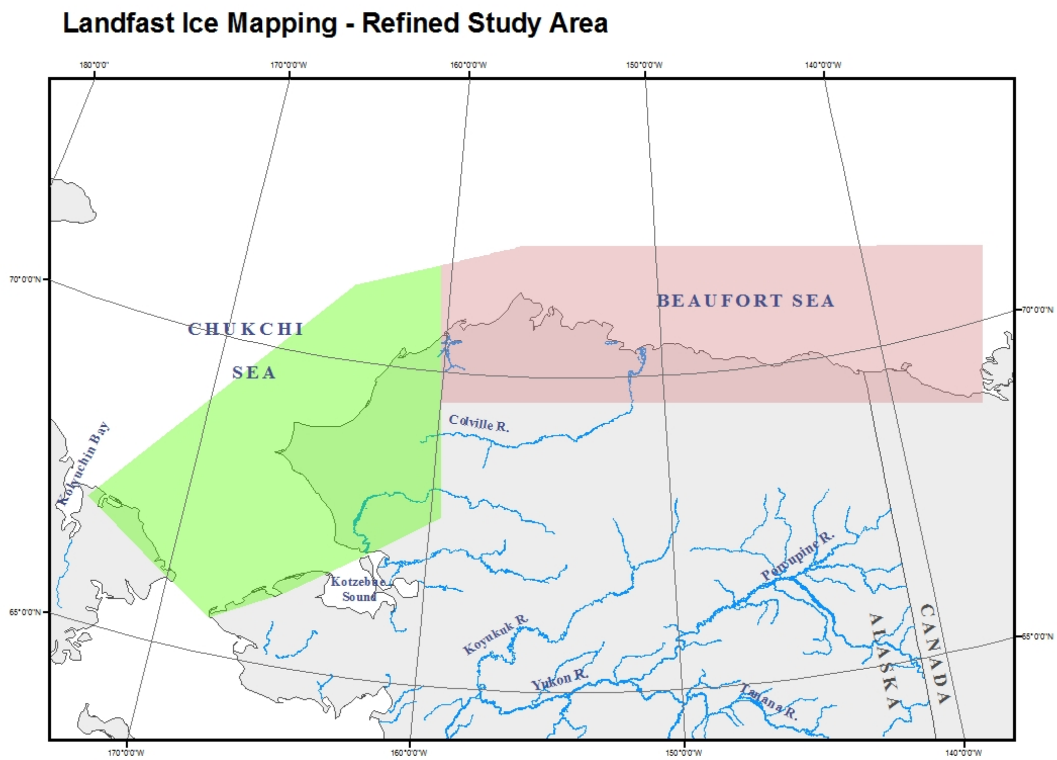

Figure 10: Refined study areas for landfast ice extent analysis, taking into consideration the observed maximum landfast ice width and project goals.

At the end of 2009, we had ordered SAR data for the 1998-99 ice season in the Chukchi study area and for both study areas for the 2004-05 ice season. After reviewing these data, we made refinements to both the Chukchi and Beaufort regions of the study area. We determined that several additional scenes would be required to provide coverage of Kotzebue Sound but that the Northern portion of the Chukchi study area could be reduced since it is unlikely the landfast ice will extend far offshore from the Chukchi coast. We also reduced the size of the Beaufort region of the study area at its northern boundary according to the maximum landfast ice extent from the previous study. This will decrease the volume of data to manage and process substantially. Figure 10 shows the updated study areas for use in clipping SAR mosaics.

Allison Gaylord met with team members at UAF on August 13th and 14th. During this time the IDL scripts from the 2003-05 were retrieved from archive and reviewed. It was determined that some minor code updates would be required to adapt the scripts for the new study. These updates were later discussed with Andy Mahoney, who wrote the original code. Andy will be joining the group at UAF in early 2010 and will complete the implementation of the updated code. We also produced new coast masks for use in the “supervised” landfast ice delineations and the subsequent analysis of landfast ice extent.

Discussions also included coordinating landfast ice mapping in the Southern Chukchi and northern Bering Sea (Bering Strait area) with the MMS study to extend the coverage further south for a few years where detailed field measurements have been collected at Wales. SAR data mining in the Northern Chukchi will be coordinated with data acquisition in the Southern Chukchi.

Assessing potential alternative approaches at deriving landfast ice edge locations and landfast ice stability

In order to assess and analyze the performance of L-band SAR interferometry for deriving and locating the landfast ice edge and landfast ice stability, we acquired several L-band SAR images of the Advanced Land Observing Satellite (ALOS) PALSAR sensor from the America’s ALOS Data Node (AADN). The data cover the coastal and nearshore areas at Barrow, Alaska. Pairs of SAR images cover the same area at different times were processed using the GAMMA RS software to produce to interferograms and interferometric coherence images. High values of interferometric coherence indicate areas in the images that remained unchanged in the time between image pairs. We therefore assume that such data contain information about the spatial extent stationary landfast ice. First results of this analysis are shown in Figure 11. This first example clearly shows areas of high coherence (white) on sea ice along the coast, corresponding to sea ice that did not move or undergo significant change during the observation interval.

To verify that regions of high coherence correspond to areas of landfast sea ice, we derived landfast sea ice extent from RADARSAT ScanSAR imagery covering the same region and time period using the technique we developed in the earlier study (AK-03-06, MMS-71707). The comparison suggests that L-band interferometric coherence images allow us to accurately delineate landfast ice areas that remained stable for the entire 46 day observation period captured by the interferogram. First investigations also indicate that the coherence data reveals small-scale structures and other local regions of potentially unstable ice, which could be valuable information for further studies of landfast and coastal ice dynamics. An abstract entitled “Monitoring Landfast Ice Through L-band SAR Interferometry” has been submitted to the 3rd ALOS Joint PI Symposium and was accepted for publication.

Following the promising results using interferometry to identify landfast sea ice near Barrow, we acquired imagery for the Seward Peninsula for the winters of 2007 and 2008. The first data pairs have been processed and an overview of their coverage is shown in Figure 12, presenting phase maps for the individual interferograms. Some fast ice is present in the two northernmost frames. The frame to the southwest shows no traces of fast ice. However, as this frame shows signs of decorrelation on the land portion of the image, the lack of visible fast ice could be due to weather related signal decorrelation. A closer examination of the data will be performed soon.

