Annual Report

1 July 2004–30 June 2005

Year 4 of Cooperative Agreement NA17RJ1224

CIFAR

Cooperative Institute for Arctic Research
University of Alaska Fairbanks

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

1 July 2004–30 June 2005

Progress reported during Fiscal Year 2005

(including some activity that occurred in but was not reported during previous periods)

September 2005
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Cover photo courtesy of Bodil Bluhm and Katrin Iken, taken during the RUSALCA cruise. The trawl catch pictured was collected on the northern Chukchi Sea shelf at 70°46'16" N and 175°30'38" W in 70 m water depth, near the mouth of Harald Canyon to the east of Wrangell Island. The fauna includes small snow crab (Chionoecetes opilio), brittle stars (Ophiura sarsi), the predatory moon snails (Natica clausa), truly Arctic sea stars (Ctenodiscus crispatus) and infaunal clams.

Report layout and production by Barb Hameister, CIFAR.

Overview

The Cooperative Institute for Arctic Research (CIFAR) was established through a Memorandum of Understanding between NOAA and the University of Alaska in April 1994. It is one of thirteen national NOAA–University cooperative 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) and to conduct research relevant to NOAA's mission as encompassed in our research themes. CIFAR is the only cooperative institute exclusively concerned with arctic research and cooperates with NOAA's Pacific Marine Environmental Laboratory (PMEL) in Seattle, the NOAA Arctic Research Office, the National Weather Service (NWS), and Alaska Fisheries Science Center (NOAA/National Marine Fisheries Service, NMFS) through the Auke Bay Laboratory. Future plans include expanding our collaborations with NOAA through new integrated initiatives addressing regional needs as prioritized by the CIFAR Fellows.

CIFAR is staffed by four people: Dr. John Walsh, Director; Dr. Susan Sugai, Associate Director; Sherry Lynch, financial administrator; and Barb Hameister, publications and meetings manager. Susan Sugai became associate director on 13 December 2004, a position formerly held by Dr. Patricia Anderson, who had been the associate 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 do not 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. CIFAR also provides an important mechanism for facilitating research collaboration between University of Alaska Fairbanks (UAF) scientists and other NOAA line offices, such as National Ocean Service (NOS), NWS, and 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 • *Arctic Oscillation* • *Arctic clouds and energy balance* • *Paleoclimates* Marine Ecosystem Studies • *Southeast Bering Sea Carrying Capacity (SEBSCC)* • *Bering Sea productivity* Tsunami Research	Climate Modeling • *Coupled models* • *Model inter-comparisons* Fisheries Oceanography • *Global Ocean Ecosystem Dynamics Program (GLOBEC)* • *Fisheries studies* Contaminant Effects • *Arctic pollution* • *Effects on indicator species*	UV and Arctic Haze Studies • *Ozone and UV radiation* • *Arctic Haze* Hydrographic and Sea Ice Studies • *Sea ice research* • *Tides and currents* • *Ocean fluxes and circulation* Data Archiving and Support

NOAA Mission Goals

CIFAR research addresses all four of NOAA's mission goals enumerated in the NOAA Strategic Plan. Each individual project report identifies 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 2004 to 30 June 2005, funding for CIFAR administration and 24 research projects was provided in Amendment 10 for a total of $3.99 M. Seven Task II projects were competitively funded as the result of the Russian–American Long-term Census of the Arctic (RUSALCA) request for proposals, while the remaining 17 are CIFAR Task III, i.e., projects funded individually by NOAA. Task II and III research projects funded in the current year address 6 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 three 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 the National Science Foundation (NSF) and NOAA.

Table 1: Summary of Projects Funded 1 July 2004–30 June 2005: By Task and Theme

Theme	No. of Research Projects	Total Amount	Subtotals by Task	Percent of Total (rounded)
Administration (Task I)			$157,200	**3.9%**
• Core Support		$110,000		2.8%
• Subaward fees (and F&A change)		$25,200		0.6%
Arctic Climate Impact Assessment		$22,000		0.6%
Research Themes (Task II)			$463,858	**11.6%**
• Fisheries Oceanography	1	$74,448		1.9%
• Marine Ecosystem Studies	4	$273,739		6.9%
• Hydrographic & Sea Ice Studies	1	$91,266		2.3%
• Contaminant Effects	1	$24,405		0.6%
Research Themes (Task III)			$3,374,569	**84.5%**
• Fisheries Oceanography	10	$756,606		18.9%
• Marine Ecosystem Studies	1	16,359		0.4%
• Tsunami Research	3	$2,471,204		61.8%
• Hydrographic & Sea Ice Studies	1	$62,400		1.6%
• Contaminant Effects	1	$58,000		1.5%
• UV and Arctic Haze	1	$10,000		0.3%
Total	**24**	**$3,995,627**	**$3,995,627**	**100.0%**

Table 2: Summary of Projects Funded 1 July 2004–30 June 2005: By Funding Source

Funding Source	Total Amount	Percent of Total (rounded)
OAR	$ 1,243,662	**31.1%**
NOS	$ 438,853	**11.0%**
NWS	$ 1,979,000	**49.5%**
NMFS	$ 334,112	**8.4%**
Total	$ 3,995,627	**100.0%**

Highlights of CIFAR Research Activities and Results

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

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) (http://www.arctic.noaa.gov/aro/russian-american/). Ten U.S. projects were selected and 7 were funded through CIFAR. Of the remaining successful proposals, one was funded through CICOR, one was funded directly through NOAA, and one requested no funding, only logistics. 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 permitted. The cruise took place 23 July–24 August 2004 on the R/V *Khromov*, a Russian ice-strengthened research ship. Hydrographic, biochemical and productivity data were collected from the northern Bering and Chukchi Seas to be combined with data from RUSALCA investigators (both in the U.S. and Russia) to assess nutrient and productivity processes. Early research findings include:

- Benthic macrofaunal biomass was very high in the southern Chukchi Sea in a known region of high water column production. Several specimens of the Northern Pacific crab *(Telmessus cheiragonus*) were collected in the southeastern Chukchi Sea at station 17, which is the third northernmost documentation of this species in the Chukchi Sea. In addition, the Pacific crab *Oregonia gracilis* and the bivalve *Pododesmus macrochisma* were also found, which appears to be the first time in the Chukchi Sea. These findings of Pacific taxa in Arctic waters may indicate a continued warming trend in the Chukchi Sea (Grebmeier).
- Clear and persistent patterns in species composition of *Pseudocalanus* exist in the study area tied to the different water masses, but there was no obvious pattern in weight-specific egg production despite strong chlorophyll gradients associated with these water masses (Hopcroft).
- In the Chukchi Sea, benthic communities differed along an east–west gradient, with the same species feeding on higher trophic levels in the east compared to the west suggesting that this may indicate a stronger pelagic link in the food web in eastern areas where pelagic primary production is limited. In western areas, the higher primary production results in a significant amount of fresh phytodetritus reaching the seafloor and feeding benthic communities directly (Iken et al.).

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 sea lions (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. Research findings include:

- Optimal foraging times have been modeled based upon estimates of aerobic dive limit (ADL) and physiological stores of juvenile Steller sea lions. Large seasonal variations in diving patterns, in combination with physiological measures, strongly suggest that juveniles (17 mo+) diving in winter face the largest constraints on their activity patterns (Burns).
- Three physical modes of variability in the oceanic–atmospheric conditions may influence Steller sea lion populations. The most dominant mode is the weakening and strengthening of the Alaska Coastal Current. The other two modes share about the same amount and variance. One is an on-shelf/off-shelf mode, and the other is the shifting of the shelf break front (Royer and Grosch).
- A well-organized, well-funded program of scientific research has limited ability to respond to the need for information required to increase certainty associated with decisions related to SSL conservation and recovery. Part of the reason is simply the length of time required for science programs to initiate and conduct hypotheses driven research. Part is a gap between academically oriented researchers, who aim to create new knowledge, and agency researchers, who are called upon for direct decision support (McBeath and Berman).

Climate

- A pan-Arctic domain (241x241 grid points with 30 km grid spacing) has been set up for the Arctic System Reanalysis. A full year MM5 forecast has been finished and utilized in creating seasonal MM5 background error statistics, which are used in a 3DVAR assimilation scheme. From four generic cases (one in each season) and three extreme cases, the above customized background error provides more realistic information in 3DVAR

assimilation and produces improved simulations of temperature, sea level pressure, winds, and precipitation in most cases (Walsh et al.).
- The accuracy of regional reanalysis (by MM5) has been found to depend more strongly on resolution than on choice of data assimilation scheme (Walsh et al.).

Contaminants

- Numerous polycyclic aromatic hydrocarbons (PAH) including organochlorine compounds and polychlorinated biphenyls were detected in air at Barrow, AK. Airborne concentrations and dominant PAH at Barrow were similar to literature values for Canadian and Russia sampling locations (Patton and Cahill).
- Trace aerosol data collected at Barrow shows Russian (including the Norilsk region) and Asian (Gobi desert dust) emissions impacting the Barrow Observatory at several different points during the study year (Patton and Cahill).

Fisheries Oceanography

- Four of the students previously funded on the Stock Assessment Training and Improvement Program (Quinn) have moved on to employment in quantitative fisheries science in Alaska, two of them with NOAA. Dr. Dana Hanselman and Dr. Kalei Shotwell are employed as Research Fishery Biologists, Alaska Fisheries Science Center, Auke Bay Laboratory.
- Genetic analyses of juvenile chum salmon showed that summer-run fish from the Yukon and Kuskokwim rivers dominate the samples collected in the eastern Bering Sea, suggesting a southwestward migration resulting in a broad distribution along the eastern Bering Sea shelf in the late summer and early fall. The fall Yukon River populations were detected south and west of the Yukon River mouth. Populations from northern Russia contributed to samples collected around St. Lawrence Island, indicating a northeastward migration of juvenile chum salmon from the northeast region of the Asian continent (Gharrett et al.).
- Pacific cod fecundity for samples from the Gulf of Alaska and eastern Bering Sea was highly correlated with fork length and directly proportional to body weight. Total female reproductive output (as estimated from measurements of gonad weight) varied among years and regions (Norcross).

Marine Ecosystem Studies

- Time series data in the northern Bering Sea show a decline in sediment oxygen uptake (a short-term indicator of carbon supply) which indicates a reduction of carbon being exported to the underlying sediments since the late 1980s to late 1990s, and a potential stabilization from 2002 onward. A coincident decline in benthic biomass (a long-term integrator of carbon export to the benthos) was also observed since the late 1980s (Grebmeier).
- Stable isotope analyses on archived Steller sea lion tooth samples assisted in filling in temporal gaps in previously analyzed osteological (mandible) bone samples and elucidating fine-scale life history changes. The range of $\delta^{13}C$ and $\delta^{15}N$ values over all collagen samples is great, suggesting large differences in feeding behavior and/or area across the whole of this species' range and decline period. The signature differences and trends isolated from tooth samples suggest that there may have been a change in $\delta^{13}C$ around regime shift periods (e.g., 1976), and that this jump may be due to alterations in local primary production (Wiesenburg/Hocutt).

Tsunami Research

- The global tsunami model developed by Kowalik that covers entire World Ocean with spatial resolution less than 1 min. was tested in its ability to simulate properties and wave travel times of the Indian Ocean tsunami of 26 December 2004. The model describes new physics in global tsunami propagation:
  a) The oceanic ridges act as ducts for tsunami waves, transferring energy for many thousands of kilometers without noticeable dissipation;
  b) Travel time computation based on Fermat's principle may lead to errors in the prediction of tsunami arrival time in tsunamis which propagate to other oceans;
  c) In passing through the straits between continents, a tsunami signal is reorganized from noisy into coherent motion; and
  d) The Coriolis force plays an important role in the global tsunami propagation.

Other CIFAR Activities

Responding to CIFAR Review

In response to recommendations made during the June 2004 review of CIFAR, we have created a CIFAR science advisory group of Institute Fellows. As stipulated by our Memorandum of Understanding, our list of prospective Fellows was approved by the CIFAR Executive Board consisting of NOAA Pacific Marine Environmental Laboratory (PMEL) director, Dr. Eddie Bernard, NOAA Arctic Research Office director, Dr. John Calder, NOAA Cooperative Institutes Program Manager, Dr. John Cortinas Jr., University of Alaska Vice President for Research, Dr. Craig Dorman, and CIFAR director, Dr. John Walsh and CIFAR associate director, Dr. Susan Sugai (*ex officio*). Dr. Virgil L. (Buck) Sharpton, Chancellor's Director of Research was added to the CIFAR Executive Board when he assumed his current position.

The CIFAR fellows for 2005 to 2008 are:

1. Dr. Mark Herrmann, Professor of Economics, School of Management, UAF, Fairbanks, AK
2. Dr. Larry Hinzman, Research Professor of Water Resources, Institute of Northern Engineering, UAF, Fairbanks, AK
3. Dr. Anne Hollowed, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA, Seattle, WA
4. Dr. Henry Huntington, Huntington Consulting, Eagle River, AK
5. Dr. Zygmunt Kowalik, Professor of Physical Oceanography, Institute of Marine Science, School of Fisheries and Ocean Sciences, UAF, Fairbanks, AK
6. Dr. Gordon Kruse, President's Professor of Fisheries, School of Fisheries and Ocean Sciences, UAF, Juneau, AK
7. Ms. Molly McCammon, Director, Alaska Ocean Observing System, Anchorage, AK
8. Dr. James E. Overland, Coastal and Arctic Research Division, Pacific Marine Environmental Laboratory, NOAA, Seattle, WA
9. Mr. James Partain, Chief, Environmental & Scientific Services Division, National Weather Service, NOAA, Anchorage, AK
10. Dr. Clarence Pautzke, Executive Director, North Pacific Research Board, Anchorage, AK
11. Dr. Carl Schoch, Science Director, Prince William Sound Science Center and Oil Spill Recovery Institute, Cordova, AK
12. Dr. Buck Sharpton, President's Professor of Remote Sensing, Geophysical Institute, UAF, Fairbanks, AK
13. Dr. Terry Whitledge, Professor of Biological Oceanography, Institute of Marine Science, School of Fisheries and Ocean Sciences, UAF, Fairbanks, AK

We have scheduled the first meeting of the CIFAR Fellows for 18 November 2005 at which time the Council of Fellows will be nominated from the Fellows and some of the other recommendations arising from the CIFAR review will be discussed.

In response to the CIFAR review, we have been begun tracking staff time on CIFAR functions more carefully. The past year has been a transition year as Susan Sugai took over as CIFAR associate director in December 2004 and Patricia Anderson retired in mid-January but continues to work part-time on Arctic Climate Impact Assessment (ACIA) tasks into October 2005. Currently, CIFAR core support funds one full-time staff position and one month of the CIFAR director's salary. However, University of Alaska funds support 9 months of the associate director's time and a second full-time staff position to meet combined CIFAR and Center for Global Change responsibilities. The actual time spent on CIFAR Task I and CIFAR project functions during the period 1 July 2004 to 30 June 2005 were as follows:

- John Walsh, CIFAR director, 20% FTE (both CIFAR Task I and ACIA)
- Patricia Anderson, CIFAR associate director: for the period 7/1/2004 to 1/15/2005: 90% FTE (both CIFAR and ACIA): for the period 1/16/2005 to 6/30/2005: 40% FTE (all ACIA)
- Susan Sugai, CIFAR associate director: for the period 12/13/2004 to 6/30/2005: 33% FTE (CIFAR Task I)
- Sherry Lynch, CIFAR fiscal administrator: 90% FTE (CIFAR and ACIA)
- Barb Hameister, publications and meetings manager: 50% FTE (CIFAR and ACIA).

As the ACIA activities will end in October 2005, distribution of staff functions will be substantially different in the coming year.

Workshop on Arctic Priorities

A Workshop on Arctic Priorities, convened by Drs. Chet Koblinsky and John Calder of NOAA on 2–3 February 2005 in Silver Spring, was coordinated by CIFAR. The workshop served to focus input to NOAA's planning process for FY2008–2012, particularly for the International Polar Year and SEARCH. Additional objectives were to identify priorities for NOAA's response to the Arctic Climate Impact Assessment and for NOAA's provisional climate services in Alaska and the Arctic. Approximately 30 scientists, primarily from NOAA and the Cooperative Institutes, participated in the workshop. The workshop report was provided to NOAA in March.

The workshop's recommendations were intended to foster the environmental and economic mission of NOAA's Office of Oceanic and Atmospheric Research by identifying priorities for Arctic research, product development, and the provision of scientific understanding and leadership in the Arctic. Among the recommendations are the establishment of several intensive atmospheric observatories around the periphery of the Arctic; a network of ice-based and moored observing sites to monitor and permit attribution of changes in the Arctic Ocean and its ice cover; extension of the operational and retrospective analyses of snow cover to Alaska and the Arctic; an Arctic System Reanalysis in coordination with the next global reanalysis; regional decision support for Alaska; and an assessment of the State of the Arctic on a regular basis. An additional priority, measurements of Arctic aerosols and their roles in cloud and radiative processes, emerged from the presentation of the workshop report to the NOAA Climate Working Group in March.

Copies of the Workshop Report can be obtained from CIFAR or from the NOAA Climate Program.

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 examined possible future impacts on the environment and its living resources, on human health, and on economic sectors that are important in the Arctic. Two reports were completed in November 2004: a synthesis document entitled "Impacts of a Warming Arctic," and a policy document providing recommendations for mitigation, adaptation, research and outreach. A detailed, peer-reviewed scientific volume will be published in October 2005. The synthesis and policy reports, as well as pre-released versions of the individual chapters of the scientific report, can be accessed through the ACIA web site at http://www.acia.uaf.edu.

The ACIA Secretariat is located at the International Arctic Research Center, University of Alaska Fairbanks, and the CIFAR staff was 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). During the past year, the primary activities of the Secretariat staff have been to support the work of the ACIA Executive; coordinate the work of the technical editors, production manager and lead authors of the ACIA science chapters; and respond to numerous inquiries from the media, science communities, non-governmental organizations and other organizations, and the general public regarding the ACIA findings and reports.

Education/Outreach

Student and Postdoctorate Support through Individual Awards

Many of the proposals funded through CIFAR involve graduate and undergraduate students. Thirty-three students (24 graduate; 9 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 (Appendix 2). This includes 3 students supported by the 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 2005 competition in May; the newly funded CIFAR projects are:

- Carrin Halffman, Anthropology, Tracking mercury levels in the arctic through time using archaeological bone: initial method validation.
- Hannah Clilverd, Institute of Arctic Biology, Surface–subsurface hydrologic exchange and nitrogen transformations in the hyporheic zone of the Tanana River in interior Alaska.
- Emily Molhoek, Geology & Geophysics, An 8 ky record of vegetation cover, fire history, and moisture availability in north-central Mongolia: impacts of global warming and aridification.
- Holly McKinney, Anthropology, Temporal variability of archaeologically deposited fish remains in the Gulf of Alaska: an assessment of human and natural impacts.

Response to Media and Other Requests

CIFAR scientists provide information and interviews requested by the media and others. Following release of the ACIA summary report, numerous climate change requests have been fielded by John Walsh from media outlets such as the New York Times television, Anchorage Daily News, BBC, and the Irish Times.

Publications and Presentations

During the current reporting period, 15 peer-reviewed publications and 13 non-peer-reviewed publications (including one Master's thesis) were reported from projects receiving their funding through CIFAR under cooperative agreement NA17RJ1224. An additional 20 papers were reported as accepted or in press and 12 were described as submitted or in review. Over 50 manuscripts were reported to be under preparation. Approximately 60 conference presentations (both national and international) and seminars were also reported.

In addition to these FY05 numbers, we received information on several publications from FY04 that had not been reported previously: nine non-peer-reviewed (including two Ph.D. dissertations and three Master's theses) and five peer-reviewed. The publication matrix in Appendix 3 reflects these additions.

Note: These numbers do not include presentations or publications from Arctic Research Initiative and Steller sea lion projects funded at NOAA laboratories, other federal agencies, or through other joint institutes.

See also Appendix 3.

Russian–American Long-term Census of the Arctic (RUSALCA)

Atmospheric Aerosols over the Bering and Chukchi Seas

Catherine F. Cahill, PI
University of Alaska Fairbanks

NOAA Goal: Understand Climate Variability and Change

CIFAR 10-066: This project is ongoing.

Primary objectives

This project aims to measure the concentrations and compositions of atmospheric aerosols above the Bering and Chukchi Seas during the Joint Russian–American Long-term Census of the Arctic (RUSALCA) cruise in summer 2004. The information collected during this cruise will assist scientists in understanding the sources, types and sizes of aerosols present over the Bering and Chukchi Seas during the Arctic summer. This information will help quantify the atmospheric deposition of specific trace metals and other elemental species to the seas and provide a measure of the influence of the aerosols on the radiative balance over the seas.

Approach/methodology

Average size-fractionated aerosol mass and trace elemental composition, including mercury concentrations, were determined for every 3 hours during the duration of the cruise. The samples were collected using a rotating drum cascade impactor and analyzed by β-gauge and Synchrotron X-Ray Fluorescence (S-XRF) techniques to determine aerosol mass and elemental composition. These techniques provided 3-hour average concentrations of mass and 42 elements from sodium through uranium, including particulate mercury, that are comparable with previous measurements made during summer 2003 in the Bering and Chukchi Seas on the Chinese research vessel, the *Xue Long*, and existing ground-based measurements in Alaska. These techniques have been used to successfully follow the international transport of specific elemental species from their source regions to the Arctic.

Research accomplishments/highlights/findings

- Size-resolved aerosol samples were successfully collected during RUSALCA.
- The samples have been analyzed by S-XRF.
- Data analysis and interpretation are underway.

NOAA relevance/societal benefits

The information collected during this cruise will assist scientists in understanding the sources, types and sizes of aerosols present over the Bering and Chukchi Seas during the Arctic summer. This information will help quantify the atmospheric deposition of specific trace metals and other elemental species to the seas (where they can be either pollutants or nutrients) and provide a measure of the influence of the aerosols on the radiative balance over the seas. The impact of the aerosols on the radiative balance could influence the effectiveness of atmospheric models for calculating climate changes.

Research linkages/partnerships/collaborators and networking

The measurements made during this research cruise are comparable to measurements made during summer 2003 in the Bering and Chukchi Seas on the Chinese research vessel, the *Xue Long*. A comparison of the two data sets, representing two different years in the same region, will be prepared for publication. The author list on this paper will include Chinese, Russian and American scientists.

Benthic Processes and Ecosystem Change in the Northern Bering and Chukchi Seas

Jackie M. Grebmeier, PI
Lee Cooper, co-PI
University of Tennessee, Knoxville

NOAA Goals: Understand Climate Variability and Change; Ecosystem-based Management

CIFAR 10-067: This project is ongoing.

Primary objectives

Our participation in the 2004 U.S.–Russia cruise as the first activity under the Russian–American Long-term Census

of the Arctic (RUSALCA) provided a strategic opportunity to continue previous studies in both U.S. and Russian waters, as well as link the RUSALCA program with currently funded work of the Shelf–Basin Interactions project and the Bering Strait Environmental Observatory, all of which will be critical to understanding the impacts of environmental change in the Arctic. Past studies in the region over multiple U.S.–Russian expeditions as part of the BERPAC program (Long-term Ecological Investigations of the Bering Sea and Other Pacific Ocean Ecosystems) allow a time-series comparison of the results from the RUSALCA cruise with these past data sets (1988 *Akademik Korolev*, 1993 *Okean*, and 1995 RV *Alpha Helix*) and allow determination of long-term observation sites for evaluation of climatic impacts on this sensitive northern ecosystem. The PIs on this project are Drs. Jackie Grebmeier and Lee Cooper from the University of Tennessee Knoxville (UTK), USA and Drs. Boris Sirenko and Sergey Gagaev from the Zoological Institute, St. Petersburg, Russia.

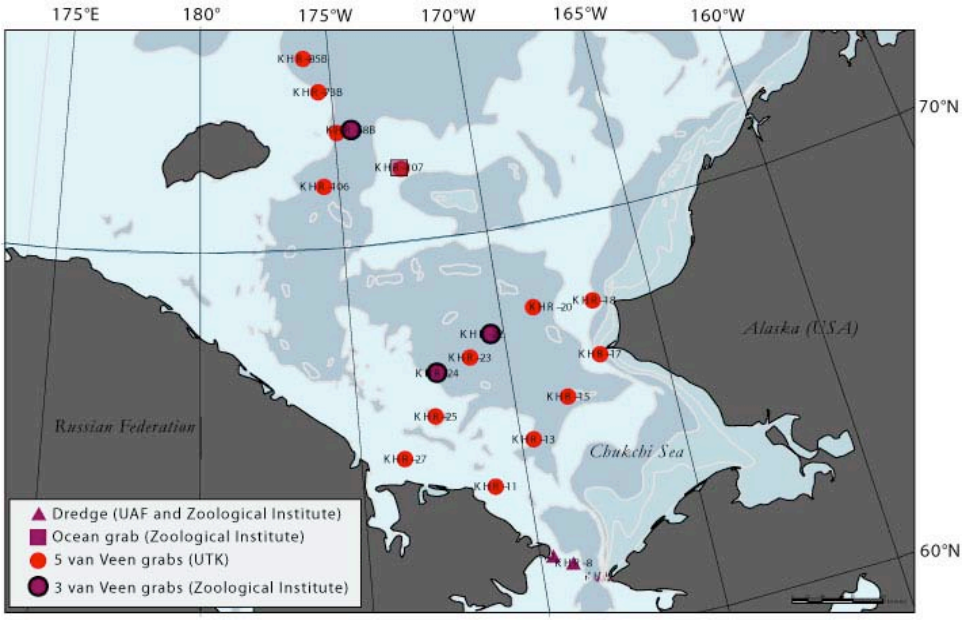

Figure 1. Locations of RUSALCA 2004 benthic sampling

Approach/methodology

During the 2004 RUSALCA cruise quantitative sediment samples were collected at 14 stations using a 0.1 m^2 van Veen grab from a depth range of 53–73 m (Figure 1). Five replicate grabs were taken at each station for UTK. The first grab was used for surface sediment sampling of total organic carbon and nitrogen, sediment grain size, sediment chlorophyll *a* content, ^{13}C, and ^{7}Be. These surface sub-samples were collected and frozen for land-based analyses at the UTK laboratory. A sediment sub-sample was also collected for trace metal analysis at the University of Alaska Fairbanks, and another for the Zoological Institute, St. Petersburg for meiofaunal analysis. The remaining four van Veen grabs were sieved separately through a 1 mm stainless steel mesh screen, preserved in 10% buffered formalin, and analyzed at the University of Tennessee. Additional van Veen grabs (three for the Zoological Institute, and 1–2 additional for Russian geologists and microbiologists) were also collected. At three stations, only three van Veen samples for Boris Sirenko (Zoological Institute) were taken, and Ocean grabs were taken for the Zoological Institute at one station (Figure 1). Dredge samples were collected by the University of Alaska Fairbanks and the Zoological Institute at three stations in Bering Strait. In addition, water samples were collected for ^{18}O at sixty-six stations for land-based analyses at UTK.

