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# Annual Report

1 July 2003–30 June 2004

Year 3 of Cooperative Agreement NA17RJ1224



Cooperative Institute for Arctic Research  
University of Alaska Fairbanks

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

1 July 2003–30 June 2004

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Cooperative Institute for Arctic Research  
P.O. Box 757740  
University of Alaska Fairbanks  
Fairbanks, AK 99775-7740  
[www.cifar.uaf.edu](http://www.cifar.uaf.edu)



# Table of Contents

<b>Overview .....</b>	<b>i</b>
<b>Progress Reports</b>	
<i>Arctic Research Initiative .....</i>	<i>1</i>
<i>Steller's Sea Lion Projects .....</i>	<i>13</i>
<i>Research Themes</i>	
Atmospheric and Climate Research .....	29
Climate Modeling.....	30
Contaminant Effects.....	32
Fisheries Oceanography .....	38
Hydrographic and Sea Ice Studies.....	56
Marine Ecosystem Studies.....	58
Tsunami Research .....	70
UV and Arctic Haze Studies.....	73
<b>Appendices</b>	
1. Projects Awarded 1 July 2003–30 June 2004 .....	75
2. Publication Activity .....	81
3. Students .....	85

*Report layout and production by Barb Hameister, CIFAR*

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## Overview

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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 thirteen national NOAA–University joint institutes. CIFAR is designed to foster collaboration between NOAA, the University of Alaska and others working in the Western Arctic (Alaska and the Bering, Chukchi and Beaufort Seas), to conduct research relevant to NOAA’s mission as encompassed in our research themes. 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. Future plans include expanding our collaborations with NOAA through new initiatives in the areas of climate and weather and integrated assessments of climate impacts that will involve the National Weather Service.

CIFAR is staffed by four people: Dr. John Walsh, Director; Dr. Patricia Anderson, Associate Director; Sherry Lynch, financial administrator; and Barb Hameister, publications and meetings manager. John Walsh became director on 1 September 2004, replacing Gunter Weller who had been the director of CIFAR since it was established. The institute does not have its own scientists, post-doctoral fellows or graduate students. Since we are very distant from the closest NOAA Lab and don’t have in-house scientific staff, we conduct research in a different manner from other cooperative institutes. A primary mechanism is to involve researchers through a competitive process involving announcements of opportunity to the entire scientific community and to select projects by peer review. As a consequence, CIFAR research is conducted not only by the faculty and staff at the University of Alaska, but also at several other U.S. universities. In addition, CIFAR provides an important mechanism for facilitating research collaboration between UAF scientists and NOAA line offices, such as NMFS.

### Research Themes

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.

Atmospheric and Climate Research <ul style="list-style-type: none"><li>• <i>Arctic Oscillation</i></li><li>• <i>Arctic clouds and energy balance</i></li><li>• <i>Paleoclimates</i></li></ul> Marine Ecosystem Studies <ul style="list-style-type: none"><li>• <i>Southeast Bering Sea Carrying Capacity (SEBSCC)</i></li><li>• <i>Bering Sea productivity</i></li></ul> Tsunami Research	Climate Modeling <ul style="list-style-type: none"><li>• <i>Coupled models</i></li><li>• <i>Model inter-comparisons</i></li></ul> Fisheries Oceanography <ul style="list-style-type: none"><li>• <i>Global Ocean Ecosystem Dynamics Program (GLOBEC)</i></li><li>• <i>Fisheries studies</i></li></ul> Contaminant Effects <ul style="list-style-type: none"><li>• <i>Arctic pollution</i></li><li>• <i>Effects on indicator species</i></li></ul>	UV and Arctic Haze Studies <ul style="list-style-type: none"><li>• <i>Ozone and UV radiation</i></li><li>• <i>Arctic Haze</i></li></ul> Hydrographic and Sea Ice Studies <ul style="list-style-type: none"><li>• <i>Sea ice research</i></li><li>• <i>Tides and currents</i></li><li>• <i>Ocean fluxes and circulation</i></li></ul> Data Archiving and Support
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### NOAA Mission Goals

CIFAR research addresses all four of NOAA’s mission goals enumerated in the NOAA Strategic Plan. Each individual project report includes which NOAA goal(s) are addressed, as well as a brief statement on societal benefits and/or the relevance of the research results to the needs of NOAA.

1. Protect, Restore, and Manage the Use of Coastal and Ocean Resources through an Ecosystem Approach to Management
2. Understand Climate Variability and Change to Enhance Society’s Ability to Plan and Respond
3. Serve Society’s Needs for Weather and Water Information
4. Support the Nation’s Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation

## Summary of Projects Funded during Reporting Period

During the period 1 July 2003 to 30 June 2004, funding for CIFAR administration and 22 research projects was provided in Amendments 7, 8 & 9 for a total of \$2.45M. All 22 projects fall under CIFAR Task III, i.e., projects funded individually by NOAA (not in response to an announcement of opportunity), and address 7 of the 9 CIFAR research themes. A full list of these projects is presented in Appendix 1, and summaries by task/theme and funding source are presented in Tables 1 and 2, respectively. In this annual submission, we present reports from these projects as well as from ongoing projects funded in the first two years of the CIFAR cooperative agreement. Note that a report is not included for the continuing ship support for GLOBEC (PI Weingartner), a cooperative effort between NSF and NOAA.

**Table 1: Summary of Projects Funded 1 July 2003–30 June 2004: By Task and Theme**

Theme	No. of Research Projects	Total Amount	Percent of Total (rounded)
Research Themes (Task III)			
• Fisheries Oceanography	10	\$ 834,027	34.0
• Marine Ecosystem Studies	5	\$ 458,221	19.0
• Tsunami Research	2	\$ 455,400	19.0
• Climate Modeling	2	\$ 352,200	14.0
• Atmospheric & Climate Research	1	\$ 102,000	4.0
• Contaminant Effects	1	\$ 50,000	2.0
• UV and Arctic Haze	1	\$ 49,900	2.0
Administration (Task I)			
• Core Support		\$ 110,000	4.5
• Subaward fees		\$ 37,800	1.5
<b>Total</b>	<b>22</b>	<b>\$2,449,548</b>	<b>100.0</b>

**Table 2: Summary of Projects Funded 1 July 2003–30 June 2004: By Funding Source**

Funding Source	Total Amount	Percent of Total (rounded)
OAR	\$1,550,800	63
NOS	\$ 520,105	21
NMFS	\$ 335,807	14
Other	\$ 42,836	2
<b>Total</b>	<b>\$2,449,548</b>	<b>100</b>

## Highlights of CIFAR Research Activities and Results

Each individual report includes a list of accomplishments and findings. Below we present highlights from the projects reported on in this document. Not surprisingly, the majority of the findings listed are for those projects that received funding prior to this reporting period.

### *Arctic Research Initiative (2-year continuing projects; first funded in 2001)*

Background: In FY 2001, CIFAR released an announcement of opportunity for the continuation of the Arctic Research Initiative, with 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.

- Tree rings have been used to reconstruct Arctic Oscillation-related temperature and sea level pressure indices back to 1650 (D'Arrigo et al.).



- Satellite (TOVS)-derived winds have been used to demonstrate a recent increase of poleward winds in the European and Pacific (including the Siberian) sectors, and an increase of equatorward winds east of Greenland. Recent (20-year) changes of sea ice contain the signature of these wind changes (Francis).
- Interannual variations in fatty acid profiles of bowhead whale blubbers indicate that changes in the relative proportions of ice algae and spring bloom phytoplankton due to climate variations are reflected in bowhead whale blubber (Springer et al.).
- A suite of state-of-the-art climate models projects a 21st-century decrease of 12–40% in the annual mean arctic sea ice cover, with larger percentage changes in summer. The length of the navigation season in the Northern Sea Route is projected to increase by several months before the end of the century (Walsh).
- Recent changes of surface air temperatures and sea level pressure show a seasonality consistent with greenhouse-driven climate model changes in the Arctic, but not in middle latitudes (Walsh).

*Steller Sea Lion Research (2-year continuing projects; first funded in 2001)*

Background: 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) had been declining for several decades and was considered endangered. 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.

- In the period since 1997, storminess in the western Gulf of Alaska has increased, with possible impacts on mixed layer depth and entrainment of nutrients (Royer and Grosch).
- Variability of the marine environment in the Bering Sea is related, in part, to transport variability through the Aleutian Island passes. Corresponding variations in shelf-break hydrography suggest that bottom-up forcing of Bering Sea ecosystem variability is important (Okkonen and Maslowski).
- Sediment cores and skeletal remains from several locations in the Aleutian Islands have been analyzed in a pilot study to reconstruct the paleo-ocean productivity of the Bering Sea. These data indicate that decadal and century-scale fluctuations in marine productivity have taken place during the past 800 years (Finney et al.).
- In a series of interviews with village residents of the Aleutian East Borough, the Aleut people point out that there have been other major declines prior to the 1970s in the marine mammal populations. Local knowledge points to a multitude of causes of substantial shifts in marine ecosystems over the past 200 years. While the majority of these shifts are "natural," a series of disruptions over the past 100 years appear to be a product of commercial fishing activities (Maschner).
- An archaeological survey of the western Alaska Peninsula and Unimak Island points to a major disruption of the North Pacific ecosystem between AD 900 and 1300. Phocids and Steller sea lions were almost nonexistent during this period. After AD 1400, Steller sea lions populations have risen to levels not seen in the previous 4000 years (Maschner).
- Recent evidence indicates that herring are a very important prey for Steller sea lions, including the endangered western stock (Thorne and Thomas).
- The oxygen storage capacity of juvenile (> 1 year) Steller sea lions is only slightly lower than that of adults, suggesting that the physiological status of juveniles is sufficient to allow independent foraging (Burns and Pfeiffer).
- In the arena of endangered species law and policy, requirements of the courts are minimal but logically rigorous. The National Marine Fisheries Service was never required to establish the definitive causes of Steller sea lion decline, but it was required to base its hypotheses on the best available scientific information and to establish a record of decision-making accordingly (McBeath and Berman).

*Climate*

- TOVS data have a major impact on global reanalyses (e.g., ERA-40) in the Arctic, affecting mid-troposphere geopotential heights by 40–50 meters (Walsh et al.).
- Symposia have been arranged for (1) the release of the Arctic Climate Impact Assessment (Reykjavik, Nov. 2004) and (2) the influence of climate change on North Atlantic fish stocks (Bergen, May 2004) (AMAP/Reiersen).

### *Fisheries Oceanography*

- The Alaska snow crab industry appears to have been a “price-taker” rather than a price-driver over the 1984–2002 period. Sustained increases in Canadian snow crab harvests have put a downward pressure on Alaska snow crab harvests in recent years (Herrmann).
- In a survey of pollock by year class in the Pribilof and eastern Bering Sea regions, non-stratified nearshore domains had the lowest abundance of both fish and zooplankton, while the stratified areas generally had the highest abundance. Abundance in the Pribilof Island area is no higher than elsewhere in the eastern Bering (Coyle).
- The reproductive output of female Pacific cod increases with size and/or age, as do total energy reserves, until reaching a plateau at about age 6 or 7 years (Norcross).
- Hatchery-bred Chinook salmon show behavioral effects within very few generations. Comparative tests have shown that hatchery stock are more aggressive as juveniles, and make greater numbers of charges, displays and nips than wild derived fish (Smoker).
- Sea surface temperatures in the eastern Bering Sea influence the width and extent of the juvenile sockeye salmon distribution and migration rate. Growth of coho salmon during open-ocean period of life cycle appears to be related to the Pacific Decadal Oscillation, an index of temperature associated with climate “regimes” (Adkison).

### *Marine Ecosystem Studies*

- In summer 2003, a subsurface mooring was deployed at 80 meters in a northern Bering biological “hot spot.” This mooring provided measurements of temperature, salinity, currents and chlorophyll. The mooring was retrieved and a new mooring deployed in July 2004 (Whitledge et al.).
- In summer 2003, several synoptic surveys (5 days each) of cross-shelf transects in the Gulf of Alaska were made in order to measure physical and biological characteristics of the Alaska Coastal Current, its offshore excursions in the Seward Eddy and Counter Eddy, the shelfbreak front, and eddies (Whitledge).
- Measurements conducted onboard the Chinese icebreaker “XueLong” during summer 2003 in the Chukchi and Beaufort Seas revealed a C-shaped chlorophyll profile in sea ice. This profile, and the associated snow conditions, are uncommon for the Arctic and could reflect ongoing changes in the Arctic sea ice regime (Gradinger and Bluhm).
- Bone collagen samples from Steller sea lions over a 55-year period reveal an isotopic composition that varies greatly according to the location and year the animal was sampled. Both  $\delta^{13}\text{C}$  and  $\delta^{14}\text{N}$  values decrease temporally in the western areas during the recent multidecadal decline of this population (Wiesenburg/Hocutt).

### **Other CIFAR Activities**

#### *Formal Review*

The formal review of CIFAR, conducted on 2–4 June 2004, consisted of an administrative review and a science/science management review. The two members of the administrative review panel were Rimas Liogys, NOAA Acquisition and Grants Office, and John Cortinas, NOAA Office of Scientific Support. Gayle Elkins, NOAA Pacific Marine Environmental Lab, also attended. The panel met with CIFAR staff and UAF personnel in sponsored programs and grants and contracts management.

The science review panel consisted of John Weatherly (Chairperson), Cold Regions Research and Engineering Lab; Gunnar Knapp, Institute of Social and Economic Research, University of Alaska Anchorage; Elizabeth Logerwell, Alaska Fisheries Science Center; Molly McCammon, Alaska Ocean Observing System; and Thomas Schroeder (Ex Officio panel member), Joint Institute for Marine and Atmospheric Research, University of Hawaii. NOAA Attendees were John Cortinas, NOAA Joint Institutes program manager; Jacqueline Rousseau, NOAA Educational Partnership Program/Minority Serving Institutions Program Director; John Calder, Arctic Research Office program manager; Eddie Bernard, PMEL director; and Gary Hufford and James Partain of the National Weather Service Alaska region. The panel met with CIFAR staff, University of Alaska Fairbanks Provost Paul Reichardt, incoming CIFAR director John Walsh, and a number of CIFAR principal investigators.

The review consisted of a number of formal presentations on CIFAR programs, as well as executive sessions with CIFAR senior management, NOAA program representatives, University of Alaska Fairbanks personnel, and the review panel by itself. The first day concluded with a poster session highlighting CIFAR-funded scientific projects and a reception with the U. S. Arctic Research Commission.

Both reviews were very positive and provided excellent feedback to CIFAR. Reports from each of the review committees have been submitted to CIFAR with a number of recommendations that will be pursued during the coming year.

#### *Arctic Research Initiative – Russian–American Long-term Census of the Arctic (RUSALCA)*

The Arctic Research Initiative is a competitive grant program begun in 1997 that addresses research topics of national interest in the Arctic and is managed by CIFAR. The latest announcement of opportunity under the Arctic Research Initiative was released in July 2003. It addressed a joint U.S.–Russia research cruise to the Bering and Chukchi Seas, the first activity under the Russian–American Long-term Census of the Arctic (RUSALCA). Details for this cruise were worked out between NOAA's Arctic Research Office and Russian authorities at a cruise planning meeting in Moscow in November 2003. CIFAR assembled a panel of experts to review the U.S. proposals submitted for the cruise. Ten U.S. projects were selected, representing an interdisciplinary mix of physical and biological oceanographic studies that included an investigation of water flow through the Western Chukchi Sea, deployment of moorings in both U.S. and Russian waters, and benthic, zooplankton, and fisheries investigations. Russian PIs from the Shirshov Institute, Roshydromet and other institutions were selected to study benthic biota, microbial activity, physical and chemical oceanography, and to look for hydrothermal-methane vents. The cruise objectives were to support the U.S. interagency Study of Environmental Arctic Change (SEARCH) Program and the NOAA Ocean Exploration Program, including the Census of Marine Life.

The primary study area was the Northern Bering Sea (north of 60 degrees latitude) and the Chukchi Sea to the extent that ice conditions permit. The cruise took place 23 July–24 August 2004 on the R/V *Khromov*, a Russian ice-strengthened research ship. This ship departed from Vladivostok and made port stops in Alaska to embark US researchers and their equipment. Project results from this cruise will be reported on in CIFAR's 2005 annual report. Further information can be found at: <http://oceanexplorer.noaa.gov/explorations/04arctic/welcome.htm>.

#### *Arctic Climate Impact Assessment*

The Arctic Climate Impact Assessment, which began in 2000, is a project under the auspices of the Arctic Council and the International Arctic Science Committee. Its goal is to evaluate and synthesize knowledge on climate variability, climate change, and increased ultraviolet radiation and their consequences in the Arctic. The aim is to provide useful and reliable information to the governments, organizations and peoples of the Arctic on policy options to meet such changes. The ACIA is examining possible future impacts on the environment and its living resources, on human health, and on economic sectors that are important in the Arctic. Two major volumes will be completed by the end of 2004: a peer-reviewed scientific volume and a synthesis document. A policy document providing recommendations for coping and adaptation measures is also planned.

The ACIA Secretariat is located at the International Arctic Research Center, University of Alaska Fairbanks, and the CIFAR staff were appointed to operate it. Funding from NOAA's Arctic Research Office supported some of the Secretariat activities during this reporting period. (The primary funding for ACIA is from the National Science Foundation.) In addition to the scientific leadership and coordination provided by past CIFAR Director Gunter Weller, the Secretariat staff organized steering committee meetings and workshops; managed the international review of the ACIA reports; coordinated the work of the technical editors, production manager and lead authors for the reports; formatted all references for the reports; handled extensive travel arrangements and reimbursements; and processed abstracts for the November 2004 ACIA Scientific Symposium, and the requests for young scientist travel support.

#### *Education/Outreach*

##### Student and Postdoctorate Support through Individual Awards

Many of the proposals funded through CIFAR involve graduate and undergraduate students. Thirty-two students (30 graduate; 2 undergraduate), as well as one postdoctorate, were supported in full or in part by the research projects covered in this report or by Task I funds. This includes 5 students supported by the Graduate Student Stipend for Stock Assessment Training and Improvement award from the Alaska Fisheries Science Center (AFSC/NMFS) that provides training for M.S. and Ph.D. students in quantitative fisheries sciences. In addition, many other students benefited from being involved in the research projects, e.g., through sample/data collection and data analysis, even though they did not receive direct salary support through CIFAR.

##### Student Research Grant Program (Graduate and Undergraduate Support)

CIFAR is a major partner in the Global Change Student Research Grant Competition, established by the UAF Center for Global Change in 1992. The competition provides support to UAF students for research on global change

presented in an interdisciplinary context, with an arctic or sub-arctic focus. The work may involve the social, biological, and physical sciences and engineering. This competition is designed to give students experience with proposal writing and the peer review system as practiced by science funding agencies.

CIFAR supports students both through indirect cost recovery, and through Task I direct support of projects of relevance to CIFAR's mission. We completed the 2004 competition in May; the newly funded CIFAR projects are:

- Cory Williams, School of Fisheries and Ocean Sciences, Tufted puffins as biological indicators of forage fish availability in the western Gulf of Alaska
- Pieter A.P. de Hart, School of Fisheries and Ocean Sciences, Stable isotope analysis of Bowhead whale baleen as a biochemical recorder of shifts in migratory patterns during recent arctic environmental change
- Susan B. Vanek, Anthropology, The regulation of time, space and classification

#### Special Requests – Academic Course Development

Special requests come to CIFAR on occasion, and if the request is modest enough, we have provided Task I support for education and outreach activities. Most recently, CIFAR provided \$2,500 toward the support of a new course, offered jointly between UAF and Hokkaido University. The UAF instructors are Hajo Eicken and Rolf Gradinger.

The course offers three individual modules:

- Sea-ice geophysics (ice growth & decay, ice microstructure, impurities in ice, physico-chemical properties & constraints on ice biota)
- Under-ice ocean processes (hydrography, nutrient dynamics, structure and dynamics of biological community)
- Sea-ice biology (structure and activity of sea ice community, from bacteria to metazoa)

The course had 12 students enrolled and took place 4–12 May 2004, Barrow, Alaska.

#### Response to Media and Other Requests

CIFAR scientists provide information and interviews requested by the media and others. For example, the past and present CIFAR directors have given numerous interviews on climate change and other topics, and presented public talks in schools, villages and for the general public.

#### CIFAR Web Site Improvements

We redesigned the CIFAR web site, making it a more useful tool for NOAA, investigators, proposal offices, and eventually a broader audience. In addition to a new visual look, we have entered all CIFAR project information for our current Cooperative Agreement with NOAA into a relational database, which we can query for information about CIFAR research projects, and use to summarize and update information for our web site.

#### **Publications and Presentations**

During the current reporting period, eight peer-reviewed publications and two non-peer-reviewed publications were reported from projects receiving their funding through CIFAR under cooperative agreement NA17RJ1224. Two Master's theses were completed by students receiving funding through CIFAR projects. An additional five papers were reported as in press and 11 were described as submitted or in review. Thirty-three manuscripts were reported to be under preparation. Approximately 50 conference presentations (both national and international) and seminars were also reported. *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.*

See also Appendix 2.

**Project Reports:**  
**Arctic Research Initiative**



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## Paleoclimatic Reconstruction of the Arctic Oscillation

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**Rosanne D'Arrigo, PI**

*Lamont-Doherty Earth Observatory, Columbia University*

**NOAA Goal 2**

Other investigators/professionals funded by this project:

**Edward R. Cook, Lamont-Doherty Earth Observatory**

**Michael E. Mann, University of Virginia**

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This project was completed during the reporting period.

*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 and are submitting the final report this year, in 2004. Our results were not as extensive as those originally planned due to our receiving only one year of funding rather than the two originally proposed.*

### **Primary objectives**

Our primary object for this project was to develop extended time series of climate related to the North Atlantic Oscillation and Arctic Oscillation indices using tree-ring and other proxy data, and to simulate these phenomena in climate modeling.

### **Approach/methodology**

Over the period of funding we have accomplished several of our major goals in developing extended, well-verified paleoclimatic reconstructions of the North Atlantic Oscillation/Arctic Oscillation/Annular mode using tree-ring analysis over the past several centuries. An additional modeling study describes the statistical simulation of the influence of the NAO on European winter surface temperatures and applications for phenological modeling.

### **Research accomplishments/highlights/findings**

- These research efforts include the development of a reconstruction of the North Atlantic Oscillation (NAO) dating back to AD 1400 based on North Atlantic sector proxy data. This study has been published in the *Journal of Climate* (Cook et al. 2002).
- A related paper is a chapter in the proceedings of the AGU Chapman Conference on the NAO which was held in Vigo, Spain in November, 2000 (Cook 2003).
- Reconstructions of Arctic Oscillation related temperature and sea-level pressure indices since AD 1650 have been developed and a related paper has been published (D'Arrigo et al. 2003, *Geophys. Res. Lett.*).
- The influence of the NAO on phenological variability in Europe was investigated through its influence on the distribution of wintertime synoptic-scale surface temperature variability (Cook et al. in press).
- We have collected samples and developed a birch tree-ring record for Greenland, a region of key importance to Atlantic studies related to the Icelandic Low, NAO and AO, which is significantly (negatively) correlated with the NAO for the winter months.

### **NOAA relevance/societal benefits**

Our results have considerable societal benefits as well as direct relevance to the goals of NOAA. The NAO and AO are large-scale features of the globe's circulation. Related weather and climate anomalies impact the populations of considerable areas of the Northern Hemisphere and globe. The extended records provided by our reconstructions yield longer time series with which to study the behavior of these important phenomena.

### **Research linkages/partnerships/collaborators and networking**

The thesis study of Z. Zhang (University of Virginia), partly funded by this project, will soon be completed and will describe large-scale reconstructions of sea-level pressure which will be used to diagnose AO/NAO related patterns. These reconstructions will be compared to those obtained from the tree-ring analyses described above.

### **Education/outreach**

This research involved and helped fund two graduate students at the University of Virginia:

Ben Cook: 3rd yr PhD student

Zhihua Zhang: 5th yr PhD student.

### **Publications and presentations**

- 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.
- 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.
- 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. In press, *Journal of Geophysical Research*.
- Cook, E. 2003. Multi-proxy reconstructions of the North Atlantic Oscillation (NAO) index: A critical review and a new well-verified winter NAO index reconstruction back to AD 1400. In: J.W. Hurrell, Y. Kushnir, G. Ottersen and M. Visbeck, eds. *The North Atlantic Oscillation: Climatic Significance and Environmental Impact* (Geophysical Monograph 134), pp. 63–79. American Geophysical Union, Washington, DC.

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## **Interactions of Laterally Advected Heat and Moisture with Arctic Cloud Properties**

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**Jennifer Francis, PI**

**NOAA Goal 2**

*Institute of Marine and Coastal Sciences, Rutgers University*

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This project was completed during the reporting period.

### **Primary objectives**

Overarching hypothesis: 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.

Objectives of the overall study:

- 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. Separate transport into poleward and zonal components, seasons, and 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*

### **Approach/methodology**

Objective 1: As described in last year's progress report, 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, thus we could not trust the advected heat and moisture fields that we had calculated with these wind fields. We therefore computed 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 at the National Ice Center, where they developed a mass-conservation technique for TOVS-derived winds, which we adapted for use in the Arctic. While the adaptation was not straightforward due to the blocking effects of Greenland, the results appear to have been worth the effort. We have



also begun to investigate the behavior of winds in varying phases of the North Atlantic Oscillation (NAO) (see research accomplishments).

Objective 2: Trends in sensible heat transport were recomputed using the revised calculations based on TOVS-derived wind fields, revealing intriguing patterns (see research accomplishments).

Objectives 3 and 4: These objectives were completed in 2003 by the University of Wisconsin (CIMSS) and the results were presented in last year's progress report.

Objective 5: Time originally designated for this task was used to produce new TOVS-derived wind fields. While we were disappointed that this objective could not be accomplished for this project, we feel that the new wind fields will be very useful for our own research objectives as well as for those of other investigators. The analysis proposed in this objective will be continued under separate funding from NSF.

### Research accomplishments/highlights/findings

- 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 (Figure 1).

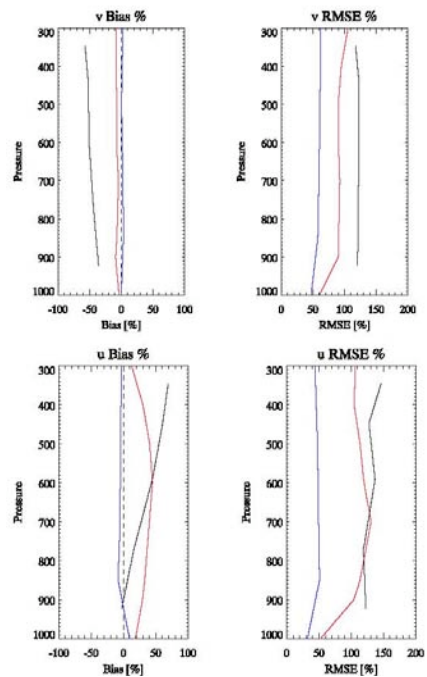


Figure 1. Comparison of biases (weighted by mean wind) in meridional (top) and zonal (bottom) winds in the Arctic from the NCEP reanalysis versus raobs from CEAREX (black), TOVS-derived versus SHEBA raobs (red) and TOVS-derived versus Macquarie Is. raobs (blue).

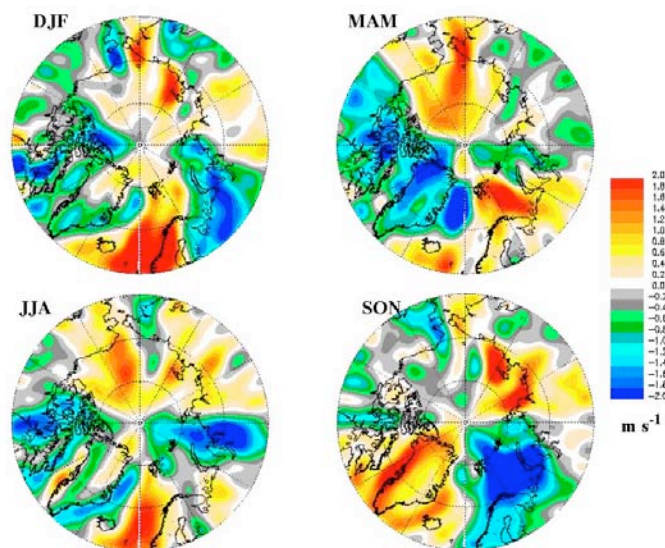


Figure 2. Differences in 700-hPa v-component winds [ $\text{m s}^{-1}$ ] between a positive NAO phase (1989–1995) and a negative phase (1980–1987) by season. Positive values are poleward, negative values are equatorward.

- Investigations of winds in varying phases of the NAO show that in all seasons except autumn, increased poleward winds are evident in the European sector of the Arctic along with northerly winds east of Greenland, and in all seasons there is also a strong increase in poleward winds in much of the Pacific sector (Figure 2).

- In the E. Siberian and Barents Seas, decreased sea ice corresponds with increased offshore winds, while in the Canadian Archipelago increased ice cover coincides with increased onshore winds. In the Fram Strait decreased ice cover is associated with increased winds blowing southward out the Strait (Figure 3).
- Figure 4 illustrates an apparent relationship between changes in spring heating of the lower troposphere caused by the convergence of advected sensible heat and the change in the date of melt onset, as determined by passive microwave observations. The large area of earlier melt onset dates in the Beaufort/Chukchi Seas corresponds to a region of strong warming trends. Preliminary analyses suggest that other TOVS-derived parameters exhibit changes in this season and region, as well: surface downwelling longwave flux and skin temperature increase, cloud fraction increases, and cloud-top height increases.

