Report from CIFAR to NOAA on the second year of Cooperative Agreement No. NA17RJ1224

1 July 2002–30 June 2003

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Overview

The Cooperative Institute for Arctic Research (CIFAR) was established through a Memorandum of Understanding between NOAA and the University of Alaska in April 1994. It is one of eleven national NOAA–University joint institutes. The goal of these institutes is to promote closer cooperation between researchers from NOAA laboratories and universities. CIFAR is the only joint institute exclusively concerned with arctic research and cooperates most closely with NOAA's Pacific Marine Environmental Laboratory (PMEL) in Seattle and the NOAA Arctic Research Office. CIFAR is staffed by a Director, Deputy Director, Administrator and Publications and Meetings Manager. The institute does not have its own scientists, post-doctoral fellows or graduate students.

A new 5-year cooperative agreement began on 1 July 2001. This Annual Report reports on activities conducted during the second year of this cooperative agreement, which includes Amendments 5 & 6. Research supported by CIFAR falls under several general research themes that characterize the scope of interest of the Institute. Thematic emphasis has changed somewhat from year to year but the themes have remained focused on the big problems of arctic research.

CIFAR RESEARCH THEMES

Atmospheric and Climate Research
- *Arctic Oscillation*
- *Arctic clouds and energy balance*
- *Paleoclimates*

Marine Ecosystem Studies
- *Southeast Bering Sea Carrying Capacity (SEBSCC)*
- *Bering Sea productivity*

Tsunami Research

Climate Modeling
- *Coupled models*
- *Model inter-comparisons*

Fisheries Oceanography
- *Global Ocean Ecosystem Dynamics Program (GLOBEC)*
- *Fisheries studies*

Contaminant Effects
- *Arctic pollution*
- *Effects on indicator species*

UV and Arctic Haze Studies
- *Ozone and UV radiation*
- *Arctic Haze*

Hydrographic and Sea Ice Studies
- *Sea ice research*
- *Tides and currents*
- *Ocean fluxes and circulation*

Data Archiving and Support

During the period 1 July 2002 to 30 June 2003, administrative support for the CIFAR office and ACIA Secretariat, and funding for 33 research projects were provided for a total of $4.35M. A full list of these projects is presented in Appendix 1, and a summary is presented in Table 1. In this report, we present progress or final reports from: 1) projects funded through the Arctic Research Initiative; 2) projects funded to address the decline of the western population of Steller's sea lion; and 3) projects funded individually by NOAA addressing CIFAR's research themes.

Table 1: Summary of Projects Funded 1 July 2002–30 June 2003.

Theme	No. of Research Projects	Total Amount
Arctic Research Initiative (Task II)	5	$ 347,411
Research Themes (Task III)	28	
• Fisheries Oceanography	14	$1,228,764
• Tsunami Research	5	$1,064,492
• Marine Ecosystem Studies	4	$ 791,275
• Contaminant Effects	3	$ 350,503
• Hydrographic & Sea Ice Studies	1	$ 50,000
• Data Archiving & Support	1	$ 40,000
Administration (Task I)		
• Core Support		$ 120,000
• ACIA Secretariat		$ 333,000
• Subaward fees		$ 25,200
Total	**33**	**$4,350,645**

Arctic Research Initiative

In FY 2001, CIFAR released an announcement of opportunity for the continuation of the Arctic Research Initiative, a competitive grant program begun in 1997 that addresses topics of interest to NOAA and is managed by CIFAR.

The 2001 Arctic Research Initiative had two research foci. The first was on climate variability and change in the Arctic, emphasizing the transport of freshwater, heat and nutrients to and from the Arctic, and a better understanding of the Arctic Oscillation. The second focus was on the productivity of the Bering Sea, the natural processes regulating productivity and the flow of energy through food webs supporting commercial, subsistence and protected or endangered species.

A total of 12 two-year projects were funded for just over $1M for the first year, with seven projects funded through CIFAR and the remainder funded directly by NOAA. A list of the CIFAR-funded projects is presented in Table 2. Project abstracts are posted on the CIFAR web site, http://www.cifar.uaf.edu. During this reporting period, second year funding was provided to five projects. Reports from the CIFAR-funded projects are included in this document.

Table 2: 2001–2003 Arctic Research Initiative Awards Funded Through CIFAR

PI	Institution	Project Title	Award Yr 1	Award Yr 2
Igor Belkin	Univ. of Rhode Island	Ocean Fronts of the Bering, Chukchi and Beaufort Seas	$ 39,586	
Rosanne D'Arrigo	Columbia Univ.	Paleoclimatic Reconstruction of the Arctic Oscillation	$ 85,946	
Jennifer Francis (with Jeffrey Key, CIMSS)	Rutgers Univ.	Interactions of Laterally Advected Heat and Moisture with Arctic Cloud Properties	$ 67,751	$ 75,004
Lyn McNutt (with James Overland, PMEL)	Univ. of Alaska Fairbanks	Do Recent Changes in Sea Ice and Snow Cover Impact the Arctic Oscillation?	$ 16,912	$ 17,437
Alan Springer	Univ. of Alaska Fairbanks	Trophic Pathways on the Chukchi-Beaufort Shelf: Where do the Ice Algae Go?	$ 208,657	$ 59,804
John Walsh	Univ. of Illinois	An Arctic Archive of Model Output and Application to SEARCH	$ 75,347	$ 77,083
Daqing Yang	Univ. of Alaska Fairbanks	Hydrologic Response of Siberian Major Rivers to Climate Change and Variation	$ 31,325	$ 118,083
Subaward costs	Univ. of Alaska Fairbanks		$ 47,100	
Total			**$ 572,624**	**$ 347,411**

Steller's Sea Lion Research

In FY 2001, NOAA received supplemental funding to provide scientific support for management decisions regarding fisheries and marine mammal interactions in the Gulf of Alaska and Bering Sea. The western population of Steller's sea lion (SSL) has been in decline for several decades and is now considered endangered. There are several possible factors causing this decline. One of these factors is commercial fishing in habitats critical to the SSL, thought to cause a harmful reduction in SSL prey availability. Current management efforts are focused on this factor alone. To determine if other factors might be important in the decline of the western SSL population, NOAA was directed to conduct research focused on two of the other hypothesized factors—impacts of ocean climate regime shifts and changes in predator/prey relationships. The NOAA Office of Oceanic and Atmospheric Research and the NOAA National Ocean Service asked CIFAR to help organize the scientific community to respond to these needs. CIFAR released an announcement of opportunity in February 2001.

A total of 12 projects were funded in this competition during 2001 at a total level of $3.8M for two years, with about $2.5M funded through CIFAR. The list of projects is presented in Table 3. Abstracts for the Steller's sea lion awards are posted on the CIFAR web site, http://www.cifar.uaf.edu, and progress reports from the CIFAR-funded projects are presented in this document. None of these projects were funded during the time frame of this report.

Table 3: 2001–2002 Steller's Sea Lion Research Awards Funded through CIFAR

PI	Institution	Project Title	2-Year Total (Awarded 2001)
Matt Berman (with Jerry McBeath)	Univ. of Alaska Anchorage	Decision-making Under Uncertainty: Management of Commercial Fisheries and Marine Mammals	$ 54,172
Jennifer Burns	Univ. of Alaska Anchorage	The Role of Physiological Constraint in the Acquisition of Foraging Ability: Development of Diving Capacity in Juvenile Steller Sea Lions	$ 153,924
Ken Coyle (with George Hunt, UC Irvine, JIMO)	Univ. of Alaska Fairbanks	Climate-driven Bottom-up Processes and Killer Whale Abundance as Factors in Steller Sea Lion Population Trends in the Aleutian Islands	$ 694,218
Ron Dearborn	Univ. of Alaska Fairbanks	Publication Support for Is It Food II? A Workshop on Steller Sea Lion Declines	$ 23,300
Bruce Finney	Univ. of Alaska Fairbanks	Impacts of Climate Change on the Bering Sea Ecosystem over the Past 500 Years	$ 198,507
Robert Foy	Univ. of Alaska Fairbanks	Seasonal Assessment of Prey Competition between Steller Sea Lions and Walleye Pollock	$ 202,308
Gerald McBeath (with Matt Berman)	Univ. of Alaska Fairbanks	Decision-making Under Uncertainty: Management of Commercial Fisheries and Marine Mammals	$ 65,828
Stephen Okkonen (with Wieslaw Maslowski, Naval Postgraduate Sch.)	Univ. of Alaska Fairbanks	Interannual Variability of Biophysical Linkages between the Basin and Shelf in the Bering Sea	$ 113,340
Thomas Royer	Old Dominion Univ.	Ocean Climate Variability as a Potential Influence on Steller's Sea Lion Populations	$ 192,548
Jan Straley (with Andrew Trites)	Univ. of Alaska Southeast	Predator/Prey Investigations of Killer Whales and Steller Sea Lions in Alaska	$ 32,655
Richard Thorne (with James Churnside, NOAA/ETL)	Prince William Sound Sci. Ctr.	Investigation of the Foraging Behavior of Steller Sea Lions in the Vicinity of Kodiak Island, Alaska	$ 541,200
Andrew Trites (with Jan Straley)	North Pacific Marine Sci. Fdn.	Predator/Prey Investigations of Killer Whales and Steller Sea Lions in Alaska	$ 168,165
Subaward costs	Univ. of Alaska Fairbanks		$ 35,325
Total			**$2,475,490**

Research Themes

Twenty-eight of the projects funded during the period 1 July 2002 to 30 June 2003 were individually funded by NOAA and address CIFAR research themes.

Contaminant Effects

The project "Persistent Organic and Trace Element Pollutants in the Alaskan and Eastern Russian Arctic" addresses the Contaminant Effects theme. It is part of the "Study of Atmospheric Deposition of Contaminants in the Arctic," jointly funded by NOAA and the U.S. State Department. A key scientific objective is to study the sources, occurrence and environmental fate of persistent organic herbicides, pesticides, industrial chlorinate compounds, and aerosol trace elements in the atmosphere of the Alaskan and Eastern Russian Arctic. Air sampling of persistent organic pollutants (POPs) and metals was initiated at Barrow at the NOAA/CMDL station in March 2002 and continuous samples collected to May 2003. Samples have been analyzed for a four-month period (mid-March to mid-July). Preliminary data reveals that the levels of POPs in Barrow air are similar to those reported for the Alert, Tagish and Dunay sampling locations in Canada.

A second study, "Sources of Mercury Reaching the Arctic: Airborne Particulate Mercury in China," was funded this year. Its objective is to quantify the temporal variations in the concentrations of particulate mercury and other aerosol components, such as heavy metals, in Chinese air that could potentially be transported to the Arctic. Results from this study will appear in next year's annual report.

NOAA provided funding through CIFAR to support the activities of the Arctic Monitoring and Assessment Programme (AMAP) Secretariat. Both NOAA and CIFAR have long-standing interests in arctic contaminants research, and in the environmental assessment of contaminants in the Arctic. The award to the AMAP Secretariat continues this joint interest and provides a framework for NOAA, CIFAR and the broader international Arctic science community to work together to provide scientific information to guide public policy actions on contaminant issues.

Fisheries Oceanography

Fourteen projects fall under the Fisheries Oceanography theme. In any given year, the largest number of individually funded projects are usually in this area. The fisheries of the Arctic, particularly the Bering Sea, are among the most productive in the world, and the productivity and sustainability of these fisheries have been the focus of numerous CIFAR-funded research projects. Research focuses primarily on the most important fish stocks in various regions, including salmon and pollock. Key findings from several of these projects are presented below. Several projects are still at the preliminary stages of data analysis.

Funding in this category includes $645,920 for continuing ship support for a Global Ocean Ecosystem Dynamics Program (GLOBEC) project, "Physical-Chemical Structures, Primary Production and Distribution of Zooplankton and Planktivorous Fish on the Gulf of Alaska Shelf: A GLOBEC Monitoring Proposal."

One of the projects focuses on training graduate students. The Alaska Fisheries Science Center of NOAA's National Marine Fisheries Service (NMFS) has agreed to offer fellowship support to University of Alaska M.S. and Ph.D. graduate students in quantitative fisheries science. To date, five students have been supported through this program.

Hydrographic and Sea Ice Studies

The project entitled "Observation and Theoretical Foundation for the Dynamics in a High-resolution Sea Ice Model" is a continuation from CIFAR's last 5-year cooperative agreement. Work in 2002–2003 focused on providing a complete set of processed SAR imagery in support of the buoy data collected as part of the Beaufort Stress Program.

Marine Ecosystem Studies

The Bering Sea ecosystem is among the most productive of high-latitude seas and supports large populations of marine fish, birds and mammals. Fish and shellfish from the region make a significant contribution to the U.S. fisheries harvest and thus to the U.S. economy. Research funded through CIFAR in this area seeks to understand the processes controlling the Bering Sea ecosystem. Four projects were funded under this theme during the reporting time frame. One of these is a small part of a large Southeast Bering Sea Carrying Capacity (SEBSCC) project ("Ecosystem Trends of the Southeastern Bering Sea") which has a NOAA employee as principal investigator and is not reported on here.

The overall objective of the project entitled "Paleoecologic and Paleoceanographic Studies of Marine Bays in Southeast Alaska" is to reconstruct changes in primary productivity, forage fish populations, oceanographic conditions and climate in several Southeast Alaska embayments at decadal or better resolution over the past 500 years. A cruise was conducted in August 2002, cores collected, and detailed analyses of stable isotopic composition, opal, forams and diatoms are in progress. A project entitled "Traditional Ecological Knowledge, Indigenous Observations, and Spatio-Temporal Dynamics of Steller Sea Lion Populations Along the Western Alaska Peninsula and Eastern Aleutians" was submitted to the Steller Sea Lion (SSL) competition in 2001 but not funded with the other SSL awards. Funds became available in 2003 for this interesting project that will be conducted in cooperation with the Aleut Marine Mammal Commission, the Aleutians East Borough, and the local village administrations. Progress will be reported in the 2004 CIFAR Annual Report.

The last of the Marine Ecosystem projects established a new program for training the next generation of scientists by providing graduate and postgraduate fellowships. The School of Fisheries and Ocean Sciences at the University of Alaska Fairbanks formed an agreement with the Alaska Fisheries Science Center of NOAA's National Marine Fisheries Service (NMFS) to provide training and advanced research on issues affecting the sustainability of the Steller sea lion. Following a competitive review process, Pieter DeHart was awarded a 2-year Ph.D. graduate research assistantship that began in January 2003, and Chris Siddon a 2-year postdoctoral appointment to commence in Fall 2003.

Tsunami Research

The threat of tsunami hazards in the North Pacific region makes the prediction of tsunamis generated by large earthquakes highly desirable. Five projects address this research theme. "Tsunami Warning and Environmental

Observatory for Alaska (TWEAK)" is designed to create an integrated observatory for tsunami research aimed toward reducing the hazards in Alaska presented by tsunamis from large earthquakes and undersea landslides, and to provide near-real-time oceanographic fisheries and weather data. TWEAK has three elements. Element 1—Accelerated Alaska Innundation Map Production. High resolution, high quality bathymetric and topographic grids are essential for accurate tsunami modeling, and this element of TWEAK focuses on developing such grids for several different areas of coastal Alaska. Element 2—Earthquake Characteristics and Finite Fault Processes: Diagnostics for Tsunamigenic Potential. This project focuses on implementing a near-real-time moment tensor inversion procedure at the Alaska Earthquake Information Center (AEIC). The goals of Element 3, which is the oceanographic component, are to devise a monitoring array that addresses exchange between the slope and shelf and that can quantify and characterize some of the mesoscale circulation variability in the Northern Gulf of Alaska. The Alaska Tsunami Inundation Mapping Project, related to TWEAK Element 1, established hypothetical tsunami scenarios for the Homer and Seldovia areas, and is working on scenarios for the Seward area. In addition, the AEIC Seismic Station Upgrade and Installation project continues work to install modern digital broadband seismic stations throughout Alaska and to maintain their operation and telemetry.

Key Findings

Below we present key findings from several research projects reported on in this document that are beyond the preliminary data analysis stage.

Arctic Research Initiative

Rosanne D'Arrigo: Paleoclimatic Reconstructions of the Arctic Oscillation

- D'Arrigo and colleagues developed a multiproxy reconstruction of the North Atlantic Oscillation (NAO) dating back to AD1400 based on North Atlantic data, and their findings have been published in the Journal of Climate. This reconstruction can be used to examine the variability of the NAO prior to 20^{th} century greenhouse forcing.
- Greenland Tree-Ring Data: The investigators processed 80 samples of birch from south Greenland, some of the only tree-ring data in existence for Greenland. The chronology dates from 1882–1999 and is significantly negatively correlated with the NAO for winter months.

Jennifer Francis: Interactions of Laterally Advected Heat and Moisture with Arctic Cloud Properties

- This work led to the discovery of significant errors in the wind fields of the NCEP and ECMWF reanalyses. Francis and colleagues computed upper-level winds from surface pressure fields and TOVS-derived thermal winds. Results show that reanalysis winds exhibited biases on the order of half actual wind speeds, while their data show biases near zero in the poleward direction and much reduced in the zonal direction.
- A new upper-level wind data set is nearly complete and will be sent to the National Snow and Ice Data Center for archival and distribution.
- Satellite retrieval techniques developed for the AVHRR Polar Pathfinder (APP) dataset were refined and validated and 18 years of APP data covering the period 1989–1999 were acquired and processed, including surface temperature, surface albedo, cloud properties and radiative fluxes.
- During winter the surface temperature averaged over the polar cap north of 60°N has been decreasing, and the primary contribution is from the central Arctic Ocean. At other times of year, the temperatures have increased.
- Surface albedo has decreased, particularly during autumn. Cloud amount decreased during the winter but increased in spring and summer; net cloud radiative forcing shows no trend.
- A dataset consisting of retrieved surface temperature and albedo, cloud properties and radiative fluxes for the area north of 60°N has been generated and been made available to the public at http://stratus.ssec.wisc.edu/index.html.

John Walsh: An Arctic Archive of Model Output and Application to SEARCH

- An archive of global climate model outputs was constructed for use by the Arctic Climate Impact Assessment (ACIA) and the Study of Environmental Arctic Change (SEARCH) program. The website for the archive is http://zubov.atmos.uiuc.edu/ACIA.
- A study of the projections of sea ice in the Arctic Ocean through 2100 was conducted and published. Model results indicate that the length of the navigation seasons for the Northern Sea Route will increase from the present 1–2 months to 3–6 months by the year 2100.
- The implications of projected climate change for fire season severity in Alaska were examined. Initial findings are that April–May temperatures over the Alaska–Bering and East Siberian regions show the strongest linkage to summer fire severity, with predictive implications for the 2–6 month timescale.

- Another study examined the frequency and intensity of the strongest cyclones in the Arctic. Results indicate that the past two decades have had a disproportionately large fraction of the strong cyclones that have occurred over the Arctic Ocean.
- A “State of the Arctic” website, depicting near-real-time distributions of arctic sea ice, snow cover, temperature, precipitation, and circulation is being designed and implemented. The prototype will be available by the end of 2003, with the final form available in June 2004.

Daqing Yang: Hydrologic Response of Siberian Major Rivers to Climate Change and Variation

- Yang and colleagues identified a significant increase in fall and winter discharge at the outlet of the watersheds during recent decades for the Lena, Yenisei and Ob Rivers. Analyses suggest that this is a consequence of recent climate warming and related to changes in permafrost conditions.
- Annual mean temperature has significantly increased since the mid-1930s in most parts of the Ob basin, eastern Yenisei basin and eastern Lena basin. The greatest increase is found in winter.
- Soil temperature at 40 cm depth over the Russian Arctic and Subarctic has increased approximately 0.9–1.1°C over the past few decades. The increase is particularly pronounced during the winter months, probably due to increase in both air temperature and snow thickness.

Igor Belkin: Ocean Fronts off the Bering, Chukchi and Beaufort Seas

- The first-ever satellite climatology of thermal fronts was produced, based on a unique 12-year (1985–1996) archive of frontal data accumulated and analyzed at the University of Rhode Island. Long-term monthly digital frontal paths for the Bering, Chukchi and Beaufort Seas are available. These frontal paths can be used in numerous studies of spatial distributions of marine life and their temporal variability.

Steller’s Sea Lion Research

Jennifer Burns: The Role of Physiological Constraint in the Acquisition of Foraging Ability: Development of Diving Capacity in Juvenile Steller Sea Lions

- Findings indicate that newborn Steller sea lions have significantly lower oxygen stores than do adults primarily due to restricted oxygen carrying capacity in blood and limited oxygen storage potential in muscle.
- Blood development appears driven by changes in erythropoietin (EPO) that lead to increased levels of red blood cell production in response to tissue hypoxia. The causes for muscle development are not yet clear, but might also be hormonally driven.
- Reduced oxygen storage capacity in young sea lions agrees with similar findings in other pinnipeds, and suggests that the ontogeny of such stores plays a critical role in nutritional independence in sea lions.

Jerry McBeath, Matthew Berman: Decision-making under Uncertainty: Management of Commercial Fisheries and Marine Mammals

- The investigators completed a review of Greenpeace vs. NMFS, a case filed in April 1998 against NMFS claiming that NMFS had failed to issue a comprehensive, programmatic environmental impacts statement for the federal actions it authorized, thus violating the National Environmental Policy Act (NEPA); and that the agency had failed to protect the Steller sea lion against jeopardy and adverse modification of its critical habitat, as required under the Endangered Species Act. A paper is being completed that definitively analyzes the factors influencing the judge’s decision that the agency had violated the laws.
- Forty interviews were conducted with those most knowledgeable about how complex decisions were made concerning the SSL controversy. Two papers are being prepared based largely on these informant interviews.

Tom Royer: Ocean Climate Variability as a Potential Influence on Steller’s Sea Lion Populations

- To determine whether there has been an increase in the number and intensity of storms, pressure data from two buoys in the Gulf of Alaska were analyzed. The data from both buoys suggest that there has been an increase in storminess in both the Gulf of Alaska and the Bering Sea in recent years. Causes are being investigated.
- To determine whether NCEP data could be used to determine changes in the ocean, differences between the NCEP-NCAR reanalysis data and actual observations from the National Weather Service (NWS) and a National Data Buoy Center (NDBC) buoy were determined. They showed that the NCEP-NCAR data were severely lacking in matching trends, means and variances that were contained in NWS and NDBC time-series. The investigators concluded that the NCEP-NCAR data should not be used for regional runoff models.

Stephen Okkonen: Collaborative Proposal: Biophysical linkages between the Bering Sea and Arctic Ocean

- An additional eight-year integration of the coupled 9-km ice-ocean model has been completed, extending the interannual model results available for analysis to cover the 23-year period from 1979–2001.

- Analyses of model results from this 23-year period indicate that the shelf break along the western Gulf of Alaska can be roughly partitioned into three regimes characterized according to the relative strengths of annual and interannual variations in temperature and salinity conditions just above the shelf break:
    a) The strongest annual-period variations in temperature and salinity signals occurred along the shelf break between Prince William Sound and the south end of Kodiak Island.
    b) The strongest interannual temperature variations occurred between the south end of Kodiak Island and Amukta Pass. Amukta Pass is the easternmost major pass through which the exchange between the North Pacific Ocean and Bering Sea occurs. In this region, generally cooler temperatures occurred during the 1980s whereas generally warmer temperatures occurred during the 1990s.
    c) The strongest interannual salinity variations occur west of Amukta Pass. These variations exhibited a periodicity of ~4–5 years and are likely associated with separation of the Alaskan Stream from the Aleutian Island arc.

Bruce Finney: Impacts of Climate Change on the Bering Sea Ecosystem over the Past 500 Years. The long-term goal of this project is to develop a new understanding of the natural variability of organisms at several levels of the food web and their relationships to climatic and oceanographic change.
- Analysis of a 5-meter sediment core from Skan Bay, Unalaska Island, representing an 800-year history, indicates that there were decadal and century-scale fluctuations in primary productivity taking place.
- A NOAA cruise in the Bering Sea allowed the collection of two sediment cores from Captain's Bay, Unalaska Island. These cores represent almost 400 years and also show oscillations in the proxies for primary productivity. Final correlation between the Skan Bay and Captain's Bay cores will be complete this winter.
- Fish scales have been removed from all cores and fish abundances estimated. These abundances are being linked chronologically with productivity and environmental changes throughout the core. Analyses are also underway on cetacean and pinniped bones collected from archaeological sites and from museum collections and will be completed by late winter.

Fisheries Oceanography

Milo Adkison: Relationship between Growth and Survival of Coho Salmon Utilizing the Coastal Gulf of Alaska. The study is designed to increase our understanding of the mechanisms by which processes in the Gulf of Alaska affect coho salmon populations.
- Several hundred adult and juvenile scales have been digitized. Based on juvenile scales from known locations and CPUE data, growth regions corresponding to the early marine, strait, and Gulf of Alaska habitats have been identified.
- Survival of jack and adult males was compared to environmental covariates and found to be related to sea surface temperature and hatchery production of pink and chum fry (a potential prey item). Adult returns were strongly related to jack returns the previous year, implying an early marine determination of survival.
- No statistically significant relationships were found between environmental variables and growth as captured in various regions of the scale.

Brenda Norcross: Processes Affecting Larval Dispersal, Settlement and Juvenile Habitat of Flatfishes. The main purpose of this project is to find a pattern in the life histories of flatfish that will provide insight for managers and researchers.
- Comprehensive analysis of juvenile flatfish data showed that juveniles of nine species of flatfish can be separated into two groups according to spawning location—shelf spawners and slope/deepwater spawners. Shelf spawners tend to spawn in the spring, and slope/deepwater spawners do so in the winter.
- Shelf spawners have larvae that develop quicker, are small at hatch, and have a more direct transport process to nursery grounds.
- Slope/deepwater spawners have larvae that develop slower, are bigger at hatch, and have a much more complicated transport process.
- Settlement characteristics differ for the two groups, but not as much as the dispersal characteristics. Newly settling juveniles of shelf spawners are smaller and settle in shallower, warmer water. Newly settling juveniles of slope/deepwater spawners are bigger and settle in deeper, cooler water.

Milo Adkison: Early Marine Growth and Survival of Bristol Bay Sockeye Salmon Smolt. The main objectives of this study is to determine if Bristol Bay sockeye salmon production is influenced by early marine growth rates, and to identify the relationship between environmental conditions and early marine growth of juvenile sockeye salmon. Preliminary results indicate that:

- Sea surface temperatures within the Eastern Bering Sea can influence the width and extent of juvenile sockeye salmon distribution and migration.
- Migration rates of juvenile sockeye salmon may affect their early marine growth.
- Early marine growth rate may affect survival rate of juvenile salmon during their ocean residence.

Additional research will focus on developing early marine growth models using historical growth data collected from adult Bristol Bay sockeye salmon scales. Future models of early marine growth and production will incorporate both abiotic and biotic mechanisms thought to be responsible for impacting early marine growth of Bristol Bay sockeye salmon.

A.J. Gharrett: Origin of Juvenile Chum Salmon Collected during ABL-OCC Cruises in the Eastern Bering Sea 2002. The main purpose of this project is to determine the geographic origin of juvenile chum salmon collected in the eastern Bering Sea during the fall 2002 ABL-OCC. Results indicate that:

- Chum salmon from Kotzebue Sound, the northernmost region of primary distribution in North America, were only recovered off the mouth of the Yukon River, implying a southward migratory pathway near the coast.
- Both fall and summer Yukon River stocks were recovered in all three sampled locations, suggesting a southwestward migration resulting in a broad distribution along the eastern Bering Sea shelf.
- Kuskokwim River stocks were primarily restricted to the south Nunivak Island collection following a westward migratory path.

Publications and Presentations

During the current reporting period, 13 peer-reviewed papers and one non-peer-reviewed paper from projects receiving their funding through CIFAR under cooperative agreement NA17RJ1224 were published. An additional five papers were reported as in press, and 16 were described as submitted or in preparation. Twenty-seven presentations were made at national and international meetings. One of these presentations was judged Best Student Poster at the 11th Annual PICES Meeting. *Note: These numbers do not include presentations or publications from Arctic Research Initiative and Steller's sea lion projects funded at NOAA laboratories, other federal agencies, or through other joint institutes.*

A number of projects funded under our previous cooperative agreement, NA67RJ0147, also reported publication activity, with 18 peer-reviewed publications (including four by NOAA investigators) and three non-peer-reviewed publications.

See Appendix 2 for a complete list of publications from the reporting period.

Project Reports:
Arctic Research Initiative

***Final Report*:** **Ocean Fronts of the Bering, Chukchi and Beaufort Seas**

***Principal Investigator*:** Igor M. Belkin, University of Rhode Island

Objectives

The main goal of the project was to produce an up-to-date climatology of all major fronts of the study area and explore the seasonal and interannual variability of the frontal pattern and individual fronts as well as their relations to environmental parameters. Both satellite and in situ data had to be used. Main objectives of the project could be summarized as follows:

1. Surface thermal fronts detection and mapping from satellite SST data.
2. Long-term seasonal climatology of SST fronts from satellite data.
3. Assembling a dataset of cross-frontal hydrographic sections.
4. Determination of fronts from the hydrographic sectional database.
5. Tracking major fronts of the Bering Sea in the alongshelf direction from Bristol Bay toward the Bering Strait and into the Chukchi Sea.
6. Interannual variability studies of major fronts; detection of possible climatic trends.
7. Elucidation of relations between fronts and environmental parameters (bottom topography, sea ice cover, air temperature, river runoff, Bering Strait transport, and wind stress) on a variety of scales, from seasonal to interannual to decadal.

Methods

Satellite SST data from AVHRR sensors flown on NOAA satellites have been processed using the front detection and cloud screening algorithms developed at the University of Rhode Island (Cayula and Cornillon, 1995; 1996; Ullman and Cornillon, 2000). The front detection algorithm uses a histogram approach at three levels (window, image and a sequence of overlapping images). For each window or image that contains a front (a relatively narrow zone of enhanced SST gradient), the corresponding SST histogram would have a minimum identified with the front. Two types of maps are used in the analysis: *long-term frontal* *__frequency maps__* and *quasi-synoptic frontal* __composite maps__. The long-term frontal *__frequency maps__* show the pixel-based frequency F of fronts normalized on cloudiness: For each pixel, F=N/C, where N is the number of times the given pixel contained a front, and C is the number of times the pixel was cloud-free. Thus, the frequency maps are best suited for displaying the most stable fronts. Some fronts, however, meander and shift, thus defying their presentation with frequency maps, in which case quasi-synoptic frontal *__composite maps__* are most helpful because they portray all the fronts detected in synoptic SST fields within a given time period.

Main Results

<u>Mapping SST fronts from Pathfinder data in the Bering, Chukchi and Beaufort Seas</u>

Surface thermal fronts have been detected from individual twice-daily SST images with 9-km resolution, then composed into monthly frontal maps. For each of the three seas a set of 144 monthly frontal composite maps, from January 1985 through December 1996, has been produced and analyzed, as well as a set of 12 long-term monthly frontal frequency maps. A computer graphics package was written in Matlab 6.5 to facilitate front tracing and visual correlation with bottom relief, other environmental variables, and biological species distributions. The seasonal visibility window of surface fronts is determined by seasonal ice cover and varies from 7 months in the Bering Sea to two months in the Chukchi and Beaufort Seas. The recent decrease of the seasonal Arctic sea ice cover has increased the seasonal visibility window. For example, this year (2003) the Chukchi Sea and the southern Beaufort Sea were largely ice-free in early July. The Bering Sea features the richest frontal pattern, up to 16 fronts in May. The Chukchi Sea has up to 7 fronts in August. In the Beaufort Sea, a robust shelf-break front is clearly visible in August–September.