Research accomplishments/highlights/findings

- Benthic macrofaunal biomass was very high in the southern Chukchi Sea stations in a known region of high water column production.
- The majority of benthic stations were composed of silt and clay grain size fractions.
- Carbon-13 surface sediment values indicate a marine phytoplankton source for the carbon in these sediments.
- Several specimens of the Northern Pacific crab *(Telmessus cheiragonus*) were collected in the southeastern Chukchi Sea at station 17, which is the third northernmost documentation of this species in the Chukchi Sea. In addition, the Pacific crab *Oregonia gracilis* and the bivalve *Pododesmus macrochisma* were also found, which

appears to be the first time in the Chukchi Sea. These findings of Pacific taxa in Arctic waters may indicate a continued warming trend in the Chukchi Sea.

- Taxa at the two most southerly transect lines (Stations 11–15, 22–25) in the south-eastern and south-central Chukchi Sea demonstrated an infaunal community composition dominated by the bivalve *Macoma calcarea* (66º50'N to 68º20'N and 168º20'W to 173º00'W), similar to previous findings in this productive area.
- Macrobenthic benthic biomass in the south-central Chukchi Sea stations averaged 1000–2000 g wet wt. m^{-2}, exceeding 4000 g wet wt. m^{-2} at Stn 13, which is extremely high for the world's oceans.
- The northwestward transit of Pacific water through Bering Strait and northward in the Chukchi Sea, ladened with high nutrients and carbon content, is a driving factor for the high productivity of the underlying benthos.
- By comparison, benthic biomass in the northwest region of the study shows a reduction in benthic biomass to 200–300 g wet wt. m-2. The northernmost transect line (Stns 58B, 62B, 73B, 85B, 106 and 107) in Herald Trough and its vicinity was dominated by polychaetes, brittle stars, and sipunculids, with a benthic biomass ranging from 100–343 g wet wt. m-2. An unexpectedly rich settlement of sedentary epifaunal organisms (soft corals, sponges and bryozoans) encrusting both pebbles and manganese nodules was encountered at Stn 62B. On this same transect line, the Remotely Operated Video filmed a Cerianthid (Tube Anemone), which was the first known observation of this taxonomic order in the Chukchi Sea.
- Future expeditions need to focus on the central and western Chukchi Sea to understand the processes controlling ecosystem structure in this very productive and species-rich Arctic area.

NOAA relevance/societal benefits

Monitoring and assessing the current status and potential change in the Bering Strait region and into the Chukchi 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. In addition, RUSALCA is part of the Census of Marine Life project and the benthic faunal collections from the RUSALCA cruise are important samples for this world-wide effort.

Research linkages/partnerships/collaborators and networking

This project is a collaborative effort with Dr. Boris Sirenko at the Zoological Institute in St. Petersburg, Russia. This project includes collaborative evaluation of field collections and future research publications. 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

Student participation

Adam Humphrey, an undergraduate student, completed a B.S. in May 2005 in Ecology and Evolutionary Biology. He assisted in infaunal sorting and general laboratory operations.

Rebecca Pirtle-Levy, a 2nd year M.S. student in Ecology and Evolutionary Biology, processed sediments for total organic carbon content and sediment grain size.

K–12 outreach

PIs Grebmeier and Cooper, along with two of our support staff gave a three-hour group presentation (audio-visual presentation, hands-on experience viewing preserved marine animals and other research samples) for over 100 middle school students at Powell Elementary School in Powell, Tennessee during spring 2005.

Public awareness

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. Preliminary results from this study were presented at the 2005 Pacific Arctic Group Symposium in Kunming, China (April 2005) and the American Association of Limnology and Oceanography (ASLO) Summer meeting in Santiago de Compostela, Spain in June 2005.

Publications

In preparation

Grebmeier, J.M., J. Overland, L. Eisner, J. Helle, L.W. Cooper, S.E. Moore and E. Carmack. Major ecosystem shifts in the northern Bering Sea. In preparation for submission to *Science*, fall 2005.

A Census of Arctic Zooplankton Communities

Russell R. Hopcroft, PI
University of Alaska Fairbanks

NOAA Goals: Understand Climate Variability and Change; Ecosystem-based Management

Ksenia Kosobokova, *Russian Academy of Sciences, Moscow*

CIFAR 10-068: This project is ongoing.

Primary objectives

Establish critical baseline information on the abundance, biomass, and composition of the zooplankton from the Bering Strait northward throughout the Chukchi Sea, because we expect the Arctic to be more sensitive to ongoing and future climate shifts than elsewhere on the globe. Determine the rate of secondary production for dominant zooplankton species (i.e., copepods).

Approach/methodology

Zooplankton were collected by a package of 4 plankton nets, consisting of two 150-µm and two 53-µm mesh nets equipped with flow meters at 32 stations. Formalin-preserved samples are being processed for composition and biomass. Ethanol samples are being scanned for representatives of the species present in each of the major water masses, and sent to the ZooGene program for determination of the Cytochrome Oxidase I sequence.

At 20 stations, additional nets were employed to collect live zooplankton for digital images of all common species. The productivity of the dominant copepod species was examined by means of egg production rates. During the cruise only *Pseudocalanus* spp. appeared in sufficient numbers for egg production experiments, and depending on abundance, 40–120 individuals were incubated in 70-ml flasks for 48 hours. Rates of egg production have been compared across the sampling region with respect to temperature, the local productivity, and the water mass types in which they occur.

Research accomplishments/highlights/findings

- Clear and persistent patterns in species composition of *Pseudocalanus* exist in the study area tied to the different water masses, but there was no obvious pattern in weight-specific egg production despite strong chlorophyll gradients associated with these water masses.
- Future increased penetration of Pacific water will lead to increased penetration of *Pseudocalanus newmani*, BUT all other things being equal, secondary production may not change significantly other than that expected from temperature-dependent rate increases alone.
- Biomass of the larvacean community was comparable to the copepods at many stations, and their production at times exceeded that of the copepods.

NOAA relevance/societal benefits

We have established critical baseline information on the abundance, biomass, and composition and production of the zooplankton in an area sensitive to climate-related shifts, such that future changes can be monitored.

Research linkages/partnerships/collaborators and networking

This research has begun a continuing collaborative effort between Hopcroft and Kosobokova.

Education/outreach

Student participation

One graduate student has been partially funded by this CIFAR project: Alexei Pinchuk, Ph.D. candidate, Biological Oceanography, expected to graduate fall 2005.

Public awareness

A presentation, "Production of *Pseudocalanus* species in the Chukchi Sea," was made at the ASLO 2005 summer meeting in Spain. A Web site with images of zooplankton species can be found at http://www.sfos.uaf.edu/research/arcdiv/watercolumn/index.html

Publications

In preparation

Hopcroft, R. and K. Kosobokova. Production of *Pseudocalanus* species in the Chukchi Sea.

Hopcroft, R., K. Kosobokova and A. Pinchuk. Patterns of zooplankton distribution in the Chukchi Sea.

Arctic Epibenthic Community Structure and Benthic Food Web Structure

Katrin Iken, PI
Bodil Bluhm, co-PI
University of Alaska Fairbanks
Kenneth Dunton, co-PI
University of Texas at Austin

NOAA Goal: Understand Climate Variability and Change

CIFAR 10-069: This project is ongoing. Field work as well as most of sample processing was completed during the reporting period. Data analysis and preparation of manuscripts are still to be done.

Primary objectives

The main objective of the project is to analyze epibenthic community structure in the Chukchi Sea to create a baseline of species composition, abundance and biomass. Epibenthic organisms are good long-term indicators of changes in oceanographic conditions, which may be caused by global climate change. Secondly, we focused on the food web structure of the benthic community and their connection to water column primary production. Benthic food web structure and distribution of feeding types are likely to change with shifts in water column processes due to global climate change.

Approach/methodology

Epibenthic communities were sampled at 17 stations using a beam trawl, otter trawl or dredge. Invertebrate species from these trawls were sorted into species or higher taxonomic groups, weighed and individuals were counted. Abundance and biomass were normalized to the trawled area as catch per unit effort (CPUE). Vouchers were preserved in 4% formalin–seawater solution buffered with hexamethylenetetramine. Size–weight frequency distributions have been measured for dominant members of the epibenthic communities. Community analysis will be performed using PRIMER software.

Benthic epifaunal and infaunal organisms as well as water column particulate organic matter (POM) and pelagic invertebrates were collected for stable isotope analysis. A total of 62 water samples, 40 surface sediment samples, 143 plankton samples and 2165 tissue samples of infaunal and epibenthic organisms were taken for stable isotope analysis at 15 stations. Tissue pieces were collected and dried on board the vessel and then prepared and measured for stable isotopes ($\delta^{13}C$ and $\delta^{15}N$) at the UAF Stable Isotope Facility.

Research accomplishments/highlights/findings

- Approximately 210 epibenthic invertebrate species were collected, representing very different community structures.
- Communities within the southern Chukchi area (St. 6–27, Figure 1) were mainly influenced by Pacific species, except for St. 20 and 25, which had a typical Arctic composition that was characterized by ophiuroids and mollusks.
- Communities within the northern Chukchi area (Harald Canyon area) had typical Arctic fauna, characterized by seastars and ophiuroids.
- Range extensions into the Arctic were seen for some crab and mollusk species.
- Substrate type seems to be a driving force for overall species richness, with higher richness associated with rocky substrates.
- POM isotopic values showed a distinct east–west trend in the southern Chukchi area plot (St. 6–27) with more enriched values in western areas, likely due to Anadyr water influence.
- Benthic communities also differed along an east–west gradient, with the same species feeding on higher trophic levels in the east compared to the west (Figure 2). We suggest that this indicates a stronger pelagic link in the food web in eastern areas where pelagic primary production is limited. In western areas the higher primary production results in a significant amount of fresh phytodetritus reaching the seafloor and feeding benthic communities directly.

NOAA relevance/societal benefits

This project assisted in NOAA's goal to create baseline data of ecosystem components that are expected to be valuable indicators of climate change effects. Benthic communities integrate processes over long time periods rendering them suitable long-term indicators of changes related to climatic effects on oceanographic conditions.

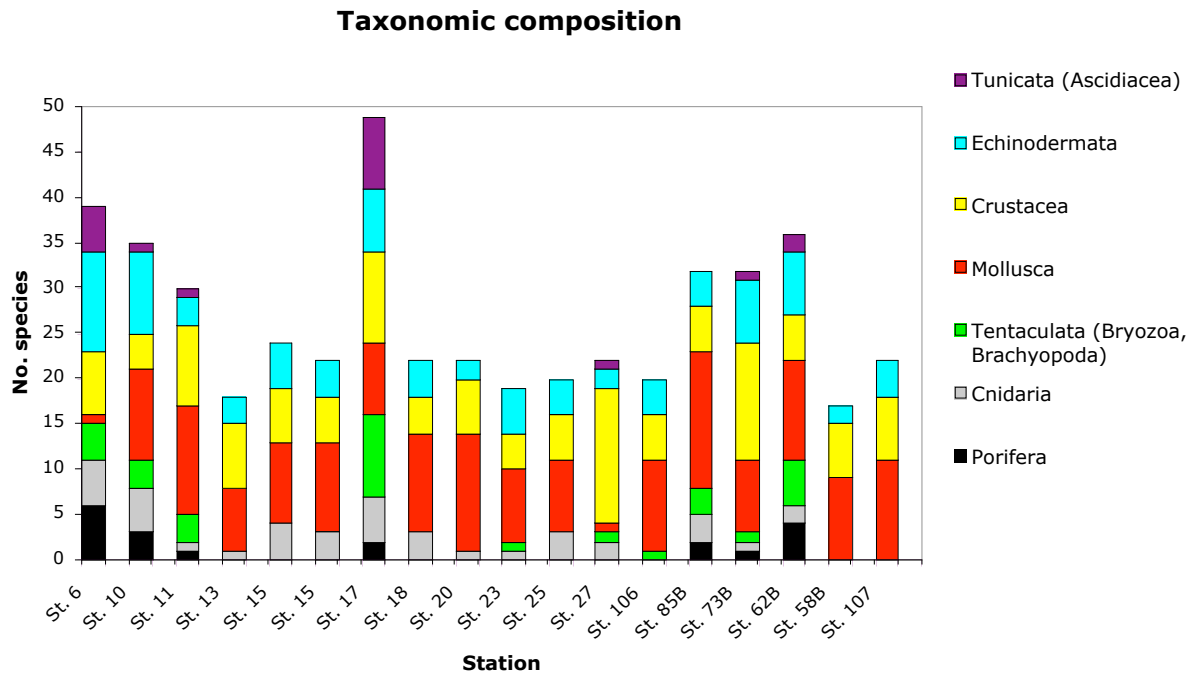

Figure 1: Taxonomic composition of epifauna

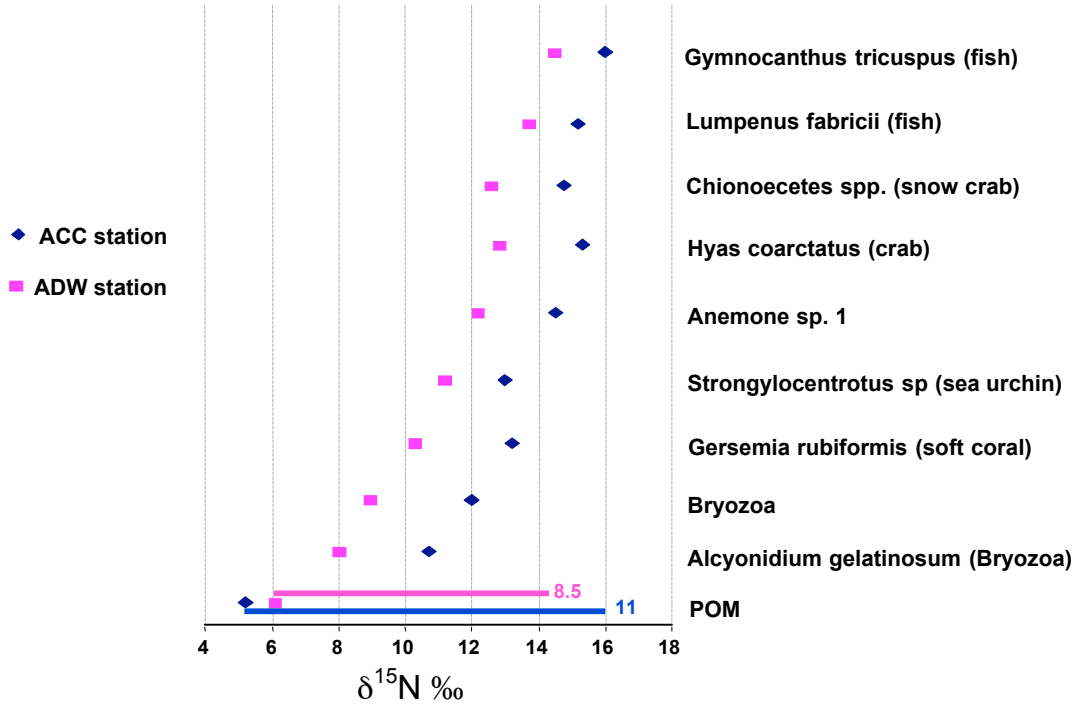

Figure 2: Example of trophic position of organisms from eastern (Alaska Coastal Current, ACC) station and western (Anadyr Water ADW) station. Higher $\delta^{15}N$ values in reference to the respective POM value indicate a higher trophic level. 8.5 and 11 per mil indicate the overall food web length at these example stations.

Research linkages/partnerships/collaborators and networking

All objectives were strongly based on conceptual and logistical cooperation with other projects within and outside RUSALCA and with other programs. The PIs are also involved in other large-scale Arctic programs, such as the NSF-funded SBI Program (Western Arctic Shelf–Basin Interactions), NOAA Ocean Exploration's Hidden Ocean projects and the Census of Marine Life's Arctic Ocean Diversity project, as well as in cooperation with Russian colleagues. Their network allows them to interpret the data in a broader context.

Education/outreach

Student participation

Two interns from the University in Marburg in Germany have been essential in sample processing and data entering. They have participated in these tasks for 6 months. One of the students used part of the stable isotope dataset for his senior thesis work, a credit requirement at his home university. Their work was mentored both by Bluhm and Iken.

K–12 outreach

Iken is regularly involved in show case and touch tank exhibitions for K–12 school groups in Fairbanks. Materials obtained during this project have been used in these interactions to familiarize school kids with the diversity of organisms living in the Arctic Ocean. Imagery collected during the RUSALCA cruise has been used to illustrate Arctic biodiversity on the "Arctic Ocean Diversity Census of Marine Life" website maintained by Bluhm and others.

Public awareness

- Presentation of preliminary results at an Institute of Marine Science seminar at UAF.
- Presentation of stable isotope results at Gordon Research Conference, Ventura CA, for Polar Marine Science.
- Contributions to news articles by Reuters reporter Jeff Jones.
- Brief news report on "Arctic Ocean Diversity Census of Marine Life" website and in "Census of Marine Life" bimonthly newsletter.

Publications

Multi-authored publications about epibenthic community structure (Bluhm as lead author) and about food web structure (Iken as lead author) are planned. Russian colleagues will co-author these publications.

Fisheries Ecology of the Bering and Chukchi Seas

Brenda L. Norcross, PI
University of Alaska Fairbanks

NOAA Goals: Understand Climate Variability and Change; Ecosystem-based Management

Other investigators/professionals funded by this project:
***Brenda A. Holladay**, University of Alaska Fairbanks*
***Morgan Busby**, NOAA/NMFS/AFSC*

CIFAR 10-070: This project is ongoing.

Primary objectives

Our overall goal is to document the fish species in the study area to provide a baseline from which to measure future changes.

1) Collect larval and juvenile fishes in specific water masses to estimate relative fish abundance and distribution.
2) Relate ichthyoplankton assemblages (species composition) to oceanographic features (water masses).
3) Determine the physical characteristics that define juvenile groundfish communities and habitat.
4) Compare ichthyoplankton, juvenile fish and adult fish distributions and communities among oceanographic domains.

Objective 4 has changed to only compare ichthyoplankton and juvenile fish because adult fish distributions are to be included in a project by David Stein (NOAA) and co-workers.

Approach/methodology

Our focus is the effect of physical and lower trophic level perturbations on fishes. To this end, we collected ichthyoplankton using a 60-cm Bongo net and juvenile groundfishes using a 3-m plumb staff beam trawl. Estimates of species abundance have been developed from these collections and are being evaluated with respect to the physical and biological data collected by other researchers.

Research accomplishments/highlights/findings

- Planned collections and participated in cruise aboard *Professor Khromov* in August 2004 in Bering and Chukchi Seas.
- Collected ichthyoplankton from 18 sites and bottom trawl samples from 17 sites.
- Ichthyoplankton and fishes have been identified, and physical and biological data are being obtained from other researchers.

NOAA relevance/societal benefits

An objective of RUSALCA was to provide a method to identify ecosystem change, and this project adds to the coordinated efforts to identify the physical and biological factors that underlie ecosystem change in the arctic, and to understand how those factors interact.

Research linkages/partnerships/collaborators and networking

This project provided fish and invertebrate tissues for several RUSALCA projects (PIs: Iken, Hopcroft, Stein). Water/fish samples were provided for non-RUSALCA research for trace elements (Nate Bickford, UAF), and for fatty acids (Alan Springer, UAF). The NOAA/NMFS/AFSC laboratory in Seattle received voucher specimens of juvenile fishes and fish larvae and eggs.

Ichthyoplankton identification and some statistical analysis, to be reported in the manuscript by Norcross et al., were performed in the NOAA/NMFS/AFSC laboratory.

Publications

Manuscript in preparation to analyze ichthyoplankton and juvenile fish assemblages and abundance in relation to oceanography of the Bering and Chukchi Seas. The primary author is Brenda Norcross, and additional authors include Brenda Holladay, Morgan Busby and Kathryn Mier.

Manuscript in preparation to describe juvenile and adult fish taxonomy and occurrence. The primary author is Catherine Mecklenburg, and additional authors include Brenda Norcross, Brenda Holladay, Morgan Busby, David Stein, Natalia Chernova, and Boris Sheiko.

Bering Strait: The Pacific–Arctic Ocean Connection

Thomas Weingartner, PI
University of Alaska Fairbanks

NOAA Goal: Understand Climate Variability and Change

CIFAR 10-071: This project is ongoing.

Primary objectives

Deploy a current meter mooring in the western channel (Russian EEZ) of Bering Strait.

Approach/methodology

Deploy 1 current meter mooring (with 1 current meter and 1 SeaCat temperature/conductivity recorder).

Research accomplishments/highlights/findings

- Mooring deployed 8/2004
- Anticipated recovery 8/20/2005

NOAA relevance/societal benefits

Bering Strait is the sole connection between the Pacific and Arctic oceans. As such it provides an efficient environmental monitoring location able to detect integrated changes in the Bering Sea ecosystem. The flux of nutrients, salinity, and heat from the Bering to the Arctic Ocean has important influences on this ecosystem and on climate.

Research linkages/partnerships/collaborators and networking

This project was part of NOAA's RUSALCA program—a multi-investigator, interdisciplinary program to conduct marine research in Bering Strait and the Chukchi Sea. The RUSALCA program afforded the first opportunity since the early 1990s for U.S. scientists to work in the Chukchi Sea.

The work conducted in the western channel is being performed in collaboration with Rebecca Woodgate and Knut Aagaard of the University of Washington. They are making complementary measurements in the U.S. EEZ under Office of Naval Research support.

Interactions of Productivity and Nutrient Processes in the Northern Bering and Chukchi Seas

Terry Whitledge, PI
University of Alaska Fairbanks

NOAA Goals: Understand Climate Variability and Change; Ecosystem-based Management

CIFAR 10-072: The project is ongoing with plans to publish a general article on the U.S.–Russian project and to attend a PI meeting in Montenegro to organize additional data analysis and to plan for possible International Polar Year (IPY) cruise(s).

Primary objectives

The goal of this research is to collect nutrient, carbon/nitrogen productivity data to assess the nutrient uptake and growth of major phytoplankton populations in the northern Bering and Chukchi Seas in relation to ambient light fields. A series of hydrographic transects were collected to allow sampling of all water masses during this late summer period. A high priority of the hydrographic survey was to collect samples across Bering Strait in support of the physical biochemical mooring(s) in western Bering Strait. The long-term goal is to obtain continuous and comprehensive monitoring within Bering Strait for several years which would require routine access to the eastern and western portions of the study area for scientific operations. The hydrographic, biochemical and productivity data from this project is being combined with other US and Russian collaborators for the joint assessment of nutrient/productivity processes.

Approach/methodology

Nutrient (nitrate, nitrite, phosphate, silicate and ammonium) and phytoplankton pigment analyses were determined in all CTD/rosette samples collected on the cruise. UAF AutoAnalyzer equipment was placed on the ship for analysis of samples without freezing. All productivity measurement equipment and fluorometer(s) were supplied by UAF. Daily primary production rate measurements were made by the $^{13}C/^{15}N$ isotope dual enrichment techniques (Bury et al., 1995). Primary production estimates were made daily at mid-day at six light depths. All transect lines had productivity stations in representative locations as time permitted. Water samples, inoculated with 20 µm ^{13}C-labeled Na_2CO_3 or 10% additions of ^{15}N-NO_3 or ^{15}N-NH_4 were incubated in 1-liter polycarbonate bottles under natural light on-deck. After incubation, light and dark samples were filtered and stored for isotope ratio analysis by mass spectrometry.

Research accomplishments/highlights/findings

- The range of nutrient, phytoplankton biomass and productivity in water masses distributed in the northern Bering and Chukchi Seas were quantified for four transects across the ecosystem.
- Physical and chemical factors that are conducive to maintenance of relatively large rates of primary production were observed and will be quantified by the primary production rates that were measured.
- Contemporary rates from this cruise will be compared with those obtained in the previous decade for assessment of rate changes under the present warm temperatures.
- A cost-effective approach for future monitoring of this critical region between the Pacific and Arctic oceans will be designed and submitted for approval.
- A combined U.S.–Russia mooring program placed two moorings in western Bering Strait which will remain in place for one year.

NOAA relevance/societal benefits

The objectives of this project are central to the SEARCH program goals. Our proposal represents a step toward implementation of a long-term observation program in the Bering/Chukchi Seas. Thus, this project will directly contribute to the NOAA goals of detecting and monitoring arctic environmental changes, especially those related to climate change.

Education/outreach

Student participation

Sang Heon Lee was supported as a graduate research assistant in Chemical Oceanography during his Ph.D. studies by this project. Approximately 75% of his support was supplied by this project. It is anticipated that Sang Lee will complete his Ph.D. studies during fall semester 2005.

Public awareness

Several newspaper articles were published by Reuters on the results of the RUSALCA cruise.

Presentations

Whitledge, T.E., K. Crane, V. Smolin, K. Wood and M. Zhdanov. 2005. Initial results of Russian–American Long-term Census of the Arctic (RUSALCA). Presented at the 16th PICES Annual Meeting in Honolulu, March 2005.

Whitledge, T.E. 2005. Chemicals as tracers of fluxes and dynamics in the Arctic. Invited Presentation to Pacific Arctic Group Symposium, Arctic Science Summit Week, Kunming, China, 22 April 2005.

Publications

Peer-reviewed

Lee, S.H. and T.E. Whitledge. 2005. Primary and new production in the deep Canada Basin during summer 2002. *Polar Biology*, 28:190–197.

In preparation

Whitledge, T.E. and others. New results in U.S.–Russian Collaborative Program in the Western Arctic. In preparation for submission to *EOS*.

References

Bury, S.J., N.J.P. Owens and T. Preston. 1995. ^{13}C and ^{15}N uptake by phytoplankton in the Marginal Ice Zone of the Bellingshausen Sea. *Deep Sea Research Part II: Topical Studies in Oceanography*, 42:1225–1252.

Steller Sea Lion Projects

Arctic Research Initiative Projects

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

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

NOAA Goal: Ecosystem-based Management

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

CIFAR 01-005: This project is ongoing.

Primary objectives

By studying the development of Steller 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 β-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 (ADF&G) and the National Marine Mammal Laboratory (NMML) and sampled for this study.

Research accomplishments/highlights/findings

- The first manuscript from this study was published, which details the hematological development (Richmond et al. 2005).
- A second manuscript is under review for the Journal of Comparative Physiology B (Richmond et al. submitted).
- We are currently working on a manuscript that details the pattern and biochemistry of muscle development. This manuscript should be submitted by December.
- We noticed that EPO and hematocrit (Hct) 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. As nursing animals often are iron limited, we have focused our attention on the possibility that heme development may be limited by iron intake rates. Therefore, we have analyzed milk samples for iron content, and are working with ADF&G to obtain additional sera samples to analyze for iron content. A paper presenting the hypothesis and background data was presented in August 2004 (published as Burns et al. 2004).
- We are currently using our estimation of aerobic dive limit (ADL) and physiological stores to model optimal foraging times and decisions using the dive data obtained as part of our NOAA / Steller Sea Lion Research Initiative–funded research project. The final information on diving patterns in juveniles was obtained in July 2005. Large seasonal variations in diving patterns, in combination with physiological measures, strongly suggest that juveniles (17 mo+) diving in winter face the largest constraints on their activity patterns.