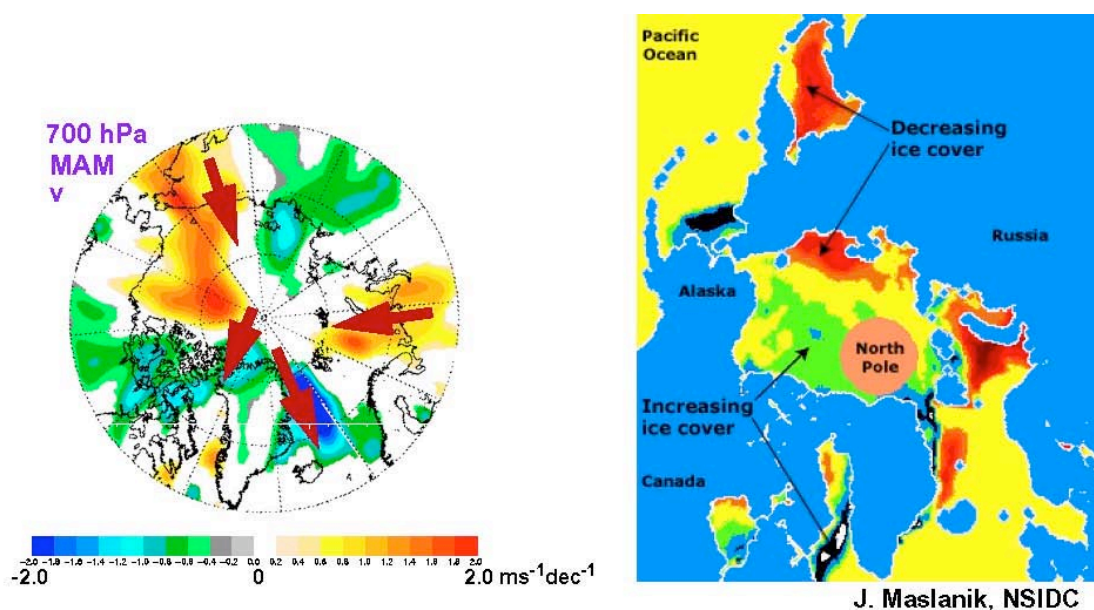


Figure 3. 22-year trends ( $>95\%$  confidence shown) in TOVS-derived meridional winds in spring (MAM) at 700 hPa (left) compared with changes in sea ice extent observed by passive microwave satellite sensors through 1996 (right).

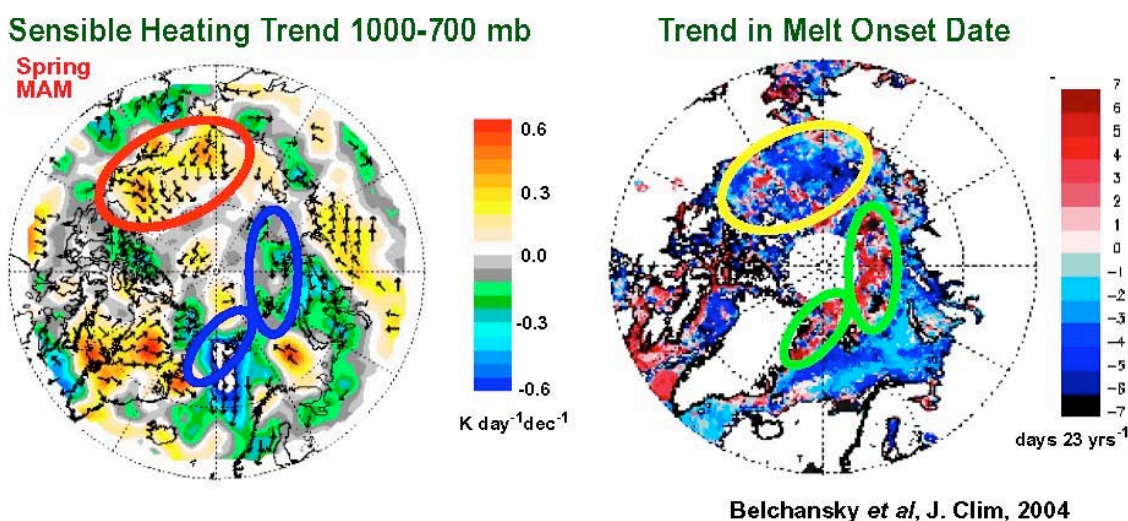


Figure 4. Left: 22-year trend in heating caused by the convergence of TOVS-derived, laterally transported, sensible heat in the layer between 1000 and 700 hPa during spring (MAM). Right: 23-year change in the date of melt onset (days per 23 years) derived from passive microwave observations. Ovals highlight regions of apparent association between advective heating (cooling) and earlier (later) melt dates.

- Later melt dates in the northern Kara Sea and Fram Strait appear to be linked with advective cooling in these areas. The region with earlier melt is also associated with changes in other TOVS-derived parameters. This information highlights the apparent linkages between advected heat, cloud properties, and surface changes, particularly in spring and autumn (not shown) when the ice surface appears to be especially sensitive to changes in surface forcing. These relationships are being explored in more depth.
- 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>.
- A new upper-level wind data set is complete, and will be packaged for archival and distribution by the National Snow and Ice Data Center. A paper describing the generation process and analyses of changes over the period of record has been submitted to the *Journal of Climate*: Arctic tropospheric winds derived from TOVS satellite retrievals, by J.A. Francis, E. Hunter, and C.-Z. Zou.

### **NOAA relevance/societal benefits**

This research examines heat and moisture transport into and within the Arctic and its relationship to cloud properties, addressing NOAA's priority to understand climate variability and change.

### **Research linkages/partnerships/collaborators and networking**

This project is in collaboration with Drs. Steven Ackerman and Jeffrey Key, Office of Research and Applications, NOAA/NESDIS. Other participants are Elias Hunter (Rutgers University) and Xuanji Wang (University of Wisconsin).

### **Publications and presentations**

- Francis, J.A. 2002. Validation of reanalysis upper-level winds in the Arctic with independent rawinsonde data. *Geophysical Research Letters*, 29, 10.1029/2001GL014578.
- 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, MD, 23–24 July 2002.
- Wang, X. and J.R. Key. 2002. Aggregate-area radiative flux biases. *Annals of Glaciology*, 34:101–105.
- Wang, X. and J.R. Key. 2002. Arctic climate characteristics and recent trends revealed by the AVHRR Polar Pathfinder Data Set, SPIE Third International Asia-Pacific Environmental Remote Sensing Symposium, 23–27 October 2002, Hangzhou, China.
- Wang, X. and J.R. Key. 2002. Arctic climate and its change revealed by surface and cloud properties and radiation fluxes based on the AVHRR polar pathfinder data set. Proceedings of SPIE's 47th Annual Meeting, 7–11 July 2002, Seattle, WA.
- Wang, X. and J.R. Key. 2002. Arctic climate characteristics and recent trends based on the AVHRR Polar Pathfinder Data Set. Proceedings of 2002 IEEE International Geoscience and Remote Sensing Symposium and 24th Canadian Symposium on Remote Sensing, 23–29 June 2002, Toronto, Canada.
- Francis, J.A. 2003. New satellite observations of recent change in the Arctic Climate. SEARCH Open Science Meeting, 27–30 October 2003, Seattle, WA.
- Francis, J.A. and E. Hunter. 2003. Arctic upper-level winds from reanalyses and TOVS satellite retrievals. 7th Conference on Polar Meteorology and Oceanography, American Meteorological Society, 12–16 May 2003, Hyannis, MA.
- Wang, X. and J.R. Key. 2003. Recent arctic climate trends observed from space and the cloud-radiation feedback. 7th AMS Conference on Polar Meteorology and Oceanography, 12–16 May 2003, Hyannis, MA.
- Wang, X. and J.R. Key. 2003. Recent trends in arctic surface, cloud, and radiation properties from space. *Science*, 299:1725–1728, 14 March 2003.
- Wang, X., J.R. Key and M.J. Pavolonis. 2003. Recent arctic climate trends observed from space, 1982–1999. 83rd AMS Annual Meeting, 9–13 February 2003, Long Beach, CA.
- Francis, J.A. 2004. Arctic change observed by satellite sounders. Central Arctic: Battleground of Natural and Man-made Climate Forcing, 7–9 January 2004, Lamont-Doherty Earth Observatory, Palisades, NY.
- Francis, J.A., E. Hunter and C.-Z. Zou. Arctic tropospheric winds derived from TOVS satellite retrievals. Submitted to *Journal of Climate*.
- Wang, X. and J.R. Key. Recent trends in the Arctic climate based on the AVHRR Polar Pathfinder dataset. In preparation for submission to *Journal of Climate*.

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## Do Recent Changes in Sea Ice and Snow Cover Impact the Arctic Oscillation?

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**S. Lyn McNutt, PI**  
*University of Alaska Fairbanks*

**NOAA Goal 2**

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This project was completed during the reporting period. It is part of a larger project for which James Overland, NOAA/PMEL, is primary PI.

### **Primary objectives**

The goal of this proposal was to investigate whether the near-surface atmospheric consequences of the Arctic Oscillation (AO) are enhanced by surface conditions. The objectives were to understand:

- 1) How low-level anomalous radiative and temperature advection fields in spring relate to large-scale climate variability, especially in association with the AO;
- 2) How low-level wind, temperature and flux fields affect ice and snow conditions in late spring and summer; and
- 3) The degree to which surface conditions feed back onto atmospheric structure in summer and early fall.

### **Approach/methodology**

First, we related stratospheric/upper tropospheric atmospheric circulation and low level atmospheric temperature and wind anomalies. This was accomplished using a combination of NCEP Reanalysis and TOVS satellite data. Second, we documented how low level wind, temperature and flux fields relate to ice and snow conditions in the late spring and early summer. For this study we used satellite data and surface measurements obtained during the Surface Heat Budget of the Arctic (SHEBA) Program. Third, we documented how anomalous snow and ice cover impacts the Arctic atmosphere, and determined if there have been any changes over the last twenty years. This was accomplished mainly using heat budget calculations applied to the data obtained in the earlier investigations.

### **Research accomplishments/highlights/findings**

This section focuses only on the work performed by S. Lyn McNutt. A complete description of the project can be obtained from James Overland.

- Provided an estimate of the influence of the local distribution of surface temperatures of sea ice on regional surface sensible and radiative heat fluxes based on temperatures from the Advanced Very High Resolution Radiometer (AVHRR) temperatures. The AVHRR data were used to derive ~1 km surface temperature values for 100 by 100 km regions for 48 cases of clear-sky conditions between December 1997 and February 1998.
- These regional flux estimates were then compared to direct flux measurements taken during the Surface Heat Budget of the Arctic Ocean (SHEBA) experiment in the Beaufort Sea. The distribution of surface temperatures within each region is skewed: most temperatures fall near the value observed at the ice camp, but the distribution has a warm tail corresponding to subregions with thinner ice. Sensible heat fluxes at the ice camp were downward, from the air to the ice.
- Although the camp was representative of the majority of the region, the upward flux from thin ice generally balanced the downward flux to thicker ice, suggesting a regional equilibrium of near-zero sensible heat flux. This was true whether the ice was less compact, as in January, or more compact, as in December and February. The only exception to this generalization occurred when the ice was under strong compression. The net regional radiative loss from the ice surface was ~22% greater than that measured on the floe at the SHEBA camp. This increase was likely due to the fourth-power temperature dependence of the radiative flux acting on the skewed distribution of surface temperature.

### **NOAA relevance/societal benefits**

The results have implications for modeling at many scales, and demonstrate that sea ice tends toward small net surface sensible heat flux on an aggregate scale, and that parameterization of the regional mosaic of surface temperatures to resolve the correct radiative balance in winter is important.

### **Research linkages/partnerships/collaborators and networking**

This was a collaborative proposal with NOAA/PMEL in Seattle, WA. Additional collaborations occurred with the Cold Regions Research and Engineering Laboratory (CRREL) when analyzing and publishing results of the research. The information played a crucial role in understanding sea ice hierarchy and modeling requirements for other projects.

### **Education/outreach**

Students at the Alaska Satellite Facility (ASF) were involved in the data acquisition, processing and graphic display of the information.

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## **Trophic Pathways on the Chukchi–Beaufort Shelf: Where do the Ice Algae Go?**

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**Alan M. Springer, PI**

*University of Alaska Fairbanks*

**NOAA Goal 1**

Other investigators/professionals funded by this project:

**C. Peter McRoy, University of Alaska Fairbanks**

**Sara J. Iverson and Suzanne Budge, Dalhousie University**

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This project is ongoing.

### **Primary 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.

### **Approach/methodology**

Plankton samples were collected in May 2002 and 2003 off Barrow, Alaska. 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. Personnel at the North Slope Borough have also made available to us samples of bowhead whale blubber taken near Barrow from 1997 to the present. 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. Individual fatty acids were determined using gas chromatography.

In addition to the samples from Barrow, our collaborator Gay Sheffield of the Alaska Department of Fish and Game collected adipose from planktivorous seabirds, and blubber samples from walruses and ringed, spotted, ribbon, and bearded seals in May 2003 from Little Diomed Island in the 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.

### **Research accomplishments/highlights/findings**

- Fatty acid profiles can be used to differentiate between ice algae and spring bloom phytoplankton.
- Ice algae contain larger amounts of C16 and n-7 fatty acids than spring bloom phytoplankton.
- This unusual FA signature is present in copepods feeding on ice algae, demonstrating the direct transfer of FA profiles through trophic levels.
- The FA profiles of bearded seals and walruses also contain elevated levels of n-7 fatty acids, indicating that they are more directly linked to lower trophic levels than ringed, ribbon or spotted seals.
- Unusual non-methylene interrupted fatty acids in bearded seals and walruses suggest that they do not compete for the same invertebrate food resources.
- These unusual fatty acids can also be used as a biomarker for polar bears feeding on those two species.
- Analyses of bowhead whale blubbers show variation in fatty acid profile with collection year, suggesting that yearly changes in relative proportions of ice algae and spring bloom phytoplankton due to climatic variation are reflected in the bowhead whale blubber.

### **NOAA relevance/societal benefits**

The study of trophic pathways of ice algae relates directly to NOAA's interests in climate change. Global warming results in the melting of sea ice; it is imperative to understand the impact that the loss of sea ice and associated ice algae may have on consumers at higher trophic levels.

### **Research linkages/partnerships/collaborators and networking**

Gay Sheffield at the Alaska Department of Fish and Game has provided essential samples that we would not otherwise have been able to collect, including walruses and bearded, ringed, ribbon and spotted seals.

### **Education/outreach**

A. Springer and S. Iverson have presented a public seminar for the residents of Barrow describing the project and its relevance to the community.

### **Publications**

- Budge, S.M., S.J. Iverson, A.M. Springer and C.P. McRoy. Tracing the fatty acid signature of ice algae to zooplankton consumers. In preparation for submission to *Polar Biology*.
- Budge, S.M., S.J. Iverson, A.M. Springer, G. Sheffield and C.P. McRoy. Spatial and temporal variation in the blubber fatty acid composition of the bowhead whale, *Balaena mysticetus*: implications for diet assessment. In preparation for submission to *Canadian Journal of Fisheries and Aquatic Sciences*.
- Budge, S.M., S.J. Iverson, A.M. Springer, G. Sheffield and C.P. McRoy. Unique fatty acid biomarkers indicate utilization of different benthic food resources in the bearded seal (*Erignathus barbatus*) and Pacific walrus (*Odobenus rosmarus*). In preparation for submission to *Marine Ecology Progress Series*.

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## **An Arctic Archive of Model Output and Application to SEARCH**

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**John E. Walsh, PI**

**NOAA Goal 2, (4)**

*University of Illinois (now at the University of Alaska Fairbanks)*

Other investigators/professionals funded by this project:

**William Chapman and Michael Timlin, University of Illinois**

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This project was completed during the reporting period.

### **Primary objectives**

The project's two main objectives were (1) to provide an archive of global climate model output for the Arctic in support of the Arctic Climate Impact Assessment (ACIA) and the Study of Environmental Arctic Change (SEARCH), and (2) to diagnose this output for evidence of greenhouse signals compatible with recent observed changes. The provision of the model output archive was to include support for ACIA authors through data extraction, processing and visualization products required for the various chapters on impacts. The diagnostic activities were to relate to the attribution issues that underlie the ACIA and SEARCH activities.

### **Approach/methodology**

The development of the model archive followed the recommendations of the ACIA Scenario Group, which met in January 2002 in Stockholm. At that meeting, five state-of-the-art global climate models, together with the B2 forcing scenario, were chosen for the ACIA archive. Our department at the University of Illinois, under support of this project, was chosen as the primary archive site. The archival activity consisted of establishing liaisons with the five modeling centers, extraction of the variables prescribed by the ACIA scenario group, reformatting to a common grid, construction of an ACIA scenario website, and handling of requests from the ACIA authors for specific information from the model archive.

The diagnostic activity emphasized two aspects of the 21st-century greenhouse simulations from the ACIA archive. First, the scenarios of sea ice retreat were analyzed by utilizing an adjustment procedure to remove the effects of biases in the control simulations. A case study then focused on the increased marine access along the Northern Sea Route. Second, the ACIA simulations were used to evaluate the presence of greenhouse signal in observed variations of the past half-century through a quantitative comparison of the seasonality of the observed and projected changes in various latitude bands.

### **Research accomplishments/highlights/findings**

- ACIA model scenario archive was constructed (<http://zubov.atmos.uiuc.edu/ACIA/>) and information from this archive was used to fill approximately 60 requests from ACIA authors.
- Graphical analysis of model results was provided for ACIA Overview in collaboration with Paul Grabhorn.



- Additional websites have been constructed for recent variations in the Arctic atmosphere and Arctic sea ice/snow cover (<http://zubov.atmos.uiuc.edu/CT/>). Products from these websites appeared in the 2003 annual climate review (*Bull. Amer. Meteor. Soc.*, 2004, 85, S1-S72).
- A2 scenario simulations by ACIA models were found to contain qualitatively similar but more rapidly evolving changes in the Arctic than corresponding B2 simulations (cf. ACIA scenario website).
- Decreases of annual mean sea ice extent projected by ACIA models for the late 21<sup>st</sup> century were found to range from 12% to 40%, with larger percentage decreases in summer and smaller percentage decreases in winter (Walsh and Timlin, 2003).
- Length of navigation of Northern Sea Route is projected to increase by several months before the end of the century (Walsh and Timlin, 2003).
- Recent changes of Arctic surface air temperature and sea level pressure show a seasonality consistent with the ACIA model projections; this consistency is detectable only in the Arctic, and it does not extend to precipitation (Walsh and Chapman, 2004).

### **NOAA relevance/societal benefits**

Products of ACIA scenario archive activity enhanced visibility of the NOAA-supported ACIA. Websites depicting ongoing Arctic changes are publicly accessible, providing broad access to recent variations of the Arctic atmosphere and sea ice. The evaluation of 21<sup>st</sup>-century sea ice projections provides a framework for Arctic marine and sea ice planning.

### **Research linkages/partnerships/collaborators and networking**

The products of the scenario archive activity were utilized directly by the authors of most ACIA chapters, making NOAA support a prominent part of the 270-author ACIA activity (leveraged by NSF and other international support). Sea ice project was in collaboration with the U.S. Arctic Research Commission (L. Brigham).

### **Education/outreach**

- Presented project results in presentation at Huslia High School, Huslia, AK, 8 January 2004.
- Websites listed under *Accomplishments* above are publicly accessible; inquiries have been received from members of the public as well as the scientific community.
- Animations of model output produced under this project were used on PBS program “Scientific American Frontiers” (aired June 2004).

### **Publications**

Walsh, J.E. and M.S. Timlin. 2003. Northern Hemisphere sea ice simulations by global climate models. *Polar Research*, 22(1):75–82.

Walsh, J.E. and W.L. Chapman. 2004. Seasonality of change in the Arctic: Observed and greenhouse driven. Submitted June 2004 to *Journal of Climate*.





**Project Reports:**  
**Steller's Sea Lion Projects**



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

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**Jennifer M. Burns, PI**  
University of Alaska Anchorage

**NOAA Goal 1**

Other investigators/professionals funded by this project:  
**David C. Pfeiffer, University of Alaska Anchorage**

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This project is ongoing.

### **Primary objectives**

By studying the development of sea lion physiological status, and then linking it with diving behavior (determined as part of other, ongoing studies), this project will identify if physiological limitations in the rate of development might influence activity patterns and foraging strategies. This research may also reveal whether rates of physiological 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 to determine physiological maturity relative to timing of independence. Ultimately, this research may offer insight into those factors that influence juvenile survival and recruitment.

### **Approach/methodology**

The development of dive capacity in juvenile Steller sea lions was investigated by measuring blood and muscle oxygen stores. Erythropoietin (EPO), a hormone stimulated in response to tissue hypoxia, was analyzed to investigate a possible mechanism for oxygen stores development. EPO was analyzed using a Radioimmunoassay kit from Diagnostic Systems Laboratories. Biochemical and histochemical characteristics of muscle were studied to determine how these criteria may change with development and how they influence dive ability. Muscle biochemical profiles of three enzymes (lactate dehydrogenase, citrate synthase and  $\beta$ -Hydroxyacyl-CoA dehydrogenase) in various age categories and two muscle types (primary swimming and non-swimming) were determined using kinetic assay. Histochemical analysis of muscle was investigated using immunohistochemical techniques validated with traditional histochemical staining techniques. Juvenile animals ranging in age from 5 to 22 months (n=46) in Southeast Alaska, Prince William Sound, and the Aleutian Islands were captured by the Alaska Department of Fish and Game and the National Marine Mammal Laboratory and sampled for this study.

### **Research accomplishments/highlights/findings**

- All samples have been collected and laboratory analysis completed except for the histology portion of the study.
- The EPO and hematology manuscript will be submitted within the month to General and Comparative Endocrinology for review and publication. The development of total body oxygen stores manuscript will be submitted within 6 months, and the biochemistry of muscle development paper should be completed within 12 months.
- EPO and hematocrit show a similar inverse relationship as seen in other mammalian species during development. Surprisingly, differences in EPO and Hct were observed among populations, which has spawned new investigation into possible causes for this difference.
- Little to no change in blood volume was observed throughout our study period; therefore changes in blood oxygen stores were due primarily to increased hemoglobin concentration.
- Myoglobin is initially elevated in the non-swimming type (latissimus dorsi) muscle and then switches early in development to the more typical pattern of elevated values in the swimming type (pectoralis) muscle. The rate of myoglobin increase slowed after the first year, but did not reach adult male values even at 29 months of age. This indicates that as animals age, myoglobin becomes an important oxygen storage site.
- Total body oxygen increased to values similar to adult females on a mass specific basis by the time juveniles were approximately 21 months of age. However, with their smaller body size and their higher mass specific metabolic rate juveniles are limited in the amount of time they can maintain aerobic metabolism relative to older age classes.

### **NOAA relevance/societal benefits**

We have demonstrated that the oxygen storage capacity of juveniles > 1 year is only slightly lower than that of adults, and shown that most dives made by juveniles are within their aerobic dive capacity. This suggests that the physiological status of juveniles > 1 year is sufficient to allow independent foraging.

### **Research linkages/partnerships/collaborators and networking**

This research would not have been possible without tremendous collaborative efforts. Alaska Department of Fish & Game and the National Marine Mammal laboratory supplied logistical support for fieldwork and provided samples. Samples were also provided by the Alaska SeaLife Center and the Aleut Community of St. Paul, Alaska.

### **Education/outreach**

Julie P. Richmond	Master of Science Degree <i>Completed</i>
Jill Prewitt	Master of Science Degree <i>In progress</i>

### **Publications and presentations**

Richmond, J.P., J.M. Burns and L.D. Rea. 2002. Investigation in blood and muscle development in the Steller sea lion: Implications for diving ability. AAAS Arctic Science Conference, Fairbanks, AK, 18–21 September, Poster Presentation.

Richmond, J.P., J.M. Burns and L.D. Rea. 2002. Biochemistry of Steller sea lion muscle as it relates to development of dive physiology. American Physiological Society Conference: The Power of Comparative Physiology: Evolution, Integration and Application, San Diego, CA. August, Poster Presentation.

Burns, J.M., M.J. Rehberg and J.P. Richmond. 2003. Diving behavior and physiology in juvenile Steller sea lions: What are the links? Marine Science in the Northeast Pacific: Science for Resource Dependent Communities, Anchorage, AK, 13–17 January, Oral Presentation.

Richmond, J.P., J.M. Burns and L.D. Rea. 2003. Developmental trends in Erythropoietin: The diving force behind blood oxygen store expansion. Conference on the Biology of Marine Mammals, Greensboro, NC, 15–19 December, Oral Presentation.

Richmond, J.P., J.M. Burns and L.D. Rea. 2003. Steller sea lion foraging ecology is an important factor in juvenile survival. Marine Science in the North Pacific: Science for Resource Dependent Communities, Anchorage, AK, 13–17 January, Oral Presentation.

Richmond, J.P., J.M. Burns, L.D. Rea, and K. Mashburn. Postnatal ontogeny of Erythropoietin and hematology in free-ranging Steller sea lions (*Eumetopias jubatus*). In preparation for submission to *General and Comparative Endocrinology*.

Richmond, J.P., J.M. Burns and L.D. Rea. Development of total body oxygen stores and aerobic dive potential in the Steller sea lion (*Eumetopias jubatus*). In preparation for submission to *Physiological and Biochemical Zoology*.

Richmond, J.P., J.M. Burns and L. Polasek. Skeletal muscle myoglobin and select oxidative and glycolytic enzyme profiles throughout development in free-ranging Steller sea lions (*Eumetopias jubatus*). In preparation for submission to *Journal of Experimental Biology*.

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## **Climate-driven Bottom-up Processes and Killer Whale Abundance as Factors in Steller Sea Lion Population Trends in the Aleutian Islands: Zooplankton and Acoustic Component**

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**Kenneth Coyle, PI**  
University of Alaska Fairbanks

**NOAA Goal 1**

This project is ongoing.

### **Primary objectives**

The western population of Steller sea lions, extending from Kodiak Island through the western Aleutian Islands, has undergone a steady decline since the mid 1970's. Current working hypotheses for the declines are:

- 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.

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.

### **Approach/methodology**

Two cruises were completed in 2001–2002. Large zooplankton and micronekton were collected with a 1-m<sup>2</sup> MOCNESS equipped with 500 µm mesh nets. Small zooplankton were collected with a 9 cm diameter CalVET net system. 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. The simultaneous collection of acoustic and net data will aid in the interpretation and scaling of the acoustic transect data.

Research Objectives:

- 1) Analysis of CalVET net data.
- 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 2005.

### **Research accomplishments/highlights/findings**

- Objectives 1, 2, 4, 5 and 6 are completed. The samples have been processed, the data have been entered into the database, and the analysis has been incorporated into the manuscript mentioned in Objective 5.
- The manuscript is: Coyle, K.O. Zooplankton distribution, abundance and biomass relative to water masses in eastern and central Aleutian Island passes. It has been accepted for *Fisheries Oceanography*. Printing and publication are pending the completion of revisions of other manuscripts in the issue.
- Revisions are underway or nearly completed for two other articles with contributions from this component of the project. They include:
  - Ladd, C., J. Jahncke, G.L. Hunt, K.O. Coyle and P.J. Staben. Hydrographic features and seabird foraging in Aleutian Passes. *Fisheries Oceanography*.
  - Jahncke, J., K.O. Coyle and J.L. Hunt. Seabird distribution, abundance and diets in the central and eastern Aleutian Islands. *Fisheries Oceanography*.
- Objective 3: The software for analysis of the narrow band data was completed and the results incorporated into the Coyle and the Ladd et al. manuscripts cited above. Preliminary work with the broadband data suggests that it is cost-prohibitive to analyze it at this time due to the huge size of the data set (about 10 GB compressed). The broad band was an experimental technology, which we used during field collection to supplement the narrow-band data at no extra cost to the project.
- I am currently collaborating with Sue Moore (NMML) to use the physical oceanographic, acoustic and zooplankton data for interpretation of the marine mammal distribution data collected during the cruises. We hope to complete analysis and generate manuscripts for publication within a year.

### **NOAA relevance/societal benefits**

Due to the declines in Steller sea lion populations and the resulting fishing restrictions on the commercial fleet in the vicinity of sea lion rookeries, NOAA was tasked to provide information on the biology and habitat of sea lions to aid in determining potential causes for the declines. This research addresses two hypotheses of interest to NOAA.

- Predation by killer whales on sea lions has increased mortality and lowered the survival of sea lion pups and juveniles.
- 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.

### **Research linkages/partnerships/collaborators and networking**

This research is done in collaboration with four principal investigators funded under separate contracts from various agencies: George L. Hunt, University of California Irvine; Sue Moore, National Marine Mammal Laboratory; Steve Zeeman, University of New England; and Phyllis Stabeno, Pacific Marine Environmental Laboratory.

Information from this research was also used by Beth Sinclair and Tom Loughlin of the National Marine Mammal Laboratory in their research on Steller sea lion biology.

### **Publications**

Coyle, K.O. Zooplankton distribution, abundance and biomass relative to water masses in eastern and central Aleutian Island passes. Accepted for *Fisheries Oceanography*.

Ladd, C., J. Jahncke, G.L. Hunt, K.O. Coyle and P.J. Stabeno. Hydrographic features and seabird foraging in Aleutian Passes. In preparation for submission to *Fisheries Oceanography*.

Jahncke, J., K.O. Coyle and J.L. Hunt. Seabird distribution, abundance and diets in the central and eastern Aleutian Islands. In preparation for submission to *Fisheries Oceanography*.

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## **Impacts of Climate Change on the Bering Sea Ecosystem over the Past 500 Years**

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**Bruce P. Finney, PI**  
*University of Alaska Fairbanks*

**NOAA Goal 1**

Other investigators/professionals funded by this project:

**Amy C. Hiron and Alan M. Springer, University of Alaska Fairbanks**

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This project is ongoing.

### **Primary objectives**

- 1) To reconstruct changes in primary productivity of the Bering Sea at decadal or better resolution over the past approximately 500 years.
- 2) To reconstruct relative changes in populations of forage fish at similar resolution to the records produced in objective 1.
- 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.

### **Approach/methodology**

- 1) 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  $\delta^{13}\text{C}$  on bone collagen from Steller sea lions to evaluate changes in marine primary production.
- 2) Piston cores collected in Skan Bay and Captain's Bay show evidence of some preserved fish scales that provide temporal productivity data for those regions.
- 3) The combined analysis of the stable isotope of oxygen ( $\delta^{18}\text{O}$ ) and Ca/Mg provides data on ocean temperature and salinity. Sequential sampling and analysis along the sediment cores provide information on temporal fluctuations that correspond to climatic changes.
- 4) The combined analysis of the stable isotope of carbon ( $\delta^{13}\text{C}$ ) and nitrogen ( $\delta^{15}\text{N}$ ) provides information on the productivity of the marine environment and the length of the food web in which the pinnipeds resided. Museum and archaeological remains of these organisms provide information on temporal fluctuations that likely correspond to environmental fluctuations.
- 5) We are developing 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.