<u>Long-term seasonal climatology of SST fronts</u>

__Bering Sea__. Since the Bering Sea has significant ice cover from December through April, SST fronts can only be unambiguously identified from May through November (Figure 1). In <u>May</u>, several fronts (#1–9) extend from Bristol Bay to Cape Navarin. The fronts are not strictly isobathic as postulated by Coachman (1986). They are located over shallow depths (~50 m) in Bristol Bay but continue over the outer shelf (100–200 m depth) farther west. Shallow fronts are observed off the Alaskan coast, #10 off Kuskokwim Bay (persists through November) and #11 in Shpanberg Strait and off Norton Sound (disappears by October). Shallow fronts (#12–13) are observed off the Anadyr Gulf; front #13 persists through November. Fronts #14–15 are associated with the Kamchatka Current

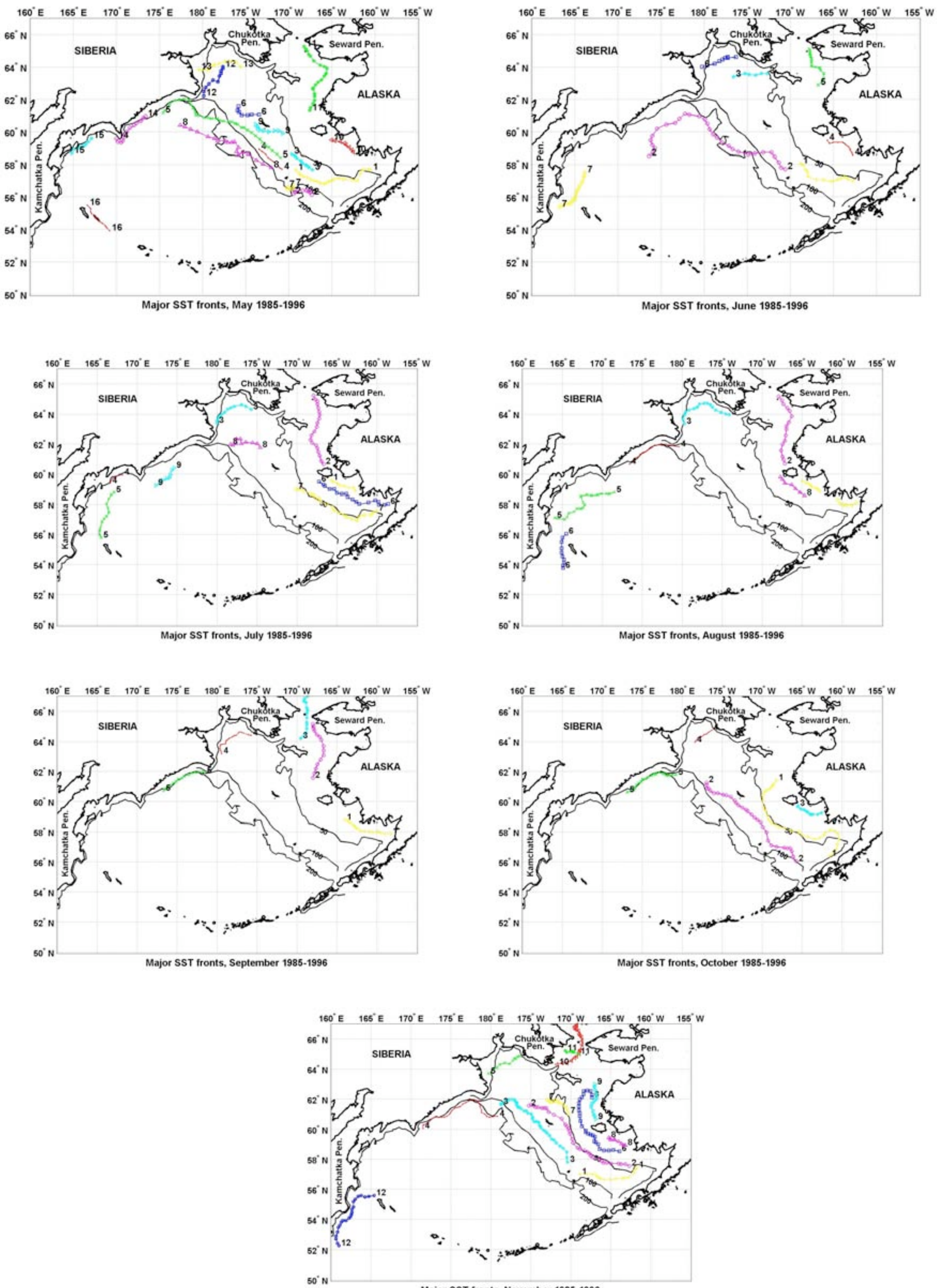

Figure 1. SST fronts in the Bering Sea, May through November (1985–1996).

that flows along the shelf break off the Koryak Coast and off Karaginsky–Olyutorsky Bays. Front #16 hugs Komandorsky Islands. In June, shallow fronts persist off Kuskokwim Bay, Norton Sound, and the Anadyr Gulf (#4–6). The slope front (#2) is markedly non-isobathic. In July, the Norton Sound–Shpanberg Strait Front (#2) reaches south to Nunivak Island. Three shallow fronts (#1,6,7) emerge in Bristol Bay. In August, the entire Alaskan coast is rimmed by inner shelf fronts (#1,2,7,8). A seasonal shelf-break front (#5) develops off the Koryak Coast that persists through November. In September, the Norton Sound–Shpanberg Strait Front (#2) begins its retreat to the north, whereas the Kuskokwim–Bristol Bay front remains intact. The Bering Strait front (#3) connects the Bering Sea to the Chukchi Sea. In October, the inner shelf front (#1) appears along the 50-m isobath while the mid-shelf front (#2) extends along the 70–80-m isobath. Both fronts persist through November (#2 and #3 respectively), when they are joined by a 30-m isobath front (#6) and shallow fronts off Kuskokwim Bay (#8) and north of Nunivak Island (#9), whereas two fronts in the northwest correspond to the northward Anadyr Current (#5) and southward Kamchatka Current (#4), both being branches of the Bering Slope Current.

The main results outlined above can be summarized as follows: Five types of SST fronts have been detected over the Eastern Bering Shelf and Slope, associated with certain depths, namely (1) slope front (200 m and deeper); (2) mid-shelf front (70–80 m); (3) inner shelf front (50 m); (4) upper shelf fronts (30 m) and (5) coastal fronts (10–20 m). The Norton Sound–Shpanberg Strait front, Kuskokwim front and Bristol Bay front are seasonally persistent. In the western Bering Sea, the Koryak–Kamchatka front and especially the Anadyr Gulf front are most robust. The entire frontal pattern changes notably on a monthly scale. Most fronts are not strictly isobathic.

Chukchi Sea. The Chukchi Sea is ice-free in August and September**,** when up to 7 fronts are distinguished (Figure 2). Fronts #1–2 are associated with the Bering Strait inflow that makes an incursion into Kotzebue Sound and along the Siberian coast. Farther north, a front (#4 in August, #5 in September) extends zonally toward Point Barrow. Another front (#5 in August, #6 in September) hugs the steep southern flank of Herald Shoal. The front associated with the Chukotkan segment of the Siberian Coastal Current (#2 in August, #3 in September) veers offshore to pass through Herald Valley east of Wrangel Island, then continues eastward between 71–72°N north of Herald Shoal. Another coastal front (#4) is observed between Wrangel Island and the Siberian coast in September.

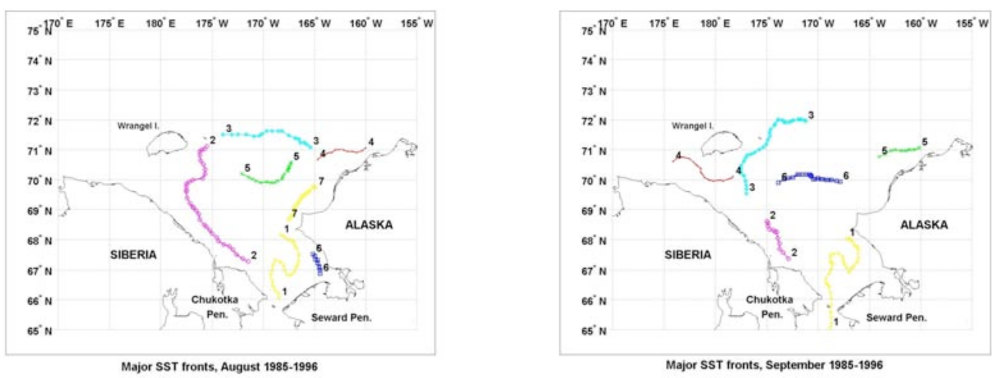

Figure 2. SST fronts in the Chukchi Sea, August through September (1985–1996).

Beaufort Sea. The Beaufort Sea fronts are detected in August–September**,** when the southern part of the sea is ice-free (Figure 3). The shelf-break front (#1) is robust, especially in September. This front stability is at maximum near 128–130°W, NW off Cape Bathurst, where the continental slope is the steepest, suggesting a strong topographic control. It is noteworthy that this region of maximum stability of the shelf-break front coincides with the Cape Bathurst Polynya and also with the maximum concentration of marine life, specifically marine mammals. A shelf front NW of Mackenzie River estuary (#2) is likely related to the Mackenzie Plume.

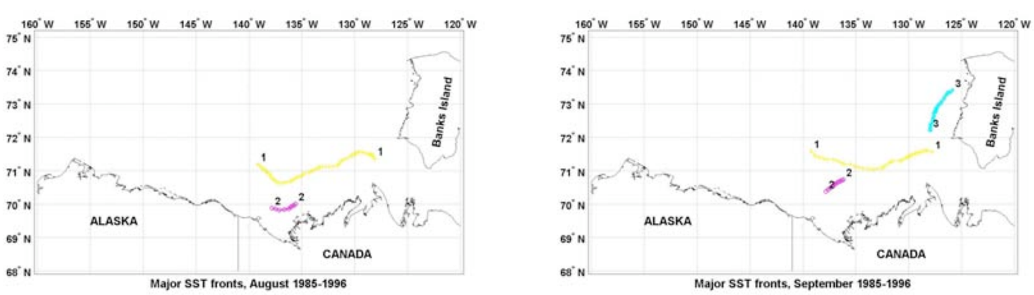

Figure 3. SST fronts in the Beaufort Sea, August through September (1985–1996).

Conclusions

The first-ever satellite climatology of thermal fronts has been produced, based on a unique 12-year (1985–1996) archive of frontal data accumulated and analyzed at the University of Rhode Island. Long-term monthly digital frontal paths for the Bering, Chukchi and Beaufort Seas are available in a simple and easy-to-use format from the PI, upon request. These frontal paths can be immediately used in numerous studies of spatial distributions of marine life and their temporal variability, from phyto- and zooplankton to fish to sea birds and marine mammals.

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Publications and Presentations Resulting from this Work

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Belkin, I.M., P.C. Cornillon and D.S. Ullman. 2003. Ocean fronts around Alaska from satellite SST data. Proceedings of the American Meteorological Society 7th Conf. on the Polar Meteorology and Oceanography, Hyannis, Massachusetts, Paper 12.7, 15 pp.

Belkin, I.M., P.C. Cornillon and D.S. Ullman. 2003. Fronts of the Arctic/Subarctic Marginal Seas from Pathfinder SST data. Presented at the Arctic Forum–2003, Arlington, Virginia, April 28–29, 2003.

Belkin, I.M. 2003. Fronts of the Alaskan Seas. Presented at the Institute of Ocean Sciences, Sidney, British Columbia, June 3, 2003.

Belkin, I.M. 2003. Fronts of the Bering, Chukchi, and Beaufort Seas (*in preparation*).

***Progress Report*:** **Paleoclimatic Reconstructions of the Arctic Oscillation**

***Principal Investigators*:** Rosanne D. D'Arrigo and Edward R. Cook, Lamont-Doherty Earth Observatory; Michael E. Mann, University of Virginia

Objectives

Please note: The funding for this grant was not received at Lamont until spring of 2002, and was not received at the University of Virginia for the Mann subcontract until fall, 2002. We therefore requested a no-funds extension for this grant. Our results are not as extensive as those originally planned due to our receiving only one year of funding rather than the two originally proposed.

Over the past year of funding we have accomplished several of our major goals in developing extended paleoclimatic reconstructions of the North Atlantic Oscillation/Arctic Oscillation/Annular mode.

These research efforts include the development of a reconstruction of the North Atlantic Oscillation (NAO) dating back to AD1400 based on North Atlantic sector proxy data. This study has just been published in the Journal of Climate (Cook et al., 2002). A related paper is also in press which is a chapter in a forthcoming volume of the proceedings of the AGU Chapman Conference on the NAO which was held in Vigo, Spain in November 2000 (Cook, in press).

Summary of Cook Papers

A new, well-verified, multiproxy reconstruction of the winter North Atlantic Oscillation (NAO) index is described that can be used to examine the variability of the NAO prior to 20th century greenhouse forcing (Cook, in press; Cook et al., 2002). It covers the period AD1400–1979 and successfully verifies against independent estimates of the winter NAO index from European instrumental and non-instrumental data as far back as 1500. The best validation occurs at interannual time scales and the weakest at multidecadal periods. The result is a significant improvement over previous proxy-based estimates, which often failed to verify back to 1850, and is related to the use of an extended reconstruction model calibration period that reduced an apparent bias in selected proxies associated with the impact of anomalous 20th century winter NAO variability on climate teleconnections over North

Atlantic sector land areas. Although 20th century NAO variability is somewhat unusual, comparable periods of persistent positive-phase NAO are reconstructed to have occurred in the past, especially before 1650.

The use of this reconstruction for identifying and characterizing long-term teleconnections between the NAO and other climate reconstructions must be done carefully. Because of the extended nature of the North Atlantic proxy network used here, long proxy reconstructions of associated climate variables, like precipitation over Morocco or the lower Mississippi Valley, cannot be compared to our multiproxy reconstruction without the danger of circularity. However, it should be useful for examining potential proxy-based teleconnections in more distant regions of the world potentially affected by the NAO and Arctic Oscillation (AO). And, provided that multiproxy reconstructions of other ocean-atmosphere processes like ENSO are based on completely independent data, it will be possible to look for relationships and interactions between these important internal global forcings.

A related topic of research and discussion is the optimality of the NAO indices presently in usage. Exploring this theme, J. Marshall of MIT (pers. comm.) has noted that the Azores High and Icelandic Low are at times decoupled, with distinct behavior. The two centers of action appear to lose coherence at low frequencies, and may be controlled by different dynamical processes. This finding suggests that there is potential value in reconstructing these elements separately (rather than using only the traditional NAO index) to learn about their distinct patterns of variability in relation to the NAO (and AO). Recent studies by E. Cook of the TRL suggest, in fact, that eastern North American proxies (even from the midwestern USA) may be critically important for reconstructing the Azores High component of the NAO. The Azores High/Icelandic Low were reconstructed independently from tree-ring chronologies in Europe and North America, along with the NAO index itself. Each reconstruction has significant ($p<0.01$) skill when compared to long instrumental pressure data from Europe. These results are a “proof of concept” test of the feasibility of reconstructing the NAO centers of action independently and will be investigated in more detail in future work.

Greenland Tree-Ring Data

As originally proposed, we have now processed approximately 80 samples of birch (*Betula* spp) from south Greenland, collected for us by M. Arsenault, University of New Hampshire. These are some of the only tree-ring data in existence for Greenland, a region of key importance to Atlantic studies related to the Icelandic Low, NAO and AO. Our previous analyses indicated a significant correlation between the only previously published tree-ring record for Greenland by Kuivenen and Lawson and a preliminary tree-ring chronology we have produced for Iceland. The new chronology dates from 1882 to 1999 and is significantly (negatively) correlated with the NAO for the winter months.

A reconstruction of Arctic Oscillation related temperatures since AD1650 has been developed and a related paper has been published (D'Arrigo et al., 2003, *Geophysical Research Letters*):

> *Abstract:* Arctic Oscillation (AO) changes are inferred from a tree-ring reconstruction of a warm-season temperature index. The reconstruction covers AD 1650–1975 and is based largely on chronologies from circumpolar-Arctic and circum-North Atlantic areas. It accounts for 48% of the variance in the instrumental AO record from 1900 to 1975, verifies using independent data, and exhibits its largest variance at low frequencies. Positive levels during 20th century periods equal or exceed values back to AD 1650. Trends (including lower values during Little Ice Age periods) resemble those of Arctic temperature reconstructions, reflecting some data overlap, but also the strong link between the AO and northern temperatures. A reconstruction of an AO summer sea level pressure index shows similar trends. Comparison of these reconstructions with proxies of the North Atlantic Oscillation (NAO) and other indices can help clarify relationships between the AO and NAO, at least during the boreal warm season.

Another paper related to this grant has been submitted to JGR (Cook et al.). This manuscript examines phenological modeling applications related to the statistical simulation of the influence of the NAO on European winter surface temperatures. Preliminary application of this model to a climate change scenario involving an increasing NAO 50 years into the future suggests the potential for a 3 to 12 day advancement to the start of the growing season.

Publications

Cook, B.I., M.E. Mann, P. D'Odorico and T.M. Smith. Statistical simulation of the influence of the NAO on European winter surface temperatures: applications to phenological modeling. Submitted to *Journal of Geophysical Research*.

Cook, E., R. D'Arrigo and M.E. Mann. 2002. A well-verified, multi-proxy reconstruction of the winter North Atlantic Oscillation index since AD1400. *Journal of Climate* 15: 1754–1764.

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D'Arrigo, R., E. Cook, M.E. Mann and G. Jacoby. 2003. Tree-ring reconstructions of temperature and sea-level pressure variability associated with the warm-season Arctic Oscillation since AD1650. June 03, 2003. *Geophysical Research Letters* 30(11): 1549. doi:10.1029/2003GL017250.

D'Arrigo, R., E. Cook, M.E. Mann and G. Jacoby. 2003. Tree-Ring reconstructions of Arctic Oscillation indices since AD 1650. Abstract, ARCUS 15th Annual Meeting and Arctic Forum. Arlington, Virginia, April 28–29, 2003.

***Progress Report*: Interactions of Laterally Advected Heat and Moisture with Arctic Cloud Properties**

Principal Investigator: Jennifer Francis, Rutgers University (collaborative with Jeffrey Key, NOAA/NESDIS)

Other Participating Researchers: Steven Ackerman and Jeffrey Key, NOAA/NESDIS; Elias Hunter, Rutgers University; Xuanji Wang, University of Wisconsin

Objectives

Our overriding hypothesis is: The patterns of heat and moisture transport into and within the Arctic basin have changed significantly during the past 20 years, and they are strongly linked to changes in surface parameters, cloud properties, and the AO. The specific objectives of the proposed study are:

1. Compute the advection of sensible heat and moisture over the Arctic basin from 20 years of TOVS Polar Pathfinder soundings of temperature and moisture, and upper-level wind fields. Poleward and zonal components of transport will be computed for each season and in three thick layers of the troposphere. Rutgers.
2. Perform spatial and time-series analyses on fields of advective heat and moisture transport to identify statistically significant regional changes during the 20-year data record, particularly comparing the pre- and post-1989 periods when other parameters appear to exhibit a significant shift in regime. Rutgers.
3. Compute cloud fractions and bulk microphysical cloud properties in selected regions and time periods with largest advective changes. NOAA/NESDIS/U. Wisconsin (CIMSS)
4. Investigate extent to which observed spatial and/or temporal variability in advective fluxes and cloud characteristics are related to variations in the AO. Rutgers and CIMSS
5. Examine cloud properties in areas of large advective change to identify likely linkages with heat and moisture transport. Compare these relationships to those in areas where advective fluxes exhibit no significant trends. Rutgers and CIMSS
6. Determine the source(s) of observed changes. Are observed trends or discontinuities in the heat (moisture) advection patterns caused by changes in the thickness (water vapor) gradients and/or changes in the wind field, and do these factors differ with region, season, and/or height? Can differences in cloud properties be attributed to changes in moisture convergence? Rutgers and CIMSS

Methods and Accomplishments

Objective 1: As explained in our original proposal, we intended to evaluate the accuracy of upper-level wind fields over the Arctic using rawinsonde data from two field experiments that we had recently discovered were not ingested into either the NCEP or ECMWF reanalyses, and thus represented independent observations. This task revealed significant errors in the reanalysis wind fields, and a paper in *Geophysical Research Letters* was written and published documenting the results. Unfortunately this left us in a predicament, as we could not trust the advected heat and moisture fields that we had calculated with these wind fields. With no alternative for obtaining sufficiently accurate winds, we commenced an effort to compute our own upper-level winds from surface pressure fields and TOVS-derived thermal winds. Fortunately, parallel efforts had been recently underway to produce winds in the Southern Ocean by C.-Z. Zou and M. Van Woert at the National Ice Center. They developed a mass-conservation technique for TOVS-derived winds, which we are adapting for use in the Arctic. While the adaptation has not been straightforward owing to the blocking effects of Greenland, I am pleased to report that the results, while not yet complete, are very encouraging. We found that reanalysis winds exhibited biases on the order of half the actual wind speeds, while our biases are near zero in the poleward direction and much reduced in the zonal direction. An AMS conference paper was written and presented on this effort, and I expect to write a peer-reviewed journal paper soon. This detour from our primary objectives has been time consuming and has delayed the achievement of follow-on tasks, but I am confident it will result in a data set that will be valuable not only to this project but to the Arctic climate community. At present we are completing the new wind fields (to be submitted to NSIDC for archival), which will pave the way to recalculating advection fields. This can proceed quickly, as the codes are already in place.

Objective 2: Trends, correlations, and cross-correlations had been computed using advective fields produced with reanalysis winds, but they will have to be recomputed with the new-and-improved fields. Preliminary results reveal intriguing patterns in 20-year wind trends, so we expect to see interesting behavior in the advected quantities, as well.

Objective 3: Satellite retrieval techniques developed for the AVHRR Polar Pathfinder (APP) dataset have been refined and validated. Retrieved parameters are surface temperature, surface albedo, cloud properties (particle phase, effective radius, optical depth, temperature, and pressure), and radiative fluxes. Data from the SHEBA experiment and two Antarctic meteorological stations have been used for validation. Eighteen years of APP data have been acquired and processed. The twice-daily, monthly, and seasonal products cover the period 1989–1999 at a spatial resolution of 25 x 25 km^2. Trends in surface temperature and albedo, cloud properties, and radiative fluxes, as well as their statistical significance, have been investigated. During winter the surface temperature averaged over the polar cap north of 60°N has been decreasing, and the primary contribution is from the central Arctic Ocean. At other times of the year temperatures have increased. Surface albedo has decreased, particularly during the autumn months. Cloud amount has decreased during winter but increased in spring and summer. Interestingly, although there are trends in the shortwave (cooling) and longwave (warming) cloud radiative forcing (CRF), the net (all-wave) CRF shows no trend. This results from the similar magnitude of the two opposing components in conditions of bright surfaces with low sun angles.

Objective 4: Time series of APP surface temperature and cloud amount have been compared to the Arctic Oscillation (AO) and North Atlantic Oscillation (NAO) monthly indices using cross-correlation analysis. Consistent with results in literature, the satellite data show that when the AO and NAO are in their high phases, Greenland is colder than normal and northern Europe is warmer than normal. As soon as TOVS-derived advective quantities are recomputed, a similar analysis will be performed with these parameters.

Objective 5 and 6: Ongoing.

Additional accomplishments:

1. A dataset consisting of retrieved surface temperature and albedo, cloud properties, and radiative fluxes for the area north of 60°N has been generated. Products include twice-daily and monthly images and means. The data and read routines are now available to the public from http://stratus.ssec.wisc.edu/index.html.

2. A new upper-level wind data set is nearly complete, and will be packaged for archival and distribution by the National Snow and Ice Data Center.

Publications Supported by or in Part by this Grant

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Francis, J.A. 2002. Observations of the arctic atmosphere for assimilation by and validation of models: new data sets, new problems, and new solutions. Workshop on Sea Ice Data Assimilation, Annapolis, Maryland, 23–24 July 2002.

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Progress Report: Do Recent Changes in Sea Ice and Snow Cover Impact the Arctic Oscillation?

***Co-Principal Investigator*:** S. Lyn McNutt, University of Alaska Fairbanks

***Other Participating Researchers*:** James Overland, NOAA/PMEL (primary PI for overall project; can be contacted for further information)

Methods and Main Results

This fiscal year has focused on analysis of sea ice data for the Western Arctic Ocean (Beaufort and Chukchi Seas) in support of the project PI, Dr. James Overland, NOAA, PMEL. These data analyses include:

- NOAA Advanced Very High Resolution Radiometer Data for 1989–1998 and 1980–1988;
- Polar Pathfinder data sets for TOVS, SSM/I and AVHRR; and
- A detailed dataset of Synthetic Aperture Radar (SAR) data for1997–1998 during the SHEBA field experiment.

The Co-I, Lyn McNutt, worked on interpretation of the snow and ice data, and contributed to discussions of the case selections, compositing methodology, and interpretation of the results.

Progress Report: Trophic Pathways on the Chukchi–Beaufort Shelf: Where do the Ice Algae Go?

***Principal Investigator*:** Alan M. Springer, University of Alaska Fairbanks

***Other Participating Researchers*:** C. Peter McRoy, University of Alaska Fairbanks; Sara J. Iverson and Suzanne Budge, Dalhousie University

Objectives

The goal of this project is to identify trophic pathways of ice algae on the Chukchi–Beaufort continental shelf using fatty acid biomarkers to trace carbon flow through the Arctic food web. Fatty acid biomarkers are used to differentiate between the two types of primary production, ice algae and spring bloom algae, consumed by organisms at higher trophic levels, specifically, Arctic cod, black guillemots, bearded and ringed seals, bowhead whales, walruses and polar bears. This, in turn, will allow us to delineate the trophic pathways of sea ice algae and its importance to those consumers.

Methods

Samples were collected over a seven-day period from May 6–12 off Barrow, Alaska in 2003. Ice algae were obtained from cores, while large volumes of water from under the ice were filtered to obtain algae from the water column. Fauna, including copepods, amphipods, polychaetes, ctenophores and ciliates, were collected with nets deployed under the ice. Amphipods recovered from the stomachs of Arctic cod were also collected in August of 2002. Lipid extraction was performed on all sample types with a modified Folch et al. (1957) method (Parrish, 1999) using chloroform and methanol, followed by fatty acid methyl ester formation with BF_3. Individual fatty acids were determined using gas chromatography (GC).

In addition to the samples from Barrow, our collaborator Gay Sheffield collected ice algae, zooplankton, planktivorous seabirds, and blubber samples from walruses and ringed, spotted, ribbon, and bearded seals in May 2003 from Little Diomede Island in Bering Strait. This is the second year she has made collections there and those data will be compared to data from Barrow to assess geographical/environmental effects on ice algae food webs.

Main Results

We have just completed the second and most important of our spring field collections and thus are just beginning many of the analyses. To date, all samples of algae and fauna collected in Barrow in 2003 have been extracted but have not yet been quantified by GC.

Fatty acid analyses of amphipod samples collected from the stomachs of Arctic cod have been completed. These animals serve as an important link between the base of the food web and higher consumers. Their fatty acid signatures were typical of amphipods, with elevated levels of 18:4n-3, 20:5n-3 and 22:6n-3. Unusually high levels of n-7 fatty acids (20:1n-7 and 22:1n-7) in *Onisimus* sp. and *Acanthostepheia behringiens* indicated extensive feeding of those species on ice algae. Principal component analyses of all 5 species of amphipod demonstrate that the species may be differentiated by fatty acid composition but, when plotted with algae fatty acid data, suggest that more complex methods using quantitative fatty acid signature analysis (QFASA) will be necessary to determine relative contribution of ice algae and water column phytoplankton to the diets of these amphipods. Such modeling will begin this summer.

Fatty acid analyses of ringed and bearded seals collected in 2002 have been completed. Most of the adult bearded seal blubbers contained unusually high levels of 18:1n-7 and 20:1n-7, similar to that seen in zooplankton and possibly indicating a more direct link than ringed seals to lower trophic levels. Diets of both ringed and bearded seals will be modeled with QFASA this summer when fatty acid signatures of their potential prey species have been determined. Fatty acids signatures of Arctic cod have also been determined and these will be used in modeling diets of black guillemots. Lastly, the fatty acid composition of blubber from bowhead whales and walruses will be quantified this fall and modeled in a similar way.

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***Progress Report*:** **An Arctic Archive of Model Output and Application to SEARCH**

***Principal Investigator*:** John E. Walsh, University of Illinois

***Other Participating Researchers*:** William L. Chapman and Michael S. Timlin

Objectives

The project has two main objectives: (1) Construction of an archive of global climate model output for the Arctic, designed for use in ACIA and SEARCH, and (2) Diagnosis synthesis of this model output for climate change applications relevant to ACIA and SEARCH. A third objective, added to the project during the past year for use in SEARCH, is the design and implementation of a “State of the Arctic” website, which contains near-real-time visualization products and other information on the current state of the major atmospheric, cryospheric and ocean surface variables in the Arctic.

Methods and Main Results

The output of global models for ACIA and have been assembled through contact persons and center-specific archives of global model simulations spanning a recent “control” period (1981–2000) and a greenhouse-driven simulation of the 21st century (2001–2100). For consistency and for compatibility with ACIA scenario requirements, the primary archive is based on B2-scenario simulations. However, we have also retrieved monthly grids of temperature and precipitation from the corresponding A2 simulations in order to meet ACIA needs concerning sensitivity to the choice of scenario.

The website for the archive is accessible at http://zubov.atmos.uiuc.edu/ACIA/. The archive consists of monthly and daily output from five coupled global climate models (GFDL, HADCM3, CCCma, MPI/ECHAM4 and NCAR/CSM). The website includes an inventory of available variables (monthly and daily) as well as visualization capabilities for the primary fields (temperature, precipitation, sea ice). One portion of this website that has been delayed (and will be completed under a requested no-cost extension) is the inclusion of corresponding “validation” fields that will allow the calculation of biases in the models' control simulations. These validation fields will be from the recently completed ERA-40 reanalysis, for which the credibility of model-derived physical fields (precipitation, cloudiness, radiative fluxes, turbulent fluxes, etc.) promises to be considerably greater than in the NCEP reanalysis (M. Serreze, pers. comm.). The ERA reanalysis was sent by ECMWF to NCAR in June 2003. Availability to the research community is scheduled for late summer 2003.

During the past year, we served as the ACIA liaison with ACIA authors who requested output for specific applications in ACIA. Approximately 35 requests were filled during the past year [ed. note: an Appendix summarizing the information provided by William Chapman, the archive designer and maintainer, was submitted with this report and is on file at CIFAR]. In addition, Chapman assisted in the maintenance of a parallel website at the Swedish Meteorological and Hydrological Institute (SMHI). This site was discontinued in early 2003, at which time we entrained the requests from European ACIA authors.

Our work on the diagnostic applications of the climate model output has been ongoing on several fronts:

(1) We have undertaken a study of projections of sea ice in the Arctic Ocean through 2100. The methodology included adjustments (by month, longitude and model) for the biases in the present-day distributions of sea ice simulated by the various models. The results have been published by Walsh and Timlin (2003, *Polar Research*). Results of this study have also been incorporated into Chapters 5 and 15 of the ACIA Draft Report (June 2003). We are continuing this work in collaboration with Lawson Brigham (Arctic Research Commission), who has enabled us to extend the results to the arena of Arctic marine navigation. Our initial focus has been on the Northern Sea Route, for which the model results indicate that the length of the navigation season will increase from the present 1–2 months to 3–6 months by the year 2100. We are in the process of preparing a paper on the marine navigation application for climatic change.

(2) In collaboration with Paul Duffy and Dan Mann of the University of Alaska Fairbanks, we have been examining the implications of projected climate change for fire season severity in Alaska. The study has two main components: (a) Documenting linkages between a yearly Alaskan fire severity index, major teleconnection indices of the atmospheric circulation (Pacific Decadal Oscillation, Pacific–North American pattern, Eastern Pacific index, Arctic Oscillation, etc.), and Alaskan climatic indices (temperature and precipitation); and (b) Synthesizing model projections of 21st-century changes in the indices and other climatic variables most relevant to Alaskan fire severity. Initial findings are that April–May temperatures over the Alaska–Bering and East Siberian regions show the strongest linkage to summer fire severity in Alaska, with predictive implications for the 2–6 month timescale. The springtime fluctuations of temperature (and precipitation) over Alaska appear to be associated with fluctuations of the Eastern Pacific teleconnection pattern. The results of the first portion of the study are described in a recently submitted paper by Duffy et al. (2003).

(3) In response to a need expressed frequently during the ACIA report preparation, we have undertaken a study of extreme events in the Arctic, beginning with an examination of the frequency and intensity of the strongest cyclones in the Arctic. This examination is being made using NCEP reanalysis output and the daily output from the five ACIA-designated global climate models. The results from the NCEP reanalysis indicate that the past two decades have had a disproportionately large fraction of the strong cyclones that have occurred over the Arctic Ocean. We are evaluating the impact of the input data stream (i.e., Arctic buoy network) on this preliminary finding. The results are scheduled for presentation at the AAAS Arctic Science Conference in September 2003. Projected changes in intense cyclones, especially in the context of a changing sea ice cover, will be evaluated from the climate model output over the next several months.

(4) An additional task that has been added to our project is the design and implementation of the "State of the Arctic" website, depicting near-real-time (current through the most recent month) distributions of Arctic sea ice, snow cover, temperature, precipitation and circulation. The displays are fully colorized maps of both the actual fields and the departures from normal, together with time series diagrams showing the recent evolution of the anomalies. This task is being coordinated with the displays at the NOAA Arctic Web Page (managed by Jim Overland and Nancy Soreide at NOAA/PMEL). This task was not in our original proposal, and we began work on it in May 2003. We expect to have a prototype website available for comments by the end of 2003. After obtaining feedback from users, we will have the final version, including the capability for automated updates, in a fully functional form by June 2004.

Publications

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***Final Report*:** **Hydrologic Response of Siberian Major Rivers to Climate Change and Variation**

***Principal Investigator*:** Daqing Yang, University of Alaska Fairbanks

***Other Participating Researchers*:** Tingjun Zhang, NSIDC; Hengchun Ye, California State University Los Angeles; Xuebin Zhang, Meteorological Service of Canada

Objectives

The primary objective of this project was to investigate the hydrologic response of major Siberian rivers to climate change and variation. We have constructed and analyzed long-term records of temperature, precipitation, snowcover, active layer depth, river discharge, ice thickness, and Arctic Oscillation (AO) index to conduct our research on the following three key aspects:

- *Investigating regional hydrologic change*. This includes a) quantifying the annual and seasonal freshwater fluxes to the Arctic Ocean from the Lena, Ob and Yenisei rivers and their inter-annual variation and long-term trends; b) developing river ice thickness climatology and examining its relation to winter low-flow for the river basins.
- *Identifying regional climate variation and trends*. This includes a) defining climatologies, trends and variability of monthly and yearly temperature, precipitation, snowcover, active layer depth, and shallow ground water storage; b) applying comprehensive statistical methods to selected key variables to identify the major spatial variation patterns and their temporal changes at different time scales.
- *Examining atmosphere-land interactions*. This includes a) multiple-correlation analysis of river runoff and ice thickness with key atmospheric circulation index (e.g., AO), temperature, precipitation, soil moisture, snow cover, active layer depth, and shallow ground water storage; b) identifying important climatic and atmospheric control factors to regional hydrological changes; and c) quantifying lengths of memory of different variables (temperature, precipitation, snowcover, etc.) and their impact on inter-annual variation of river discharge.

Methods

During the last two years, we have focused our effort on dataset developments and analyses. We have acquired long-term monthly records for temperature, precipitation, snow cover, ground temperature, active layer depth, river discharge, and river ice thickness for the three large watersheds. We also obtained AO index and SST data for the northern Atlantic and Pacific oceans. We used statistical approaches to examine the observational evidence of associations between river discharge and atmospheric and terrestrial variables, such as air temperature, precipitation, snowcover, timing and duration of the active layer depth, river ice thickness, and AO index.

Main Results

<u>Hydrology Component</u>

We identified remarkable changes in the hydrologic regime of the Lena, Yenisei and Ob rivers. A significant increase in fall and winter discharge at the outlet of the watersheds has been found during recent decades for all three rivers, particularly for the Yenisei basin. An earlier start of snowmelt period toward mid May was found in the Lena basin. A decrease of river ice thickness has also been detected for the Lena River (Yang et al., 2002). A shift of the Ob River's maximum monthly discharge from spring snowmelt period towards summer season (July, August and September) has also been discovered. Our analyses of influences of atmospheric and climatic variables on seasonal and annual discharge changes and variations suggest that changes in river discharge of large Siberian rivers are the consequence of recent climate warming and are also related to changes in permafrost conditions (Yang et al., 2002).