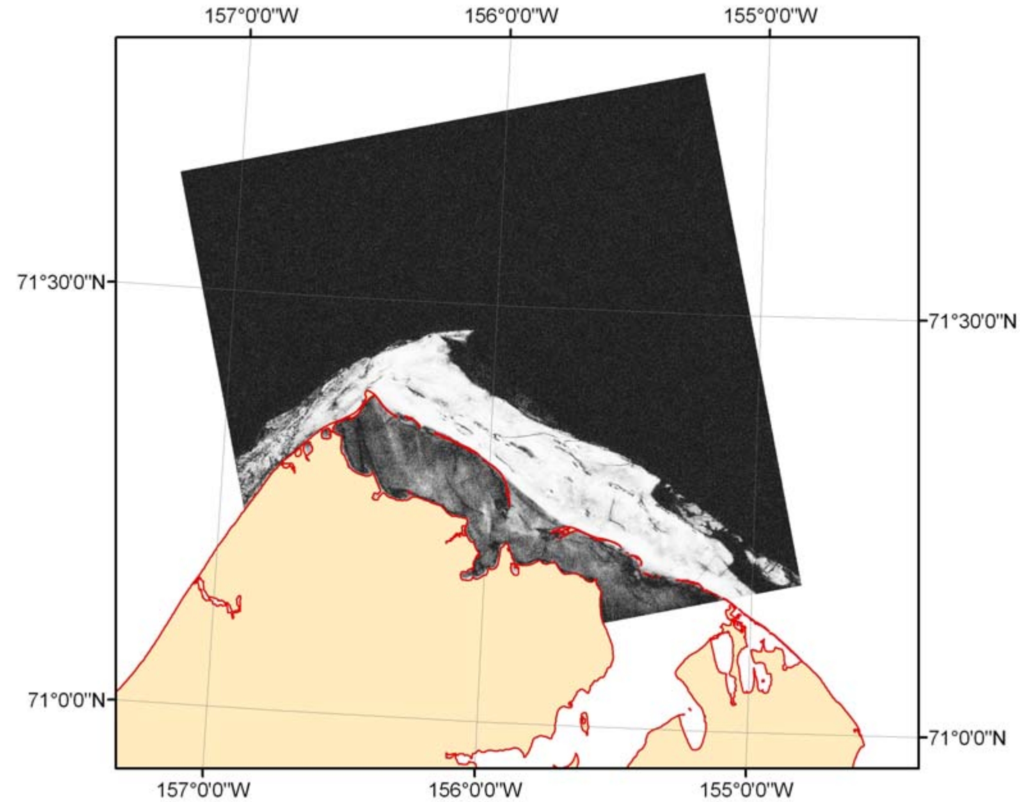

Figure 11: Coherence map (dark – low coherence, bright – high coherence) for an ALOS L-band interferogram for images acquired 6 March and 21 April 2008. All land areas area masked out.

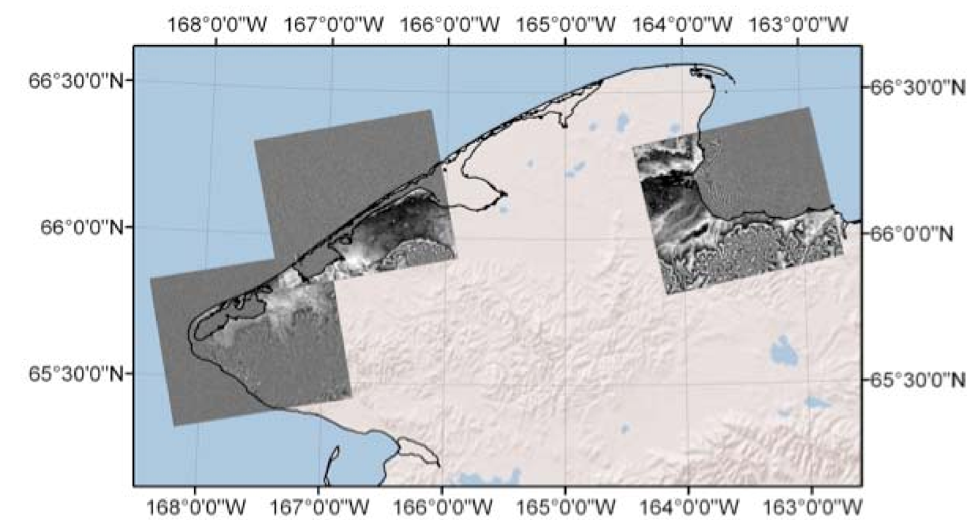

Figure 12: Interferograms processed for Seward Peninsula as of January 2010.

Reference landfast sea ice outlines derived from Radarsat data have been converted to shapefiles. The comparison of InSAR based fast ice extent with reference data will be performed next using Arcmap. An undergraduate student, Casey Denny, has started work on the project to help with the InSAR data compilation and analysis. Ms. Denny has previously worked for the Alaska Satellite Facility and brings significant expertise in SAR data processing to the project.

Miscellaneous

The existing website for the previous MMS project (AK-03-06, MMS-71707) has been updated with information about the expanded geographic scope of the new project. This site will be kept for public access of the data and findings from the first project. This site has retained its original URL: http://mms.gina.alaska.edu.

Jason Grimes from GINA has implemented the Content Management System (CMS) for the project web site and is building the page templates for the new, expanded site, which will be for internal project use and hosted behind a password until final release of the project data. The URL of the new site is http://mms-new.gina.alaska.edu.

Significant meetings held or other contacts made in connection with project

Prior to the start of the project, a planning meeting was held on 24 April 2009 with all investigators and to plan work schedule and related issues. Following this, a series of project meetings involving all investigators (with the exception of Lew Shapiro, who was inspecting water wells in Ghana for much of August) was held during Gaylord's visit to UAF over a period of 2 two days in mid-August. Another meeting was held with John Cologgi, Allan Reece and Warren Horowitz on October 14 in association with the MMS Workshop held in Anchorage, AK. This meeting discussed specific information of value to industry in the lease sale area. Hajo Eicken gave a presentation at the CMI Annual Review Meeting, December 10, 2009 in Fairbanks.

Project timeline

Study is proceeding roughly along projected timeline and is on target for delivery of final report in 2012.

Student status

As of October 2009, Casey Denny, an undergraduate student, is working on the project helping with InSAR data processing and analysis as part of an undergraduate research project.

Subsistence Use and Knowledge of Beaufort Salmon Populations

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Abstract

The designation of the entire Outer Continental Shelf (OCS) of the Beaufort Sea as Essential Fish Habitat for Pacific salmon populations combined with local observations of increasing numbers of salmon in subsistence fisheries has generated a need for more information about salmon use, distribution, and survival in the North Slope region. This study will address this knowledge gap by synthesizing relevant research and conducting ethnographic fieldwork with Inupiat informants about changing salmon populations. This study will provide a better understanding of the human and ecological environments that could be potentially affected by offshore oil and gas development in the Beaufort Sea.

Introduction

In 2005, the National Marine Fisheries Service (NMFS) designated the entire Outer Continental Shelf of the Beaufort Sea as Essential Fish Habitat (EFH) for the five species of Pacific salmon (chinook [*Oncorhynchus tshawytscha*], coho [*O. kisutch*], pink [*O. gorbuscha*], sockeye [*O. nerka*], and chum [*O. keta*)]). This EFH designation requires Minerals Management Service (MMS) to consult with NMFS to assess the impacts of potential oil and gas development on local salmon habitat. However, little information has been documented about salmon distribution and habitat use in this region. Although, historically this region did not support viable salmon populations (Craig 1989, Fechhelm and Griffiths 2001), as climatic changes continue and winters warm in this region, the distributional range of salmon present and spawning areas appear to be expanding. Pink and chum salmon have been observed in recent years in the Beaufort Sea, Colville River, and other novel regions across the Arctic (Bendock 1979, McElderry and Craig 1981, Craig and Haldorson 1986, Babaluk et al. 2000). In addition, fall subsistence fisheries for these species have been noted in the Colville and Itkillik rivers (George 2004, cited in BLM 2007). Local residents have recently noted increasing numbers of salmon present in their subsistence fisheries, suggesting the potential of viable spawning stocks. Previous studies have not conclusively documented juvenile life stages or spawning areas present in this region; however, Fechhelm and Griffiths (2001) suggest that a few isolated spawning populations of chum and pink salmon may occur in the Colville and Sagavanirktok rivers based on their survey of Beaufort Sea salmon (BLM 2007).

Through ethnographic research with Inupiat experts, this project will address this gap in knowledge of the status of salmon populations in local rivers and streams and along the Beaufort Sea coastline. This information will assist MMS and NMFS in assessing any potential impacts on EFH and Inupiat subsistence in this region.

Objectives and Hypothesis

As local ecological factors are changing in this region, local elders and fishermen are among the most knowledgeable sources of information concerning salmon distribution. This study will document the historic and current importance of salmon as a subsistence resource and will also contextualize salmon among the suite of subsistence resources in this region. The specific objectives of this project are to:

(1) Establish strong rapport with local community residents and regional experts.
(2) Document the current subsistence use of Beaufort Sea salmon populations in Barrow, Nuiqsut, and Kaktovik or Atqasuk.
(3) Document the local and traditional ecological knowledge of historic and recent trends in salmon use, abundance, and distribution.
(4) Better understand the Inupiat context for ecological observations and appropriate uses of such knowledge.
(5) Use spatial and ethnographic data to identify steams and coastal areas where salmon have been harvested or observed.