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. However, the deep and long diving patterns observed during winter months result in a large fraction of bout dives that approach or exceed the calculated ADL. This suggests that the winter prior to the second summer of life is a critical period for young Steller sea lions.

Research linkages/partnerships/collaborators and networking

This research would not have been possible without tremendous collaborative efforts. Alaska Department of Fish & Game and NOAA/NMML 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

Student participation

Julie P. Richmond	Master of Science Degree	*Completed in FY04*
Jill Prewitt	Master of Science Degree	*In progress*

Presentations

Burns, J.M., C.A. Clark, and J.P. Richmond. 2005. The influence of dietary iron on hematological development in juvenile pinnipeds. Invited talk presented at International Union of Physiological Sciences, San Diego, California, 31 March–5 April 2005.

Burns, J.M., M.J. Rehberg and J.P. Richmond. 2004. Juvenile Steller sea lion (*Eumetopias jubatus*) dive patterns during long and short trips-to-sea. Talk presented at Sea Lions of the World: Conservation and Research in the 21st Century, Anchorage, Alaska, 30 September–3 October 2004.

Richmond, J.P., J.M. Burns and L.D. Rea. 2004. Examination of blood and muscle development in the Steller sea lion (*Eumetopias jubatus*): Implications for diving and foraging ability. Talk presented at Sea Lions of the World: Conservation and Research in the 21st Century, Anchorage, Alaska, 30 September–3 October 2004.

Publications

Peer-reviewed

Burns, J.M., C.A. Clark and J.P. Richmond. 2004. The impact of lactation strategy on physiological development of juvenile marine mammals: implications for the transition to independent foraging. *Comparative Physiology and Biochemistry, International Congress Series*, 1275:341–350.

Richmond, J.P., J.M. Burns, L.D. Rea and K. Mashburn. 2005. Postnatal ontogeny of erythropoietin and hematology in free-ranging Steller sea lions (*Eumetopias jubatus*). *Journal of Comparative Endocrinology*, 141:240–247.

Peer-reviewed

Richmond, J.P. 2004. Ontogeny of Total Body Oxygen Stores and Aerobic Dive Potential in Steller Sea Lions (*Eumetopias jubatus*). Master's thesis, University of Alaska Anchorage.

Submitted or in preparation

Richmond, J.P., J.M. Burns and L.D. Rea. Ontogeny of total body oxygen stores and aerobic dive potential in Steller sea lions (*Eumetopias jubatus*). Submitted to *Journal of Comparative Physiology B*.

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*.

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

Kenneth Coyle, PI ***NOAA Goal: Ecosystem-based management***
University of Alaska Fairbanks

CIFAR 01-007: 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^2 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 NOAA/Pacific Marine Environmental Laboratory (PMEL).
6) Prepare a presentation for the special session on the Aleutians at the ASLO meeting in February 2004.

Research accomplishments/highlights/findings

- The manuscript "Zooplankton distribution, abundance and biomass relative to water masses in eastern and central Aleutian Island passes" (K.O. Coyle) will be included in an upcoming special issue of Fisheries Oceanography. Publication has awaited completion of other manuscripts in the issue. This summer I completed a requested figure modification and await receiving proofs for the correction.
- Two additional articles with contribution from this component will appear in the same issue:
  - Ladd, C., J. Jahncke, G.L. Hunt, K.O. Coyle and P.J. Stabeno. Hydrographic features and seabird foraging in Aleutian Passes.
  - Jahncke, J., K.O. Coyle and G.L. Hunt Jr. Seabird distribution, abundance and diets in the eastern and central Aleutian Islands.
- Sue Moore (National Marine Mammal Laboratory, NMML) and I are collaborating on completing analysis of physical oceanographic, acoustic and zooplankton data for interpretation with respect to whale distributions. We hope to complete analysis and generate manuscripts for publication soon.

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, NMML; Steve Zeeman, University of New England; and Phyllis Stabeno, PMEL.

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

Publications

In press

Coyle, K.O. Zooplankton distribution, abundance and biomass relative to water masses in eastern and central Aleutian Island passes. *Fisheries Oceanography*, in press (vol. 14, suppl 1).

Jahncke, J., K.O. Coyle and G.L. Hunt Jr. Seabird distribution, abundance and diets in the eastern and central Aleutian Islands. *Fisheries Oceanography*, in press (vol. 14, suppl 1).

Ladd, C., J. Jahncke, G.L. Hunt Jr., K.O. Coyle and P.J. Stabeno. Hydrographic features and seabird foraging in Aleutian Passes. *Fisheries Oceanography*, in press (vol. 14, suppl 1).

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

Bruce P. Finney, PI
University of Alaska Fairbanks

NOAA Goals: Understand Climate Variability and Change; Ecosystem-based Management

Other investigators/professionals funded by this project:
Amy C. Hirons and Alan M. Springer, *University of Alaska Fairbanks*

CIFAR 01-010: 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 $\delta^{13}C$ 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 ($\delta^{18}O$) 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 ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) 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

- Foraminifera (*E. excavatum*) sieved and preliminary identification conducted for both sediment cores. $\delta^{18}O$ analyses for Skan Bay samples have been completed and Captain's Bay samples are awaiting analysis on the mass spectrometer. Ca/Mg samples have been prepared for both cores and are awaiting trace element analysis.
- Museum and archaeological faunal material has been analyzed for $\delta^{13}C$ and $\delta^{15}N$.
- Cross-correlation analyses begun 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 though NOAA via the North Pacific Universities Marine Mammal Research Consortium (*Impacts of Climate Change on Steller Sea Lion Populations during the Past Century*, $50,000), NSF Arctic Social Science Collaborative proposal: *Investigating Complex Human-Ecological Relationships over Multidimensional Scales: the Sanak Islands Project*, $100,000), and the Pollock Conservation Cooperative Research Consortium (*Food Web Dynamics of the Bering* Sea, $75,162) on subjects dealing with climatic impact on trophic structure, marine productivity and resource utilization.

Education/outreach

Student participation

- Molly Boughan, M.S.-seeking graduate student, Geological Oceanography - collection and identification of foraminifera.
- Molly Odell, undergraduate anthropology student - preparation of bone samples for stable isotope analysis and studying sedimentation in marine cores.

K–12 outreach

Project generation and data have been presented to area middle and high school students as part of Career Day – Science. A student participating in the Alaska Science Symposium has also been introduced to the project and its implications as a potential avenue for their project.

Publications.

In press

Trites, A.W., A.J. Miller, H.D.G. Maschner, M.A. Alexander, S.J. Bograd, J.A. Calder, A. Capotondi, K.O. Coyle, E. Di Lorenzo, B.P. Finney, E.J. Gregr, C.E. Grosch, S.R. Hare, G.L. Hunt, J. Jahncke, N.B. Kachel, H.-J. Kim, C. Ladd, N.J. Mantua, C. Marzban, W. Maslowski, R. Mendelssohn, D.J. Neilson, S.R. Okkonen, J.E. Overland, K.L. Reedy-Maschner, T.C. Royer, F.B. Schwing, J.X.L. Wang, and A.J. Winship. Bottom-up forcing and the decline of Steller sea lions in Alaska: Assessing the ocean climate hypothesis. *Fisheries Oceanography*, in press.

In preparation

Hirons, A.C., B.P. Finney, A.M. Springer and C. Potter. Evidence of environmental fluctuation since the 19th century in Steller sea lions (*Eumetopias jubatus*) using stable isotope ratios. In preparation for submission to *Limnology and Oceanography*.

Two additional manuscripts are being prepared for scientific journal submission. One 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.

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

Jerry McBeath, PI
University of Alaska Fairbanks
Matt Berman, PI
University of Alaska Anchorage

NOAA Goal: Ecosystem-based management

CIFAR 01-015 and 01-004: Work initiated by McBeath was 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, M.S. 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, Alaska Department of Fish and Game (ADFG), and the U.S. Environmental Protection Agency (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

- This research suggests that a well-organized, well-funded program of scientific research has limited ability to respond to the need for information to increase the certainty of decisions related to SSL conservation and recovery.
- Part of the reason is simply the length of time required for science programs to mobilize to formulate and test hypotheses in a systematic way.
- But also part of the problem is the gap in understanding between academically oriented researchers, who aim to create new knowledge, and agency researchers, who are called upon for direct decision support. Bridging this gap is both institutionally and scientifically challenging.

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

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 by Jerry McBeath, "Oil Transportation Infrastructure: The Trans-Alaska Pipeline System and the Challenge of Environmental Change" that was prepared for an upcoming book: Matthias Ruth (Ed.). *Smart Infrastructure and Global Climate Change*. Publisher: M.E. Sharpe, Armonk, NY.

The research also is related to development of an EPA-funded proposal on contaminants in aquatic ecosystems. This is a cooperative agreement among the U.S. Environmental Protection Agency, the North Slope Borough, and the University of Alaska. Project title (from 2002 to 2005) is *Reducing Risk through Capacity-Building: Community Assessment of Climate Change Impacts on Aquatic Ecosystems in the Alaska North Slope*. My collaborator is Carl Shepro, UAA. One product from this research is the article *The effects of environmental change on an Arctic Native communit*y, accepted for publication in the *American Indian Quarterly*, to appear in Volume 31, no. 1 (Winter 2007). Total funding for this project was $99,500.

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*.

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. The research has led to collaboration with NOAA personnel at the Pacific Marine Environmental Lab (PMEL) in a proposal (under review) to create a Regional Integrated Sciences and Assessments (RISA) program in Alaska. The research has also led to new partnerships with marine mammal and fishery researchers at the University of British Columbia, leading to three proposals, two of which were funded, with work to start in August 2005. The two funded proposals are: *Valuation of Critical Habitat Closures* (North Pacific Research Board, $61,194), which will estimate net economic costs of specific fisheries closures in Steller sea lion critical habitat; and *Estimating the Cost to Fisheries of Marine Mammal Habitat Designations* (North Pacific Universities Marine Mammal Consortium, $60,643), which will link outputs and data from spatial ecological models to economic models of fisheries harvest.

NOAA personnel participated as key informants in interviews by both McBeath and Berman. Berman would like to acknowledge specifically the assistance of Lowell Fritz, Doug DeMaster, Joe Terry, and Allan Haynie (Alaska Fisheries Science Center); Phyllis Stabeno (Pacific Marine Environmental Laboratory), and Pete Jones (NOAA Alaska Region).

Education/outreach

Student participation

Christina Talley, an undergraduate student at Seattle University, was supported in part by the CIFAR award in summer 2004.

Darcy Dugan, an undergraduate Earth System Science student at Stanford University (B.A., June 2005), was supported in part by the CIFAR award in spring 2005, and continued to work on the project as a professional employee of the University of Alaska Anchorage after her graduation.

Public awareness

Berman presented on estimating costs of marine reserves to ocean fisheries at the North American Association of Fisheries Economics (NAAFE) Forum in Vancouver, BC, May 2005.

Publications

Peer-reviewed

McBeath, J. 2004. Management of the Commons for Biodiversity: Lessons from the North Pacific. *Marine Policy*, 28:523–539.

Submitted or in press

McBeath, J. Science and politics in marine mammal conservation. *Journal of Wildlife Law and Policy*, in press.

Berman, M. and U.R. Sumaila. Let's start a conversation on the role of discounting and amenities on the economic viability of marine ecosystem restoration. Submitted to *Marine Resource Economics*, June 2005.

Berman, M. Modeling effects of habitat closures in ocean fisheries. *Proceedings of the North American Association of Fisheries Economists (NAAFE) Forum 2005: Fisheries Benefits for All Generations*, Vancouver, BC, in press. (To be submitted to a special issue of *Marine Resource Economics*, August 2005.)

In preparation

Berman, M. Science and decision-making under uncertainty: Analysis of congressionally designated funding for Steller sea lion research. In preparation.

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

Thomas C. Royer, PI *Old Dominion University*

NOAA Goal: Ecosystem-based Management

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

CIFAR 01-018: This project is ongoing.

Primary objectives

We hypothesize that the combination of many of the oceanic-atmospheric forces with bidecadal cycles could lead to the regime shift in the North Pacific that occurred in the late 1970s. 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 method, a locally weighted regression (Loess) method of seasonal trend decomposition, 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).

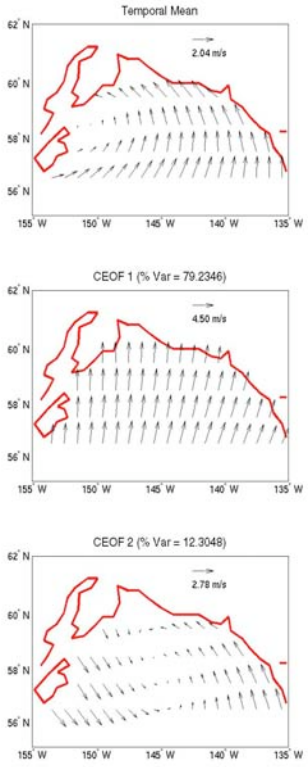

Figure 1. Wind field in the Gulf of Alaska since 1992 with the temporal mean (top), CEOF1 (middle) and CEOF2 (bottom).

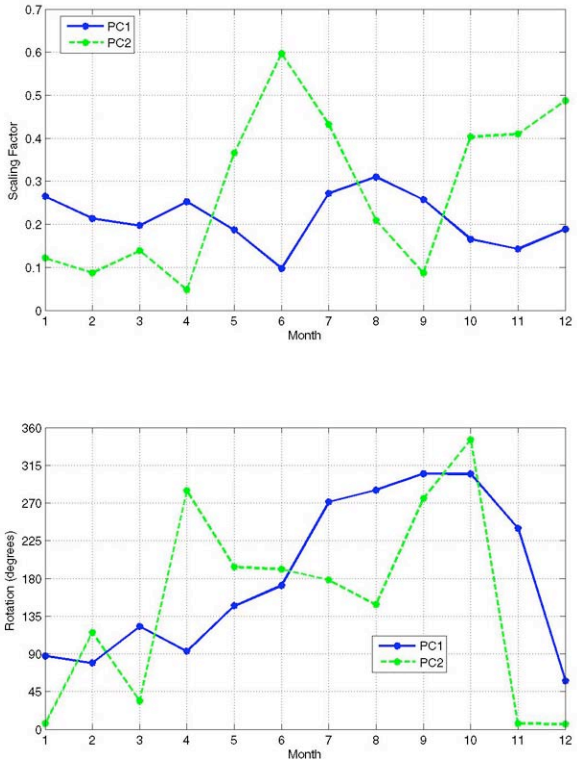

Figure 2. Complex Empirical Orthogonal Function (CEOF) for winds in the Gulf of Alaska since 1992 with the scaling (top) and rotation (bottom) for the first two principal components.

Research accomplishments/highlights/findings

Using wind speed vectors measured by scatterometers onboard ERS1, ERS2, and QuikSCAT satellites, mesoscale wind field climatology has been determined for the Gulf of Alaska. Complex Empirical Orthogonal Function analysis was used to decompose the wind field into temporal mean and variance modes. The first two modes account for approximately 90% of the variance. Figure 1 shows the spatial pattern of the temporal mean (top), CEOF1

(middle) and CEOF2 (bottom). CEOFs have two scaling factors; a magnitude scaling, shown in Figure 2 (top), and a rotation (rotations are counter-clockwise), shown in Figure 2 (bottom). Note that CEOF1, when added to the mean could either strengthen or weaken it, depending on the magnitude of the scaling and the rotation. In the same way, CEOF2, a cyclonic vorticity mode, can either add to or subtract from the vorticity of the temporal mean. All reconstructions using the scaling magnitudes, rotations and CEOFs are relative to the temporal mean (Figure 1, top). The resulting mesoscale wind fields consist of cyclonic vorticity centered approximately around 59N–149W, during the months of October, November, and December. The analysis results show that the mesoscale wind fields in October, November and December are due to a shift to larger scaling factors of PC2 during these months (Figure 2, top). For May, June and July the shift to larger scaling factors of PC2 results in the weakening of the temporal mean and not in the formation of mesoscale wind fields due to the 180^{o} rotation in the wind vectors. The climatology of the wind field will allow for the identification of anomalous wind patterns during the period of the scatterometer wind record (1992–present). The anomalous wind patterns will have an impact on the ocean physics and thus the biological productivity.

Empirical Orthogonal Function (EOF) analysis of the GLOBEC Seward line hydrographic data suggests the presence of three physical modes of variability. The most dominant mode is the weakening and strengthening of the Alaska Coastal Current. The other two modes share about the same amount and variance. One is an on-shelf/off-shelf mode, and the other is the shifting of the shelf break front.

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) (see publication list). They are continuing to study the impact of glacial ablation on ocean circulation in the Northeast Pacific.

- National Science Foundation, GLOBEC: Gulf of Alaska Long Term Monitoring Program, 2000–2005. $339,391
- National Science Foundation/National Oceanic and Atmospheric Administration, GLOBEC Studies in the NE Pacific, subcontract from the University of Alaska, 1997–2001. $160,610

Education/outreach

Student participation

Isaac Schroeder, a Ph.D. candidate at Old Dominion University, has been supported full time on this grant since 2001. The title of his Ph.D. dissertation is "Annual and Interannual Variability in the Wind Field and Hydrography Along the Seward Line in the Northern Gulf of Alaska."

Presentations

Royer, T.C., C.E. Grosch, T.J. Weingartner and S. Danielson. 2004. A fresher, warmer northern Gulf of Alaska? Presented at the 13th Annual PICES meeting, Honolulu, Hawaii, 20 October 2004.

Royer, T.C. 2005. Alaskan oceanography: Past, present and Future – A personal perspective. Keynote Presentation at the Alaska Marine Science Symposium, Anchorage, Alaska, January 2005 (Invited Paper).

Royer, T.C. and C.E. Grosch. 2005. Sea level changes associated with the warming and freshening of the coastal northern north Pacific. Presented at the PICES/GLOBEC Workshop on Climate Variability and Sub-Arctic Marine Ecosystems, Victoria, BC, 18 May 2005.

Royer, T.C. 2005. A maritime window of opportunity for human migration during the last glacial maximum. Presented at the Paths Across the Pacific IV Conference in Sitka, Alaska, 22 July 2005.

Publications

Peer-reviewed

Royer, T.C. 2005. Hydrographic responses at a coastal site in the northern Gulf of Alaska to seasonal and interannual forcing. *Deep-Sea Research II*, 52:267–288.

Weingartner, T.J., S.L. Danielson and T.C. Royer. 2005. Freshwater variability and predictability in the Alaska Coastal Current. *Deep-Sea Research II*, 52:169–191.

Non-peer-reviewed
Royer, T.C. et al. 2005. *Developing a Research and Restoration Plan for Arctic-Yukon-Kuskokwim (Western Alaska) Salmon*. The National Academies Press, Washington, DC. 207 pp.
In preparation or in press
Trites, A.W., A.J. Miller, H.D.G. Maschner, M.A. Alexander, S.J. Bograd, J.A. Calder, A. Capotondi, K.O. Coyle, E. Di Lorenzo, B.P. Finney, E.J. Gregr, C.E. Grosch, S.R. Hare, G.L. Hunt, J. Jahncke, N.B. Kachel, H.-J. Kim, C. Ladd, N.J. Mantua, C. Marzban, W. Maslowski, R. Mendelssohn, D.J. Neilson, S.R. Okkonen, J.E. Overland, K.L. Reedy-Maschner, T.C. Royer, F.B. Schwing, J.X.L. Wang, and A.J. Winship. Bottom-up forcing and the decline of Steller sea lions in Alaska: Assessing the ocean climate hypothesis. *Fisheries Oceanography*, in press.
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*.

ARCTIC RESEARCH INITIATIVE

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

Alan M. Springer, PI
University of Alaska Fairbanks

NOAA Goals: Understand Climate Variability and Change; Ecosystem-based Management

Other investigators/professionals funded by this project:
C. Peter McRoy, *University of Alaska Fairbanks*
Sara J. Iverson and Suzanne Budge, *Dalhousie University*

CIFAR 06-019b: 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 2003–2005 from Little Diomede Island in the Bering Strait. This data will be compared to data from Barrow to assess geographical/environmental effects on ice algae food webs.

In November 2004, compound-specific isotope analysis was carried out on 10 representative samples of each type, including ice algae, phytoplankton, copepods, fish, sea birds, seals, walruses and whales (n=120). This analysis provides a carbon stable isotope ratio for individual fatty acids and was carried out on those fatty acids that are derived exclusively or predominantly from diatoms.

Research accomplishments/highlights/findings

- Carbon isotopic analysis of specific fatty acids present in diatoms differed in ice algae and spring bloom phytoplankton. Fatty acids with enriched isotope ratios, derived from ice algae, were present in zooplankton,

black guillemots, arctic cod, bearded seals and walruses, indicating the importance of ice algal primary production to these higher trophic level consumers.

- Analyses of bowhead whale blubbers show variation in fatty acid profile with age, season and collection year. These results indicate that both adults and sub-adults foraged to some extent on different prey, and that both age classes of bowheads consumed copepod prey in the Beaufort Sea in summer at sufficient levels to significantly alter their blubber fatty acid profiles. Yearly variation indicates that changes in fatty acid composition of species at the base of the food web in response to climate variation are being reflected in the blubber fatty acid profiles. Exceptionally low values of particular fatty acid components correspond to anomalously low values for both the Arctic Oscillation and North Pacific Index.
- Preliminary results of compound-specific isotope analysis indicates that ice algae and phytoplankton incorporate different isotope ratios into two specific fatty acids, 16:4n-1 and 20:5n-3. We expect that the isotope ratios of these fatty acids in consumers at higher trophic levels will reflect the relative importance of those two sources of primary production to the consumer. We anticipate receiving the final isotope data in August 2005.

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. The Barrow and Kaktovik whaling captains and the North Slope Borough provided blubber samples from bowhead whales.

Publications

In preparation

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.*

References

Folch, J., M. Lees and G.H.S. Stanley. 1957. A simple method for the isolation and purification of total lipides from animal tissues. *Journal of Biological Chemistry*, 226:497–509.

Parrish, C.C. 1999. Determination of total lipid, lipid classes, and fatty acids in aquatic samples. In: Arts, M.T. and B.C. Wainman (Eds.), *Lipids in Freshwater Ecosystems*. Springer-Verlag, New York, pp. 5–20.

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

Correction of Systematic Errors in TOVS Radiances

Jennifer Francis, PI
Rutgers University

NOAA Goals: Understand Climate Variability and Change; Serve Society's Need for Weather and Water Information

CIFAR 08-056: 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

Rutgers University (Francis)

- Acquired additional rawinsondes from field experiments and ships, reformatted, then sent them to NESDIS to join existing data base.
- Coordinated frequent teleconferences to discuss problems, solutions, and progress.

NOAA/NESDIS (Reale)

- Historical rawinsonde data base has been completed.
- Screening protocols are being adapted and finalized.
- Complete level 1-b TOVS radiance data base is being transferred from U. of Washington to NESDIS.
- Relational data base containing TOVS radiances and collocated raobs completed. Many issues identified and resolved, IDL programs written by A. Schweiger were provided to NESDIS staff to aid in data structure generation and consistency checking.
- Test year (1995; Figures 1 and 2) of raobs collocated with NOAA-11 High-Resolution Infrared Sounder (HIRS) and Microwave Sounding Unit (MSU) radiances completed. Data from NOAA-12 are in process.
- Collocated raobs with radiances for SHEBA (Surface Heat Budget of the Arctic Ocean) year (fall 1997 to fall 1998) being generated.
- Website and diagnostic tools created and available to access and monitor collocation data (http://www.orbit.nesdis.noaa.gov/smcd/opdb/poes/polarsearch/).

University of Washington (Schweiger)

- Acquired and configured two radiative transfer models (RTTOV and 3R) for computation of brightness temperatures (TBs) from rawinsonde profiles and compare them to satellite- observed values.
- Computed systematic differences between TBs from each forward model to assess errors contributed by models.
- Merged radiance/rawinsonde collocation data sets generated by NESDIS with corresponding surface meteorological observations to facilitate cloud detection/filtering, verify surface temperature, and provide additional verification of sounding quality.

- Developed scheme to extend incomplete rawinsondes to higher altitudes using data base called TIGR (Thermodynamic Initial Guess Retrieval) that is a component of the 3I TOVS retrieval algorithm.
- Developed software to link NESDIS collocation data base and quality assurance scheme with radiative transfer models.
- Assisted NESDIS in identifying and resolving a variety of problems and inconsistencies in rawinsonde data and collocation procedure.
- Generated initial set of brightness temperature biases for all HIRS channels for the entire year of 1995. Initial results suggest that the methodology is successful, as differences between observed and calculated TBs have expected magnitudes and signs owing to likely cloud contamination (observed would be colder if undetected cloud is present). Biases in some channels vary substantially with season; in winter the values are more negative, suggesting the existence of some undetected clouds below the surface-based inversion.

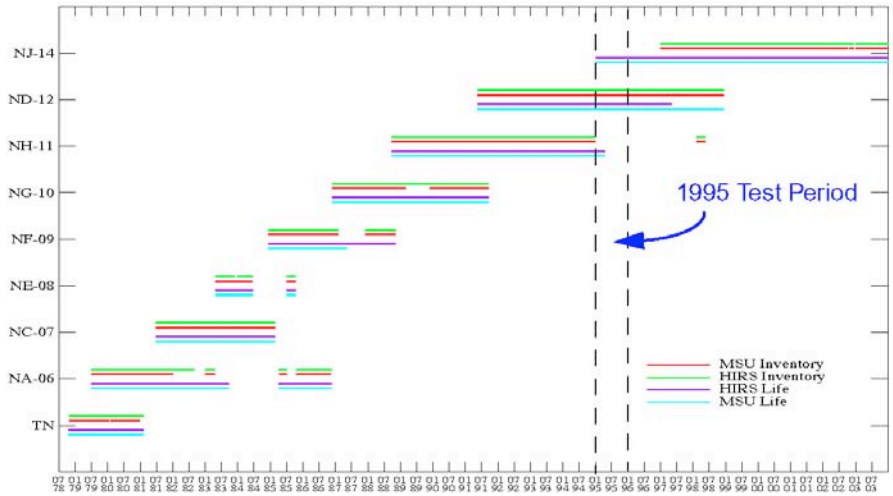

Figure 1. Inventory of data from the High-Resolution Infrared Sounder (HIRS) and the Microwave Sounding Unit (MSU), which are part of the TOVS instrument.