Human activities, such as changing land surface and building large dams, influence the hydrologic regime and its change. We have collected information necessary to document large dams in the northern river basins, including their size, year of completion, and ways of operations. We found that peak discharge in the Lena River has been reduced by 20–30% and low flow has been significantly increased by 50–60%. As a result, the discharge trend derived from the observed records has been underestimated in summer and overestimated in winter (Ye et al., 2003). Winter discharge increase may also impact river ice condition. These results suggest the need for more research attention to the human dimension of arctic environment changes.

Climate Component

1). Temperature: Based on long-term global climatic data sets, our analyses show that annual mean temperature has increased since the mid-1930s in almost all of the three basins. Statistically significant trends are observed in most parts of the Ob basin, eastern Yenisei basin and eastern Lena basin. The greatest increase was found in winter. Significant warming during winter (over 4°C) during 1936–1995 was found in the southern Ob and Yenisei basins, and eastern Lena basin. The greatest warming during spring is over 3°C for the 1936–1995 period in the northwestern Ob basin, southeastern Yenisei basin, and eastern Lena basin. Summer temperature shows significant warming trends in a small area of the eastern Ob basin, the northeastern Yenisei basin, and eastern Lena basin. Fall temperature shows significant positive trends in most of the southern Ob basin and southeastern Yenisei basin. It is apparent that the warming in winter contributed most to the positive trend in the annual mean daily temperature.

2). Precipitation: Lena basin annual precipitation significantly decreased by about 20% during 1936–1995 in a small area over the northeast and no significant increase trends were found. Winter shows significant increasing trends in the north, and spring shows no significant trends. Summer shows significant negative trends in the northern Lena basin, and fall has significant positive trends over a very small area in the north. Yenisei River annual precipitation significantly decreased by 20–30% during 1936–1995 in part of the southern region. Winter and fall show some significant positive trends in the north, and spring shows positive trends in the east. Summer shows significant negative trends in the northern and central area, and winter and fall also have similar trends over a very small area in the south. Ob basin annual precipitation increased by 10–30% during 1936–1995 over the western part of the basin. Among the four seasons, significant increase trends are only found in winter, as high as 70–90% increases over the southern Ob basin. Significant decrease trends are found in the northeastern Ob basin.

3) Snowcover: Maximum snow depth shows large inter-annual and inter-decadal variations over all three basins during the study time period of 1936–1995. Significant increasing trends in maximum annual snow accumulation are found in the Ob and Lena basins, with the most significant increases over the last 30 years (Ye et al., 2003a). The increased snow cover partially contributed to the increased runoff in melting seasons (Ye et al., 2003a).

Permafrost Component

1). Permafrost Distribution: Based on data from the International Permafrost Association's *Circum-Arctic Map of Permafrost and Ground Ice Conditions,* we conducted statistics on permafrost distribution over major arctic river basins. Results indicate that the permafrost fraction increases from the western Russian Arctic region to the eastern Russian Arctic region. The Ob River basin has the smallest permafrost fraction; approximately 4–10% of the basin is underlain by permafrost. The Yenisei River basin has about 36–55% of its area under permafrost. The Lena River basin has the largest permafrost fraction, 78–93% (Zhang et al., 2003). Existence of permafrost has significant impact on the surface water budget. For example, mean runoff ratios (runoff vs. precipitation) in the colder and permafrost-dominated Yenisei and Lena river basins are higher (0.41–0.55) than for the warmer and largely permafrost-free Ob River basin (0.26).

2). Soil Temperature: Soil temperature at 40 cm depth over the Russian Arctic and Subarctic has increased approximately 0.9–1.1^{o}C over the past few decades. The increase is particularly pronounced during the winter months, probably due to the increase in both air temperature and snow thickness. Increase in soil temperature implies thawing and degradation of permafrost over the study area (Zhang et al., 2003). Future work is needed to better understand the thermal status of soils and permafrost over various parts of the river basins.

3). Active Layer Thickness: Based on ground-based measurements from 11 stations over the Lena River basin, maximum thickness of the active layer increased by about 30 cm between the late 1960s and mid 1980s. Increase in maximum active layer thickness increases water storage capacity, thus partitioning the surface water budget. Our work continues to detect changes in active layer thickness over the large basins and to investigate their impacts on river runoff change (Zhang et al., 2003).

4). Impact on River Runoff: Recent studies (Yang et al., 2002; Ye et al., 2003) show that runoff over the Siberian arctic drainage basin in the past several decades has increased substantially, especially during the cold season (October–April). This research indicates that changes in the active layer and permafrost dynamics may play a key role in the recent changes in the Arctic hydrological regime. Our estimation suggests that thawing of 30 cm of the active layer would produce sufficient water to account for the increase in the runoff over the major Siberian river basins. The length of thaw season is also increased. Increase in the length of thaw season and thickening of the active layer delay the freeze-up date of the active layer. Late freeze-up date of the active layer may partly explain the increased runoff during winter months (Zhang et al., 2003).

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Project Reports:
Steller's Sea Lion Projects

***Progress Report*:** **The Role of Physiological Constraint in the Acquisition of Foraging Ability: Development of Diving Capacity in Juvenile Steller Sea Lions**

***Principal Investigator*:** Jennifer M. Burns, University of Alaska Anchorage

***Other Participating Researchers*:** David C. Pfeiffer, University of Alaska Anchorage

Objectives

By studying the development of sea lion physiological status, and then linking it with diving behavior (determined by the National Marine Fisheries Service and Alaska Department of Fish and Game), this project will advance our understanding of how physiological limitations imposed by age and body size might affect activity patterns and foraging strategies. In addition, this research will reveal whether rates of physiological and behavioral development are tailored to meet specific life history patterns or instead limit them. Data obtained from sea lions will be compared with that from other pinnipeds in an attempt to determine when sea lion juveniles are physiologically ready to become independent. Ultimately, this research may offer insight into those factors that influence juvenile survival and recruitment.

Methods

To investigate the development of the physiological dive capacity of juvenile Steller sea lions we measured blood and muscle oxygen stores. We also studied changes in biochemical and histochemical characteristics of muscle to determine how these criteria may change with development and how they influence dive ability. Juvenile animals ranging in age from 5 to 22 months (n=46) captured by the Alaska Department of Fish and Game and the National Marine Mammal Laboratory in Southeast Alaska, Prince William Sound, and the Aleutian Islands were sampled for this study.

Blood oxygen stores were calculated using hematocrit (Hct), hemoglobin (Hb), and plasma volume determined by the Evans Blue dye method (ICSH, 1973; Kooyman et al., 1980; Foldager and Blomqvist, 1991; Ponganis et al., 1993; El-Sayed et al., 1995). Erythropoietin (EPO), a hormone that stimulates red blood cell production in response to tissue hypoxia (Brunner et al., 1992; MacDonald et al., 1995), was analyzed to investigate what may be driving some of the changes in oxygen stores. EPO was analyzed using a Radioimmunoassay (RIA) kit from Diagnostic Systems Laboratories.

Muscle oxygen stores were calculated using total muscle mass, determined by complete dissection of four 1-month old Steller sea lions pups, and myoglobin content in swimming and non-swimming muscles in juveniles (Kanatous, 1997). Myoglobin varies significantly between swimming and non-swimming muscle in adults (Kanatous, 1997). To get an accurate estimation of total myoglobin load we sampled two different muscles, pectoralis (the primary swimming muscle) and latissimus dorsi (a superficial non-swimming muscle) from over 40 animals from 6 different age classes.

Muscle development was investigated through immunohistochemistry and validated with traditional histochemical staining techniques (Dearolf et al., 2000; Stegall, 2001). This analysis allowed us to determine the fiber type profile of swimming versus non-swimming muscle and whether the ratio of these fiber types changed with development. Biochemical profiles included determination of enzyme activity in muscle tissue of one glycolytic enzyme, lactate dehydrogenase, and two oxidative enzymes, citrate synthase and β-Hydroxyacyl-CoA dehydrogenase (Castellini and Somero, 1981; Reed et al., 1994).

Main Results

Since we received permit authorization to conduct the research on juvenile sea lions, we have been busy with field collection. Over 40 animals have been sampled within the last 8 months (Table 1). Blood oxygen stores have been determined for 33 animals ranging in age from 5 to 22 months. Mass specific blood volume did not change through the first year of life, but was significantly lower in animals less than 2 years when compared with adult females ($p<0.05$). Hematocrit and Hb seem to be the factors that contribute most to changes in blood oxygen store development, increasing until reaching values similar to adults around 10 months of age. Muscle biopsies for determination of muscle oxygen stores have been collected from 38 animals ranging in age from 5 to 29 months. Preliminary results indicate that even at 2 years of age muscle myoglobin has not yet reached adult values. In combination with the blood data this indicates that not only does muscle development lag that of blood, but also juvenile animals may be limited in their dive ability due to decreased oxygen storage potential of muscle.

Our investigations into EPO have been very successful. We have validated that the RIA kit can be used to determine EPO concentration in Steller sea lions, and have produced the first EPO values for any free-ranging otariid. To date, we have measured EPO in 235 Steller sea lions ranging in age from 1 month to 3 years. Results indicate an inverse relationship with Hct ($p<0.001$), and no relationship with blood volume. There were significant changes in EPO concentration throughout development ($p<0.001$), with values elevated in early development that generally decreased through the first year. Analysis also revealed an unexpected difference in EPO concentration among populations. EPO tends to be lower in declining populations ($p<0.01$) than in stable, increasing populations. Since there are no regional differences in hematocrit, this suggests other factors may also be influencing EPO levels.

Table 1: Age of Steller sea lion juveniles sampled for CIFAR project since November 2002 when permits were obtained

	Age in Months						
Location	**5**	**9**	**10**	**17**	**21**	**22**	**29**
Southeast AK	12			11			3
Kodiak AK		9					
Aleutian Islands AK			7		2	2	

In addition to the muscle biopsies taken from free-ranging animals, muscle samples were also collected from 3 stranded adult Steller sea lions off the coast of Alaska, 6 sub-adults harvested by the Native communities of the Pribilof Islands, and 3 juveniles culled as a part of predator control program in Canada. These samples will be used to compare muscle development of yearlings and juveniles from our biopsied animals with older juveniles and adults. Biochemical and histochemical profiles of muscle tissue are underway, but have not been completed for juvenile samples. Preliminary results of the oxidative and glycolytic enzymes in 1-month-old pups indicate that while adults show significant differences in the concentrations of enzymes in swimming versus non-swimming muscles, pups show no difference ($p>0.05$). Adults tend to have higher concentrations of oxidative enzymes in swimming versus non-swimming muscles (Kanatous, 1997). This in conjunction with higher myoglobin loads in swimming muscles indicates that these muscles have a higher aerobic capacity. We expect histochemical profiles of muscle will mirror the differences observed in enzyme concentrations between different muscle types since distinct fiber types tend to produce these enzymes at different rates. For example, slow oxidative type fibers produce more oxidative enzymes than fast glycolytic fibers.

Collectively, our findings indicate that newborn Steller sea lions have significantly lower oxygen stores than do adults primarily due to restricted oxygen carrying capacity in blood and limited oxygen storage potential in muscle. Blood development appears driven by changes in EPO that lead to increased levels of red blood cell production in response to tissue hypoxia. The causative factors for muscle development are not yet clear, but might also be hormonally driven. Hypoxia inducible factor-1 is responsible for activating the transcription of EPO in response to low oxygen tensions (Gassmann and Wenger, 1997). This transcription factor is also responsible for stimulating many other proteins that are involved in tissue response to hypoxia (Semenza, 1999) and therefore may play a role in the development of muscle oxygen stores. Additional conclusions about muscle development await the results from biochemical testing. Overall, the reduced oxygen storage capacity in young sea lions agrees with similar findings in other pinnipeds, and suggests that the ontogeny of such stores plays a critical role in the transition to nutritional independence in sea lions, as it likely does in other species.

While not part of this project per se, our SSLRI-funded project that examines the diving patterns of juvenile SSL has shown that SSLs younger than 10 months perform only limited behaviors suggestive of foraging, while some animals older than a year make longer and deeper dives, and longer and more distant trips away from the rookeries. Since longer and deeper dives have increased post-dive surface intervals, juvenile sea lions are utilizing diving oxygen stores in qualitatively the same manner as older age classes. These findings suggest that many physiological changes necessary for diving and foraging occur within the first year of life, but that development continues through at least 2 years of age.

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***Progress Report*:** **Climate-driven Bottom-up Processes and Killer Whale Abundance as Factors in Steller Sea Lion Population Trends in the Aleutian Islands**

***Principal Investigator*:** Kenneth O. Coyle, University of Alaska Fairbanks

***Other Participating Researchers*:** George L. Hunt, University of California Irvine; Sue Moore, NOAA/NMML; Steve Zeeman, University of New England; Phyllis Stabeno, NOAA/PMEL

Note: The principal investigators listed above were funded under separate contracts from various agencies. They will therefore submit individual reports as required by their organizations and funding sources. However, since this research is a cooperative effort, parts of their contributions to the overall project appear in this report.

Background

Steller sea lions are large pinnipeds that breed along the west coast of North America from California to the Pribilof Islands in the north and westward along the Aleutian Archipelago. The western population, extending from Kodiak Island through the western Aleutian Islands, has undergone a steady decline since the mid 1970s. Due to the decline, the western population has been listed as an endangered species and the new listing has required severe restrictions on the groundfish fishery in regions where the sea lions breed and forage. The potential negative impact of these restrictions on the fishery has generated an immediate need to clarify the potential causes for the Steller sea lion population declines. The current working hypotheses for the declines are the following:

1) Commercial fisheries are out-competing the Steller sea lions for the supply of available forage fish in the western part of the range.

2) Predation by killer whales on sea lions has increased mortality and lowered the survival of sea lion pups and juveniles.
3) Climate cycles in the North Pacific and southern Bering Sea have resulted in substantial declines in ecosystem productivity, thus lowering the overall food base for the Steller sea lions.

Recent studies of the population biology of Steller sea lions in the western portion of their range suggest that the population trajectories of sea lions may vary with rookery location. In the vicinity of Unimak Pass and the eastern Aleutian Islands, populations are holding their own or increasing slowly, whereas in the central Aleutians, population trends are still strongly downward. This spatial variation in the population trends of sea lions provides the opportunity to compare a variety of environmental variables in the two regions, and provides the possibility of identifying the factors responsible for the differences in these trends. This research tests the second and third hypotheses by measuring production indices and whale populations in the Akutan–Unimak area, where sea lion populations are steady or increasing, and in the Seguam–Amukta area, where the populations are in rapid decline. The research objectives are as follows:

Objectives

1) Measure the current flow and water column structure in the Akutan–Unimak and Seguam–Amukta regions.
2) Determine the location and intensity of frontal systems associated with the passes.
3) Measure primary production in and around the above two regions.
4) Measure zooplankton abundance and distribution in both regions relative to the frontal structure and distribution of water masses.
5) Generate acoustic measures of the distribution of forage fish and micronekton in both regions relative to frontal structure and water masses.
6) Estimate the abundance of apex predators (birds and mammals) in both regions.
7) Estimate the abundance of killer whales in both regions.
8) Obtain lipid samples from killer whales to determine their primary prey in both regions.
9) Compare the results of the above measurements in each region to identify consistent differences that would indicate climate and/or killer whale effects on the Steller populations.

This report deals with the zooplankton and acoustic components, objectives 4 and 5.

Methods

Since this report deals mainly with the zooplankton and acoustic components, I will restrict my presentation of the methods to that portion of the project.

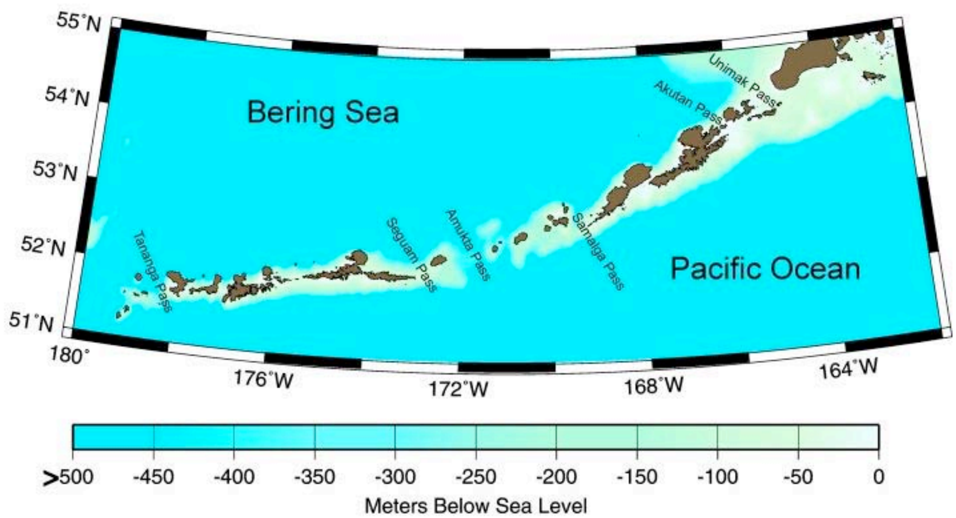

Figure 1. Major passes surveyed in the eastern and central Aleutian Islands during June 2001 and June 2002.

Two cruises have been completed. During year 1, June 4–June 24 2001, samples were collected in Unimak, Akutan and Seguam passes. During year 2, May 16–June 19 2002, samples were collected in Unimak, Akutan, Umnak, Samalga, Amukta, Seguam and Tananga passes (Figure 1). During year 1 a total of 128 MOCNESS samples and 78 CalVET samples were collected. During year 2, 230 MOCNESS and 82 CalVET samples were collected. A detailed cruise report on our year 2 effort is available from Hunt (the chief scientist for the cruise) on request. His e-mail address is glhunt@uci.edu.

Sample processing and data entry for all samples listed above have been completed. The methods for zooplankton sample collection and processing are outlined below.

Large zooplankton and micronekton were collected with a 1-m^2 MOCNESS equipped with 500-μm mesh nets. The MOCNESS has eight nets, which can be opened at discrete depths to provide information on the abundance and species composition of organisms in specific scattering layers identified by the acoustic equipment. Samples were collected in 20-m depth increments from 100 m to the surface. The MOCNESS simultaneously collected data on salinity, temperature, fluorescence, depth, net angle, volume sampled, time and GPS position.

Small zooplankton were collected with a 9-cm diameter CalVET net system. The CalVET was equipped with 150-μm mesh nets towed vertically from the bottom to the surface. Samples were taken from 100 m to the surface at stations deeper than 110-m depth. The CalVET system was equipped with General Oceanics digital flowmeters to record volume filtered.

The samples were preserved in a 10% formalin seawater solution. The zooplankton samples were processed as follows: Each sample was poured into a sorting tray and large organisms, primarily shrimp and jellyfish, were removed and enumerated. The sample was then sequentially split using a Folsom splitter until the smallest subsample contained about 100 specimens of the most abundant taxa. The individual taxa were identified, staged, enumerated and weighed. Each larger subsample was examined to identify, enumerate and weigh the larger, less abundant taxa. The CalVET samples were subsampled with a Stempel pipet to produce subsamples with about 100 specimens of the most abundant taxa. Blotted wet weights of all specimens of each taxa and stage were taken for each sample and the coefficient of variation in average wet weight was computed. If the coefficient of variation for any given taxa and stage changed by less than 5% when additional weights were taken from subsequent samples, wet weights were no longer measured for that taxa for that cruise and the wet weight biomass was estimated by multiplying the specimen count by the mean wet weight. In practice, only calanoid copepods had consistent wet weights after weighing each taxa and stage in about 10–15 samples. Therefore, wet weights on euphausiids, shrimp and other larger taxa were measured and recorded for each sample individually. Wet weight measurements were done on a Cahn Electrobalance or Mettler top loading balance, depending on the size of the animal. All animals in the samples were identified to the lowest taxonomic category possible. Copepodid stages were identified and recorded. The data were uploaded to a Microsoft Access database for sorting and analysis. Analysis will be done with standard statistics software.

Acoustic surveys were done through each pass to document large-scale distributional patterns of zooplankton and micronekton. Acoustic data were collected with a Hydroacoustic Technology Inc. (HTI) model 244 split-beam digital system. In year 1, the system included the following transducers: 43 kHz 6º split beam, 120 kHz 6º split beam, 200 kHz 3º split beam, 420 kHz 6º single beam. In year 2 the 43 kHz transducer was replaced with a 38 kHz transducer and the 420 kHz single beam transducer was replaced with a 420 kHz split beam transducer. The system multiplexes through each transducer collecting simultaneous 20 and 40 log R data for both integration and target strength determination. The transducer array was towed beside the vessel 3 m below the surface at about 6 knots. The data were integrated at 15-second time intervals and 1-m depth intervals. GPS time and position from the ship's navigation system were appended to each record before writing the data to disk. During year 2 the 38 kHz transducer failed. This failure compromised our ability to discriminate fish targets from zooplankton targets. However, during year 2, in addition to the HTI equipment, we were deploying a SciFish broadband acoustic system, which was multiplexed with the HTI system. The broadband system measured the frequency response between 110 and 190 kHz for all detected targets in the upper 200 m. The broadband system used in the capacity is experimental. Nevertheless, the data may permit us to discriminate between fish and zooplankton targets, despite the failure of the 38 kHz transducer.

The acoustic system was also deployed during each MOCNESS tow. The simultaneous collection of acoustic and net data will aid in the interpretation and scaling of the acoustic transect data.

Main Results

Preliminary results for the MOCNESS data are currently available for years 1 and 2. Additional analysis will be undertaken to incorporate the CalVET data in the analyses. The study area in the eastern and central Aleutian archipelago included Unimak, Akutan, Umnak, Samalga, Amukta, Seguam and Tananga passes (see Figure 1). MOCNESS, CalVET, CTD and acoustic transects were run through the passes to the north or south, depending on the current. Flow through the passes generated distinct frontal regions, particularly on the north side. The frontal region in the central passes (Amukta, Samalga, Tananga) was characterized by a sharp change in surface temperature from colder unstratified water in the passes to warmer stratified conditions north of the passes. Changes in temperature at the front were accompanied by distinct changes in salinity and density associated with the frontal region. The higher salinity and colder temperatures observed in the central passes indicate upwelling generated by flow through the passes. The upwelling intensity was related to the size and depth of the pass. Shallower, narrower passes had stronger currents and more intense mixing associated with turbulence. Higher water column stability in the frontal regions relative to the passes was characterized by elevated water column fluorescence, indicating higher phytoplankton concentrations in the front relative to water in the pass to the south.

Highest abundances of the major copepod and fish taxa occurred primarily in the frontal region at the north end of the passes. Lower densities of the copepods *Neocalanus plumchrus*, *N. flemingeri* and *Eucalanus bungii,* and Pollock larvae, *Theragra chalcogramma*, were observed in the high density, upwelled water in the passes. Elevated volume scattering was observed north of the passes in the frontal regions. Elevated volume scattering is generally associated with elevated concentrations of zooplankton, including copepods. Elevated concentrations of zooplankton, in particular oceanic copepods (*N. plumchrus, N. flemingeri, N. cristatus, E. bungii*), were noted in the frontal regions. In 2002, the oceanic euphausiid *Euphausia pacifica* was present in the central passes.

Hydrography in the eastern passes was more characteristic of shelf conditions. A well-developed seasonal thermocline over the south Aleutian shelf was characterized by elevated surface temperatures and lower salinity. Temperature was elevated in the passes due to mixing of water above and below the seasonal thermocline. High water column salinity and density on the north side of the passes indicated intrusion of Bering Sea basin water onto the shelf. Elevated fluorescence was observed above the thermocline south of the passes and in regions of elevated salinity over the shelf break on the north end of the passes. Euphausiid scattering layers were commonly observed in the eastern passes. The dominant euphausiid species was *Thysanoessa inermis*, a species characteristic of deep regions on continental shelves. Abundance and biomass of the major zooplankton taxa was dominated by copepods. In contrast to the central passes, the copepod community in the eastern passes was dominated by the shelf species *Calanus marshallae* in addition to the ubiquitous species *Metridia pacifica* and *Eucalanus bungii*, which were observed in both eastern and central passes.

Tasks Remaining for Completion

1) Analysis of CalVET net data. The CalVET data contains the smaller zooplankton component.
2) Complete analysis of the MOCNESS for 2002.
3) Develop software for analysis of broad band acoustic data. This includes data extraction software and neural net software to relate the acoustic signatures to major taxa in the MOCNESS net samples. As the broad band is experimental equipment and the analysis procedures are under development, the outcome of the analysis is uncertain.
4) Complete analysis of the HTI narrow band acoustic data. The failure of the 38 kHz transducer during the cruise makes analysis problematic. Information from task 3 above may help interpret the narrow band data.
5) Manuscript preparation. Prepare a manuscript for the Sea Lion special issue in Fisheries Oceanography being organized by Allen Macklin at PMEL. The first draft should be ready for submittal in September.
6) Prepare a presentation for the special session on the Aleutians at the ASLO meeting in February.

***Progress Report*:** **Impacts of Climate Change on the Bering Sea Ecosystem over the Past 500 Years**

***Principal Investigator*:** Bruce P. Finney, University of Alaska Fairbanks

***Other Participating Researchers*:** Amy C. Hirons and Alan M. Springer, University of Alaska Fairbanks

Objectives

1. To reconstruct changes in primary productivity of the Bering Sea at decadal or better resolution over the past approximately 500 years.

We will study cores from two locations to insure that regional changes are determined. We will also use multiple productivity proxies to develop a robust interpretation. We will also measure δ^{13}C on bone collagen from Steller sea lions to evaluate changes in marine primary production.

2) To reconstruct relative changes in populations of forage fish at similar resolution to the records produced in objective 1.

Utilizing box and piston cores previously collected in Skan Bay, we are reconstructing high-resolution records of forage fish abundances through previous funding. Preliminary data from Skan Bay demonstrate the high potential for yielding excellent long-term data. To determine if the record from Skan Bay is representative of a larger region, we will also analyze sediment cores from one or more locations in the Aleutian Islands.

3) To determine paleoceanographic changes in factors such as ocean temperature, salinity, and nitrate utilization for the cores discussed above.

4) To determine any changes in the trophic position of Steller sea lions.

5) To synthesize our results with available paleoclimatic, paleoceanographic and paleoecological data, and with retrospective and modern process studies in the North Pacific and Bering Sea.

Ultimately, we will develop a new understanding of natural variability of organisms at several levels of the food web (phytoplankton, zooplankton, forage fish, salmon, marine mammals) in this region, and their relationships to climatic and oceanographic change. This long-term perspective is necessary to evaluate the recent changes, and to better understand the scales and processes of ecosystem change in this region**.**

Results

In an effort to reconstruct the paleocean productivity of the Bering Sea, we have collected and analyzed a 5-meter sediment core from Skan Bay, Unalaska Island. We have δ^{13}C data, carbon content and percent opal (from diatoms), all of which are proxies for primary productivity. Reconstruction of productivity from analysis of organic carbon mass accumulation rate and δ^{13}C ratio of organic matter is strongly controlled by photosynthetic rate. Diatoms are generally the dominant primary producers in this region and the silica (opal) preserved in their tests give a good indication of their abundances through time. These data all indicate there were decadal and century-scale fluctuations in productivity taking place. Calibration of AMS and Pb-210 dating of the core indicates it represents almost 800 years.

Many recent studies have shown that the δ^{15}N ratio of marine organic matter is related to the δ^{15}N of the nutrient pool, which in turn is controlled by nitrate supply (e.g., Altabet and Francois, 1994). The δ^{15}N analysis is complete and the data for the Skan Bay core was more consistent than the δ^{13}C data over its length. However, the nitrogen data did have a few significant declines that may coincide with certain paleoclimatic events.

Fish scales have been removed from both the Skan Bay and Captain's Bay cores and forage fish abundances estimated. These abundances are being linked chronologically with productivity and environmental changes throughout the core. Scales are being dated to corroborate the age and sedimentation rates of both sediment cores. Foraminifera are being removed individually from the small sediment fraction and being identified taxonomically. They will then be shipped this fall to a commercial lab for δ^{18}O and Ca/Mg analyses in an effort to assess the ocean temperature and salinity throughout the time period the cores represent.

Cetacean and pinniped bones have been collected from archaeological sites on Unalaska Island and Kodiak Island through the time of occupation, generally the mid-19th century. The more modern samples of bone (~1850–1950 AD) have been collected from the Smithsonian and Carnegie Museums. The collagen extraction and stable isotope analyses are completed on marine mammal bones from the previous 150 years. A significant decline in carbon isotope ratios occurred during this time period. Sample analysis has begun and continues on bones from archaeological sites dating prior to the mid-nineteenth century and Russian occupation. Initial analyses of these later periods show changes in the carbon isotopes through time that are potentially similar to the carbon isotopes from the sediment cores. A greater number of faunal samples will need to be collected and analyzed before further hypothesis testing can be done. More samples will also be necessary from several different trophic level mammals to assess any changes in the δ^{15}N and, hence, changes in the length of food webs over time. More samples are currently being collected from sites on Unalaska Island in an effort to acquire samples for time periods currently not covered by previously collected faunal samples. Completion of these analyses is expected to occur by late winter.

Logistical difficulties have prevented us from accessing Shagak Bay, Adak Island and collecting a sediment core as originally proposed. However, we made other provisions to collect sediment cores at another appropriate location. A NOAA cruise in the Bering Sea gave us the opportunity to collect sediment cores from Captain's Bay, Unalaska Island. Calibration of AMS and Pb-210 dating of the core have just returned from their respective laboratories and they indicate the two cores from this site represent almost 400 years. We have δ^{13}C data, carbon content and percent opal (from diatoms), all of which are proxies for primary productivity. The δ^{13}C data show oscillations similar to those seen in the Skan Bay core. The $\delta^{15}N$ analysis is complete and the data for the Captain's Bay core was more consistent than the $\delta^{13}C$ data over its length. Final correlation between the two cores is currently taking place and is expected to be complete this winter.

Dating and stable isotope correlation is currently taking place between the cores from Skan Bay and Captain's Bay to more accurately reflect the climatic and environmental conditions during the time period the cores represent. The relationship of climatic and oceanographic changes has had varied impact on organisms in North Pacific Ocean. Sockeye salmon data has been compiled and their abundance differences have been introduced into the large-scale analysis. There appear to be periods of close correlation between productivity and abundance changes. Current results of our data have been presented at an international stable isotope conference in Australia this summer and at the annual American Fisheries Society meeting early in 2003.

References

Altabet, M.A. and R. Francois. 1994. The use of nitrogen isotopic ratio for reconstruction of past changes in surface ocean nutrient utilization. In: *Carbon Cycling in the Glacial Ocean*, NATO ASI Series, edited by R. Zahn, M.A. Kaminski, L. Labeyrie, and T.F. Pederson, pp. 281–306.

***Progress Report*:** **Seasonal Assessment of Prey Competition between Steller Sea Lions and Walleye Pollock**

***Principal Investigator*:** Robert J. Foy, University of Alaska Fairbanks

Objectives

The goal of this study is to assess the level of competitive interaction on a seasonal basis between walleye pollock and Steller sea lions within designated sea lion critical habitat. In particular the objectives are to:

1) Determine the seasonal diet composition of pollock from within Steller sea lion critical habitat.
2) Determine consumption and evacuation rates of pollock based on varied diets consistent with diets determined in situ, while taking into account pollock size and water temperature.
3) Calculate the potential removal (daily ration) of particular prey species by pollock given published pollock biomass and size frequency data.
4) Compare the removals of pollock prey to the diets of Steller sea lions to determine the extent of competitive interaction.
5) Address the efficacy and effects of restricting pollock harvests inside Steller sea lion critical habitat.

Methods/Analyses

Fifty pollock stomachs were collected from within the Long Island Steller sea lion critical habitat area in May, July, November 2001, and March, May and July 2002 in conjunction with the Gulf Apex Predator-prey study in Kodiak. In November 2002 fifty pollock stomachs were also collected. One hundred fish were also collected from local processors that represent areas outside of sea lion critical habitat from which to compare the diets. A comparison of diets among localized groups of pollock will give some idea of small-scale variability as has been found with local abundances of pollock subpopulations (Bailey et al., 1999).

Prior to stomach content analysis, each fish was blotted dry, weighed to the nearest 0.1 g, and measured (standard length) to the nearest 1.0 mm. To test for seasonal and spatial differences in fish size, analysis of variance comparisons will be made on log (x + 1) transformed length and weight values. Post hoc multiple comparisons of fish weights and lengths among sampling strata will be made by the Tukey post hoc method for unequal sample sizes (Spjotvoll and Stoline, 1973).

To measure the relative amount of food in pollock stomachs, stomach content weight as % body weight (%BW) will be reported by dividing the stomach content weight by the total fish weight. Excised stomachs were weighed to the nearest 0.01 g, cleared and reweighed to determine stomach content weight. All empty stomachs were noted as well. %BW data will be arcsine transformed to satisfy the assumptions of normality by a Shapiro-Wilks W test of normality before inclusion in univariate regression models. Arcsine (%BW) will be regressed as a function of time of year and standard length of the fish. A stepwise function will be used to eliminate non-significant variables for the final regression. Post hoc multiple comparisons will be made by Tukey, Dunnett and Sidak methods.

Taxa from each stomach were enumerated and identified to the lowest possible taxonomic level. Life history stages were identified when possible. In some cases, due to digestion, it was only possible to identify prey to a broad taxonomic grouping.

Taxa composition of fish diets will be examined by ordination of dissimilarity indices. Bray-Curtis dissimilarities of pollock diets will be calculated on root-root transformed counts of taxa found in the stomach contents. The diversity of taxa in the pollock diets will be assessed by indices of richness and evenness.

Fifty pollock of multiple year classes were collected by jigging. Two 800-gallon tanks were set up to acclimate and maintain the fish with running seawater at a rate to replenish seawater every hour. Fish feed was acquired from aquaculture sites in British Columbia, which have experience raising pollock. The condition of the pollock has been monitored to establish a daily regime. Feeding studies will begin July 15, 2003 and continue until October 1, 2003. For consumption and evacuation rate experiments, three sets of feeding trials based on different temperatures are underway on each size class of fish. Size classes will be determined by the availability from catches. The three temperatures will be representative of the range and mean temperatures encountered seasonally by pollock in the collection area around Kodiak. Mito et al. (1999) estimated lower daily rations during colder seasons (fall and winter). Light levels will be held constant at approximately 10 hours of light at a constant intensity.