### **Research accomplishments/highlights/findings**

- $\delta^{13}\text{C}$  data, carbon content and percent opal (from diatoms), all of which are proxies for primary productivity, conducted for both Skan Bay and Captain's Bay sediment cores.

- AMS and Pb-210 dating of Skan Bay core represents almost 800 years and dating of Captain's Bay core represents almost 400 years.
- Foraminifera sieved and preliminary identification conducted for both sediment cores.  $\delta^{18}\text{O}$  and Ca/Mg analyses need to be completed.
- Fish scale sieving and counts conducted for both cores.
- Museum faunal material analyzed for  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ . Additional isotopic analysis of archaeological material being completed.
- Cross-correlation analyses being conducted with climatic data.

### **NOAA relevance/societal benefits**

In a pilot study effort to reconstruct the paleocean productivity of the Bering Sea, we have collected and analyzed sediment cores and skeletal remains from several locations in the Aleutian Islands. These data indicate decadal and century-scale fluctuations in marine productivity took place during the 800-year time period. Information of this kind is useful for addressing management and conservation concerns over recent changes in abundance of several species, such as pollock and sea lions.

### **Research linkages/partnerships/collaborators and networking**

This research has led to additional research and funding through NOAA, the North Pacific Universities Marine Mammal Research Consortium, NSF Arctic Social Science, and the Pollock Conservation Cooperative Research Consortium on subjects dealing with climatic impact on trophic structure, marine productivity and resource utilization.

### **Education/outreach**

Undergraduate and graduate oceanography, anthropology and geology students have participated in the collection and identification of foraminifera, preparation of bone samples for stable isotope analysis and studying sedimentation in marine cores (students Molly Boughan and Molly Odell). Preliminary results of these data have been presented orally and in poster format at a climate meeting (SEARCH '03), stable isotope conference (Pan Pacific Australasian conference '02), marine ecosystem meeting (PICES '02) and physical science conference (American Geophysical Union '03). These data were also presented to the public at museums (Museum of the Aleutians, National Museum of Natural History), agency and investigator meetings.

### **Publications**

Two separate publications are being prepared for scientific journal submission. One manuscript deals with the climatic data as evidenced in the sedimentary record while the other addresses the environmental and trophic data recorded in the skeletal remains of lower and upper trophic level organisms.

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## **Seasonal Assessment of Prey Competition between Steller Sea Lions and Walleye Pollock**

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**Robert J. Foy, PI**  
University of Alaska Fairbanks

**NOAA Goal 1**

This project was completed during the reporting period.

### **Primary objectives**

The goal of this study was to assess the level of competitive interaction between walleye pollock and Steller sea lions within designated sea lion critical habitat. Specific objectives were to:

- 1) Determine the seasonal diet composition of pollock within sea lion critical habitat.
- 2) Determine consumption and evacuation rates of pollock.
- 3) Calculate the potential removal of particular prey species by pollock.
- 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.

### ***Approach/methodology***

Two hundred pollock stomachs were collected from within the Long Island Steller sea lion critical habitat area between 2001 and 2003 as part of the Gulf Apex Predator–prey study in Kodiak. Stomach content analysis was completed and seasonal and spatial differences in taxa found in the diet were assessed. Stomach contents were determined as a percentage of body weight and species composition was assessed using diversity and ordination indices.

Fifty pollock of multiple year classes were also collected by jigging for consumption and evacuation rate experiments. Three sets of feeding trials were concluded to establish feeding parameters at multiple temperatures. Daily ration estimates of each prey species were collected from published literature on predator biomass, calculated consumption and evacuation rates. This data will be compared to Steller sea lion diets from the Gulf Apex Predator–prey study in Kodiak, AK. Sea lion diet data was 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.

### ***Research accomplishments/highlights/findings***

- Diets of pollock have been established seasonally and interannually within the study area.
- Adult pollock diets were dominated by juvenile pollock, tanner crab, eulachon and euphausiids. Juvenile pollock diets are dominated by euphausiids and larval fishes.
- Feeding parameters of Walleye pollock were calculated from laboratory experiments yielding important estimates of consumption, evacuation and daily ration for use in determining prey removals.
- Steller sea lion diets were assessed during the same time period for a comparison between diets.
- Results suggest that the diets of walleye pollock and Steller sea lions are sufficiently different in the Kodiak region.
- Walleye pollock are competing with other Steller sea lion prey for critical resources, some of which have commercial value as well.

### ***NOAA relevance/societal benefits***

One stock of Steller sea lions in the North Pacific Ocean declined substantially between the 1960's and 1990's. This study tested NOAA hypotheses regarding the trophic interactions between Steller sea lions and one commercial prey species (walleye pollock) which had management implications as a result of the decline.

### ***Research linkages/partnerships/collaborators and networking***

This project directly supports the Gulf Apex Predator–prey study which is designed to assess trophic interactions with an ecosystem minded approach. This program has included the collaboration of University of Alaska, University of Washington, Alaska Department of Fish and Game, National Marine Fisheries Service, and National Marine Mammal Lab.

### ***Education/outreach***

Students funded as part of this CIFAR award include Mary Beth Louwen, a continuing MS student, and Heather Finkle, who has completed her MS degree. Multiple K–12 visits have occurred during this study. The results of this study and its implication on the community of Kodiak were discussed.

### ***Publications***

Foy, R.J. Competitive interactions between Steller sea lions and walleye pollock inside sea lion critical habitat: a diet comparison. In preparation.

Foy, R.J. Seasonal lipid content and feeding habits of walleye pollock in Kodiak, AK. In preparation.



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## Decision-Making under Uncertainty: Management of Commercial Fisheries and Marine Mammals

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**Jerry McBeath, PI**  
University of Alaska Fairbanks

**NOAA Goal 1**

**Matt Berman, PI**  
University of Alaska Anchorage

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Work initiated by McBeath will be completed in August 2004. Work initiated by Berman is ongoing.

### **Primary objectives**

- a) Examination of the structure of decision-making concerning Steller Sea Lions (SSL) and commercial fisheries management, with a focus on the National Marine Fisheries Service (NMFS) Alaska Region (legal and regulatory bases and affected interests);
- b) Etiology of the SSL crisis, based on available sources;
- c) Policy analysis of scientific literature of SSL decline since the Endangered Species Act (ESA) listing in 1990;
- d) Analysis of the political, socio-economic, and environmental risks of management failure; analysis of court, congressional, and agency use of science and certainty thresholds before taking action; and
- e) Analysis of the degree to which science research can respond quickly to provide knowledge that could increase certainty regarding effects of management decisions and thereby reduce risks associated with management actions.

### **Approach/methodology**

The approach of the project involves collection of both primary and secondary data, with both quantitative and qualitative dimensions. The secondary data are of four types: a) the four court orders of *Greenpeace v. National Marine Fisheries Service*, the briefs of plaintiffs, defendants, and defendant-intervenors and the voluminous (20,000 plus pages) administrative record, b) the published scientific literature on the causes of SSL decline, the SSL controversy itself, and its ramifications—in books, journal articles, MS and doctoral theses, and agency/interest group reports, c) environmental impact statements and biological opinions on the SSL and its critical habitat, and d) recent and current research projects in the NOAA-funded SSL science program.

Primary data collection consists of nearly 100 mostly qualitative interviews on fisheries and endangered species management with officials of NMFS (past/present), NOAA general counsel office, North Pacific Fishery Management Council, ADFG, and EPA; political leaders (federal, state, local) active in fisheries and endangered species issues, including staff; interest group representatives (industry, environmental, Native organizations), and marine scientists.

### **Research accomplishments/highlights/findings**

- Understanding how courts treat scientific uncertainty in issues concerning species and critical habitat protection as required by ESA;
- Understanding what causes an agency “culture” (behavioral norms and operational codes) to form and change;
- Understanding the role of interest group pressure in fisheries management decisions;
- Understanding the role of Congress (and particularly, the impact of veteran, majority, committee chairs) in influencing management and fiscal policy decisions of agencies on endangered species/habitat issues;
- Understanding, in a comparative perspective, why the boundaries of science and politics so often are blurred in decision-making to protect endangered species.

### **NOAA relevance/societal benefits**

This research demonstrates that, so far as endangered species law and policy are concerned, requirements of the courts are minimal but logically rigorous. NMFS was never required to establish the definitive causes of SSL decline. It was required to base its hypotheses on the best available scientific information, and then to establish a record of decision-making logically consistent with its hypotheses.

### **Research linkages/partnerships/collaborators and networking**

(for McBeath) This research has led to a new partnership with the National Center for Smart Growth Research and Education at the University of Maryland (and its Marine, Estuarine and Environmental Sciences and Conservation

Biology and Sustainable Development sections), leading to a chapter on Alaska prepared for an upcoming book. The research also is related to development of an EPA-funded proposal on contaminants in aquatic ecosystems. Further, McBeath's research on endangered species will be reflected in a book on "Comparative Environmental Politics," part of Springer's environmental policy series, and is the inspiration for a book contract with Edward Elgar Publishing Co. on "Biodiversity Conservation in Greater China."

(for Berman) The research has contributed to the development of the human dimensions aspects of the Implementation Plan for the interagency research program Study of Environmental Change (SEARCH) and the proposed Bering Sea Ecosystem Study (BEST) plan.

### **Education/outreach**

Christina Talley, an undergraduate student at Seattle University, was supported in part by the CIFAR award in summer 2004. In addition, R. "Burr" Neely, a UAF graduate student in Northern Studies, was supported in part by the CIFAR award in 2002–2003. He graduated in May 2003.

McBeath used the SSL controversy in lectures on U.S. Biodiversity Protection at China Foreign Affairs University (Beijing) and Guangxi Normal University (Guilin) to several hundred students in the social sciences and life sciences.

### **Publications**

McBeath, J. 2004. Greenpeace v. National Marine Fisheries Service: Steller Sea Lions and Commercial Fisheries in the North Pacific. *Alaska Law Review*, June 2004, Vol. XXI, No. 1, pp. 1–42.

McBeath, J. Management of the Commons for Biodiversity: Lessons from the North Pacific. *Journal of Marine Policy*, in press.

McBeath, J. Science and Politics in Marine Mammal Conservation. *Journal of Wildlife Law and Policy*, in press for publication in August 2004.

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## **Interannual Variability of Biophysical Linkages between the Basin and Shelf in the Bering Sea**

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**Stephen Okkonen**

*University of Alaska Fairbanks*

**NOAA Goal 1, (2)**

Other investigators/professionals funded by this project:

**Wieslaw Maslowski, Naval Postgraduate School, Monterey, CA**

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This project was completed during the reporting period, pending revision/acceptance of submitted manuscripts.

### **Primary objectives**

The general objective for this project has been to investigate interannual and decadal variations of property exchanges between the Bering Sea and North Pacific Ocean and between the Bering Sea and Arctic Ocean. The primary tool for this investigation has been a 9-km, 45-level Naval Postgraduate School coupled ice-ocean numerical model.

### **Approach/methodology**

We focused on two aspects of property exchanges: (1) quantification of mean and interannual exchange (mass, heat, and fresh water fluxes) through the Bering Strait and through the passes of the eastern and central Aleutian Islands and (2) identification of vertical and longitudinal variations of shelf break hydrography in the western Gulf of Alaska as indicators of exchange between the shelf and slope.

### **Research accomplishments/highlights/findings**

- Annual period variability dominates hydrographic variability in the northern Gulf of Alaska.
- Interannual hydrographic variability is comparable to or exceeds annual period hydrographic variability near the eastern Aleutian Islands.
- Mesoscale eddies drive interannual variability of shelf break hydrography.
- Interannual hydrographic variability is greater at depth than at the surface
- The region near Samalga Pass and Amukta Pass is a transition zone between coastal and marine environments.

- The model is able to reproduce the characteristics of major water masses across the Bering Sea Shelf and in Bering Strait, however, future improvements to include more riverine input and to better resolve the narrow Alaska Coastal Current are planned.
- The northern Bering Sea maintains high eddy kinetic energy throughout the annual cycle, especially in the Chirikov Basin, Anadyr and Bering Straits, which may be important for primary and secondary production in these regions.

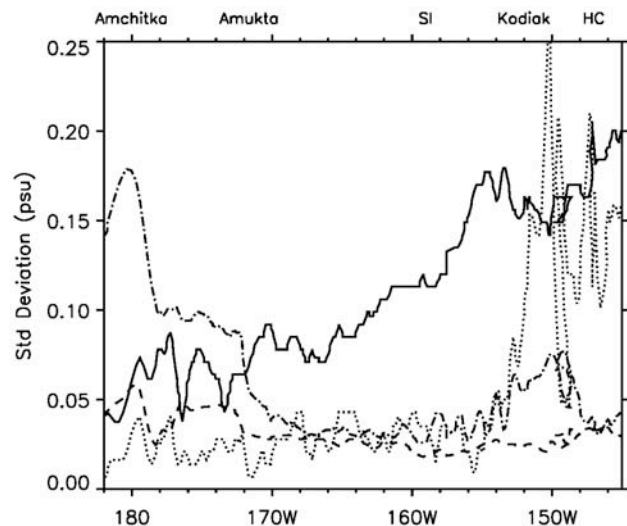


Figure 1. Standard deviations of annual period surface layer salinity (solid), annual period deep layer salinity (dotted), interannual period surface layer salinity (dashed), and interannual period deep layer salinity (chain dot) along the shelf break in the western Gulf of Alaska. Note that deep layer interannual salinity deviations west of Amukta Pass are comparable to surface layer and deep layer annual period salinity deviations east of Kodiak.

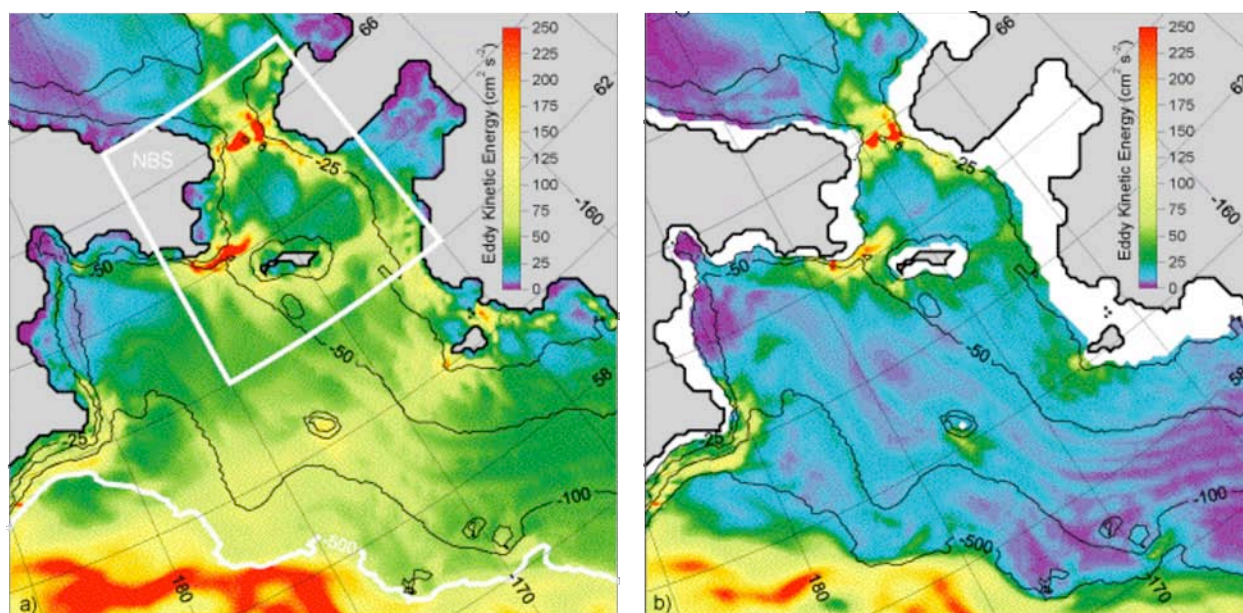


Figure 2. Eddy kinetic energy ( $\text{cm}^2/\text{s}^2$ ) calculated from daily 1987 snapshots (against 23 yr mean): a) surface level, b) 20–26 m (level 5).

### NOAA relevance/societal benefits

Our research suggests that variability of the marine environment in the Bering Sea is related, in part, to transport variability through the Aleutian Island passes. The western Gulf of Alaska can be partitioned into three biophysical domains according to the relative importance of annual and interannual variations in shelf break hydrography. These observations suggest that bottom-up forcing of ecosystems is important.

### **Research linkages/partnerships/collaborators and networking**

Dr. Phyllis Stabeno (NOAA/PMEL) provided current meter data for comparison with and validation of the numerical model output. Model eddy kinetic energies (EKE) were compared with TOPEX altimeter-derived measurements of EKE.

### **Education/outreach**

Graduate student - J.L. Clement, Naval Postgraduate School (W. Maslowski, advisor)

Public awareness - Our results have been presented at the Marine Science Symposium in Anchorage and at the AGU Ocean Sciences meeting in Honolulu.

### **Publications**

- Maslowski, W., J.L. Clement, S.R. Okkonen, P.J. Stabeno and W. Walczowski. 2004. On the mean ocean circulation and property transport from the Alaskan Stream through eastern and central Aleutian Island passes – model results. *Fisheries Oceanography* (in revision).
- Okkonen, S.R. and W. Maslowski. 2004. Numerical investigations of seasonal and interannual variability of shelf break hydrography in the western Gulf of Alaska. Submitted to *Journal of Geophysical Research*.
- Trites, A.W., A. J. Miller, H.D.G. Maschner, M.A. Alexander, S.J. Bograd, A. Capotondi, K.O. Coyle, E. Di Lorenzo, T.C. Royer, E.J. Gregr, C.E. Grosch, B.P. Finney, L. Fritz, G.L. Hunt, J. Jahncke, N.B. Kachel, H.-J. Kim, C. Ladd, N.J. Mantua, C. Marzban, W. Maslowski, D.J. Neilson, J.E. Overland, S.R. Okkonen, K.L. Reedy-Maschner, J.X.L. Wang and A.J. Winship. 2004. Bottom-up forcing and the decline of Steller sea lions in Alaska: Assessing the ocean climate hypothesis. In preparation for submission to *Fisheries Oceanography*.
- Clement, J.L., W. Maslowski, L.W. Cooper, J.M. Grebmeier and W. Walczowski, 2004. Ocean circulation and exchanges through the northern Bering Sea: 1979–2001 model results. In preparation for submission to *Deep Sea Research*.

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## **Ocean Climate Variability as a Potential Influence on Steller Sea Lion Populations**

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**Thomas C. Royer, PI**  
*Old Dominion University*

**NOAA Goal 1**

Other investigators/professionals funded by this project:  
**Chester E. Grosch, Old Dominion University**

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This project is ongoing.

### **Primary objectives**

We hypothesize that the combination of many of the oceanic-atmospheric forces with bi decadal cycles could lead to the regime shift in the North Pacific that occurred in the late 1970s. Low frequency fluctuations could influence the amount and distribution of biomass in the ecosystem. How are the sea level slopes and ocean circulation related to the coastal freshwater discharge and coastal sea levels in the Gulf of Alaska? Do coastal freshwater discharge, coastal sea level and other long term environmental records contain information on interdecadal changes in the marine ecosystem in the North Pacific and Bering Sea?

### **Approach/methodology**

We have assembled long time series of environmental parameters that include air temperatures, precipitation, runoff, water temperatures and salinities. NOAA buoy observations (one of the best and longest ocean observations), upwelling indices, sea surface temperatures from satellites and ships, and surface winds from satellite scatterometers. We have taken advantage of the ability of the maximum entropy and wavelet analysis methods to estimate very low frequency fluctuations from relatively brief time series. For example, we can estimate the relative strength of a 50 year period signal in a record length of about 75 years. We are also using the STL (Seasonal Trend Loess) method to determine changes in the amplitude and/or phasing of the seasonal signal in these environmental records. Recently available global wind data are being analyzed using complex empirical orthogonal function (CEOF) analysis to determine wind stress patterns over the North Pacific and Bering Sea and to compare them to the historical “point” measurements from buoys. Interactions with principal investigators of other disciplines are important to understand the relationships between the physical environment and biology (primary and secondary production and higher trophic levels including mammals and birds).

### Research accomplishments/highlights/findings

- Coastal air temperature seasonalities for South Coast and Southeast Alaska have differed since 1980.

The annual air temperature cycles for Southeast and South Coast Alaska have been calculated using STL for the period 1935 to 2003 (Fig. 1). After the very cold winter of 1971 and subsequent winter warming, the annual cycle has been very different. In Southeast Alaska a 25-year cycle in the winter minimum temperatures is apparent while the maximum summer temperatures remain nearly unchanged. In South Coast Alaska the minimum winter temperatures were nearly constant from about 1980 to the present with a small oscillation in maximum summer temperatures. This suggests a different climate in these two coastal regions from about 1980 to the present.

- Since November 1997, storminess in the western Gulf of Alaska has increased from 4.4 incidents per month to 6.3 incidents.

Using data from buoy 46001 (56.9N, 148.2W) in the Gulf of Alaska, the occurrence of low pressure spikes in the daily average sea level pressure, indicating storm passage, were found for four periods: December 1974–July 1978, March 1979–December 1990, June 1994–June 1996, November 1997–December 2001 (Fig. 2). In the first three periods the average number of low pressure days per month was 4.4 and the variance was 16.1 while in the last period the average was 6.3 and the variance was 26.8. It appears that, since late 1997, the incidence of storms has increased. This may have an impact on mixed layer depth and entrainment of nutrients.

- Complex Empirical Orthogonal function analysis of satellite winds over the Northeast Pacific will allow detailed descriptions and analyses of mesoscale wind fields.

Using scatterometer data from ERS-2 and QuikSCAT, complex empirical orthogonal functions of the weekly mean wind field for the North Pacific (40N–61N, 170W–120W) have been computed.

### NOAA relevance/societal benefits

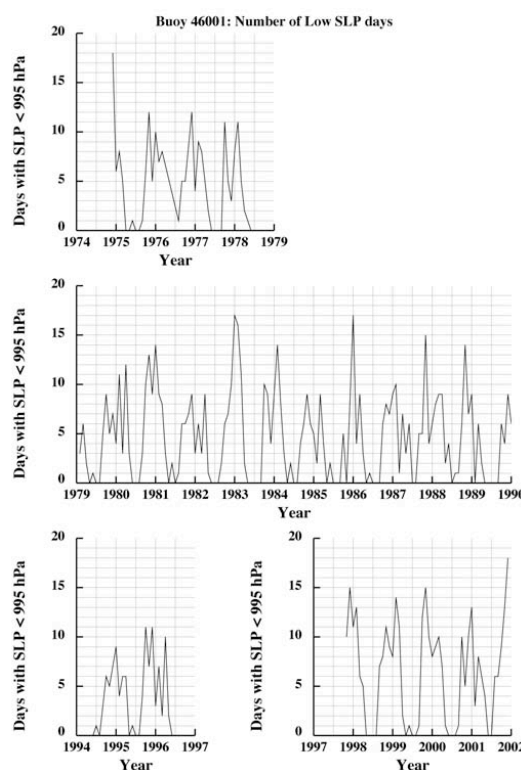
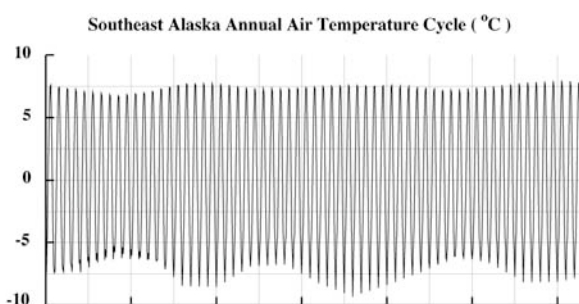
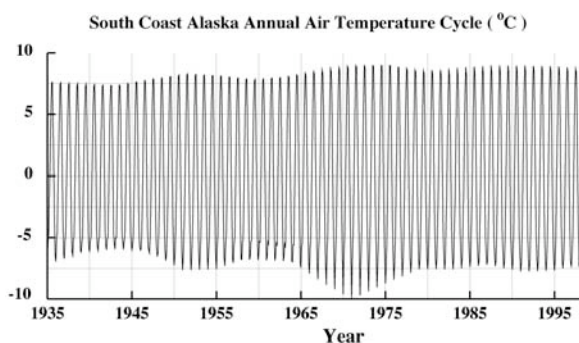
The Gulf of Alaska and Bering Sea are two of the most productive ecosystems in the United States and contain a majority of U.S. fisheries. A better understanding of the decadal changes in this ecosystem will help us to understand and manage these important marine resources.

### Research linkages/partnerships/collaborators and networking

The PIs are also working on other related research programs in this region including Northeast Pacific GLOBEC (NOAA/NSF funding) and the Arctic-Yukon-Kuskokwim Sustained Salmon Initiative (AYK SSI). They will continue to study the impact of glacial ablation on ocean circulation in the Northeast Pacific.

### Education/outreach

Isaac Schroeder, a PhD candidate at Old Dominion University, is supported full time on this grant.



## **Publications**

Royer, T.C. Hydrographic responses of the coastal Gulf of Alaska to seasonal and interannual forcing. Under review to *Deep Sea Research*.

Schroeder, I., C.E. Grosch and T.C. Royer. NCEP-NCAR reanalysis: Comparison with observations from the Coast of Alaska and the Gulf of Alaska. In preparation for submission to *Journal of Climate*.

Trites/Miller et al. Bottom-up forcing and the decline of Steller sea lions in Alaska: Assessing the ocean climate hypothesis. In preparation for submission to *Fisheries Oceanography*.

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## **Investigation of the Foraging Behavior of Steller Sea Lions in the Vicinity of Kodiak Island, Alaska**

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**Richard E. Thorne, PI**

**NOAA Goal 1**

Prince William Sound Science Center, Cordova, AK

Other investigators/professionals funded by this project:

**Gary L. Thomas, Prince William Sound Science Center**

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This project was completed during the reporting period.

### **Primary objectives**

The overall objective of this two-year project was to transfer the methodology used in Prince William Sound for study of herring/Steller sea lion relationships to the Kodiak region. Specific objectives included determination of the abundance and distribution of over-wintering herring schools around Kodiak Island and assessment of Steller sea lion foraging activity on these schools, including coverage throughout the extended Alaskan winter.

### **Approach/methodology**

The techniques that were developed in Prince William Sound include a combination of acoustic-net sampling, infrared scanners and aerial surveys. Acoustic technology is used to locate and measure the biomass of over-wintering herring schools. Net sampling, typically using purse seines, provides biological information on the fish. Infrared scanning technology is 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" (12° by 6° 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 video cameras with infrared emitters.

### **Research accomplishments/highlights/findings**

- Six cruises were completed, three each year. Seasonal coverage ranged from November through March.
- The major overwintering area identified for herring was Uganik Bay. Biomass estimates for this area ranged up to 18,000 metric tons.
- Steller sea lions were observed in small foraging groups, large rafting groups and haulout groups in previously undocumented areas of Uganik Bay, and were adjacent to the large concentrations of herring. Sea lion abundance was variable, but at times exceeded 300 animals.
- Substantial differences were observed between the east and west sides of Kodiak. Pollock were observed in nearshore habitat on the east side, a habitat type typically occupied by herring during winter, and both herring and Steller sea lions were less abundant in surveyed areas on the east side.
- The infrared scanner was able to detect Steller sea lions at distances over one mile. Underwater video cameras were found to be very effective for fish species identification, reducing reliance on expensive direct capture techniques.
- The transfer of technology to Kodiak was successfully completed. ADF&G has continued the study beyond the scope of the CIFAR project, and additional studies are funded for 2005 and 2006.



### **NOAA relevance/societal benefits**

Recent evidence indicates that herring are a very important prey for Steller sea lions, including the endangered western stock. The successful transfer of monitoring techniques to Kodiak will allow long-term evaluation of the herring stocks around Kodiak.

### **Research linkages/partnerships/collaborators and networking**

This was a cooperative effort between the Prince William Sound Science Center and the Kodiak office of the Alaska Department of Fish and Game. ADF&G has continued the study beyond the scope of the CIFAR project, and additional studies are funded for 2005 and 2006. The observations in this program also provided groundtruth information for a LIDAR survey effort led by James Churnside (NOAA Environmental Technology Laboratory, Boulder, CO).

### **Education/outreach**

Elements of the project were incorporated into the educational outreach program of the Prince William Sound Science Center for both K12 and public, including the Cordova High School presentation in the Alaska regional tournament for the National Ocean Science Bowl (4<sup>th</sup> place finish for effects of oil on herring).

### **Publications and presentations**

Thorne, R.E., G.L. Thomas and M. Foster. 2003. Application of combined optical and acoustic technologies for fisheries and marine mammal research in Prince William Sound and Kodiak, Alaska. Proceedings Ocean 2003 MTS/IEEE, Holland Publications, Escondido, CA.  
Thorne, R.E. Acoustic surveying of pelagic fish in shallow water. Proceedings IGARSS04. IEEE Publications, Escondido, CA., 4 p. In press.  
Thorne, R.E. and G.L. Thomas. Pacific herring as forage: Fisheries and conservation in conflict. Fourth World Fisheries Congress. In peer review.

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## **Predator/Prey Investigations of Killer Whales and Steller Sea Lions in Alaska**

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**Andrew W. Trites, PI**

**NOAA Goal 1**

*North Pacific Marine Science Foundation, Seattle, WA;*

*North Pacific Universities Marine Mammal Research Consortium, Vancouver, BC*

Other investigators/professionals funded by this project:

**Craig O. Matkin, North Gulf Oceanic Society**

**Dena Matkin, National Park Service**

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This project was completed during the reporting period.

### **Primary objectives**

Our primary objectives were to collect data on killer whale populations in Alaska needed to refine estimates of the effect of killer whale predation on Steller sea lions by (1) using mariner surveys to determine killer whale distribution and "hotspots," (2) initiating a photo-census of killer whales in the Kodiak and eastern Aleutian region and continuing this work in southeastern Alaska, and (3) initiating genetic/acoustic studies, and collection of data on predation to estimate the impact of killer whale on Steller sea lions in both western Alaska and southeastern Alaska.