We hypothesize that the increased presence of salmon in the region will be related to an increased importance of salmon to Inupiat communities. We also predict that knowledge about salmon in the region will be contextualized in a broad network of environmental knowledge accumulated over long time periods of close interaction between local people and their surroundings, transmitted through oral history. Knowledge about salmon is likely to be closely related to knowledge about changing ocean, coastal, river, lake, habitat, and climatic conditions.

Methods and Status

We are currently finalizing the first phase of this research – a literature review on current knowledge about the use and distribution of salmon in the Beaufort Sea region. This review includes an analysis of published and archival material on Inupiat subsistence in the region, focusing on the communities of Barrow, Nuiqsut, Kaktovik and Atqasuk. The subsistence and bibliographic material collected in previous studies have assisted in this effort (North Slope Borough no date, BLM 2005, BLM 2007). In September 2009, UAF Fisheries undergraduate, Shelley Woods, was hired as an hourly employee to assist with the literature review and annotated bibliography. Ms. Woods will be starting as an M.S. degree in Fisheries to begin in January 2010. She will be the graduate student research assistant for this project, and will base her Master's thesis on this research

The initial set-up for the field research is nearly complete. The UAF Institutional Review Board application for research with human subjects has been submitted and approved. A preliminary visit to the community of Barrow was conducted in June 2009, prior to the period of performance. This trip was taken to give the PI an opportunity to introduce herself and the project to local leaders. She met with individuals at the Native Village of Barrow Iñupiat Traditional Government, the North Slope Borough, the Alaska Eskimo Whaling Commission, *Utqiagvigmiut Agviqsuqtit Agnanich* (the whaler's wives association), as well as Ilisagvik community college, the Iñupiat Heritage Center, and the Barrow Arctic Science Consortium. The process of obtaining formal tribal permissions and other permits is currently underway. Several meetings with Sverre Pedersen at the Alaska Department of Fish and Game (*Exploring an Emerging Subsistence Salmon Fishery in Three Chukchi Sea Communities: Point Hope, Point Lay, and Wainwright*) have provided an opportunity to share research insights and survey protocol. The agency has formalized this collaboration by offering matching funds to this project in year 1, with a potential for additional matching funds in years 2 and 3.

Ethnographic fieldwork is scheduled to be conducted in the North Slope region during the summer of 2010. We will focus our data collection efforts in the hub community of Barrow. Two smaller communities have been selected to contrast freshwater and coastal subsistence fisheries. Research conducted in Nuiqsut, on the Colville River, will enable us to collect information about salmon use, knowledge, and geographic distribution along this river system. The coastal community of Kaktovik would provide an opportunity to gather information about coastal distribution and use of salmon; however, regional experts and previous data have suggested that salmon are a very minor fishery in this community (Booth and Zeller 2008). Depending on informant interest and knowledge, this community may not be ideal to include in the project. In this case, Atqasuk would be selected as the third community. This research project is designed to be useful to the communities involved. After meeting with the North Slope Borough and community leaders again in spring 2010, specific community selection and research plans may change to accommodate the requests and needs of local communities.

Knowledgeable individuals in each community will be identified using snowball sampling methods (Bernard 2002). Semi-structured interviews will be conducted with these expert informants to generate a set of knowledge about salmon in this region (Spradley 1979). We will focus our interviews on the collection of local and traditional ecological knowledge about the historic and recent trends in salmon distribution, potential spawning activity, and subsistence use. Knowledge about salmon will be contextualized within a broader subsistence fishery framework. Interviews with key informants will be audio-taped and transcribed. Expert informants will also be asked to identify specific geographic areas where they have harvested or observed salmon. Local maps will depict grid blocks of sufficient scale to document observed changes in salmon distribution over time. If culturally appropriate, participatory mapping methods (Lauer and Aswani 2008, Kuznar and Werner 2001) will be used to document this geographic information.

Timeline

Due to a reorganization of the initial research proposal submitted and the development of research collaboration with the Alaska Department of Fish and Game, the project implementation has been delayed. The literature review and bibliography development was delayed by one quarter (beginning October 1 and finishing March 31, 2010). An initial site visit was made prior to the period of performance in June 2009. Ethnographic interviews will take place during June – September 2010. The remainder of the project timeline remains unchanged. The project is still expected to be completed by December 31, 2012.

Presentations

Carothers, C. 2009. Subsistence Use and Knowledge of Beaufort Salmon Populations (Year 1). Project report for CMI review presented at Fairbanks Alaska on 10 December 2009.

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Trophic Links – Forage Fishes, Their Prey, and Ice Seals in the Northeastern Chukchi Sea

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Abstract

Oil exploration is likely to take place in the northeast Chukchi Sea simultaneously with increasing rates of global change. There is a paucity of data and limited ecological understanding for pelagic and demersal fishes in Lease Sale 193. It will not be possible to discern the extent or cause of effects on this Arctic ecosystem without first determining its current status. The rapidly receding sea ice in the Arctic has received much attention recently and record minima were recorded in three consecutive years since 2007. The loss of habitat for ice seals has resulted in two Arctic phocid species still being considered for listing under the Endangered Species Act. Thus, not only is there a pressing need for knowledge about fishes in the Chukchi Sea, but it is also essential to evaluate those fishes as prey resources, i.e., forage, for marine mammals. We hypothesize that dietary differences among forage fishes in the vicinity of Lease Sale 193 may propagate into higher trophic levels such as ice seals. This research will use stable carbon and nitrogen isotopes from fishes, their stomach contents, and ice seals from 2007, 2008, and 2009 as a tool to test this hypothesis and to produce a more comprehensive picture of forage fishes in the Chukchi Sea. Trophically relating fishes and their prey to ice seals and their diets in the Chukchi Sea is essential to understanding this ecosystem. Basic knowledge of the Chukchi Sea ecosystem will help facilitate good stewardship by the oil and gas industry. Currently, samples from archived and recent fish and ice seal collections are being processed in agreement with our proposed timeline.

Introduction

The northeast Chukchi Sea from Point Hope to Barrow is undergoing increased oil and gas resource survey and development pressure. From the early 1990s until recently, the Chukchi Sea did not receive as much attention from Minerals Management Service (MMS) as did the

Beaufort Sea. However, that dramatically changed in February 2008 with Lease Sale 193 and 488 blocks were leased within the Chukchi Sea Planning Area (Figure 1). Lack of recent baseline data for fish species in the Chukchi Sea is compounded with climate change. It will not be possible to distinguish between natural and anthropogenic effects without high-quality baseline data. Thus, it is critical to assess the distribution and abundance of fishes in the Chukchi Sea prior to oil exploration or development of commercial fisheries.

Not only is there a pressing need for knowledge about fishes in the Chukchi Sea, but also it is essential to evaluate those fishes as prey resources for marine mammals. The rapidly receding sea ice in the Arctic has received much attention recently and record minima were recorded in 2007, 2008, and 2009. For many marine mammals in the Arctic, sea-ice is an important platform for resting, mating, pupping, and as a base for foraging. In response to significant sea ice habitat loss, potentially limited access to prey, and increased anthropogenic interaction in the Arctic, ice-associated pinnipeds followed the polar bear (*Ursus maritimus*) in proposals for listing as threatened or endangered under the Endangered Species Act. The decision to list is still pending for ringed seals (*Phoca hispida*) and bearded seals (*Erignathus barbatus*) and a decision will be announced in November 2010. Ribbon (*Phoca fasciata*) and spotted seals (*Phoca larga*) were also proposed for listing; however, NOAA announced their decisions not to list these seal species at this time. Potential listing underscores the need to learn as much as possible about ice seals in the vicinity of Lease Sale 193, including trophic linkages with forage fishes.