Daily ration estimates of each prey species will then be collected from published literature on predator biomass, calculated consumption and evacuation rates (Elliott and Persson, 1978). Size of fish before and after the study has been noted to relate feeding behavior to growth rates. This data will be compared to Steller sea lion diets from concurrent studies. Sea lion diet data is being collected from scat samples collected on Long Island and as such represents frequency of occurrence data. This data will be used to identify important prey species and will be compared to pollock diet frequency of occurrence using similarity indices.

Results

Eight sampling cruises have taken place and 300 pollock have been sampled for diet analyses and proximate composition. Proximate composition analysis has been run on 300 pollock samples ranging from 8 cm to 60 cm from 2001–2002. Average protein content increased from 15.3 to 16.2% for a 50-cm fish. Average lipid increased from 1.7 to 4.1 percent between May and November 2001. Adult pollock diets from 2001 were dominated by juvenile pollock, tanner crab, eulachon and euphausiids. Juvenile pollock diets are dominated by euphausiids and larval fishes. Pollock have been collected and are acclimatizing in captivity. Growth studies to determine growth rate, consumption and evacuation rates will be complete by October 2003.

References

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Elliott, J.M. and L. Persson. 1978. The estimation of daily rates of food consumption for fish. *Journal of Animal Ecology* 47: 977–991.

Mito, K., A. Nishimura and T. Yanagimoto. 1999. Ecology of groundfishes in the Eastern Bering Sea, with emphasis on food habits. *In* Loughlin, T.R. and K. Ohtani (eds), *Dynamics of the Bering Sea*. University of Alaska Sea Grant, Fairbanks, Alaska. pp. 537–580.

Spjotvoll, E. and M. R. Stoline. 1973. An extension of the T-method of multiple comparison to include the cases with unequal sample sizes. *Journal of the American Statistical Association* 68: 975–978.

Expected Publications

Fall 2003. Competitive interactions between Steller sea lions and walleye pollock inside sea lion critical habitat: a diet comparison.

Spring 2004. Seasonal lipid content and feeding habits of walleye pollock in Kodiak, AK.

Progress Report: Decision-Making Under Uncertainty: Management of Commercial Fisheries and Marine Mammals

Principal Investigators**:** Jerry McBeath, University of Alaska Fairbanks; Matt Berman, University of Alaska Anchorage

Objectives and Methods

In 2001 we proposed to CIFAR a two-year project, for the amount of $210,000, composed of four elements: a) An examination of the structure of the decision-making system—the relevant authorities, government managers, and affected interests; b) Analysis of the etiology of the SSL crisis including treatment of early warning signs, economic and political pressures to continue resource use, bureaucratic accommodation in the absence of certain data;

c) Policy analysis of the scientific literature on SSL decline, focusing on existing knowledge that can guide decisions in the present (including hypothetical cost-benefit analysis comparing draconian to mild fisheries limitations, and their differentiated impact on SSL recovery); and d) Policy analysis of decision-making under conditions of uncertainty, including investigation of the political, socio-economic, and environmental risks of policy failures; estimates of the degree of certainty in scientific findings necessary before taking action. We proposed to use two primary data sources: files of government agencies and interviews with federal and state government officials, industry representatives, non-governmental organizations (Native, environmental, public interest), and scientists.

The project was funded in 2001, but at a reduced ($120,000) level, which necessitated changes in the scope of proposed work. Instead of eliminating any of the proposed project elements (quite difficult because they were interrelated), we determined to narrow our focus to specific aspects of each of the hypotheses and objectives. Further, we planned, insofar as possible, to reduce the amount of interviewing required and rely on secondary sources more strongly (particularly in analysis of the etiology and the scientific literature).

Main Results to Date

Because of other research commitments, we did not begin work on the project until January 2002. In last year's progress report, we mentioned initial work on the *Greenpeace v. National Marine Fisheries Services* case in U.S. District Court (Western District of Washington [Seattle]), some project-related interviews, and completion of a chronology of the SSL controversy. Since that progress report, we have completed analysis of the Greenpeace quartet of court decisions and concluded most interviews pertaining to how the agency made decisions on the SSL in the climate of uncertainty. We discuss progress by data source:

A. *Greenpeace v. NMFS*. The case, filed April 1998 in the U.S. District Court of the Western District of Washington (Seattle), is the most significant legal action concerning endangered species, environmental protection, and climate regime shift issues in the North Pacific. The plaintiffs (Greenpeace, American Oceans Campaign, and Sierra Club) claimed that NOAA-Fisheries had failed to issue a comprehensive, programmatic environmental impact statement for the federal actions it authorized (fishery management plans and amendments, TAC limits, etc.), thus violating terms of the National Environmental Policy Act (NEPA); and that the agency had failed to protect the Steller Sea Lion against jeopardy and adverse modification of its critical habitat, as required under the Endangered Species Act (ESA). In four orders (Greenpeace I–IV), District Court Thomas Zilly found that the agency had violated the laws; he enjoined the fisheries briefly in mid–late 2000, and on three occasions remanded biological opinions, reasonable and prudent alternatives (RPAs), and preliminary SEISs to the agency. Without doubt, this recently concluded (March 2003) case represents the most serious challenge to the management of the North Pacific fisheries by NOAA-Fisheries and the North Pacific Fisheries Management Council.

We have now completed our review of the Greenpeace decisions. This includes close reading of briefing documents of the plaintiffs, defendants, and the intervenor-defendants, oral arguments, court orders, and a good part of the immense (more than 50,000 page) administrative record (AR) filed by the agency to support its decisions in the case. We wrote an analytical paper on how the judge made his decisions in Greenpeace I–III, and then submitted this to participants in the case (including the judge) for their critical commentary. We have now nearly completed a revision of this paper, including Greenpeace IV and responses to critical comments, which will definitively analyze the factors influencing the judge's decisions (pertaining less to the state of science than to the flawed decisional process of the agency).

B. Informant Interviews. To the present, we have conducted nearly 40 interviews with those most knowledgeable about how complex decisions have been made concerning the SSL controversy. Our respondents, identified by site and agency, include:

In Washington, DC: NOAA-Fisheries, Protected Resources, Marine Mammal Commission; Office of Senator Ted Stevens (R-Alaska).

In Seattle: National Marine Mammal Laboratory, Director's Office, Alaska Fisheries Science Center, the North Pacific Fisheries Management Council; industry representatives (United Catcher Boats, At-Sea Processors Association), environmental organization representatives (Greenpeace, Earthjustice).

In Juneau: NOAA-Fisheries, Offices of Sustainable Fisheries, Protected Resources, NEPA coordination, NOAA General Counsel; the North Pacific Fisheries Management Council; Alaska Department of Fish & Game; coastal communities' representatives (Aleutians East Borough), environmental organization representatives (Earthjustice); industry representative (United Fishermen of Alaska).

In Anchorage: NOAA-Fisheries, Office of Protected Resources, the North Pacific Fisheries Management Council; industry (At-Sea Processors), environmental: Trustees for Alaska

The particular focus of these interviews has been on the critical junctures of the decisional process concerning protection of the SSL, for example:

- How the agency came to make a jeopardy determination in BiOp #1 (December 1998), including development of the local depletion hypothesis and scientific evidence supporting it;
- Why the agency withdrew the groundfish management plan to reinitiate consultation (challenged in *Greenpeace II*) in 1999;
- Conflict in the agency (primarily between OSF and OPR) and between the agency and Council in formulation of the FMP BiOp (November, 2000);
- Mechanisms and processes through which the Stevens rider (December 15, 2000) was developed and its impact on both agency and Council processes;
- How the agency developed and implemented both the global control rule and zonal approach, ultimately adopted in the 2001 BiOp;
- How the agency resolved intra-agency disagreement about alternative scientific approaches (including how the agency integrated new scientific information on climate regime shift and predators); and
- Throughout, how industry worked through the Council structure, through the development of its RPA committee (now the SSL mitigation committee), and independently to achieve its objectives to protect the status quo fishery.

Papers and Publications

Two papers have issued from the research conducted to date: 1) the paper "Science and Politics in Marine Mammal Conservation" was prepared and presented to the 2002 Berlin Conference on the Human Dimensions of Global Environmental Change ("Knowledge for the Sustainability Transition: The Challenge for Social Sciences") in December 2002. The paper was included with featured presentations in the conference proceedings. 2) the paper "Willy-Nilly Zilly? How the Court Rules the Oceans (and the Steller Sea Lions)" was presented to the 40th annual conference of the Western Regional Science Association, meeting in Arizona in late February 2003. As mentioned, this paper has now been reviewed by a dozen participants in the SSL controversy and shortly will be submitted (by invitation) to the *Alaska Law Review* for publication.

Two other papers are being prepared, based largely on informant interviews, for presentation to conferences in August 2003: 1) the paper "Management of the Commons for Biodiversity: Lessons from the North Pacific," will be presented to the regional conference of the International Association for the Study of Common Property, meeting in Anchorage, August 17–21; and 2) the paper "Decision-Making in Marine Mammal Conservation," will be presented to the annual conference of the Association for Politics and the Life Sciences, meeting in Philadelphia, August 28–31. Both papers will be submitted to refereed journals in September. Finally, although travel funding has not been secured yet, we have been invited to present results of our investigations to the SSL Climate–Ocean Regime Shift Synthesis Workshop, meeting early December in California.

***Progress Report*:** **Biophysical Linkages between the Bering Sea and Arctic Ocean**

***Principal Investigators*:** Stephen Okkonen, University of Alaska Fairbanks; Wieslaw Maslowski, Naval Postgraduate School, Monterey, California

***Other Participating Researchers*:** Terry Whitledge, University of Alaska Fairbanks

Objectives

The general objective for this project has been to investigate interannual and decadal variations in the exchanges of properties and nutrients between the North Pacific Ocean, Bering Sea, and Arctic Ocean.

This past year our analyses have focused on the oceanic conditions associated with the shelf break regime and Aleutian Island passes of the eastern Bering Sea and western Gulf of Alaska (Figure 1).

Significant Results

1) An additional eight-year integration of the coupled 9-km ice–ocean model has been completed, extending the interannual model results available for analysis to cover the 23-year period from 1979–2001.

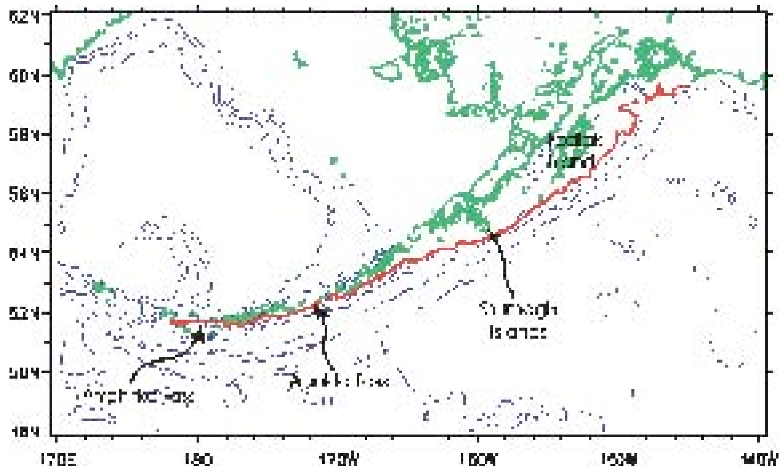

Figure 1. Map of the western Gulf of Alaska region. The red line indicates a ~300-km-long segment of the 200-m isobath along and above which Naval Postgraduate School coupled ice–ocean model monthly mean temperatures and salinities have been extracted.

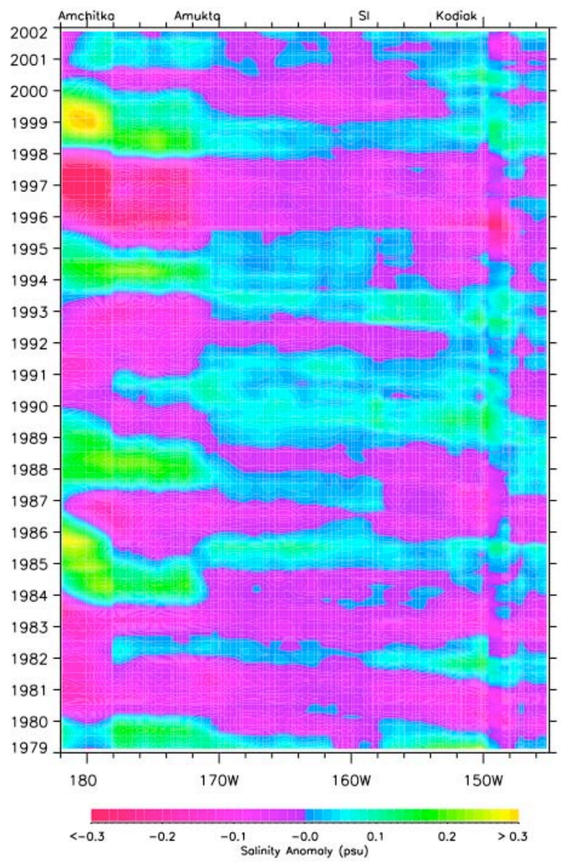

Figure 2. Time–longitude plot of smoothed (13-month boxcar) monthly mean salinity anomalies at 165-m depth along the shelf break segment shown in Figure 1. Negative (positive) salinity anomalies indicate locally fresher (saltier) conditions. The largest salinity variations occur downstream from Amukta Pass. The locations of Amchitka Pass, Amukta Pass, the Shumagin Islands (SI), and Kodiak Island are indicated at the top of the plot.

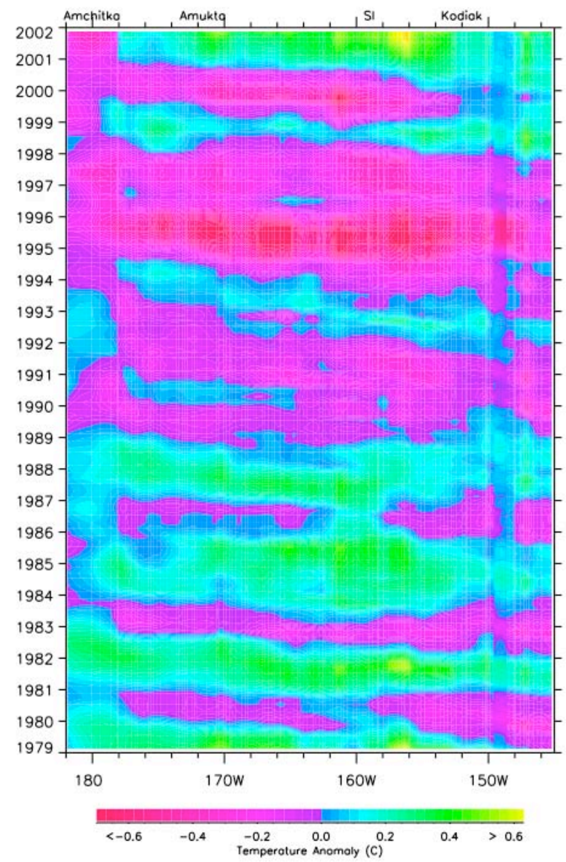

Figure 3. Time–longitude plot of smoothed (13-month boxcar) monthly mean temperature anomalies at 165-m depth along the shelf break segment shown in Figure 1. Negative (positive) temperature anomalies indicate locally cooler (warmer) conditions. Generally warmer temperatures occurred during 1980s while generally cooler temperatures occurred during the 1990s. The locations of Amchitka Pass, Amukta Pass, the Shumagin Islands (SI), and Kodiak Island are indicated at the top of the plot.

2) Analyses of model results from this 23-year period indicate that the shelf break along the western Gulf of Alaska can be roughly partitioned into three regimes characterized according to the relative strengths of annual and interannual variations in temperature and salinity conditions just above the shelf break (Figures 2 and 3):

a) The strongest annual-period variations in temperature and salinity signals occurred along the shelf break between Prince William Sound and the south end of Kodiak Island.

b) The strongest interannual temperature variations occurred between the south end of Kodiak Island and Amukta Pass. Amukta Pass is the easternmost major pass through which the exchange between the North Pacific Ocean and Bering Sea occurs. In this region, generally warmer temperatures occurred during the 1980s and generally cooler temperatures occurred during the 1990s.

c) The strongest interannual salinity variations occur west of Amukta Pass. These variations exhibited a periodicity of ~4–5 years and are likely associated with separation of the Alaskan Stream from the Aleutian Island arc.

We have recently begun investigating annual and interannual variations in the flows through the eastern Aleutian passes.

Publications and Presentations

No manuscripts have yet been submitted. The following presentations of research results have been made:

Towards Understanding Environmental Conditions and Their Variability in the Gulf of Alaska and Bering Sea – Model Results Part I. Maslowski, W., Naval Postgraduate School; Okkonen, S.R., University of Alaska Fairbanks; Whitledge, T.E., University of Alaska Fairbanks. 2003 Symposium, Marine Science in the Northeast Pacific: Science for Resource Dependent Communities, Anchorage, Alaska, 13–17 January 2003.

Towards Understanding Environmental Conditions and Their Variability in the Gulf of Alaska and Bering Sea – Model Results Part II: Site Specific Seasonal, Interannual, and Interdecadal Variability. Okkonen, S.R., University of Alaska Fairbanks; Maslowski, W., Naval Postgraduate School; Whitledge, T.E., University of Alaska Fairbanks. 2003 Symposium, Marine Science in the Northeast Pacific: Science for Resource Dependent Communities, Anchorage, Alaska, 13–17 January 2003.

***Progress Report*:** **Ocean Climate Variability as a Potential Influence on Steller's Sea Lion Populations**

***Principal Investigators*:** Thomas C. Royer and Chester E. Grosch, Old Dominion University

Objectives

We hypothesize that interdecadal changes in the ocean climate will influence the biological productivity in the North Pacific and Bering Sea. The combination of many of the oceanic–atmospheric forces with bidecadal cycles could lead to the regime shift in the North Pacific that occurred in the late 1970s (Francis et al., 1996). These low frequency fluctuations could influence the amount of biomass in the ecosystem and its trophic level distributions. In order to address this hypothesis two important questions must be addressed: (1) How are the sea level slopes and ocean circulation related to the coastal freshwater discharge and coastal sea levels in the Gulf of Alaska? (2) Do coastal freshwater discharge and coastal sea level records contain information on interdecadal changes in the marine ecosystem in the North Pacific and Bering Sea?

Methods and Results

Some climate modelers have predicted that one result of global warming will be an increase in the number and intensity of storms. In many regions, particularly at high latitudes, there is little or no historical data of the number and intensity of storms. Fortunately there are data sets of a direct proxy for storminess: sea level atmospheric pressure (SLP) measurements at National Data Center Buoys in the Gulf of Alaska (Buoy 46001 at 56.30N, 148.17W) and the Bering Sea (Buoy 46035 at 56.91N, 177.81W).

Low pressure "spikes" in these data sets are indicators of the passage of storm systems over the buoy. The passage of these storms, which seldom last more than a few days, are extremely important in the formation and deepening of the oceanic mixed layer. It is hypothesized that the major source of macronutrients for the northern Gulf of Alaska and the Bering Sea is the subsurface water and the deepening of the mixed layer during storm events is probably an important mechanism to bring these nutrients upward into the euphotic zone.

The SLP time series at Buoy 46001 begins at mid 1974 and continues through the present and that at Buoy 46035 begins in the latter part of 1987 and exists until almost the end of 2001. Unfortunately both time series have some gaps. However, there are continuous segments of these time series varying in length from 25 to 131 months. The number of days having low pressure "spikes," defined as days with average SLP < 995 hPa, in these continuous segments of the SLP time series were counted.

The results for Buoy 46001 are given in Table 1. There each segment; its duration; N, the number of low SLP days; <N>, the average number per month; and Var(N), the variance are given.

Table 1. Time series for Buoy 46001 (Gulf of Alaska): duration of each segment of the SLP time series; N, the number of low SLP days; <N>, the average number per month; and Var(N), the variance.

Segment	Duration	N	<N>	Var(N)
1	12/74–7/78 (38 months)	166	4.3684	15.536
2	3/79–12/90 (131 months)	609	4.6489	19.276
3	6/94–6/96 (25 months)	105	4.2000	13.417
4	11/97–12/01 (50 months)	316	6.3200	26.753

The periods from 1974 through 1978 and mid 1994 to mid 1996 have the lowest values of <N> and of the variance of N. The 1980s and 1990s had a somewhat higher <N> and variance while the most recent period, from the end of 1997 to the end of 2001, had a very much higher number of low pressure days and of the variance.

In order to test the significance of the differences on <N> and Var(N), t-tests for equality of the means and F-tests for equality of variances were applied to each pair of segments. Equality is accepted if the probability of such is equal to or greater than 0.95. The results of these tests for Buoy 46001 are given in Table 2. The numbers at the top of the table and in the leftmost column are the segment numbers from Table 1.

Table 2. Results of the t- and F-tests for equality of the means and variances of each pair of segments of the SLP time series at Buoy 46001 (Gulf of Alaska).

	2				3				4			
	t	P(t)	F	P(F)	t	P(t)	F	P(F)	t	P(t)	F	P(F)
1	-0.731	0.47	1.241	0.45	0.230	0.82	1.158	0.72	-2.668	0.01	1.722	0.09
2					-1.170	0.25	1.437	0.30	-2.284	0.03	1.388	0.15
3									-2.898	0.01	1.994	0.07

The highest probabilities of equality of means and variances are those between Segments 1 and 3; however, they are only 0.82 and 0.72, respectively. The extremely low probabilities of equality of both means and variances between Segments 1 to 3 and Segment 4 should be noted. The results of these tests suggest that the most recent period, from November 1997 to December 2001, had a very significantly higher mean number of low SLP days and also higher variance of the mean than any of the three previous periods. The probabilities of equality of the means and variances among the other three segments are all less than 0.82 so one can conclude that the means and variances are not equal.

The results, duration, N, <N>, and Var(N) for Buoy 46035 are given in Table 3.

Table 3. Time series for Buoy 46035 (Bering Sea): duration of each segment of the SLP time series; N, the number of low SLP days; <N>, the average number per month; and Var(N), the variance.

Segment	Duration	N	<N>	Var(N)
1	9/87–4/91 (44 months)	213	4.8409	18.649
2	10/91–12/95 (51 months)	249	4.8824	20.866
3	10/96–12/01 (51 months)	257	5.0392	22.758

The results for Buoy 46035 are similar to those for Buoy 46001; the most recent period, from late 1996 to December 2001, had the highest average number of low SLP days as well as the highest variance. Also note that these results suggest an increasing trend in both <N> and Var(N) from 1987 to the end of 2001.

Just as was done for the data from Buoy 46001, t-tests for equality of <N> and F-tests for equality of Var(N) were applied to each pair of segments. The results of these tests for Buoy 46035 are given in Table 4. The numbers at the top of the table and in the leftmost column are the segment numbers from Table 3.

Table 4. Results of the t- and F-tests for equality of the means and variances of each pair of segments of the SLP time series at Buoy 46035 (Bering Sea).

	2				3			
	t	P(t)	F	P(F)	t	P(t)	F	P(F)
1	-0.065	0.95	1.119	0.71	-0.297	0.77	1.220	0.51
2					-0.235	0.82	1.091	0.76

The results of these tests show that there is not a significant difference in the means between Segments 1 and 2. The probabilities that the mean and variance of the most recent period are different from those of the other two periods are a maximum of 0.82 for the means and 0.77 for the variances. Thus it can be concluded that the most recent period has both a significantly higher mean and variance than the earlier periods.

In summary, at Buoy 46001 in the Gulf of Alaska, the most recent period, from November 1997 to December 2001, had a significantly higher mean number of low SLP days and also higher variance than any of the three previous periods. At Buoy 46035 in the Bering Sea, there is an apparent increasing trend in both <N> and Var(N) with time and the most recent period has significantly higher values of <N> and Var(N). The data from both buoys suggest that there has been an increase in storminess in both the Gulf of Alaska and the Bering Sea.

If both <N> and Var(N) have increased, what are the possible causes? It could be that there really has been an increase in the number of storms and in the variability of their occurrence. On the other hand, the same increase in <N> and Var(N) could occur if there were substantial increased variability of the storm tracks. This would bring more storms over these buoys with more variability in their occurrence. The evidence available to us is not sufficient to decide between these alternatives. Perhaps modeling could yield an answer but, in view of the problems with the NCEP/NCAR reanalysis, this is problematical.

We have used spectral techniques and wavelet analysis to analyze the relation between the coastal freshwater discharge and the Pacific Decadal Oscillation. We found that they have a cross-correlation coefficient of 0.38, (>99 Confidence Level). Enhanced freshwater discharge favors the establishment of a positive phase of the PDO. Briefly, enhanced coastal precipitation along the eastern coast of the Gulf of Alaska enhances the buoyancy driven (Schumacher and Reed, 1980; Royer, 1981) coastal flow (northward) that then brings more heat from the south into the Gulf of Alaska. The increased heating will increase cyclogensis here that will again increase the precipitation and buoyancy driven flow. Royer et al. (2001) found that fluctuations in the marine ecosystem have periodicities that are similar to those of the forcing functions of atmospheric pressure and freshwater discharge. Periodicities of zooplankton at Ocean Station P (50 N, 145 W) have similar periodicities to those found in the Alaskan coastal freshwater discharge.

We are interested in better determining the hydrology cycle for this coastal region to address potential changes on the physics and biology. We investigated whether the NCEP data can be used as a replacement for the divisional averages used previously. Our approach was to make comparisons of surface temperature, barometric pressure and precipitation with National Weather Service (NWS) observations along the coast of Alaska and observations from a National Data Buoy Center (NDBC) buoy in the Gulf of Alaska.

We wrote a paper entitled "NCEP-NCAR Reanalysis: Comparison with Observations from the Coast of Alaska and the Gulf of Alaska." The paper discusses the differences between the NCEP-NCAR reanalysis data and actual observations from the National Weather Service (NWS) and a National Data Buoy Center (NDBC) buoy. The NCEP-NCAR data were severely lacking in matching trends, means and variances that were contained in NWS and NDBC time-series. We concluded that the NCEP-NCAR data should not be used for regional runoff models. The paper has been submitted to the *Bulletin of the American Meteorological Society* for review.

The NCEP temperature and precipitation data should be used with caution for the coastal Gulf of Alaska since they did not present well the available observations. This is especially critical since the sources of supplementary data are very limited. Point observations with long-term ocean buoy measurements are helping to fill these data gaps and will provide data with synoptic time scales. The only significant trend in the Southeast or South coast data is in the South coast precipitation. Precipitation is increasing, which will have a tendency to accelerate the alongshore flow. The lack of any significant trend of temperature could be attributed to the presence of glacial fields. While significant increases in heating might be taking place, this heat would be used to melt the glacial field rather than raise the air temperature. This will continue until the ice fields are melted. At that time, a dramatic increase in the air temperature might occur, accompanied by a decrease in the coastal freshwater discharge. Also the phasing of the seasonal freshwater discharge would be altered and the spring subpeak would disappear. This could have some serious ramifications on the spring plankton blooms and general biological productivity.

We are using ocean altimeter measurements (Topex/Poseidon) to provide spatial variations of sea level slopes to be used as an index of gyre scale circulation; the strength of the Alaska Gyre and Alaska Stream. These sea level slopes will be compared with the longer time series of coastal sea level to determine if historical circulation changes can be detected in the coastal observation. These coastal observations have a longer record than the 8 years of altimeter measurements. Regional spatial variabilities of the physical environment will be investigated since they could be very important. Important questions include: Do the Northeast Pacific and Bering Sea fluctuate in or out of phase? Evidence of out of phase ecosystems is demonstrated by the historical salmon catches along the British Columbia / Washington coast being out of phase with those in the Bering Sea (Bristol Bay).

Modifications have been made to normal mode analysis (NMA) as presented by Eremeev et al. (1995) for scalar fields and the extension to vector fields by Lipphardt et al. (2000). The modifications were to allow for computations on a high aspect ratio grid. The modified NMA was performed on GLOBEC hydrographic data along the Seward line. The results were presented in a poster titled "Annual Spatial Variability of the Hydrographic Structure Along the Seward Line" at the January 13–17 *Marine Science in the Northeast Pacific: Science for Resource Dependent Communities* meeting in Anchorage.

We are working on computing the complex empirical orthogonal functions (CEOF) for hourly tidal data from stations along the Gulf of Alaska. The analysis is to determine if there is a propagation of the 1997–1998 El Niño sea level signal. Anomalously high sea levels were experienced in late 1997 to early 1998 along tidal stations in the gulf. An animation of this positive anomaly can be seen in an animation at the following web site: http://www.co-ops.nos.noaa.gov/sltrends/animation.gif.

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***Progress Report*: Investigation of the Foraging Behavior of Steller Sea Lions in the Vicinity of Kodiak Island, Alaska**

***Principal Investigators*:** Richard E. Thorne and Gary L. Thomas, Prince William Sound Science Center, Cordova, Alaska

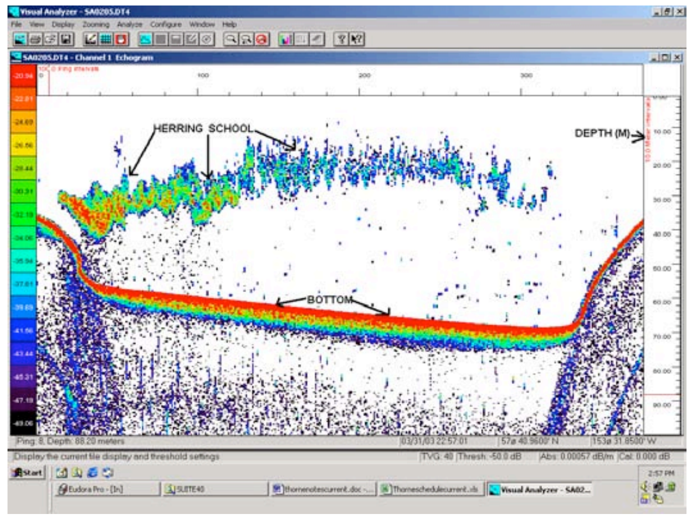
***Other Participating Researchers*:** Kevin Brennan, Matt Foster and Mark Witteveen, Alaska Department of Fish and Game

Objectives

The overall objective of this project is to investigate the role of Pacific herring (*Clupea pallasi*) as overwinter forage for Steller sea lions (*Eumetopias jubatus*) in the vicinity of Kodiak Island. The study is an extension of previous work conducted in Prince William Sound and intends to transfer the methodology used in Prince William Sound to the Kodiak region. Specific objectives include determination of the abundance and distribution of overwintering herring schools around Kodiak Island and assessment of Steller sea lion foraging activity on these schools.

Methods

The techniques that were developed in Prince William Sound are a combination of acoustic-net sampling, infrared and aerial surveys. Acoustic technology is used to locate and measure the biomass of overwintering herring schools. Net sampling, typically using purse seines, provides biological information on the fish. Infrared surveys are used in conjunction with the acoustic surveys to detect the association of marine mammals and birds with the fish schools. Aerial surveys are used to determine the numbers and distribution of marine mammals in association with the schools and are helpful in locating herring schools. The Kodiak surveys used a 38 kHz BioSonics DT4000 digital transducer system for the acoustic data and a Raytheon Model 200 "Nightsight" (12º by 6º field of view) for the infrared. These techniques were used from the F/V *Captain Kidd*, a 56' Alaskan seine boat. Biological sampling was conducted using the F/V *Natalia***,** a purse seine vessel with a 150' fathom net, 1600 meshes deep. Aerial surveys were conducted by the Alaska Department of Fish and Game. In addition to the purse seine sampling, additional species identification was obtained using underwater cameras with infrared emitters.



DT4000 Visual Display of Concentration of Herring in Uganik Bay, South Arm

This project also coordinates with a NOAA project that uses LIDAR to investigate fish and marine mammal distributions (Principal Investigator, James Churnside).

Main Results

We conducted three joint PWSSC/ADF&G surveys during the second year of this study. In addition, ADF&G conducted several targeted herring assessments. The first joint survey took place November 2–7, 2002 and covered the northwestern quarter of Kodiak Island. The major overwintering concentration of herring was located in Uganik Inlet, primarily in the South Arm. Several acoustic transects were run on this concentration. Unlike previous surveys conducted in late winter 2002, no Steller sea lions were observed foraging on this concentration during the cruise. The fish schools were more scattered than previously seen, possibly due to extreme tides during this time period. Aerial surveys detected large numbers of Steller sea lions in this area after the completion of the cruise.

The second and third surveys were conducted back-to-back off the west and east sides of Kodiak Island during February 2003. The major concentrations of herring on the west side were in Uganik Bay. Concentrations were located and surveyed in both South Arm and Northeast Arm. The survey on the east side of Kodiak Island covered Ugak Bay, Gull Cape, Kiliuda Bay and Shearwater Bay. Appreciable quantities of herring were located and surveyed only at Gull Cape. Large concentrations of pollock were located in Kiliuda and Shearwater Bays. While not surveyed due to weather and time constraints, a large concentration of pollock was seen in Port Hobron and some herring in Three Saints Bay.

Still image captured from infrared scanner video showing Steller sea lions hauled out at Cape Ugat

During winter period surveys in 2002, we saw large numbers of Steller sea lions actively foraging on herring in Uganik Bay, over 70 in January 2002 and over 300 in March 2002. During the February 2003 survey, we saw several hundred Steller sea lions hauled out at Cape Ugat just outside Uganik Bay, but less than 10 were seen in the water near the herring concentrations.

The situation was similar on the east side. Our infrared scanner detected many sea lions hauled out at Gull Cape when we transited the area at night, but we saw very few in the water during either day or night at any location. Most of the bays and straits on the east side had large concentrations of pollock. The pollock distribution showed similar characteristics to that of herring. On several occasions, schools of fish were detected on the sonar that looked like herring, but the underwater camera revealed the species to be pollock. On close examination, the pollock schools were generally smaller, slightly deeper in the water column, and closer to the bottom. Nevertheless, the high abundance of pollock near shore and in relatively shallow water during the winter was a surprise. Such distributions have not been observed in Prince William Sound, or on the west side of Kodiak during the acoustic surveys. These observations, including the surprisingly variable Steller sea lion behavior, show that we still have a lot to learn about the distributional characteristics of these key species.