### **Approach/methodology**

- The Alaska Killer Whale Count was conducted for 3 days in July (19–21, 2002) and for 7 days in March (1–7, 2003). Dates were chosen to coincide with favorable weather conditions and commercial fishing timelines. Surveys were distributed via the Internet, harbor master offices, fishing associations; and promoted through the media.
- The field work by trained killer whale specialists relied on placing small, low cost vessels in areas of possible killer whale abundance in Kodiak, the eastern Aleutians, and southeast Alaska. Methods employed were based on those developed over the past 25 years during our work in British Columbia, Canada and Prince William Sound/Kenai Fjords, Alaska. The study relied on (1) photo-identification of individual animals for census, (2) acquisition of skin biopsies for genetic analysis of population structure, (3) acquisition and acoustic analysis of underwater recordings, and (4) direct observations of killer whale foraging behavior and predation. We did

not rely on transect methodology, but in all years and in all areas, searches for killer whales were based on current and historical sighting information, and use of directional hydrophones and VHF radio reports to locate whales.

### ***Research accomplishments/highlights/findings***

- Distributions of reported whale sightings through the Alaska Killer Whale Count survey were similar in summer and winter, and did not reveal any new sites of killer whale concentrations previously unknown to killer whale biologists between Southeast Alaska and the Eastern Aleutians. Unfortunately, no vessels participated in the central and western Aleutians—due perhaps to the low number in those regions.
- The site specific studies carried out by killer whale specialists revealed that resident and transient ecotypes (fish eaters and mammal eaters) of killer whales are genetically and acoustically identifiable in western Alaska
- In southeast Alaska most encounters were with transient (marine mammal eating) killer whales while most encounters in western Alaska were with resident killer whales (except during the grey whale migration). Despite this, Steller sea lions are stable or increasing in southeast Alaska, yet declining in western Alaska.
- Thus far, Steller sea lions do not appear to be a primary prey item in either region during the study months, however, data from western Alaska is very limited.
- Additional study will be necessary to delineate the ecological role of the two killer whale ecotypes and assess their impact on Steller sea lions.

### ***NOAA relevance/societal benefits***

This study provided information about killer whales in Alaska needed to assess the role that killer whales may be playing in the decline of Steller sea lions in western Alaska.

### ***Research linkages/partnerships/collaborators and networking***

The study combined the expertise of 7 researchers working at 6 different agencies/institutions and organizations, and has set the foundation for continued collaborations and further study of killer whales in Alaska. Collaborators were: Craig O. Matkin, M.Sc., North Gulf Oceanic Society, Homer, AK; Lance Barrett-Lennard, Ph.D., University of British Columbia; Graeme Ellis, Department of Fisheries and Oceans, Nanaimo, BC; John Ford, Ph.D., Vancouver Aquarium Marine Science Centre, Vancouver BC; Jan Straley, University of Alaska Southeast; Dena Matkin, National Park Service, Gustavus, AK.

### ***Education/outreach***

The data collected on killer whales has been presented at conferences and public lectures. Additional awareness was achieved through newspaper articles and radio interviews.

### ***Publications***

The data collected have not yet been published, and will form the basis for future publications.

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# **Project Reports: Research Themes**

**Atmospheric and Climate Research**  
**Climate Modeling**  
**Contaminant Effects**  
**Fisheries Oceanography**  
**Hydrographic and Sea Ice Studies**  
**Marine Ecosystem Studies**  
**Tsunami Research**  
**UV and Arctic Haze Studies**



## ***Atmospheric and Climate Research***

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### **Correction of Systematic Errors in TOVS Radiances**

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**Jennifer Francis, PI**  
*Rutgers University*

**NOAA Goal 2, (3)**

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This project is ongoing.

#### ***Primary objectives***

In this collaborative project, we will attempt to identify, quantify, and mitigate errors in radiances measured by the Television Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS). These errors result from changes to satellite orbits, instruments, and/or calibration method. We expect to produce a 22-year (or more) record of TOVS radiances and retrieved products that are as error-free as is practicable, given available resources. Many of the known errors should be regionally and seasonally independent, but we suspect that some may be peculiar to or exacerbated by Arctic conditions. Thus while our efforts will be global, our focus will be primarily Arctic. The expected product of this investigation will be a data set of tremendous value both for geophysical retrievals with sufficient accuracy to identify changes since 1979, as well as for direct assimilation by numerical atmospheric models.

#### ***Approach/methodology***

Our approach to removing systematic errors from the TOVS radiances will take several parallel avenues, to be undertaken collaboratively by personnel at NOAA/NESDIS, University of Washington and Rutgers University. We have begun by extracting as much applicable information as possible from existing work. Our first few months have been focused on assessing the status of existing Arctic radiosonde data sets in the NOAA archive and searching for data sets that were not ingested into the GTS operational weather system. Through personal inquiries, Internet searches, and an Internet list-server request for data via the ArcticInfo network, we have been able to identify and obtain thousands of additional arctic radiosondes that were not part of the standard archive. Already the interest level by the community has been high for the eventual compilation of these data.

#### ***Research accomplishments/highlights/findings***

Funds were not received by Rutgers University until December 2003 so our progress has been limited during this reporting period. However, there have been a number of achievements by each institution involved; those for Rutgers are listed here.

- Searched archives at the National Snow and Ice Data Center, Atmospheric Radiation Measurement Program, and other sources identified on the Internet for Arctic radiosondes not included in the GTS data set. Several sources of field data were found.
- Broadcast request for Arctic radiosonde data on the ArcticInfo listserver that is maintained by the Arctic Research Consortium of the United States (ARCUS). Approximately 30 responses were received and several new data sets were identified and obtained.
- Radiosondes from new data sources compiled and sent to T. Reale at NOAA/NESDIS on CDROM. New data sets are still arriving.

#### ***NOAA relevance/societal benefits***

TOVS data can be used both for weather forecasting and climate applications, both of high priority to NOAA.

#### ***Research linkages/partnerships/collaborators and networking***

Co-P.I.s on the overall SEARCH project are Tony Reale, NOAA/NESDIS; Axel Schweiger, University of Washington.

### Initiation of Arctic Reanalysis Activity in SEARCH

**David Bromwich, PI**  
Ohio State University

**NOAA Goal 2, (3)**

Other investigators/professionals funded by this project:  
**Keith Hines and Lesheng Bai, Ohio State University**

This project is ongoing.

#### **Primary objectives**

The project's two main objectives are (1) the adaptation of the Weather Research and Forecasting (WRF) model for use in the Arctic, and (2) an assessment of the performance of the ERA-40 reanalysis in the Arctic. Both objectives pertain to the design of an Arctic System Reanalysis (ASY), which will be performed for a period of at least several decades and will draw upon all available data for the Arctic atmosphere, sea ice, land surface and upper ocean.

#### **Approach/methodology**

Toward objective (1), WRF is currently being evaluated with high-resolution mesoscale simulations over Greenland and vicinity. We are employing a 110x100 grid with 40 km horizontal resolution and 28 levels in the vertical. The domain includes much of the North Atlantic region north of 45°N. Previous work comparing MM5 with in-situ observations has shown that the Greenland domain represents an ideal opportunity to test and improve the physical parameterizations for mesoscale polar simulations (Bromwich et al., 2001, *Mon. Wea. Rev.*, 129, 2290–2309). The model is tested for winter Greenland conditions in simulations for the first half of December 2002. Diffusion and boundary layer physics are based upon parameterizations adapted from the National Centers for Environmental Prediction (NCEP) ETA model. The NCEP Aviation Model (AVN) output is used for initial and boundary conditions. A series of 2-day simulations are performed starting each day at 0000 UTC during the test period, following previous studies.

Toward objective (2), the Polar Meteorology Group has also been examining the Arctic atmospheric circulation diagnosed by ERA-40. Previous research has revealed some significant differences between reanalysis winds from ERA-15 and NCEP-NCAR and those measured by independent rawinsonde observations (CEAREX) from the Atlantic Arctic (e.g., Francis, 2002, *GRL*, 29(9), 1–4). This comparison has been re-evaluated and extended to ERA-40.

#### **Research accomplishments/highlights/findings**

- Synoptic-scale variations over the Greenland domain are well captured by WRF.
- Biases in the WRF simulations of the Greenland domain include boundary layer temperatures that are too warm and boundary layer wind speeds that are underestimated relative to *in situ* measurements.
- Improvements of the horizontal pressure gradient force for the non-hydrostatic mesoscale simulations are nearly complete.
- ERA-40 captures the day-to-day wind variability much better than NCEP/NCAR, when compared with rawinsonde measurements.
- ERA-40's winds are on average too westerly and too northerly relative to CEAREX winds, especially in the middle and upper troposphere. However, the fact that CEAREX winds lack the vertical shear found in surrounding rawinsonde profiles suggests that the reanalysis-derived winds may be more correct than the CEAREX winds.

#### **NOAA relevance/societal benefits**

The effort will lead to a regional atmospheric model optimized for use in the Arctic. When combined with data assimilation strategies developed by other ASR (Arctic System Reanalysis) projects, the payoff will be a vehicle for the Arctic regional reanalysis that has been established as a high priority in SEARCH. The ASR will be a high-resolution regional prototype that complements the global reanalyses carried out by NCEP.

#### **Research linkages/partnerships/collaborators and networking**

The NOAA funding of the Arctic system reanalysis supports the following investigators, with whom we are actively collaborating (*see also the project report by J. Walsh*):

J. Tilley, University of North Dakota  
M. Serreze, CIRES/University of Colorado  
J. Walsh and X. Fan, University of Alaska/Fairbanks

### **Education/outreach**

The enhanced WRF model will be made available for general use. The Antarctic version of this model is currently used for operational forecasting in support of logistical operations in Antarctica.

### **Publications**

None resulting directly from this support. Extended abstract submissions to the AMS Conference on Polar Meteorology and Oceanography are in preparation.

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## **Initiation of an Arctic Reanalysis Activity in SEARCH**

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**John E. Walsh, PI**  
*University of Alaska Fairbanks*

**NOAA Goal 2, (3)**

Other investigators/professionals funded by this project:

**Mark Serreze, CIRES/University of Colorado at Boulder**  
**Jeff Tilley, University of North Dakota**  
**Xingang Fan, University of Alaska Fairbanks**

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This project is ongoing.

### **Primary objectives**

The project's main objectives are (1) the adaptation of the Weather Research and Forecasting (WRF) model for use in the Arctic, (2) an assessment of the performance of the ERA-40 reanalysis in the Arctic, and (3) tests of data assimilation strategies for Arctic regional models. These three objectives pertain to the design of an Arctic System Reanalysis (ASR), a NOAA initiative for SEARCH (Study of Environmental Arctic Change). The ASR is intended to integrate all available observations into a consistent framework, providing a vehicle for monitoring and diagnosing changes in the Arctic atmosphere, sea ice, upper ocean and terrestrial components.

### **Approach/methodology**

Toward the objectives listed above, the Ohio State group is testing Polar-MM5 over a Greenland domain and experimenting with parameterizations of Arctic processes; emphases include topographically-affected flows in the Arctic, ice-ocean surface fluxes, Arctic stratus, etc. Particular attention has been given to precipitation and winds over Greenland. (See report by PI Bromwich, above.)

The Arctic output of global reanalyses (ERA-40, NCAR/NCEP) is being validated against observational data by the Colorado and UAF groups. Attention is being given to precipitation, clouds and radiative fluxes, and upper-air winds. The effects of assimilation of TOVS data over sea ice are receiving particular emphasis because the assimilated profiles impact the upper-air winds, thermal structure and cloud distribution. The radiative fluxes and cloud-radiative fluxes in ERA-40 are being compared with in situ measurements.

Three-dimensional variational (3DVAR) data assimilation methodologies are being explored with the MM5 model in conjunction with experiments addressing sensitivity to resolution. The experiments include assimilation of various combinations of observation types, and are being performed on domains of different sizes. The experiments with different nudging and blending strategies are being performed for typical synoptic regimes and for extreme events affecting the Arctic in different seasons the past several years. This task involves the North Dakota and UAF groups.

### **Research accomplishments/highlights/findings**

- Synoptic-scale variations over the Greenland domain, including precipitation over Iceland and katabatic winds over Greenland, are well captured by WRF.
- Biases in the WRF simulations of the Greenland domain include boundary layer temperatures that are too warm and boundary layer wind speeds that are underestimated relative to *in situ* measurements.

- ERA-40 captures the day-to-day wind variability much better than NCEP/NCAR, when compared with rawinsonde measurements. ERA-40's winds are on average more westerly and northerly relative to CEAREX winds, especially in the middle and upper troposphere, pointing to biases in CEAREX winds.
- TOVS data have a major impact on global reanalyses (ERA-40) in the Arctic, affecting 500 mb heights by 40–50 meters.
- ERA-40's temperature and precipitation fields over central Arctic are problematic, especially during summer.
- Fields of Arctic cloudiness, radiative fluxes and cloud-radiative forcing are improved in ERA-40 relative to ERA-15 and NCEP/NCAR. A possible discrepancy with *in situ* measurements is the abruptness of the seasonal transition between positive and negative cloud radiative forcing in ERA-40.
- The accuracy of regional reanalysis (by MM5) has been found to depend more strongly on resolution than on choice of data assimilation scheme.

### **NOAA relevance/societal benefits**

The Arctic System Reanalysis (ASR) will permit the integration of all available observations into a consistent framework, providing a vehicle for monitoring and diagnosing environmental change in the Arctic. The ASR will be a high-resolution regional prototype that complements the global reanalyses carried out by NCEP.

### **Research linkages/partnerships/collaborators and networking**

In addition to the investigators supported by this award, NOAA funding of the Arctic system reanalysis also supports David Bromwich, Ohio State University (see previous project report).

The results of the collective effort were recently reported at the U.S./Sino Workshop on Arctic Climate, held in Beijing (July 27–28, 2004).

### **Education/outreach**

The enhanced WRF model will be made available for general use. The Antarctic version of this model is currently used for operational forecasting in support of logistical operations in Antarctica.

### **Publications**

Fan, X., J.S. Tilley and J.E. Walsh. Application of 3D variational assimilation at high latitudes: Resolution sensitivity. Submitted July 2004 to *Geophysical Research Letters*.

Serreze, M.C., A. Barrett and F. Lo. Northern high latitude precipitation as depicted by atmospheric reanalyses and satellite retrievals. *Monthly Weather Review*, in press.

## **Contaminant Effects**

### **Sources of Mercury Reaching the Arctic – Airborne Particulate Mercury in China**

**Catherine F. Cahill, PI**  
University of Alaska Fairbanks

**NOAA Goal (2)**

This project is ongoing.

### **Primary objectives**

The primary objectives of this project are 1) to determine the quantity of mercury in atmospheric aerosols originating in China that is reaching the Arctic and 2) to establish a collaborative working relationship with Chinese scientists.

### **Approach/methodology**

The scientific approach used to reach the goals of this project is to collect and analyze size- and time-resolved aerosol samples from China and the Arctic for their chemical, including mercury, composition. A 3-stage DRUM aerosol impactor collects the aerosol samples which are then analyzed for mass by  $\beta$ -gauge, optical absorption by Ultra-Violet/visible spectroscopy, organic content by proton elastic scattering analysis and selected elements from sodium through uranium by synchrotron x-ray fluorescence. The Chinese research vessel, the Xuelong, collected the aerosol samples during the Second Chinese National Arctic Research Expedition (CHINARE II) and the 19<sup>th</sup> Chinese Antarctic Research Expedition (CHINARE 19). The second goal, establishing collaborative working relationships with Chinese scientists, involved identifying and working with the Chinese scientists best able to

collaborate with the U.S. Principal Investigator (PI). Identifying the best scientists in China for the collaborative aspects of this work occurred during NOAA-sponsored meetings in China. Scientists identified during these meetings are now jointly conducting the research described above.

### **Research accomplishments/highlights/findings**

- The aerosols over the Bering and Chukchi Seas during CHINARE II, conducted during summer 2003, do not appear to have a significant contribution from Chinese anthropogenic aerosols.
- The aerosols leaving the Asian continent near Chinese industrial regions have high concentrations of many anthropogenic aerosols indicative of coal fired power plants and industrial factories.
- The anthropogenic aerosols concentrations decrease as the distance south from China increases (see Figure 1).
- The PI has developed a good collaborative relationship with Chinese scientists from the Chinese Arctic and Antarctic Administration, the Polar Research Institute of China and the Third Institute of Oceanography.

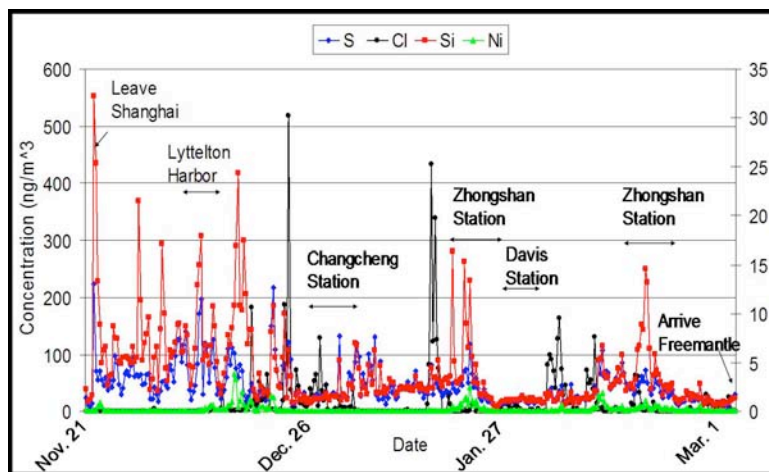


Figure 1. Selected Elements for CHINARE 19 (0.34-1.15  $\mu\text{m}$  in aerodynamic diameter. Si and Ni plotted on secondary axis.).

### **NOAA relevance/societal benefits**

This research advances NOAA's goals of understanding the sources of aerosols, particularly mercury, impacting the peoples and ecosystems of the Arctic. It also fulfills the NOAA goals outlined by the U.S.–China Polar Science Panel by developing working relationships with Chinese scientists conducting Arctic research.

### **Research linkages/partnerships/collaborators and networking**

This project was successful in developing relationships between the PI and scientists from the Chinese Arctic and Antarctic Administration, the Polar Research Institute of China and the Third Institute of Oceanography. These relationships have led to funding from outside sources and will lead to additional joint research between the participants.

### **Education/outreach**

Results from this research have been presented in China at the Sino–U.S. Joint Arctic Climate Workshop, in a National Science Foundation lecture in Fairbanks, Alaska, and in a National Science Foundation Research Experiences for Undergraduates seminar at the University of Alaska Fairbanks.

### **Publications**

No publications have been submitted yet. In preparation is a paper to the Journal of Geophysical Research on the transport of aerosols, especially mercury, to the Arctic from China. The results of this research will also be presented at the American Meteorological Society meeting in San Diego, California, in January 2005. This conference presentation will result in a published extended abstract.

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## Persistent Organic and Trace Element Pollutants in the Alaskan and Eastern Russian Arctic

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**Greg Patton, PI**  
Battelle Pacific Northwest Division

**NOAA Goal (2)**

**Catherine F. Cahill, PI**  
University of Alaska Fairbanks

Other investigators/professionals funded by this project:

**L. Barrie, World Meteorological Organization**

**E. Crecelius, Battelle Marine Sciences Laboratory**

**P. Fellin, AirZone One, Inc.**

**G. Stern, Freshwater Institute of Canada**

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This project is ongoing.

### **Primary 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* funded by NOAA's Arctic Research Initiative and the U.S. State Department's Environmental Diplomacy Fund for the U.S./Russian Atmospheric Contaminants Program. The scientific objectives of the project are: (i) gain insight into the sources, occurrences, and environmental fates of persistent organic (e.g., chlorinated herbicides, pesticides, and industrial chemicals) pollutants (POPs) and aerosol trace elements in the atmosphere of the Alaskan Arctic and eastern Russian Arctic, (ii) contrast the occurrence of POPs and trace elements in this region with other Arctic air sheds and (iii) provide data in a form compatible with existing data from the international Arctic Monitoring and Assessment Program (AMAP) to be used in assessing the potential risks to the environment and human inhabitants in the Arctic.

### **Approach/methodology**

For one year the atmospheric concentrations of 90 polychlorinated biphenyl compounds, 40 organochlorine pesticides/herbicides or their metabolites, 14 polycyclic aromatic hydrocarbons (PAH), and trace metals were measured at the NOAA baseline air chemistry laboratory in Barrow, Alaska. Suspended particles and gases were 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 the air masses sampled. Three stages of activity were planned: (i) preparation of collection site, development of the measurement methodology, and training sample collection personnel (ii) a one-year measurement period and (iii) data analysis, interpretation and reporting.

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 AMAP (international) and the Northern Contaminants Program (Canadian). It also standardizes protocols of sampling, analysis, and data archiving.

### **Research accomplishments/highlights/findings**

- Established an air monitoring station at the NOAA baseline air monitoring station at Barrow, Alaska.
- Trained NOAA staff at Barrow, Alaska on the sampling methodology.
- Conducted air monitoring for POPs and metals from March 2002 to April 2003.
- Issued a preliminary data report in May 2003.
- Completed final analytical processing in June 2004.
- Completed data base entry and verification for POPs data on July 2004.
- Submitted an abstract on the POPs air monitoring project to *Society of Environmental Toxicology and Chemistry, Fourth World Congress* in Portland, Oregon in November 2004.

### **NOAA relevance/societal benefits**

Additional work is needed to improve our understanding of the complex process of long range contaminant transport to the Arctic. Continuing scientific issues include: documenting contaminant sources, source apportionment,



atmospheric transport and depositional processes, seasonal trends for transport processes, the role of meteorology/climate on transport processes, and long-term trends in environmental levels. Results from this study will be useful for modeling contaminant flux into the Arctic and estimating ecological and human risks from the contaminants.

### **Research linkages/partnerships/collaborators and networking**

The project has developed a number of key research linkages. This work has allowed NOAA to establish an air monitoring station at Barrow, Alaska that generated directly comparable data to the existing Northern Contaminants Program network in Canada and the international Arctic Monitoring and Assessment Program. This was accomplished by cooperative interactions between the University of Alaska, Fairbanks; Battelle Pacific Northwest Division; Freshwater Institute of Canada; AirZoneOne, Inc.; Environment Canada; and NOAA/CMDL.

### **Education/outreach**

The preliminary results for POPs air monitoring at Barrow, Alaska were presented by Dr. Patton as a lecture for a combined undergraduate/graduate (CHEM 481/581 Environmental Chemistry) course at Washington State University–TriCities, Richland, Washington.

### **Publications**

- A preliminary report on the initial sampling results was produced May 2003.
- Data will be available as part of the Northern Contaminants Program database.
- An abstract for a presentation titled *Persistent Organic Pollutants in Ambient Air at Barrow, Alaska* was submitted to the Society of Environmental Toxicology and Chemistry (SETAC) 4<sup>th</sup> World Conference, November 14–18, 2004 to be held in Portland, Oregon.

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## **Arctic Monitoring and Assessment Programme (AMAP)**

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**Lars-Otto Reiersen, PI**  
*Executive Secretary, AMAP*

**NOAA Goal 2, 1**

This project is ongoing.

The support to the AMAP project has been spent on 6 sub-projects. The following is a status on these 6 sub-projects.

### **1. Analysing and modelling of new mercury data and support to an intensive field project on mercury at Barrow, Alaska.**

#### **Primary objectives**

To study the “Sunrise phenomena” in more detail to understand the mechanisms and the size of the phenomena.

#### **Approach/methodology**

Different methods have been used to study the washout of mercury from the atmosphere and its relation to changes in ozone, UV and climate.

#### **Research accomplishments/highlights/findings**

The workshop was held during winter/spring of 2004 at Barrow. Scientists from several Arctic countries participated, e.g., Canada, Denmark, Norway and USA. The data are being analysed and will be reported when ready.

#### **NOAA relevance/societal benefits**

The study should be of great importance for NOAA and work related to atmospheric processes linked to climate change, UV/ozone and pollution.

### **Research linkages/partnerships/collaborators and networking**

Scientists from National Atmospheric Research Institutes in Canada, Denmark, Norway, Russia and USA are working closely on the issue of concern.

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## **2. Arctic Council joint assessment on Oil and Gas, to be presented in 2006.**

### ***Primary objectives***

To assess the situation related to oil and gas activities within the Arctic region, including ongoing and future plans for activities, the effects these activities might have on social life and the economy within the region, and the pollution situation and future threats.

### ***Approach/methodology***

Expert groups have been established for each of the main topics. Different assessment methods will be applied by scientists and experts from the eight Arctic countries. The work will to a far extent be based on existing data.

### ***Research accomplishments/highlights/findings***

An international workshop was held in Washington, DC in January 2004. The next workshop will be arranged in Oslo in September 2004. A baseline survey to document the levels of hydrocarbons in the Arctic and Adjacent Seas has been initiated.

### ***NOAA relevance/societal benefits***

This project should be of great interest for NOAA and the work with pollution of the marine environment.

### ***Research linkages/partnerships/collaborators and networking***

Links have been established to scientists and research institutes in the eight Arctic countries.

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## **3. AMAP assessment on acidification and effects of acidifying substances, to be presented in 2006.**

### ***Primary objectives***

To assess the situation related to acidification of Arctic areas, to document any trends and effects at hot spot sites and circumpolar.

### ***Approach/methodology***

Expert groups have been established for each of the main topics. Different assessment methods will be applied by scientists and experts from the eight Arctic countries. The work will to a far extent be based on existing data.

### ***Research accomplishments/highlights/findings***

The assessment work has been initiated. An international workshop was held in Helsinki, January 2004.

### ***NOAA relevance/societal benefits***

This project should be of great interest for NOAA's work with atmospheric pollution.

### ***Research linkages/partnerships/collaborators and networking***

Links have been established to scientists and research institutes in the eight Arctic countries.

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## **4. Production of the ACIA reports.**

### ***Primary objectives***

The primary objective of ACIA (Arctic Climate Impact Assessment) is to assess changes in climate and UV/ozone and its effects on Arctic environment and human life.

### ***Approach/methodology***

Expert groups have been working with the main topics over the last 2–3 years. Different assessment methods have been applied by scientists and experts from the eight Arctic countries. Based on selected scenarios from IPCC models have been used as a core part of the assessment work. The work has been based on existing data.

**Research accomplishments/highlights/findings**

The assessment work has been completed, final editing is ongoing and the ACIA reports will be handed over to the printing company in October. A close cooperation has been established among scientists in the eight Arctic countries and some countries that are involved in Arctic climate and UV research. There will be several additional publications in international journals over the years to come.

**NOAA relevance/societal benefits**

This project should be of great interest for NOAA and its work related to climate and ozone/UV.

**Research linkages/partnerships/collaborators and networking**

Links have been established to scientists and research institutes in the eight Arctic countries.

**Education/Outreach**

The reports should be very useful as textbooks at schools and Universities. A special film/video is under preparation.

**Publications**

The ACIA reports are in the final stages of preparation.

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**5. The 2004 ACIA climate and UV conference.****Primary objectives**

To present the results from the ACIA assessment and the latest results related to changes in Arctic climate and ozone/UV from ongoing research and monitoring.

**Approach/methodology**

Standard procedure to call for an International conference has been followed.

**Research accomplishments/highlights/findings**

The ACIA Symposium has been arranged for November 9–12, 2004 in Reykjavik, Iceland. A scientific programme has been prepared based on received abstracts and the ACIA work.

**NOAA relevance/societal benefits**

The Symposium should be of interest for NOAA, the latest results from research and monitoring will be presented and discussed.

**Research linkages/partnerships/collaborators and networking**

Not relevant for the practical arrangement of the symposium.

**Education/Outreach**

Special grants for young investigators have been arranged.

**Publications**

A special Proceeding for all extended abstracts is under preparation.

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**6. ICES symposium in Bergen.****Primary objectives**

To bring forward the latest results from research and monitoring related to the issue of concern.

**Approach/methodology**

Standard procedure to call for an International conference has been followed.

**Research accomplishments/highlights/findings**

The symposium “Influence of Climate Change on North Atlantic Fish Stocks” was arranged, May 11–14, 2004 in Bergen, Norway.

**NOAA relevance/societal benefits**

The Symposium should be of interest for NOAA, and its work with marine systems and climate change.

**Research linkages/partnerships/collaborators and networking**

Not relevant for the practical arrangement of the symposium.

**Publications**

A special Proceeding for all presentations is under preparation.

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**Fisheries Oceanography**

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

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**Milo Adkison, PI**  
University of Alaska Fairbanks

**NOAA Goal 1**

This project is ongoing.

**Primary objectives**

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. As a bonus, we contemplate making comparisons among growth and survival rates of female, male jack, and male hooknose fish to examine the costs and benefits of alternative life history choices.

**Approach/methodology**

*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.

*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.

*Life history tradeoffs.* Results to date were based on digitized images of juvenile coho captured in nearshore marine waters, and on scales of adult female coho returning to Auke Creek. In the next stage of the project, we will incorporate two additional data sets: (1) scale growth increments from adult males, both jacks (one summer at sea) and hooknose (one year plus a summer at sea), and (2) the sex ratio and characteristics of smolts emigrating from freshwater to saltwater. The literature provides both theoretical and empirical bases for expecting differences in growth and survival between the sexes (Holtby and Healey 1990) and between males employing the jack and hooknose reproductive strategies (Gross 1985, 1991; Young 1999). These new data will allow us to examine these differences in the Auke Creek stock and their implications for the interaction of coho salmon and the marine environment.

**Research accomplishments/highlights/findings**

- Size at return appears to be set during the latter, open-ocean period of the life cycle.
- Growth during this period appears related to the Pacific Decadal Oscillation (Mantua et al. 1997), an index of temperature associated with climatic “regimes.”
- However, marine survival appears to be set earlier in the life cycle, based on several lines of evidence:
  - “hooknose” and “jack” male survival, which differ in habitat after the first few months in the marine environment, is strongly correlated.
  - survival of Auke Creek coho is correlated with survival of other SE Alaskan stocks, but not with stocks at longer distances, and
  - survival is correlated with the number of juvenile pink and chum salmon released from the DIPAC hatchery, a distinctly localized phenomenon.
- Early marine growth did not appear to be related to cohort survival.

- A manuscript describing patterns of survival is under review at a major fisheries journal. An additional manuscript describing growth patterns is in preparation.

### **NOAA relevance/societal benefits**

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 that have occurred recently in much of Alaska, as well as for conservation and maintenance of coho salmon populations when climatic conditions shift.