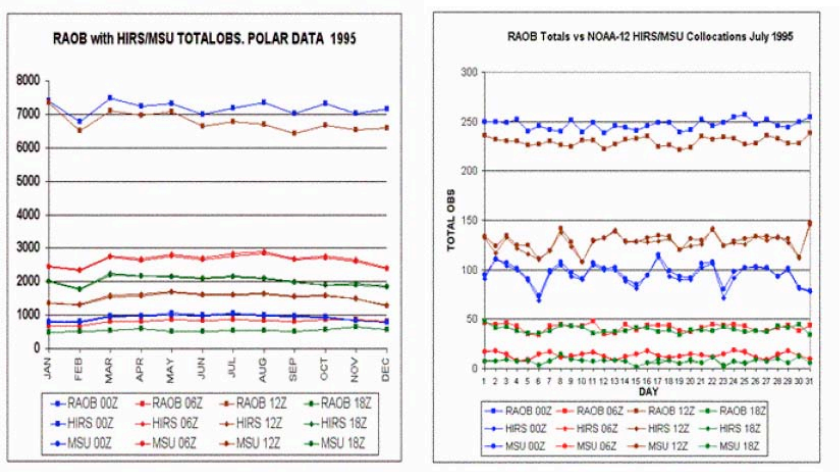

Figure 2. Pilot data sets from NOAA-12 for 1995. Plots show number of rawinsondes and corresponding collocated TOVS radiances (HIRS and MSU) for entire year (left) and for the month of July (right).

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 funded through JISAO.

Initiation of Arctic Reanalysis Activity in SEARCH

David Bromwich, PI
Ohio State University

NOAA Goals: Understand Climate Variability and Change; Serve Society's Need for Weather and Water Information

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

CIFAR 08-055: 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 (ASR), 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 110×100 grid with 40 km horizontal resolution and 28 levels in the vertical. The domain includes much of the North Atlantic region north of 45ºN. 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). The model is tested for summer and winter Greenland conditions in simulations of July and December 2002, respectively. Different boundary layer and land surface parameterizations are evaluated. Options available in WRF version 2.0 include boundary layer physics based upon parameterizations adapted from the National Centers for Environmental Prediction (NCEP) ETA model, and from the newly developed YonSei University scheme. Options for the treatment of the land surface include the 5-layer slab surface scheme from MM5 and the newer 4-layer Noah scheme. The NCEP Aviation Model (AVN) output is used for initial and boundary conditions. In order to allow for spin-up of the model fields consistent with the model physics, simulations are performed by a series of 2-day runs starting each day at 0000 UTC during the test period. Hours 24–48 of the simulations are then combined to represent the duration of the test period. Results are compared to Automatic Weather Station (AWS) data of the Greenland Climate Network (GC-NET).

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). This comparison has been re-evaluated and extended to ERA-40.

Research accomplishments/highlights/findings

- Compared to the Greenland AWS observations, biases that vary from station to station are found in the WRF simulations of boundary layer temperature and velocity. Work is continuing to diagnose the cause of the biases.
- In collaboration with Antarctic WRF modelers at NCAR, it is found that the initially assigned temperature within the subsurface layer of ice sheets can be unrealistic. This can produce biases in the prediction of surface temperature.

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 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; K. Manning and J. Powers, National Center for Atmospheric Research

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.

Presentations:

Bromwich, D.H. and K.M. Hines. 2003. Polar optimized WRF for Arctic System Reanalysis of arctic meteorology over recent decades. *Workshop on Short-to-Medium Range NWP in the Arctic and Antarctic*, Fairbanks, Alaska, 8–10 October 2003.

Bromwich, D.H., K.M. Hines and E.R. Toracinta. 2005. Regional modeling with WRF in the Arctic and coupling issues with GCMs. *Workshop on Research Needs and Directions of Regional Climate Modeling Using WRF and CCSM,* Boulder, Colorado, 22–23 March 2005.

Bromwich, D.H. and S. Wang. 2005. Arctic performance of recent atmospheric reanalyses. *2005 Joint Assembly*, New Orleans, Louisiana, 23–27 May 2005.

Hines, K.M., D.H. Bromwich and J.E. Box. 2005. An evaluation of WRF over the Greenland Ice Sheet. *Fifth Antarctic Mesoscale Prediction System (AMPS) Users Workshop*, Columbus, Ohio, 8–10 June 2005.

Publications

Non-peer-reviewed

Bromwich, D.H. and R.L. Fogt. 2005. Strong trends in the skill of the ERA-40 and NCEP/NCAR reanalyses in the high and middle latitudes of the Southern Hemisphere, 1958–2001. Preprints, *Eighth Conference on Polar Meteorology and Oceanography*, San Diego, California, 9–13 January 2005, American Meteorological Society, CD-ROM.

Hines, K.M. and D.H. Bromwich. 2005. On adapting a next-generation mesoscale model for the polar regions. Preprints, *Eighth Conference on Polar Meteorology and Oceanography*, San Diego, California, 9–13 January 2005, American Meteorological Society, CD-ROM.

In press or in preparation

Bromwich, D.H. and S.-H. Wang. Evaluation of the NCEP/NCAR and ECMWF 15/40-yr reanalyses using rawinsonde data from two independent Arctic field experiments. *Monthly Weather Review,* in press.

Hines, K.M., D.H. Bromwich and J.E. Box. A polar ice sheet evaluation of WRF over Greenland. In preparation for submission to *Monthly Weather Review*.

References

Bromwich, D.M., J.J. Cassano, T. Klein, G. Heinemann, K.M. Hines, K. Steffen and J.E. Box. 2001. Mesoscale modeling of katabatic winds over Greenland. *Monthly Weather Review*, 129:2290–2309.

Francis, J.A. 2002. Validation of reanalysis upper-level winds in the Arctic with independent rawinsonde data. *Geophysical Research Letters*, 29. doi: 10.1029/2001GL014578.

Initiation of an Arctic Reanalysis Activity in SEARCH

John E. Walsh, PI
University of Alaska Fairbanks

NOAA Goals: Understand Climate Variability and Change; Serve Society's Need for Weather and Water Information

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*

CIFAR 09-063: This project is ongoing.

Primary objectives

The project's main objectives are (1) an assessment of the performance of the ERA-40 reanalysis in the Arctic, (2) tests of data assimilation strategies for Arctic regional models, and (3) the adaptation of the Weather Research and Forecasting (WRF) model for use in the Arctic. 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

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.

The Arctic output of global reanalyses (ERA-40, National Center for Atmospheric Research (NCAR)/National Centers for Environmental Prediction (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.

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 collaborator D. Bromwich, funded through separate channels.)

Research accomplishments/highlights/findings

- A pan-Arctic domain (241x241 grid points with 30 km grid spacing) has been set up for the Arctic System Reanalysis. A full year MM5 forecast has been finished and utilized in creating seasonal MM5 background error statistics, which are used in a 3DVAR assimilation scheme. From four generic cases (one in each season) and three extreme cases, the above customized background error provides more realistic information in 3DVAR assimilation and produces improved simulations of temperature, sea level pressure, winds, and precipitation in most cases.
- ERA-40's precipitation fields over central Arctic are still problematic, especially during summer, but much improved in comparison to the NCEP/NCAR reanalysis. The aerological water budget appears to be quite good. Compared to NCEP/NCAR, the atmospheric and surface budget is well closed.
- The ERA-40 data assimilation scheme for 2-m temperatures appears to provide for realistic fields over topographically complex terrain and could be adopted within the Arctic System reanalysis.
- 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 community NOAH (NCEP, Oregon State University, Air Force, Hydrologic Research Lab) land surface model that will likely be used in the Arctic System Reanalysis presently suffers from non-conservation of water and energy, and produces excessive evaporation over snow-covered surfaces.
- Pilot investigations demonstrate that assimilation of soil temperatures through Kalman filtering approaches could be incorporated as a post-processing step in an Arctic System Reanalysis framework.

NOAA relevance/societal benefits

The 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 separate project report).

The results of the collective effort were recently reported at the U.S./Sino Workshop on Arctic Climate and discussed with potential Chinese collaborators in Beijing (27–28 July 2004).

Some of the work to evaluate the NOAH land surface model is being coordinated with Dr. Ken Mitchell, NOAA/NCEP.

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.

Presentations

Presentation at MM5/WRF Workshop, Boulder, Colorado, 22–25 June 2004.

Presentation at workshop on Arctic System Reanalysis, Boulder, Colorado, 13–14 October 2004.
Presentations at AMS conference, San Diego, California, 9–13 January 2005.

Publications

Peer-reviewed

Frauenfeld, O.W., T. Zhang and M.C. Serreze. 2005. Climate change and variability using European Centre for Medium Range Weather Forecasts reanalysis (ERA-40) temperatures on the Tibetan Plateau. *Journal of Geophysical Research*, 110, D02101. doi:10.1029/2004JD005230.

Non-peer-reviewed

Fan, X., J.R. Krieger, X. Meng, R.W. Smith and J.E. Walsh. 2005. Assimilation of MODIS retrievals with the MM5/3DVAR system in an Arctic extreme rain event. Preprints, *Eighth Conference on Polar Meteorology and Oceanography*, AMS, San Diego, California, 9–13 January 2005, P3.19.

Fan, X., J.S. Tilley and J.E. Walsh. 2004. Application of MM5/3DVAR at high latitude: Resolution sensitivity. Preprints, *Fifth WRF/14th MM5 User's Workshop*, NCAR, June 22–25, 2004, Boulder, Colorado, 5.10.

Tilley, J.S., X. Fan and J.E. Walsh. 2005. Application of a mesoscale 3DVAR system at high latitudes as a step towards Arctic reanalysis. Preprints, *Eighth Conference on Polar Meteorology and Oceanography*, AMS, San Diego, California, 9–13 January 2005, JP2.11.

In press or in preparation

Fan, X. and J.S. Tilley. Dynamic assimilation of MODIS-retrieved humidity profiles within a regional model for high latitude forecast applications. Submitted to *Monthly Weather Review*; conditionally accepted after minor revisions.

Fan, X., J.S. Tilley and J.E. Walsh. Application of 3D variational assimilation at high latitudes: Resolution sensitivity. Submitted to *Scientific Online Letters of the Atmosphere* (SOLA).

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.

Serreze, M.C., A. Barrett, A.J. Slater and 7 others. The large-scale freshwater cycle of the Arctic. In preparation for submission to *Journal of Geophysical Research*.

Contaminant Effects

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

Catherine F. Cahill, PI
University of Alaska Fairbanks

NOAA Goal: Understand Climate Variability and Change

CIFAR 06-042: 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 β-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 *Xue Long*, collected the aerosol samples during the Second Chinese National Arctic Research Expedition (CHINARE II) and the 19th 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

- Presented the preliminary aerosol results from CHINARE II and CHINARE 19 at the American Meteorological Society annual meeting in San Diego, CA, during January 2005. Two Chinese scientists, Liqi Chen and Zhongyong Gao, were co-authors on the paper.
- The good relationship between the PI and Chinese scientists led to the collection of aerosols during August 2004 at the new, established in 2004, Chinese Yellow River Station in Ny Alesund.
- The aerosols observed during the CHINARE 19 (Antarctic) and CHINARE II (Arctic) cruises demonstrate the difference in aerosol sources between the Antarctic and Arctic. Locally generated aerosols dominate Antarctica's anthropogenic aerosols, while more distant sources produce the anthropogenic aerosols observed in the Arctic.
- Meteorological back trajectories from the NOAA Air Resources Laboratory (ARL) HYSPLIT transport and dispersion model and the composition of the aerosols during several periods sampled during CHINARE II suggest that emissions from Norilsk, Russia, are impacting the aerosol loading over the Bering and Chukchi Seas during summer.
- The elements produced by anthropogenic sources, such as fossil fuel power generation (sulfur, some silicon, and nickel), and natural sources, such as soils (most of the silicon), decreased during CHINARE 19 as the ship moved towards Antarctica. However, peaks occurred in these elements when the *Xue Long* was near Antarctic research stations or in port, implying that the stations are producing local pollution.
- Silicon, a tracer of soil and anthropogenic activities, decreased as the *Xue Long* traveled south, away from continents and large industrial complexes, during CHINARE 19. The small spikes in silicon around Antarctica appear to be associated with local pollution generated by fossil fuel combustion at the various Antarctic research stations.

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.

Publications

No journal publications have been submitted yet, but a paper to the Journal of Geophysical Research on the transport of aerosols, especially mercury, to the Arctic from China is in preparation. The work also appeared in the proceedings of the American Meteorological Society Annual Meeting.

Non-peer-reviewed

Cahill, C.F., L. Chen and Z. Gao. 2005. Aerosols collected during the 19th Chinese Antarctic Research Expedition (CHINARE 19) and the Second Chinese National Arctic Research Expedition (CHINARE II). Proceedings, *AMS 85th Annual Meeting*, San Diego, California, Paper P1.12.

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

Greg Patton, PI
Battelle Pacific Northwest Division

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*

NOAA Goal: Understand Climate Variability and Change

CIFAR 06-002c and CIFAR 06-006b: This project is complete.

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

- Presented an interactive poster on the POPs air monitoring project to *Society of Environmental Toxicology and Chemistry*, *Fourth World Congress* in Portland, Oregon in November 2004.
- Produced a final project report *Persistent Organic Pollutants in the Atmosphere at Barrow, Alaska* (PNWD-3540)
- Presented preliminary POPs data as a component of a platform presentation at the *American Chemical Society Northwest Regional Meeting* in Fairbanks, Alaska in June 2005.
- Submitted the abstract "Seasonal variation in POPs air sampling results at Barrow, Alaska and Little Fox Lake, Yukon" to the 25th International Symposium on Halogenated Environmental Organic Pollutants and POPs in August 2005, Toronto, Canada.
- Numerous polycyclic aromatic hydrocarbons (PAH) were detected in air at Barrow, AK. Airborne concentrations and dominant PAH at Barrow were similar to literature values for Canadian and Russia sampling locations. Naphthalene, fluorene, and phenanthrene had average concentration above 100 pg/m^3. Other PAH

with average concentrations above 10 pg/m^3 were acenaphthene, chrysene, fluoranthene, pyrene, and benzo(b)fluoranthene.

- Numerous organochlorine (OC) compounds were detected in air at Barrow. Airborne concentrations and dominant OC compounds at Barrow were similar to literature values for Canadian and Russia sampling locations. However, chlorobenzene, hexachlorocyclohexanes (HCH), chlordane, mirex and toxaphene were typically lower at Barrow, whereas the concentration of pentachloroanisole was typically higher at Barrow. Levels of HCH compounds at Barrow correspond to the dramatic decrease in HCH levels in Arctic air since the mid-1980s which is a result of reduction in the global use of these compounds.
- Changing ratios of a-HCH/g-HCH, trans-chlordane/cis-chlordane, and DDE/DDT were observed at Barrow and may be useful for determining source regions for these chemicals.
- Polychlorinated biphenyls (PCBs) were detected in air at Barrow. Airborne concentrations and dominant PCBs at Barrow were similar to literature values for Canadian and Russia sampling locations, with the tri-chlorinated homolog having the highest concentration. There was little indication of seasonal trends for PCB concentrations at Barrow.
- Trace aerosol data collected at Barrow shows Russian (including the Norilsk region) and Asian (Gobi desert dust) emissions impacting the Barrow Observatory at several different points during the study year.
- The year long air sampling effort at Barrow, AK provided valuable information for assessing the current status and trends of POPs. This information will be particularly useful when used in context with data, as it becomes available, from the other Arctic POPs air monitoring conducted by the Canadian Northern Contaminants Program and the measurements from the Russian Arctic.

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 collaboration between the University of Alaska, Fairbanks, Battelle Pacific Northwest Division, Freshwater Institute of Canada, AirZoneOne, Inc., Environment Canada, and NOAA/CMDL.

The sampling and analytical methodology produced two types of sample archives for POPs. According to the project proposal, an aliquot (50%) of each original sample was placed into a sample archive. This original sample archive was transferred from Battelle's Sequim Laboratory to AirZone in March 2005 and will be managed as part of the long-term Northern Contaminants Program archive. The second archive is the remaining extracts from the samples that were processed and analyzed for POPs by this study. The second archive was transferred from Freshwater Institute of Canada to Ms. Liisa Jantunen of Environment Canada. Ms. Jantuten will be analyzing these samples for chiral components using existing funding at Environment Canada.

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.

Ted Wu presented some of the POPs data during a lecture to graduate and undergraduate students as a part of Chemistry 481/482 (an undergraduate seminar class) at the University of Alaska Fairbanks, Fairbanks, Alaska.

Conference presentations

Patton, G., T. Fortman, P. Fellin, G. Stern and L. Barrie. 2004. Persistent organic pollutants in ambient air at Barrow, Alaska. Fourth Society of Environmental Toxicology and Chemistry (SETAC) World Congress and 25th Annual Meeting, Portland, Oregon, 15–18 November 2004.

Su, Y., H. Hung, P. Blanchard, G. Patton, P. Fellin, H. Li, C. Geen, G. Stern, B. Rosenberg and L. Barrie. 2005. Seasonal variations of organochlorine pesticides at two arctic sites. Twenty-fifth International Symposium on Halogenated Environmental Organic Pollutants and POPs (Dioxin 2005), Toronto, Canada, August 2005.

Wu, T.H. and C.F. Cahill. Using semi-permeable membrane devices (SPMDs) as passive air samplers to assess persistent organic pollutants (POPs) in Alaska. American Chemical Society Northwest Regional Meeting, Fairbanks, Alaska, June 2005.

Publications

Non-peer-reviewed

Patton, G., P. Fellin, C. Cahill, G. Stern, L. Barrie, C. Green, H. Li, T. Fortman, E. Crecelius and B. Fritz. 2005. *Persistent Organic Pollutants in the Atmosphere at Barrow, AK*. PNWD-3340. Prepared for the National Oceanic and Atmospheric Administration under Contract No. 41759A.

In press or in preparation

Data will be available as part of the Northern Contaminants Program database.

A journal article is being produced by Environment Canada, Battelle, and AirZone under the direction of Dr. Hung (Environment Canada). This report will include results from Barrow, Alaska station, the Canadian Northern Contaminants stations, and the Russian Arctic station.

A journal article on the comparability between active and passive POPs sampling at Barrow, Alaska, is being prepared for submission to *Environmental Science and Technology*.

A journal article on the use of trace contaminants to identify the sources of POPs observed at Barrow, Alaska, is being prepared for the *Journal of Geophysical Research*.

Arctic Monitoring and Assessment Programme (AMAP)

Lars-Otto Reiersen, PI
Executive Secretary, AMAP

NOAA Goals: Understand Climate Variability and Change
Ecosystem-based Management

CIFAR 10-052b: 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

- Data was collected during the winter and spring of 2004 at Barrow.
- A workshop was held in December 2004 in Tennessee, USA. Scientists from several Arctic countries participated, e.g., Canada, Denmark, Norway and USA.
- The data has been analyzed and will be reported in a special AMAP report when ready.
- Follow-up projects in connection with the International Polar Year (IPY) have also been prepared.

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.

Publications

Under preparation.

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
- International workshops to prepare the assessment have been held in Washington, DC, USA, in January 2004; Oslo, Norway, September 2004; Helsinki, Finland, February 2005; and Washington, DC, USA, June 2005. In September 2005 an International Symposium will be arranged as part of the assessment process in St. Petersburg, Russia.
- A baseline survey to document the levels of hydrocarbons in Arctic Seas and Adjacent Seas has been performed and results are under evaluation.

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.

Education/outreach
The activity has been presented to the Arctic Council and the Barents Council.

Publications
Under preparation for release in 2006.

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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. International workshops have been held in Helsinki, Finland, January 2004 and in Kilpisjärvi, Finland, March 2005. The next workshop will be held in Tromsø, Norway, October 2005.

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.

Education/outreach
The activity has been presented to the Arctic Council and the Barents Council.

Publications
Under preparation for release in 2006.

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 several 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 and the ACIA Overview report, *Impacts of a Warming Arctic*, was published in November 2004. 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 ACIA Overview report has been presented to the Arctic Council, the Barents Council, the IPCC process and at several international meetings and organizations. The report should be very useful as a textbook at schools and Universities.
- A special film/video was prepared and has been widely distributed.

Publications
Arctic Climate Impact Assessment. 2004. Impacts of A Warming Arctic. Cambridge University Press, 139 pp. (This report has also been translated to German, Dutch, Russian, Norwegian and Saami.)

The ACIA Scientific report is in the final stages of preparation. Pre-release versions of the chapters are available from the web (http://www.acia.uaf.edu).

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 was followed.

Research accomplishments/highlights/findings
The ACIA Symposium was arranged 9–12 November 2004 in Reykjavik, Iceland. More than 300 experts participated.

NOAA relevance/societal benefits
The Symposium was of great interest for NOAA, the latest results from research and monitoring was 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 were arranged.

Publications
A special Proceeding for all extended abstracts was prepared and is available from AMAP web site, http://www.amap.no.

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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 was followed.

Research accomplishments/highlights/findings
The symposium "Influence of Climate Change on North Atlantic Fish Stocks" took place 11–14 May 2004 in Bergen, Norway, and a special proceedings volume has been prepared.

NOAA relevance/societal benefits
The Symposium was of great 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 has been prepared and will soon be available from ICES (http://www.ices.dk).

Fisheries Oceanography

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

Milo Adkison, PI ***NOAA Goal: Ecosystem-based Management***
University of Alaska Fairbanks

CIFAR 10-027c: 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 (GOA); 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

- Archived scales from male hooknose and jack coho salmon returning to Auke Creek weir have been digitized and saved as image files. Scale growth data has been collected from the images for all years available (1980–2003). A database has been created which includes scale growth data, and to which environmental index data and other biological data will be added for correlation analyses. Male and jack scale growth data has been organized into the three phases of marine growth: juvenile nearshore/coastal, juvenile Gulf of Alaska, and adult. Exploratory analysis is presently underway for this data set.

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 pursuing complementary research projects funded by US GLOBEC. Alex Wertheimer is most heavily involved in the CIFAR-supported studies, 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 have been fully supported for master's theses on this research project. The first, Ryan Briscoe, graduated in December 2004 after 2.5 years of support. The second, Josh Robins, started his research one year ago. Briscoe has presented his research results in local, statewide, and national scientific symposia.

Publications

Non-peer-reviewed

Briscoe, J.R. 2004. Factors Affecting Growth and Survival of Auke Creek, Alaska Coho Salmon (*Oncorhynchus kisutch*). M.S. thesis, University of Alaska Fairbanks, 57 pp.

In press or in preparation

Briscoe, R.J., M.D. Adkison, A. Wertheimer and S.G. Taylor. 2005. Biophysical factors associated with the marine survival of Auke Creek, Alaska coho salmon. In July issue of *Transactions of the American Fisheries Society*.

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

Milo Adkison, PI
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NOAA Goal: Ecosystem-based Management

CIFAR 10-040b: 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 (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

- A manuscript is in review at a major fisheries journal titled “Critical size distribution and size selective mortality of juvenile Bristol Bay sockeye salmon.”
- A manuscript is in preparation titled “Spatial variations in feeding and condition of juvenile Bristol Bay sockeye salmon in relation to ocean conditions along the eastern Bering Sea shelf.”

NOAA relevance/societal benefits

These studies will increase our understanding of the mechanisms by which smolt growth as a function of nearshore processes affects 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 review. Another manuscript describing spatio-temporal variation in feeding and condition 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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University of Alaska Fairbanks

C.M. Kondzela and R.L. Wilmot, cooperators
NOAA, AFSC, Auke Bay Laboratory

CIFAR 06-044: This project is complete.

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 2002 ABL-OCC cruises. This work is part of a larger effort to improve our understanding of the physical and biological mechanisms that affect the distribution, migration, growth, and survival of juvenile chum salmon in western Alaska, a region that has experienced severe declines in returns of adult chum salmon in recent years.

Approach/methodology

Juvenile chum salmon (*Oncorhynchus keta*) were collected from the eastern Bering Sea using a midwater rope trawl towed at the surface between September 2 and October 7, 2002 (Farley et al. 2003). Sampling stations were between longitudes 165 and 172.5º W and between latitudes 58 and 63º 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 20 protein-coding loci (Aebersold et al. 1987; Kondzela et al. 1994). The genetic variation was analyzed using a conditional maximum likelihood method of mixture analysis (ADF&G 2001; Pella and Masuda 2001) and the Pacific Rim chum salmon allozyme baseline (Kondzela et al. 2002). An analysis of the complete dataset using the 356-population baseline indicated that the fish originated from Russia and western Alaska, therefore a reduced baseline of 49 populations was used for subsequent analyses. Estimates of geographic origin were made from data pooled across stations into five geographic locales.

Research accomplishments/highlights/findings

- The starch gel electrophoretic analysis for 20 protein-coding loci has been completed for the entire set of 2002 juvenile chum salmon collection from the eastern Bering Sea.
- The data has been pooled into five locales, each of which has been analyzed to determine area of origin (Table 1).
- Summer-run fish from the Yukon and Kuskokwim rivers dominate the samples collected, suggesting a southwestward migration resulting in a broad distribution along the eastern Bering Sea shelf in the late summer and early fall. The fall Yukon River populations were detected south and west of the Yukon River mouth. The two late-run Kuskokwim populations did not contribute significantly to any locale. Populations from northern Russia contributed to the samples collected around St. Lawrence Island, indicating a northeastward migration of juvenile chum salmon from the northeast region of the Asian continent.
- Summer-run populations from western Alaska, e.g., Yukon and Kuskokwim, cannot be distinguished with the allozyme baseline. Finer-scale resolution of populations for mixtures containing western Alaska populations will require development of other genetic markers (e.g., microsatellite or SNP loci).

Table 1. Regional estimates of juvenile chum salmon collected in the eastern Bering Sea in fall 2002 using a conditional maximum likelihood method. Below each point estimate is the 95% non-symmetric confidence interval. Estimates significantly greater than zero are in bold font.

		Regional Allocation			
Collection Locale	N	Yukon/Kuskokwim summer	Yukon fall	Kuskokwim late	N. Russia
SE Nunivak Is.	306	**0.941** (0.901–1)	0.041 (0–0.081)	0 (0)	0.012 (0–0.25)
SSW Nunivak Is.	478	**0.612** (0.454–0.742)	**0.337** (0.207–0.486)	0.037 (0–0.074)	0.011 (0–0.023)
WNW Nunivak Is.	337	**0.560** (0.336–0.670)	**0.382** (0.265–0.584)	0.0.035 (0–0.070)	0.023 (0–0.047)
E St. Lawrence Is.	314	**0.692** (0.578–0.827)	**0.196** (0.085–0.293)	0 (0)	**0.113** (0.042–0.180)
S St. Lawrence Is.	278	**0.572** (0.425–0.778)	0.166 (0–0.270)	0.038 (0–0.076)	**0.224** (0.129–0.302)

NOAA relevance/societal benefits

This work is part of a larger effort by NOAA and member countries of the North Pacific Anadromous Fish Commission (NPAFC) 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 E. Farley, NOAA, AFSC, Auke Bay Laboratory.

Education/outreach

Presentation

Farley, E.V. Jr., C.M. Kondzela, J.M. Murphy and A. Middleton. 2004. Stock-specific distribution and migration of juvenile chum salmon along the eastern Bering Sea shelf. In: *NPAFC Technical Report 5: Workshop on Application of Stock Identification in Defining Marine Distribution and Migration of Salmon*, Honolulu, Hawaii, 1–2 November 2003, p. 27.