The infrared scanner was able to detect the presence of Steller sea lions on haul-outs at distances of over one mile, and to resolve individual animals at closer ranges. The combination of acoustic gear and underwater cameras proved to be very effective. We could rapidly locate schools with the acoustic gear, then lower the camera and identify the species within five minutes.

A major goal of this program was to transfer the assessment capability that was developed in Prince William Sound to Kodiak. ADF&G successfully applied the technology during additional surveys. An inverse transfer of technology also took place. The underwater cameras with infrared emitters that were used by ADF&G personnel were so effective that they have been incorporated into Prince William Sound Science Center surveys.

Publications

One manuscript has been completed and will be included in the electronic publication of the proceedings of Oceans 2003.

***Progress Report*: Predator/Prey Investigations of Killer Whales and Steller Sea Lions in Alaska**

***Principal Investigator*:** Andrew W. Trites, North Pacific Marine Science Foundation

***Other Participating Researchers*:** Craig O. Matkin, North Gulf Oceanic Society; Lance Barrett-Lennard, Vancouver Aquarium; Graeme Ellis and John Ford, Department of Fisheries and Oceans Canada; Jan Straley, University of Alaska Southeast *(see report immediately following)*

Introduction

This project was an initial effort to develop more refined estimates of the effect of killer whale predation on Steller sea lions by collecting data on killer whale populations for the continued development of the current sea lion predation model constructed by Barrett-Lennard et al (1995).

Objectives

1. Using mariner surveys to determine distribution and "hot spots," as well as initial population estimates for killer whales in western Alaska.
2. Initiating a photo-census of killer whales in the Kodiak and eastern Aleutian region and continuing this work in southeastern Alaska.
3. Initiating genetic studies examining population affiliations of killer whales in these regions.
4. Providing observational data on predation to estimate the impact of killer whale predation on Steller sea lions in both western Alaska and southeastern Alaska.
5. Comparing data on killer whale numbers and population structure and predation from the western Alaska region where Steller sea lions have declined with southeastern Alaska where sea lion stocks are stable or increasing.
6. Making initial estimates of numbers and distribution of killer whales in western Alaska using mariner surveys.

In this second and final year (2002–2003) of CIFAR funding we continued our fieldwork in the Glacier Bay–Icy Strait region of southeastern Alaska where the work was supported primarily by CIFAR. In the eastern Aleutians (False Pass region) we conducted a spring survey (mid-May to early June) in 2003. This work was primarily supported by an SSLRI grant, however, some CIFAR funds were used to support logistics. We include both a summary of the 2002 southeastern Alaska work and the early 2003 work in False Pass in this progress report.

Methods

Field data collection relied on methods developed over the past 25 years during our work in British Columbia, Canada and Prince William Sound/Kenai Fjords, Alaska. A thorough description of research procedures is found in Matkin et al. (1999a). The project relied on photo-identification of individual animals for census, acquisition of skin biopsies for genetic analysis of population structure (Barrett-Lennard, 2000), acquisition and acoustic analysis of underwater recordings (Ford and Morton, 1990), and observations of killer whale foraging behavior and predation. In 2002 searches for killer whales were based on current and historical sighting information, both in the southeastern Alaska and the False Pass (eastern Aleutian) regions. Whales were also located by listening for killer whale calls with a directional hydrophone (calls can be heard up to 25 km away), or by responding to VHF radio calls from other vessels reporting sightings of whales.

The primary vessel used to secure identification photographs and other field data in southeastern Alaska was a 22-ft aluminum cabin skiff, R/V *Kingfisher* with outboard engine. In False Pass (eastern Aleutians) we used the 42-ft inboard diesel fishing vessel F/V *Lucky Dove* with open skiff.

The winter Alaska Killer Whale Count was conducted between March 1 and 7, 2003. Jordan Beblow was hired to contact participants, prepare questionnaires, compile data and assist with analysis. Survey questionnaires were sent to harbormaster offices in Sitka, Juneau, Petersburg, Cordova, Seward, Kodiak and Dutch Harbor. Press releases were sent out the week prior to the survey and e-mails were sent to all individuals who participated in the July count. Interviews were given by Dr. Trites to a number of radio stations and newspapers to encourage people to participate. In addition, individuals were hired in Sitka, Juneau, Seward, Kodiak and Dutch Harbor throughout the survey period and 2 days prior to walk the docks, answer questions, and distribute and collect questionnaires.

Main Results

In the Eastern Aleutians (False Pass/Unimak Island) in May/early June 2003, there were 13 encounters with killer whales during 18 days of field effort. Preliminary examination of photographs indicated at least 60 individuals could be identified and that all individuals were transient whales. Groups appeared to number as many as 30 whales or more in some cases. Initial examination indicated most of these whales had not been identified in our previous fieldwork in the region or in other published catalogues (Dahlheim, 1997).

Large groups of transients had not been observed previously in the region and may be temporary associations that increase efficiency of killer whale predation upon gray whales during the migration of gray whales into the Bering Sea. Three apparent predation events were noted, all identified by large oil slicks that suggested the presence of a whale carcass lying on the bottom. Each slick was in relatively shallow water, and the whales were diving repeatedly and surfacing with pieces of muscle, blubber, or skin in their mouths. Samples of this tissue were obtained from two of these kills and will be identified genetically. Biopsies were taken from 9 killer whales during different encounters. Genetic analysis of these samples is in progress. Extensive acoustic recordings were made during several of the encounters and initial analysis indicates these calls were of transient type (marine mammal eating) killer whales. A detailed acoustic analysis is scheduled.

In the Glacier Bay/Icy Strait region of southeastern Alaska in 2002, (the second year of the study) we had 20 killer whale encounters during the 45 days of field work. From previously compiled catalogues (Matkin et al., 1999b) we were able to identify all individuals present in each encounter. Thirteen of the encounters were with known transient killer whales from the West Coast transient population. Nine of the encounters were with resident whales of either AF22, AF5, or AG pods. This is very similar to the composition of encounters in the previous year (2001) when a majority of encounters were with mammal-eating transient whales rather than with fish-eating residents. Harassment of marine mammal prey by transient whales was observed on two occasions, and on another two occasions killer whales killed a marine mammal. Genetic identifications of prey remains are pending. Resident killer whales were only observed feeding on fish. Complementary work by Jan Straley in the Sitka/Frederick Sound region of southeastern Alaska will be reported separately. *[See report immediately following.]*

Analysis of the Killer Whale Survey data shows that 170 surveys were returned from all parts of Alaska, with the greatest number from Southeast Alaska, followed by the Gulf of Alaska and Aleutian Islands. All of the vessels in the Aleutians were commercial fishing boats, while in Southeast Alaska they were dominated by recreational boaters. The mix of participants in the Gulf of Alaska was more balanced between recreational boaters, ferries, tugs, researchers, charter boats and commercial fishermen. One coast guard vessel participated in Southeast Alaska.

Total number of hours surveyed was 1003 in the Aleutians, 152 hours in the Gulf of Alaska, and 235 hours in Southeast Alaska. Approximately 350 whales were seen in total (all parts of Alaska), with the highest densities reported in the Gulf of Alaska and Aleutian Islands/Bering Sea.

The data are considered preliminary until the final analysis and report is submitted.

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***Progress Report*:** **Predator/Prey Investigations of Killer Whales and Steller Sea Lions in Alaska**

***Principal Investigator*:** Jan Straley, University of Alaska Southeast (in collaboration with Andrew Trites; *see previous report*)

***Other Participating Researchers*:** see above

Progress

During the course of this study there were 79 small boat surveys and one large vessel survey conducted in southeastern Alaska between 17 August 2002 and 05 June 2003. The boat survey tracklines totaled 2322 nm over 324.88 survey hours. Total time with all whales (humpback and killer whales) totaled 43.66 hours. Time with killer whales totaled 26.97 hours. These surveys resulted in 14 encounters with killer whales sighted in southeastern Alaska during this same time period. Three biopsies of killer whales were collected. One predation event was observed. Available prey species observed within 100 m of killer whales were: humpback whales, harbor porpoises, sea lions, harbor seals and sea otters.

An extensive sighting network was established region wide (southeastern Alaska). This included a ‘killer whale hot line’ cell phone, notices at boat harbors throughout southeastern Alaska, VHF radio calls, public service radio announcements and newspaper advertising. The Coast Guard Air Station Sitka and Buoytender MAPLE participated by calling in sightings. Air taxis called in sightings. Alaska Department of Fish and Game participated by calling in sightings and taking calls from fishermen without access to a cell phone. The fishing community of southeastern Alaska turned in sightings on a regular basis; workers on the Alaska Marine Highway ferries called in sightings and tugboats traveling between the smaller communities were regular callers. University of Alaska graduate student Jamie Womble, who flew on a monthly basis throughout the fall, winter and spring, reported any killer whales that were sighted near sea lion rookeries and haulouts. This sighting network resulted in 128 groups of killer whales reported from Dixon Entrance to Lynn Canal during July 2002 to June 2003. Five reliable reports of predation were obtained from this sighting network.

Project Reports:
Research Themes

Contaminant Effects
Data Archiving and Support
Fisheries Oceanography
Hydrographic and Sea Ice Studies
Marine Ecosystem Studies
Tsunami Research

Research Themes: Contaminant Effects

***Progress Report*:** **Sources of Mercury Reaching the Arctic: Airborne Particulate Mercury in China**

***Principal Investigator*:** Cathy Cahill, University of Alaska Fairbanks

Project Objectives

The *scientific objective* is:

To quantify the temporal variations in the concentrations of particulate mercury and other aerosol components, such as heavy metals, in Chinese air that could potentially transport to the Arctic.

The *capacity building* objectives are:

1. Develop a high-resolution aerosol trace element sampling and analysis capability to complement existing air quality measurements at the Institute of Atmospheric Physics meteorological tower in Beijing, China.
2. Develop contacts with Chinese scientists working on aerosol sources and long-range contaminant transport and to build a joint capability for aerosol measurement, analysis and interpretation.

Specific Nature of the Proposed Work to be Undertaken

A contaminant measurement project was planned for October 2002 to March 2004 involving three stages of activity: (i) preparation of site and measurement methodology (ii) a one-year measurement period and (iii) a data analysis, interpretation and reporting step. For at least 12 months, size-fractionated aerosol mass and trace elemental, including mercury, composition will be made using a rotating drum cascade impactor and trace elemental analysis by β-gauge and X-Ray Fluorescence (XRF) techniques. These techniques will be used to obtain 3-hour average concentrations of particulate mercury, other elements from sodium through uranium, and mass that are compatible with existing measurements in Alaska and previous measurements in Beijing. In addition, the principal investigator will attend the US–China Polar Science Panel meeting (originally scheduled for Spring 2003) to further the initial collaboration and identify new collaborative efforts.

Current Progress

The Beijing sampling has not commenced due to the Institute of Atmospheric Physics in Beijing refusing to initiate sampling until the first US–China Polar Science Panel meeting occurs. This panel meeting was scheduled for Spring 2003, but was delayed due to Severe Acute Respiratory Syndrome (SARS) and homeland security issues. The current plan is for the Polar Science Panel to meet in October. If this meeting occurs, the sampling in Beijing should commence immediately after the meeting because the sampler for these measurements is already in Beijing. In addition, there is the potential to gain access to samples collected by a different Institute of Atmospheric Physics aerosol sampler during the spring 2003 period. If these samples can be analyzed by XRF, the elemental/mercury data from spring 2003 could be recovered.

***Progress Report*:** **Persistent Organic and Trace Element Pollutants in the Alaskan and Eastern Russian Arctic**

***Principal Investigators*:** Greg Patton, Battelle Pacific Northwest Division, Richland, Washington; Cathy Cahill, University of Alaska Fairbanks

***Other Participating Researchers*:** L. Barrie, Global Atmospheric Watch Program, World Meteorological Organization; P. Blanchard, Environment Canada; E. Crecelius, Battelle Marine Sciences Laboratory, Sequim, Washington; P. Fellin, AirZone One, Inc., Mississauga, Ontario, Canada; R. Schnell, NOAA/CMDL; G. Stern, Freshwater Institute of Canada

Objectives

This project is part of the Study of Atmospheric Deposition of Contaminants in the Arctic: A Paired Study of a Site in Alaska and a Site in the Russian Far East by the National Oceanic and Atmospheric Administration’s Arctic Research Initiative and the U.S. State Department’s Environmental Diplomacy Fund for the U.S./Russian Atmospheric Contaminants Program. The project scientific objectives are: (i) to gain insight into the sources, occurrence, and environmental fate of persistent organic herbicides/pesticides and industrial chlorinated compounds (POPs) and aerosol trace elements in the atmosphere of the Alaskan and eastern Russian Arctic, (ii) to contrast the occurrence of POPs and trace elements in this region with other Arctic air sheds and (iii) to provide data in a form compatible with existing AMAP data to be used in assessing the potential risks to the environment and human inhabitants in the Arctic due to POPs.

Methods

For one year, the atmospheric concentrations of 90 polychlorinated biphenyl compounds, 40 organochlorine pesticides/herbicides or their metabolites, 14 polycyclic aromatic hydrocarbons (PAHs), and 42 selected elements from sodium through uranium (including trace metals) were measured at the Barrow NOAA baseline air chemistry laboratory. Suspended particles and gases are collected separately and chemically analyzed. The compositional signature of PAHs together with high time resolution size-segregated multi-elemental analyses, other Barrow baseline aerosol and gas observations and meteorological data will be used to identify the origin of air in which the POPs measurements are made. Three stages of activity were planned: (i) preparation of site and measurement methodology, (ii) a one-year measurement period and (iii) a data analysis, interpretation and reporting step.

Observed POPs and trace aerosol concentrations will be used to estimate atmospheric inputs of these substances to the Arctic. Collaboration with Canadian laboratories in this research ensures access to a set of similar observations with current observations being made in the Canadian and Russian Arctic under the Arctic Monitoring and Assessment Program. It also standardizes protocols of sampling analysis and data archiving.

Main Results

Currently the first and second stages (site preparation and 1-yr of sampling) of this project have been completed. Air sampling for POPs and metals was initiated at the Barrow, Alaska NOAA/CMDL station in March 2002. Continuous samples were collected during March 2002 to May 2003. The final stage of this project is data analysis, interpretation, and reporting. Currently data is available for the first portion of the sampling effort and an initial data report was sent to NOAA in May 2003.

Levels and Trends in Air

Barrow air samples for POPs have been analyzed for a four-month period (mid-March to mid-July), thus detailed discussions of seasonal trends are fairly limited. However, the current data set does provide some trend data for the early spring to mid-summer period. For this report, comparisons of levels of POPs in Barrow air will be made to the air concentrations reported for the Alert, Tagish, and Dunay sampling locations reported in Macdonald et al. (2000). At the present time, 2002–2003 POPs concentrations have not been reported from the Canadian Northern Contaminants Stations; detailed comparisons between these locations and the Russian stations will be possible once the data is finalized.

The concentration ranges and dominant PAHs were similar to observations at Alert, Dunay, and Tagish locations in the early 1990s (Macdonald et al., 2000). However, the limited Barrow data does not follow the trend at other Arctic monitoring locations that typically have increased PAH in the winter. The Barrow data shows a slight increase in PAH levels from late winter to summer.

Generally, the organochlorine compound levels observed at Barrow are similar to the observations at Alert, Dunay, and Tagish. However, the chlorobenzene, hexachlorocyclohexane, chlordane, mirex, and toxaphene groups are typically lower at Barrow. The air concentration of the industrial chemical, pentachloroanisole, is typically higher at the Barrow location but the results are highly variable. Changing ratios of g-HCH/a-HCH, TC/CC, and DDE/DDT were observed at Barrow and these may provide insight into the history of the air masses sampled at Barrow.

The mean concentration for total PCBs at Barrow was similar to the 1993 values reported at Alert, Tagish, and Dunay. The Barrow observations were similar to the other northern sites in that the tri-chloro homolog had the highest concentrations and there was little indication of seasonal trends.

The preliminary elemental analyses of the aerosol data for the first sampling period, March 14 to April 23, 2002, shows the influence of several aerosol sources, including Asian deserts, at Barrow. This is consistent with data obtained at Barrow by other NOAA researchers, such as Robert Stone, and model back-trajectories (obtained using NOAA's HYSPLIT transport and dispersion model).

This report provides the first data summary and preliminary trends for the Barrow air sampling stations. Future data reviews will incorporate the final Barrow air data for POPs, comparison of Barrow POPs and metals data, detailed comparison of Barrow and other northern contaminants data for 2002–2003, and use of NOAA's HYSPLIT transport and dispersion model to determine air mass origins.

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Publications

Preliminary reports on the initial sampling results were sent to NOAA in May 2003.

Progress Report: Financial Contribution from USA to the Arctic Monitoring and Assessment Programme (AMAP) Secretariat for the Period 1 April 2002–30 June 2006

***Principal Investigator*:** Lars-Otto Reiersen, AMAP Secretariat

***Other Participating Researchers*:** Inger Utne and Simon Wilson

Introduction

In 1991 the Arctic Monitoring and Assessment Programme (AMAP) was established by the governments of the eight Arctic nations "to provide reliable and sufficient information on the status of, and threats to, the Arctic environment, and to provide scientific advice on actions to be taken" in order to support Arctic governments in their efforts to take remedial and preventive actions related to contaminants. AMAP is now a working group of the Arctic Council.

The primary objectives of AMAP are the measurement of the levels of anthropogenic pollutants and assessment of their effects in all relevant compartments of the Arctic environment. AMAP monitoring activities cover the atmospheric, terrestrial, freshwater and marine environments, and human health. AMAP assessments are presented in status reports to Ministers and form a basis for necessary steps to be taken to protect the Arctic and its inhabitants from pollution.

In 1997 AMAP produced its first State of the Arctic Environment Report (SOAER), which was considered by Arctic Ministers at the Third AEPS Ministerial Conference in Alta, Norway. In 1998 AMAP published the AMAP Assessment Report (AAR), a fully referenced report that provided the technical background information that had been summarized for the general public in SOAER.

Objectives

Project 1. Support for the production of the 2002 AMAP Assessment reports: To present an updated assessment regarding pathways for pollutants, the pollution of persistent organics (POPs), radionuclides and heavy metals in the Arctic environment and the biological effects on biota and humans. The financial support will together with contributions from other Arctic countries, be used for scientific editing and for preparation of graphs, charts, maps and other visual means of portraying the scientific findings.

Project 2. Arrangement of the 2nd International AMAP Symposium on Environmental Pollution of the Arctic: To arrange the 2nd international AMAP symposium in Rovaniemi, Finland in October 2002. The financial contribution will together with contributions from other Arctic countries be used to arrange the Symposium and provide necessary facilities and support travel of Russian scientists and indigenous peoples to participate in the conference.

Project 3. Documentary Film Production of AMAP Phase 2 Assessment Results: To produce a documentary on the main results of the AMAP Phase 2 assessment and present it at the Third Arctic Ministerial Meeting, Inari/Saariselka, Finland, 9–10 October. This is intended to be a co-production funded by several donors.

Main Results

A second State of the Arctic Environment Report (SOAER), based on updated information and a substantial amount of additional data, was prepared by AMAP and delivered to the Arctic Council Ministers at their meeting in Inari, Finland, in October 2002. AMAP also prepared four AMAP Assessment Reports on the sources, pathways, levels, trends and effects of POPs, heavy metals, radioactivity and human health. (The remaining topics will be treated in additional assessment reports scheduled for delivery to the Ministers in 2004.)

The Second AMAP International Symposium on Environmental Pollution in the Arctic was held in Rovaniemi, Finland, 1–4 October 2002. The second SOAER and AMAP assessment reports mentioned above were the primary documents under consideration at the symposium. The symposium is an important part of the process by which AMAP communicates the results and conclusions of the assessments to Arctic stakeholders. AMAP delivered its assessments concerning POPs, heavy metals, radioactivity and human health to Ministers at their meeting in Inari, Finland, immediately following the symposium.

Below we include an itemized overview of the objectives met during the first year of this award.

1. Support to the production of the 2002 AMAP Assessment Reports (total financial contribution USD 63,500):

- Order 600 copies of Arctic Pollution 2002 at USD 30 per copy (USD 18,000*)
- Partial financial contribution to the production and printing of the 2002 AMAP five scientific reports (USD 45,500**):
  - AMAP Assessment 2002: Human Health in the Arctic*
  - AMAP Assessment 2002: The Influence of Global Change on Arctic Contaminant Pathways*
  - AMAP Assessment 2002: Persistent Organic Pollutants in the Arctic**
  - AMAP Assessment 2002: Heavy Metals in the Arctic**
  - AMAP Assessment 2002: Radioactivity in the Arctic**

*The copies have been forwarded to NOAA, Oceanic and Atmospheric Research R/AR, Silver Spring, MD, USA, attn: Dr. John Calder.

**The reports are under production at the printers and will be distributed to the AMAP member countries, including USA, during fall 2003.

2. Arrangements of the 2nd International AMAP Symposium on Environmental Pollution of the Arctic, Rovaniemi, Finland, 1–4 October 2002 (total financial contribution USD 16,500):

- Travel and accommodation, AMAP Secretariat (4 persons)
- Travel and accommodation, Russian Participants, Indigenous Peoples (7 persons)

AMAP contracted with the Finnish Forest Research Institute (METLA), Rovaniemi, to organize and handle the practical arrangements for the Symposium at a total of EUR 80,000, including the arrangement of travel and accommodations for the Russian participants at the meeting. The USD 16,500 was a part of the payment for the contract.

A copy of the Symposium Proceedings was given to Dr. John Calder, NOAA, Oceanic and Atmospheric Research R/AR, Silver Spring, MD, USA, who participated in the Symposium.

3. Documentary Film Production of AMAP Phase 2 Assessment Results (total financial contribution USD 20,000):

AMAP II – The Results, Produced by Loke Film Denmark. Total production costs were USD 40,000; CIFAR funding provided 50% financial support.

The documentary was presented at the Second AMAP International Symposium in Rovaniemi, 1–4 October 2002 and at the Senior Arctic Official (SAO) Meeting, 7–8 October 2002, Inari, Finland. One copy of the documentary has been forwarded to the AMAP member countries, including NOAA, Oceanic and Atmospheric Research R/AR, Silver Spring, MD, USA, attn: Dr. John Calder. One copy of the documentary has also been forwarded to the AMAP Permanent Participants.

Research Themes: Data Archiving and Support

Final Report: **Integrated Analysis of Climate Change in the Bering Sea**

Principal Investigator: S. Lyn McNutt, University of Alaska Fairbanks

Objectives

This project focused on the development of functional requirements for a knowledge-based discovery system for integrating physical and biological data in the Bering Sea, called the MARine Integrated Analysis System (MARIA).

The System Functional Requirements Specification (SFRS) translates the needs of the MARIA user community to utilize a system for ingesting and integrating widely varied datasets on climate indices and supporting materials, analyze these datasets, model the sensitivity of the interrelations of the information, access and apply modeling functions to the data, display and manipulate the data in a distributed, web-based environment, and display and distribute the data and results in a variety of formats.

Final Results

1. A meeting was held at NOAA/PMEL on 19–20 May 2002 to delineate the functional requirements for the MARIA System. The Workshop consisted of the MARIA user community at the National Oceanic and Atmospheric Administration (NOAA) Pacific Marine Environmental Laboratory (PMEL) held in Seattle, Washington. Results of this meeting were used to create the SFRS for MARIA.
2. Presentations on MARIA were made at the Alaska Oceans and Watershed Workshops on 18–19 June 2002 and 25–26 July 2002, both in Anchorage, Alaska. The MARIA concept was well-received and was considered in an overall strategy of observing and analyzing Alaskan issues.
3. The SFRS formed the basis for the Coastal Ocean Database for Alaska (CODA) submitted to the NASA CAN Announcement of Opportunity for the REASoN Program. (Not funded.)
4. The consensus reached on the CODA system is now under consideration as a prototype model for the Alaska Ocean Observing System (AOOS) and the Exxon Valdez Oil Spill Trustee Council Gulf Environmental Monitoring Program.
5. We have also begun to investigate the possibility of expanding the MARIA project as a DEPSCoR project.

Research Themes: Fisheries Oceanography

***Progress Report*:** **Relationship between Growth and Survival of Coho Salmon Utilizing the Coastal Gulf of Alaska**

***Principal Investigator*:** Milo Adkison, Juneau Center, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks

***Other Participating Researchers*:** Ryan Briscoe, graduate student; Alex Wertheimer, NOAA Auke Bay Laboratory

Objectives

Coho salmon in the northeast Pacific have had substantially different population trends in the Pacific Northwest compared to Alaska. Coho salmon in the Pacific Northwest have declined precipitously (Weitkamp et al., 1995), to the extent that most populations in the region have been listed as threatened or endangered under the federal Endangered Species Act. At the same time, coho salmon catches in Alaska in the 1990s have been at historically high levels (Byerly et al., 1999); while data on the status of individual populations is sparse, an analysis of available escapement data for coho salmon in southeast Alaska showed generally stable or increasing trends (Baker et al., 1996). Clearly, terrestrial habitat conditions have contributed to these dichotomous trends; much of Alaska habitat remains in pristine condition (Wertheimer, 1996), while degradation and destruction of freshwater habitat has reduced the range and caused much of the decline of coho salmon in the Pacific Northwest (Weitkamp et al., 1995). However, during this same time period, conditions in the marine environment have contributed to the different population trends as well. For example, ocean survival of Oregon Production Index coho salmon has declined from an average of nearly 6% throughout the 1970s to 0.5% in recent years (Weitkamp et al., 1995). In contrast, ocean survival for coho salmon at Auke Creek in southeastern Alaska has averaged 19% over the same time period, ranging from 8 to 37% (Taylor and Lum, 2000).

These regional differences in marine survival are consistent with the general inverse response of Pacific salmon in the two regions to changing environmental conditions (Hare et al., 1999). Climatic conditions have been strongly correlated with salmon abundance in the Gulf of Alaska (Downton and Miller, 1998; Beamish et al., 1999), as well as with changes in zooplankton abundance and species composition in the Gulf of Alaska (Brodeur and Ware, 1992; Anderson and Piatt, 1999). While changes in temperature and other biophysical conditions in the Gulf of Alaska have obviously benefited Alaska salmon populations, our understanding of the mechanisms of this coupling and how they relate to growth and survival of salmon in the marine environment is poor. There is considerable evidence to indicate that growth rates during the first year of marine residency are a critical factor for surviving to adulthood (Beamish and Mahnken, 1999; Mortensen et al., 2000). This relationship between growth and survival of salmon, and the phase of the marine life history at which it occurs, underlies the major hypotheses of the Global Ecosystem (GLOBEC) research program in the Gulf of Alaska.

This study will use archived scales from both adult and juvenile coho salmon to examine the relationships between growth during specific marine phases and subsequent survival to adult and size at maturity, and to evaluate how these parameters vary in relation to biophysical data sets. These studies will increase our understanding of the mechanisms by which processes in the Gulf of Alaska affect coho salmon population responses, and may lead to enhanced predictability of the response of the resource to changing climate conditions. Such information is important in developing robust management approaches that can respond to both times of high survival and abundance as have occurred recently in much of Alaska, as well as for conservation and maintenance of coho salmon populations when climatic conditions shift.

Methods

A. Digitizing and analysis of juvenile scale collections. Scales collected from juvenile coho salmon in coastal habitats of Southeast Alaska are being digitized and analyzed to identify the transition period from nearshore to GOA waters.

B. Digitizing and analysis of Auke Creek scale collections. Archived scales taken from adult and jack coho salmon returning to Auke Creek weir are being digitized and analyzed to determine interannual growth patterns. Marine growth will be evaluated for three phases: juvenile nearshore/coastal; juvenile Gulf of Alaska; and adult.

C. Data management, analysis, and reporting. A data base of scale data will be created and linked to biological data on Auke Creek coho salmon and environmental data for nearshore waters of southeast Alaska and for the GOA. Relationships between scale growth, marine survival, size at return, and environmental data sets will be analyzed using appropriate statistical methodology.

Main Results

1. Several hundred adult and juvenile scales have been digitized. Based on juvenile scales from known locations and CPUE data, growth regions corresponding to the early marine, strait, and Gulf of Alaska habitats have been identified.
2. Survival of jack and adult males was compared to environmental covariates and found to be related to sea surface temperature and hatchery production of pink and chum fry (a potential prey item). Adult returns were strongly related to jack returns the previous year, implying an early marine determination of survival.
3. No statistically significant relationships were found between environmental variables and growth as captured in various regions of the scale. Previous power analyses allow us to assert the implausibility of a large influence of the environmental variables we examined on growth.
4. Analyses of growth-survival relationships are underway. A manuscript based on the work to date is planned for this fall.

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***Progress Report*:** **Early Marine Growth and Survival of Bristol Bay Sockeye Salmon Smolt**

***Principal Investigator*:** Milo Adkison, Juneau Center, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks

***Other Participating Researchers*:** Ed Farley, graduate student; Steve Ignell and Jack Helle, NOAA Auke Bay Laboratory

Objectives

1) Determine if Bristol Bay sockeye salmon production is influenced by early marine growth rates.
2) Identify the relationship between environmental conditions and early marine growth of juvenile sockeye salmon in the eastern Bering Sea.

Methods

The approach to analyzing early marine growth of Bristol Bay sockeye salmon will be broken into two parts: 1) a retrospective analysis, relating early marine growth of Bristol Bay sockeye salmon to adult salmon production and changes in the marine environment using time series analyses; and 2) a model of growth potential relating environmental characteristics (forage density and water temperature) to juvenile sockeye salmon biological characteristics (growth, distribution, diet, and thermal experience) to make relative comparisons of juvenile sockeye salmon growth rate potential between oceanographic habitats (coastal, middle, and outer domains; see Kinder and Schumacher (1981) for description of physical habitat in the eastern Bering Sea) and years.

Data for the retrospective analysis of early marine growth are from previously digitized (annulus and circuli growth) sockeye salmon scales (1959–2000) from the Kvichak (age classes 1.2, 1.3, 2.2, and 2.3) and Egegik (age classes 1.3, 2.2, and 2.3) River systems. Early marine growth rates of juvenile sockeye salmon taken from the first marine growth year, adult survival, and changes in the environment will be modeled using univariate and multivariate Time Series Analysis (Box and Jenkins, 1976; Wei, 1990). Factors affecting early marine growth rate potential will be analyzed using data from annual fall surveys (1999 to 2003) of juvenile sockeye salmon in the eastern Bering Sea conducted by the Ocean Carrying Capacity program (Farley et al., 1999; 2000; 2001) and explored using a spatially explicit model of growth potential (Brandt et al., 1992; Brandt and Kirsch, 1993; Mason et al., 1995; Nislow et al., 2000).

Main Results

Eastern Bering Sea research cruises have been conducted by scientists from the Auke Bay Laboratory, Ocean Carrying Capacity (OCC) program during July 1999 (summer) and August and September 1999–2002 (fall) to study the early marine distribution, migration, and growth of juvenile sockeye (*Oncorhynchus nerka*) salmon from Bristol Bay. The principal goal of this research is to understand the relationship between adult Bristol Bay sockeye salmon survival and annual variations in the biological characteristics (growth, migration, and distribution) of juvenile Bristol Bay sockeye salmon.

Preliminary results from these surveys indicate: 1) Sea surface temperatures within the eastern Bering Sea can influence the width and extent of juvenile sockeye salmon distribution and migration rate. —During July 1999, juvenile sockeye salmon were caught east of Port Moller where sea surface temperatures were 6°C or more; sea surface temperatures in offshore waters during July were 4–5°C. The westerly extent of juvenile sockeye salmon distribution captured during fall 1999 was 164°W; during fall 2000 through 2002, catch per unit effort (CPUE) of juvenile sockeye salmon along the 166°W transect was lowest during 2000, slightly higher during 2001, and highest during 2002. Coincidently, sea surface temperatures during fall were generally coldest during 1999 (9–10°C), similar during 2000 and 2001 (8.5–11°C) and warmest during 2002 (10–12°C), possibly indicating that sea surface temperatures influenced seaward migration rates. 2) Migration rates of juvenile sockeye salmon may affect their early marine growth. —Zooplankton densities are generally greatest within offshore, deeper, waters of the eastern Bering Sea. Juvenile sockeye salmon (ages 1.0 and 2.0) caught during fall 1999 were significantly smaller than those captured during the falls of 2000 and 2001, perhaps indicating that the delayed seaward migration of juvenile sockeye salmon during 1999 negatively impacted their early marine growth. 3) Early marine growth rate may affect survival rate of juvenile salmon during their ocean residence. —For example, ocean age *.2 returns of adult sockeye salmon to Bristol Bay were dramatically lower during 2001, suggesting that reduced early marine growth of juvenile sockeye salmon during 1999 may have negatively impacted their survival at sea.

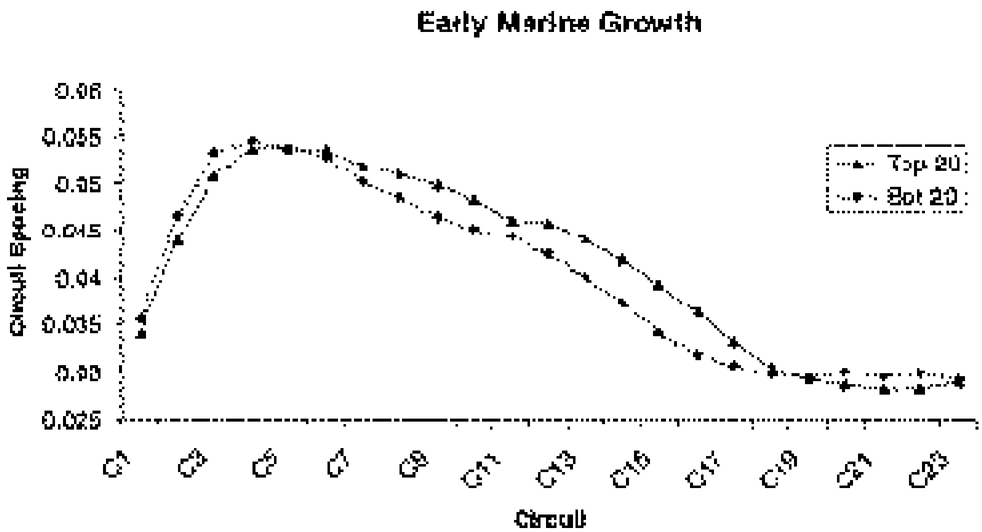

Figure 1. Circuli spacing (growth) for Bristol Bay sockeye salmon during the first year in the ocean for the top 20% and bottom 20% of returning adults 1956 to 2001.