### **Research linkages/partnerships/collaborators and networking**

The principal linkages are between the University of Alaska Fairbanks and personnel at NOAA's Auke Bay Laboratory. Alex Wertheimer is most heavily involved, serving on the committees of the graduate student research assistants. Other associated NOAA personnel include Gerri Taylor, Joe Orsi, and William Heard. Wertheimer and Taylor are co-authors (along with Adkison and Briscoe) of the two journal manuscripts prepared to date.

### **Education/outreach**

Two graduate students are basing master's theses on this research project. The first, Ryan Briscoe, graduated last winter. The second, Josh Robins, will start his research this fall. Briscoe has presented his research results in local, statewide, and national scientific symposia.

### **Publications**

Briscoe, R.J., M.D. Adkison, A. Wertheimer and S.G. Taylor. Biophysical factors associated with the marine survival of Auke Creek, Alaska coho salmon. *In review*.

Briscoe, R.J., M.D. Adkison, A. Wertheimer and S.G. Taylor. Factors influencing marine growth of Auke Creek, Alaska coho salmon. *In preparation*.

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## **Early Marine Growth and Survival of Bristol Bay Sockeye Salmon Smolt**

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**Milo Adkison, PI**  
University of Alaska Fairbanks

**NOAA Goal 1**

This project is ongoing.

### **Primary objectives**

- To determine if Bristol Bay sockeye salmon production is influenced by early marine growth rates.
- To identify the relationship between environmental conditions and early marine growth of juvenile sockeye salmon in the eastern Bering Sea.

### **Approach/methodology**

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).

### **Research accomplishments/highlights/findings**

- Sea surface temperatures within the eastern Bering Sea can influence the width and extent of juvenile sockeye salmon distribution and migration rate.
- 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.
- There appears to be strong size-selective mortality in the ocean.

### **NOAA relevance/societal benefits**

These studies will increase our understanding of the mechanisms by which smolt growth as a function of nearshore processes affect sockeye 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 that have occurred recently in much of Alaska, as well as for conservation and maintenance of sockeye salmon populations when climatic conditions shift.

### **Research linkages/partnerships/collaborators and networking**

The principal linkages are between the University of Alaska Fairbanks and personnel at NOAA's Auke Bay Laboratory. Ed Farley, employed at the Auke Bay lab, is a graduate student leading this study. Steve Ignell and Jack Helle are also involved.

### **Education/outreach**

One graduate student, Ed Farley, is basing his Ph.D. on this research. Farley has presented his research results in local, statewide, and national scientific symposia.

### **Publications**

A manuscript describing the observed size-selective mortality in the ocean is in preparation.

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## **Origins of Juvenile Chum Salmon (*Oncorhynchus keta*) Collected During ABL-OCC Cruises in the Eastern Bering Sea**

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**A.J. Gharrett, PI**  
University of Alaska Fairbanks

**NOAA Goal 1**

This project is ongoing.

### **Primary objectives**

The primary objective of this study was to continue the work from 2002 and to determine the geographic origin of juvenile chum salmon collected in the eastern Bering Sea during fall 2003 ABL-OCC cruises. However, this objective changed due to the lack of discrimination by major river systems of western Alaska chum salmon using allozyme analysis. Further work on eastern Bering Sea chum salmon juveniles is on hold pending development of a DNA marker baseline. In the interim, work will focus on stock identification of immature chum salmon caught in the eastern Bering Sea which can be from Japan, Russia, Southeast Alaska, British Columbia, and the Pacific Northwest U.S. The allozyme baseline is sufficient to detect fish from these regions.

### **Approach/methodology**

Immature chum salmon (*Oncorhynchus keta*) were collected from the eastern Bering Sea 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 164 and 166° W and between latitudes 56 and 58° 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). The genetic variation of the collections will then be 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 will be made for each collection.

### Research accomplishments/highlights/findings

- The starch-gel electrophoretic analysis for 20 protein-coding loci has been completed for the entire 2002 immature chum salmon collection from the eastern Bering Sea.
- The data is currently being analyzed with the Bayesian mixture analysis program to determine area of origin.

### NOAA relevance/societal benefits

This work is part of a larger effort by NOAA and member countries of the North Pacific Anadromous Fish Commission called The Bering-Aleutian Salmon International Survey (BASIS) intended to improve our understanding of the physical and biological mechanisms that affect the distribution, migration, growth, and survival of salmon in the Bering Sea.

### Research linkages/partnerships/collaborators and networking

This work is being performed in collaboration with C. Kondzela, R. Wilmot and E. Farley, National Marine Fisheries Service, Auke Bay Biological Laboratory.

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## Population Structure in Alaskan Pacific Ocean Perch (*Sebastes alutus*)

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A.J. Gharrett, PI

University of Alaska Fairbanks

NOAA Goal 1

This project is ongoing.

### Primary objectives

The population structure of a species underlies the basis of its production and provides crucial information for its effective management and conservation. Genetic studies can provide information on population structure. The objective of this project is to characterize the population genetic structure of Pacific ocean perch (POP) in Alaskan waters of the Gulf of Alaska and Bering Sea, and to evaluate the structure in the context of geographic and oceanographic features and the life history of POP. Both mitochondrial and microsatellite markers will be used in the study.

### Approach/methodology

In the early stages of this study, we examined the mtDNA variation in POP and concluded that there was too little variation to warrant continuation of that work. Preliminary analyses of microsatellite variation, however, revealed genetic divergence among geographically distinct samples and encouraged us to continue the microsatellite analysis. We plan to use approximately ten microsatellite loci to quantify the variation within and among the Alaskan POP population. Samples have been obtained from a range of locations throughout Alaskan waters. Additional samples from areas around the Gulf of Alaska should be collected in summer 2005 to complete the range of Alaskan waters. Allele frequencies and distributions will be compared between and among populations to determine if genetic structure exists. These data should be able to characterize the genetic structure of POP in Alaskan waters. Additionally, the mitochondrial work performed on these samples will be linked with the microsatellite analysis. We plan to analyze more than one thousand fish in this study.

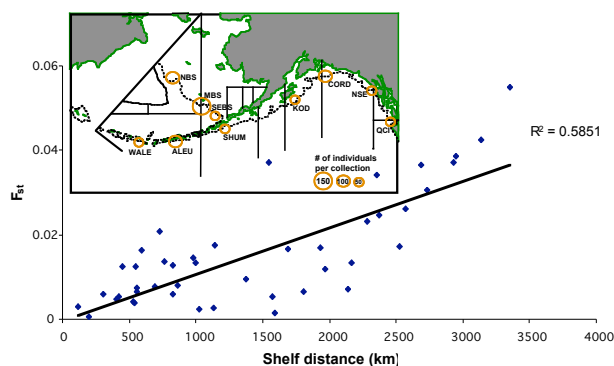


Figure 1. Isolation by distance from distances along the continental shelf line and pairwise  $F_{st}$ s. Points represent each population pair.

### Research accomplishments/highlights/findings

- Using four microsatellite loci to survey 12 collections in 10 geographically distinct areas in Alaskan waters, we observed substantial divergence that correlates with geographic separation of the collections (Figure 1).

- In addition, we have contacted R. Withler (Department of Fisheries and Oceans, Canada) and obtained samples from British Columbia (Withler et al. 2001), which will extend the range of samples and allow for the standardization of data between labs.
- Currently in lab, six to eight other microsatellite loci are being developed to obtain the goal of 10 to 12 loci total for analysis in this project.

#### **NOAA relevance/societal benefits**

Effective management and conservation of a species requires knowledge of its population structure. Knowledge of sub-populations will yield information on POP movement between birth and reproduction and aid in preventing depletion of these smaller populations. More research into POP population structure and basic biological development would aid in understanding population distribution, the location of critical habitats throughout this distribution, and the times of the year when these habitats are necessary for survival.

#### **Research linkages/partnerships/collaborators and networking**

Funding for this project comes through collaboration with the National Marine Fisheries Service Auke Bay Laboratory. Additionally, the preliminary funding for this project has enabled the graduate student, K. Palof, to obtain a Rasmuson fellowship through the University of Alaska Fairbanks for the 2004/2005 academic year. See also bullet #2 under research accomplishments.

#### **Education/outreach**

Graduate student Katie Palof has completed her first year of Master's work.

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## **Species Composition and Spatial Distribution of GOA and BS Young-of-the-Year Rockfish Species (Phase I)**

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**A.J. Gharrett, PI**  
University of Alaska Fairbanks

**NOAA Goal 1**

Other investigators/professionals funded by this project:

**Z. Li, University of Alaska Fairbanks**

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This project is ongoing.

#### **Primary objectives**

Young-of-the-year (YOY) *Sebastes* rockfish were collected as "bycatch" during NOAA Ocean Carrying Capacity surveys of salmon juveniles in the Gulf of Alaska (GOA) and the Bering Sea (BS) in 1998, 2000, 2001, 2002, and 2003. The capture of the rockfish was serendipitous, and the first time that such large concentrations of juvenile rockfish have been observed in the GOA. YOY rockfish were caught along several different transects in the GOA in the same year and there is some coincidence of sample locations between years. From preliminary genetic studies supplemented by morphological analysis, we identified seven different species, the most abundant of which is the Pacific ocean perch (*S. alutus*; POP). These collections provide an unparalleled opportunity 1) to fill in some of the gaps in knowledge of the early life histories of several Alaskan rockfish species, 2) to explore the possibility of developing morphological methods for species identification. This proposal is the second in a series of projects to accomplish those goals.

#### **Approach/methodology**

One focus of this project is to examine the variation in the temporal and spatial distribution of rockfish species in the eastern GOA at different locations within a year and between years. The second focus is the extent of genetic divergence that occurs between year classes of a species. There are three distinct but parallel questions we will ask in both facets of this study. Questions for the species distribution focus are: 1) Is there interannual variation in the relative abundances of YOY rockfish species at a location within the GOA? 2) Do the relative abundances and distributions of species vary across the region sampled in the GOA within a year? And 3) Does the composition vary along a transect within a year?

Because morphological distinctions among species often fail, we are taking an alternative approach. We developed a scheme to delineate species based on mtDNA markers (Gharrett et al. 2001). Recently, we (Li, Gray,



Love, and Gharrett in preparation) extended the study to more than 70 *Sebastes* species, including all the species reported in the GOA.

### **Research accomplishments/highlights/findings**

In December 2003, June 2004, and July 2005 all the YOY rockfish collected during OCC research surveys between 1998 and 2003 were sorted to identify species. Several different morphologies can be visually distinguished, but several species are quite similar-looking. Previously we determined that most, but not all, of the latter group are POP. More than 9400 fish were sorted to identify non-POP-type fish; 377 fish (POP-type and non-POP type) were set aside for morphologic and genetic species identification analyses. In addition, 2072 POP-type fish were processed for genetic analysis (for an NPRB-funded project); of these, 559 were sampled for otoliths, 442 for stomach-content analysis, and 55 for species ID analysis. Remaining POP-type fish were refrozen (-70°C) in either tubes or groups of 10 fish per Whirlpak bag and are available for future or additional analyses. Dr. Kendall has completed morphological analysis of more than 100 specimens. We have not yet conducted genetic analysis on those fish.

### **NOAA relevance/societal benefits**

Effective management and conservation of a species requires knowledge of the life histories of the species being managed and of their predators and prey. At present virtually nothing is known about the early life histories of Alaskan rockfish species or the habitat that is critical to their success at different stages of their life histories.

### **Research linkages/partnerships/collaborators and networking**

Funding for this project comes through collaboration with the National Marine Fisheries Service Auke Bay Laboratory.

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## **Regional Economic Impact of the Bering Sea/Aleutian Islands Crab Fisheries: Snow Crab Market Model**

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**Mark Herrmann, PI**  
University of Alaska Fairbanks

**NOAA Goal 1**

Other investigators/professionals funded by this project:

**Joshua Greenberg, Hans Geier and Charles Hamel, University of Alaska Fairbanks**

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This project was completed during the reporting period.

### **Primary objectives**

The background to this project is the decline of the Bering Sea snow crab fishery harvests that began in 2002. The goal of this study was to build a market model for the Bering Sea/Aleutian Island (BSAI) snow crab fishery. The purpose of building the market model was to integrate it with a regional economic impact model of the BSAI snow crab industry being constructed for the Alaska Department of Fish and Game (ADFG).

The specific objectives for the CIFAR funded market study portion of the project are summarized as follows:

- 1) Build a supply and demand equilibrium econometric model for Alaska and Canadian snow crab.
- 2) Simulate the market model to estimate the interaction between exvessel prices, revenues, and snow crab landings.
- 3) Analyze the revenue impacts that the recent vast expansion of Canadian snow crab harvests have had to the Alaska snow crab fishery.

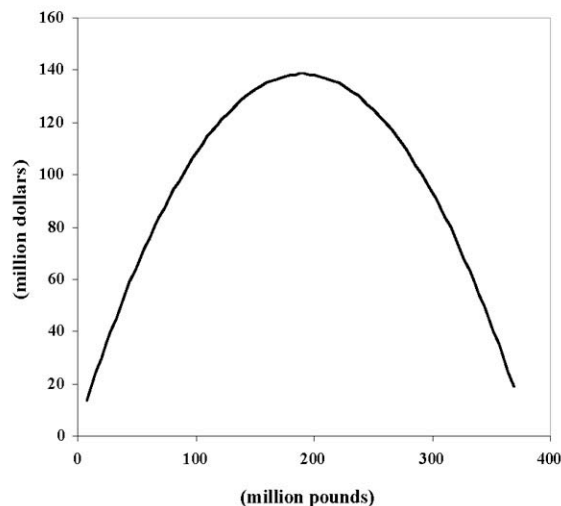
### **Approach/methodology**

The international supply and demand equilibrium model for Alaska and Canada snow crab consists of eight behavioral equations and twelve market clearing identities. The complete system includes twenty endogenous variables and twenty equations. The behavioral structural equations include the Alaskan allocation of snow and Tanner crab to Japan and the United States, the United States demand for Alaska and Canada snow and other crab, the Alaskan exvessel price of snow crab, the Canadian allocation of snow and other crab to Japan and the United States, the Japanese demand for Alaska and Canada crab, and the Canadian exvessel price of snow crab.

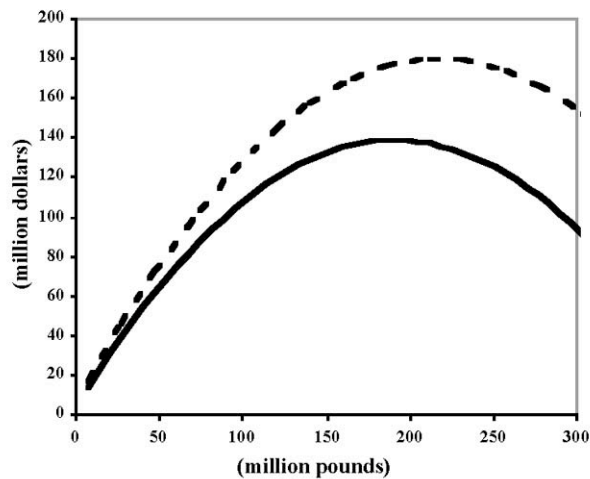
The behavioral equations were estimated using the three-stage least squares (3SLS) econometric method. The 3SLS method is a full-information systems method in that it utilizes the complete information on the other structural

equations in the system through the use of the variance-covariance matrix. Annual data from 1984 to 2002 was utilized to estimate the model.

Dynamic simulations are performed by combining the use of the Newton Algorithm and Monte Carlo simulations. The simulated prices were used to perform two major sensitivity analyses for the 2002 season. The first analysis was conducted by varying Alaska landings holding all other variables constant at their 2002 levels. This was done to estimate a demand and a total exvessel revenue curve for the Alaska snow crab industry. The second analysis repeated the first but the simulations were performed varying Canadian harvest levels to investigate the effects of the substantial Canadian snow crab landings on the markets for U.S. snow crab.



*Figure 1. Simulated 2002 Alaska snow crab exvessel revenues for changes in Alaska snow crab landings.*



*Figure 2. Simulated 2002 Alaska snow crab exvessel revenues for changes in Alaska snow crab landings (solid line) and with Canadian landings fixed at 1989 level of 49.3 million pounds (dashed line).*

### **Research accomplishments/highlights/findings**

- Alaska exvessel revenues are affected in two ways as Alaska snow crab landings are varied in the analysis. They vary with both the changes in harvest levels and with the resulting changes in exvessel prices, simulated from all the interactions captured in the estimated system of equations. The total exvessel revenue curve was estimated by varying Alaska snow crab landings away from their 2002 level of 33.6 million pounds (with an associated exvessel revenue of \$45.8 million) while holding all other variables at their actual 2002 levels (see Figure 1).
- Simulated exvessel revenues initially increase with growth in landings, reaching a peak of \$137.8 million at 190.8 million pounds and then declining with further expansion of landings. In evaluating these results it is important to note that in 2002 the Alaska snow crab harvest of 32.4 million pounds made a relatively small contribution to a world snow crab market dominated by the Canadian harvest of 235.5 million pounds.
- Alaska appears to have been a price taker with wholesale price and exvessel price relatively insensitive to changes in the Alaska harvest level. Given this insensitivity of Alaska prices to changes in volume at low landings levels, exvessel revenues first grow at a rate similar to that of changes in landings. However, as Alaska landings are expanded in the sensitivity analysis (and Alaska accounts for a growing share of world supply) its prices become increasingly sensitive to further changes in landings. For harvest levels greater than 190.8 million pounds the rate of decline in exvessel prices exceeds the rate of growth in landings and subsequently Alaska exvessel revenues decline.
- Further insight into effects of Canadian snow crab harvest levels to the Alaska snow crab industry can be gained through simulations where the Canadian harvest is reduced to its lower levels of previous years. For example, the total revenue curve for the Alaska 2002 snow crab season, under different harvest levels, was simulated fixing the Canadian snow crab harvest at its 1989 level of 49.3 million pounds. This total revenue curve is compared to the simulated total revenue curve when Canadian landings were at their 2002 levels. The result of this simulation is shown in Figure 2.
- It is evident that the sustained increases in Canada snow crab harvests have put downward pressure on Alaska snow crab exvessel revenues. The simulated decrease in the 2002 price, due to Canadian snow crab harvests

being increased from their 1989 levels, is \$0.23 per pound or a decrease in total exvessel revenues of \$7.73 million. At the lower level of Canadian harvest, the model simulates an Alaska exvessel revenue curve that is maximized at Alaska landings of 217 million pounds. This would maximize the simulated exvessel revenue at \$178.7 million with an exvessel price of \$0.82/lb. This simulated Alaska exvessel revenue maximum is \$40.9 million greater than that achieved with Canadian snow crab harvest at its 2002 level.

### **NOAA relevance/societal benefits**

Understanding the relationship between snow crab harvest levels and community impacts is important to regional, state and national economies.

### **Research linkages/partnerships/collaborators and networking**

This research was funded by two awards from NOAA—one through the Alaska Department of Fish and Game and the other through CIFAR. Efforts to obtain industry participation (harvesters, catcher-processors and processors) in this research were largely unsuccessful. The National Marine Fisheries Service has also failed to collect similar types of voluntary data; this widespread problem has been taken up by the North Pacific Fishery Management Council.

### **Publications**

A 338-page report covering the combined body of work, entitled “Regional Economic Impact Assessment of the Alaska Snow Crab Fishery Integrated with an International Snow Crab Market Model” was published in March 2004 as UAF School of Management Working Series Report 2004-001.

A paper will be prepared for the 2004 International Institute of Fisheries Economics and Trade and also an article will be submitted to the *Canadian Journal of Agricultural Economics*.

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## **Effects of Bottom Trawling on Bering Sea Infauna: 2002 Benthic Taxonomy**

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**Stephen Jewett, PI**  
*University of Alaska Fairbanks*

**NOAA Goal 1**

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This project was completed during the reporting period.

### **Primary 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 and continued in the summer of 2002. This report addresses collections made in 2002. 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 1997–2001, 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.

### **Approach/methodology**

A total of 72 0.1 m<sup>2</sup> van Veen grab samples (36 control and 36 experimental) were collected 20–23 June, 2002 by NOAA scientists aboard the F/V *Ocean Explorer*. These samples were received at UAF in February 2003 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 was entered on a PC computer and 100% verified.

### **Research accomplishments/highlights/findings**

Data from the processed 2002 benthic samples were submitted to NMFS (Dr. Robert A. McConnaughey) in electronic form on 6 February, 2004. The submission included a disk containing three files: TRAWLEX02STAT.xls (actual data); TRAWLEX02META.xls (description of the actual data files); and TRAWLEX02TAXON.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 and UAF personnel at a to-be-determined date.

### **NOAA relevance/societal benefits**

Information from this work 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.

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## **Reproductive Potential of Pacific Cod**

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**Brenda L. Norcross, PI**  
University of Alaska Fairbanks

**NOAA Goal 1**

This project is ongoing.

### **Primary objectives**

The reproductive potential (the number and quality of eggs spawned) of female fish is a central determinant of recruitment success. Most stock assessment models predict recruitment with little regard for individual variation in reproduction, despite increasing evidence that such variability may be substantial. This project examines factors that influence the reproductive potential of female Pacific cod (*Gadus macrocephalus*). We hypothesize that reproductive potential varies positively with age, size, and energy reserves (condition) in cod. Because condition is likely to be influenced by the environment, this work will also give us insight into the effect of climate changes on cod reproduction.

### **Approach/methodology**

Adult female Pacific cod are being collected during the spawning season for three consecutive years in two regions where cod are managed separately by NOAA Fisheries: the Gulf of Alaska (GOA; 2002–2004) and the eastern Bering Sea (EBS; 2003–2005). Fish are collected over a size range of 45–100 cm. Collections in the GOA are complete; we have one year of collections remaining in the EBS. We have collected 450 fish from the GOA and anticipate collecting a total of 1000 fish from the EBS. From these samples, tissues are dissected out to perform the following laboratory analyses:

- Age determination from otoliths
- Energy reserves estimated by measuring liver lipid content
- Fecundity (number of eggs) by counting of ovary subsamples
- Egg quality estimated by measuring egg weight and lipid content

In addition, for a subset of the fish sampled in the EBS we are performing a more detailed analysis of egg quality by quantifying different types of metabolic fuels (i.e., lipid classes, free amino acids, and protein).

### **Research accomplishments/highlights/findings**

Preliminary results were presented in:

OA Ormseth and BL Norcross (2003) A quick look at the reproductive potential of Pacific cod. Oral presentation, Annual Meeting of the Alaska Chapter of the American Fisheries Society, November 2003

These results are based on gross morphology as explained below. Ages were estimated using length data and tables of age-length relationships for GOA and EBS cod stocks from the North Pacific Management Council's 2002 Stock Assessment and Fisheries Evaluation documents. Due to space limitations, only two of the relevant figures are included. We have made these preliminary observations:

- Reproductive output increases with age and/or size. This is absolute output estimated simply by gonad weight, so it increases either with greater number of eggs or greater size of eggs, or both.
- Conversely, reproductive investment appears to level off around age 7 (based on gonad index: gonad weight/body weight). This is the proportion of her body weight that a female is devoting to reproduction.
- Energy reserves appear to follow the same pattern. Total reserves (by weight) appear to increase steadily with age, while relative energy storage (liver index: liver weight/body weight) reaches a plateau at about age 6 or 7.
- Low energy reserves (liver index) seem to be associated with low reproductive investment (gonad index), while high energy reserves are associated with high reproductive investment (Fig. 1). This relationship holds through older age classes, where almost all of the fish should be mature (e.g., age 7).
- Reproductive output (gonad weight) is similar between the GOA and EBS. But because EBS fish are larger, reproductive investment is lower in the EBS (Fig. 2).
- Reproductive investment is lower in the EBS even though cod in the EBS maintain higher absolute and relative energy reserves.

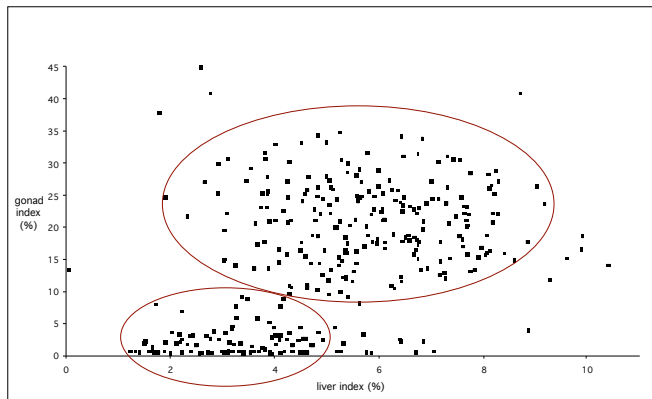


Figure 1. Relationship between liver index and gonad index. Data are pooled 2002 and 2003 from the GOA,  $N = 343$ . Circles indicate suggested grouping.

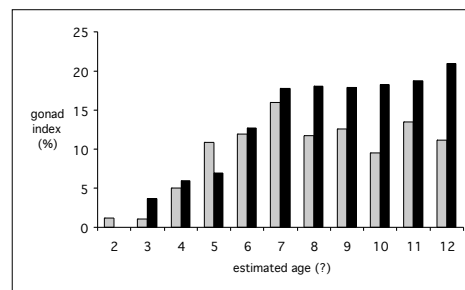


Figure 2. Comparison of gonad index between GOA (black bars;  $N = 343$ ) and EBS (gray bars;  $N = 351$ ) Pacific cod. Error bars omitted for clarity.

### **NOAA relevance/societal benefits**

This research will improve management of Pacific cod in Alaska by enhancing the ability of NOAA Fisheries to estimate Pacific cod recruitment and set catch targets. This work will also help to clarify differences between GOA and EBS cod stocks and contribute to our knowledge of the effects of climate change on fish.

### **Research linkages/partnerships/collaborators and networking**

This project has resulted in a close working relationship between UAF personnel and students and NOAA Fisheries personnel (Dr. Anne Hollowed and Dr. Grant Thompson, NMFS/REFM, Seattle).

### **Education/outreach**

Olav Ormseth, Ph.D. candidate, University of Alaska Fairbanks, is supported by this award.

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## **Processes Affecting Larval Dispersal, Settlement, and Juvenile Habitat of Flatfishes**

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**Brenda L. Norcross, PI**  
University of Alaska Fairbanks

**NOAA Goal 1**

Other investigators/professionals funded by this project:  
**Brenda A. Holladay, University of Alaska Fairbanks**

This project was completed during the reporting period.

### **Primary objectives**

- To compare distribution of larval (RACEBASE) and juvenile (Norcross et al.) flatfishes in the Gulf of Alaska.
- To investigate patterns of larval supply and nearshore settlement.

### **Approach/methodology**

- Chose flatfish species whose juveniles use nearshore nursery areas
- Used refereed and grey literature
- Used historic field collections of eggs and larvae
- Used historic field collections of juveniles
- Grouped nine species of flatfishes by spawning location into “Shelf Spawners” and “Slope/Deepwater Spawners.”

- Compared intra- and inter-specifically for the following variables:
  - Spawning location
  - Spawning time
  - Egg distribution pattern
  - Larval distribution in space and time
  - Size of larval fish

### ***Research accomplishments/highlights/findings***

- Larval dispersal – Shelf and Slope/Deepwater spawners have different spawning and early life history strategies
  - Shelf species – smaller; process is quicker and more direct
  - Slope/Deepwater species – bigger; process is slower and more complicated
- Juvenile dispersal – somewhat different between Shelf and Slope/Deepwater spawners
  - Shelf species – smaller; settle in shallower and warmer water
  - Slope/Deepwater species – bigger, settle in deeper cooler water

### ***NOAA relevance/societal benefits***

- Provides NOAA and fisheries scientists with compilation and comparison of basic early life history information for nine species of flatfishes in the Gulf of Alaska.
- Useful for Essential Fish Habitat determination
  - Proves that supply and habitat, spawning location and larval and juvenile behavior are important variables to consider when evaluating Essential Fish Habitat.
  - Provides evidence that habitat models should include hydrographic and ecophysiology components.

### ***Research linkages/partnerships/collaborators and networking***

This project has resulted in a close working relationship between UAF personnel (Dr. Brenda Norcross and Ms. Brenda Holladay, IMS/SFOS/UAF, Fairbanks) and NOAA Fisheries personnel (Dr. Kevin Bailey and Dr. Janet Duffy-Anderson, NMFS/REFM, Seattle). The concepts generated from this research were used as the basis of the field design and analysis for another CIFAR project, “Feasibility to design and implement a nearshore juvenile flatfish survey – Eastern Bering Sea.”

### ***Publications and presentations***

The manuscript is still being written and revised by the four authors: Brenda Norcross, Janet Duffy-Anderson, Brenda Holladay and Kevin Bailey. The following presentations have been made:

- Norcross, B.L., J.T. Duffy-Anderson, B.A. Holladay and K.M. Bailey. Larval dispersion and settlement of flatfishes. 5<sup>th</sup> International Flatfish Ecology Symposium, Isle of Man, UK, November 2002. (Invited – Keynote)
- Norcross, B.L. Larval and juvenile flatfishes in the Gulf of Alaska. Joint Groundfish Plan Teams, NPFMC, Seattle, WA, November 2002.
- Norcross, B.L., J.T. Duffy-Anderson, B.A. Holladay and K.M. Bailey. Larval dispersal and settlement patterns of juvenile flatfishes in the Gulf of Alaska. 27<sup>th</sup> Larval Fish Conference, Santa Cruz, CA, August 2003.
- Norcross, B.L. A new hypothesis for larval dispersion and settlement of flatfishes in the Gulf of Alaska. IMS Seminar Series, University of Alaska Fairbanks, 2003.
- Norcross, B.L. and B.A. Holladay. Larval dispersion and settlement of flatfishes in the Gulf of Alaska. CIFAR review, Fairbanks, AK, June 2004.

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## Feasibility to Design and Implement a Nearshore Juvenile Flatfish Survey – Eastern Bering Sea

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**Brenda L. Norcross, PI**  
*University of Alaska Fairbanks*

**NOAA Goal 1**

Other investigators/professionals funded by this project:  
**Brenda A. Holladay, University of Alaska Fairbanks**

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This project was completed during the reporting period.

### **Primary objectives**

- To examine feasibility of monitoring nursery areas in the Southeastern Bering Sea for use as an index of flatfish recruitment.
- To gather baseline data on timing and location of flatfish settlement.
- To describe habitat of juvenile flatfishes with respect to depth, sediment, and location of the oceanographic frontal system.
- To obtain physical data on the location and structure of the inner front.