Understanding potential effects of climate change or oil and gas exploration in Lease Sale 193 requires investigating trophic links between Arctic fishes and their prey and between the fishes and their ice seal predators. This will entail examining a variety of fish species, life histories, and life stages. A recent search of FishBase (Froese and Pauly 2006) indicates 80 fish species inhabiting the Chukchi Sea. The dominant Arctic fish families are Gadidae (cods), Zoarcidae (eelpouts), Liparidae (snailfishes), Cottidae (sculpins), and Salmonidae (salmonids). Most of what is known about ecology and life history of Alaskan Arctic marine fishes originates from work associated with marine mammals (Frost and Lowry 1981, 1983, 1984) and oil and gas exploration (Craig and McCart 1976, Craig et al. 1982, 1984). The general consensus seems to be that little is known and much work needs to be done on Arctic marine fishes (e.g., Johnson 1997, Power 1997, Mecklenburg et al. 2002, 2008, and MMS 2006). There is even less known about diets of marine fishes in the Chukchi Sea than of fish distribution. Feeding styles of Chukchi fishes are diverse. As the Arctic ecosystem changes fish diets will likely change. Therefore past information about fish diets should be expanded with information about recent diets and trophic linkages between fish prey and their consumers.

Ice or pagophilic seals, as the name implies, are strongly dependent on Arctic sea ice, but individual species are selective for different habitats within this ecosystem (Simpkins et al. 2003) and exhibit different feeding ecologies (Dehn et al. 2007). Ice seals eat midwater forage fishes, demersal fishes, and invertebrates, yet the particular prey taxa consumed by different seal species can be dissimilar. For example, cods are significant prey to ringed seals, in particular to adult ringed seals and euphausiids and amphipods can be equally important (Lowry et al. 1980a, Dehn et al. 2007). In contrast, bearded seals are benthic feeders and fishes are commonly identified from bearded seal stomachs, including eelpouts, cods, sculpins, rainbow smelt (*Osmerus mordax*), flatfishes (Lowry et al. 1980b, Dehn et al. 2007), pricklebacks (Antonelis et al. 1994), and Pacific sand lance (*Ammodytes hexapterus*) (Lowry et al. 2000). Spotted seals are piscivorous, eating both pelagic and benthic fish species, and rely heavily on Pacific herring (*Clupea pallasi*), cods, rainbow smelt, capelin (*Mallotus villosus*), and Pacific sand lance (Dehn et al. 2007); salmonids can be seasonally important in their diet (Lowry et al. 2000). Little is known about ribbon seal feeding in the Arctic, but fishes, e.g., walleye pollock, appear to be important prey (Frost and Lowry 1980, Dehn et al. 2007)

Stable nitrogen and carbon isotope analyses of animal tissues are used frequently to examine the structure of food webs and to determine the food sources (Hobson and Welch 1992, Hobson et al. 1993, 1996, Dehn et al. 2006, Bentzen et al. 2007, Greenberg et al. 2007, Knoche et al. 2007). The stable isotopic composition of a material is given in delta (δ) notation, indicating the deviation in parts per thousand from an international standard (Peterson and Fry 1987). Stable nitrogen isotopes are integrated into consumer tissues with enrichment occurring at each trophic step due to the preferential incorporation of the heavier isotope ($\delta^{15}N$) into tissues (Kelly 2000). Using this relationship it is possible to describe a food web, determine trophic relationships, and examine the feeding ecology of organisms (Peterson and Fry 1987, Fry 1988, Hobson and Welch 1992, Rau et al. 1992, Hobson et al., 2002). Stable nitrogen isotope analyses can be coupled with stable carbon isotope analyses ($\delta^{13}C$) of an organism, illustrating habitat usage when distinct changes in foraging habitat occur during movements or migrations (Fry et al. 1984, Fry and Sherr 1984, Schell et al. 1989, Knoche et al. 2007).

Stable isotope ratios of nitrogen and carbon have been used extensively in marine mammal ecology to investigate trophic position and relationships, habitat use, migratory patterns, and contaminant transfer (Hobson et al. 1996, 1997, Hobson and Schell 1998, Hoekstra et al. 2003, Dehn et al. 2006, 2007). For seal muscle (based on captivity studies) nitrogen enrichment was estimated at 2.4 ‰ from prey to predator (Hobson et al. 1996). However, without prior knowledge of typical prey species consumed and their respective isotope ratios, only general statements can be made, e.g., if the diet is likely to be pelagic or benthic. It is important to establish prey isotope libraries to both infer the diet of the predator and estimate contribution of particular prey species, thus enabling effective monitoring of changes over time by sampling only a few milligrams of tissue. Isotopic mixing models have become powerful tools to evaluate proportional importance of prey with different isotopic signatures (Phillips and Koch 2002, Phillips and Gregg 2003, Phillips et al. 2005, Moore and Semmons 2008) and have been used successfully in the Arctic to describe polar bear diets (Bentzen et al. 2007).

Our study will incorporate stable isotope analysis to establish trophic links within the Chukchi Sea food web. Carbon and nitrogen isotope ratios will be determined from fishes, their prey, and muscle and liver tissues of seals. Muscle is generally considered a medium turn-over tissue and will provide dietary information over a period of about one month (Tieszen et al. 1983). In contrast liver is highly metabolically active and will turn-over within 1-2 weeks (Tieszen et al. 1983, Sponheimer et al. 2006). In addition to liver and muscle tissues, isotope analysis of seal claws can give information on historical diet and prey utilization. Keratin layers in seal claws are annually deposited (Benjaminsen 1973), similar to growth layer groups observed in teeth or otoliths (Figure 2). Growth layers of keratin in seal claws can provide a long-term record of diet and/or seasonal importance of prey for up to 10 years. After that time, the claws will wear at the distal end. Many studies have utilized stable isotopes in teeth (Hobson and Sease 2006), baleen (Schell et al. 1989), whiskers/vibrissae (Hobson et al. 1996, Hirons et al. 2001, Zhao and Schell 2004, Cherel et al. 2009), and other keratinized structures to assess long term feeding records, monitor diet, and determine potential prey switching of marine mammals. Historic trophic data from fish and seals will be combined with current trophic information obtained from ice seal liver and muscle tissues, morphometric data, stomach contents data, and age information.

Objectives and Hypothesis

The overall project objective is to document critical baseline data on diet of forage fishes in the eastern Chukchi Sea and the trophic links from fish prey to fish to ice seals. Specific objectives include:

(1) Determine diet composition of forage fishes
(2) Establish trophic level of forage fish species and of their prey

(3) Analyze interannual differences in diet of fishes and in the trophic level of fishes and their prey
(4) Determine trophic level of ice seals
(5) Determine ice seal trophic history
(6) Develop isotopic mixing models
(7) Compare trophic levels of forage fishes to those of ice seals
(8) Provide diet and trophic level data to MMS in electronic format
(9) Complete data archiving with National Oceanographic Data Center (NODC) and make available to MMS in GIS compatible format.

We hypothesize that dietary differences of pelagic and demersal fishes among sites in the Lease Sale 193 may propagate into higher trophic levels such as ice seals. As stable isotope values of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) are indicators of trophic level, we will use this technique to test our hypothesis by establishing a trophic relationship from prey of forage fishes through individual species of forage fishes up to ice seals.