Additional research will focus on developing early marine growth models using historical growth data collected from adult Bristol Bay sockeye salmon scales. Preliminary analyses comparing adult sockeye salmon returns and early marine growth indicate that lower returns (bottom 20% of returns) are associated with lower growth during the first few months at sea (circuli growth C6 to C18) and vice versa (Figure 1). Possible mechanisms affecting early marine growth, such as the examples given above, are actively being investigated during the annual eastern Bering Sea surveys. Future models of early marine growth and production will incorporate both abiotic and biotic mechanisms thought to be responsible for impacting early marine growth of Bristol Bay sockeye salmon.

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***Progress Report*: Origin of Juvenile Chum Salmon (*Oncorhynchus keta*) Collected during ABL-OCC Cruises in the Eastern Bering Sea 2002**

***Principal Investigator*:** A.J. Gharrett, Juneau Center, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks

***Other Participating Researchers*:** C. Kondzela, R. Wilmot and E. Farley, NOAA/Auke Bay Laboratory

Objectives

The primary objective of this study is to determine the geographic origin of juvenile chum salmon collected in the eastern Bering Sea during fall 2002 ABL-OCC (Auke Bay Laboratory–Ocean Carrying Capacity) cruises. This work is part of a larger effort to improve our understanding of the physical and biological mechanisms that affect the distribution, migration, growth, and survival of juvenile chum salmon in western Alaska, a region which has experienced severe declines in returns of adult chum salmon in recent years.

Methods

Juvenile chum salmon (*Oncorhynchus keta*) were collected from the eastern Bering Sea shelf using a midwater rope trawl towed at the surface between August 17 and October 13, 2002 (Farley et al., 2003). Sampling stations were between longitudes 161 and 168º W and between latitudes 60 and 65º N. Whole fish were frozen onboard the contracted fishing vessel *Sea Storm*. In the laboratory, muscle, liver, heart and eye tissues were removed from each fish for genetic analysis. Starch-gel electrophoresis was used to determine genetic variation at more than 20 protein-coding loci (Aebersold et al., 1987; Kondzela et al., 1994). For an initial analysis, samples from three collection areas were examined—southwest of Nunivak Island, southwest of St. Lawrence Island, and west of the Yukon River mouth. Samples from additional collection sites continue to be analyzed in the laboratory. The genetic variation of the collections was then analyzed using a Bayesian method of mixture analysis (Pella and Masuda, 2001) and the Pacific Rim chum salmon allozyme baseline (Kondzela et al., 2002). Estimates of geographic origin and 95% confidence intervals were made for each collection.

Main Results

Table 1. Regional estimates (mean ± s.d.) of juvenile chum salmon collected in the eastern Bering Sea in Fall 2002 using a Bayesian method. Below each point estimate is the 95% probability interval for the true estimate. Estimates significantly greater than zero are in bold font. (---) indicates the region was removed from the baseline after initial analysis indicated no contribution

		Regional Allocation				
Collection	N	Kotzebue Sound	Yukon, summer	Yukon, fall	Kuskokwim	N. Russia
SW Nunivak Is.	149	---	0.289 ± 0.250	**0.318 ± 0.122**	**0.393 ± 0.227**	---
			(0 - 0.802)	(0.061 - 0.545)	(0.004 - 0.773)	
South of St. Lawrence Is.	119	---	0.225 ± 0.162	**0.318 ± 0.106**	0.137 ± 0.127	**0.320 ± 0.063**
			(0 - 0.554)	(0.052 - 0.506)	(0 - 0.423)	(0.203 - 0.451)
West of Yukon River	145	**0.300 ± 0.121**	**0.446 ± 0.161**	0.257 ± 0.207	---	---
			(0.027 - 0.518)	(0.108 - 0.739)	(0 - 0.737)	

The estimates of origin for the three collections are given in Table 1. Most of the estimates are associated with low precision given the small collection sizes (< 200 fish each) and the small scale of the geographic regions chosen. In every collection, stocks from more than one geographic region were recovered. The majority (>70%) of juvenile chum salmon from the southwest Nunivak Island collection are from Kuskokwim River and fall Yukon River stocks, with the remainder (29%) from summer Yukon River stocks. Fish caught west of the Yukon River are primarily from Kotzebue Sound (30%) and summer Yukon River (45%) stocks; the remainder is from fall Yukon River stocks. Juvenile chum salmon caught southwest of St. Lawrence Island contained the greatest diversity of stocks. Significant contribution came from northern Russia and fall Yukon River stocks (32% each), with lesser contribution from summer Yukon River and Kuskokwim River stocks.

From the perspective of where stocks migrate from a given geographic region, our results indicate that: 1) chum salmon from Kotzebue Sound, the northernmost region of primary distribution in North America, were only recovered off the mouth of the Yukon River, implying a southward migratory pathway near the coast, 2) both fall and summer Yukon River stocks were recovered in all three collections, which suggests a southwestward migration resulting in a broad distribution along the eastern Bering Sea shelf, 3) Kuskokwim River stocks were primarily restricted to the southern Nunivak Island collection following a westward migratory pathway, 4) no significant fraction of stocks from Bristol Bay or the Alaska Peninsula were recovered, and 5) at least some fraction of juvenile chum salmon from the Anadyr River region of northeastern Russia migrate nearly due east as far as 171º W.

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Pella, J. and M. Masuda. 2001. Bayesian methods for analysis of stock mixtures from genetic characters. *Fisheries Bulletin* 99: 151–167.

Publications

To be published as an extended abstract in the November 2003 NPAFC International Workshop on Application of Stock Identification in Defining Marine Distribution and Migration of Salmon (E. Farley's presentation).

Progress Report: Population Structure in Alaskan Pacific Ocean Perch (*Sebastes alutus*), Phase II

***Principal Investigator*:** A.J. Gharrett, Juneau Center, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks

***Other Participating Researchers*:** Z. Li, Research Associate; K. Palof, Graduate Student

Objectives

The objective of this project is to continue work describing the population structure of Pacific ocean perch (*Sebastes alutus*) from the Alaskan waters of the Gulf of Alaska and Bering Sea. The analysis will be based on variation observed for microsatellite loci and build on the information we obtained in Phase I. This project will be completed in Phase III.

Status

Funding was originally requested for this project to begin on 1 July 2002. Funding was not made available until January 2003. I do not have a "stable" of researchers that can start instantaneously and cannot instantaneously begin a project. In the case of this project, Ms. Z. Li, who was originally proposed to do this work, was assigned to other projects. Consequently, I could not "recruit" until I had money in hand. Recruitment is not instantaneous. Ms. K. Palof, a graduate student, was recruited for this project and will begin on 1 July 2003. I was also fortunate in obtaining first-year stipend support from the Alaska Sea Grant College Program. Therefore I intend to apply much of this grant to Ms. Palof's 2004 summer salary and a small amount to Ms. Li.

We have most of the samples and await Ms. Palof's arrival at the first of July. In the interim we secured a second DNA sequencer for microsatellite analysis that will increase the efficiency of the lab as a whole.

Progress Report*:** **Regional Economic Impact of the Bering Sea/Aleutian Islands Crab Fisheries: Snow Crab Market Model *[Project previously titled Regional Economic Impact of the Steller Sea Lion RPAs on Kodiak, Alaska]

***Principal Investigators*:** Mark Herrmann, Joshua Greenberg, Charles Hamel and Hans Geier, University of Alaska Fairbanks; Keith Criddle, Utah State University

Objectives

This is a progress report for the project currently titled "Regional Economic Impact of the Bering Sea/Aleutian Islands Crab Fisheries: Snow Crab Market Model" which was formally titled "Regional Economic Impact of the Steller Sea Lion RPAs on Kodiak, Alaska." The focus of this study was changed with permission from the Cooperative Institute for Arctic Research (CIFAR) after collaboration with the National Marine Fisheries Service. The original due date was also extended to September 2004. Specifically, in the revised proposal we are building a snow crab market model that will tie into a regional economic model for snow crab being built for the Alaska Department of Fish and Game. By combining the crab market model with the regional economic model we will have a more comprehensive model to assess the impacts of changes in the scale of snow crab harvests to regional communities and with which to assist policy makers in analyzing the effects of crab rationalization.

Methods

Nine behavioral equations are being estimated to describe price formation in the Alaska snow crab industry. This model includes the major snow crab producing regions of Alaska and Canada and the major markets of Japan and the United States. The estimated model will be simulated using the dynamic Newton algorithm and confidence intervals will be generated using a Monte Carlo approach. The simulated market model will examine how changes in landings and other exogenous factors (such as exchange rates and income levels) affect the price wholesalers and fishermen receive for snow crab. This model will then be integrated in with a regional input-output model to measure the effect of estimated changes in fishery landings and the effects of alternative management policies on Alaska fishery dependent coastal communities.

Main Results

Substantial progress has been made on the market model: the equations are estimated and initial simulations have been performed. The PIs are waiting on some 2002 data to update the model (it is now estimated using annual data from 1984–2001), and preliminary results should be forthcoming Input-output models have been regionalized for several communities, and we are beginning to assimilate survey responses from harvesters and catcher processors as stand alone production functions within the models—though we are still waiting on data from the shoreside processing sector. We are very pleased with the progress on this grant. The ADF&G component is slated to be finished by the end of 2003, at which point we will begin integrating the two models. The CIFAR project should be finished on time.

Publications

None yet.

***Final Report*:** **Effects of Bottom Trawling on Bering Sea Infauna: 2001 Benthic Taxonomy**

***Principal Investigator*:** Stephen C. Jewett, University of Alaska Fairbanks

***Other Participating Researchers*:** Max Hoberg and Arny Blanchard, University of Alaska Fairbanks

Objectives

Data from the 1997–1999 studies were used to design a multi-year experimental study of short-term trawl impacts and recovery that began in summer 2001. The objective of this study was to provide a qualitative and quantitative description of selected benthic stations in the eastern Bering Sea. This information, in addition to data collected from 1997–1999, will be used by NMFS to assess the impact of trawling on soft bottom community in an effort to determine essential fish habitat as mandated by the new Magnuson-Stevens Sustainable Fisheries Act.

Methods

A total of 144 0.05 m^2 van Veen grab samples were collected; 72 samples before and after trawling. These samples were received at UAF in late 2001 from Dr. Robert A. McConnaughey, NMFS, Seattle. The samples had been sieved through 1.0 mm mesh and the invertebrates were fixed in buffered formalin, stained, and transferred to 50% isopropyl alcohol prior to arrival at UAF. Processing each sample included identification to at least the family level of taxonomy, counting, and wet weighing (blotted dry). The 1990 NODC code was used for all taxonomic data. All data were entered on a PC computer and 100% verified.

Results

Data from the processed 2001 benthic samples were submitted to NMFS (Dr. Robert A. McConnaughey) in electronic form on September 30, 2002. The submission included a disk containing three files: TRAWLEX01STAT.xls (actual data); TRAWLEX01META.xls; and TRAWLEX01TAXON.xls (taxon list and codes). This submission fulfilled the contractual obligation of UAF. Statistical and ordination analyses and interpretation of these data will be conducted by NMFS personnel.

***Final Report*: Granulometry and Organic Carbon Contents of Sediments, Bering Sea, Alaska**

***Principal Investigator*:** A. Sathy Naidu, University of Alaska Fairbanks

Objectives

To analyze the grain size distribution, organic carbon, nitrogen and their stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) in 144 sediment samples provided by Dr. R.A. McConnaughey of NMFS Alaska Fisheries Science Center, Seattle.

Methods

The sediment granulometry was analyzed by the combined sieve-pipette method and the grain size statistical parameters were calculated following the methods outlined in Folk (1980). The analyses of the carbon and nitrogen contents and their stable isotopes were according to the methods enumerated in Naidu et al. (2000), using a Europa 20/20 mass spectrometer.

Main Results

Generally, the sediments are well-sorted fine to medium sands with nearly symmetrical or positive-skewed size distributions. Gravel, silt and clay size particles occur in minor to trace amounts.

The organic carbon contents in the sediments are generally low. Based on the ranges of C/N ratio, and the carbon and nitrogen isotope ratios, it is suggested that the predominant source of organic matter in the sediments is of marine origin. This is consistent with the ratios that were reported for the productive regions of the northern Bering Sea (Naidu et al., 2001). The very high correlations ($P<0.05$) between percents N and C and the intercept of the binary plot at 0% indicates that almost all of the nitrogen in the sediment is organic with little inorganic bound (adsorbed) nitrogen present. No significant correlations. The lack of a significant correlation (at $P<0.05$) between percents mud (<62 micron size fraction, silt + clay) and organic carbon indicates that factors other than granulometry control the amount of OC in the sediments.

[The data from this project were submitted by the PI to Dr. McConnaughey in November 2002. They are also on file at the CIFAR office.]

References

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***Progress Report*: Reproductive Potential of Pacific Cod**

***Principal Investigator*:** Brenda L. Norcross, University of Alaska Fairbanks

***Other Participating Researchers*:** Olav A. Ormseth, Ph.D. student, University of Alaska Fairbanks

Objectives

Pacific cod (*Gadus macrocephalus*) are an important ecological and economic resource in the North Pacific Ocean. The cod fishery in Alaska is the state's second largest groundfish fishery (NMFS, 2000). Pacific cod are also a major component of North Pacific Ocean ecosystems, serving as predators of numerous species of invertebrates and smaller fish and as prey for other fish and marine mammals (NMFS, 2000). Like most marine fishes, Pacific cod exhibit significant recruitment variability at interannual and decadal time scales (NPFMC, 2001). This results in changes in cod abundance that affect both the human and non-human communities that depend on cod.

Recruitment success depends in part on the fate of offspring during egg and larval life stages, which generally experience high mortality (Chambers and Trippel, 1997). Therefore, recruitment may benefit from factors that increase the number of eggs spawned and/or the likelihood that eggs will survive to older stages. In a number of species, individual female spawners differ substantially in the number of eggs they produce, the amount of energetic resources they provide each egg, and the timing and duration of the spawning season (Chambers and Trippel, 1997). For example, in Atlantic cod (*Gadus morhua*), older spawners produce more and bigger eggs than young spawners, and spawn over a longer period of time (Trippel, 1998). In addition, females possessing greater energy reserves are more likely to be successful spawners (Kjesbu et al., 1991).

In Pacific cod, little is known about the factors that influence female reproductive potential. Relative fecundity (fecundity per unit body weight) increases with length of fish (Hattori et al., 1995), and female cod appear to depend on energy stored in the liver to produce eggs and survive the spawning period (Smith et al., 1990). Thus variability in age, size, and energy stores of females may be an important source of variability in reproductive success and recruitment in Pacific cod.

To explore the influence of maternal attributes on reproductive potential in Pacific cod, we are conducting a study of female cod caught in Alaskan waters during the spawning season. We are investigating how the age, size, and energy reserves of these females relate to their fecundity and the quality of the eggs they produce.

Methods

Changes in research design. This study was originally designed to include only cod from the western Gulf of Alaska (GOA). Because Alaskan cod are managed as two separate stocks (GOA and Bering Sea/Aleutian Islands), we felt it was important to include Bering Sea cod in the project. Therefore, during the winter of 2002–2003 we participated in several research cruises chartered by the National Marine Fisheries Service (NMFS) in the southern Bering Sea. In 2002, fish from the Gulf of Alaska were collected solely through the assistance of NMFS observers in fish processing plants in Kodiak, Alaska. Those collections were continued in 2003 and supplemented by cod caught on a short research cruise near Kodiak during March. The purpose of this cruise was to increase the number of samples collected and to allow a large number of fish to be collected immediately prior to spawning.

Sample collection. Whole female cod or cod tissues were collected through the following means:

- During February and March of 2003, a total of 52 female cod were collected by the NMFS plant observers in Kodiak. The ability of the observers to collect fish was reduced because only two plants were available for collections and by an early closure of the cod fishery. The collected cod were frozen whole and stored at a commercial facility in Kodiak.
- During March 8–10, 2003, 98 female cod were collected aboard the F/V *Mythos*, a commercial fishing boat equipped with jig gear that was chartered as part of this project. All cod were collected from a region approximately five nautical miles northeast of the town of Kodiak on Kodiak Island. Fish were frozen whole and stored at a commercial facility.
- During the winter of 2003, cod tissues were collected on three separate cruises in the Bering Sea. From December 29, 2002 to January 4, 2003, tissues were collected from 59 cod caught northwest of Cape Sarichef on Unimak Island in the southern Bering Sea. From February 5–16, 2003, 152 cod were sampled in a wider area extending from Cape Sarichef northeast to Amak Island. From March 18–31, 2003, 161 cod were sampled northwest of Cape Sarichef. Fish were caught using pot gear, killed, and immediately dissected. Livers and one ovary were refrozen for later analysis. The remaining ovary was preserved in 10% formalin.

Stomach contents were weighed and otoliths removed. In addition, a short section of vertebrae and a fin clip were removed for use on separate projects.

Preliminary analysis. During June 2003, tissues were collected from the previously stored fish at Kodiak. Fish were thawed, weighed, and measured for length. The liver and ovaries were removed, weighed, and refrozen for later analysis. Stomach contents were weighed and otoliths were removed. The collected tissues were transported to Fairbanks for analysis.

Laboratory analyses. These analyses are ongoing and include the following:

- Age will be determined by NMFS personnel using the collected otoliths.
- Energy reserves are being assessed by measuring the fat content of the liver using a solvent extraction apparatus. In addition, we are calculating condition factor (weight/length^3) and hepatosomatic index (liver weight/body weight).
- Reproductive potential is being determined by using collected ovaries to measure fecundity and determine the fat and protein content of individual eggs. We are also calculating gonadosomatic index (gonad weight/ body weight).

Results

Laboratory analyses are currently being performed; therefore formal results are not yet available. One interesting result from the Bering Sea cruises, however, was the observation that males appeared to have smaller livers than females. Because of this, 101 male cod were collected as part of the 372 total fish obtained on the three cruises. In addition, measurements of relative liver and gonad weight were made for fish from which tissues were not collected. Preliminary results indicate that male livers weighed less and constituted a smaller percentage of total body weight (Table 1). Such differences support the hypothesis that energy stores are of greater importance to female cod and may affect reproduction.

Table 1. Morphology of male versus female cod caught in the southern Bering Sea, winter 2003. Mean values of all fish regardless of age or maturity stage are reported. HSI = hepatosomatic index = liver weight/body weight. N = 114 for males, N = 348 for females.

	mean length	mean weight	mean liver weight	mean HSI
Male	62.7 cm	3.24 kg	112 g	3.9%
Female	65.6 cm	3.97 kg	206 g	5.4%

References

Chambers, R.C. and E.A. Trippel. 1997. *Early Life History and Recruitment in Fish Populations*. Chapman & Hall, London. 596 pp.

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Smith, R.L., A.J. Paul and J.M. Paul. 1990. Seasonal changes in energy and the energy cost of spawning in Gulf of Alaska Pacific cod. *Journal of Fisheries Biology* 36: 307–316.

Trippel, E.A. 1998. Egg size and viability and seasonal offspring production of young Atlantic cod. *Transactions of the American Fisheries Society* 127(3): 339–359.

Publications

An overview of this project was presented at the annual PICES meeting where it won the best student poster award:

Ormseth, O.A. and B.L. Norcross. 2002. Linking the environment to the distribution and recruitment of Pacific cod in the North Pacific Ocean. 11th Annual PICES Meeting, Qingdao, China, October 2002.

An oral presentation was also made in the past year:

Ormseth, O.A. and B.L. Norcross. 2002 Seasonality and individual variation in the reproductive potential of female Pacific cod in the North Pacific Ocean. 53rd Arctic Science Conference, Fairbanks, AK, September 2002.

***Progress Report*: Feasibility to Design and Implement a Nearshore Juvenile Flatfish Survey—Eastern Bering Sea**

***Principal Investigator*:** Brenda L. Norcross, University of Alaska Fairbanks

***Other Participating Researchers*:** Brenda A. Holladay, University of Alaska Fairbanks

Objectives

This project will examine the feasibility of monitoring key nursery grounds in the Eastern Bering Sea for use as an index of flatfish recruitment. Gear and methods previously applied in the Gulf of Alaska will be field-tested for effectiveness with the habitats and fauna of the Eastern Bering Sea during one 16-day research cruise in August 2003. As no previous research has targeted newly settled flatfishes in this area, the collections from this cruise will provide baseline information on juvenile flatfish settlement timing and habitat. We will test our hypothesis that cross-shelf winds advect larvae from spawning locations to the inner front of the Bering Sea, and therefore the inner front is the most likely place for juvenile flatfishes to aggregate.

If this pilot study is successful, it will provide a basis for future research which will improve recruitment predictions for commercially harvested flatfish populations and improve understanding of the mechanisms underlying decadal shifts in production of selected species within the Eastern Bering Sea.

Methods

Sample gear and collection methods are identical to those used in surveys of newly settled flatfishes near Kodiak Island and along the Alaskan Peninsula (Norcross et al., 1995; 1997; 1999). Gear will include a 10-ft plumbstaff beam trawl net having 7-mm body mesh and a 4-mm codend liner, a sediment grab, and a vertical conductivity/temperature/depth (CTD) profiler having an internal memory. At each site, the net is fished for 10 minutes, and the grab and CTD are deployed. Juvenile fishes and invertebrates are enumerated, and fishes are measured using an electronic fish measuring board.

The research cruise is scheduled for 11–27 August 2003, and will include up to 12 sampling days. Samples will be collected along a series of transects positioned 20 nm apart, running perpendicular to the 50 m isobath in northwestern Bristol Bay. The goal for each transect is to collect samples at least three sites inshore of the inner front in the coastal domain, at sites within the inner front, and at least three sites offshore of the inner front in the middle domain.

At the end of each day's sampling, the position and width of the inner front will be determined based on vertical profiles of salinity and temperature. The distribution of young-of-the-year flatfishes will be examined relative to the position of this front. The following days' sample sites will be based on the observed position of the front. The distribution of juvenile flatfishes across the inner frontal region, as observed during the field collections, will be used in determining the geographic scope of the collections.

Post-cruise analysis will examine and interpret the distribution of juvenile flatfishes relative to the oceanographic front, depth, and sediment grain size.

Main Results

The first year of this project has been devoted to planning the research cruise. A review of literature (peer reviewed and gray) relative to the oceanography of the Eastern Bering Sea and the flatfishes in that region was used to determine the appropriate sampling time and location. We decided that the area south/southeast of Nunivak Island would be the optimal region to fish, based partially on examinations of the oceanographic front (Kachel et al., 2002). The *F/V Big Valley*, a crabber, has been contracted to support the scientific research. The cruise will be during the last half of August, when we expect most young-of-the-year flatfishes to have settled to the bottom, where the trawl net can capture them. Brenda Holladay will act as chief scientist, and will be assisted with field collections by two University of Alaska Fairbanks volunteers and one National Marine Fisheries Service employee.

Dr. Norcross will present a paper at the Larval Fish Conference in Santa Cruz, California during August 2003. The conference and the research cruise are concurrent, but preliminary data from the research cruise are expected to be incorporated into the presentation. Dr. Norcross will be in satellite phone contact with Brenda Holladay to discuss sample collections throughout the duration of the cruise.

References

Kachel, N.B., G.L. Hunt, S.A. Salo, J.D. Schumacher, P.B. Stabeno and T.E. Whitledge. 2002. Characteristics and variability of the inner front of the southeastern Bering Sea. *Deep-Sea Research. Part II, Topical Studies in Oceanography* 49 (26): 5889–5909.

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Norcross, B.L., A. Blanchard and B.A. Holladay. 1999. Comparison of models for defining nearshore flatfish nursery areas in Alaskan waters. *Fisheries Oceanography* 8(1): 50–67.

***Progress Report*:** **Processes Affecting Larval Dispersal, Settlement, and Juvenile Habitat of Flatfishes: a Manuscript**

***Principal Investigator*:** Brenda L. Norcross, University of Alaska Fairbanks

***Other Participating Researchers*:** Brenda Holladay, University of Alaska Fairbanks; Kevin Bailey, AFSC/NMFS (unfunded); Janet Duffy-Anderson, AFSC/NMFS (unfunded)

Objectives

A key to understanding flatfish life history and productivity is integrating knowledge about spawning, larval and juvenile stages. One of the key gaps in information that we have is the distribution of juvenile flatfishes, and especially that of age-0 fish. This is information that should be utilized in development of plans to manage and conserve fisheries and in defining critical habitat. The purpose of this project is to comprehensively analyze juvenile flatfish data that have been collected by the Norcross lab at UAF and larval collections in RACEBASE. The main objective is to find a pattern in the life histories that will provide insight for managers as well as researchers.

Methods

We compared distribution of larval flatfishes in the Gulf of Alaska to distribution of juveniles. We used as much literature as possible to collate these data. We also included collections of eggs, larvae and juveniles by the authors that are not published elsewhere. Larval dispersal was examined in collaboration with Kevin Bailey and Janet Duffy-Anderson, scientists from AFSC's FOCI group, who used an extensive twenty-year time series on the distribution of flatfish larvae. We summarized all juvenile flatfish collections from the Norcross lab, including the following collections: Kodiak Island: 1991 and 1992; Chiniak Bay: 1991–1996; Kachemak Bay: 1994–1996; Shelikof Strait: 1995; Sitkinak Strait: 1995; and Cook Inlet: 1996.

From our analysis of all of our collections we determined that we had enough data for analysis of nine flatfish species: northern rock sole (*Lepidopsetta polyxystra*) and southern rock sole (*Lepidopsetta bilineata*); English sole (*Parophrys vetulus*); flathead sole (*Hippoglossoides elassodon*); Alaska plaice (*Pleuronectes quadrituberculatus*); Pacific halibut (*Hippoglossus stenolepis*); Dover sole (*Microstomus pacificus*); rex sole (*Glyptocephalus zachirus*); and arrowtooth (*Atheresthes stomias*). These species were all used in further analysis, with the exception that juveniles of rock sole were only identified to one species of rock sole.

We used knowledge about the adult spawning location, larval and juvenile distributions and physical oceanography of the area to infer larval drift patterns and mechanisms.

Main Results

Juveniles of all nine species of fish can be found in relatively shallow waters on the shelf. However, patterns of larval fish dispersal were separated into two groups according to spawning location in the north central Gulf of Alaska—shelf spawners (the first 5 in the list of fish in the Methods) and slope/deepwater spawners (the last 4 in the list of fish in the Methods). Examination of time and size of eggs and larvae showed that most shelf spawners spawned in the spring, whereas slope/deepwater spawners spawned somewhat earlier, i.e., in the winter. By virtue of location, it was not surprising to find shelf spawners spawning in shallower water than slope/deepwater spawners. Eggs of shelf spawners were smaller and had a shorter duration than those of slope/deepwater spawners. Larvae of shelf spawners hatched and metamorphosed at smaller sizes, had shorter stage duration and were found in shallower waters than those of slope/deepwater spawners.

These two groups of flatfishes developed different early life history strategies that relate to their spawning location in the Gulf of Alaska. The different spawning and early life history strategies for larval dispersal can be succinctly summarized. Shelf spawners have larvae that develop quicker, are smaller at hatch, and have a more direct transport process to nursery grounds. Slope/deepwater spawners have larvae that develop slower, are bigger at hatch, and have a more complicated transport process. Settlement characteristics differ for the two groups, but not as much as dispersal characteristics. The timing and sediment used by both groups are similar, though specific details differ. Newly settling juveniles of shelf spawners are smaller and settle in shallower, warmer water. Newly settling juveniles of slope/deepwater spanners are bigger, and settle in deeper, cooler water.

This information about life history characteristics of flatfish species in the Gulf of Alaska led Norcross to a related hypothesis for flatfish species in the Bering Sea, i.e., that flatfish species in the Bering Sea can be grouped as "Inner shelf" and "Outer shelf" spawners to examine larval transport patterns and mechanisms and subsequent juvenile settlement. This hypothesis is being tested in a separately funded CIFAR project "Feasibility to design and implement a nearshore juvenile flatfish survey—Eastern Bering Sea."

Publications

Brenda Norcross gave an invited keynote address at the International Flatfish Ecology Symposium and presented the results of this research:

Norcross, B.L., J.T. Duffy-Anderson, B.A. Holladay and K.M. Bailey. Larval dispersion and settlement of flatfishes. 5th International Flatfish Ecology Symposium, Isle of Man, UK, November 2002.

There is currently a draft manuscript of these results. The manuscript is being completed by the first author (Norcross) and will be reviewed and approved by all authors prior to submission to the *Journal of Sea Research* (the journal for the refereed Symposium proceedings).

***Progress Report*:** **Student Research about Local Pollock Abundance Using Hydroacoustic Data**

***Principal Investigator*:** Terrance J. Quinn II, Juneau Center, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks

***Other Participating Researchers*:** Vidar Wespestad; Jim Ianelli and Martin Dorn, NOAA/NMFS/AFSC

Objectives, Methods and Main Results

We are conducting research through a grant from the Pollock Conservation Cooperative regarding the deployment of hydroacoustic data loggers aboard pollock fishing vessels. This is a novel approach to the study of "localized depletion" of pollock. Since acoustic imaging is an important source of information on pollock aggregations, all catcher/processors in the pollock fishery are equipped with state-of-the-art echosounders. The basic premise is that by "looking over the shoulder" of the fishing master we will be able to obtain random samples of acoustic data during the exploration/searching process that all fishing vessels engage in before making decisions about where to fish.

The CIFAR-funded project provides for two years of graduate student funding to support this research. Efforts in the last year have been devoted to seeking a qualified student to conduct this research. While there have been few suitable applicants, we believe we have finally found a student with the proper qualifications. His application is in progress and we hope that he will be able to start in January 2004.

Publications resulting from this work

None so far.

Progress Report: University of Alaska Fairbanks Graduate Student Stipend for Stock Assessment Training and Improvement

***Principal Investigator*:** Terrance J. Quinn II, Juneau Center, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks

***Other Participating Researchers*:** Milo Adkison and Gordon Kruse, University of Alaska Fairbanks; Anne Hollowed, NOAA/NMFS/AFSC

Objectives, Methods and Main Results

The Alaska Fisheries Science Center (AFSC) of the National Marine Fisheries Service supports the training of M.S. and Ph.D. students in quantitative fisheries science, including population dynamics, management, and stock assessment. In 2001, this support was provided by a direct grant to Quinn at SFOS. In 2002 and 2003, proposals were submitted to provide for the transfer of $72,000 per year in funds from AFSC to UAF through CIFAR. AFSC has indicated its desire to continue funding this program at $72,000 per year, subject to availability of funds, through CIFAR.

This fellowship is open to M.S. and Ph.D. graduate students with solid quantitative ability and achievement. Generally, research focus is related to the mandate of the Alaska Fisheries Science Center, which includes marine and anadromous waters of the Alaska region. However, other interesting projects are considered. A committee of AFSC and SFOS quantitative scientists evaluates applications. Up to 3 fellowships per year can be awarded. Also, "gap" funding is available to support quantitative students without other financial support to help them complete their research programs.

Applications are made to the AFSC Scholarship Committee, Fisheries Division, School of Fisheries and Ocean Sciences, 11120 Glacier Highway, Juneau AK 99801-8677, E-mail: fisheries@uaf.edu. The applicant is a UAF professor or a student with sponsorship from a UAF professor. The applicant details research in a quantitative arena of fisheries science, such as mathematics, statistics, and modeling. Applications are evaluated as they are received; there is no formal date of application.

To date, five SFOS quantitative students have been supported through the scholarship program: Ben Williams (M.S.), Colin Schmitz (M.S.), John Moran (M.S.), Dana Hanselman (Ph.D.), and Kalei Shotwell (Ph.D.). The supported research has been diverse, including flatfish growth, pollock movement, abundance estimation of harbor seals and rockfish, and salmon dynamics.

The AFSC Scholarship Committee has worked in the last year to publicize the fellowships through the American Fisheries Society and the SFOS web page. The committee has recently developed a set of examples of suitable topics that will be added to the web page.

Publications resulting from this work

None so far.

Progress Report: Tag Retention in Snow Crabs

***Principal Investigator*:** Thomas C. Shirley, Juneau Center, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks

***Other Participating Researchers*:** Julie Nielsen, Graduate Research Assistant, University of Alaska Fairbanks

Project Summary

The objective of this research was to develop a tag for snow crabs that is inexpensive in cost and application, has a high retention through molting, and is not detrimental to crabs. The tag must have high visibility to fishers and processors, and be thoroughly tested to insure that it is not lost because of agonistic interactions or grooming activities of crabs. The ultimate goal of the research is utilization of simple tags to measure molt increments and movements of Bering Sea snow crabs.

Materials and Methods

The initial year of the study was laboratory based and used both juvenile snow crabs and Tanner crabs as test subjects. Tanner crabs were used as surrogates because of their similar size and morphology to snow crabs, their local availability, and because of lesser concerns about pathogens and genetic contaminations. Juvenile snow crabs (40–60 mm carapace width, CW) were collected in the Bering Sea in July and August 2002 in separately funded experiments and transported to the Juneau Center in insulated containers within a one-day period. Juvenile Tanner crabs (40–90 mm CW) were collected from Glacier Bay, Alaska in commercial shrimp pots in summer, 2002 and by scuba divers from along the Juneau road system in fall and winter, 2002–2003.

Crabs were cultured in a flowing sea water system at the Juneau Center, School of Fisheries and Ocean Sciences. Previously, we have maintained Dungeness, red and golden king crabs, and Tanner and snow crabs for extended periods (>1 year). Juvenile crabs were reared in individual compartments in a "crab condo" constructed from deep-tray salmon egg incubators. Having crabs in individual containers eliminated the potential for cannibalism and agonistic interactions, major sources of mortality during the vulnerable molting period. Crabs were fed chopped herring ad libitum once per week, with rearing containers cleaned the day subsequent to feeding. Molt stage of crabs was assessed using setagenesis, which involves assessing the probability of molting by microscopic examination of cuticular layers from setae collected from mouth appendages. Survival, tag retention, presence of deformities, missing legs and pre- and post molt carapace width (measured with Vernier calipers to the nearest 0.1 mm) were recorded for each crab.