### **Approach/methodology**

- Research cruise in the southeastern Bering Sea 11–26 August 2003.
  - Collected bottom fauna, salinity, temperature, depth and sediment
  - Four transects passed through the Middle Domain, Inner Front, and Coastal Domain
  - One quantitative tow at each of the 39 sites, i.e., 13 quantitative tows in each domain
- Separate data for analysis into Outer-shelf and Inner-shelf Spawners.

### **Research accomplishments/highlights/findings**

- The Middle Domain, Inner Front, and Coastal Domain were evident as separate water masses in temperature contours of Transects A, D, H, and K
- Juvenile flatfishes of ages 0–1 were caught at 92% of all sites. A total of 3,908 flatfishes were caught, composed of 88% northern rock sole, 8% yellowfin sole, and 2% Alaska plaice.
- Youngest juvenile flatfishes are distributed according to spawning location
- Flatfishes with different spawning mechanisms and larval dispersal strategies share nursery habitat by age-1.
- Outer-shelf spawners
  - Northern rock sole, arrowtooth flounder, flathead sole, Bering flounder, Pacific halibut
  - Age-0 fishes settle in middle domain and inner front
  - Older juveniles move to inshore nursery habitats
- Inner-shelf spawners
  - Yellowfin sole, Alaska plaice
  - Age-0 fishes settle only in coastal domain
  - Older juveniles remain in inshore nursery habitats

### **NOAA relevance/societal benefits**

- Establish baseline knowledge of juvenile life history processes, including fish/habitat associations for juvenile age classes.
- By understanding physical mechanisms that influence year-class survival, even only on a decade-scale basis, we create a tool to assist stock assessments beyond that available solely using spawner/recruit models.
- With the ability to produce better assessments of the future productivity of flatfish stocks, harvest levels could be adjusted upward or downward to compensate for the presence or absence of a strong year class.
- The physical data collected are of interest to oceanographers at PMEL (P. Staben, pers. comm.). Our vertical profiles expand the data collected by the Inner Front Project 1997–1999 and complement the data received from Mooring 2.
- Useful for Essential Fish Habitat determination
  - Proves that to examine supply and habitat, spawning location and larval and juvenile behavior are an important variable to consider when evaluating.
  - Habitat models should include hydrographic and ecophysiology components.

### **Research linkages/partnerships/collaborators and networking**

This project has resulted in a close working relationship between UAF personnel and NOAA Fisheries personnel (Dr. Anne Hollowed and Tom Wilderbuer, NMFS/REFM, Seattle).

The concept generated from this research was used as the basis of a proposal to continue the work “Recruitment and settlement of juvenile flatfishes in the Eastern Bering Sea.” This proposal was submitted to NPRB in December 2003 for fieldwork in 2004; unfortunately it was not funded.

The hypothesis generated from this research of larval and juvenile fish being distributed by water mass was used as a basis for another CIFAR proposal “Fisheries Ecology of the Bering and Chukchi Seas.” That project is funded and a cruise will take place in the Northern Bering and Chukchi Sea in August 2004.

We will use the results of this study to develop a plan for an expanded study in the Bering Sea; that proposal will be submitted to NSF.

### **Education/outreach**

We have not yet finished analysis, thus other than talking to people at conferences and in agencies, there has been no presentation of these data.

### **Publications**

The first draft of the manuscript is being written by Brenda Norcross and Brenda Holladay. Revisions will include the third author, Tom Wilderbuer.

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## **University of Alaska Fairbanks Graduate Student Stipend for Stock Assessment Training and Improvement**

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**Terrance J. Quinn II, PI**  
University of Alaska Fairbanks

**NOAA Goal 1**

This project is ongoing.

### **Primary objectives**

This fellowship, funded by 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. This fellowship is open to M.S. and Ph.D. graduate students with solid quantitative ability and achievement. Generally, a student’s research focus is related to the mandate of the AFSC, 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 three 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.

### **Approach/methodology**

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 either 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, or modeling. Applications are evaluated as they are received; there is no formal date of application.

### **Research accomplishments/highlights/findings**

- To date, five SFOS quantitative students have been supported through the fellowship 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, which will be added to the web page.



**NOAA relevance/societal benefits**

This joint program between UAF and NOAA/NMFS/AFSC is designed to prepare young scientists for careers in fish stock assessment, a field that requires strong quantitative skills. The NMSF Stock Assessment Improvement Plan requires such scientists for its implementation, and the available pool of qualified applicants is shrinking.

**Education/outreach**

The following graduate students have been supported through this fellowship program: Ben Williams (M.S.), Colin Schmitz (M.S.), John Moran (M.S.), Dana Hanselman (Ph.D.), and Kalei Shotwell (Ph.D.). Dana Hanselman is now employed by NOAA.

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**Student Research about Local Pollock Abundance using Hydroacoustic Data**

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**Terrance J. Quinn II, PI**  
University of Alaska Fairbanks

**NOAA Goal 1**

This project is ongoing.

**Project objectives and approach**

This project provides graduate student funding to support research on deployment of hydroacoustic data loggers aboard pollock fishing vessels. The research goals are to develop variables related to school density, composition, and frequency, and to examine changes in these variables during the course of the fishing season.

**Research accomplishments/highlights/findings**

A Ph.D. graduate student has now been identified for this project and will begin work shortly.

**NOAA relevance/societal benefits**

This project will employ a novel approach to the study of localized depletion of pollock.

**Education/outreach**

This project provides graduate student support.

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**Tag Retention in Snow Crabs;  
Movement of Primiparous Female Tanner Crabs: Spatial Dynamics of Tanner  
Crab Recruitment**

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**Thomas C. Shirley, PI**  
University of Alaska Fairbanks

**NOAA Goal 1**

These projects are ongoing. Modifications to a digital ultrasonic transmitter had not yet been completed by the manufacturer. The new transmitters would permit smaller transmitter sizes to be attached to the smaller size female crabs. The newer transmitters became available only late this summer after unexpected delays in their manufacture.

**Primary objectives**

The initial 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 tags to measure molt increments and movements and other life history of Bering Sea snow crabs.

**Approach/methodology**

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 were collected in the Bering Sea in July and August, 2002 in separately funded experiments and transported to the Juneau Center in insulated containers. Juvenile Tanner crabs 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. A variety of different tags designs and insertion locations were used in premolting, juvenile crabs; success of tag retention through the molt, and effects upon survival and molting success were compared to control crabs which were untagged. The second phase of the research planned for 2003–2004 was to place digital, ultrasonic tags on crabs and to monitor their movements in Glacier Bay, as part of a larger crab movement study. The sonically tagged juvenile crabs would help us locate the simpler, analog tags. We anticipate continuing this study in the coming year.

### **Research accomplishments/highlights/findings**

- T-bar tags were found to be inefficient as methods for long term tagging of juvenile crabs. The tags greatly increased mortality associated with molting, in comparison to an untagged, control group.
- Survival was high (94%) among the control group, but 24% had lost appendages during the molt. Three different treatments had almost identical survival (73–75%) and tag retention (64–67%). The effective retention, the percentage of crabs that survived and retained tags was also similar (47–50%).
- However, T-bar tags hold promise for large scale tagging of adult crabs that no longer undergo molting. Tag retention was high and mortality low.

### **NOAA relevance/societal benefits**

Movements of Bering Sea snow crabs have been inferred from changes in spatial distribution of different size classes of crabs as recorded in the annual Bering Sea survey. The actual movements of crabs remain unsubstantiated. Development of an effective, inexpensive tag that could be applied quickly to large numbers of crabs could provide data to analyze movements of crabs. Development of a tag and long-term tracking movements of juvenile snow and Tanner crabs could help determine if some areas or habitats serve as ‘nursery’ areas and whether or not emigration from these areas occurs with growth of the crabs. Although these goals remain largely unrealized as yet, we have made some progress.

### **Research linkages/partnerships/collaborators and networking**

This research was possible mainly because of other ongoing research on snow and Tanner crabs being conducted by the University of Alaska Fairbanks and funded by the Alaska Department of Fish and Game (ADF&G). Collections of Bering Sea crabs within our limited budget were possible only through the assistance of ADF&G (Kodiak and Dutch Harbor) and NMFS personnel in Kodiak. The Biological Research Division of USGS, Glacier Bay Field Station generously assisted with collections of Tanner crabs in Glacier Bay and provided office space to the graduate student supported by this grant.

The Rasmuson Fisheries Research Center provided a Fellowship for the graduate student (see below) using this research as part of her thesis.

### **Education/outreach**

Julie Nielsen, Graduate Research Assistant, Juneau Center, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks is supported by this award. Julie is an M.S. candidate in good standing at the Juneau Center, SFOS, UAF.

### **Publications and presentations**

Julie Nielsen has a draft manuscript of a portion of her M.S. thesis. After completion of her thesis, I anticipate that two manuscripts will be submitted for publication to peer-reviewed journals. Several oral presentations of this work have been made:

- Nielsen, J., T. Shirley and J. Taggart. Spatial patterns in size frequency distribution for Tanner crabs in Glacier Bay, Alaska: identification of possible nursery areas and implications for marine reserve design. Symposium within the International Meeting of the Estuarine Research Society, September 14–18, 2003, Seattle, Washington.
- Nielsen, J. and T. Shirley. Conventional and sonic tags for *Chionoecetes*. Interagency Crab Meetings held in Anchorage, Alaska, December 12–14, 2002 and December 16–18, 2003.
- Nielsen, J. Reproductive export from marine reserves? Glacier Bay National Park (Glacier Bay Marine Reserve Research Program) May 10, 2003.
- Nielsen, J. Habitat and movement of juvenile Tanner crabs: nursery areas in Glacier Bay. Rasmuson Fisheries Research Center, Anchorage, Alaska, March 22, 2004.
- Nielsen, J. Spatial dynamics of Tanner crab *Chionoecetes bairdi* recruitment: the role of nursery areas. JCSFOS Graduate Student Symposium, April 11, 2003, Juneau, Alaska.

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## Analysis of Genetic and Phenotypic Differentiation between Wild and Hatchery-bred Chinook Salmon

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**William Smoker, PI**  
University of Alaska Fairbanks

**NOAA Goal 1**

This project was completed during the reporting period.

### **Primary objectives**

Design and conduct behavioral experiments to contrast responses of Chinook salmon from related wild and hatchery lineages. Experiments conducted at NOAA Fisheries research station at Little Port Walter in collaboration with NOAA scientists measured behavioral responses including measures of predator avoidance, agonistic behavior, distribution in water column. Describe morphological differences between lineages. Test hypothesis that hatchery lineages diverge as a consequence of selection or drift from wild lineages.

### **Approach/methodology**

This study tested for genetic differences between lines derived from a hatchery stock of chinook salmon and from its ancestral wild stock of chinook salmon. Second generation hybrids between them were also tested. All lines were produced from parents cultured in the same environment and all fish tested were raised in the same environment. Equal numbers of individuals from equal numbers of families from each line were tested. A balanced, nested design allowed tests for family effects as well as the effect of line.

Because behavior has a direct effect on fitness we looked for differences in agonistic behavior between the hatchery and wild lines. Because levels of aggression in salmonids are associated with dominance, the ability of hatchery fish and the hybrids to establish dominance over the wild fish was tested to determine the real world impact of any agonistic behavioral differences.

Changes in morphological traits, e.g., body size and shape, can also occur quickly during domestication and body morphology can have a direct influence on ability to exploit the environment. Because of this we employed thin plate spline analysis of lateral images to test for differences in body shape between the hatchery and wild lines.

### **Research accomplishments/highlights/findings**

- Juveniles in a hatchery stock of chinook salmon that has experienced five generations of hatchery culture were significantly more aggressive than juveniles derived from the wild founding stock but produced from parents cultured in the same hatchery environment as the hatchery stock. Hatchery fish made more charges, displays, and nips than wild derived fish.
- Second generation hybrids between the two lines also made significantly greater numbers of charges, displays, and nips than wild derived fish but made significantly fewer displays than hatchery fish.
- These results suggest that behavioral differences detected are genetic in origin and are consistent with divergence of the hatchery stock from the founding wild stock, however no difference was detected in the ability of fish lines to win dyadic dominance contests.
- Body morphology differed significantly between juvenile hatchery chinook salmon that have experienced five generations of hatchery culture and juveniles produced from parents cultured in the same environment but derived from the wild founding stock. Thin-plate spline analysis showed that hatchery fish had a more compressed body, a narrower head, shorter maxillae, and a longer and narrower caudal peduncle than wild fish. Canonical discriminant analysis was able to correctly classify 88% of hatchery fish and 90% of wild fish.
- Second generation hybrids of the two lines were morphologically intermediate to but significantly different from both the hatchery and wild lines, and they appeared to be more similar to the wild line.
- These results suggest that shape differences between lines are largely genetic in origin and may be a result of divergence of the hatchery stock from the founding wild stock.

### **NOAA relevance/societal benefits**

Conservation of threatened or endangered Evolutionarily Significant Units of chinook salmon requires that domestication and other effects of hatchery culture be understood and minimized. This research is an opportunity to study effects of culture in a situation in which the ancestral wild population is not threatened or endangered and in which genetic exchange between the cultured and wild populations is minimal. The apparent demonstration of domestication effects in very few generations is important evidence for NOAA Fisheries in setting policy and writing regulations under its ESA responsibilities.

### **Research linkages/partnerships/collaborators and networking**

NOAA Fisheries and the University of Alaska Fairbanks collaborated in this research. Each provided financial resources to the collaboration, including NOAA's contract with UAF for the research reported here.

### **Education/outreach**

Maria Wessel (nee Lang), MS Fisheries, University of Alaska Fairbanks, 2004, was supported by this grant. She is now under private contract with UAF with support from Alaska Department of Fish and Game to work on related NOAA research. Ms. Wessel presented results of this research to the Alaska Chapter, American Fisheries Society, Annual Symposium in Fairbanks, November 2003.

### **Publications**

- Maria Wessel. 2004. Variation of Agonistic Behavior and Morphology among Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) of Hatchery, Wild, and Hybrid Origin under Common Rearing Conditions. MS Thesis, University of Alaska Fairbanks. vii + 81pp.
- Wessel, M., W.W. Smoker and J.E. Joyce. Differences in juvenile morphology between a hatchery population of chinook salmon and their founding stock. *Transactions of the American Fisheries Society*, in review.
- Wessel, M., W.W. Smoker, R. Fagen and J.E. Joyce. Differences in agonistic behavior between juveniles in a hatchery population of chinook salmon (*Oncorhynchus tshawytscha*) and juveniles derived from its source population. In preparation.

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## **Analysis of Genetic and Phenotypic differentiation between Inbred and Outbred Lines of Steelhead and Rainbow Trout**

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**William Smoker, PI**  
University of Alaska Fairbanks

**NOAA Goal 1**

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This project was completed during the reporting period.

### **Primary objectives**

The general purpose of this research is to determine if lakes and reservoirs as refuges could provide an alternative to hatcheries or captive rearing for the conservation of threatened or endangered salmonid stocks. Salmonids in a refuge might not be subject to domestication selection and might be better candidates for reintroduction to a restored habitat because they would not acquire the unnatural behavior patterns learned or selected for in hatchery culture. The objective here is to determine if behavioral differences can be detected between juveniles derived from lake-sequestered *O. mykiss* and juveniles derived from their ancestral anadromous steelhead population.

### **Approach/methodology**

We conducted behavioral experiments to contrast responses of juvenile steelhead trout with those of lake-sequestered trout derived from the same steelhead population. In laboratory aquaria we measured predator avoidance, agonistic behavior, distribution in water column and tested hypotheses that sequestration (a model for potential method for conservation of threatened and endangered steelhead trout) had no effect on the population. Resident trout derived from a population that had been sequestered in a lake for seventy years were compared to fish from their founding anadromous steelhead trout population as well as to hybrid crosses of the two populations. All of the subject trout were bred in captivity and subject to the same environmental conditions during their entire lives. Comparisons were made in aggression, dominance and predator evasion by observing trout in replicate laboratory aquaria under standardized conditions and by exposing cultured trout to a predator.

### **Research accomplishments/highlights/findings**

In aggression trials the lake-derived population chased more than stream-derived *O. mykiss* at two life stages, age-0 and age-1. Lake-derived fry and the lake x stream hybrid fry also chased more than the stream x lake hybrid fry. In a common environment fin conditions (dorsal and pectoral fin lengths, an index of aggression) did not differ significantly. In dominance acquisition the stream x lake hybrid were least frequently dominant of all the crosstypes, and stream-derived parr were less dominant than lake-derived parr. Avoidance of a Dolly Varden predator by fry showed that the stream x lake hybrids achieved the highest survival rates. Seventy years of sequestration in a lake

may be adequate time for divergence in aggressive behavior, social dominance and predator evasion between lake-resident and stream, *O. mykiss* populations.

### **NOAA relevance/societal benefits**

Threatened and endangered Evolutionarily Significant Units of steelhead trout are conserved through artificial culture in hatcheries or in captive rearing or breeding programs. Temporarily sequestering populations in natural lacustrine habitats is an alternative, more natural approach to maintaining fitness characteristics populations while the degraded freshwater environments that led to reduced productivity have been sufficiently restored. Salmonids in an isolated lacustrine refuge would not be subjected to domestication selection pressures associated with artificial culture that can occur within several generations. Fish produced from such a “natural” environment might be better candidates for reintroduction to a restored habitat because they would not acquire the unnatural behavior patterns learned or selected for in hatchery culture. This research demonstrates that while sequestration may be a desirable method of conservation, it is not without effects on the sequestered population.

### **Research linkages/partnerships/collaborators and networking**

NOAA Fisheries and the University of Alaska Fairbanks collaborated in this research. Each provided financial resources to the collaboration, including NOAA’s contract with UAF for the research reported here.

### **Education/outreach**

Erika Ammann earned her MS in Fisheries as a graduate research assistant supported by this award. Ms. Amman presented “Agonistic behavior and social dominance of *Oncorhynchus mykiss* from lake and stream parents” to the Propagated Fish in Resource Management, AFS Special Symposium, June 17, 2003, and presented results of this research to the Alaska Chapter, American Fisheries Society, Annual Symposium in Fairbanks, November 2003.

### **Publications**

Erika Ammann. Agonistic Behavior, Social Dominance, and Predator Evasion of *Oncorhynchus mykiss* from Lake and Stream Parents. An Evaluation of Lacustrine Refuges as a Conservation Strategy for Threatened or Endangered Salmonids. MS Thesis, University of Alaska Fairbanks. vii + 78pp.

Ammann, E., W.W. Smoker and F.P. Thrower. 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. In preparation for submission to *Alaska Fisheries Research Bulletin*.

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## **GLOBEC-NEP: Topographic Control of Mesoscale Variability in the Gulf of Alaska**

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**Terry Whitley, PI**  
University of Alaska Fairbanks

**NOAA Goal 1**

This project is ongoing.

### **Primary objectives**

This research studies the physical and biological distributions and processes and their effect on juvenile salmon recruitment on the Gulf of Alaska shelf. The spatial scope of the study was from Montague Strait to west of the Chiswell Ridge. The overriding theme of the proposal was that along-shelf and cross-shelf mesoscale structures are due to bathymetric control of the currents. Physical and biological oceanographic characteristics associated with the Alaska Coastal Current, its offshore excursions in the Seward Eddy and Seward Counter Eddy, the shelfbreak front, slope eddies and meanders and the deep flow were investigated during both of the 21-day cruises in May and August.

### **Approach and research accomplishments/highlights/findings**

In May and July, 2003, we conducted two to three synoptic surveys (5 days each) of cross-shelf transects spaced every 10 km alongshelf. An undulating, underwater, towed vehicle (SeaSoar) was used to continuously map salinity, temperature, depth (CTD), biooptical parameters, and mesozooplankton (optical plankton counter). Surface samples of the above (minus depth), nutrients, and chlorophyll fluorescence were measured continuously using similar sensors. We used an Acoustic Doppler Current Profiler (ADCP) to measure along- and cross-track velocities to 150 m. We calibrated the above with on-station samples of salinity, temperature, nutrients, and phytoplankton. The mesoscale features observed were quite dramatic with temporal variations that demonstrated the importance of

frontal regions and tidal fluctuations. A large scale eddy was also surveyed which contained significant amounts of shelf water that was embedded in offshore source water. These large eddies probably have a major impact on the biological processes on the northern Gulf of Alaska shelf.

#### **NOAA relevance/societal benefits**

This research is important to building a better understanding of mesoscale variability in the coastal ocean especially in an area that is critical habitat for salmon.

#### **Research linkages/partnerships/collaborators and networking**

This project is part of GLOBEC (Global Ocean Ecosystem Dynamics), a large multi-agency effort that is strongly supported by both NOAA and the National Science Foundation. David Musgrave of the University of Alaska Fairbanks is directly collaborating on this project, funded by NSF.

#### **Education/outreach**

The broader impacts of this study include the training of two Ph.D. students (Amy Childers and TaeKeun Rho) in multidisciplinary oceanography and a better understanding of the effects of oceanographic effects on salmon variability in the Gulf of Alaska.

#### **Presentations**

- Whitledge, T.E. Climate change and nutrient cycling in the Gulf of Alaska. Invited Seminar for Louisiana Universities Marine Consortium, Cocodrie, LA, 17 July 2003.
- Childers, A.R., T.E. Whitledge and D.A. Stockwell. Seasonal and interannual variability of nutrients and chlorophyll a across the southcentral Alaska Shelf: 1998–2000. AGU 2004 Ocean Sciences Meeting, Portland, 26–30 January 2004.
- Stockwell, D.A., T.E. Whitledge and A.R. Childers. Gulf of Alaska GLOBEC monitoring program plankton biomass and primary productivity distributions on the southcentral Alaskan Shelf. AGU 2004 Ocean Sciences Meeting, Portland, 26–30 January 2004.
- Pegau, W.S., D. Musgrave, R.A. Potter, T.E. Whitledge, H. Statscewich and S. Laney. Bio-optical regimes along the southcentral Alaskan Shelf. AGU 2004 Ocean Sciences Meeting, Portland, 26–30 January 2004.
- Potter, R.A., D. Musgrave, H. Statscewich, T.E. Whitledge and W.S. Pegau. Observations of a deep-water eddy in the Gulf of Alaska. AGU 2004 Ocean Sciences Meeting, Portland, 26–30 January 2004.
- Musgrave, D., H. Statscewich, R.A. Potter, T.E. Whitledge and W.S. Pegau. Mesoscale surveys of the southcentral Alaskan Shelf. AGU 2004 Ocean Sciences Meeting, Portland, 26–30 January 2004.
- Whitledge, T.E. Northeast Pacific GLOBEC: A summary of results from the Gulf of Alaska over the past six years. Invited Presentation, AGU 2004 Ocean Sciences Meeting, Portland, 26–30 January 2004.
- Whitledge, T.E., D. Musgrave, R.A. Potter, H. Statscewich and W.S. Pegau. Coastal shelf features and nitrate-salinity relationships observed along the southcentral Alaskan Shelf. AGU 2004 Ocean Sciences Meeting, Portland, 26–30 January 2004.
- Whitledge, T.E. Investigations of biophysical origins for Gulf of Alaska continental shelf production. Invited Seminar to Monterey Bay Aquarium Research Institute, Moss Landing, 26 May 2004.

## **Hydrographic and Sea Ice Studies**

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

**S. Lyn McNutt**  
University of Alaska Fairbanks

**NOAA Goal 2, (4)**

This project was completed during the reporting period.

#### **Primary objectives**

Together, thermodynamic and dynamic processes determine the thickness distribution of the ice cover, which governs the exchange of energy between the atmosphere and the ocean. Key to the dynamic processes is the mechanical behavior of the ice cover. During the SHEBA field experiment, we deployed sensors to measure the internal ice stress at several locations within a 15 km x 15 km area. These measurements are combined with

satellite-derived ice motion and imagery products. The objective is to make a first step towards using these data sources as a direct means of evaluating sea ice dynamics models, by assessing whether the stress signal can be qualitatively linked to the regional-scale (10–100 km) deformation activity.

### **Approach/methodology**

We first obtained in situ measurements of ice stress taken during the Surface Heat Budget of the Arctic (SHEBA) Program, and then compared these to regional satellite-derived ice motion and surface heat products from Synthetic Aperture Radar (SAR) and AVHRR. Four case studies were prepared, each with distinguishing characteristics: consolidation of the seasonal ice zone against the Alaskan coast (5–7 December 1997); advancement of the consolidation zone into the perennial ice pack (11–13 December); extreme divergence (14–17 January); and consolidation of the pack against Wrangel Island and the Siberian coast (20–23 February). Each case demonstrated a different sea ice state, and provided data on a wide range of ice forcing and deformation conditions across the Western Arctic Ocean.

### **Research accomplishments/highlights/findings**

The results of this analysis

- demonstrate that stress measurements are related to the regional deformation behavior of the ice cover,
- confirm that regional-scale ice dynamics is primarily a function of coastal geometry, and sustained, large-scale wind direction and magnitude,
- provide continued evidence that the ice pack behaves as a granular hardening plastic, and
- encourage pursuit of efforts to use direct measurements of ice stress and deformation in the formulation and development of sea ice dynamics models.

### **NOAA relevance/societal benefits**

The results have implications for modeling at many scales. The work documents qualitative evidence of a relationship between internal ice stress measurements and ice deformation at the regional scale. The relationship between the internal ice stress and deformation is complex due the effects of the state of the ice cover, coastal boundaries, and forcing conditions. In general, internal ice stresses develop in the winter ice cover when: 1) the seasonal ice cover has completely developed between the perennial ice and the coast, 2) moderate to high winds occur over a sustained period of at least 2–3 days, and 3) these winds drive the ice towards a coastal boundary. Understanding these relationships is critical to developing an accurate sea ice forecasting and modeling capability.

In addition, we were able to work with the Alaska Satellite Facility (ASF) to develop two new software products. The first combines temperature data from the AVHRR with SAR data, and provides a new view of sea ice from space. The second allows users to turn complex SAR images into jpegs and geotiffs for use on the web and in Geographic Information Systems (GIS). Unfortunately, distribution policy for RADARSAT data prevents us from making any of the images available outside of the PIs. We hope that this will be remedied in the near future.

### **Research linkages/partnerships/collaborators and networking**

This was a collaborative proposal with Dr. James Overland at NOAA/PMEL in Seattle, WA, and Dr. Jackie Richter-Menge of the Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, NH. When analyzing and publishing results of the research, further collaborative efforts were made with Dr. Ronald Kwok of the Jet Propulsion Laboratory, Pasadena, CA. We worked with ASF at the University of Alaska on the data analysis and the development of the jpeg/geotiff tools. Additionally, the information played a crucial role in understanding sea ice hierarchy and modeling requirements for other projects.

### **Education/outreach**

Students at the Alaska Satellite Facility (ASF) were involved in the data acquisition, processing and graphic display of the information.

### **Publications**

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–Oceans*, 10.1029/2000JC000477  
McNutt, S.L. and J.E. Overland. 2003. Spatial hierarchy in Arctic sea ice dynamics. *Tellus*, 55A:181–191.

## **Marine Ecosystem Studies**

### **Pollock Year Class Strength: Synthesis of Acoustic and Net Data for Age-0 Pollock with Distributions of Predators, Prey and Environmental Data**

**Kenneth Coyle, PI**  
*University of Alaska Fairbanks*

This project was completed during the reporting period.

(This research is part of a larger Southeast Bering Sea Carrying Capacity (SEBSCC) project led by Gordie Swartzman, University of Washington, that studied the Pribilof Island Ecosystem. This report is extracted from the final report of Swartzman.)

#### **Primary objectives**

The Pribilof Island region was chosen in part because it is thought to be a major nursery area for age-0 walleye pollock. Also, its location at the transition between the Eastern Bering Sea Shelf and the Eastern Bering Sea Basin provides a variety of shelf, slope and canyon habitats and fronts within close proximity of the islands. The Pribilof area has been the target of extensive survey activity from 1994–1999. Acoustic surveys occurred along 4 transects near the Pribilof Islands during September of each of these years. Coyle's work addressed the following main project objectives: How does the abundance of juvenile pollock near the Pribilof Islands compare with abundance along the Bering Sea shelf, how accessible is this area from major pollock spawning regions and what percentage of juvenile pollock is represented by the Pribilof Island population?

#### **Approach/methodology**

A comparison of acoustic data between the Pribilof region and several acoustic transects in the Inner Front region of the Eastern Bering Sea was conducted by Andreas Winter (Ph.D. student, University of Washington) and Ken Coyle. Initial work was needed to standardize the data between the two surveys, because different acoustic systems were used for the different surveys. The main difference between the acoustics was the horizontal resolution of the data. Direct comparisons of pollock (and zooplankton) abundance were made for 1997, 1998 and 1999 survey years, when data were available in both areas. Acoustic data were collected at Slime Banks near Unimak Pass and Port Moller along the Aleutian inner front and Nunivak and Newenham transects on the Northern Inner Front region. Previous comparison of net samples between these surveys by Coyle and Pinchuk (2002) suggested that the abundance of both age-0 pollock and zooplankton would be about the same order of magnitude as the Pribilof. This was corroborated by the acoustic data comparison. In each region data were subdivided into nearshore, offshore stratified and transition regions. A comparison was made with data collected along transect A near the Pribilof Islands.

#### **Research accomplishments/highlights/findings**

- Nearshore domains in all transects and years generally had the lowest abundance of both fish and zooplankton, while the stratified region generally had the highest abundance for both groups.
- There was general agreement in year-to-year changes in age-0 pollock abundance between all Inner Front and Pribilof transects, with 1997 having the lowest and 1999 generally having the highest abundance.
- A comparison of the depth distribution of young-of-the-year pollock and zooplankton showed no apparent differences between regions and no consistent patterns.
- Comparison of the abundance of zooplankton and fish around the Pribilof Islands with other front areas suggest that abundance in the Pribilof Region is no higher than in other eastern Bering Sea frontal regions. While standing stocks are higher in the front region than nearshore, they appear to be generally higher in stratified waters offshore of the coastal front.

#### **NOAA relevance/societal benefits**

Walleye pollock resources in the north Pacific and Bering Sea support the largest single commercial fishery in the United States and one of the largest commercial fisheries in the world. NOAA/NMFS has fishery management responsibilities for this species.

#### **Research linkages/partnerships/collaborators and networking**

This work is part of a SEBSCC project led by Gordie Swartzman at the University of Washington.