Methods and Status

Fishes available to this project were caught by bottom and midwater trawls in the Chukchi Sea and northern Bering Sea during 2007–2009 (Figures 3, 4 and 5). Fishes caught by bottom trawl (beam trawl and otter trawl 2007–2009) are primarily <150 mm, while fishes caught by Isaacs-Kidd midwater trawl (2009) are <50 mm, and fishes caught by CanTrawl (2007) are <400 mm. Approximately 220 and 880 fish specimens are planned for stable isotope and diet examination, respectively. Ringed, bearded, and spotted seals were sampled during Alaskan Native subsistence harvests of these species mainly in June and July of 2007, 2008, and 2009. Few samples of ribbon seals were collected, as this species has a very remote distribution in front zone of the pack ice covering deep continental shelf waters (Simpkins et al. 2003). Ice seal samples were obtained from the communities of Little Diomede, Point Hope, and Kotzebue in collaboration with the Alaska Department of Fish and Game (ADFG) Arctic Marine Mammal Program and in Wainwright and Barrow in collaboration with the North Slope Borough Department of Wildlife Management (Figure 3, 4, and 5). Seal sample collections in 2009 were successful, however a larger sample size of claws was expected and sampling in 2010 will continue in collaboration with ADFG and the North Slope Borough to improve the sample size and achieve the target goal. Available seal species and tissues have been inventoried (Table 1). Some of these tissues are archived at the Museum of the North in Fairbanks, and a tissue loan has been initiated to gain access to these samples. Spotted seals from the Fall 2009 hunt are not yet available, because the harvest just recently concluded and samples are still being received and inventoried by ADFG.

Stable isotope analysis will be performed to assess the trophic level of the fish species that are consumed by ice seals. Lipid content in fish muscle can significantly alter carbon isotope signatures (Pinnegar and Polunin 1999). We are presently examining the effect of lipid-removal on stable carbon and nitrogen isotope ratios of fishes. Approximately 10 specimens of each of Arctic cod (*Boreogadus saida*), Bering flounder (*Hippoglossus stenolepis*), and Arctic staghorn sculpin (*Gymnocanthus tricuspis*) were freeze dried, and homogenized using mortar and pestle. Some of our specimens may have organs removed (liver, spleen, and stomach) for processing in a separate study. To determine the impact this will have on isotope analysis, we examined five specimens of whole fish and five specimens where liver, spleen and stomach were removed. Otoliths were removed from all fishes for analysis in a separate study. After each whole body fish specimen was homogenized into a powder, the sample was divided in half. One half was weighed directly in the Stable Isotope Laboratory at the University of Alaska Fairbanks and lipids were removed from the remainder by the following process. Samples were washed in a 2:1 chloroform:methanol mixture, agitated for 5 minutes and centrifuged for 5 minutes. The supernatant was discarded and the process was repeated twice. The lipid-extracted samples were frozen and returned to the freeze-dryer for 12 hours and then re-homogenized prior to placing samples into crucibles for weighing. Homogenized samples were weighed on micro-scales at the Stable Isotope Laboratory. Carbon and nitrogen isotope ratios are currently being analyzed using a Finnigan MAT DeltaPlusXL Isotope Ratio Mass Spectrometer (IRMS) directly coupled to a Costech Elemental Analyzer (ESC 4010); stable isotope ratios will be determined following the procedure described by Dehn et al. (2005), and data are pending. Once lipid-extraction effects are determined, we will begin preparing the remaining fishes for isotope analysis.

Diet analyses will assess the relative importance of functional groups of prey taxa in the diet of each fish species. Diet analysis of fishes has just begun. The four species to be examined over three years will be examined first, i.e. Arctic cod, Bering flounder, slender eelblenny (*Lumpenus fabricii*), and Arctic staghorn sculpin. Thus far, the stomach contents of 29 Bering flounder caught during 2009 have been examined; most stomachs contained gammarid amphipods and mysids. The trophic level of the functional groups of prey taxa (described above) found in fish stomachs will be examined using stable isotope analyses. Due to the small size of some prey taxa, the prey type will sometimes have to be pooled from the stomachs of several fishes to achieve sufficient mass of the prey for stable isotope analysis, i.e., five copepods from each of 10 fish stomachs pooled to yield one sample for stable isotopes. Therefore, prey will be taken from among the same specimens of predatory fishes analyzed using stable isotopes, the particular prey individuals will not be traceable back to the specific predatory fish.

For seals, stable isotope analysis will be preformed on liver, muscle and claws of ringed, bearded, spotted, and ribbon seals. Tissues of samples collected in 2009 and most of the archived tissues (approximately 5g) have been freeze-dried and homogenized for consequent weighing and analyzes at the Stable Isotope Laboratory. The extraction of lipids has no effect on stable carbon and nitrogen ratios in muscle of Arctic cetaceans and pinnipeds (Hoekstra et al. 2002), and therefore lipids were not extracted from ice seals tissues. Growth layers within seal claws (Figure 2) are in the process of being analyzed. Each claw is rinsed in a Vibration Bath for approximately 15 minutes to remove dirt and the cuticle and then rinsed for an additional 5 minutes. The claw is then cleaned with methanol and chloroform to remove any lipids that may adhere to the outside. After cleaning, each seasonal growth layer is drilled into a fine powder with a Dremel Tool. The prominent growth layers (either light or dark bands which ever stood out more) are drilled first (Figure 6). The band closest to the base is the starting point. At least 0.4mg of powder is extracted from the band and placed in glass vials until weighing. After the band is drilled, the claw is wiped with chloroform and methanol to remove remnant powder.

Drilling continues until the last band at the distal end of the claw is reached (Figure 7). Once the first set of bands are completely drilled the other seasonal growth bands are processed from base to distal end in the same manner (Figure 8). All samples will then be weighed and analyzed at Stable Isotope Laboratory at UAF as described above.

Analysis of stomach contents, along with morphometric data and age, will provide additional insight into pinniped life history. This ancillary data will be made available to this study by the Arctic Marine Mammal Program of the ADFG once their analysis is completed by approximately fall 2010.

Timeline

The project is on target to be completed by 31-Dec-2012. There are three differences from the proposed timeline. Fishes are available from collections during Oct-2009 in addition to those collected Aug-2007 through Sep-2009. Additional seal collections are anticipated during 2010 that will increase the sample size of seal tissues. Fish stomach analysis began in Nov-2009 rather than April-2009 due to delays in funding and conflict with summer fieldwork.

Presentations

Dehn, L.-A., S.S. Carroll, B.L. Norcross and B.A. Holladay. 2009. Trophic links – forage fishes, their prey, and ice seals in the northeastern Chukchi Sea (Year 1). Project report for CMI review presented at Fairbanks Alaska on 10 December 2009.

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Table 1. Seal species and tissues available for this study from 2007–2009 collections. Additional samples were collected in Wainwright during 2009 by the North Slope Borough, Department of Wildlife Management; information on species, sex, and type of samples collected is not yet available. Sampling effort in 2010 will continue in collaboration with ADFG and the North Slope Borough to improve the sample size and achieve the target goal.

Species	*Year*	*Location*	*Sex*	*Age Range*	*Muscle* *	*Liver*	*Claws*
Bearded Seal	2007	Point Hope, Diomede	5 males, 4 females	1–10 years	*n*=9	*n*=9	NA
	2008	Point Hope, Diomede	20 males, 12 females 2 unknown	<1–20 years	*n*=34	*n*=34	NA
	2009	Point Hope, Diomede	12 males, 11 females 5 unknown	not yet aged	*n*=28	*n*=28	*n*=9
	2009	Barrow	17 males, 11 females	not yet aged	*n*=28	*n*=28	NA
Ringed Seal	2007	Point Hope, Diomede	1 male, 1 female	16 and 7 years	*n*=2	*n*=2	NA
	2008	Point Hope, Diomede	8 males, 2 females	<1–26 years	*n*=10	*n*=10	NA
	2008	Kotzebue	1 male, 2 females	not yet aged	*n*=2	NA	*n*=3
	2009	Point Hope, Diomede	10 males, 2 females	not yet aged	*n*=12	*n*=12	*n*=5
	2009	Barrow	4 males, 3 females,	not yet aged	*n*=7	*n*=7	*n*=7
Spotted Seal	2007	Diomede	4 males, 2 females	1–7 years	*n*=6	*n*=6	NA
	2008	Point Hope, Diomede	1 female, 1 unknown	not yet aged	*n*=2	*n*=2	NA
	2009	Fall hunt	NA	NA	NA	NA	NA
	2009	Barrow	1 female	not yet aged	*n*=1	*n*=1	*n*=1
Ribbon Seal	2007, 2008	Point Hope, Diomede	2 males, 1 female	2–13 years	*n*=3	*n*=3	*n*=1
*Some of the muscle samples are archived at the University of Alaska Museum of the North in Fairbanks							