Tags of a number of different lengths and thickness were initially assessed, but a fine fabric double-T tag made by Floy Manufacturing, Inc., ultimately was used for all experiments. The Floy tag is a monofilament streamer with a T bar on the end to serve as an anchor and prevent the tag from exiting the carapace. A second "T" prevents the tag from slipping through the insertion hole into the carapace or internal cavity. The tag is applied with a tagging gun equipped with a needle to puncture the carapace; we used the smallest possible needle bore to preclude infections and tag loss. The monofilament streamer with polyethylene tubing sheath remains on the exterior of the crab. Floy tags have been used in prior tagging efforts for *Chionoecetes* crabs, although sample sizes have been small because of culturing problems.

Digital photography was utilized to record the location of the tag insertion for individual crabs, to record molting success, or to record impediments to tag retention and internal arrangement of the tag in the exuvium following tag loss or crab mortality.

Our preliminary studies suggested two optimal locations for placement of tags, therefore crabs were divided into two treatments based on tag location and a control (no tag). Control animals were not tagged, but molted in the same size containers as tagged crabs. In one treatment, double-T Floy tags were inserted along the postero-lateral epimeral line (molting or suture line) of the crabs, such that the "T" anchor was into the dorsal musculature ("dorsal"). We have had good success using this type of tag and tag location in field studies with Dungeness crabs, having tag retention across multiple molts, for more than four years in some individuals. A second treatment had tag placement such that the anchor was in the internal cavity containing the hepatopancreas, heart, gonads and digestive tract, but not anchored in musculature, and was labeled "internal." A third treatment using single-T tags (made from double-T tags) also had tags inserted into the internal cavity.

Results

Setagenesis revealed 63 crabs were nearing molt and crabs were randomly distributed among the treatments. By August 1, 2003, all crabs in the experiment had molted (Table 1). Survival was high (94%) among the control group, but 24% had lost appendages during the molt. The three treatments had almost identical survival (73–75%) and tag retention (64–67%). The effective retention, the number that survived and retained tags was also similar (47–50%). No one treatment was more effective than the others. Crabs that successfully molted with tags had high survival, although several have since lost their tags (apparently "chewed" off by other crabs in the tank).

Approximately 50 more juvenile males and 20 more juvenile females are still in culture that can be used for further treatments. The results might not be comparable since the crabs have been kept in the lab for a much longer time before tagging. Additional crabs will become available in an October research cruise and we hope to conduct at least one more treatment with a single-T tag in the dorsal position. The double-T tag may have been responsible for a portion of the mortality observed during molting; use of a single-T tag might decrease the mortality and thus increase effective retention.

Table 1. Number of crabs (n) by treatment (tag location) and tag type (single or double T). The percent that molted, survived, and retained the tag across molts is listed, as well as the % of deformities and missing legs (% with missing legs is the proportion of crabs that lost at least 1 leg during the molt).

Treatment	Tag type	n	#molted	% survival	%retention for survivors	%effective retention (survived & retained tag)	% with deformities	% with missing legs
control	--------	17	17	94	---	---	0	24
dorsal	double	15	15	73	64	47	13	13
internal	double	16	16	75	67	50	13	0
internal	single	15	15	73	64	47	7	7

Publications Resulting from this Work

This research is partially serving as the basis for the M.S. thesis research for Ms. Julie Nielsen. She has completed her initial year of graduate school and is in good standing. Although no publications have resulted yet, Ms. Nielsen gave a talk on the progress of her research at the Interagency Crab Meetings held in Anchorage, Alaska, December 12–14, 2002.

Progress Report: Analysis of Genetic and Phenotypic Differentiation between Inbred and Outbred Lines of Steelhead and Rainbow Trout

***Principal Investigator*:** W.W. Smoker, Juneau Center, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks

***Other Participating Researchers*:** Erika Amman, Research Assistant/M.S. Candidate; Frank Thrower, U.S. NOAA Fisheries Auke Bay Laboratory; Barry Berejikian, U.S. NOAA Fisheries NW Fisheries Science Center; Robert Fagen, University of Alaska Fairbanks School of Fisheries and Ocean Sciences

Objectives

The purpose of this research is to investigate the effectiveness of using lakes and reservoirs as natural refugia for declining salmonid populations. Degraded freshwater habitats have led to critical declines in salmon populations in the continental United States. Hatchery propagation of salmon for conservation has exhibited some disadvantages, where hatchery fish created differ from the wild runs in their genetic makeup as well as their learned behaviors (Allendorf and Phelps, 1980; Olla et al., 1994; Reisenbichler and Rubin, 1999). Lakes could possibly provide a more natural environment to hold populations while still mitigating losses to the population through mortalities incurred in migration. Aggressiveness and acquisition of social dominance is an area where differences have been seen in hatchery vs. wild populations (Swain and Riddell, 1990; Berejikian et al., 1996; Fenderson et al., 1986). These differences have important implications on the survival of the populations (Chilcote et al., 1986), the interactions between hatchery and wild fish (Bachman, 1984), and the efficiency of hatchery fish with regard to resource allocation (McMichael et al., 1999). In this work the aggressive behaviors and acquisition of social dominance were studied for a stream *Oncorhynchus mykiss* population and a lake population sequestered for seventy years derived from the stream population. The founder population is located in Sashin Creek on the southeastern tip of Baranof Island. The transplanted population was planted in Sashin lake approximately seventy years ago (Anonymous, 1938). An impassible waterfall blocks access from the stream up to the lake. However, there is evidence that some *O. mykiss* from Sashin Lake do smolt out of the lake and join the stream population.

Methods

The inherited effects of sequestration on aggression were compared between lake-ancestry (n=35) and stream-ancestry (n=37) parr, and between lake-ancestry (n=39), stream-ancestry (n=40), and hybrid fry (n=40,41). The duration and number of events observed in independent trials involving pairs of fish in 200-liter aquaria were recorded for the aggressive behaviors chase, nip, display, charge, and approach. Two independent observers used the Jwatcher™ event-recording program to record outcomes of replicate trials.

The inherited effects of sequestration on dominance were compared by observing sets of four fish, one fish from each of the four crosstypes (lake-ancestry, stream-ancestry, and the two hybrids; n=43 sets) in aquaria. Dominant individuals were removed each day and given a rank until only one fish remained in the aquaria.

Fin condition was also assessed as an indirect measurement of aggression in the populations. Fin condition (fin height as a percentage of body length; Kindschi, 1987) was recorded for 100 individual fish from each of the four crosstypes (stream, lake, stream x lake hybrid and lake x stream hybrid). The aggressive behavior of fish involves nipping on the dorsal fin and will result in the fish's dorsal fin being shortened if it sustains many nips. Because salmon fins grow with a relatively constant proportion to body size, dividing by the body length of the fish allows the fin condition to be compared over a range of fish sizes.

Variance of these observations of aggression, dominance rank, and fin condition were analyzed grouped by cross type.

Provisional Results

In observations of aggression among parr, lake-ancestry fish chased more often and with longer duration than did stream-ancestry fish ($p= 0.007$ events, $p= 0.032$ durations), indicating that sequestration has resulted in divergence of the populations. Among emergent fry, lake-ancestry fish chased more often and with longer durations than one hybrid group ($p= 0.017$ event, $p= 0.032$ duration). In the dominance experiment the ranking showed that the lake-ancestry, stream-ancestry, and lake x stream hybrid groups established dominance more frequently than the stream x lake hybrid group ($p= 0.009$).

Fin condition calculations resulted in a significant difference between the two hybrid groups as well as a difference between the lake x stream hybrid and the lake crosstypes.

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Publications

Poster presentation of preliminary results made at the AFS Propagated Fish in Resource Management Conference in Boise, Idaho, June 2003.

In Progress: Masters Thesis from University of Alaska Fairbanks, Division of Fisheries: "Agonistic Behavior, Social Dominance, of *Oncorhynchus mykiss* from Lake and Stream parents. An evaluation of lacustrine refuges as a conservation strategy for threatened or endangered salmonids" by Erika Amman. Estimated date of completion December 2003.

***Progress Report*:** **Analysis of Genotypic and Phenotypic Differentiation between Wild and Hatchery-bred Chinook Salmon**

***Principal Investigator*:** W.W. Smoker, Juneau Center, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks

***Other Participating Researchers*:** Maria Lang, Research Assistant/M.S. Candidate; John Joyce, U.S. NOAA Fisheries Auke Bay Laboratory; Robert Fagen, University of Alaska Fairbanks

Objectives

Domestication of fish within the hatchery may cause genetic divergence from the wild population, although the degree to which domestication causes changes in fitness is not known. When cultured fish are released into a common environment with wild populations, either intentionally or accidentally, they compete for resources and potentially reproduce alongside and with the wild fish. Reproduction between hatchery and wild fish may result in the introgression of divergent genes (from the domesticated fish) into the wild population. This, in turn, may cause reduced fitness in the wild population through the disruption of locally adapted gene complexes. Because of this, it is important to learn the degree to which domestication occurs in Pacific salmon experiencing hatchery culture.

This research will use laboratory observations of chinook salmon fry to determine if there are behavioral differences between a) chinook salmon that have undergone 5 generations of domestication in hatchery culture, and b) fish from their founding wild stock which have now experienced 1 generation of hatchery culture, and to determine how these differences may be expressed in F2 hybrid crosses. Chinook salmon are threatened and endangered in parts of their range; healthy populations are found in Alaska. Two populations are being studied in the isolated hatchery at Little Port Walter by NOAA Fisheries scientists. Their research is a general study of domestication that may have occurred in 25 years of hatchery culture; it entails observations of putatively domesticated fish and controls—chinook salmon recently recruited into the hatchery system. This research takes advantage of their research to observe behavioral differences between the domesticated and control lines of chinook salmon.

Methods

Experiments will be conducted on newly emerged fry to test hypotheses concerning agonistic activity, predator avoidance strategies and foraging behavior. The specific hypotheses are as follows:

H_o: Levels of agonistic activity in newly emerged chinook salmon fry are not dependent on parentage.
H_o: Number of food strikes by newly emergent chinook salmon fry is not dependent on parentage.
H_o: Food patch choice (risky or safe) by newly emergent chinook salmon fry is not dependent on parentage.
H_o: Location of food strikes by newly emergent chinook salmon fry is not dependent on parentage.
H_o: Position in water column of newly emergent chinook salmon fry is not dependent on parentage.

This experiment will involve five replicate trials. Pure HHxHH and WWxWW types will be tested along with F2 hybrids, WHxWH and HWxHW types. Each trial will include 5 tanks of each type and each tank will contain only one type. Four size-matched fry will be placed in each tank in the evening and allowed to acclimate overnight. The tank will be divided longitudinally with a vexar screen that allows passage of fry but not of larger fish. Food will be introduced into both sides of the tank once the first evening and then again the following morning. At least two hours after the introduction of the morning food, positions of the fish will be recorded 4 times at approximately one-minute intervals. Position observation will include downstream/upstream position, height in the water column, and front/back of divider. Ten-minute observations will be conducted on each tank by scan sampling. Food will be introduced on both sides at the beginning and five-minute mark of the observation. Behaviors recorded will include agonistic behaviors and number of food strikes. Fish will again be fed on both sides in the evening of day one and the following morning (day two). After observations are completed fish will be removed and another trial will be set up.

Aggressive behavior will be measured through observation and quantification of specific habitual acts. These acts include (from Rosenau and McPhail, 1987):

1) Lateral Displays—Extended dorsal and anal fins, opening of the mouth, and a stiffening of the body with an accentuated swimming motion. Body parallel to opponent. Possibly "quivering." This display will be further defined after observation.
2) Charge—swimming with increased velocity directly at another fish.

3) Chase—one fish pursues another fish past the point from where the chased fish was originally stationed.
4) Nip—a bite directed toward or physically touching another fish.

Dominance will be assessed by observation of behavioral interactions between fish as well as position of fish in tank as follows (from Rosenau and McPhail, 1987):

1) Color—submissive salmonids usually become dark along the sides, whereas dominant fish remain light.
2) Nipping—dominant fish nip more often than submissive fish.
3) Position of dorsal fin—submissive salmonids typically drop their dorsal fin lower than dominant fish. Submission usually includes depression of the anal fin and a folding of the caudal fin.
4) Position of fish in tank—dominant fish is typically in front portion of tank while submissive fish is behind.

Measurement of these behaviors will be accomplished by recording the number of occurrences of the specific behaviors as well as the durations of the behaviors that have a recordable duration (i.e., all behaviors excluding "nip," which has no recordable duration). J-Watcher, software specific to behavioral observations using a computer, will be used to facilitate this data collection. Statistical analysis of spatial distribution and levels of agonistic activity will be done with one-way ANOVA or the Kruskal-Wallis test with parentage as the main factor.

Provisional Results

Studies in 2002 were corrupted by misidentification of fish in different treatment groups during other phases of the research, outside the control and responsibility of participants in this study. Laboratory observations are being repeated in 2003 on reliably identified fish.

References

Rosenau, M.L. and J.D. McPhail. 1987. Inherited differences in agonistic behavior between two populations of coho salmon. *Transactions of the American Fisheries Society* 116: 646–654.

Research Themes: Hydrographic and Sea Ice Studies

***Progress Report*:** **Observation and Theoretical Foundation for the Dynamics in a High-Resolution Sea Ice Model**

***Principal Investigator*:** S. Lyn McNutt, University of Alaska Fairbanks

***Other Participating Researchers*:** James Overland, NOAA/PMEL; Jacqueline Richter-Menge, CRREL

Methods and Main Results

Work in 2002–2003 focused on providing a complete set of processed SAR imagery in support of the buoy data collected as part of the Beaufort Stress Program. Two papers were published and one presentation was made (see below).

Case studies are now being identified by the PIs. SAR data for the same periods will then be mosaicked to show sea ice conditions. We are in the process of obtaining RGPS analyses for the entire season. AVHRR data will also be collected to support the case studies. This work led to another study, "Stochastic Analysis of Sea Ice Deformation" with Cathleen Geiger at CRREL. I also anticipate preparing a proposal to NSF with Ron Kwok of JPL and Mark Hopkins of CRREL to study further the differences in sea ice deformation in first-year vs. multiyear ice. The original analysis of this concept came from this research, and was presented at IGARSS 01 (McNutt, S.L., N. LaBelle-Hamer and J.E. Overland, Combining SAR and AVHRR to understand sea ice dynamics in the seasonal and perennial ice zones of the Beaufort and Chukchi Seas, Proceedings, IEEE 2001 International Geoscience and Remote Sensing Symposium, 9–13 July, Sydney, Australia, v. 1, 177–180, 2001).

Activity on this project will be completed in FY 2004.

Publications and Presentations

McNutt, S.L. and J.E. Overland. 2003. A model hierarchy based on sea ice dynamics. Presented at The Joint Assembly for European Geophysical Society and the American Geophysical Society, 6–10 April, Nice, France.

McNutt, S.L. and J.E. Overland. 2003. Spatial hierarchy in Arctic sea ice dynamics. *Tellus* 55A, 181–191.

Richter-Menge, J.A., S.L. McNutt, J.E. Overland and R. Kwok. 2002. Relating arctic pack ice stress and deformation under winter conditions. *Journal of Geophysical Research* 107(C10), 8040, doi: 10.1029/2000JC000477.

Research Themes: Marine Ecosystem Studies

***Progress Report*:** **Paleoecologic and Paleoceanographic Studies of Marine Bays in Southeast Alaska**

***Principal Investigator*:** Bruce P. Finney, University of Alaska Fairbanks

***Other Participating Researchers*:** Steve Ignell, NOAA Auke Bay Lab

Introduction and Objectives

Many marine bays in Southeast Alaska have great potential for high-resolution paleoceanographic work, due to their fast sedimentation rates and their preservation of a wide variety of paleo-proxies. Based on our previous pilot studies on cores from 18 bays, we have selected several promising bays for detailed work. The overall objective of this project is to reconstruct changes in primary productivity, forage fish populations, oceanographic conditions and climate in several Southeast Alaska embayments at decadal or better resolution over the past 500 years. This information will be compared with results from a similar study presently underway in the Bering Sea.

Specific objectives (completion assumes a second year of funding at a similar level):

- This project will focus on 2 bays. The cores from each bay will be accurately dated using ^{210}Pb and AMS radiocarbon (^{14}C) techniques.
- Primary productivity will be reconstructed from each bay at ~decadal resolution over the length of the record using opal, organic matter accumulation and $\delta^{13}C$.
- Forage fish populations will be reconstructed for these bays from analysis of preserved bones and scales.
- Diatom species analyses will be conducted on one core.
- Oceanographic conditions will be reconstructed in these cores using analyses of foraminifera $\delta^{18}O$ and Mg/Ca (temperature and salinity), and $\delta^{15}N$ of organic matter (changes in nitrate utilization).

Methods

Previous reconnaissance coring of 18 embayments in Southeast Alaska has uncovered two sites with forage fish remains (bones and scales) preserved in the sediments. We will collect deeper cores at each site and conduct analyses of the sediment to reconstruct historical changes in climate and fish species and abundance. Cores will be dated by ^{210}Pb and AMS radiocarbon (^{14}C) techniques. Reconstruction of paleoproductivity will utilize a multiproxy approach using standard paleoceanographic tools. Diatoms are generally dominant primary producers in this region, and thus, sedimentary biogenic silica abundance/mass accumulation rate will be determined. We will also reconstruct productivity from analysis of organic carbon mass accumulation rate. The third proxy we will use is the $\delta^{13}C$ ratio of organic matter. Downcore changes in salinity and temperature will be done through analyses of foraminifera (forams) for $\delta^{18}O$ and Mg/Ca; changes in nitrate utilization will be assessed by analyses of $\delta^{15}N$ of organic matter. Sediments will be gently sieved through nested screens of graded mesh sizes and forage fish remains identified under a microscope.

Results

A cruise aboard the F/V *Ocean Cape* was conducted during August 28–September 2, 2002. Longer cores (~4–4.5 m) at four different bays were collected with a submersible vibracorer (Rossfelder VT-1 submersible vibracorer), and at these same sites cores with intact sediment–water interfaces were collected with a lightweight gravity corer. This cruise successfully completed the field portion of this project.

Thus far, we have initiated a number of analyses, including core descriptions and determination of organic carbon and calcium carbonate concentrations. We have examined smear slides and the coarse fraction of sieved sediments at regularly spaced intervals to determine the general abundance of key paleoceanographic proxies. Basal radiocarbon dates were submitted to Lawrence Livermore National Lab for AMS dating, and the preliminary results indicate ages of about 1000 BP near the base of the cores from 2 key sites. Detailed analyses of stable isotopic composition, opal, forams and diatoms are in progress. This time-consuming project is in the preliminary stages; thus the data to date are insufficient to comment on detailed interpretations, except to say that the cores appear to be outstanding to meet the objectives of the project. An M.S. student, Molly Boughan, has been recruited to work on this project, and will start in Fall 2003.

***Progress Report*:** **University of Alaska Living Marine Resources Graduate and Postgraduate Fellowship**

***Principal Investigator*:** Charles Hocutt, University of Alaska Fairbanks

Overview

The goals of NOAA's strategic plan are to build sustainable fisheries, to recover protected species, and to sustain healthy coasts. These goals require the support of sound scientific research to build the knowledge base for maintaining economically viable fisheries and, at the same time, minimize anthropogenic impacts on marine ecosystems. The School of Fisheries and Ocean Sciences (SFOS), University of Alaska Fairbanks, entered into an agreement in FY 03 with NMFS's Alaska Fisheries Science Center, Seattle to provide training and advanced research on issues affecting the sustainability of the Steller sea lion (SSL) in the northeast Pacific Ocean and Bering Sea. This program is administered through the Cooperative Institute for Arctic Research (CIFAR).

Training

A 2-year Ph.D. Graduate Research Assistantship was awarded to Pieter DeHart, beginning in January 2003. Chris Siddon will commence a 2-year Research Associate (postdoctorate) appointment in August 2003. Both were selected after a competitive review process. Pieter completed his Master's degree at Boston College having conducted research on harbor seals. Chris will complete the requirements for a Ph.D. at Brown University in August 2003.

Research Programs

The cooperative NMFS AFSC/SFOS program will have two research thrusts: (1) historical ecology of Steller sea lions, and (2) testing the hypotheses that food limitation and predation have caused the dramatic decline of the Steller sea lion population.

Historical ecology of Steller sea lions. The causes for decline in Steller sea lion populations in the North Pacific region over the past 30 years remain an unknown, despite substantial advances in understanding the ecology and functioning of the system. Pieter de Hart has commenced to study this decline using both a historical and modern perspective. He is examining the stable carbon and nitrogen isotopic composition of SSL populations to elucidate shifts in diet, diversity in trophic inputs, as well as regional differences that correlate with the population decline. De Hart will collect osteological samples from SSL throughout their range from Russia to Northern California over a 55-year period, and analyze them with respect to four distinct regions: Bering Sea, western and eastern Aleutian Islands, and Gulf of Alaska. He will also analyze tissue and teeth from both museum and fresh samples to evaluate shifts in individual diets over time.

Test the hypotheses that food limitation and predation have caused the dramatic decline of the Steller sea lion population. Stage-class population modeling has been widely utilized to address the management and recovery of threatened or endangered species. These models allow prediction of whether a population is increasing or decreasing, and which stage class (e.g., pup, juvenile, adult) is most sensitive to a perturbation. Chris Siddon will work in affiliation with Dr. Terry Quinn. They will test (1) the importance of carrying capacity as related to the decline of the SSL population; (2) whether population growth of SSL is density-dependent; and (3) if SSL behavior is modified due to food limitations and temporal shift in prey availability.

Results to Date

DeHart has visited the National Marine Mammal Laboratory (NMML) in Seattle and collected 120 osteological (mandible) samples from the archival collection. Data from samples included size, age, sex, and location. These samples are being prepared to examine the isotopic composition of the collagen present, with the analyses to be conducted in September 2003–March 2004.

Chris Siddon has also established contact with the NMML, although he has not yet formally started his Research Associate post at this date.

Research Themes: Tsunami Research

***Progress Report*:** **Alaska Earthquake Information Center Seismic Station Upgrade and Installation**

***Principal Investigator*:** Roger Hansen, University of Alaska Fairbanks

***Other Participating Researchers*:** Steve Estes, Martin LaFevers, Josh Stachnik, Ed Clark, Otina Fox, John MacCormack

Objectives

This continuing contract is to install a total of 18 new modern digital broadband seismic stations throughout Alaska and to maintain their operation and telemetry. FY2003 has proven to be very productive toward these goals.

Installations

A total of seven new installations were completed during the current reporting period. This includes 5 new seismic stations and 2 remote communications sites:

ATKA - Seismic station on the Aleutian Island of Atka.

DCPH - New seismic station on Deception Hills south of Yakutat. Radio receive site established at Yakutat NOAA Weather Service Office.

FALS - New seismic station on Unimak Island near the village of False Pass.

NIKO - New seismic station on Umnak Island near the village of Nikolski.

PPLA - Site survey performed in small aircraft. New seismic station southwest of Mt. McKinley, near abandoned Purkepile Mine area along Boulder Creek.

Minchumina - Communications hub to receive data from PPLA and place on dedicated intranet via FTS circuit.

Yakutat - Communications hub at NOAA weather service tower installed to receive data from DCPH and PIN and place on dedicated intranet via FTS circuit.

Permits Obtained

Permits for new stations were finalized at 4 additional sites:

DOT - This will be an upgraded short period site with internet communications (to be installed in FY2004). Arrangements made to have a post hole vault for the Broadband instrument.

PAX - This will be an upgraded site with intranet communications via FTS circuit. Installation began in FY2003, but was postponed due to snow and cold in Fall of 2002. This broadband instrument will reoccupy a previously abandoned 38-foot borehole.

Coldfoot - A new seismic station site was selected and permissions obtained from Bureau of Land Management and Alyeska for installation. Installation will be completed in FY2004. Communications will be through dedicated intranet via FTS circuit.

Juneau - A new seismic station site was selected on Bessie Mountain co-located with an AT&T com site. Communications will be through dedicated intranet via FTS circuit. Permission from US Forest Service has been obtained including a letter of non-objection from AT&T. Installation will be in FY2004.

Maintenance

Site visits were made to the following existing sites for routine service and maintenance repairs:

UNV - Replaced malfunctioning digitizer. Routine check of operation. PIN - Replaced malfunctioning digitizer, communications radio, and damaged coax cabling.

EYAK - FTS circuit installed. Access server and router installed at seismic station for data transmission.

SWD - Upgraded cabling and seismometer. Revisited for communication problems. Now online.

TNA - Repairs made to vault that was compromised by water. Upgraded cabling. Instrument replaced.

SPIA - Repaired vandalized vault system, upgraded seismometer. GAMB - Site visited, seismometer placed into borehole and leveled, Communication through local school hardened. DIV - Site visit as the receive site for BMR. BMR - Replace both seismometer and digitizer due to malfunction.

Note that more detailed field notes are available on request.

The long-term operation, archiving and telemetry of the operational stations is progressing well with sharing of data to the tsunami warning centers, the USGS, and the IRIS Data Management Center for further sharing of the data with the University community.

***Progress Report*:** **Alaska Tsunami Inundation Mapping Project** and **TWEAK Element I: Accelerated Alaska Inundation Map Production** *(progress report for two related projects that fund the following work)*

***Principal Investigator*:** Roger Hansen, University of Alaska Fairbanks

***Other Participating Researchers*:** Elena Suleimani, Duncan Marriott and Zygmunt Kowalik, University of Alaska Fairbanks

1. Grid Development Summary

High resolution, high quality bathymetric and topographic grids are vital to accurate tsunami modeling. The current project involves numerical modeling of tsunami propagation from historical and hypothetical sources to coastal Alaskan communities, including inundation calculations. To support this project, we attempt to locate the best currently available data for each region of interest to build a series of embedded grids with increasing resolution. The source data resolution should be at least as high as the grid spacing of the finest resolution grid. In a number of communities in Alaska this is a difficult criteria to meet due to lack of current high-resolution surveys.

To achieve this goal, we performed a series of searches and collaborations with other agencies to find, purchase, or produce new data when the available data is insufficiently accurate or dense. This data is then tested to assure its quality, transformed into the selected projection and datum, and then integrated into the series of grids. Each community presents unique challenges to develop accurate grids.

Kodiak:

Although the inundation mapping report has been published for Kodiak, interest in different aspects of the results continues to require additional investigation. Using the inundation line and the Kodiak 1-sec grid, the elevation of maximum inundation was plotted along four stretches of coastline around the city. These plots show that the wave reached higher elevations in some areas then in others, showing the effects of dynamic wave action.

Homer/Seldovia:

Development of the merged topographic/bathymetric high-resolution grid for the Homer area was a long process due to lack of quality topographic data. Initially, the prospects of new data from the Alaska SAR facility, and the SRTM program assured us of a quality grid, but these sources were unable to deliver the necessary grids. The next step was a time-consuming process of digitizing paper maps, which yielded good quality data from air photos taken in 1982 covering most of the area of interest. Serendipitously, AeroMap had been simultaneously working on a very high quality and up-to-date DEM for the area derived from LIDAR measurements taken in 2002, which was available at reasonable cost. The TIME center, Kenai Peninsula Borough, and the Homer City Planning department participated in a joint purchase of this dataset to further lower the cost. The TIME center then integrated this new high quality dataset with the existing high-resolution grid, and delivered it to ATMT. This new grid was then inspected for anomalies and connectivity. There were some anomalous values where the grids were merged together, which were hand edited out to produce the final high-resolution grid for modeling. Currently the majority of modeling in the Homer/Seldovia areas is finished, and ATMT is drafting the report.

Seward:

Seward had a problem similar to the Homer one: good quality bathymetry data, and low quality topography data. The only quality controlled topography available for the Seward area is based on the USGS 7.5 min. topographic maps, which were made from air photos taken in 1976 and hand contoured at 20-meter contour intervals. This gives adequate coverage for steep areas, but in the coastal lowlands there are very large areas with no contours (one kilometer or more), which means no data coverage for these areas. This is compounded by the fact that these coastal areas are of the most interest because of their proximity to the water and their higher density of infrastructure.

After an extensive data assessment process that involved local city, borough, state, and federal organizations, only small areas of more accurate data were found around the new Alaska Railroad dock, and the small boat harbor. The US Forest Service flew a series of air photos over the Kenai Peninsula during 1997–2000. The series taken in

1998 includes a number of overlapping stereo pairs covering the Seward area. The ATMT and the USGS Glaciology department collaborated to use their photogrammetry software to produce an accurate DEM from these new air photos.

Using ten air photos and the APEX software, along with several precisely located GPS points, we developed a new precisely georeferenced and highly accurate DEM with a 5-meter grid spacing. A variety of techniques were then used to remove the effects of buildings and trees to yield a bald earth model. Finally the new DEM was resampled to match the finest resolution grid produced by the TIME center and combined with all other data, using the most recent and accurate data in each region. We now have a complete set of bathymetry/topography grids with current high-resolution data ready for modeling in Seward.

Sitka:

Our next community of interest is Sitka. Unfortunately, both the topography and the bathymetry in the Sitka region are of limited resolution. All of the best available topographic data is based on the USGS contours of either 20-meter contour interval, or 100-feet contour interval. Once again, the important region between the coastline and 20 meters of elevation is represented entirely by interpolated points. The SRTM data covers Sitka, but currently is in an un-edited form with many possible errors. Almost all of the high-resolution bathymetry is from surveys preformed between 1938 and 1941, and large portions of the 2.66- and 8-second grids contain data with only about 2-minute resolution bathymetry. I have performed some initial searches and discussions with the Sitka city planning department, who do not have any better data available. I will continue discussions with a variety of other local sources. We have the potential to use the most recent available air photos to make a new DEM similar to the process in Seward. The city of Sitka has ordered new small-scale air photos this June, which would be excellent for photogrammetry. With regard to bathymetry, there are currently new surveys scheduled for the next few years, but that data will not be available until 2005.

2. Inundation Mapping Project

The tsunami code that runs on the SV1ex computer at the Arctic Regional Supercomputing Center was modified to use Fortran 90 modules to contain each grid. This includes dynamic allocation of grids, thus allowing a variable number of grids with variable topologies connecting them. Also, the code was modified to run from an input configuration file without re-compiling the code for multiple runs that require different initial and boundary conditions.

ATMT has established the hypothetical tsunami scenarios for the Kachemak Bay modeling. We considered two earthquake scenarios as potential sources of tsunami waves that can affect the Kachemak Bay communities of Homer and Seldovia. The first one is the 1964 earthquake, which is probably the worst-case scenario of a tsunami for most of the Alaskan coastal communities (Figure 1). The second scenario is a hypothetical event that ruptures the section of the Border Ranges fault that crosses Kachemak Bay to the west from Homer (Figure 2). The Border Ranges fault is a major fault of southern Alaska. It extends eastward from Kodiak Island to the St. Elias Mountains. The hypothetical earthquake with moment magnitude of 7.5 was modeled using 3 subfaults (Figure 2), with the uniform slip of 3 meters.

Numerical calculations were performed for Homer and Seldovia for both hypothetical tsunami scenarios. The waves were propagated to Homer and Seldovia through the set of embedded grids (Figures 3–5). For both communities, we calculated the extent of maximum inundation for the two tsunami scenarios, depths of inundation on dry land, and the maximum velocity current distribution in the inundation zones. Also, at selected locations we computed wave history and time series for the absolute values of velocity and its azimuth. Currently we are working on the inundation maps and the Inundation Mapping Report for the Kachemak Bay communities.

In March, the ATMT had a meeting to outline the hypothetical tsunami scenarios for Seward inundation modeling project. We have established 6 potential tsunami sources, one of which is an underwater landslide, similar to the one that happened in Resurrection Bay in 1964. Currently, we are performing preliminary runs for all the Seward grids with the 1964 tectonic deformation as an initial condition. At the same time, a 2-D numerical model for the waves generated by an underwater landslide is being developed.

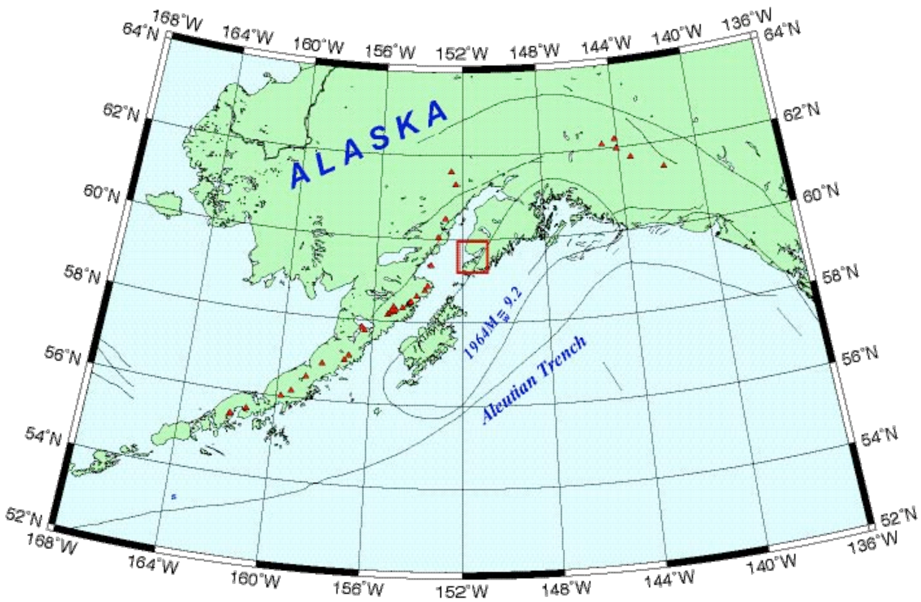

Figure 1.