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## Paleoecologic and Paleoceanographic Studies of Marine Bays in Southeast Alaska

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**Bruce P. Finney, PI**  
University of Alaska Fairbanks

**NOAA Goal 1**

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This project is ongoing.

### **Primary 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.

### **Approach/methodology**

- 1) Sediment cores from two bays are being dated using  $^{210}\text{Pb}$  and AMS radiocarbon ( $^{14}\text{C}$ ) techniques.
- 2) To reconstruct primary productivity, we are using 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 can be determined. We are also reconstructing productivity from analysis of organic carbon mass accumulation rate. The third proxy we are using is the  $\delta^{13}\text{C}$  ratio of organic matter.
- 3) Downcore changes in salinity and temperature will be determined through analyses of foraminifera for  $\delta^{18}\text{O}$  and  $\text{Mg}/\text{Ca}$ ; changes in nitrate utilization are being assessed by analyses of  $\delta^{15}\text{N}$  of organic matter.
- 4) Forage fish populations will be reconstructed for these bays from analysis of preserved bones and scales. Sediments will be gently sieved through nested screens of graded mesh sizes and forage fish remains identified under a microscope.
- 5) Oceanographic conditions will be reconstructed in these cores using analyses of foraminifera  $\delta^{18}\text{O}$  and  $\text{Mg}/\text{Ca}$  (temperature and salinity), and  $\delta^{15}\text{N}$  of organic matter (changes in nitrate utilization).

### **Research accomplishments/highlights/findings**

- 1) AMS and Pb-210 dating have been completed for all but four of the cores from Southeast Alaska.
- 2)  $\delta^{13}\text{C}$  data, carbon content and percent opal (from diatoms), all of which are proxies for primary productivity, are currently being conducted or are completed for cores from Big Port Walter, Bay of Pillars, Eliza Harbor and Inner Redoubt Bay.
- 3) Sieving of foraminifera and preliminary identification are being conducted for cores from Bay of Pillars, Eliza Harbor and Inner Redoubt Bay.  $\delta^{18}\text{O}$  and  $\text{Ca}/\text{Mg}$  analyses still need to be completed.
- 4) Fish scale sieving and diatom analysis are still to be conducted for cores.
- 5) Cross-correlation analyses will be conducted with climatic data.

### **NOAA relevance/societal benefits**

This work comprises the first effort to use paleoceanographic sampling methods to produce high resolution data on decadal to century scale variability in oceanographic and ecological processes in Southeast Alaska. Such information is part of that needed to address practical management and conservation concerns over recent changes in marine animal populations. By learning how variable systems have been over both short and long-time scales, we are also developing understanding of fundamental ecological processes and how ecosystems will respond to regional and global climate change.

### **Research linkages/partnerships/collaborators and networking**

This research has led to additional research and funding through NOAA, NSF Arctic Social Science and an NSF ocean drilling project in the Gulf of Alaska on subjects dealing with changes in primary productivity, forage fish populations, oceanographic conditions and climate.

### **Education/outreach**

This project is supporting an Oceanography Masters degree student, Molly Boughan. She is conducting sediment core analyses, collection and analysis of foraminifera and stable isotope analyses of three cores at this time. A French exchange student conducted analyses on the Big Port Walter core. These data will be included in the final report. Preliminary results of these data have been presented orally at agency and investigator meetings.

### **Publications**

We anticipate two manuscripts and a Masters thesis resulting from this work. One manuscript will describe the cores and their sedimentary characteristics (late 2004). The second manuscript will be on high-resolution paleoceanographic reconstructions of oceanographic characteristics and ecological changes (e.g., primary productivity and forage fish abundance) in two southeastern Alaska regions (late 2005).

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## **Activity and Diversity of Sea Ice Biota in the Chukchi and Beaufort Seas**

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**Rolf Gradinger, PI**

*University of Alaska Fairbanks*

**NOAA Goal 1**

*Other investigators/professionals funded by this project:*

**Bodil Bluhm, University of Alaska Fairbanks**

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This project is ongoing.

### **Primary objectives**

Our proposal focused on the structure and dynamics of Arctic sea ice communities. The studies were conducted onboard the Chinese icebreaker 'XueLong' in summer 2003 in close co-operation with US and Chinese scientists. The specific objectives of our study were: (1) to determine the vertical distribution of microalgae, ice meiofauna and dissolved and particulate exopolymeric substances (EPS) in sea ice and the underlying water, (2) to determine the EPS production of sea ice and planktonic communities using short term in situ incubations, and (3) to measure the activity of ice algae using short term in situ incubation and fluorometry.

### **Approach/methodology**

Ice cores were taken using ice augers, and water samples were collected with a Kemmerer sampler. Light was recorded with LICOR light sensors, and a T/S sensor measured temperature and salinity below the ice. Biomass data (Chlorophyll *a*, POC, PON,  $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ ), salinity, and nutrient concentrations (N compounds,  $\text{SiO}_4$ ,  $\text{PO}_4$ ) were assessed on melted ice core sections over the entire ice thickness. The ratios of stable isotopes ( $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ ) of natural communities as well as POC and PON were determined on filtered samples at the stable isotope facility at UAF. Stable isotope techniques were used to determine the ice algal nutrient uptake kinetics ( $^{15}\text{N}$ ) and carbon assimilation ( $^{13}\text{C}$ ) under *in-situ* conditions using incubations on the floes. P vs. I (production versus irradiance) curves were established using optical techniques (Water Pam fluorometer). Dissolved and particulate EPS were determined using a modified phenol-sulfuric-acid method. Bottom segments of ice cores were melted and subsamples fixed directly for protist counts, while the rest of the sample was concentrated over 20 $\mu\text{m}$  gauze, fixed and used for meiofauna abundance determination.

### **Research accomplishments/highlights/findings**

- Snow covered the summer pack ice and a slush-layer was found in the ice–water interface.
- The vertical distribution of ice algal biomass mostly followed C-shaped curves with elevated concentrations at the bottom and the top of the ice.
- The snow accumulation and the C-shaped chlorophyll curves are uncommon for the Arctic and could be an indication for ongoing changes in the Arctic sea ice regime.
- The biomass and activity of the shade adapted ice algae was at the lower end of typical Arctic ice values.
- The ice meiofauna was mainly constricted to the bottom 10cm of the ice and was dominated by turbellarians, harpacticoid copepods and nematodes.
- Potential meiofaunal ingestion rate was about 1% of published daily algal production rates.

### **NOAA relevance/societal benefits**

This study will help evaluate the effect of global change on the Arctic ecosystem. This grant facilitated close collaboration with Chinese colleagues, creating a stepping stone to further strengthen the US–Chinese co-operation in Arctic science.

### **Research linkages/partnerships/collaborators and networking**

The grant supported the co-operation with Dr. Meiners (Yale University). The collected material was combined with data from the NOAA-funded Ocean Exploration 2002 expedition and will further be used to study the diversity of sea ice biota as part of the Arctic Census of Marine Life (<http://www.sfos.uaf.edu/research/arcddiv/>).

### **Education/outreach**

Part of the samples and data collected during this study were used for the first international course on “Field techniques in interdisciplinary sea ice research” conducted in spring 2004 in Barrow, Alaska.

### **Publications**

Gradingier, R.R., K. Meiners, G. Plumley, Q. Zhang and B.A. Bluhm. Abundance and composition of the sea ice meiofauna in off-shore pack ice of the Beaufort Gyre in summer 2002 and 2003. Submitted to *Polar Biology*.

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## **Ecosystem Change in the Northern Bering Sea**

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**Jackie M. Grebmeier, PI**  
*University of Tennessee, Knoxville*

**NOAA Goal 1**

This project is ongoing.

### **Primary objectives**

This project is investigating recent changes observed on the northern Bering Sea shelf coincident to decadal-scale atmospheric/sea ice/oceanographic processes, which reflect regime-induced climate changes in the western Arctic. Recent work indicates that there are “hot spots” of biological productivity southwest of Saint Lawrence Island, and that this productivity has been decreasing over the past decade. Recent findings indicate that the Bering Sea is shifting to an earlier spring transition based on changes in ice melt and atmospheric circulation patterns. Since the trend in Arctic Oscillation appears to be a clearly increasing climate signal, the northern Bering Sea is an important location to monitor ecosystem change.

### **Approach/methodology**

Our project is undertaking the following tasks to understanding ecosystem change in the northern Bering Sea: 1) A retrospective analysis of all northern Bering Sea data to put future changes into context and to provide an objective measure for change detection; 2) Establishment of a northwest Bering Sea biophysical oceanographic mooring to document ongoing changes, similar to the successful multiyear FOCI mooring M2 on the southeast Bering Sea shelf; and 3) Process studies of the northern biological hot spots, primarily funded by non-NOAA sources. Oceanographic logistics are provided in collaboration with Dr. Ed Carmack (Institute of Ocean Sciences, IOS) and the Canadian Coast Guard ship *Sir Wilfrid Laurier* enroute to resupply communities in the Canadian Arctic via NSF and NOAA funding. We are utilizing this platform to reoccupy key sites on the northern Bering Sea shelf for hydrographic, biochemical and sediment collections. A Seabird CTD with rosette is used to collect salinity, temperature and water column collections for measurements of nutrients, chlorophyll and oxygen-18 content. Sediment is collected using grabs and cores for faunal population and biomass analyses, sediment grain size, carbon content, and other sediment tracers to document pelagic–benthic coupling and carbon deposition sites in the benthos.

### **Research accomplishments/highlights/findings**

- Retrospective sediment and benthic faunal data from the northern Bering Sea from the 1970s through 2003 have been entered into Excel spreadsheet format for inclusion in a long-term data base; some of the early 1990s data from the region south of St. Lawrence Island is currently available through the Joint Office of Science Support Shelf–Basin Interactions database (example—Fig. 1);
- Nineteen hydrographic and benthic stations were occupied annually in 2003 and 2004 north and south of Bering Strait in collaboration with the National Science Foundation–funded Bering Strait Long-Term Observatory (LTO) project (<http://arctic.bio.utk.edu/>);

- Field studies in 2003 and 2004 extended a time-series of CTD, nutrients, chlorophyll and sediment flux measurements of dissolved oxygen, benthic biomass, and other chemical and biological parameters at productive benthic stations (see Fig. 1);
- In summer 2003 and 2004, a subsurface mooring was emplaced in 80 m of water southwest of St. Lawrence Island through funding by the NOAA Arctic Research Office; and
- Time series retrospective studies indicate a decline in both sediment respiration (carbon supply) and benthic standing stock in this region (Fig. 1) coincident with increased seawater temperature (Stabeno and Overland, EOS, 2001).

### **NOAA relevance/societal benefits**

Monitoring and assessing the current status and potential change in the northern Bering Sea ecosystem in response to climate change is directly relevant to the goals of the NOAA-supported SEARCH: Study of Environmental Arctic Change multi-agency global change project and similar efforts of the NOAA Arctic Research Office.

### **Research linkages/partnerships/ collaborators and networking**

This project is a collaborative effort with Dr. Jim Overland at NOAA/PMEL and Dr. Terry Whitledge at UAF to investigate the status and change in the northern Bering Sea ecosystem. This project includes deployment of a mooring array coincident with retrospective data analysis and fieldwork. This joint project is directly related to the SEARCH project to investigate potential impacts of climate change on the marine ecosystem and goals of the international Pacific Arctic Group (PAG).

### **Education/outreach**

Ms. Alicia Clarke, a minority undergraduate student working in my laboratory, was supported to participate in the 2004 cruise and undertake a student project on identifying phytoplankton types in surface sediments coincident with our sediment chlorophyll measurements.

A high school teacher from Vermont (Betty Carvellas) participated in the 2004 cruise as part of the Teachers Experiencing the Antarctic and Arctic program through NSF funding (see <http://tea.rice.edu>). She maintained a website with daily journals that summarized results from the joint NOAA–NSF research in the northern Bering Sea. She also interacted with the public via questions and answers on the website.

Presentations of the scientific results from this study have been made to local schools and via professional meetings and international science planning groups for global change research. Results from this study were presented at the 2004 ASLO/TOS meeting in Honolulu, Hawaii.

### **Publications**

Currently I am working on a paper entitled “The Northern Bering Sea: An Arctic Ecosystem in Change,” to be presented at the AGU Fall Conference, December 2004 in San Francisco, CA. Portions of this paper will also be presented as part of a global change talk at the ACIA International Scientific Symposium “Climate Change in the Arctic,” 9–12 November 2004 in Reykjavik, Iceland. This paper will be submitted to a peer-reviewed journal.

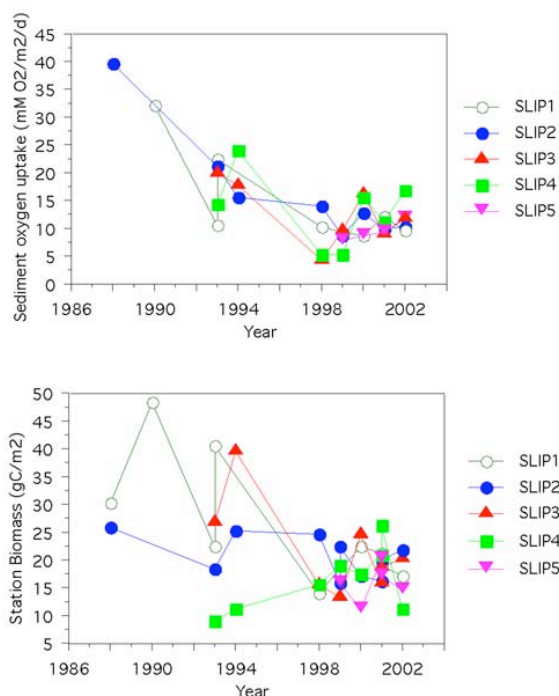


Figure 1. Time series measurements of sediment oxygen uptake (carbon supply) and benthic biomass southwest of St. Lawrence Island, northern Bering Sea.

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# Traditional Ecological Knowledge, Indigenous Observations, and Spatio-temporal Dynamics of Steller Sea Lion Populations along the Western Alaska Peninsula and Eastern Aleutians

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**Herbert D.G. Maschner**  
Idaho State University

**NOAA Goal 1**

Other investigators/professionals funded by this project:

**Katherine L. Reedy-Maschner and Sharon Plager, Idaho State University**

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This project is ongoing.

## **Primary objectives**

The Aleut of the western Alaska Peninsula invited us to conduct studies of the decline in the western Gulf of Alaska Steller sea lion (SSL) that used anthropological and archaeological data—an area of inquiry lacking in all other studies in the region. Our research objectives during this reporting period were:

- Conduct interviews with elder members of the communities of Sand Point, King Cove, False Pass, Akutan and Nelson Lagoon to gather information on long-term changes in the distributions of SSLs, observations on predator–prey interactions, traditional use of SSLs, and other information on SSL ecology to build databases.
- Analyze bones from archaeological sites on the western Alaska Peninsula that span the last 5000 years. This is the largest paleoecological data set in the southern Bering Sea and one in which long-term changes in SSL populations and concomitant species can be documented.

## **Approach/methodology**

Anthropology: Interviews were conducted with fishermen and other local elders and residents of the villages of the Aleutians East Borough. They demonstrated a willingness to share their vast knowledge of their environment. The foci of these interviews were on their observations of SSLs throughout their lives, subsistence hunting and use in previous years, and data on predators and prey.

Archaeology: The Lower Alaska Peninsula Project has conducted ten years of research on the western Alaska Peninsula and Unimak Island. Over 100 ancient village sites spanning the last 6000 years have been documented. Nearly 500,000 sea mammal, bird and fish bones have been collected from deposits in all time periods resulting in the largest paleoecological data set in the southern Bering Sea and north Pacific region. The majority of the faunal data come from five sites on the western Alaska Peninsula and Unimak Island where major excavations have been conducted. Smaller but significant samples come from six other sites scattered around the region. Because of time constraints, many of these faunal remains are unanalyzed; this project is finishing the analysis of these remains. These data are being correlated and compared with paleoclimatic data collected by the project, as well as extensive data provided by Bruce Finney, also funded by NOAA/CIFAR.

## **Research accomplishments/highlights/findings**

Anthropology:

- Aleut people point out that this is not the first time there have been major declines in the numbers of sea mammals in the region. Aleut oral histories mention that significant declines have occurred a number of times in the past.
- Traditional knowledge of local fishermen has demonstrated that the north Pacific ecosystem has undergone a series of disruptions over the last 100 years that appear to be a product of commercial fishing activities.
- While we are still cataloging and summarizing the local knowledge data, and many more interviews are scheduled for the next year, the local people have clearly recognized the complexities of the north Pacific, that these changes are caused by a multitude of causes and that there have been substantial shifts in the marine ecosystem over the last 200 years and that ultimately, the majority of these shifts are ‘natural’.

Archaeology:

- In examining the number of SSL elements in an assemblage, the  $r^2$  is .21 when a correlation is run between distance to the nearest haul out or rookery and percentage of SSLs as a ratio of all seals and sea lions in the assemblage. This suggests that every village had haul outs or rookeries within its harvesting zone, and that the percentage of SSL in the assemblage is a rough measure of their actual density in the region at any one time.
- Based on a sample of our data, the percentages of Steller sea lion in the archaeological samples appears to gradually increase through time. SSL make up approximately 10% of the marine mammal diet from 2500 BC to

AD 500, a period of 3000 years. Over this same time period, phocids, primarily harbor seal, fulfill between 65 and 90% of the diet. Between AD 900 and 1300, there are almost no archaeological samples and those that do exist show that there was a major disruption in the north Pacific ecosystem. Phocids and SSL are almost non-existent and the prehistoric inhabitants of the region had to make a shift to lower ranked species. This is the time period where caribou and sea otters become much more common in the record. This is also the period of oceanic warming and reduced primary productivity.

- After AD 1400, or well into the Little Ice Age, SSL populations rise to levels not seen in the previous 4000 years. The ratio of phocids to SSL in the archaeological middens shifts from approximately 7:1 to approximately 1:1. These data demonstrate that there have been shifts in the abundance of other species as well. The fact that sea otters are notoriously absent from most of the middens except during periods of economic stress, and given the large literature on their economic importance prior to the arrival of the Russians, indicates that they were never very common in the region.
- When we plot the difference from the mean harvest of SSL over 4000 years, we see that during cooler periods, the harvest is greater than average, while during warmer periods the harvest is less than the long-term average. While these climate indicators are general, there does appear to be a trend in the data. We are working to refine the climate proxies at this time through collaboration with Bruce Finney.
- Our archaeological and anthropological analyses have provided data for time scales that are currently not available in any other form of analysis. They demonstrate that the north Pacific and southern Bering seas have been dynamic, volatile, and subject to great fluctuations over the last hundreds to thousands of years. This requires that we evaluate our current models in order to determine where in one of these large cycles we are now positioned.

#### **NOAA relevance/societal benefits**

Anthropology and archaeology contribute to understanding the long-term trends in the distribution of Steller sea lions. These data are important because NMFS has no count or survey data prior to 1959, and no scientifically valid counts prior to the 1970s.

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## **Grain Size Distributions and Organic Carbon Concentrations in TRAWLEX/2002 Sediments, Eastern Bering Sea**

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**Sathy Naidu, PI**  
*University of Alaska Fairbanks*

**NOAA Goal 1**

This project was completed during the reporting period.

#### **Primary objectives**

The primary objective was to analyze the grain size distributions, organic carbon, nitrogen and their stable isotopes ( $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ ) of 72 sediment samples collected from Eastern Bering Sea by Dr. R.A. McConnaughey (NMFS). An additional objective was to submit a brief report providing the highlights of the results of the analyses.

#### **Approach/methodology**

The textural analysis on the sediment samples was by the combined sieve-pipette method, and calculation of the grain size statistical parameters was according to the methods described in Folk (1980). The analyses of the concentrations of organic carbon and nitrogen and determinations of the carbon and nitrogen stable isotope ratios ( $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ ) of carbonate-free sediment samples were based on the methods outlined in Naidu et al. (2000), using a Delta Plus XP isotope ratio mass spectrometer interfaced with a Carlo Erba elemental analyzer (Model NC2500). Statistical analysis was restricted to the determination of correlation coefficients between mud % and organic carbon (C), organic carbon and total nitrogen (N),  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ , and C/N and  $\delta^{13}\text{C}$ .

#### **Research accomplishments/highlights/findings**

The sediment data were tabulated in the Excel format and provided on a disc to Dr. McConnaughey (copy also provided to CIFAR). Generally, the sediments are medium- to well-sorted sands admixed with minor silt and clay and occasional gravel, and with positive- to very positive-skewed size distributions. The concentrations of organic carbon and nitrogen are relatively low for marine shelf sediments, and the  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  and C/N ratios indicate that generally the sediments have a large proportion of marine-derived organic matter.

Significant correlations (at 99% confidence level) were noted between C% and N%, and also the intercept of the regression line close to zero on the Y-axis. These suggest that most of the nitrogen in the sediment is bound to the particulate organic carbon with little, if any, partitioned in the adsorbed phase on clays. The lack of significant correlations between mud% and C% was somewhat surprising, as both fine-sized mud particles and POC tend to get co-deposited. One of the reasons for the lack of positive correlations could be ascribed to the overall low concentrations of mud and a low spread in the contents of mud in all the samples, which makes it difficult to assess the correlations. The other binary plots showing significant correlations were between  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ , which suggest a common source origin for C and N in the sediments investigated. A copy of the Final Report and the sediment tabulated data accompanied by the different binary plots that was submitted to Dr. McConnaughey was also provided to CIFAR.

#### **NOAA relevance/societal benefits**

One of the major research objectives of NOAA's office of National Marine Fisheries Service/Alaska Fisheries Science Center, Seattle is to assess the impact of bottom trawling on benthos in the Bering Sea region. This research is an effort to determine essential fish habitats as mandated by the Magnuson-Stevens Sustainable Fisheries Act. The current project is part of the above program, led by Dr. R.A. McConnaughey (NMFS/AFSC) and in collaboration with Dr. A. Sathy Naidu, IMS/UAF, to investigate the role of sediment granulometry and organic carbon contents in the distribution of benthos prior and subsequent to bottom trawling in Eastern Bering Sea shelf. Naidu's task has been to analyze the sediments for the above two parameters, and through another CIFAR award Dr. S.C. Jewett (IMS/UAF) has been analyzing the benthos taxonomy and abundance.

#### **Research linkages/partnerships/collaborators and networking**

See previous section. Data on sediments and benthos on samples collected simultaneously from the same stations have been collected and analyzed for at least two consecutive years, in conjunction with geophysical (side-scan) surveys of the sea floor, within portions of the Eastern Bering Sea region, prior and subsequent to trawling operations. Plans are to integrate this database and assess the effect of trawling on the benthos. An overall benefit of this collaborative research between UA/NMFS will be to help NOAA/NMFS/AFSC to formulate guidelines to manage effectively bottom fisheries in the Bering Sea.

#### **Education/outreach**

Two UAF graduate students, Mr. Satish Dinakaran and Neil De Cunha, assisted Dr. Naidu in the analyses of the sediment samples. These students were hired on a part-time basis as Laboratory Assistants, but their thesis work was outside the scope of the project work.

#### **Publications**

There are plans to publish results of the investigations following integration of the sediment and benthic data. We hope additional funding will be forthcoming from NOAA/NMFS to collaborate with Dr. McConnaughey in the preparation of a manuscript.

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## **Ecosystem Change in the Northern Bering Sea: Nitrate Sensors on the Mooring and Retrospective Nutrient Analyses**

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**Terry Whittedge, PI**  
University of Alaska Fairbanks

**NOAA Goal 1**

This project is ongoing.

#### **Primary objectives and approach/methodology**

This project investigates the hypothesis that recent anomalous spring and summer productivity on the Northern Bering Sea shelf relates to decadal-scale atmospheric/sea ice/oceanographic processes, which reflect regime-induced climate changes in the western Arctic. Recent work (Grebmeier and Dunton 2002; Cooper et al. 2002) shows that there are hot spots of biological productivity southwest of Saint Lawrence Island, and that this productivity has been decreasing over the past decade. Staben and Overland (2001) report the Bering Sea is shifting to an earlier spring transition based on ice melt and changes in atmospheric circulation patterns. Since changes in the North Pacific Oceans show little long-term trend while the trend in Arctic Oscillation appears to be a clearly increasing climate signal, the northern Bering Sea is an important location to monitor ecosystem change. The combination of these

studies demonstrates the timeliness for increased focus on the ecosystem of the northern Bering Sea. As a result, the following tasks are being undertaken:

- A retrospective analysis of all northern Bering Sea data to put future changes into context and to provide an objective measure for change detection. (Whitledge, Overland and Grebmeier)
- Establishment of a northwest Bering Sea biophysical oceanographic mooring to document continuing changes, similar to the successful multiyear FOCI mooring, M2, on the southeast Bering Sea shelf. (Whitledge and Overland)
- Process studies of the northern biological hot spots, primarily funded by non-NOAA sources. (Grebmeier)

### **Research accomplishments/highlights/findings**

- Mooring Deployment Near SLIP 1 and SLIP 2—In summer 2003, we deployed a subsurface mooring in 80 m of water near SLIP-1 and SLIP-2 in the northern Bering biological hot spot (Region A) through funding by the NOAA/OAR Arctic Research Office. This mooring consists of two seacats and ten microcats to measure profiles of temperature and salinity, one fluorometers (2 instruments were planned to be deployed, but one was not functional at sea) to assess chlorophyll (phytoplankton biomass), two current meters and an ISUS nitrate sensor (Figure 1).
- Historical hydrographic and productivity data from 1970–1990's has been found and is being entered into an electronic format database. Three cruises from 1990–1993 in the northern Bering/Chukchi Sea have been entered to date and the effort will continue during the next year with the capture of data from the 1980's.
- The mooring will be retrieved and a new mooring will be deployed at the same location during July 2004. A new ISUS instrument will be deployed to provide a quick turnaround and deployment of a fully calibrated instrument.
- As mentioned previously, additional hydrographic and productivity data will be placed into an electronic data base and analyzed for possible changes over the past 2–3 decades.

### **NOAA relevance/societal benefits**

Monitoring and assessing the current status and potential change in the northern Bering Sea ecosystem in response to climate change is directly relevant to the goals of the NOAA-supported SEARCH: Study of Environmental Arctic Change multi-agency global change project and similar efforts of the NOAA Arctic Research Office.

### **Research linkages/partnerships/collaborators and networking**

This project is a collaborative effort with Dr. Jim Overland at NOAA/PMEL and Dr. Jackie Grebmeier at the University of Tennessee, Knoxville, to investigate the status and change in the northern Bering Sea ecosystem. It is directly related to the SEARCH project to investigate potential impacts of climate change on the marine ecosystem and goals of the international Pacific Arctic Group (PAG).

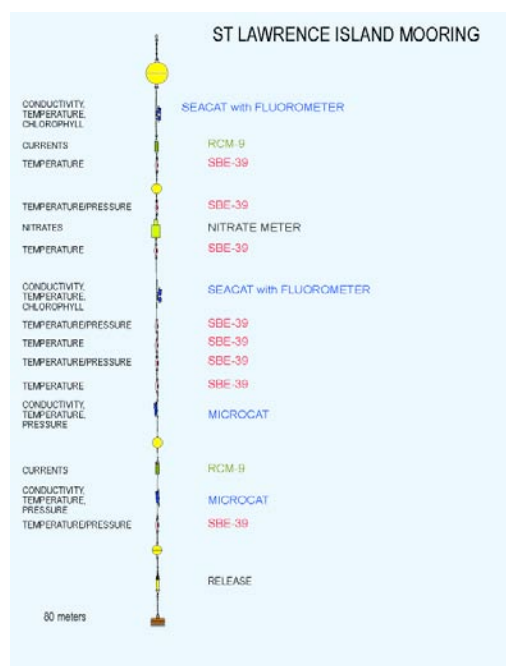


Figure 1. Mooring deployed on 14 July 2003 at 62.08N and 174.99W at the 82 m isobath.



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## Continuation of Observations on the Bering Sea Shelf: Biophysical Moorings at Site 2

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**Terry Whittedge, PI**  
University of Alaska Fairbanks

**NOAA Goal 1**

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This project is ongoing.

### **Primary objectives**

This research continued biophysical measurements at mooring site 2 and collected samples along the southeast Bering Sea transect. Mooring Site 2 has been maintained almost continually since 1995, and provides the longest near continuous time-series of biophysical variables on the Bering Sea shelf. Long-term observations provide critical data that allow comparisons among habitats and years, characterizations of interannual variability, quantification of regime shifts and climate change, and a database necessary for model simulations. Data from the moorings and transects have provided the basis for a number of advancements in our understanding of how the Bering Sea shelf functions, and resulted in over a dozen publications and many more presentations.

The objectives of our project are twofold:

- to continuously monitor the temporal variability of biophysical properties over the southeast Bering Sea ecosystem using moorings and shipboard measurements;
- making results available via the world wide web for all end users, including scientists, managers, industry, educators, students and the general public.

### **Approach/methodology**

Wet chemical (NAS) and optical (ISUS) sensors are integrated into the PMEL biophysical mooring.

### **Research accomplishments/highlights/findings**

Moorings Deployment and Recovery Cruises

<b>Instrument</b>	<b>Deployment Date</b>	<b>Vessel</b>	<b>Location</b>	<b>Data</b>
NAS#2240	March 2003	Miller Freeman	M2	partial
NAS#2266	May 2003	Miller Freeman	M2	good
ISUS #21	28 September 2003	Miller Freeman	M2	good
NAS#2302	28 September 2003	Miller Freeman	M4	instrument flooded
NAS#2266	28 April 2004	Miller Freeman	M2	
NAS#2236	28 April 2004	Miller Freeman	M4	

NAS instrument (#2240) was deployed from Miller Freeman at M2 mooring site in March 2003 and was subsequently recovered in May 2003. Nitrate data was successfully recovered for the period of 4–15 March 2003 when the reagents did not dispense and no further data was collected. The moorings at M2 and M4 were redeployed in May 2003 with NAS instruments #2266 and #2302 and were recovered in September 2003 with excellent data for the entire period of approximately five months at M2 but no data at M4. An In Situ Ultraviolet Spectrometer (ISUS) #21 was deployed at M2 on 28 September 2003 and recovered in April 2004 with full data. NAS #2266 was deployed at the M2 site on 28 April 2004 and will be recovered in October 2004. NAS#2236 was deployed at the M4 site and will be recovered in October 2004.