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

A.J. Gharrett, PI ***NOAA Goal: Ecosystem-based Management***
University of Alaska Fairbanks

CIFAR 09-045a: This project is ongoing and continues CIFAR 06-045. Phase 1 was in previous cooperative agreement.

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 planned to use approximately twelve microsatellite loci to quantify the variation within and among the Alaskan POP populations. Our samples represent most of the Alaskan geographic range. This summer, additional samples will be collected from areas around the Gulf of Alaska to complete the range of POP in 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. These data also form a framework for evaluating young-of-the-year samples of POP collected in the northern Gulf of Alaska and Bering Sea supported by the North Pacific Research Board (NPRB) as discussed in *Research linkages* below.

Research accomplishments/highlights/findings

- Using ten 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).
- For this initial analysis, we used microsatellite loci *Sal1*, *Sal2, Sal3, Sal4*, and *Sal6* (Miller et al. 2000); *SR7-2, SR7-25, SR7-7* (Westerman et al. 2005); *Sma7* and *Sma5* (Wimberger et al. 1999).
- Currently we are evaluating additional microsatellite loci for their potential to supplement the study or to replace those loci that may have amplification problems, which will be determined in further statistical analysis. Those loci are: *Seb33* (Roques et al. 1999); *Sma11* (Wimberger et al. 1999); *Spi4*, *Spi6*, *Spi10*, *Spi12* (Uchida et al. 2003); *Sth3B* (Sekino et al. 2000) and *Ssc69* (Yoshida et al. 2005).
- In addition, we obtained samples from R. Withler (Department of Fisheries and Oceans, Canada) from the British Columbia area (Withler et al. 2001) in an attempt to standardize data between labs.

- Three additional collections are currently being taken by NOAA Gulf Surveys in the Gulf of Alaska to complete the range of samples.

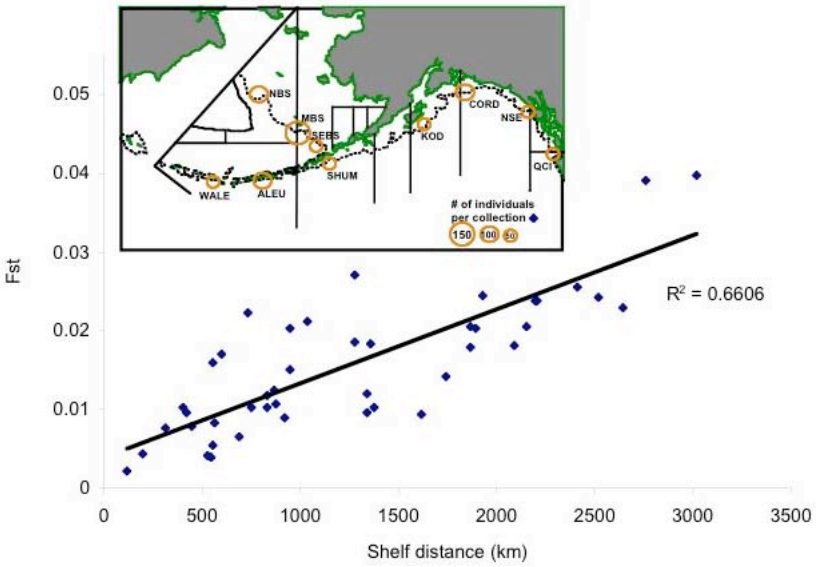

Figure 1. Isolation by distance from distances along the continental shelf line and pairwise F_{st}. Points represent each population pair.

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. These data will also provide a reference for the young-of-the-year POP which we are examining to learn about dispersion of young fish.

Research linkages/partnerships/collaborators and networking

Funding for this project comes through collaboration with the National Marine Fisheries Service Auke Bay Laboratory. International collaboration with the Department of Fisheries and Oceans, Canada (see third bullet under *Accomplishments*) has also resulted from this project. The NOAA investment in CIFAR 09-045a and CIFAR 10-062a: *Species Composition and Spatial Distribution of Gulf of Alaska and Bering Sea Young-of-the-Year Rockfish Species* provided baseline data that has leveraged funding through NPRB projects F0420, *Interannual and Spatial Variation in Population Genetic Composition of Northeastern Gulf of Alaska Young-of-Year POP*, $105,000, 9/1/2004 to 8/31/2005 and F0512, *Juvenile POP Genetics*, Phase 2, 9/1/2005 to 2/28/2007, $116,830, that examine the dispersion of juvenile POP.

Education/outreach

Graduate student Katie Palof has completed her second year of Master's work. The preliminary funding for this project has enabled her to obtain a Rasmuson fisheries fellowship through the University of Alaska Fairbanks for both the 2004 to 2005 and 2005 to 2006 academic years.

Presentations

Palof, K.J., A.J. Gharrett and J. Heifetz. Population structure of Alaska Pacific ocean perch (*Sebastes alutus*). Poster presented at 2004 Alaska Chapter American Fisheries Society, November 2004.

Palof, K., A.J. Gharrett and J. Heifetz. Population structure of Alaska Pacific ocean perch (*Sebastes alutus*). Poster to be presented at Biology, Assessment, and Management of North Pacific Rockfishes, 23rd Lowell Wakefield Fisheries Symposium, September 2005.

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Species Composition and Spatial Distribution of GOA and BS Young-of-the-Year Rockfish Species

A.J. Gharrett, PI ***NOAA Goal: Ecosystem-based Management***
University of Alaska Fairbanks
C.M. Kondzela, cooperator
NOAA Fisheries, AFSC, Auke Bay Laboratory

Other investigators/professionals funded by this project:
Z. Li, S. Walden
University of Alaska Fairbanks

CIFAR 10-062a: This project is ongoing.

Primary objectives

Young-of-the-year (YOY) *Sebastes* rockfish were collected as "bycatch" during NOAA Ocean Carrying Capacity (OCC) 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 to 1) fill in some of the gaps in knowledge of the early life histories of several Alaskan rockfish species and 2) explore the possibility of developing morphological methods for species identification.

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 et al. in press) extended the study to more than 70 *Sebastes* species, including all the species reported in the GOA (Kendall 2000; Love et al. 2002).

Research accomplishments/highlights/findings

- Dr. Kendall has completed morphological analysis of more than 100 specimens and has begun examination of an additional 148 fish. The POP had considerable morphologic variation, particularly in body pigmentation, which confounds species identification of morphologically similar species, e.g., *aleutianus, ciliatus,* and

entomelas. Genetic analysis is complete for the 377 POP-type and non-POP type fish, as well as an additional 600 from the 2072 POP-type. Twenty-eight of the 600 POP-type fish (~5%) were genetically characterized as other species: *aleutianus, ciliatus/crameri/polyspinis, entomelas/mystinus*, and *flavidus*. While genetic analysis is necessary to identify several species unequivocally, morphologic analysis easily separates *S. crameri* from *S. ciliatus/polyspinis*, and is helpful in separating *S. entomelas* from *S. mystinus*, which are genetically identical with the mtDNA markers we used.

- To date, we have identified 13 species of *Sebastes* rockfish from the OCC collections: *aleutianus, alutus, borealis, ciliatus, crameri, flavidus, entomelas, melanops, pinniger, proriger, reedi, ruberrimus*, and *zacentrus*. A number of these species have never or rarely been described in the juvenile life history stage.
- Future analysis will focus on describing the spatial and temporal distribution in the Gulf of Alaska and Bering Sea of the species identified and will include specimens identified as other than POP in the remaining POP-type samples (~1500 samples to be analyzed for another project).

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 an independent contractor (A. Kendall) and use of laboratory facilities at the National Marine Fisheries Service, Auke Bay Laboratory. Most of the rockfish obtained in this study are Pacific ocean perch. The population genetic structure of those fish is being investigated at our UAF laboratory through support provided by NPRB project number F0420, *Interannual and spatial variation in population genetic composition of northeastern Gulf of Alaska young-of-the-year Pacific ocean perch*, 1 year September 2004 to August 2005, $105,000.

Stephanie Walden and Rachel Riley of the University of Alaska Fairbanks provided laboratory support.

Publications

Non-peer-reviewed

Kondzela, C.M., A.W. Kendall, Z. Li, D. Clausen and A.J. Gharrett. 2003. Preliminary evaluation of the rockfish (*Sebastes* spp.) species collected during ABL-OCC cruises in the Gulf of Alaska in 1998–2002. Section 2, Chapter 7. In: *Final Report: The Ecological Role of Natural Reefs and Oil and Gas Production Platforms on Rocky Reef Fish of Southern California: Genetics subse*ction, to L.K. Thorsteinson, U.S. Geological Survey, Biological Resources Division.

In preparation

Kondzela, C.M., A.W. Kendall, Z. Li, D.M. Clausen and A.J. Gharrett. Preliminary evaluation of juvenile rockfish species collected in the Gulf of Alaska, 1998–2002. In preparation for a poster presentation (September 2005) and subsequent publication in the 23rd Wakefield Fisheries Symposium proceedings.

References

Gharrett, A.J., A.K. Gray and H. Heifetz. 2001. Identification of rockfish (*Sebastes* spp.) by restriction site analysis of the mitochondrial ND-3/ND-4 and 12S/16S rRNA gene regions. *Fishery Bulletin*, 99:49–62.

Kendall, A.W. Jr. 2000. A historic review of *Sebastes* taxonomy and systematics. *Marine Fisheries Review*, 62:1–23.

Li, Z., A. Gray, M. Love, A. Goto, T. Asahida and A. Gharrett. A key to selected rockfishes (*Sebastes* spp.) based on mitochondrial DNA restriction fragment analysis. *Fishery Bulletin*, in press.

Love, M.S., M. Yoklavich and L. Thorsteinson. 2002. *The Rockfishes of the Northeast Pacific*. University of California Press, Berkeley, California.

Energy, Diet, and Condition of Juvenile Pink Salmon, *Oncorhynchus gorbuscha*, in the Gulf of Alaska

Nicola Hillgruber, PI
University of Alaska Fairbanks

NOAA Goal: Ecosystem-based Management

CIFAR 10-076: This project is ongoing.

Primary objectives

Juvenile pink salmon are most vulnerable to mortality during their first months at sea, when prey abundance, competition, predation, and environmental changes can impact their growth and survival. Because early marine growth is critical for survival, it is important to understand juvenile energy requirements. Whole body energy content (WBEC) can indicate overall condition and growth potential. WBEC of juvenile pink salmon from three Prince William Sound hatcheries (Armin F. Koernig, Wally Noerenberg, and Solomon Gulch) was compared to wild juveniles in the Gulf of Alaska. WBEC and condition factor were used to determine and compare fitness for these four groups.

Approach/methodology

Juvenile pink salmon were collected during Ocean Carrying Capacity (OCC)/GLOBEC Gulf of Alaska (GOA) research cruises on 34 stations along three transects: Gore Point (GP), Seward Line (GAK), and Cape Cleare (CCL). The cruises were conducted in July–August, 2001–2002 on board the F/V *Great Pacific* using a 198-m-long midwater rope trawl with hexagonal mesh wings and body, and 1.2-cm mesh liner in the codend. Fork length and body weight were measured for up to 50 juvenile pink salmon per haul. Fish were frozen and returned to the lab for further analyses. Hatchery origin was determined by identifying the otolith thermal marks; fish lacking thermal marks were considered wild. From each transect a subsample of 30 fish per origin was selected and whole body energy content, the composition of protein, fat, and water content in somatic tissue, was determined using a Parr 1425 semi micro bomb calorimeter. Analysis of variance was used to test for significant differences in WBEC by year, transect, and origin of the pink salmon juveniles. Pairwise differences between transects and hatcheries were identified using a multiple comparison Tukey Kramer HSD test. Relationships between WEBC and length, weight, condition factor and percent dry weight were also examined.

Research accomplishments/highlights/findings

- Year, transect, and hatchery origin explained a significant amount of the variation in WBEC of pink salmon juveniles.
- Juvenile pink salmon collected from the two transects closest to Prince William Sound had significantly different WBEC than those from the transect farthest from the sound.
- Only juveniles from the Armin F. Koernig and Wally Noerenberg hatcheries differed statistically in WBEC from one another.
- Overall, pink salmon from Wally Noerenberg hatchery had the highest energy density in both years, followed closely by wild fish. Armin F. Koernig and Solomon Gulch pink salmon juveniles had lower WBEC in both years.
- No strong correlations between length, weight or condition factor and energy density existed, indicating that size of the fish is a poor predictor of WBEC.
- A strong correlation was identified between WBEC and percent dry weight.

NOAA relevance/societal benefits

Since the mid 1980s wild pink salmon returns to Prince William Sound have noticeably declined. Early marine growth, which is critical for survival, is a function of the juvenile's condition. This study is aimed to better understand energy requirements of wild and hatchery reared juvenile pink salmon during their early marine life.

Research linkages/partnerships/collaborators and networking; and Education/outreach

The funded project is part of a graduate study conducted by Angela M. Middleton, NOAA research fisheries biologist, who is actively pursuing a M.S. degree in Fisheries. CIFAR funding supported 0.75 months of the graduate student's committee chair at the University of Alaska Fairbanks, School of Fisheries and Ocean Sciences and Angela's graduate study conducted at the Auke Bay Lab (NOAA/NMFS/AFSC) in Juneau, Alaska through the University of Alaska Fairbanks, School of Fisheries and Ocean Sciences.

Publications

In preparation

A manuscript detailing the results of the present study is currently being prepared by C. Rodgveller, J. Moss and A. Middleton of the Auke Bay Lab, Juneau, Alaska. The manuscript is intended to be submitted to the Alaska Fishery Research Bulletin.

Grain Size Distributions, and Concentrations and Stable Isotope Ratios of Organic Carbon and Nitrogen in Marine Sediments Near the Islands of Four Mountains, Aleutian Chain, Southeastern Bering Sea

Sathy A. Naidu, PI
University of Alaska Fairbanks

NOAA Goal: Ecosystem-based Management

CIFAR 10-073: This project is ongoing.

Primary objectives

This study will determine sediment characteristics from five sites near the Islands of Four Mountains, west of Dutch Harbor on the Aleutian chain, southeastern Bering Sea, to assist in determining the role of sediment substrate as habitat for juvenile rockfish. Each site was mapped using towed side-scan sonar and multi-beam sonar systems. These instruments collected bathymetry and reflectivity data using sound characteristics reflected from the sea floor. Sediment samples were collected from the seafloor using a van Veen grab to groundtruth the acoustic observations. These samples will be used to interpret reflectivity, a measure of seafloor hardness collected using the sidescan sonar system by determining the grain-size of each sediment sample. In addition to sediment grain size distributions, samples will be analyzed for organic carbon (OC), total nitrogen (N), OC/N ratio, and stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) of OC and N to provide more insight into the processes controlling fish-habitat relationships.

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 ($\delta^{13}C$ and $\delta^{15}N$) 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), $\delta^{13}C$ and $\delta^{15}N$, and C/N and $\delta^{13}C$.

Research accomplishments/highlights/findings

We have finished the analyses on grain sizes and chemistry on all 52 samples on hand. Minor statistical analysis is pending receiving additional samples. Out of the total 52 samples, there were 16 samples that were composed of predominantly gravel size particles. We could not calculate the conventional statistical grain size parameters (mean, sorting, skewness and kurtosis) for these samples because the weight percentage of the largest gravel particles was well above 5%, precluding calculation measures by the Folk (1980) method. There were 24 samples that had either zero percent or traces of mud fraction particles. No chemical analyses could be conducted on these very coarse (gravelly or sandy gravel) samples.

NOAA relevance/societal benefits

Early life history is thought to be critical in rockfish recruitment, a slow-growing and long-lived commercial fish. The NOAA fisheries Groundfish Assessment Program is tasked with assessing the value of the Aleutian Islands archipelago habitat to juvenile Pacific Ocean Perch. Using multi-beam and side-scan sonar, researchers are able to observe how certain habitats affect both survival and growth of rockfish**.** However, these acoustic mapping techniques need to be groundtruthed through grain-size analyses of collected sediment samples for which reflectivity data has been collected.

Research linkages/partnerships/collaborators and networking

NOAA Fisheries biologists have collected the acoustic and sediment samples with funding from NOAA and the North Pacific Research Board Project F0416: "Determining the value of habitat to juvenile rockfish in the Aleutian Islands" ($163,402).

References

Folk, R.L. 1980. *Petrology of Sedimentary Rocks*. Hemphill Publishing Co., Austin, TX. 182 pp.

Naidu, A.S., L.W. Cooper, B.P. Finney, R.W. Macdonald, C. Alexander and I.P. Semiletov. 2000. Organic carbon isotope ratios ($\delta^{13}C$) of Arctic Amerasian continental shelf sediments. *International Journal of Earth Sciences*, 89:522–532.

Reproductive Potential of Pacific Cod

Brenda L. Norcross, PI ***NOAA goal: Ecosystem-based Management***

University of Alaska Fairbanks

CIFAR 10-031a: 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. 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

1) Sample collections in the central and western Aleutian Islands (AI) were conducted in February and March 2005 to enhance our examination of regional variability in cod reproduction.
2) All sample collections are now complete. We have samples from these regions and years:
    - GOA: 2002, 2003, 2004
    - EBS: 2003, 2004, 2005
    - AI: 2005
3) We have collected tissues from a total of 1,752 fish. By region and year, sample sizes are:
    - GOA: 201 (2002) + 159 (2003) + 81 (2004) = 441 total
    - EBS: 366 (2003) + 324 (2004) + 321 (2005) = 1,011 total
    - AI: 300
4) We have collected morphometric information for approximately 300 additional fish.
5) Fecundity has been determined for a portion of the 2003 samples from the GOA and EBS. Fecundity was highly correlated with fork length (GOA R^2= 0.89; EBS R^2= 0.87; $p<0.05$) and body weight (GOA R^2= 0.92; EBS R^2= 0.92; $p<0.05$). The relationship between fecundity and fork length was of the form $F=\alpha L^{\beta}$, where F is fecundity, L is fork length, and α and β are constants. Fecundity was directly proportional to body weight. Table 1 shows

the β constant as well as predicted fecundities for 60, 80, and 100 cm fish. Values from previous studies in Canada and Japan are included for comparison.

6) Total female reproductive output (as estimated by measurements of gonad weight) varied among years and regions (see Figure 1). These are preliminary data and statistical analyses of these relationships have not been performed. For sample sizes see above.

Table 1. Pacific cod fecundity.

region, year	N	β	F @ 60 cm	F @ 80 cm	F @ 100 cm
British Columbia 1986-89[a]	266	n/a	1.8×10^6	3.7×10^6	8.0×10^6
GOA 2003	27	4.00	1.4×10^6	4.3×10^6	10.6×10^6
EBS 2003	30	3.27	1.7×10^6	4.3×10^6	9.0×10^6
Mutsu Bay, Japan[b]	17	2.80	1.3×10^6	4.0×10^6	7.5×10^6

N = sample size, β = power function exponent, F = predicted fecundity (# of eggs) at stated length. GOA and EBS data are from the current study; a is from Foucher and Tyler (1990); b is from Hattori et al. (1995).

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.

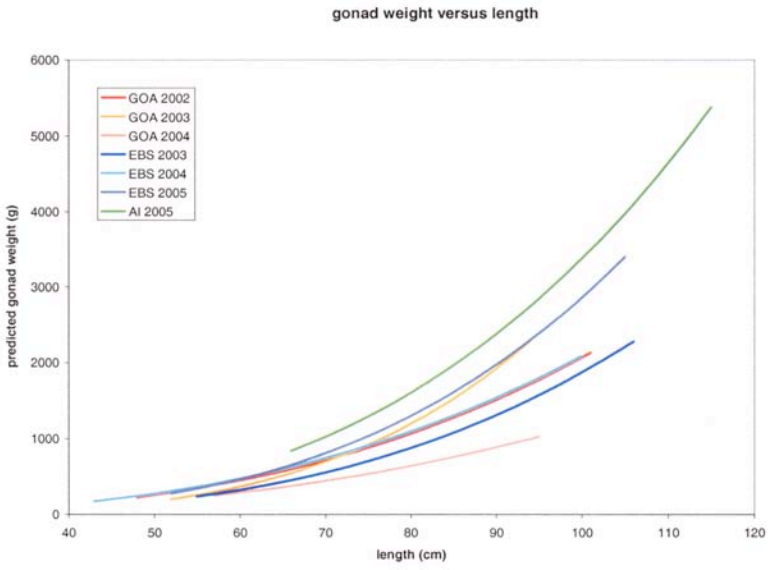

Figure 1. Gonad weight versus fork length of female Pacific cod in different regions and years. GOA = Gulf of Alaska; EBS = eastern Bering Sea; AI = Aleutian Islands. Lines indicate predicted values resulting from nonlinear regression of observed gonad weights.

Research linkages/ partnerships/collaborators and networking

This project has resulted in a close working relationship between UAF personnel (Norcross) and a student (Ormseth) and NOAA Fisheries personnel (Dr. Anne Hollowed and Dr. Grant Thompson, NMFS/REFM, Seattle). In addition, during our sampling we have collected tissues for use by other research projects, including analyses of population genetics and length-at-maturity.

Education/outreach

Student participation

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

During the 2004–2005 academic year, two undergraduate students at the University of Alaska Fairbanks assisted in laboratory work connected to this project through an independent study course.

Presentation

Olav Ormseth presented an overview of Pacific cod reproduction and early life history, as well as preliminary results from this study, to an expert panel reviewing the Pacific cod longline fishery for certification by the Marine Stewardship Council. Seattle, WA, June 2005.

References

Foucher, R.P. and A.V. Tyler. 1990. Estimation of the Fecundity of Pacific Cod (*Gadus macrocephalus*). *Canadian Manuscript Report of Fisheries and Aquatic Sciences*, 2088. 49 pp.

Hattori, T., Y. Sakurai and K. Shimazaki. 1995. Fecundity of spawning Pacific cod (*Gadus macrocephalus*) in Mutsu Bay, Japan. *Bulletin of the Tohoku National Fisheries Research Institute*, 57:1–5.

Student Research about Local Pollock Abundance using Hydroacoustic Data

Terrance J. Quinn II, PI ***NOAA Goal: Ecosystem-based Management***

University of Alaska Fairbanks

CIFAR 06-050: This project is ongoing.

Primary objectives of the project

This collaborative project between UAF, Alaska Fisheries Science Center (AFSC), and the pollock industry seeks to investigate whether localized depletion of pollock is occurring by the eastern Bering Sea pollock fishery. Acoustic data loggers have been installed on 7 catcher/processors (about half the fleet); each data logger interfaces with the ship's 38 kHz echo sounder and captures the acoustic backscatter. The backscatter data is post-processed and integrated with observer and logbook data. The research goals are to develop variables related to pollock school density, composition, and frequency, and to examine changes in these variables during the course of the fishing season.

Approach/methodology

The CIFAR funding provides support for 2 years to Ph.D. graduate student Haixue Shen. She will be developing a thesis proposal this summer. Tentatively her committee will consist of UAF professors Quinn and Smoker and AFSC scientist Dr. Martin Dorn and Dr. Vidar Wespestad, former AFSC scientist. Haixue was in Seattle for two weeks starting May 23 to learn Echoview® software and learn how to process hydroacoustic data on pollock in the Bering Sea, working with project employee Matt Kookesh and the Seattle members of her committee.

The scope of her thesis project is as follows:

1) Focus on smaller scale processes, and in particular, on fishing impacts on pollock distributions.
2) Address the localized depletion issue as the primary objective.
3) Use the school descriptor module in Echoview to evaluate changes in school structure due to fishing impacts.
4) Examine the processed acoustic data in databases put together by AFSC researchers Steve Barbeaux and Matt Kookesh, although the school descriptor algorithm in Echoview may require raw ping-by-ping data.
5) Classify the searching behavior of the vessels, identify pollock aggregations detected while searching, and evaluate what inferences, if any, can be made concerning the rate at which those aggregations are reduced in abundance or altered in size and shape.

Research accomplishments/highlights/findings

Results will be obtained in the next year.

NOAA relevance/societal benefits

This project will employ a novel approach to the study of localized depletion of pollock. There is international interest in the use of hydroacoustics data from commercial fishing vessels. An international meeting will be held in Hobart, Tasmania in December, sponsored by the Fisheries Acoustics Sciences and Technology (FAST) committee of the International Council for Exploration of the Sea (ICES).

Research linkages/partnerships/collaborators and networking

This project has received funding ($251K, 2001–2006) from the Pollock Conservation Cooperative Research Center (PCCRC), a fishing industry–funded program administered by the University of Alaska. As mentioned above AFSC scientists are serving as members of Ms. Shen's graduate advisory committee. We are collaborating with a committee housed in the Alaska Fisheries Science Center to provide coordinated databases and analytical methods for processing hydroacoustic data.

Education/outreach
Ms. Haixue Shen, a Ph.D. fisheries student, began working on this project in August 2004.

Research done in a NOAA laboratory
Some work was done at the Alaska Fisheries Science Center, Seattle, WA.

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

Terrance J. Quinn II, PI ***NOAA Goal: Ecosystem-based Management***
University of Alaska Fairbanks

CIFAR 10-051b: This project is ongoing.

Primary objectives of the project
This fellowship, funded by the Alaska Fisheries Science Center (AFSC) of the National Marine Fisheries Service (NMFS), 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 School of Fisheries and Ocean Sciences (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
Four of the students previously funded by this grant have moved on to employment in quantitative fisheries science in Alaska, two of them with NOAA. Specifically:

- Dana Hanselman is currently a Research Fishery Biologist, NOAA/NMFS, Auke Bay Laboratory, Alaska Fisheries Science Center, Juneau, AK.
- John Moran is a research associate in Natural Sciences at University of Alaska Southeast working with Dr. Brendan Kelly. He is working on the North Pacific Research Board (NPRB)-funded project, Ice Seal Movements and Stock Structure in a Changing Cryosphere. Peter Boveng, National Marine Mammal Laboratory, NMFS is a co-principal investigator on this project.
- Kalei Shotwell is currently a Research Fishery Biologist, NOAA/NMFS, Auke Bay Laboratory, Alaska Fisheries Science Center, Juneau, AK.
- Ben Williams is currently employed as a fisheries biologist at LGL Alaska in Anchorage.

All three students (William Bechtol, Sara Miller, and Cindy Tribuzio) supported during the 2004 to 2005 period have moved on to other research funding.

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 NMFS Stock Assessment Improvement Plan requires such scientists for its implementation, and the available pool of qualified applicants is shrinking. This project has already produced two Ph.D.-level quantitative fisheries professionals, who were immediately hired by NOAA after graduation.

In the 2004–2005 period, student fellowships were provided to Cindy Tribuzio (1 year, advisor Professor Gordon Kruse), Sara Miller (1 year, advisor Professor Terrance Quinn), and William Bechtol (1.5 months, advisor Professor Gordon Kruse). All three students have now received funding from other grants: Miller through NPRB, Tribuzio and

Bechtol through Rasmuson Foundation. This shows that the program is working effectively to leverage NOAA funds to provide initial student funding which then leads to funding from other sources.