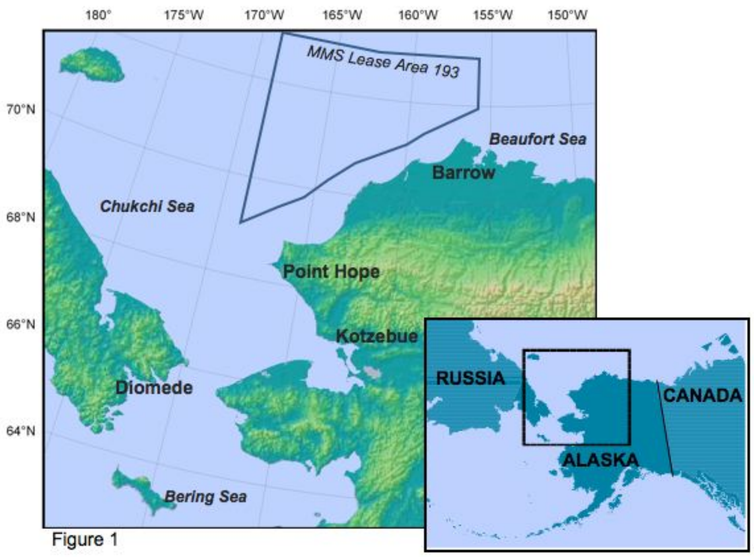

Figure 1

Figure 1. Study area in the eastern Chukchi Sea and northern Bering Sea.

Figure 2

Figure 2. Front flipper claw from a ringed seal harvested in Barrow in 2002. Approximately nine growth layer groups can be distinguished. The darker, smaller bands represent growth during late spring and summer, a period of fasting and the nutritionally demanding molt and pup rearing. The lighter, wider bands show growth during the autumn and winter months when seals deposit large amounts of reserves for the coming winter and breeding season. White circles have been added to the dark bands for purposes of visualization.

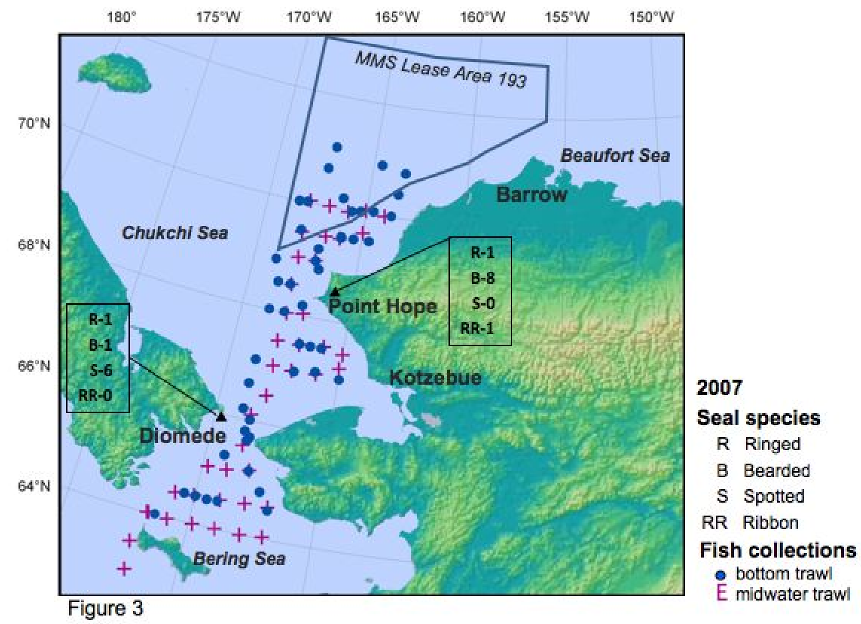

Figure 3. Number of ice seal specimens and sites of fish collections during 2007

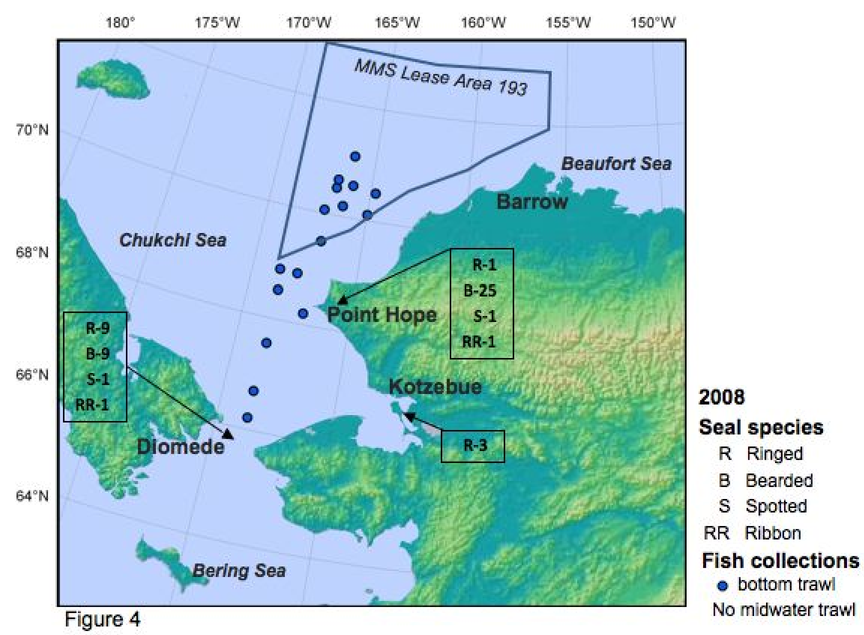

Figure 4. Number of ice seal specimens and sites of fish collections during 2008

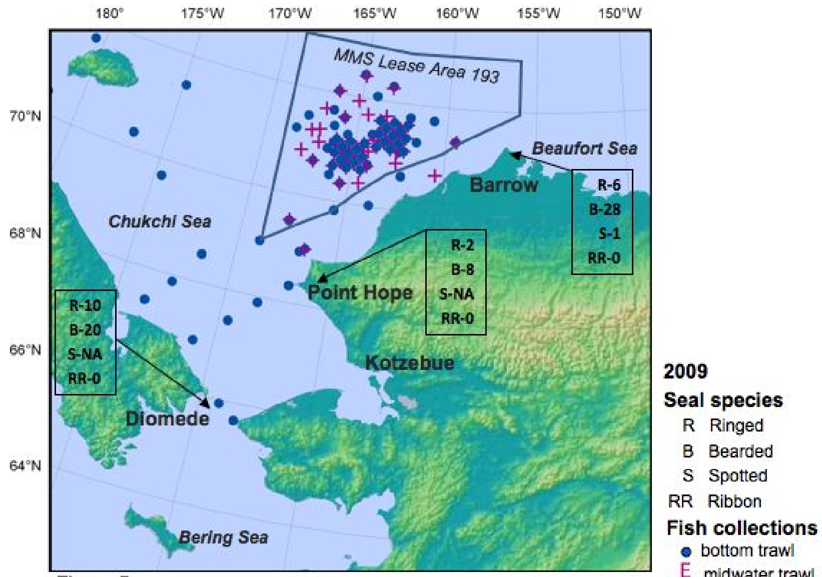

Figure 5

Figure 5. Number of ice seal specimens and sites of fish collections during 2009

Figure 6

Figure 6. Bearded seal claw (BS-4-01) before drilling. This seal is 19 years old (estimated by counting growth layers in the cementum of canine or postcanine teeth), and 18 seasonal growth layers (9 light bands and 9 dark bands, i.e., approximately 9 years) are visible in the claw. The most recent growth layer at the base of the nail is a dark band. The growth layers are more apparent when the claw is moistened.