### **NOAA relevance/societal benefits**

The biophysical moorings at the M2 and M4 sites are the only long term observations (1995–2004) that have been collected continuously in this important fishing area. The data have been provided to numerous scientists and resource managers for use in both applied and basic research studies. Additional sensors are being considered to broaden the range of variables that can be monitored, including large marine mammals.

### **Research linkages/partnerships/collaborators and networking**

This work is being done in collaboration with Phyllis Stabeno and Jeff Napp, NOAA/PMEL.

### **Publications and presentations**

(partial list of reports and manuscripts that use the M2/M4 data)

- Kachel, N.B., G.L. Hunt, S.A. Salo, J.D. Schumacher, P.J. Stabeno and T.E. Whitledge. 2002. Characteristics and variability of the inner front of the southeastern Bering Sea. *Deep-Sea Research II* 49:5889–5909.
- Stabeno, P.J., N.B. Kachel, J.D. Schumacher and T.E. Whitledge. 2002. Variability of physical and chemical characteristics along the 70 meter isobath of the southeastern Bering Sea. *Deep-Sea Research II* 49:5931–5943.
- Whitledge, T.E. Investigations of biophysical origins for continental shelf production. Invited Seminar to Monterey Bay Aquarium Research Institute, Moss Landing, CA, 26 May 2004.
- Whitledge, T.E. Nutrient and phytoplankton dynamics in the SE Bering Sea for the past five years. Invited Seminar for Graduate School of Fisheries Sciences, Hokkaido University, Hakodate, Japan, 30 January 2003.
- Whitledge, T.E. Nutrient and phytoplankton dynamics in the SE Bering Sea for the past five years. Seminar for Graduate School of Environment and Earth Science, Hokkaido University, Sapporo, Japan, 28 January 2003.
- Whitledge, T.E., S. Saitoh, N. Tanaka, H. Enomoto, K. Shin, C.P. McRoy, L. McNutt, J. Wang and T. Weingartner. Marine ecosystem and geochemical dynamics of climate-related substances in sub-arctic marginal seas and the Arctic Ocean. Hokkaido University–University of Alaska Fairbanks Joint Workshop on Establishment of Future Joint Research Collaboration in 2003, Sapporo, Japan, 27 January 2003.
- Whitledge, T.E., P. Stabeno and J. Napp. Keeping mooring 2 alive: continuing long-term biophysical measurements over the southeastern Bering Sea shelf. Marine Science in the Northeast Pacific: Science for Resource Dependent Communities, Anchorage, AK, January 2003.

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## **Living Marine Resources Graduate and Postgraduate Fellowship**

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**Denis Wiesenburg, PI (formerly Charles Hocutt)**  
*University of Alaska Fairbanks*

**NOAA Goal 1**

Other investigators/professionals funded by this project:

**Chris Siddon, postdoctoral fellow, University of Alaska Fairbanks**

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This project is ongoing.

### **Primary objectives**

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. To help meet these goals, the School of Fisheries & Ocean Sciences, University of Alaska Fairbanks, entered into an agreement in FY 03 with NMFS's Alaska Fisheries Science Center to provide training to graduate students and postgraduates, as well as advanced research on issues affecting the sustainability of the Steller sea lion (SSL) in the northeast Pacific Ocean and Bering Sea. This program is funded through the Cooperative Institute for Arctic Research (CIFAR).

### **Approach/methodology**

- A 2-year Ph.D. fellowship was awarded to Pieter deHart in January 2003. He has completed two semesters of training in courses related to his research project; his project forms part of his Ph.D. research.
- Chris Siddon commenced a 2-year Research Associate (postdoctorate) appointment in September 2003, upon successful completion of the Ph.D. requirements at Brown University. His research is being conducted in affiliation with Dr. Terry Quinn.

The causes for decline in Steller sea lion (SSL) populations in the North Pacific region over the past 30 years remain unknown, despite substantial advances in understanding the ecology and functioning of the system. deHart is studying this decline using both a historical and modern perspective. deHart 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.

Chris Siddon is studying the cause:effect relationship between food availability and predation vs. population decline in the SSL. He is employing stage-class population modeling, which has been widely utilized to address the management and recovery of threatened or endangered species. Siddon is testing (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.

### **Research accomplishments/highlights/findings**

deHart collected 120 osteological (mandible) samples from the National Marine Mammal Laboratory (NMML) archived collection. The samples are from SSL throughout their range from Russia to Northern California over a 55-year period. Data from samples included size, age, sex, and location. All samples were extracted for their bone collagen and analyzed for their stable isotope composition. Rather than a uniform isotopic composition,  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values in SSL populations vary greatly according to the location and year the animal was sampled ( $\delta^{13}\text{C} = -17$  to  $-11\text{‰}$ ;  $\delta^{15}\text{N} = 14$  to  $22\text{‰}$ ), with signatures indicative of their home range and feeding source. Lower  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values in SSL from more western areas could be the result of consuming lower trophic level fish species. Additionally, both  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values decrease temporally, correlating with the multi-decadal span of this population decline. deHart plans to target teeth samples in his follow up research, since the NMML collection of teeth can provide greater temporal and spatial resolution compared with the currently processed bone samples.

Siddon has made significant progress on each of his three approaches (population modeling, experimental manipulation in a model system, and short-term movement behavior of SSL). *SSL census data/matrix modeling initiated*: SSL census data was acquired from the NMML and examined for spatial and temporal patterns to be incorporated into population models. Exercises in matrix population modeling, inverse matrix models, and density-dependent models are ongoing. *Site selection, natural history data for LTRE*: The Life Table Response Experiment (LTRE) designed to explicitly test the importance of carrying capacity and predation on the vital rates in a model system has begun. In addition, experimental field sites are being assigned and initial tagging studies have commenced. The experimental setup will be completed by mid June and data collection will continue through Summer 2005. *Collaboration with UBC on SSL movement*: Contact with UBC post-doctoral researchers was initiated during Fall 2003 and Spring 2004, and will continue in order to combine their tagging data and movement modeling techniques to address temporal changes in movement behavior of SSL in Southeast Alaska..

### **NOAA relevance/societal benefits**

The benefits of this program relate to the increase in the number of trained scientists available to study problems of interest to NOAA, and an increased understanding of the decline in Steller sea lion populations.

### **Research linkages/partnerships/collaborators and networking**

This program is an example of collaboration between NOAA and the University of Alaska Fairbanks in the training of young scientists.

### **Education/outreach**

Pieter deHart, Ph.D. candidate, is supported by this award.

### **Presentations:**

deHart, P.A.P. and M.J. Wooller. 2004. A multi-organismal isotopic study of north Pacific and Bering Sea marine mammals: responses to a changing environment. Isotopes in Ecological Research Meeting. April 2004. Wellington, New Zealand.

deHart, P.A.P. and M.J. Wooller. 2004. Mammalian responses to a changing environment: an isotopic study of Steller Sea Lions. American Society of Mammalogy conference. June 2004. Arcata, California.

## ***Tsunami Research***

### **Alaska Tsunami Inundation Mapping Project**

**Roger Hansen, PI**  
*University of Alaska Fairbanks*

**NOAA Goal 1, (4)**

Other investigators/professionals funded by this project:

**Elena Suleimani and Duncan Marriott, University of Alaska Fairbanks**  
**Rod Combellick, State of Alaska Division of Geological and Geophysical Surveys**

This project is ongoing.

#### ***Primary objectives and approach***

The Geophysical Institute/Alaska Earthquake Information Center participates in the National Tsunami Hazard Mitigation Program (NTHMP) by evaluating and mapping potential inundation of selected parts of Alaska coastlines using numerical modeling of tsunami wave dynamics. The communities are selected for inundation modeling in coordination with the Division of Homeland Security and Emergency Management (DHSEM) with consideration to location, infrastructure, availability and quality of bathymetric and topographic data, and community involvement. Kachemak Bay and Prince William Sound are high-priority regions for Alaska inundation mapping. They have several communities with significant population and extensive fishing resources (Homer, Seldovia, Seward, Valdez). Emergency managers need tsunami evacuation maps for these communities, showing the extent of inundation with respect to human and cultural features, and evacuation routes.

#### ***Research accomplishments/highlights/findings***

- We have completed inundation modeling and mapping for the communities of Homer and Seldovia in Kachemak Bay, Alaska. The report (see Publications) is currently in the review process. It includes tsunami hazard maps for Homer and Seldovia that show the extent of inundation resulting from the “worst case scenario,” which is the maximum inundation of the modeled scenarios. It also includes inundation maps that present inundation lines calculated for two different hypothetical tsunami scenarios. Numerical simulations yield runup heights, depths of inundation on dry land, and maximum velocities in the inundation zones.
- We continue to work on the Seward inundation mapping project. We performed numerical calculations for three of the six hypothetical tsunami scenarios in Resurrection Bay. The results show that the destructive waves of the 1964 Alaska tsunami in Seward were generated by the sea floor displacements in the Prince William Sound asperity of the 1964 rupture zone.
- We obtained the raw, high-resolution multi-beam bathymetry data from the 2002 NOAA survey of Resurrection Bay, with a grid spacing of approximately 4.5 meters. This dataset had many holes and did not reach to the coastline. To create a smooth surface for bathymetry analysis, we created a tin using these elevations points along with a high-resolution coastline to interpolate and fill the regions of no data. Using this dataset, we created a smooth surface model of the seafloor in order to inspect the current morphology for evidence of past submarine landslides. To facilitate close analysis of the regions of interest, small subsections of the resulting grid adjacent to the coastline were clipped out and used to make detailed shaded three-dimensional relief plots for visual inspection. These regions included the coastal areas stretching from south of Lowell Point around Resurrection Bay to south of Fourth of July Creek.
- We have begun to examine submarine landslide features in Resurrection Bay near Seward, Alaska. We have studied 3D bottom topography near Seward, and identified features suggesting that a small part of the seaward portion of the post-glacial delta underlying Seward collapsed during the 1964 earthquake, generating a tsunami. Our preliminary work shows that we can identify the scarp and the extent of the submarine slide from the DEM image. We have also identified several smaller slide scarps near the large slide, suggesting the tsunami generation mechanism was complex and involved more than one submarine slide.
- We continue to work on the 3-D numerical model for the waves generated by underwater landslides, expanding the model to include the subaerial component of the landslide.

#### ***NOAA relevance/societal benefits***

These activities all pertain to the National Tsunami Hazard Mitigation Program with NOAA’s Weather Service.

### **Research linkages/partnerships/collaborators and networking**

Collaborations for this work include the Alaska Division of Geological and Geophysical Surveys, the Alaska Department of Emergency Services, the Alaska Tsunami Warning Center, and the Pacific Marine Environmental Laboratory of NOAA in Seattle.

### **Education/outreach**

- Investigators visited Alaska communities in cooperation with the NOAA tsunami warning center and the Alaska State Emergency Services offices.
- Results of this work form much of the basis for the award-winning video *Ocean Fury: Tsunamis in Alaska*, produced in spring 2004 by Alaska Sea Grant with the Alaska Earthquake Information Center and the Alaska Division of Homeland Security and Emergency Management.

### **Publications**

Suleimani, E.N., R.A. Combellick, D. Marriott, R.A. Hansen, A.J. Venturato and J.C. Newman. Tsunami Hazard Maps of the Homer and Seldovia areas, Alaska. Alaska Division of Geological and Geophysical Surveys Report of Investigations. In the review process.

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## **Alaska Earthquake Information Center Seismic Station Upgrade and Installation**

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**Roger Hansen, PI**

*University of Alaska Fairbanks*

**NOAA Goal 1, (4)**

Other investigators/professionals funded by this project:

**Steve Estes, Martin LaFevers, Josh Stachnik, Ed Clark, Otina Fox, John MacCormack and Natalia Ratchkovski, University of Alaska Fairbanks**

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This project is ongoing.

### **Primary 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. FY2004 has proven to be very productive toward these goals.

### **Installations and Maintenance**

A total of 7 new installations were completed during the current reporting period. This includes 5 new seismic stations and 2 remote communications sites:

DCPH - Updated the communication antennas for better data transmission.

NIKO - Seismic station on Umnak Island near the village of Nikolski was vandalized. Site visit to repair.

PPLA - Seismic station southwest of Mt. McKinley failed. Site visit to swap out equipment and re-establish

BESE - Installation for a new station north of Juneau, Alaska. Co-located with the AT&T site on Bessie Mountain, utilizing their power and phone services for FTS circuit.

COLD - Installation of a new station near Coldfoot, Alaska.

DOT - Augmented an existing station with a borehole vault with downhole broadband and uphole strong motion.

PAX - Upgraded and hardened existing seismic vault with broadband and strong motion system. Established digital communications link through co-located AT&T site with FTS circuit.

Minchumina - Communications hub to receive data from PPLA and place on dedicated intranet via FTS circuit. Added a standalone seismic station and upgraded receive antennas.

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

Dot Lake - Communications hub to receive data from DOT and place on the GCI School Access internet at the Dot Lake school. Education and Outreach opportunity with school teachers.

Coldfoot - Communications hub to receive data from COLD and place on the FTS phone circuit. Co-located with the Park Service and BLM presence in Coldfoot.

GAMB - Site visited, seismometer placed into borehole and leveled, Communication through local school hardened. Strong motion instrument swapped out.

DIV - Site visit as the receive site for BMR.

BMR - Inspect seismometer and digitizer replaced a year ago due to malfunction.

NIKO - Site visited and vandalism found. Spare equipment sent, and installed.

PIN - Bad equipment replaced with spare seismometer, comm radio, and improved yagi antenna. Site functional.

SWD - Site visited twice due to power difficulties in the community. Modem reprogrammed. Site functional.

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 NOAA tsunami warning centers, the USGS, and the IRIS Data Management Center for further sharing of the data with the University community.

#### **NOAA relevance/societal benefits**

Improved detection of tsunamigenic earthquakes by AEIC and NOAA tsunami warning centers.

#### **Research linkages/partnerships/collaborators and networking**

Partnerships and collaborators include the NOAA tsunami warning centers, the state of Alaska emergency services offices, the USGS, and other regional seismic centers. Improved detection, location, and magnitude are available from large earthquakes in the vicinity of Alaska and the greater tsunamigenic regions of the Pacific Ocean.

#### **Education/outreach**

Education and Outreach activities included the publication of “The Next Big Earthquake in Alaska” Pamphlet included in local newspapers throughout Alaska on the anniversary date of the 1964 Great Alaska Earthquake.

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

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**David L. Musgrave, PI**  
*University of Alaska Fairbanks*

**NOAA Goal 1, (4)**

This project is ongoing.

#### **Primary objectives**

- 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.

#### **Approach/methodology**

We proposed to install a high frequency ocean surface current radar system (CODAR Ocean System’s Seasonde) to map the surface velocity field at a resolution of ~3km at 3/times hour. The viewing field would cover approximately 80 km (subject to environmental constraints).

#### **Research accomplishments/highlights/findings**

Based on approval from Dr. Eddie Bernard (PMEL/NOAA) we tested the HF radar not southwest of Kodiak Island as originally proposed but in Cook Inlet with a field of view down Shelikof Strait. We were particularly interested in the range of the HF radar and interference from ionospheric effects. We found negligible interference and the range was about 170 km, of that suggested by the manufacturer of the HF radar.

In June 2004, we deployed two HF radar systems at Rugged and Middleton Island to test the field of view from each location and to prepare logistically for a full deployment at these locations in 2005. Fortuitously, we obtained 360 degrees of radial velocities over a distance of about 160 km from Middleton Island.

We obtained overlapping radial velocities at both sites and were able to combine these into two-dimensional surface velocities in the outer coast of Southcentral Alaska.

#### **NOAA relevance/societal benefits**

NOAA has long had interest in the physical oceanography and marine ecosystem on the shelf of Alaska. The data collected next year in the full deployment will help determine the spatial and temporal variability of the currents in the Gulf of Alaska.

### **Research linkages/partnerships/collaborators and networking**

This work has already garnered the interest of the Alaska Ocean Observing System (AOOS) and we expect that continued operational funds for the maintenance of the systems will be forthcoming from AOOS.

## **UV and Arctic Haze Studies**

### **Long Term Trends and Spatial Variability in Arctic Haze at Four Sites in Western Alaska**

**Glenn E. Shaw, PI**  
*University of Alaska Fairbanks*

**NOAA Goal 2**

This project is ongoing.

#### **Primary objectives**

The main objective of this project is to assess the long-term trends in Arctic Haze and ascertain the cause of the observed trends by continuing measurements of aerosol chemical composition at four Alaskan sites at Barrow, Poker Flat, Denali Park and Homer in the Gulf of Alaska. In recent years we are seeing evidence of pollution from Asian sources reaching Alaska, around late spring at a time of large dust-storms in China and the Gobi Desert areas.

Our goal is generally to combine the chemical information with meteorological information to determine how sources of the pollution reaching Alaska change on inter-seasonal to inter-annual time scales.

#### **Approach/methodology**

In 2001/2002 the network's ability to discriminate different far-away pollution sources was improved by installing impactors to size select submicron aerosols. These fine particles have long residence times in the atmosphere.

At Barrow, the submicron samples are collected daily. At the other three sites, atmospheric samples are collected on a weekly basis. Samples are analyzed for major anions (chloride, nitrate, sulfate, and methanesulfonate) and cations (sodium, ammonium, potassium, magnesium, and calcium).

Information about sources of aerosol to Western Alaska can be ascertained from the chemistry. For example, methanesulfonate has a purely biogenic source and follows local biological productivity, peaking strongly in summer. Sulfate and nitrate are primarily produced through anthropogenic combustion processes. Sodium serves as a tracer for sea salt, magnesium and calcium as tracers for dust, and potassium as a tracer for biomass burning.

#### **Research accomplishments/highlights/findings**

- This year we have maintained the sampling network with almost 100 percent collection at the four stations. (This was in spite of the fact that we continue to have problems with air pumps: they are heavily stressed pulling 30 liters per minutes of air through a half atmosphere pressure differential. The pumps have failed in ways ranging from bearings burning out to pump casings being worn through. We are presently conferring with GAST engineers trying to understand why this batch of pumps has had so many problems. It is hoped that we can purchase more reliable pumps in the near future: down time in our sampling network has primarily been caused by pumps failing.)
- Alaska has been plagued with extreme forest fires during the summer of 2004 and we expect to be able to use the chemical composition from the collected aerosol smoke from these fires as a basis to establish a chemical fire fingerprint for use in identifying long range imported smoke from fires that sometimes burn in Siberia and southern Eastern Russia.
- We have carried out measurements of the aerosol size distribution at the Poker Flat Research Range during the spring and summer of 2004 in order to help establish knowledge of the size modes from imported aerosols to Alaska.

#### **NOAA relevance/societal benefits**

Alaska's air is polluted from Arctic Haze and is episodically contaminated from dust mixed with industrial air pollution from the Orient. China's economy and attendant air pollution is rapidly growing. This study assesses long-term trends and ascertains the cause of the observed trends.

***Research linkages/partnerships/collaborators and networking***

This work is done in collaboration with Dr. Patricia Quinn of NOAA/PMEL, with additional assistance from the following individuals:

- Andrea Blakesley of the National Park Service operates the sampling station at Denali Park.
- Dr. Scott Pegau of the Kachemak Bay Research Reserve and NOAA operates the sampling station at Homer.
- John Ray of the National Park Service has helped maintain a meteorological system at the Poker Flat Research Station.

***Education/outreach***

A number of scientists and students have visited the air sampling site at Poker Flat in the past year.

***Publications***

A publication summarizing trends and chemical signatures is under preparation.



# **Appendix 1**

**Projects awarded during the third year of CIFAR Cooperative Agreement  
NA17RJ1224 (1 July 2003–30 June 2004)**

**CIFAR Projects Awarded  
1 July 2003 – 30 June 2004**

Last	First	Institution	Proposal Title	Proposal Budget	Subaward F&A	Total Award	Research Theme	Funding Source
<b>Amendment 7</b>								
Hansen	Roger	UAF	Alaska Earthquake Information Center Seismic Station Upgrade and Installation	\$ 269,400	n/a	\$ 269,400	Tsunami Research	OAR
Jewett	Stephen	UAF	Effects of Bottom Trawling on Bering Sea Infauna	\$ 51,507	n/a	\$ 51,507	Fisheries Oceanography	NMFS
Naidu	A. Sathy	UAF	Grain Size Distributions & Organic Carbon Concentrations in TRAWLEX/2002 Sediments, Eastern Bering Sea	\$ 21,885	n/a	\$ 21,885	Marine Ecosystems	NMFS
<b>Subtotal Amendment 7</b>				\$ 342,792		\$ 342,792		
<b>Amendment 8</b>								
Bromwich	David	Ohio State University	Initiation of Arctic Reanalysis Activity in SEARCH	\$ 140,000	\$ 12,600	\$ 152,600	Climate Modeling	OAR
Francis	Jennifer	Rutgers University	Correction of Systematic Errors in TOVS Radiances	\$ 102,000	\$ 12,600	\$ 114,600	Atmospheric Climate	OAR
Gradinger	Rolf	UAF	Activity and Diversity of Sea Ice Biota in the Chukchi and Beaufort Seas	\$ 36,200		\$ 36,200	Marine Ecosystems	OAR
Grebmeier	Jackie	Univ. Tennessee	Ecosystem Change in the Northern Bering Sea	\$ 154,400	\$ 12,600	\$ 167,000	Marine Ecosystems	OAR
Hansen	Roger	UAF	Alaska Tsunami Inundation Mapping Project	\$ 186,000		\$ 186,000	Tsunami Research	OAR
Reiersen	Lars-Otto	AMAP	Arctic Monitoring and Assessment Programme (AMAP)	\$ 50,000		\$ 50,000	Contaminant Effects	OAR
Shaw	Glenn	UAF	Long-Term Trends & Special Variability in Arctic Haze at Four Sites in Western Alaska	\$ 49,900		\$ 49,900	UV and Arctic Haze	OAR
Weingartner	Thomas	UAF	ALPHA HELIX for 2003/04 GLOBEC	\$ 385,560		\$ 385,560	Fisheries Oceanography	NOS
Weller	Gunter	UAF	CIFAR Task I: Administration (Year 3)	\$ 100,000		\$ 100,000	Administration	OAR
Weller	Gunter	UAF	CIFAR Task I: Administration Supplement	\$ 10,000		\$ 10,000	Administration	OAR
Whitledge	Terry	UAF	GLOBEC-NEP: Topographic Control of Mesoscale Variability in the Gulf of Alaska	\$ 134,545		\$ 134,545	Fisheries Oceanography	NOS
Whitledge	Terry	UAF	Ecosystem Change in the Northern Bering Sea: Nitrate Sensors on the Mooring and Retrospective Nutrient Analysis	\$ 202,900		\$ 202,900	Marine Ecosystems	OAR
<b>Subtotal Amendment 8</b>				\$ 1,551,505	\$ 37,800	\$ 1,589,305		

**Amendment 9**

<b>Adkison</b>	<b>Milo</b>	<b>UAF</b>	Relationship Between Growth and Survival of Coho Salmon Utilizing the Coastal Gulf of Alaska	\$	38,191		\$	38,191	Fisheries Oceanography	NMFS
<b>Adkison</b>	<b>Milo</b>	<b>UAF</b>	Early Marine Growth and Survival of Bristol Bay Sockeye Salmon Smolt	\$	10,563		\$	10,563	Fisheries Oceanography	NMFS
<b>Gharrett</b>	<b>A.J.</b>	<b>UAF</b>	Population Structure in Alaskan Pacific Ocean Perch ( <i>Sebastes alutus</i> ), Phase III	\$	24,997		\$	24,997	Fisheries Oceanography	NMFS
<b>Gharrett</b>	<b>A.J.</b>	<b>UAF</b>	Species Composition and Spatial Distribution of GOA and BS Young-of-the-Year Rockfish Species. Phase I	\$	50,000		\$	50,000	Fisheries Oceanography	NMFS
<b>Norcross</b>	<b>Brenda</b>	<b>UAF</b>	Feasibility to Design and Implement a Nearshore Juvenile Flatfish Survey-Eastern Bering Sea	\$	50,000		\$	50,000	Fisheries Oceanography	NMFS
<b>Quinn II</b>	<b>Terrance</b>	<b>UAF</b>	University of Alaska Fairbanks Graduate Student Stipend for Stock Assessment Training and Improvement	\$	72,000		\$	72,000	Fisheries Oceanography	NMFS
<b>Shirley</b>	<b>Thomas</b>	<b>UAF</b>	Movement of Primiparous Female Tanner Crabs: Spatial Dynamics of Tanner Crab Recruitment	\$	16,664		\$	16,664	Fisheries Oceanography	NMFS
<b>Walsh</b>	<b>John</b>	<b>UAF</b>	Initiation of an Arctic Reanalysis Activity in SEARCH	\$	212,200		\$	212,200	Climate Modeling	OAR
<b>Whitledge</b>	<b>Terry</b>	<b>UAF</b>	Continuation of Observations on the Bering Sea Shelf: Biophysical Moorings at Site 2	\$	42,836		\$	42,836	Marine Ecosystems	Other Agency
<b>Subtotal Amendment 9</b>				\$	517,451		\$	517,451		
<b>Grand Total</b>					<b>\$ 2,411,748</b>	<b>\$ 37,800</b>		<b>\$ 2,449,548</b>		



# **Appendix 2**

## **Publication Activity**



## Appendix 2. Publication activity.

### *Work that was published, accepted, or in press during the reporting period.*

- Ammann, E. 2004. Agonistic Behavior, Social Dominance, and Predator Evasion of *Oncorhynchus mykiss* from Lake and Stream Parents. An Evaluation of Lacustrine Refuges as a Conservation Strategy for Threatened or Endangered Salmonids. MS Thesis, University of Alaska Fairbanks. vii + 78pp.
- 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. *Journal of Geophysical Research*, in press.
- Cook, E. 2003. Multi-proxy reconstructions of the North Atlantic Oscillation (NAO) index: A critical review and a new well-verified winter NAO index reconstruction back to AD 1400. In: J.W. Hurrell, Y. Kushnir, G. Ottersen and M. Visbeck, eds. *The North Atlantic Oscillation: Climatic Significance and Environmental Impact* (Geophysical Monograph 134), pp. 63–79. American Geophysical Union, Washington, DC.
- Coyle, K.O. Zooplankton distribution, abundance and biomass relative to water masses in eastern and central Aleutian Island passes. Accepted for *Fisheries Oceanography*.
- Herrmann, M., J. Greenberg, C. Hamel and H. Geier. 2004. Regional Economic Impact Assessment of the Alaska Snow Crab Fishery Integrated with an International Snow Crab Market Model. UAF School of Management Working Series Report 2004-001. 338 pp.
- Ling, F. and T. Zhang. 2003. Numerical simulation of permafrost thermal regime and talik development under shallow thaw lakes on the Alaskan Arctic Coastal Plain. *Journal of Geophysical Research*, 108(D16), 4511, doi:10.1029/2002JD003014.
- Ling, F. and T. Zhang. 2004. A numerical model for surface energy balance and thermal regime of the active layer and permafrost containing unfrozen water. *Cold Regions Science and Technology*, 38:1–15.
- McBeath, J. 2004. Greenpeace v. National Marine Fisheries Service: Steller Sea Lions and Commercial Fisheries in the North Pacific. *Alaska Law Review*, June 2004, Vol. XXI, No. 1, pp. 1–42.
- McBeath, J. Management of the Commons for Biodiversity: Lessons from the North Pacific. *Journal of Marine Policy*, in press.
- McBeath, J. Science and Politics in Marine Mammal Conservation. *Journal of Wildlife Law and Policy*, in press for publication in August 2004.
- Serreze, M.C., A. Barrett and F. Lo. Northern high latitude precipitation as depicted by atmospheric reanalyses and satellite retrievals. *Monthly Weather Review*, in press.
- Thorne, R.E., G.L. Thomas and M. Foster. 2003. Application of combined optical and acoustic technologies for fisheries and marine mammal research in Prince William Sound and Kodiak, Alaska. Proceedings Ocean 2003 MTS/IEEE, Holland Publications, Escondido, CA.
- Thorne, R.E. Acoustic surveying of pelagic fish in shallow water. Proceedings IGARSS04. IEEE Publications, Escondido, CA, 4 pp., in press.
- Wessel, M. 2004. Variation of Agonistic Behavior and Morphology among Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) of Hatchery, Wild, and Hybrid Origin under Common Rearing Conditions. MS Thesis, University of Alaska Fairbanks. vii + 81pp.
- Yang, D., D. Robinson, Y. Zhao, T. Estilow and B. Ye. 2003. Streamflow response to seasonal snowcover extent changes in large Siberian watersheds. *Journal of Geophysical Research*, 108(D18), 4578, doi: 10.1029/2002JD003149.
- Ye, H., D. Yang, T. Zhang, X. Zhang, S. Ladochy and M. Ellison. 2004. The impact of climatic conditions on seasonal river discharges in Siberia. *Journal of Hydrometeorology*, 5(4):286–295.
- Ye, B., D. Yang and D. Kane. 2003. Changes in Lena River streamflow hydrology: human impacts vs. natural variations. *Water Resources Research* 39(7), 1200, doi: 10.1029/2003WR001991.
- Ye, H., D. Yang, X. Zhang and T. Zhang. 2003. Connections of Yenisei River discharge to sea surface temperatures, sea ice, and atmospheric circulation. *Journal of Geophysical Research*, 108(D24), 4776, doi:10.1029/2003JD003759.

### *Summary table of publications during the current cooperative agreement*

	JI Lead Author			NOAA Lead Author			Other Lead Author		
	FY02	FY03	FY04	FY02	FY03	FY04	FY02	FY03	FY04
Peer-reviewed	0	8	5	0	0	0	0	4	3
Non Peer-reviewed	0	1	4	1	0	0	0	1	0





# **Appendix 3**

## **Students**



### **Appendix 3. Students.**

Many of the proposals funded through CIFAR involve graduate and undergraduate students. Thirty-two students (30 graduate; 2 undergraduate), as well as one postdoctorate, were supported in full or in part by the research projects covered in this report or by Task I funds. This includes 5 students supported by the Graduate Student Stipend for Stock Assessment Training and Improvement award from the Alaska Fisheries Science Center (AFSC/NMFS) that provides training for M.S. and Ph.D. students in quantitative fisheries sciences. In addition, many other students benefited from being involved in the research projects, e.g., through sample/data collection and data analysis, even though they did not receive direct salary support through CIFAR.