Research linkages/partnerships/collaborators and networking

Bechtol: CIFAR 10-051b funds covered William Bechtol's stipend and tuition for the period 16 May 2005 through 30 June 2005. He was one of the award winners of the Rasmuson Fisheries Research Fellowship, which will cover his stipend and tuition for the period 1 July 2005 through 30 June 2006 for his research on *Retrospective analysis of Kodiak red king crab.* He will apply for renewal of his Rasmuson Fellowship thereafter.
Miller: CIFAR 10-051b funds covered Sara Miller's stipend and tuition for the period 1 July 2004 through 30 June 2005. Sara's research is being supported through NPRB Project F0505, *Feasibility of estimating movement within a spatially-explicit stock assessment model of eastern Bering Sea walleye Pollock (Theragra chalcogramma)*, which was funded for $63,996 for one year (1 July 2005–30 June 2006).
Tribuzio: CIFAR 10-051b funds covered Cindy Tribuzio's stipend and tuition for the period 1 July 2004 through 30 June 2005. She was one of the award winners of the Rasmuson Fisheries Research Fellowship, which will cover her stipend and tuition 1 July 2005 through 30 June 2006. She will apply for renewal of her Rasmuson Fellowship thereafter. All other costs associated with this project are covered under two grants from the North Pacific Research Board (NPRB). NPRB Project F0418, titled *Abundance, life history, and population demographics of spiny dogfish*, was funded for $86,591 for one year (July 2004–July 2005) and NPRB Project F0511 (same title) was funded at $129,150 for two years (July 2005–July 2007).

Education/outreach

Graduate student support

The following UAF fisheries graduate students have been supported through this fellowship program: Ben Williams (M.S.), Colin Schmitz (M.S.), John Moran (M.S.), Sara Miller (M.S.), Cindy Tribuzio (Ph.D.), Dana Hanselman (Ph.D.), Kalei Shotwell (Ph.D.) and William Bechtol (Ph.D.). Williams, Moran, Hanselman, and Shotwell have completed their graduate degrees; Bechtol, Miller and Tribuzio are currently pursuing their graduate degrees.

K–12 outreach

Shotwell: Participated in Sea Week at the Auke Bay Laboratory (Identification of aquarium critters for sixth graders)
Tribuzio: What is a Dogfish? Is it a Dog? Or a Fish? Oral presentation given by Cindy Tribuzio as part of *Sharks in Alaska* series at the opening of *Sharkabet* exhibit at the Alaska State Museum. May 2005.

Presentations

Moran:

Moran, J.R., M.D. Adkison and B.P. Kelly. 2003. Counting Seals: Estimating the Unseen Fraction Using a Photographic Capture–Recapture and Covariate Model. 15th Biennial Conference on the Biology of Marine Mammals, Greensboro, North Carolina, 14 November–19 December 2003.

Shotwell:

Utility of Climate Variation in Western Alaska Chum Forecast. Poster presentation. Alaska Chapter American Fisheries Society Annual Conference, Girdwood, Alaska, 21–24 October 2002.

Accounting for Climate Variability in Forecasting Northwest Alaskan Chum Salmon in Data Limited Situations. Paper presentation. 21st Lowell Wakefield Fisheries Symposium, Anchorage, Alaska, 22–23 October 2003.

Accounting for Climate Variability in Forecasting Northwest Alaskan Chum Salmon in Data Limited Situations. Paper presentation. AYK Salmon Workshop. Bering Sea Fishermen's Association, Anchorage, Alaska, 18–20 November 2003.

Utilizing Multi-Source Abundance Estimation and Climate Variability to Forecast Pacific Salmon Populations. Thesis presentation. University of Alaska Fairbanks–School of Fisheries and Ocean Sciences Seminar Series, Juneau, Alaska, 27 February 2004.

Utilizing Multi-Source Abundance Estimation and Climate Variability to Forecast Pacific Salmon Populations. Poster presentation. CIFAR Formal Review, Fairbanks, Alaska, 3–4 June 2004.

Tribuzio:

Investigation of the Life History and Ecology of Spiny Dogfish, *Squalus acanthias*, in Alaska: A Progress Report. Oral presentation by Cindy Tribuzio and Gordon H. Kruse (presenter) at the First International Symposium on the Management and Biology of Dogfish Sharks, Seattle, Washington, 13–15 June 2005.

Demography, Endocrinology and the Management of Spiny Dogfish (*Squalus acanthias*) in Puget Sound. Oral presentation by Cindy Tribuzio at the First International Symposium on the Management and Biology of Dogfish Sharks, Seattle, Washington, 13–15 June 2005.

Life History, Ecology and Population Dynamics of Spiny Dogfish, *Squalus acanthias*, in Alaska. Oral presentation by Cindy Tribuzio at the Marine Science in Alaska Symposium, Anchorage, Alaska, January 2005.

Advances in Spiny Dogfish Research in the Face of Commercial Fishing. Oral presentation by Cindy Tribuzio at the American Fisheries Society, Alaska Chapter Annual Meeting, Sitka, Alaska, November 2004. Awarded "Best Student Oral Presentation."

Publications

Peer-reviewed

Hanselman, D.H., T.J. Quinn II, C. Lunsford, J. Heifetz and D. Clausen. 2003. Applications in adaptive cluster sampling of Gulf of Alaska rockfish. *Fishery Bulletin*, 101:501–513.

Hanselman, D.H. and T.J. Quinn II. 2004. Sampling rockfish populations: adaptive sampling and hydroacoustics. In: W.L. Thompson (Ed.), *Sampling Rare or Elusive Species: Concepts, Designs and Techniques for Estimating Population Parameters*, pp. 271–296. Island Press, Washington, D.C. 429 pp.

Shotwell, S.K. and M.D. Adkison. 2004. Estimating indices of abundance and escapement of Pacific salmon for data-limited situations. *Transactions of the American Fisheries Society*, 133(3):538–558.

Non-peer-reviewed

Courtney, D., S. Gaichas, J. Boldt, K.J. Goldman and **C. Tribuzio**. 2004. Sharks in the Gulf of Alaska, eastern Bering Sea, and Aleutian Islands. In: Appendix A, *Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions*, pp. 1009–1073. North Pacific Fishery Management Council, Anchorage, Alaska.

Hanselman, D.H. 2004. Gulf of Alaska Pacific Ocean Perch: Stock Assessment, Survey Design and Sampling. Ph.D. dissertation, University of Alaska Fairbanks, 172 pp.

Hanselman, D.H., J. Heifetz, J. Fujioka and J. Ianelli. 2003. Gulf of Alaska Pacific ocean perch. In: *Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska*, pp. 429–479. North Pacific Fishery Management Council, Anchorage, Alaska.

Moran, J. Jr. 2004. Evaluation of Covariates Affecting Harbor Seal (*Phoca vitulina*) Haulout Behavior Using Photographic Mark–Recapture. M.S. thesis, University of Alaska Fairbanks, 49 pp.

Shotwell, S.K. 2004. Using Multi-source Abundance Estimation and Climate Variability to Forecast Pacific Salmon Populations. Ph.D. dissertation, University of Alaska Fairbanks, 143 pp.

Williams, B.C. 2003. Growth Dynamics of Juvenile Yellowfin Sole (*Pleuronectes asper*) and Northern Rock Sole (*Lepidopsetta polyxystra*) in the Eastern Bering Sea. M.S. thesis, University of Alaska Fairbanks, 99 pp.

In press or in preparation

Hanselman, D.H. and T.J. Quinn. Are modern age-structured stock assessments reliable in the presence of large survey measurement errors? In review for *Canadian Journal of Fisheries and Aquatic Sciences*.

Moran, J.R., M.D. Adkison and B.P. Kelly. Counting seals: estimating the unseen fraction using a photographic capture–recapture and covariate model. In preparation for submission to *Canadian Journal of Zoology*.

Williams, B.C., T.J. Quinn II and L.J. Haldorson. Influence of year and year-class effects on growth of juvenile yellowfin sole and northern rock sole in the eastern Bering Sea. In preparation for submission to *Canadian Journal of Fisheries and Aquatic Sciences*.

Williams, B.C., T.J. Quinn II and L.J. Haldorson. Relationships among biomass, recruitment, environmental variation, and growth of juvenile yellowfin sole and northern rock sole in the eastern Bering Sea. In preparation for submission to *Canadian Journal of Fisheries and Aquatic Sciences*.

Research done in a NOAA laboratory

Miller: This research involved collaborations with research scientists at the Auke Bay Lab and the Alaska Fisheries Science Center (Anne Hollowed, Paul Spencer, Jim Ianelli, Martin Dorn, Jon Heifetz, Phil Rigby, Dave Clausen, Jeff Fujioka, Pat Livingston).

Tribuzio: The research was not conducted in a NOAA laboratory, but some of the field work is conducted in collaboration with Dean Courtney and Chris Lundsford of the NMFS Auke Bay Laboratory. Also, the Resource Ecology and Fisheries Management branch of the AFSC kindly provided training on prey identification of groundfish stomachs.

Habitat Analysis of Major Fishing Grounds on the Kodiak Shelf, Alaska

Jennifer Reynolds, PI
Brenda Norcross, co-PI
University of Alaska Fairbanks

NOAA Goal: Ecosystem-based Management

CIFAR 10-078: This project is ongoing.

Primary objectives

The overall goal of this research is to understand the distribution of commercially important species on fishing grounds along the continental shelf east of Kodiak Island, and how it is affected by geological, biological, and oceanographic factors. These locations are known for extensive bottom trawl and longline fisheries for groundfish.

Approach/methodology

An important step in defining essential fish habitat and potential mitigative measures is to understand the relationship between habitat characteristics, fish distribution, and fishing effort. In Alaska, major fisheries occur on the continental shelf and slope, but very few areas of benthic habitat in these regions have been described.

The study will analyze and compare three study areas: Portlock Bank, Albatross Bank, and southwest of Chirikof Island. The study will incorporate habitat classifications of the mapped areas, existing biological and physical data from fishery surveys, commercial fisheries, and oceanographic and geological surveys.

Methodology:

- Ground truth multibeam-sonar-based habitat maps, using submersible video and records of geological grab samples from the literature.
- Map benthic biological assemblages, using submersible video and NOAA fishery databases.
- Examine associations of fish communities and benthic macrofauna with benthic habitats (including biohabitats), depth, and oceanography.
- Examine species richness, composition and relative abundance of fish communities at multiple scales.
- Extrapolate results from groundtruth sites to the full study area, and provide quantitative predictions of community distribution and composition.

Research accomplishments/highlights/findings

- Background research, compiling databases for the region. Filed formal request for access to confidential NOAA data (fisheries observer database) for this research.
- Delta submersible dive cruise to Albatross Bank, June 28–July 2, 2005 (funded separately by NOAA). Participated in cruise planning and conducted submersible dives.

NOAA relevance/societal benefits

This research will lead to improved understanding of the natural environment and its relationship to fishery resources, and will assist NOAA/NMFS in its mission to manage and conserve the Nation's resources. This research is also part of the graduate education of a new fisheries scientist.

Research linkages/partnerships/collaborators and networking

This is a collaborative effort between marine scientists at the University of Alaska Fairbanks, a M.S. graduate student in UAF's Fisheries program in Juneau, and biologists at NOAA's Auke Bay Laboratory in Juneau. It also incorporates habitat classifications based on multibeam sonar maps, from Moss Landing Marine Laboratory. Research is conducted at NOAA/NMFS Alaska Fisheries Science Center, Auke Bay Laboratory (Juneau, AK).

Education/outreach

The CIFAR funds support M.S. thesis research by a UAF graduate student, in close collaboration with NOAA biologists at the Auke Bay Laboratory. Sean C. Rooney, M.S. Fisheries, University of Alaska Fairbanks (Fisheries Division in Juneau), was supported for 10 months (100%) in the reporting period. The reporting period 1 September 2004–30 June 2005 was his first year in the program.

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

Thomas C. Shirley, PI ***NOAA Goal: Ecosystem-based Management***
University of Alaska Fairbanks

CIFAR 06-053 and 09-065: These projects are ongoing.

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 ensure 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. Sonic tags will be attached to adult female Tanner crabs in October 2005.

Research accomplishments/highlights/findings

- Inspection of T-bar locations within the body tissue of crabs that molted successfully and retained the tag indicated that the tags would prevent many of these crabs from completing additional molts. Therefore the effective retention of tags observed in this experiment should be viewed as a conservative figure that is likely to decrease significantly with successive molts.
- Molt increments for tagged crabs were not significantly different from those of control crabs, although carapace deformities were observed for some crabs in tagging treatments.
- T-bar tags hold promise for large-scale tagging of adult crabs that no longer undergo molting. Tag retention was high and mortality low during intermolt periods.

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.

Follow-up

Julie Nielsen is currently making final edits to her thesis and is also a fisheries research trainee for the USGS. She, along with principal investigators Tom Shirley and Jim Taggart, is beginning work on a research project funded by the West Coast and Polar Regions Undersea Research Center to search for seasonal aggregations of adult female Tanner crabs in Glacier Bay National Park. A large, annually recurring seasonal aggregation of adult female Tanner crabs has been observed in one location near Kodiak; at this location, extreme aggregation of adult female crabs coincides with release of larvae into the water column during April or May. If seasonal aggregations of female Tanner crabs are an important life history characteristic for Tanner crabs throughout their geographical range of distribution, determining aggregation locations and the proportion of females that participate in them would be extremely important information for fisheries managers. For example, this information could be used to designate critical reproductive habitat for Tanner crabs, plan marine reserves, or form the basis for spatially explicit spawning stock/recruitment models. However, such aggregations have not been observed for Tanner crabs in other locations. The depth (150 m), extreme spatial aggregation, and relatively short duration of the Kodiak aggregation is likely to make finding similar aggregations in other areas difficult. The research effort in Glacier Bay features the use of ultrasonic telemetry to locate female aggregation(s) (if aggregation occurs there) by observing seasonal movements of adult female Tanner crabs and characterizing the degree of aggregation of tagged crabs during April and May 2006. Julie will take the lead in organizing fieldwork, analyzing data, and writing the resulting manuscript for this project. Her salary will be provided by a combination of West Coast and Polar Regions Undersea Research Center and USGS funds. Her goal is to obtain full-time employment as a fisheries researcher in Alaska focusing on spatial and temporal trends in crab distribution and abundance.

Education/outreach

Student participation

Julie Nielsen, Graduate Research Assistant, Juneau Center, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks is supported by this award. Julie defended her M.S. thesis entitled "Distribution and movement of juvenile Tanner crabs (*Chionoecetes bairdi*) in Glacier Bay National Park" in May 2005 and will graduate in December 2005.

Presentations

Nielsen, J. Distribution and movement of juvenile Tanner crabs *Chionoecetes bairdi*. Thesis defense, University of Alaska Fairbanks, May 2005.

Nielsen, J. Distribution, habitat and movement of juvenile Tanner crabs (*Chionoecetes bairdi*). Rasmuson Fisheries Research Center, Anchorage, Alaska, March 2005.

Nielsen, J., J. Taggart, T. Shirley, J. Mondragon and A. Andrews. Glacial fjords in Glacier Bay National Park: nursery areas for Tanner crabs? Western Society of Naturalists Conference. Rohnert Park, California, November 2004.

Nielsen, J., J. Taggart, T. Shirley, J. Mondragon and A. Andrews. Glacial fjords in Glacier Bay National Park: nursery areas for Tanner crabs? Glacier Bay Science Symposium. Juneau, Alaska, October 2004.

Publications

In preparation

Nielsen, J.K. Distribution and Movement of Juvenile Tanner Crabs *Chionoecetes bairdi*. Master's Thesis, UAF School of Fisheries and Ocean Sciences. In preparation.

Nielsen, J.K., T.C. Shirley, S.J. Taggart and J. Mondragon. Distribution of juvenile and adult Tanner crabs *Chionoecetes bairdi* in a glacial fjord ecosystem: implications for understanding recruitment processes. In preparation.

Nielsen, J.K., T.C. Shirley and S.J. Taggart. Trans-molt retention of Floy tags in Tanner crabs *Chionoecetes bairdi*. In preparation.

Nielsen, J.K., T.C. Shirley and S.J. Taggart. Nursery areas for Tanner crabs in Glacier Bay? In preparation.

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

Terry Whitledge, PI ***NOAA Goal: Ecosystem-based Management***
University of Alaska Fairbanks

CIFAR 10-058a: 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 July/August.

Approach/methodology

In May and July/August, 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.

Research accomplishments/highlights/findings

Recent accomplishments with this project were in organizing the very large sets from these two cruises and merging them to produce a uniform time and geo-referenced data base. A meeting of the cruise participants was held to coordinate the analysis of variables and to integrate physical, chemical and optical biological measurements for a set of joint publications.

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. Approximately 30% of the support for these students was derived from this project.

Publications

No publications were prepared during the reporting period. Several are being planned for this next period which will be written after the data base manipulations are completed.

Monitoring Sea Ice Thickness in the Arctic Ocean Using Seafloor-Moored Ice Profiling Sonar

Humfrey Melling, PI
Fisheries and Oceans Canada
Institute of Ocean Sciences, Sidney, BC

NOAA Goals: Understand Climate Variability and Change; Safe, Efficient and Environmentally Sound Transportation

CIFAR 10-077: This project is ongoing.

Primary objectives

One of the main goals of NOAA's SEARCH initiative is to produce an annual report of the state of and change in the Arctic sea ice cover, which will be widely distributed. Under this CIFAR project, we establish an ice monitoring site in the northern Chukchi Sea, in a key location for describing variability in Arctic sea-ice thickness. From a sub-surface oceanographic mooring, we use ice-profiling and Doppler sonar to measure ice draft, ridging and velocity of drift. The site is part of a larger array with sites in the southeastern Beaufort Sea (Canadian funds), at the North Pole (NSF funds) and in the Canadian Arctic Archipelago.

Approach/methodology

Year 1

- Identify a platform for initial deployment.
- Fabrication of 2 mooring packages.
- Establishment of mooring site CH01.
- Deployment of ice-mass balance (IMB) buoy in vicinity of CH01.

Year 2

- Recovery and re-deployment of instruments at mooring site CH01.
- Deployment of IMB buoy in vicinity of CH01.
- Analysis, archiving and reporting of the data collected from the drifting buoys.
- Presentation of results, including development of a webpage.

Research accomplishments/highlights/findings

- Two mooring packages were built (one is now at work in the North, the other for substitution at sea).
- Participation on 2 cruises (CCGS *Louis S St Laurent*, USCG *Healy*) for mooring deployment at 76.1°N, 168°W, and for recovery/re-deployment.
- IMBs were deployed further to the northeast, where ice was more suitable.
- Observations from the first year are now in hand, with 100% data recovery.
- Data calibration and processing are presently underway.
- Manuscript was recently submitted concerning trends in seasonal pack ice observed by the element of our ice-monitoring array located in the Beaufort Sea.

NOAA relevance/societal benefits

This project is providing information on the impact of changing climate on Arctic ice pack. It will provide the means of assessing the accuracy of numerical forecasts of future Arctic ice conditions. It will permit study of the relative importance of various influences on Arctic ice—air temperature, sea temperature, snow cover, ice circulation and ice deformation. Such information and understanding are essential for appropriate and timely societal adaptation to changing conditions—shipping, offshore oil and gas, traditional lifestyles.

Research linkages/partnerships/collaborators and networking

This project forms a part of an internationally coordinated effort under CliC (the Climate and Cryosphere project of the World Climate Research Programme) to monitor the state of the northern marine cryosphere and its variability (http://nsidc.org/noaa/moored_uls/index.html). In particular it fosters a bi-lateral collaboration between the Canadian Department of Fisheries and Oceans, which has monitored ice thickness in the Beaufort Sea since 1990 and recently established sites in the Canadian Arctic Archipelago, and the USA agencies NOAA and NSF. Together, we now maintain an observational network that spans a third of the Arctic Ocean. Logistics are provided at incremental cost

by icebreakers of the U.S. and Canadian Coast Guards. The moorings can provide a substrate for instrumentation needed for other types of measurement in remote areas of the Arctic Ocean—oceanography and biology.

Publications

Submitted

Melling, H., D.A. Riedel and Z. Gedalof. Trends in thickness and extent of seasonal pack ice, Canadian Beaufort Sea. Submitted to *Geophysical Research Letters*.

Marine Ecosystem Studies

Paleoecologic and Paleoceanographic Studies of Marine Bays in Southeast Alaska

Bruce P. Finney, PI
University of Alaska Fairbanks

NOAA Goals: Understand Climate Variability and Change; Ecosystem-based Management

CIFAR 06-043: 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 are being dated using ^{210}Pb and AMS radiocarbon (^{14}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 δ^{13}C ratio of organic matter.
3) Downcore changes in salinity and temperature will be determined through analyses of foraminifera for δ^{18}O and Mg/Ca; changes in nitrate utilization are being assessed by analyses of δ^{15}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 δ^{18}O and Mg/Ca (temperature and salinity), and δ^{15}N of organic matter (changes in nitrate utilization).

Research accomplishments/highlights/findings

1) We have obtained basal dates on sediment cores from 20 bays using AMS radiocarbon (^{14}C) techniques. In addition, cores from 4 bays have been dated in more detail using AMS, and 2 of these bays have been dated using ^{210}Pb techniques for the more recent part of the record.
2) Paleoproductivity has been reconstructed for 5 sites using a multiproxy approach (biogenic silica and organic carbon mass accumulation rates, and the δ^{13}C ratio of organic matter). The sites are Big Port Walter, Bay of Pillars, Eliza Harbor, Inner Redoubt Bay and Gulf of Alaska station GAK4.
3) Sieving and identification of foraminifera are complete or nearly so for cores from Bay of Pillars, Eliza Harbor and GAK4. δ^{18}O and Ca/Mg analyses of the foraminifera are underway.
4) The original project was conceived assuming multi-year funding. As only one year of funding was received, the fish scale component was omitted due to its time-consuming nature.
5) The bulk of the data synthesis and interpretation is part of the M.S. thesis of Molly Boughan. She is in the final stages of labwork, and plans on completing her thesis in Spring 2006. Preliminary results and comparison to similar data in the Bering Sea will be published in Trites et al. (*Fisheries Oceanography*, in press).

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 is collaborative with NOAA personnel at the Auke Bay Lab, Juneau. This CIFAR-funded research has led to additional research and $50,000 funding though NOAA via the North Pacific Universities Marine Mammal Research Consortium for the project "Impacts of Climate Change on Gulf of Alaska Steller Sea Lion Populations During the Past Century." Also, data from this project helped lead to a 5-PI NSF ocean drilling site survey project entitled "Collaborative Research: Establishing a High-resolution Temporal Record of Quaternary Climate-Glacial-Ocean Linkages in Southern Alaska (and IODP Site Survey)" on subjects dealing with changes in primary productivity, oceanographic conditions and climate. The cruise took place in Sept. 2004. Finney's funding for his involvement in this project was $47,000 plus ship time.

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 (University of Bordeaux) conducted analyses on the Big Port Walter core. Several undergraduates have received training and education as part of work on this project (Kim Streeter, Molly Odell, Sheldon Gaylor). Results from this research have been presented at several meetings, including the Fall 2004 AGU meeting.

Publications

In press

Trites, A.W., A.J. Miller, H.D.G. Maschner, M.A. Alexander, S.J. Bograd, J.A. Calder, A. Capotondi, K.O. Coyle, E. Di Lorenzo, B.P. Finney, E.J. Gregr, C.E. Grosch, S.R. Hare, G.L. Hunt, J. Jahncke, N.B. Kachel, H.-J. Kim, C. Ladd, N.J. Mantua, C. Marzban, W. Maslowski, R. Mendelssohn, D.J. Neilson, S.R. Okkonen, J.E. Overland, K.L. Reedy-Maschner, T.C. Royer, F.B. Schwing, J.X.L. Wang, and A.J. Winship. Bottom-up forcing and the decline of Steller sea lions in Alaska: Assessing the ocean climate hypothesis. *Fisheries Oceanography*, in press.

Several other publications will result from this project. Papers resulting from M. Boughan's thesis should be submitted following her defense in 2006.

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

Rolf Gradinger, PI
University of Alaska Fairbanks

NOAA Goals: Understand Climate Variability and Change; Ecosystem-based Management

Other investigators/professionals funded by this project:
Bodil Bluhm, *University of Alaska Fairbanks*

CIFAR 08-057: 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 *Xue Long* in summer 2003 in close co-operation with U.S. 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, $\delta^{13}C$, $\delta^{15}N$), salinity, and nutrient concentrations (N compounds, SiO_4, PO_4) were assessed on melted ice core sections over the entire ice thickness. The ratios of stable isotopes ($\delta^{13}C$, $\delta^{15}N$) 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}N) and carbon assimilation (^{13}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 20µm 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

The published results will be useful in evaluating 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 U.S.–Chinese cooperation in Arctic science.

Research linkages/partnerships/collaborators and networking

In addition to the U.S.–Chinese collaboration, the grant supported the co-operation with Dr. Meiners (Yale University). For publication purposes, the collected material was combined with data from the NOAA-funded Ocean Exploration 2002 expedition to a similar area. The materials will further be used to study the diversity of sea ice biota as part of the Arctic Ocean Diversity project of the Census of Marine Life program. (http://www.sfos.uaf.edu/research/arcdiv/).

Education/outreach

Student participation

The collected ice algal material will form the backbone for a thesis of a future graduate student at the School of Fisheries and Ocean Sciences (focus: diatom diversity).

Presentations

Gradinger, R., H. Eicken and B.A. Bluhm. 2005. Does sea ice contribute to the biogeochemical cycles of the Bering Sea? Climate Variability and Sub-Arctic Marine Ecosystems Symposium, Victoria, B.C., Canada, 16–20 May 2005 (talk).

Publications

Peer-reviewed

Gradinger, R.R., K. Meiners, G. Plumley, Q. Zhang and B.A. Bluhm. 2005. Abundance and composition of the sea-ice meiofauna in off-shore pack ice of the Beaufort Gyre in summer 2002 and 2003. *Polar Biology*, 28:171–181, doi:10.1007/s00300-004-0674-5.

In preparation

Meiners, K. and R. Gradinger. Extracellular polymeric substances in sea ice of the Beaufort and Chukchi seas during spring and summer. In preparation for submission to *Polar Biology*.