Figure 7

Figure 7. Bearded seal claw (BS-4-01) after light bands have been drilled.

Figure 8

Figure 8. Bearded seal claw (BS-4-01) after dark and light bands have been drilled.

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Population Connectivity in Bering, Chukchi and Beaufort Sea Snow Crab Populations

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Abstract:

Climate trends in the Arctic appear to be impacting marine species distributions and community structure on multiple trophic levels. Superimposed upon this changing landscape are potential human impacts, including fishing pressures and petroleum resource exploration. The commercially valuable Alaskan snow crab, *Chionoecetes opilio,* has shown considerable fluctuations in population size within exploited areas of the Bering Sea over the last 25 years, and appears to be undergoing a northward range contraction due to changing climate conditions. Currently, the Bering Sea snow crab fishery is managed as a single panmictic unit; however, actual population structure and larval dispersal distances are not known for this species. Moreover, snow crab stocks are essentially unexplored north of the Bering Strait, although sizeable Chukchi and Beaufort populations do exist. Knowledge of population structure and estimates of genetic connectivity between exploited and unexploited areas are critical in management decisions, and of particular importance given recent interest in resource exploration and fishing in a more ice-free Arctic. Prevailing hydrographic conditions suggest that the long-lived planktonic larvae of snow crab might facilitate long-distance dispersal with northerly currents passing through the Bering Strait, into the Chukchi Sea, and along the Beaufort Shelf. Thus, Chukchi and Beaufort populations could well be genetically linked to commercially exploited Bering Sea populations, with gene flow occurring in the direction of water mass movement. We are using microsatellite methods to investigate the broad-scale genetic population structure of *C. opilio* in the Bering, Chukchi and Beaufort Seas, and determine whether larval dispersal distances can be estimated using these methods.

Introduction

The snow crab, *Chionoecetes opilio*, is a widely distributed and commercially valuable species that occurs commonly in the Bering, Chukchi and Beaufort Seas around Alaska, as well as in the NW Atlantic. While the Tanner crab, *C. bairdi*, is larger, faster growing, and historically more valuable than *C. opilio*, harvests for *C. bairdi* declined steadily through the 1980's and were closed from 1995 until 2008 (cf., Bowers *et al.* 2008). Rapid development in the *C. opilio* fishery accompanied the decline in *C. bairdi*. The Eastern Bering Sea snow crab fishery is managed as one continuous population, but may extend into Russian waters to an unknown degree (NPFMC 2007). Existing shellfish management units in both Alaskan and Canadian waters were originally established primarily according to historical fishing grounds—typically for red king crab in Alaska—and/or in accordance with natural geographic barriers (Merkouris *et al.* 1998, FRCC

2005). However, these designations do not necessarily correspond to real snow crab population structure in the region. In fact, genetic studies in both Alaskan and Canadian fishing areas do point to the existence of distinct subpopulations in Tanner and snow crabs (Bunch *et al.* 1998, Merkouris *et al.* 1998; Puebla *et al.* 2008). Recent studies in the Eastern Bering Sea also suggest spatial separation, and possible migrations, of various ontogenetic stages (Ernst *et al.* 2005, Orensanz *et al.* 2007). These patterns suggest more population structure than has been accounted for in current management models.

Given the growing pressure being placed upon fisheries resources in both Alaskan and Canadian waters, the need for improved knowledge of population structure and connectivity is clear. Despite fairly thorough stock assessments in fishing-intensive areas, virtually no attention has been paid to *C. opilio* stocks in the Chukchi and Beaufort Seas (but see Paul *et al.* 1997), where sizeable populations do appear to exist (e.g., Feder *et al.* 2005, Bluhm *et al.* 2009). These unexplored populations may well be sources or sinks for genetic exchange with other, more intensively fished populations. The need for additional studies is increasingly pressing, given recent evidence of a declining Bering Sea snow crab population and concurrent northward range contraction, apparently due to shifting water temperature regimes in the region (Dionne *et al.* 2003, Orensanz *et al.* 2004, Lovvorn 2008). Should this northward range contraction continue, and the Chukchi Sea become the new southern limit of this species' range, any impacts of ongoing oil and gas exploration/resource development on *C. opilio* populations may constitute additional pressure on this commercially important species.

In crabs and other species with planktonic larval phases, movement away from detrimental habitat conditions and/or re-colonization of an area after a disturbance can be achieved through larval dispersal. Dispersal also constitutes a means of genetic exchange between geographically distant populations. Thus, knowledge of dispersal patterns and degrees of genetic connectivity between populations are essential in determining the spatial scales over which localized disturbances will be felt, and over which environmental impact studies should be conducted. Furthermore, directionality of dispersal may indicate sensitive areas "downstream" from impacts which need to be considered in management plans. Hydrographic flow in the study area is predominantly northward, with a 6-month transit time recorded for water parcels moving from the Bering Strait up to Barrow (Winsor and Chapman 2004). Length of the planktonic period has not been measured for snow crab at temperatures typical of the study area, but larvae could remain in the water column for several months. Thus, potential larval dispersal distances could be significant, allowing for a great deal of genetic mixing between distant populations. However, in a study of Atlantic snow crab, Puebla *et al.* (2008) found a genetically distinct subpopulation that was within range of larval drift, and in an area lacking obvious barriers to gene flow via dispersal. Other studies have also detected distinct genetic differentiation occurring in species with apparently continuous distributions (e.g., Taylor and Hellberg 2003, Becker *et al.* 2007), suggesting populations of snow crab in Alaskan waters should not be assumed to undergo continuous gene flow over their entire range.

Objectives

We are combining genetic analysis with data from field observations of adult distributions of *Chionoecetes opilio* in the N Bering, Chukchi, and Beaufort Seas to examine adult population structure and spatial scales of genetic connectivity. Our overall objective is to determine whether populations are truly panmictic, given potential long-distance dispersal of larvae. In addition, we will determine whether planktonic larvae collected from plankton tows can be attributed to source populations, thereby providing a quantitative measure of larval dispersal distance.

Study area and methods

Sampling was conducted in the Chukchi and Beaufort Seas during a series of expeditions from 2007-2009. Several hundred tissue samples of *Chionoecetes opilio* were collected opportunistically in 2007 and 2008, and preserved for genetic analysis. In 2009, whole crabs were collected from the US and Russian sectors of the Chukchi, and will be sized, sexed, and given indices of shell condition prior to removal of tissue samples for genetics. Samples were contributed by J. Lovvorn from the N. Bering Sea, but these samples were later determined to be of poor quality. In place of the Lovvorn samples, additional collections are planned for the central and eastern Bering Sea in summer 2010 on the National Marine Fisheries Service annual trawl surveys. Plankton samples were collected in the Chukchi Sea in 2007 and preserved in ethanol. Planktonic crab larvae will be removed from these samples using a dissecting microscope.

We will use DNA microsatellites to genotype each individual crab for our population genetic analyses, targeting eight previously established microsatellite loci found to be informative in N. Atlantic populations of *C. opilio* (Puebla *et al.* 2003, Puebla *et al.* 2008). Microsatellites are short segments of nuclear DNA composed of tandemly-repeated units a few base pairs in length. These segments are generally neutrally inherited, and undergo high rates of mutation, making them extremely useful in population genetic studies. Microsatellite studies have proven useful in fisheries stock assessments due to their ability to detect differences in genetic identity with high resolution (reviewed in Chistiakov *et al.* 2006). To attain the proper statistical power, sample sizes of at least 40-50 individuals from each site will be targeted (Ryman *et al.* 2006). Both F-statistics and Bayesian statistics will be used to determine whether genetically distinct subpopulations of *C. opilio* exist within the Alaskan portion of its range. Bayesian methods will first be employed which make no a priori assumptions about population structure, but rather define genetic boundaries wherever they may occur in our sampling region. A secondary approach using *F*-statistics will then be used to examine differences between identified populations.