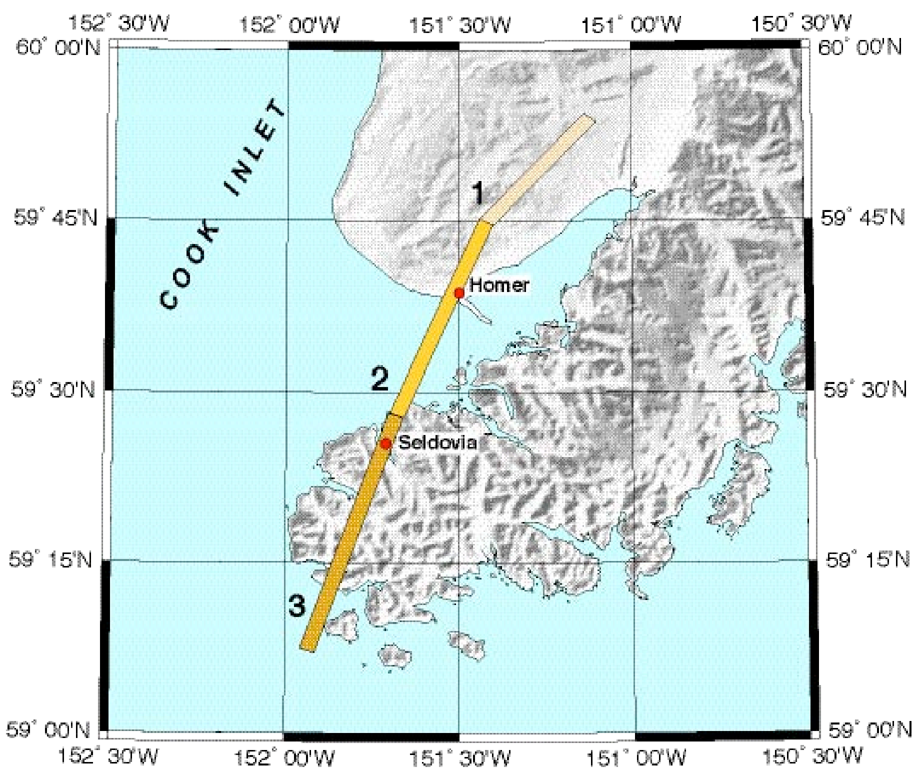

Figure 2.

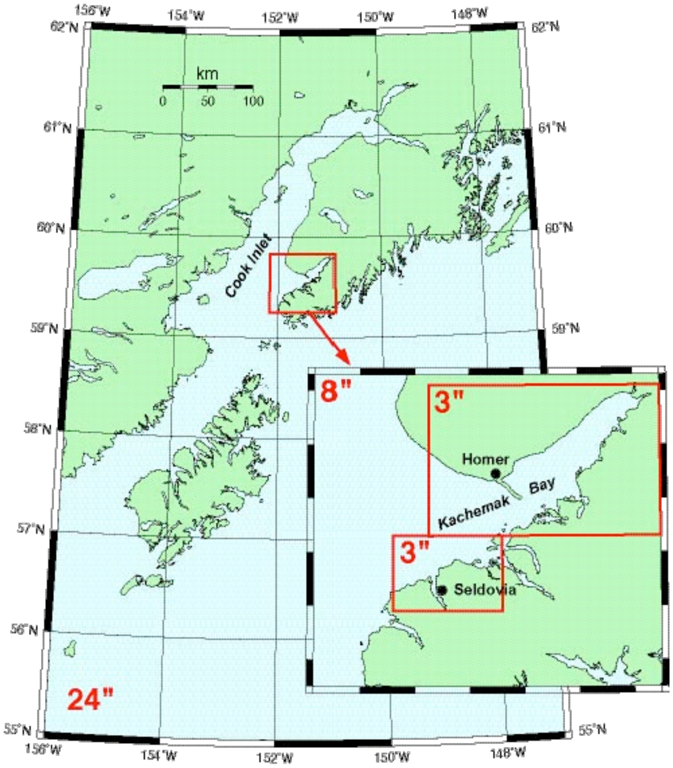

Figure 3.

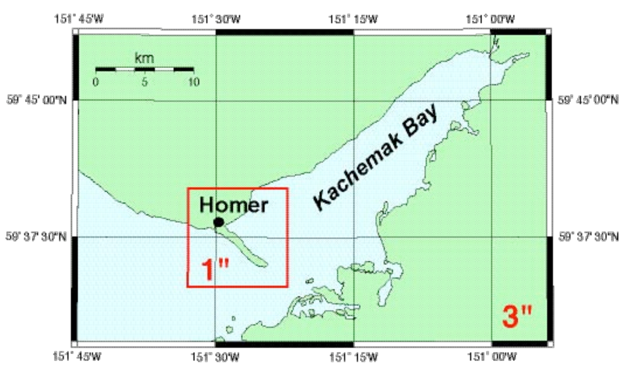

Figure 4.

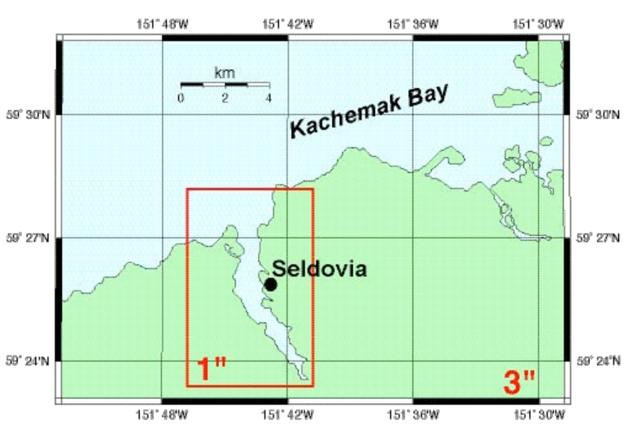

Figure 5.

***Progress Report*:** **TWEAK Element 2: Tsunami Warning and Environmental Observatory for Alaska (Earthquake Characteristics and Finite Fault Processes: Diagnostics for Tsunamigenic Potential)**

***Principal Investigator*:** Roger Hansen, University of Alaska Fairbanks

***Other Participating Researchers*:** Natalia Ratchkovski, Kelly Kore

Report on Implementation of the Real-time Moment Tensor Inversion Procedure at AEIC

This past year we have focused on implementing a near-real-time moment tensor inversion procedure at AEIC (Alaska Earthquake Information Center). The real-time earthquake detection system at AEIC is based on the Antelope software package from BRTT, Inc. Multiple additional modules have been developed to fit particular needs of the AEIC. Automatic earthquake locations are searched over a pre-calculated three-dimensional grid to find the best fit for the set of arrivals included into an event trigger packet. Once the event is located, its magnitude is calculated. Location and magnitude along with the set of associated arrivals and other information are written into the real-time earthquake database. A moment tensor inversion program is then triggered by a module that watches continuously the real-time earthquake database. When a new event above a certain magnitude level (M 3.8) has been recorded, it triggers the execution of the moment tensor inversion module. The procedure consists of several steps. First, the waveforms are extracted for the broad-band stations. If the waveforms within a certain epicentral distance are available, then the moment tensor inversion is performed. The moment-tensor inversion is based on a software package by Douglas Dreger as used at the Berkeley Seismological Laboratory for automatic moment tensor calculations. It performs a time domain inversion of three-component seismic data for the seismic moment tensor. It uses a library of precalculated Green’s Functions to compute synthetic seismograms for a range of source depths (from 5 to 70 km with 5 km interval). Currently, we use 3 regionalized velocity models: (1) Aleutian Islands region east of 157W longitude; (2) central Alaska region north of 62.5N latitude; (3) southern Alaska region south of 62.5N latitude and east of 157W longitude. The epicentral location is given by the automatic event location system. Synthetic seismograms are compared with the actual data and the result with the best fit is identified as the inversion output. The program generates a series of output files including postscript graphics file with the actual and synthetic waveforms and the best fit moment tensor parameters, a map with the earthquake location and the focal mechanism obtained, and an ascii file with the moment tensor parametric data. Once the inversion is successfully completed, the last step is the information distribution currently via the worldwide web. The automatic moment tensor information is available through the AEIC webpage http://www.aeic.alaska.edu/html_docs/moment_tensors.html in three forms: (1) gif file with the actual and synthetic waveforms and the best fit moment tensor parameters (Figure 1); (2) map with the earthquake location and obtained focal mechanism (Figure 2); and (3) text file with the moment tensor results parametric data. The automatic moment tensors are reviewed by the data analyst on the same or next business day and necessary adjustments are performed. The updated information replaces automatic solutions on the web.

There are still known problems with the automatic moment-tensor inversion that are identified for further development:

(1) An important problem is the data quality control. Station health has to be monitored continually and bad stations have to be taken in a timely manner off the list of potentially usable stations for the moment tensor inversion.

(2) In cases when both strong motion and weak motion waveform records are available, the program can use either one or the other but not a combination of both. A selection scheme needs to be implemented. This is important for larger events when velocity records could potentially go off scale.

(3) The moment tensor inversion programs need more development (adjustments and improvements) to fit particular data needs at AEIC.

(4) Last, but most important, more regional velocity models need to be developed throughout Alaska for computing Green’s Functions for the inversion process, especially for southern and south-east Alaska. The inherent nature of the 3-dimensional earth structure throughout Alaska requires delicate fine tuning of the Green’s Functions through careful estimation of velocity structures appropriate for the source-receiver propagation path. This will continue to be a major focus of our ongoing studies.

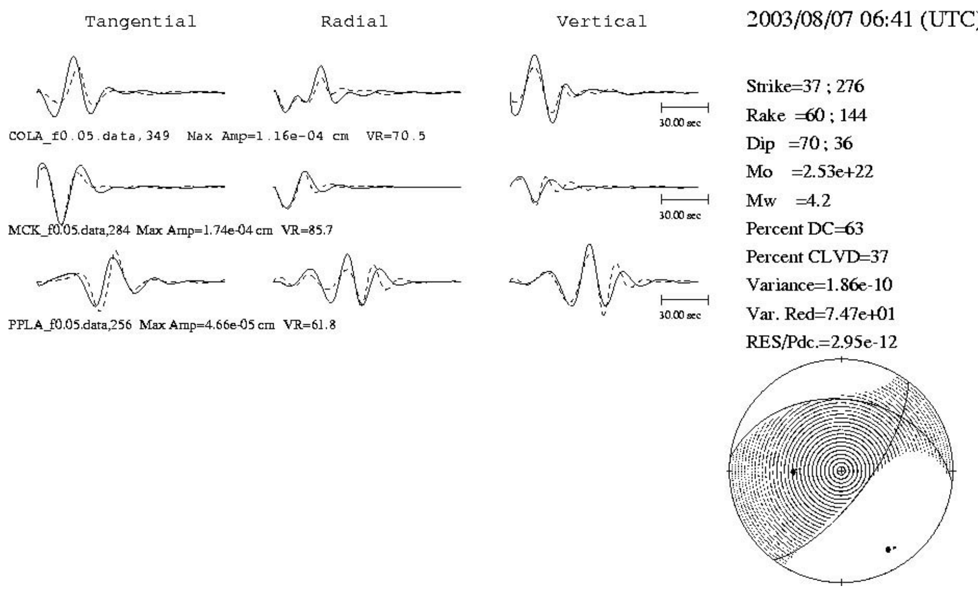

Figure 1. Graphics file generated by the moment tensor inversion program (reviewed by analyst).

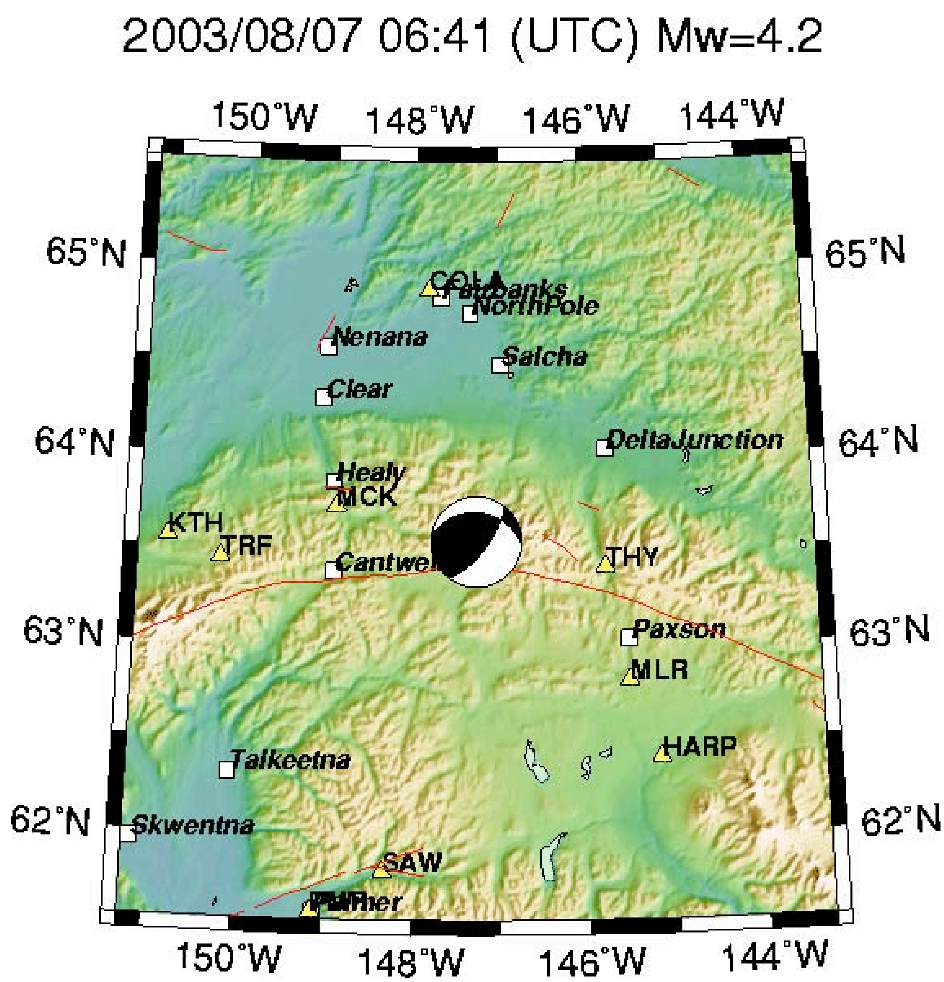

Figure 2. Map with the earthquake location and obtained focal mechanism.

***Progress Report*:** **TWEAK Element III: Tsunami Warning and Environmental Observatory for Alaska**

***Principal Investigator*:** Dave Musgrave, University of Alaska Fairbanks

Objectives

The goals of the TWEAK III oceanographic component are to devise a monitoring array that addresses exchange between the slope and shelf and that can quantify and characterize some of the mesoscale circulation variability in Northern Gulf of Alaska. The measurements we propose would also enhance modelling efforts in this area (and others) of the Gulf of Alaska. In particular we propose to deploy moorings in combination with surface current mapping radars and remote sensing to:

1. Characterize the mesoscale flow field (kinematics, dynamics, and biological importance).
2. Address mechanisms of cross-shelf exchange, particularly those involving the interaction of a swift western boundary current, interacting with a cross-shelf canyon.
3. Provide an unprecedented opportunity to examine how fluctuations in a boundary current (Alaskan Stream) affect transfer between the shelf and slope.
4. Quantify the temporal (tidal – interannual) variability in the circulation and water mass properties (temperature, salinity, nutrients, and productivity patterns).

Our original objective was to deploy and operate a High Frequency (HF) radar to measure surface currents in the Northern Gulf of Alaska. At the onset of the TWEAK III project, the islands at the western end of Shelikof Strait were thought to be the final destination for the research associated with this project including the deployment of two CODAR sites. However, due to the problems listed in Main Results our geographical focus changed to the Gulf of Alaska GLOBEC area.

Methods

1. (FY02) A high frequency ocean surface current radar system (CODAR Ocean System's SeaSonde) to map the surface velocity field at a resolution of ~3 km at 3 times/hour. The viewing field would cover approximately 80 km (subject to environmental constraints).
2. (FY03 and beyond) Two subsurface oceanographic moorings to measure temperature, salinity, vertical profiles of horizontal currents, nutrients, and fluorescence (an index of chlorophyll concentration) at hourly intervals.

Note that #2 depended on additional funding that did not materialize. This report focuses on #1.

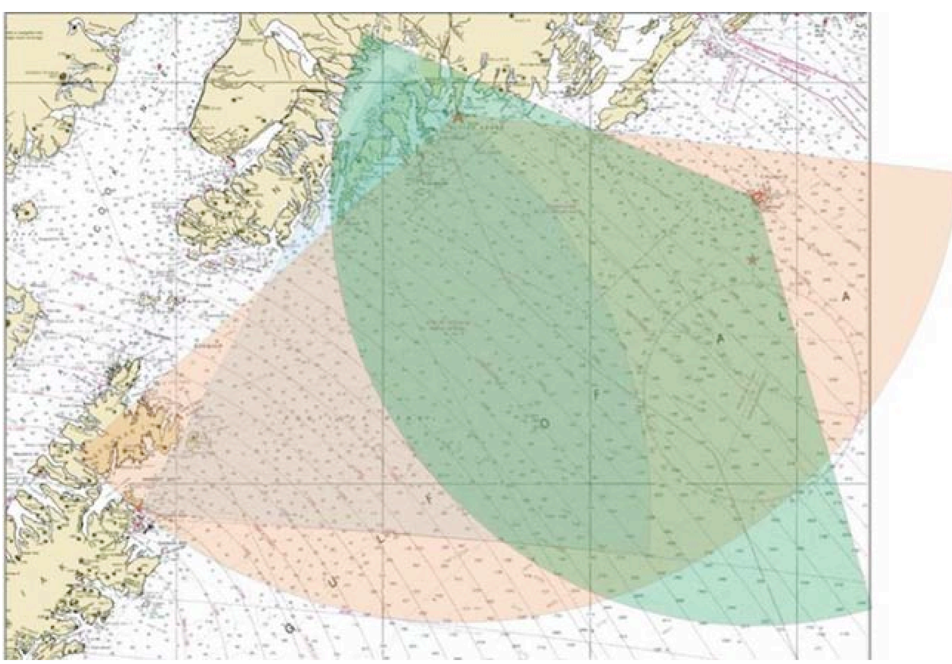

Figure 1. Nautical chart of the region of interest. HF RADAR installations at Middleton and Rugged Islands would provide total surface current maps over the region where the red and green shaded areas overlap.

Main Results

A. Site Scouting

Talks were initiated with land owners and managers and access was granted for members of our group to conduct site visits at locations on Chirikof, Chowiet and Sutwik Islands. In September 2002, site visits were conducted at the sites mentioned above as well as sites along the northern edge of Kodiak, Afognak and Shuyak Islands. At this time it was decided that the remote nature of deployments in this area may prove to be cost prohibitive due to the long ship/fixed wing/helicopter transits involved with deploying our equipment in these areas.

Due to the large interest in the area west of Kayak Island and east of Gore Point by academic and NOAA investigators as part of the Gulf of Alaska GLOBEC project, we shifted our focus for the deployment of the two CODAR sites east towards the Northern Gulf of Alaska. This location will give researchers better data on the synoptic circulation of this region. We have decided that installations at Rugged Island and Middleton Island would be optimal for creating two-dimensional surface current maps of the region (Figure 1).

We have scouted the Rugged and Middleton Islands sites and have found potential locations for the two CODAR sites.

Using separate funding, a related project has provided funds for CODAR deployments in Cook Inlet as a test bed before more permanent installation at remote sites in Prince William Sound. Surface current maps of the type obtained by this instrumentation have been made for a region in upper Cook Inlet (Figure 2).

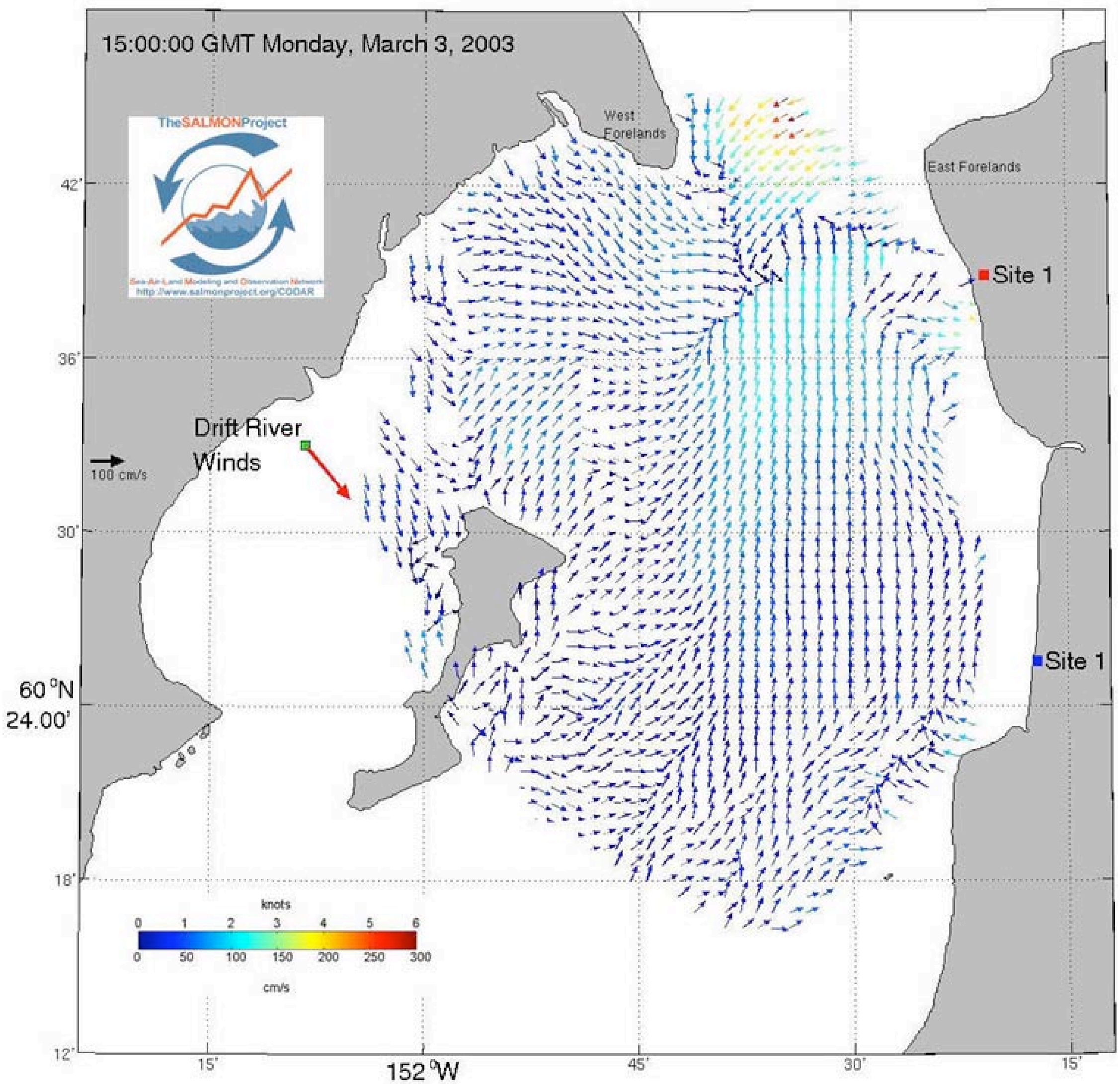

Figure 2: An example of a typical surface current map obtained from the CODAR instrumentation in Cook Inlet, Alaska.

B. Permitting

- Pursued land status and ownership issues with the BLM office in Fairbanks, AK.
- Initiated discussions with land owners at all potential sites (USCG at Rugged and Chugach Alaska Corporation at Middleton Islands).
- Obtained USCG permit for locating the CODAR system on Rugged Island.
- Applied and are awaiting FAA permits for Middleton Island.

C. Remote Power Development

- Began discussions with CODAR Ocean Sensors on DC-powered SeaSonde parameters.
- Received two 24-volt, DC-powered SeaSonde units from CODAR Ocean Sensors.
- Completed local testing and remote power module design. We have preliminary tests of the power module in Cook Inlet and we are proceeding with more tests and re-engineering based on those tests.

D. Instrument Testing

- Set-up and deployed two 24-volt DC Long Range (5 MHz, 200 km) CODAR installations in Cook Inlet as a preliminary test.
- Telemetry for remote installations is still being developed. Starband systems seem to be best suited for our purposes with respect to bandwidth, economy, and robustness, but current design changes and software updates have led us to believe that an upcoming satellite modem (model 480) will be superior to the current models and will be compatible with the Macintosh brand laptops necessary for the CODAR instrumentation. We are also testing Freewave modems for the Rugged Island site.

Future Plans

Most of the funds for this project have been spent except for some salary which will be used in conjunction with funding from NASA for the deployment and operation of the CODAR units in fall/winter 2003 and 2004.

With the TWEAK III and the NASA funding we will: obtain land use permits for Middleton Island and test the CODAR unit at Rugged Island in September 2003.

With the best-case scenarios for site permits, weather and more engineering we hope to deploy fully remote CODAR units on Middleton and Rugged Islands by November 2003.

Appendix 1

Projects funded during the second year of CIFAR Cooperative Agreement NA17RJ1224 (1 July 2002–30 June 2003)

CIFAR Projects Awarded
1 July 2002 – 30 June 2003

Research Theme	Investigator Last	First	Institution	Proposal Title	AMD#	Proposal Budget	Subaward F&A	Total Award Amt.
Admin	**Weller**	**Gunter**	U. Alaska Fairbanks	TASK I: Arctic Climate Impact Assessment (ACIA) Meetings	5	$ 33,000		$ 33,000
Admin	**Weller**	**Gunter**	U. Alaska Fairbanks	TASK I: Administration	5	$ 10,000		$ 10,000
Admin	**Weller**	**Gunter**	U. Alaska Fairbanks	TASK I: ACIA Secretariat Support	6	$ 300,000		$ 300,000
Admin	**Weller**	**Gunter**	U. Alaska Fairbanks	TASK I: Administration (Year 2)	6	$ 100,000		$ 100,000
Admin	**Weller**	**Gunter**	U. Alaska Fairbanks	TASK I: Administration	6	$ 10,000		$ 10,000
Subtotal Task I Administration						**$ 453,000**		**$ 453,000**
ARI	**Francis**	**Jennifer**	Rutgers University	Interactions of Laterally Advected Heat and Moisture with Arctic Cloud Properties	6	$ 75,004		$ 75,004
ARI	**McNutt**	**Lyn**	U. Alaska Fairbanks	Do Recent Changes in Sea Ice and Snow Cover Impact the Arctic Oscillation?	6	$ 17,437		$ 17,437
ARI	**Springer**	**Alan**	U. Alaska Fairbanks	Trophic Pathways on the Chukchi-Beaufort Shelf: Where do the Ice Algae Go?	6	$ 59,804		$ 59,804
ARI	**Walsh**	**John**	University of Illinois	An Arctic Archive of Model Output and Application to SEARCH	6	$ 77,083		$ 77,083
ARI	**Yang**	**Daqing**	U. Alaska Fairbanks	Hydrologic Response of Siberian Major Rivers to Climate Change and Variation	6	$ 118,083		$ 118,083
Subtotal Arctic Research Initiative						**$ 347,411**		**$ 347,411**
Contaminants	**Cahill**	**Cathy**	U. Alaska Fairbanks	Persistent Organic and Trace Element Pollutants in the Alaskan and Eastern Russian Arctic	6	$ 13,258		$ 13,258
Contaminants	**Cahill**	**Cathy**	U. Alaska Fairbanks	Persistent Organic and Trace Element Pollutants in the Alaskan and Eastern Russian Arctic	6	$ 24,446		$ 24,446
Contaminants	**Cahill**	**Cathy**	U. Alaska Fairbanks	Sources of Mercury Reaching the Arctic - Airborne Particulate Mercury in China	6	$ 50,000		$ 50,000
Contaminants	**Patton**	**Greg**	Battelle Memorial Institute	Persistent Organic and Trace Element Pollutants in the Alaskan and Eastern Russian Arctic	6	$ 76,301		$ 76,301
Contaminants	**Patton/Barrie**	**Greg/Len**	Battelle Memorial Institute	Persistent Organic and Trace Element Pollutants in the Alaskan and Eastern Russian Arctic	6	$ 86,498		$ 86,498
Contaminants	**Reiersen**	**Lars-Otto**	AMAP	Arctic Monitoring and Assessment Programme (AMAP)	6	$ 100,000	$ 12,600	$ 112,600
Subtotal Contaminants						**$ 350,503**	**$ 12,600**	**$ 363,103**
Data Arch	**McNutt**	**Lyn**	U. Alaska Fairbanks	Integrated Analysis of Climate Change in the Bering Sea, Alaska	5	$ 40,000		$ 40,000
Subtotal Data Archiving & Support						**$ 40,000**		**$ 40,000**
Fisheries	**Adkison**	**Milo**	U. Alaska Fairbanks	Early Marine Growth and Survival of Bristol Bay Sockeye Salmon Smolt	6	$ 10,563		$ 10,563
Fisheries	**Adkison**	**Milo**	U. Alaska Fairbanks	Relationship Between Growth and Survival of Coho Salmon Utilizing the Coastal Gulf of Alaska	6	$ 36,000		$ 36,000
Fisheries	**Coyle**	**Kenneth**	U. Alaska Fairbanks	Pollock Year-Class Strength: Synthesis of Acoustic and Net Data for Age-0 Pollock w/Distributions of Predators, Prey, and Environmental Data	5	$ 20,613		$ 20,613
Fisheries	**Gharrett**	**A.J.**	U. Alaska Fairbanks	Origins of Juvenile Chum Salmon (*Oncorhynchus keta*) Collected During ABL-OCC Cruises in the Gulf of Alaska 2000	6	$ 54,499		$ 54,499
Fisheries	**Gharrett**	**A.J.**	U. Alaska Fairbanks	Population Structure in Alaskan Pacific Ocean Perch (*Sebastes alutus*), Phase II	6	$ 24,999		$ 24,999

CIFAR Projects Awarded
1 July 2002 – 30 June 2003

Research Theme	Investigator Last	Investigator First	Institution	Proposal Title	AMD#	Proposal Budget	Subaward F&A	Total Award Amt.
Fisheries	**Herrmann**	**Mark**	U. Alaska Fairbanks	Regional Economic Impact of the Bering Sea/Aleutian Islands Crab Fisheries: Snow Crab Market Model (project previously titled Regional Impact of the Effect of Steller Sea Lion RPAs on the Fishing Economy of Kodiak, Alaska)	6	$ 25,000		$ 25,000
Fisheries	**Norcross**	**Brenda**	U. Alaska Fairbanks	Feasibility to Design and Implement a Nearshore Juvenile Flatfish Survey - Eastern Bering Sea	6	$ 115,000		$ 115,000
Fisheries	**Norcross**	**Brenda**	U. Alaska Fairbanks	Processes Affecting Larval Dispersal, Settlement, and Juvenile Habitat of Flatfishes, a Manuscript	6	$ 12,600		$ 12,600
Fisheries	**Quinn II**	**Terrance**	U. Alaska Fairbanks	Student Research about Local Pollock Abundance using Hydroacoustic Data	6	$ 72,000		$ 72,000
Fisheries	**Quinn II**	**Terrance**	U. Alaska Fairbanks	University of Alaska Fairbanks Graduate Student Stipend for Stock Assessment Training and Improvement	6	$ 72,000		$ 72,000
Fisheries	**Shirley**	**Thomas**	U. Alaska Fairbanks	Tag Retention in Snow Crabs	6	$ 63,480		$ 63,480
Fisheries	**Smoker**	**William**	U. Alaska Fairbanks	Analysis of Genetic and Phenotypic Differentiation between Inbred and Outbred Lines of Steelhead and Rainbow Trout	6	$ 38,045		$ 38,045
Fisheries	**Smoker**	**William**	U. Alaska Fairbanks	Analysis of Genetic and Phenotypic Differentiation between Wild and Hatchery-bred Chinook Salmon	6	$ 38,045		$ 38,045
Fisheries	**Weingartner**	**Thomas**	U. Alaska Fairbanks	ALPHA HELIX for 2001 GLOBEC	5	$ 645,920		$ 645,920
Subtotal Fisheries Oceanography						**$ 1,228,764**		**$ 1,228,764**
Hydro/Sea Ice	**McNutt**	**Lyn**	U. Alaska Fairbanks	Observation and Theoretical Foundation for the Dynamics in a High-resolution Sea Ice Model	6	$ 50,000		$ 50,000
Subtotal Hydrographic and Sea Ice Studies						**$ 50,000**		**$ 50,000**
Marine Ecosys	**Finney**	**Bruce**	U. Alaska Fairbanks	Paleoecologic and Paleoceanographic Studies of Marine Bays in Southeast Alaska	6	$ 85,000		$ 85,000
Marine Ecosys	**Hocutt**	**Charles**	U. Alaska Fairbanks	University of Alaska Fairbanks Living Marine Resources Graduate and Postgraduate Fellowship	6	$ 300,000		$ 300,000
Marine Ecosys	**Maschner**	**Herbert**	University of Idaho	Traditional Ecological Knowledge, Indigenous Observations, and Spatio-Temporal Dynamics of Steller Sea Lion Populations along the Western Alaskan Peninsula and Eastern Aleutians	6	$ 393,245	$ 12,600	$ 405,845
Marine Ecosys	**Springer**	**Alan**	U. Alaska Fairbanks	Ecosystem Trends of the Southeastern Bering Sea	5	$ 13,030		$ 13,030
Subtotal Marine Ecosystems						**$ 791,275**	**$ 12,600**	**$ 803,875**
Tsunami	**Hansen**	**Roger**	U. Alaska Fairbanks	Alaska Earthquake Information Center Seismic Station Upgrade and Installation	6	$ 201,452		$ 201,452
Tsunami	**Hansen**	**Roger**	U. Alaska Fairbanks	Alaska Tsunami Inundation Mapping Project	6	$ 48,000		$ 48,000
Tsunami	**Hansen**	**Roger**	U. Alaska Fairbanks	TWEAK ELEMENT I: Accelerated Alaska Inundation Map Production - Year 2	6	$ 175,273		$ 175,273
Tsunami	**Hansen**	**Roger**	U. Alaska Fairbanks	TWEAK ELEMENT II: Tsunami Warning and Environmental Observatory for Alaska - Year 2	6	$ 164,767		$ 164,767
Tsunami	**Musgrave**	**Dave**	U. Alaska Fairbanks	TWEAK ELEMENT III: Tsunami Warning and Environmental Observatory for Alaska	6	$ 475,000		$ 475,000
Subtotal Tsunami Research						**$ 1,064,492**		**$ 1,064,492**
Grand Total						**$ 4,325,445**	**$ 25,200**	**$ 4,350,645**

Appendix 2

Papers published or in press during the reporting period

Appendix 2. Papers published or in press during the reporting period.
*publications from projects funded under NA67RJ0147 (previous 5-year cooperative agreement)
†publications with NOAA first authors

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