Ecosystem Change in the Northern Bering Sea

Jackie M. Grebmeier, PI
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NOAA Goals: Ecosystem-based Management; Understand Climate Variability and Change

CIFAR 08-060: 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 2004 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—Figure 1).
- Nineteen hydrographic and benthic stations were occupied annually in 2003, 2004 and 2005 north and south of Bering Strait in collaboration with the National Science Foundation–funded Bering Strait Environmental Observatory (BSEO) project (http://arctic.bio.utk.edu/aeo).
- Field studies in 2003, 2004 and 2005 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 Figure 1).
- CTD time series data indicate a recent increase in bottom water temperatures within the "cold pool" SW of St. Lawrence Island (SLI), indicative of a reduction of cold, brine-produced water within the SLI polynya the previous winter before our summer sampling, likely tied to ice production (Grebmeier et al. in prep.).
- Time series data indicate a decline in sediment oxygen uptake (a short-term indicator of carbon supply) which indicates a reduction of carbon being exported to the underlying sediments since the late 1980s to late 1990s, and a potential stabilization from 2002 onward (Figure 1, top; Grebmeier and Cooper 2004; Grebmeier et al. in prep.).
- Coincident decline in benthic biomass (a long-term integrator of carbon export to the benthos) since the late 1980s (Figure 1, bottom; Grebmeier and Cooper 2004; Grebmeier et al. in prep.).
- There has been a change over time in the dominant clam species from a tellinid bivalve with thin shell and more caloric content, to a smaller one that has a thicker shell, less caloric content, thus influencing the threatened diving sea ducks in the region (Lovvorn et al. 2003, 2005; Grebmeier unpubl. data).
- Time series data of bivalve length/weight (L/W) measurements since the 1930s indicates an overall decline in the L/W for the dominant species, which earlier were *Macoma calcarea,* which have been replaced by the less nutritious *Nuculana radiata.*

- Sediment time series grain size data indicate an increase in the fine fraction of silt in the sediments SW of SLI, indicating a reduction in current flow and settling out of the smaller sizes fractions which can influence the benthic community composition.
- In summer 2003, a subsurface mooring was emplaced in about 80 m of water southwest of St. Lawrence Island through funding by the NOAA Arctic Research Office. Unfortunately, the mooring deployed in 2003 was lost due to ice impact. The July 2004 mooring deployed was recycled in fall 2004 to lower it in the water column to reduce the potential of ice impact (Overland component), although a 90-day record was retrieved. No nutrient meter was attached on this fall redeployment due to a malfunction upon retrieval (Whitledge component).
- In July 2005, this biophysical mooring was successfully retrieved and a new mooring was deployed at the same location, albeit without a nutrient sensor due to equipment limitations. The mooring will be recycled again during the fall of 2005 and a new nutrient instrument will be deployed, along with the suite of physical sensors and a fluorometer and will be retrieved in July 2006.

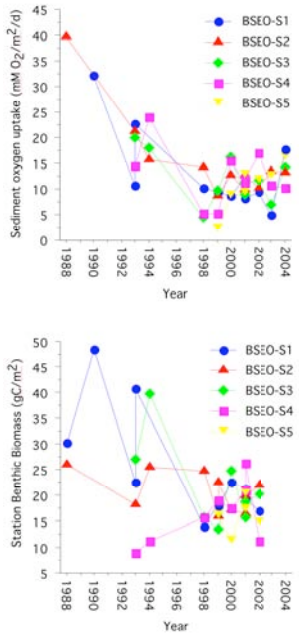

Figure 1. Time series measurements of sediment oxygen uptake (carbon supply) and benthic biomass southwest of St. Lawrence Island, northern Bering Sea (see Grebmeier and Cooper 2004).

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

Student participation

Alicia Clarke, a minority undergraduate student completed a B.S. degree in May 2005 in Ecology and Evolutionary Biology. She 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. Her support continued though July 2005.

Adam Humphrey, an undergraduate student, completed a B.S. in May 2005 in Ecology and Evolutionary Biology. He assisted in infaunal sorting and general laboratory operations.

Rebecca Pirtle-Levy, a 2nd year M.S. student in Ecology and Evolutionary Biology, processed sediments for total organic carbon content and sediment grain size. Rebecca also participated in all oceanographic cruises associated with this project at sea.

K–12 outreach

A high school teacher from Vermont (Betty Carvellas) participated in the 2004 and 2005 cruises 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.

PIs Grebmeier and Cooper, along with two of our support staff, gave a three-hour group presentation (audio-visual presentation, hands-on experience viewing preserved marine animals and other research samples) for over 100 middle school students at Powell Elementary School in Powell, Tennessee during spring 2005.

Presentations
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 Arctic Climate Impact Assessment conference in Reyjkavik, Iceland (November 2004); the 2005 Pacific Arctic Group Symposium in Kunming, China (April 2005); and the American Association of Limnology and Oceanography (ASLO) Summer meeting in Santiago de Compostela, Spain.

Publications

Non-peer-reviewed

Grebmeier, J.M. and L.W. Cooper. 2004. Biological implications of arctic change. In: *Arctic Climate Impact Assessment*, *Extended Abstracts*. Arctic Monitoring and Assessment Programme, Reykjavik, 2004. ISBN 82-7971-041-8. Also available at www.amap.no.

In press or in preparation

Grebmeier, J.M. and J.P. Barry. Benthic processes in polar polynyas. In: W.O. Smith and D. Barber (Guest Editors), *Polynyas: Windows into Polar Oceans*. Elsevier Oceanography Series. Accepted.

Grebmeier, J.M., J. Overland, L. Eisner, J. Helle, L.W. Cooper, S.E. Moore and E. Carmack. Major ecosystem shifts in the northern Bering Sea. In preparation for submission to *Science*, fall 2005.

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Lovvorn, J.R., L.W. Cooper, M.L. Brooks, C.C. De Ruyck, J.M. Grebmeier and J.K. Bump. 2005. Organic matter pathways to zooplankton and benthos under pack ice in late winter and open water in late summer in the north-central Bering Sea. *Marine Ecology Progress Series*, 291:135–150.

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

Herbert D.G. Maschner, PI ***NOAA Goal: Ecosystem-based Management***
Idaho State University
Katherine L. Reedy-Maschner, co-PI
Idaho State University

Other investigators/professionals funded by this project:
Amber Tews, Jack Nielson, *Idaho State University*

CIFAR 06-047: 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 restricted to the anthropology, specifically: 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.

Approach/methodology

Anthropology: We have conducted over fifty interviews with fishermen, young and old, in King Cove, Sand Point, False Pass and Nelson Lagoon. These were unstructured interviews that allowed the participants to express ideas, observations, and knowledge over a range of topics. The results of these interviews are often quite different and certainly more informative than structured surveys or questionnaire surveys done through the mail (e.g., Heise et al. 2003). The regional survey conducted by Heise and others to document orca–SSL interaction on the North Pacific was heavily biased by responses from the eastern Gulf where the majority of fishermen are of European ancestry and very limited in the western Gulf and Aleutians where the bulk of the fleet is Aleut owned. We have found that indigenous observers are much more likely to recognize the importance of predator–prey interactions and to

maintain an oral history of traditional ecological knowledge. From our interviews, a number of patterns were evident in local perceptions of the problem.

Research accomplishments/highlights/findings

Anthropology:

On the Steller sea lion decline. During the 1960s and 70s, SSLs were seen everywhere, "great herds of them," "1000s." Every offshore island was covered: "It looked like they were moving like a kaleidoscope," according to one elder. "Sea lions were on all of the small islands, used to be packed." All agree that there has been a major decline in the numbers of SSL throughout the western Gulf of Alaska and eastern Aleutian Islands. Some of the oldest fishermen also mentioned that in their fathers' or grandfathers' times, there were periods with many fewer sea lions than were around after the 1940s.

Causes of the SSL decline. Few carcasses have ever been seen. One 70-year-old elder, who trapped and fished the entire Alaska Peninsula region for 55 years, has seen four his entire life. That is more than anyone else has reported. Culprits were listed as: orcas (primarily), overfishing and big draggers taking the bottomfish (maybe)—"Draggers take the bottom fish. If you cut draggers down and the population would pop back up," and SSLs moving around (often). It is always mentioned that the numbers of SSLs are underestimated because the biologists did not know where to look: "How can they count all the sea lions in one day on a coastline of 1500 miles or more? Sea lions migrate to follow their food just like a fisherman has to."

One King Cove Aleut fishermen stated, "Instead of chasing salmon and herring which are real oily and rich fish, they are chasing pollock and cod. We think—I think, and I'm not the only one, that they are starving with full bellies. No oil and no fat in cod and pollock, very little. They are starving to death with full bellies. … Yeah, there were 100s and 100s and 1000s of sea lions [in the 1930s and 1940s] from here all the way to the Aleutians. They've only started to disappear after the cod and pollock came into being. It is all just a natural cycle and they can't blame fishermen for sea lions disappearing 'cause the salmon and herring are still there and the sea lions aren't eating them. The sea lions that are eating salmon are probably living."

The ultimate cause of the SSL decline, as recorded in nearly every interview, is predation from orcas. Incidences of this predation, from the 1950s through the 1990s, are found throughout the region. Local peoples have video of pods of orcas attacking haulouts. This explanation was repeatedly given in public testimony to a number of federal agencies, and, according to our informants, representatives of several environmental groups refused to watch home videos of orcas attacking SSLs.

Intensity of Aleut interactions with SSLs. Historic Aleut interactions with SSLs comes in three forms. The first is direct hunting. The rookery at Rose Island was the traditional hunting territory and harvesting location for the Aleut of Belkofski, a village now abandoned. The people of Sanak Island traditionally harvested sea lions at the haulouts south of Sanak, an adjacent place called "clubbing rocks," and Cherni Island. The peoples of Ikatan and False Pass hunted a number of haulouts around the Ikatan Peninsula. Those living on the north shore of the western Peninsula hunted at Amak. While the first three were harvested up until the 1960s, the Amak area has not been hunted for nearly a century.

The second type is passive interaction where the Aleut fished around SSL rookeries and haulouts. Here the Aleut were passive observers, especially in the last 50 years when SSL played little role in the subsistence economy. Fishing is now closed in these areas.

The third type is active interaction, where the Aleut fish with SSLs continually lunging at their nets, trying to eat the caught salmon. It is ironic that most damage to SSLs from human interaction is out in open water with SSLs stalking and harassing boats, and where the animals actively seek out salmon fishermen.

Spatial geography of SSLs. Rookeries and haulouts listed by Aleuts are: Clubbing Rocks by Cherni Island; Bird Island on the other side of Cape Pankoff; Outer Cove on Unimak; Ugamak Island—"a huge rookery over there"; Amak Island, where there's a SSL rookery north of there; and also on Rock Island (south Unimak). Thousands were reported around Ikatan. One fishermen stated, "you make a set, and some days you would get all sea lions." Belkofski people used to camp on Sushilnoi Island to hunt SSLs on Rose Island. There are two rookeries by Cherni: "Bob Jones [former Fish & Wildlife manager in Cold Bay] did a count of maybe 5000 [in the 1960s or 70s], now there are maybe 500. We can't go close enough to count them." The biggest herd was reported by Cherni. There are a few by East Anchor. Around Caton Island, "there's a few back there so they closed it off to us."

Fishermen described SSLs' spatial distributions today as the following. "We see very few sea lions anymore." When setnetting along Dolgoi, some fishermen "saw a few." "On the bar east of Belkofski Point, there's always a batch of sea lions there in late July. In the summer, there are little bunches." "Cape Pankoff, there's two big rocks, haulouts. See them sunning themselves." "In the winter, sea lions are on the haulout around Caton and south of Sanak. Last January, there were young ones in Caton's harbor." "About eight sea lion adults come into the King

Cove harbor each year; never see any little ones." "Big ones in King Cove harbor. They never do leave here. They're eating off the boats. Some leave the harbor in March." Occasionally there is "one sitting on the Cold Bay buoy." Many fishermen reported seeing groups of SSL moving on the open water, even in summer in areas where they have not been seen in the past.

Modern interactions and modern uses of SSLs. Although subsistence harvests of SSLs are legal for Alaska Natives, many Aleut do not attempt the hunt. This is in part because there is a local perception that it is still illegal for them. In fact, some Aleut hunters learned from Reedy-Maschner and Maschner the actual laws regarding SSL harvesting, since Fish & Game's posters and advertising materials about the endangered species do not indicate any exceptions. Still others stated that the hunt was too contentious, and they did not want to risk bringing any controversy on themselves. One individual stated that he did in fact hunt a SSL annually but will never report it. Fish & Game reports that a mere 1.0% of Sand Point households and 1.3% of King Cove households used Steller sea lions in 1992, although none reported actually hunting them (Fall et al. 1993:32). Only one False Pass household reported harvesting a sea lion to Fish & Game in their 1987/88 study year, and none reported any SSL harvest or use in 1992–1995 (Fall et al. 1996:63; Wolfe and Mishler 1993). The subsistence hunts that have been recorded indicate a small number of successful hunters in the villages, and through our fieldwork we have found that some hunters are known for taking SSLs and redistributing the meat to certain relatives and friends. Many Aleut state that they miss eating SSL meat, and that it "makes a nice roast." Some fishermen joked about writing a sea lion cookbook as a way of saving the SSL, under the assumption that if it was to be saved, then one should create a market for it (we assume along the lines of saving ancient rare breeds of sheep, cattle, and fowl in the U.S. and Europe).

Aleut fishermen spend extraordinary amounts of time on their boats at sea, making frequent observations of SSLs. SSLs are largely regarded as pests and very dangerous, following boats, picking fish out of nets, threatening and even succeeding in pulling fishermen off the decks of their boats. For example, in March 2004, Ray Dushkin, Jr. of King Cove was pulled from the deck of a boat while fishing by a 12-feet long sea lion. The 1,200 to 1,500 pound animal latched onto the seat of his pants and yanked him backwards into the water. Luckily he was able to break free (Porco 2004). SSLs are often seen scavenging along boats and in the harbor.

Many have concluded that their aggressive behavior is due to starvation. Yet one man argued, "If they starved, we would have found them [their carcasses]. Look for the damned killer whale scat." Every Aleut elder interviewed stated they have either never seen an SSL carcass or they have only seen a few in their lifetime of fishing and beach combing, even at the rookeries and haulouts. Veniaminov observed in the 1830s that, "A sea lion which is killed in the water sinks at once. The body floats only when its insides begin to rot" (Veniaminov 1984:354). Nearly all Aleut fishermen asked this one simple question: "the dead eventually float—where are the bodies?"

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.

Research linkages/partnerships/collaborators and networking

Aleut Marine Mammal Commission. Interactions included sharing information and data. We also gave presentations to their annual meeting and consulted with them as needed. We regularly gave advice and guidance as they created their new research agendas. No funds were involved.

Education/outreach

Student participation

Two students were funded in part by this research.

- Amber Tews completed an M.S. in Anthropology specializing in the analysis of faunal remains. Her thesis defense is scheduled for early fall semester 2005. She identified nearly 10000 Otariid bones.
- Jack Nielson completed an undergraduate degree in anthropology and geographic information systems. He finished the project GIS.

K–12 outreach

Lectures in the Sand Point, Nelson Lagoon, and King Cove Schools.

Presentations

Aleutian Pribilof Islands Association Board meeting.

Aleut Marine Mammal Commission.

Humans, Climate, and the Marine Ecology of the Greater Beringian Region. Science Day Presentation. Seventh Arctic Science summit Week. Kunming, China. 20 April 2005.

Building an Aleut Anthropology and Archaeology that Matters: Heritage, Fisheries, and Legacy. Keynote presentation to the annual meeting of the Aleut Corporation. 23 October 2004.

Misarti, N., B. Finney and H. Maschner. Ecosystem change in the Northeast Pacific. Paper presented at the Annual Meeting of the Alaska Anthropological Association, Anchorage, 10–12 March 2005.

Tews, A. and H. Maschner. Seafood: It's what's for dinner (breakfast and lunch). Poster presented at the Society for American Archaeology Annual Meeting, Montreal, 2–5 April 2004.

Maschner, H., B. Finney and A. Tews. Did the North Pacific/Bering Sea ecosystem collapse in AD 1150? Paper presented in the symposium: The Northern World AD 1100–1350. Society for American Archaeology Annual Meeting, Montreal, 2–5 April 2004.

Maschner, H. Humans within ecosystems: Getting beyond "human impacts" along the Southern Bering Sea and North Pacific. Paper presented at the NSF HARC Science Meeting, 25–26 October 2003.

Maschner, H.D.G., J.W. Jordan, N. Huntly, B.P. Finney and K.L. Reedy-Maschner. The ecology and paleoecology of human–landscape interactions on the North Pacific and Southern Bering Sea: Investigating the role of the Aleut as ecosystem engineers. Paper presented to the First NSF SEARCH Open Science Meeting, Seattle, Washington, 27–30 October 2003.

Maschner, H. The complex dynamic of social and environmental catastrophe: The southern Bering Sea and north Pacific in a dynamic global system. Plenary Keynote Address, Arctic Section, American Association for the Advancement of Science, Arctic Science Conference, Fairbanks, Alaska. 22 September 2003.

Publications

In press, submitted or in preparation

Maschner, H.D.G., K.L. Reedy-Maschner and A. Tews. Anthropological investigations on the decline of the Steller sea lion (*Eumetopias jubatus*) in the Western Gulf of Alaska and Southern Bering Sea. *Arctic,* in review.

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Bogoslof Island Mapping for Invertebrate Colonization Study

Jennifer Reynolds, PI
University of Alaska Fairbanks

NOAA Goal: Ecosystem-based Management

CIFAR 10-079: This project is ongoing.

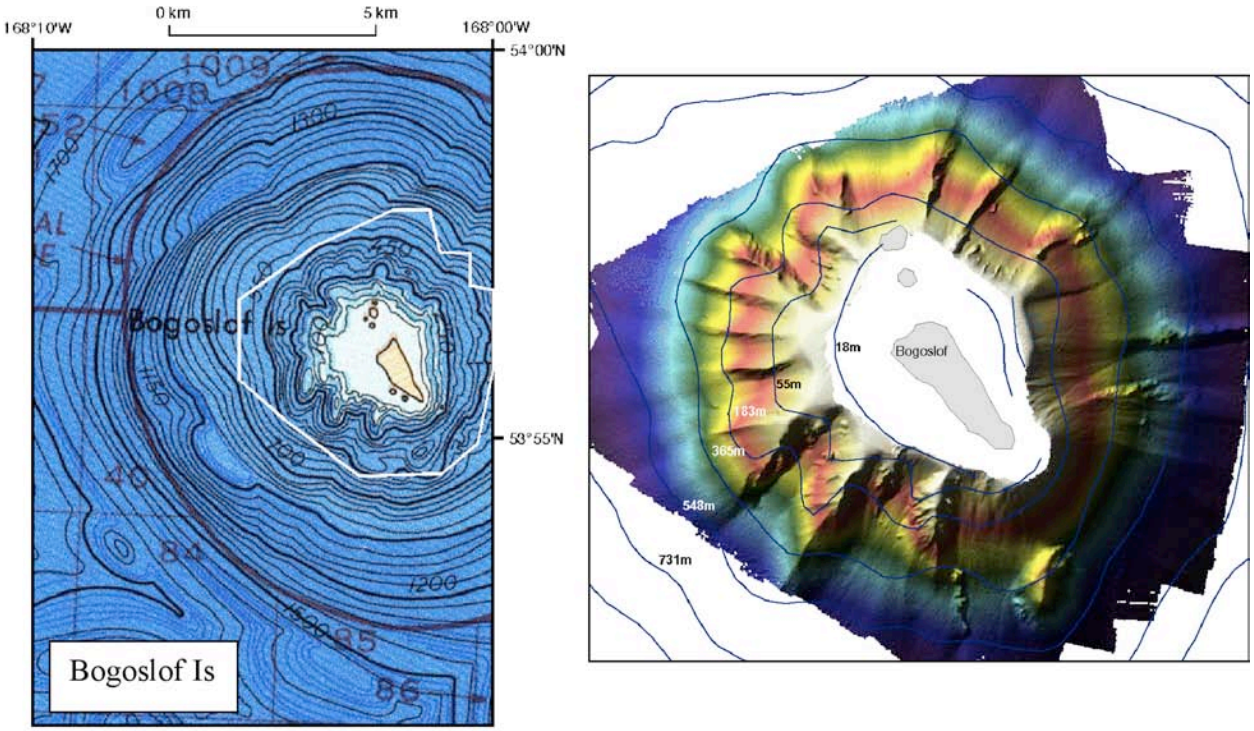
Primary objectives

The role of benthic invertebrates in marine ecosystems, such as deep corals and sponges, and their vulnerability to disturbance by fishing activity, is a topic of increasing concern. However, little is known about the recovery of these species after disturbance in Alaskan waters except that it probably takes decades. This is the first phase of a study of the colonization process of benthic invertebrates at hard-bottom sites decades old on Bogoslof Volcano, as a proxy for measuring recovery from benthic fishing activities.

Approach/methodology

Bogoslof provides a natural laboratory for this study because lava and tephra from historical eruptions (since 1790) have resurfaced different areas of the shallow seafloor around the island. We first need to construct a preliminary map of the "seafloor ages" and habitat classification on the upper slopes of the volcano. These maps will guide placement of ROV video/sampling transects in the next phase of the study (to be funded separately).

We will acquire high-resolution multibeam bathymetry and backscatter of the seafloor around Bogoslof Island, through a NOAA contract with Fugro TGPI. This survey will be done with a 100 kHz Reson SeaBat 8111, currently operated as a pole-mounted system for hydrographic charting. The new multibeam sonar data will be used, in combination with the historical eruption record and the geology of the island, to predict areas of seafloor that were resurfaced by specific eruptions and thus would have known surface ages in the range of 10–200 years. Surface ages will be confirmed in the next phase of the study, by matching rock sample compositions from ROV dives to the volcanic products of documented eruptions.



Left panel: Bathymetric map of the seafloor around Bogoslof Island (NOAA/NOS, 1983). This map was based on 1935-1940 data, and was the most precise bathymetric map available prior to our 2004 survey.
Right panel: Overview of the 2004 bathymetric map of the seafloor surrounding Bogoslof Island, Alaska, from 20 to 750 m. Regional bathymetric contours are superimposed for reference; even at this scale, the dramatic improvement in resolution with the new multibeam data is evident. The central white area is a shallow platform at 20m depth.

Research accomplishments/highlights/findings

- Acted as Chief Scientist for mapping operations at sea, June 2004 on the R/V *Kvichak Surveyor I*. Surveyed 30.6 square km around Bogoslof Island at 20–820 m water depth.
- After completion of the Bogoslof survey, used remaining ship time to survey 26.8 square km of shelf at Lava Point off Akutan Island, 78–482 m water depth.

NOAA relevance/societal benefits

This research will provide information needed for fisheries management by defining an upper bound on natural colonization and growth rates for estimating the recovery of sessile hard bottom invertebrates from benthic fishing activities. The research will also complement ongoing studies of the distribution and habitat relationships of deep corals.

Research linkages/partnerships/collaborators and networking

This project is a fully interdisciplinary collaboration between Mark Zimmerman, a biologist from NOAA's Alaska Fisheries Science Center and a geologist from the University of Alaska Fairbanks. Interest in the results has also been expressed by the Alaska Volcano Observatory, the National Marine Mammal Laboratory, and the U.S. Fish & Wildlife Service.

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

Terry Whitledge, PI
University of Alaska Fairbanks

NOAA Goal: Ecosystem-based Management

CIFAR 08-061: 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. Stabeno 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 (Fisheries-Oceanography Coordinated Investigations) 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 the summer of 2004, a Satlantic In Situ Ultraviolet Spectrometer (ISUS) sensor for nitrate was deployed between SLIP-1 and SLIP-2 (hereafter called M8). There was a subsequent notification from the instrument manufacturer that faulty bulkhead connectors had been found on most of their instruments. Since the mooring was being recovered and redeployed in October because of threats from ice, the ISUS sensor was removed from the M8 mooring on 9 October 2004 and returned to the manufacturer for repair at no cost to the project. The ISUS therefore collected data from 16 July–9 Sept 2004 (Figure 1).
- Data from four additional cruises from the 1930s have been located and are being placed in electronic format for comparison with the other historical data over a span of five to seven decades. This effort will allow a long-term assessment of hydrographic and nutrient trends. See Table 1.

- The mooring will be retrieved and a new mooring will be deployed at the same location during the fall of 2005. A new ISUS instrument will be deployed to provide a quick turnaround and deployment of a fully calibrated instrument. Future mooring at M8 are proposed to be supported by the Alaska Ocean Observing System (AOOS).

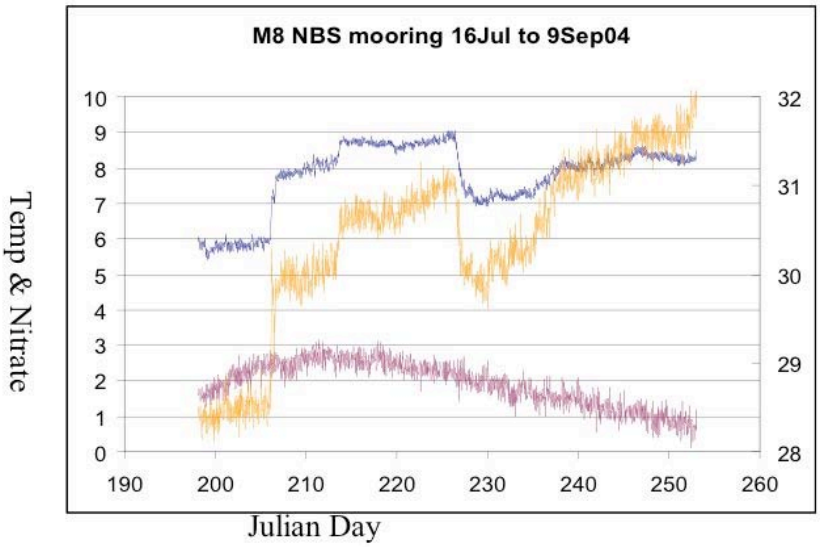


Figure 1. Temperature (deg C, left axis, top curve), salinity (parts per thousand, right axis, most variable curve) and nitrate concentrations (0 to 3 micromolar, left axis, least variable, bottom plot) at ca. 16 m on M8 mooring site during the summer of 2004. Plots are unedited raw data.

Table 1. Historical Data Compilation

13 April 2005

Cruise	*Ship*	*Dates*	*Sta*	*Area*	*Status*
BERCHUK	Gannet	Jun–Aug 33	34	Bering/Chukchi	1
BERCHUK	Chelan	Jun–Aug 34	125	Bering/Chukchi	1
BERCHUK	Northland	Jun–Sept 37	215	Bering/Chukchi	1
BERCHUK	Northland	Jul–Sept 38	171	Bering/Chukchi	1
BERPAC 77	Volna	Jul–Aug 77	48	N Bering	2
BERPAC 84	Korolev	Jul 84	26	N Bering	3
BERPAC 88	Korolev	Jul–Aug 88	113	N Bering/Chukchi	3
CHOEX/ICE	Khromov	Jul–Aug 90	117	Chukchi	3
CHOEX/ICE	Surveyor	Sept–Oct 90	156	Chukchi	3
CHOEX/ICE	Surveyor	Sept–Oct 91	58	Chukchi	3
BERPAC 93	Okean	Aug–Sept 93	63	N Bering/Chukchi	3
AH235	Alpha Helix	Aug–Sept 00	53	Chukchi*	3
AH250	Alpha Helix	Sept 01	54	Chukchi*	3
AH260	Alpha Helix	June 02	98	Chukchi*	3
AH274	Alpha Helix	Jun–Jul 03	123	Chukchi*	3
RUSALCA	Khromov	Aug 04	77	Chukchi	3
AH290	Alpha Helix	Aug–Sept 04	121	Chukchi*	3

* Data collected only in US EEZ
1 Data found but still needs to be entered into electronic database
2 Data is in electronic format but needs to be reformatted
3 Data is fully installed into Ocean Data View database

Notes: The data files being compiled contain a mixture of hydrographic, productivity, and other biological measurements. All cruises include nutrients on nearly all stations but chlorophyll and productivity measurements were collected on a reduced number of stations. The ODV files will carry the hydrographic data along with nutrient and chlorophyll concentrations. Other biological data will be available as a separate Excel file. A metadata file will also be included for each cruise to describe measurement protocols.