Results

Graduate student Greg Albrecht began work on the project in August 2009. DNA has been extracted from 150 crab samples to provide a working stock of DNA for use in protocol development and preliminary analyses. We have thus far been working to develop the gene amplification protocols, and have nearly completed the necessary trouble-shooting for this phase. All eight microsatellite primers can now be successfully amplified, and amplification conditions are currently being adjusted to maximize efficiency and success rates. We expect to begin genotyping samples *en masse* in late January 2010. Additional field work is planned for summer 2010, and the necessary arrangements have been made for Greg to sample on the NMFS trawl surveys in the Eastern Bering Sea.

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TO/CA No.	Title	PI	Status
35269	**Pre-migratory Movements of Physiology of Shorebirds Staging on Alaska's North Slope**	**Abbie N. Powell** *ffanp@uaf.edu* Institute of Arctic Biology and U.S. Geological Survey, Alaska Fish and Wildlife Research Unit University of Alaska Fairbanks Fairbanks, AK 99775-7020	This report is in the process of being published at CMI.
37357	**Evaluating a Potential Relict Arctic Invertebrate and Algal Community on the West Side of Cook Inlet, Alaska**	**Nora R. Foster** *fyaqua@uaf.edu* Marine Invertebrate Collection University of Alaska Museum of the North 907 Yukon Drive Fairbanks, AK 99557	This report is in the process of being published at CMI.
39380	**Assessment of the Direction and Rate of Alongshore Transport of Sand and Gravel in the Prudhoe Bay Region, North Arctic Alaska**	**A. Sathy Naidu** *ffsan@uaf.edu* Institute of Marine Science University of Alaska Fairbanks Fairbanks, AK 99775-7220	This report is in the process of being published at CMI.
39921	**Synthesis of Time-Interval Changes in Trace Metals and Hydrocarbons in Nearshore Sediments of the Alaska Beaufort Sea: A Statistical Analysis**	**A. Sathy Naidu** *ffsan@uaf.edu* Institute of Marine Science University of Alaska Fairbanks Fairbanks, AK 99775-7220	This report is in the process of being published at CMI.
M0713300/12485	**Satellite Tracking of Pacific Walruses: The Planning Phase**	**Lori Quakenbush** *loriq@ims.uaf.edu* Affiliate Assistant Professor Institute of Marine Science University of Alaska Fairbanks Fairbanks, AK 99775-7020	This report is in the process of being published at CMI.
M07AC13418/ 12506	**Traditional Knowledge Regarding Bowhead Whales in the Chukchi Sea**	**Lori Quakenbush** *loriq@ims.uaf.edu* Affiliate Assistant Professor Institute of Marine Science University of Alaska Fairbanks Fairbanks, AK 99775-7020	This report is in the process of being published at CMI.

CMI Program 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.

Fiscal Year	Program	Students	MMS Funds	Matching Funds
1994	PhD	1	$22,558	$9,220
	M.S.	6	$65,107	$37,411
	Undergrad	1	$4,270	$0
	Source Total		**$91,935**	**$46,631**
1995	PhD	4	$53,061	$9,523
	M.S.	8	$90,367	$64,380
	Undergrad	5	$4,297	$13,933
	Source Total		**$147,725**	**$87,836**
1996	PhD	5	$75,499	$8,499
	M.S.	5	$80,245	$18,661
	Undergrad	2	$4,644	$0
	Source Total		**$160,388**	**$27,160**
1997	PhD	2	$37,714	$0
	M.S.	2	$22,798	$0
	Undergrad	2	$2,610	$0
	Source Total		**$63,122**	**$0**
1998	PhD	2	$17,109	$17,109
	M.S.	2	$26,012	$7,200
	Undergrad	2	$0	$2,548
	Source Total		**$43,121**	**$26,857**
1999	PhD	6	$66,750	$38,073
	M.S.	4	$31,650	$8,730
	Undergrad	4	$0	$10,704
	Source Total		**$98,400**	**$57,507**
2000	PhD	6	$61,383	$30,551
	M.S.	2	$5,868	$10,135
	Undergrad	7	$0	$21,299
	Source Total		**$67,251**	**$61,985**
2001	PhD	2	$19,159	$22,019
	M.S.	1	$0	$5,800
	Undergrad	3	$10,983	$5,761
	Source Total		**$30,142**	**$33,580**

Fiscal Year	Program	Students	MMS Funds	Matching Funds
2002	PhD	3	$48,476	$0
	M.S.	5	$66,676	$7,500
	Undergrad	0	$0	$0
	Source Total		**$115,152**	**$7,500**
2003	PhD	3	$45,032	$12,000
	M.S.	5	$79,448	$7,500
	Undergrad	1	$1,349	
	Source Total		**$125,829**	**$19,500**
2004	PhD	4	$55,365	$15,000
	M.S.	2	$34,715	$0
	Undergrad	0	$0	$0
	Source Total		**$90,080**	**$15,000**
2005	PhD	2	$30,942	$0
	M.S.	2	$6,385	$0
	Undergrad	1	$1,398	$0
	Source Total		**$38,725**	**$0**
2006	PhD	2	$21,132	$6,667
	M.S.	1	$0	$0
	Undergrad	2	$0	$0
	Source Total		**$21,132**	**$6,667**
2007	PhD	0	$0	$0
	M.S.	1	$82,635	$0
	Undergrad	0	$0	$0
	Source Total		**$82,635**	**$0**
2008	PhD	0	$0	$0
	M.S.	2	$124,086	$27,423
	Undergrad	0	$0	$0
	Source Total		**$124,086**	**$27,423**
2009	PhD	0	$0	$0
	M.S.	0	$0	$0
	Undergrad	0	$0	$0
	Source Total		**$0**	**$0**

	MMS	Matching
Totals to Date	**$1,299,723**	**$417,646**

Total CMI Funding

The total MMS funding committed to CMI projects through calendar year 2009 is approximately $15.6 million. Since all CMI-funded projects require a one-to-one match with non-federal monies, total CMI project commitments through calendar year 2009 have totaled approximately $28.2 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	Dept. of Fisheries and Oceans Canada	UAF Institute of Arctic Biology
Alaska Beluga Whale Committee	Exxon Valdez Oil Spill Trustee Council	UAF Institute of Marine Science
Alaska Dept. of Environmental Conservation (ADEC)	Frontier Geosciences, Inc.	UAF International Arctic Research Center (IARC)
Alaska Dept of Fish and Game (ADF&G)	Golden Plover Guiding Co.	UAF School of Agriculture & Land Resources Management
ADF&G – Kachemak Bay Research Reserve	Japanese Marine Science and Technology Center (JAMSTEC)	UAF School of Fisheries and Ocean Sciences
Alaska Dept of Transportation and Public Facilities	Kodiak Island Borough	UAF School of Management
Alaska Science and Technology Foundation	Littoral Ecological & Environmental Services	UAF School of Mineral Engineering
Alyeska Pipeline Service Company	North Slope Borough	University of Alaska Museum
Ben A. Thomas Logging Camp	Oil Spill Recovery Institute	University of Alaska Natural Resources Fund
BP Amoco	Phillips Alaska, Inc.	University of Alaska Southeast
BP Exploration (Alaska) Inc.	Pollock Conservation Cooperative Research Center	University of California, Los Angeles
Canadian Wildlife Service	Prince William Sound Aquaculture Corporation	University of Northern Iowa
CODAR Ocean Sensors	Simon Frasier University	University of Texas
Cominco Alaska, Inc.	University of Alaska Anchorage	Wadati Fund
ConocoPhillips Alaska, Inc.	University of Alaska Fairbanks	Water Research Center
Cook Inlet Regional Citizens Advisory Council	UAF College of Science, Engineering & Mathematics	Woods Hole Oceanographic Institution
Cook Inlet Spill Prevention & Response, Inc.	UAF Frontier Research System for Global Change, IARC	

CMI Publications

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The Department of the Interior Mission

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