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).

References

Cooper, L.W., J.M. Grebmeier, I.L. Larsen, V.G. Egorov, C. Theodorakis, H.P. Kelly and J.R. Lovvorn. 2002. Seasonal variation in sedimentation of organic materials in the St. Lawrence Island Polynya Region, Bering Sea. *Marine Ecology Progress Series*, 226:13–26.

Grebmeier, J.M. and K.H. Dunton. 2000. Benthic processes in the northern Bering/Chukchi seas: Status and global change. In: H.P. Huntington (Ed.), *Impacts of Changes in Sea Ice and Other Environmental Parameters in the Arctic*. Marine Mammal Commission Workshop, Girdwood, Alaska, 15–17 February 2000, pp. 80–93.

Stabeno, P.J. and J.E. Overland. 2001. Bering Sea shifts toward an earlier spring transition. *EOS, Transactions of the American Geophysical Union*, 82:317,321.

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

Terry Whitledge, PI ***NOAA Goal: Ecosystem-based Management***

University of Alaska Fairbanks

CIFAR 09-064: 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 (In Situ Ultraviolet Spectrometer; ISUS) sensors are integrated into the PMEL biophysical mooring.

Research accomplishments/highlights/findings

Mooring Deployment and Recovery Cruises

Instrument	Deployment Date	Vessel	Location	Data
NAS#2266	28 April 2004	Miller Freeman	M2	good
NAS#2236	28 April 2004	Miller Freeman	M4	good
ISUS	15 September 2004	Miller Freeman	M2	
ISUS	20 April 2005	Miller Freeman	M2	

NAS #2266 was deployed at the M2 site on 28 April 2004 and was recovered in October 2004. NAS#2236 was deployed at the M4 site and was recovered in October 2004. An ISUS instrument was deployed at M2 in September 2004 and was recovered in April 2005. An ISUS was redeployed at M2 and M4.

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.

Education/outreach

Presentations (partial list of presentations that use the M2/M4 data)

Stabeno, P.J., J.M. Napp and T.E. Whitledge. 2005. The changing southeastern Bering Sea shelf. Invited presentation to Climate Variability and Sub-Arctic Marine Ecosystems, GLOBEC Symposium – Ecosystem Studies of Sub-Arctic Seas (ESSAS), Victoria, B.C., 16–20 May 2005.

Saitoh, S.-I., T. Lida, T.E. Whitledge, T.K. Rho, A. Shiomoto and K. Sasaoka. 2005. Comparative study of primary production between the Okhotsk Sea and the Bering Sea using satellite and in situ data sets. Invited presentation to Climate Variability and Sub-Arctic Marine Ecosystems, GLOBEC Symposium – Ecosystem Studies of Sub-Arctic Seas (ESSAS), Victoria, B.C., 16–20 May 2005.

Whitledge, T.E., J.M. Napp and P.J. Stabeno. 2005. Long term mooring observations of nutrients, fluorescence and temperature/salinity at mooring sites M2 and M4 in the middle shelf of the SE Bering Sea. Presentation to Climate Variability and Sub-Arctic Marine Ecosystems, GLOBEC Symposium – Ecosystem Studies of Sub-Arctic Seas (ESSAS), Victoria, B.C., 16–20 May 2005.

University of Alaska Fairbanks Living Marine Resources Graduate and Postgraduate Fellowship

Denis Wiesenburg, PI ***NOAA Goal: Ecosystem-based Management***
University of Alaska Fairbanks

Other investigators directly funded by this project:
Chris Siddon, Postdoctoral Fellow, *University of Alaska Fairbanks*

CIFAR 06-046: 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. The School of Fisheries and Ocean Sciences (SFOS), University of Alaska Fairbanks, entered into an agreement in Fiscal Year 2003 with NOAA/National Marine Fisheries Service (NMFS)'s Alaska Fisheries Science Center, Seattle to provide training and advanced research on issues affecting the sustainability of the Steller sea lion (SSL) in the northeast Pacific Ocean and Bering Sea.

Approach/methodology

This project has funded Pieter deHart, a Ph.D. student working with Dr. Matthew Wooller, and Dr. Chris Siddon, a postdoctoral fellow working with Dr. Terrance Quinn II.

Pieter deHart was awarded a 2-year Ph.D. Graduate Research Assistantship, beginning in January 2003. Pieter advanced to Candidacy at the end of 2004.

Historical ecology of Steller sea lions: The causes for decline in Steller sea lion populations in the North Pacific region over the past 30 years remain unknown, despite substantial advances in understanding the ecology and functioning of the system. Pieter deHart has studied 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 commenced a 2-year Research Associate (postdoctorate) appointment in September 2003, joining the Juneau Center upon successful completion of the Ph.D. requirements at Brown University. His research is being conducted in affiliation with Dr. Terrance Quinn II.
Test the hypotheses that food limitation and predation have caused the dramatic decline of the Steller sea lion population: In the previous reporting period, Chris Siddon commenced his studies on the cause:effect relationship between food availability and predation vs. population decline in the SSL. He was employing stage-class population modeling, which has been widely utilized to address the management and recovery of threatened or endangered species. These models allow prediction of whether a population is increasing or decreasing, and which stage class (e.g., pup, juvenile, adult) is most sensitive to a perturbation. Siddon began 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. However, it became apparent that this research plan was overambitious, and subsequently was modified as described under "Research Accomplishments" (below) to focus on experimental manipulation in a model system.

Research accomplishments/highlights/findings

Historical ecology of Steller sea lions: In fall 2004, Pieter deHart collected 74 SSL teeth from the collection held by the Alaska Department of Fish and Game (ADF&G). Data from samples included size, age, sex, and location. The tooth samples were segmented into longitudinal sections representing growth layers and corresponding years (potentially 222 temporal data points) of the SSL diet, and all teeth were extracted for their collagen and analyzed for their stable isotope composition at the Alaska Stable Isotope Facility. Tooth collagen analyses assisted in filling temporal gaps in previously analyzed osteological (mandible) bone samples and elucidating fine-scale life history changes. The range of $\delta^{13}C$ and $\delta^{15}N$ values over all samples is great, suggesting large differences in feeding behavior and/or area across the whole of this species' range and decline period. The signature differences and trends isolated from tooth samples suggest that there may have been a change in $\delta^{13}C$ around regime shift periods (e.g., 1976), and that this jump may be due to alterations in local primary production.
Test the hypothesis that food limitation has caused the dramatic decline of the Steller sea lion population: In the current funding year, Research Associate Chris Siddon focused on experimental manipulation in a multiple predator model system. An Individual Mark-Recapture experiment was conducted to quantify movement, mortality, and growth rates of the lyre whelk, *Neptunea lyrata*, as a function of urchin and seastar predators. This invertebrate system was used to gain insight on the importance of multiple predators (on different life history stages) and behavioral changes on the population dynamics of organisms. Two hundred adult snails and 10 egg masses were tagged, measured, released and followed over the summer of 2005. Results showed that 1) Movement behavior (velocity) increases in the presence of the seastar *Pycnopodia helianthoides*, 2) Urchins are an important predator on *Neptunea* egg cases, 3) Adult snail mortality is very low (0.5% over 3 months), 4) Average fecundity of *Neptunea* is 90 ± 12 (SD). These data are currently being analyzed and will be incorporated into a matrix population model to examine the importance of each response variable on the population growth rate of *Neptunea*. Manuscripts from this research are to be submitted in early 2006 (see below).

NOAA relevance/societal benefits

This project has provided training and advanced research on issues affecting the sustainability of the Steller sea lion in the northeast Pacific Ocean and Bering Sea. Using stable isotope mixing models, the new dataset analyzed by this research will help to isolate specific sources of isotopic depletion, illuminate the importance of nutritional limitation, and ultimately further our understanding of natural population foraging and mammalian reactions to environmental changes.

Research linkages/partnerships/collaborators and networking

Partnerships were established with NOAA/National Marine Mammal Laboratory (NMML) (Jim Thomason, Mike Etnier, and Tom Loughlin), ADF&G (Lorrie Rea, Vicki Stegall, and Jamie King), and the University of California Santa Cruz (Paul Koch).

Education/outreach

- deHart served as a volunteer teaching assistant for the Stable Isotope Techniques in Environmental Research course at UAF in the Spring of 2004.
- During Summer 2005, Siddon served as a mentor for one undergraduate as a part of the NSF-sponsored Research Experience for Undergraduates program through UAS and for an undergrad volunteer.

- Siddon participated in the Population Dynamics class (Fall 2004 and Spring 2005) taught by Terry Quinn and gave guest lectures for Marine Ecosystems (taught by Professors Tom Shirley and Gordon Kruse).

Presentations

deHart, P.A.P. and M.J. Wooller. 2004. Shouldn't we ask where? Stable isotopic evidence of geographical variations in Steller sea lion (*Eumetopias jubatus*) diets. Sea Lions of the World Conference, Anchorage, Alaska, September 2004.

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, Arcata, California, June 2004.

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, Wellington, New Zealand, April 2004.

Siddon, C.E. 2004. Meta-analysis of multiple predator effects. Oral Presentation. Western Society of Naturalists.

Publications

In preparation or in review

deHart, P.A.P., M.J. Wooller, V.K. Stegall, B.P. Finney and P.L. Koch. The historical ecology of Steller sea lions: An isotopic study of mammalian responses to a changing environment. In preparation for submission to *Marine Mammal Science*.

Siddon C.E. Effects of multiple predators on the fecundity, mortality, and movement behavior of the lyre whelk, *Neptunea lyrata*. In preparation.

Siddon, C.E and K. Sawyer. Comparison of the reproductive strategies of two subtidal gastropods, *Fusitriton oregonensis* and *Neptunea lyrata* in southeastern Alaska. In preparation.

Siddon, C.E. and J.D. Witman. Meta-analysis of multiple predator effects. In review.

Follow-up

Pieter deHart will be finishing his Ph.D. work, including stable isotope work on Bowhead whale migration patterns and oxygen and hydrogen isotopic analyses of arctic ecosystems. Upon completion and defense of his dissertation, Pieter will apply his experience to the workforce in either the NOAA/NMFS or at a small research university.

Dr. Chris Siddon has been hired as a Biometrician II at the Alaska Department of Fish and Game in Juneau. He will be responsible for stock assessments of and research on the commercially harvested shellfish species in southeastern Alaska, which include King crab, Dungeness crab, Tanner crab, scallops, shrimp, geoducks, sea urchins and sea cucumbers, among others.

Tsunami Research

Alaska Earthquake Information Center Seismic Station Upgrade and Installation and TWEAK (Tsunami Warning and Environmental Observatory for Alaska): Seismic Network Expansion and Upgrades

Roger Hansen, PI *University of Alaska Fairbanks*

NOAA Goals: Serve Society's Needs for Weather and Water Information
Safe, Efficient and Environmentally Sound Transportation

Other investigators/professionals directly funded by this project:
Steve Estes, Martin LaFevers, Josh Stachnik, Ed Clark, Otina Fox, John MacCormack, Natalia Ruppert, Lily Wong, Elizabeth Fuerst, and Rebecca Sanches, *University of Alaska Fairbanks*

CIFAR 10-013c: This project is ongoing.

Primary objectives

This continuing project is to install a total of 18 new modern digital broadband seismic stations throughout Alaska and to maintain their operation and telemetry.

Installations and maintenance

- Alaska Earthquake Information Center (AEIC) personnel continue to monitor and process data from the combined CREST (Consolidated Reporting of Earthquakes and Tsunamis) network funded by the National

Tsunami Hazard Mitigation Program (NTHMP). In the past year, 11 seismic or communication sites needed attention for either routine maintenance or hardening for harsh weather. They are listed below:

BMR (Bremner River - east of Valdez) - Replaced seized wind charger and changed Guralp 3T seismometer.
COLD (seismic station installed in FY04 near Coldfoot, AK) - Replaced Guralp 3T seismometer.
DCPH (Deception Hills seismic station south of Yakutat) - Updated the communication antennas and radios for better data transmission. Replaced GPS antenna twice.
DIV (Divide - East of Valdez) - Replaced DM24 digitizer and exchanged episensor with CMG-5T.
DOT (Dot Lake) - Replaced digitizer, ups interface card and converted from 24VDC to 48VDC.
EYAK (near Cordova) - Relocated and replaced GPS antenna.
NIKO (Seismic station near Nikolski installed in FY03) - Inspected vault, looks good.
PAX (Paxson) - Trench communication and power cable in conduit to AT&T site with FTS circuit.
PIN (Pinnacle - north of Yakutat) - Replaced exhausted batteries and power controller. Improved antenna system.
SPIA (St. Paul Island) - Replaced Guralp ESP seismometer.
Yakutat - Communications hub at NOAA weather service tower. Upgraded antennas.

- Additionally, this year's funding included a significant upgrade to the Alaska Tsunami Warning Center (ATWC) seismic network. A total of four Streckeisen STS-2 seismometers were purchased and installed at four of the ATWC sites. AEIC personnel also assisted in site surveys for some of these sites. An AEIC site was upgraded at Reindeer Mountain with equipment from this project.
- We began the conversion for improved telemetry of seismic data through IP delivery over VSAT (Very Small Aperture Terminal) technology. A significant effort was required to research and identify a company willing to deliver a system that is both low power, and can behave as an independent (non-proprietary) IP pipe capable of handling both UDP and TCP type data packets. A vendor was chosen, and a pilot system was obtained and tested in Fairbanks. The ultimate test came by placing the system in the field in a remote setting. An opportunity to transmit 8 real-time broadband sensors arose through an independently funded NSF project for tectonic study of the Bering Glacier area and the Yakataga seismic gap. The VSAT dish was installed at the BLM Bering Glacier research camp. Power for the system was engineered at AEIC to include banks of rechargeable batteries, solar panels, and two wind generators. Intelligent power switchers are used to appropriately control the power distribution system. Eight seismic stations telemeter data from various sites surrounding the Bering Glacier into a central receiving site and collected into a field computer that connects to the VSAT. The data from 24 channels has been robustly collected now for the past two months. Further expansion of this type data telemetry system awaits confirmation that the system can function autonomously from this remote area.

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

- Outreach to the public was accomplished through our annual participation at the Tanana Valley State Fair.
- Collaboration with Denali National Park has improved both our outreach efforts and our data communication capabilities through our participation with the Murie Science and Learning Center (MSLC). Data shared with the tsunami warning centers is now available through the MSLC, providing an elevated awareness for the park and a reduced cost for AEIC.
- In collaboration with the Alaska Department of Homeland Security and Emergency Management (DHS&EM), we are purchasing two All Hazards Alert Broadcast (AHAB) systems for warning two remote communities of potential hazards from earthquakes, volcanoes, or tsunamis. Equipment has been identified as the same that is being installed at other locations within the NTHMP areas of Washington. Equipment has been ordered, and installation will proceed in FY06. As part of the Emergency Alert System, the AHAB system can be manually activated to alert the areas of any hazard. This critical component of public safety represents a viable means of immediate emergency communication which could save property and lives. It is also intended to be an enhanced NOAA Weather Radio Warning system, capable of loud and widespread broadcast of any necessary messages.

Alaska Tsunami Inundation Mapping Project and TWEAK (Tsunami Warning and Environmental Observatory for Alaska) Element I: Accelerated Alaska Inundation Mapping Production

Roger Hansen, PI *University of Alaska Fairbanks*

NOAA Goals: Serve Society's Needs for Weather and Water Information; Safe, Efficient and Environmentally Sound Transportation

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*

CIFAR 10-014c and 06-028a: These related projects are ongoing.

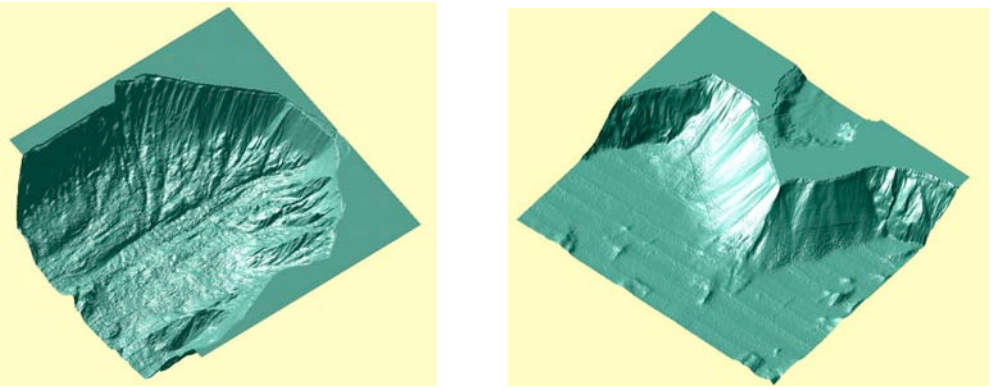
Primary objectives and approach

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, and 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:

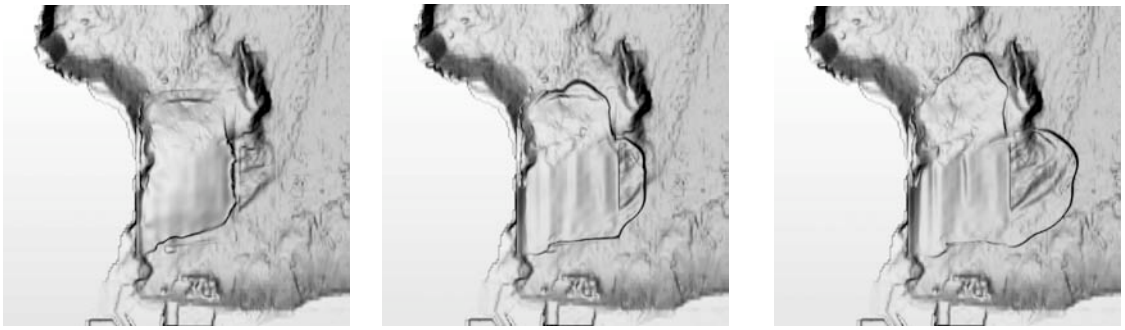
We have revisited inundation modeling and mapping for the communities of Homer and Seldovia in Kachemak Bay, Alaska to include a new tsunami scenario that was suggested at a meeting with Homer officials. The report (see Publications) is currently in the review process. It includes tsunami hazard maps 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 obtained the raw, high-resolution multi-beam bathymetry data of Valdez Arm with a grid spacing of approximately 4.5 meters. Also, the digital elevation model (DEM) of the Valdez area was purchased from AeroMap US. To facilitate close analysis of the regions of interest, small subsections of the bathymetric data adjacent to the coastline were clipped out and used to make detailed shaded three-dimensional relief plots for visual inspection. These sub-grids cover the entire Valdez Arm.
- We have begun to examine submarine landslide features in Valdez Arm. We have studied 3-D bottom topography near the old town site, Shoup Bay, and Pipeline terminal. There are several features suggesting that there were more than one landslide caused by the 1964 earthquake, as well as some older submarine slides scarps visible in the data.



High-resolution multi-beam bathymetric images of Valdez Arm: the old town site (left) and Shoup Bay (right).

- 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 and to calculate inundation of dry land caused by the slide-generated tsunami waves. We have applied this model to the major underwater slide in the upper Resurrection Bay that was triggered by the 1964 earthquake and destroyed the Seward waterfront. We continue to work on the Seward inundation mapping project. We have performed numerical calculations for three additional hypothetical tectonic scenarios that could produce tsunami waves potentially dangerous for Seward. First, we have modified the 1964 scenario to include the Patton Bay fault. It was extended to be 235 km in length, according to recent studies. The second scenario is the rupture of the transition zone between the Yakutat block and the Pacific plate. The last one includes the rupture of the Pamplona zone between the Yakutat block and the North America plate. Inclusion of slip on the Patton Bay fault increased the inundation depth and extent compared to the results from the scenario that does not include the Patton Bay fault. Inundation from the scenarios originating near the Yakataga area (the second and third scenarios above) was insignificant in Resurrection Bay.



Snapshots from a numerical simulation of the 1964 Seward waterfront slide. The three images show the position of the underwater slide at 10, 30 and 50 seconds after the slide was triggered by strong ground shaking due to the M_w=9.2 earthquake.

- We have conducted a numerical study of the December 26, 2004 North Sumatra tsunami. The numerical model is based on vertically integrated shallow water equations of motion and continuity. The computational domain covers the Indian Ocean with a grid of 2-arc minute resolution. Calculations were performed on the Cray X1 machine at the Arctic Region Supercomputing Center for 10 hours of tsunami propagation time. We have calculated the initial surface displacement of the ocean surface for three different source functions that describe the orientation and structure of the earthquake rupture area. Then, the resulting surface heights in the Indian Ocean were compared with the Jason-1 satellite altimetry measurements. In order to calculate sea surface height along the satellite path, we created an algorithm that finds the closest grid point in the numerical domain to the point in the satellite record. The results show that two of the modeled source functions miss the major amplitude peaks in the satellite record, and the third function provides a good match to the satellite data, both in amplitude and timing of the major peak.

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.

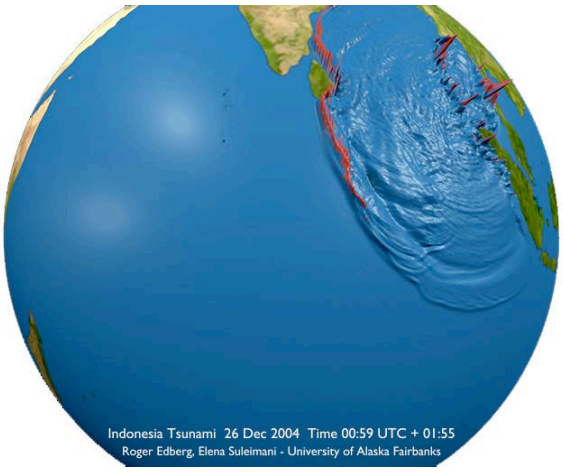
Education/outreach

- Investigators visited the community of Homer for final presentation of inundation maps and the tsunami inundation mapping report. Several comments and suggestions from the community officials were accepted, including the additional tsunami scenario.
- Investigators visited the community of Valdez for the 2005 Tsunami/Earthquake conference where they educated the community on the hazards of earthquakes and tsunamis in the Valdez area, and discussed measures for better preparedness in the community. The conference was broadcast live.

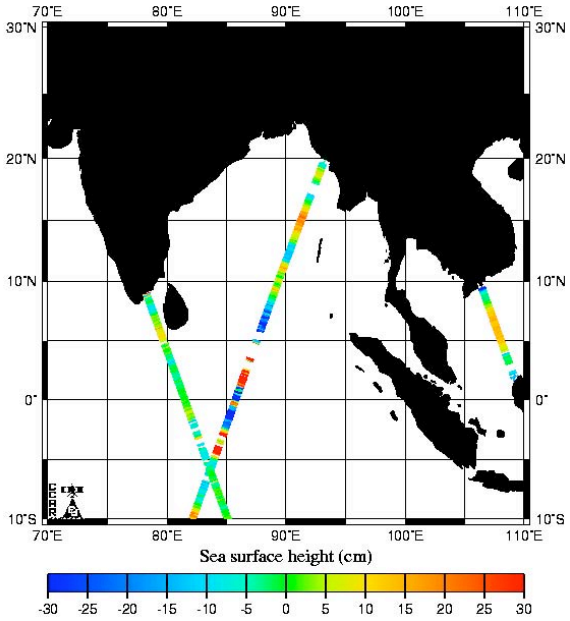
Presentations

Suleimani, E.N., J. Beget, R.A. Hansen and D. Marriott. 2005. Tectonic and landslide source scenarios for tsunami inundation mapping in Seward, Alaska. Proceedings of the 22nd International Tsunami Symposium, Chania, Greece, 27–29 June 2005, p. 319.

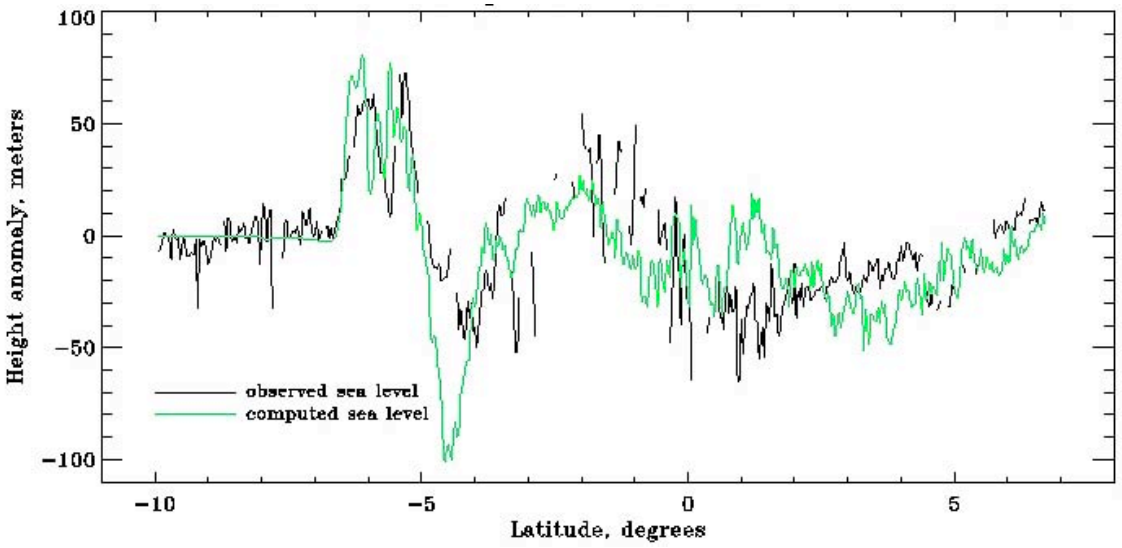
Suleimani, E. and R. Hansen. 2005. Numerical study of the December 26, 2004 North Sumatra tsunami. Seismological Society of America 2005 Annual Meeting, Incline Village, Nevada, 27–29 April 2005. *Seismological Research Letters*, 76(2):221.



Snapshot from a numerical simulation of the Indian Ocean tsunami at the time when the path of the Jason-1 satellite altimeter crossed the tsunami wave front.



The multi-colored ribbon represents track 129 of cycle 109 from the Jason-1 satellite altimetry mission on December 26, 2004 that recorded the tsunami wave heights in the open ocean.



Comparison between observed and calculated sea level heights along the Jason track 129. Sea level heights were calculated from the shallow water equations of motion and continuity. Three source functions of the December 26, 2004 North Sumatra earthquake were constructed and tested against observation data.

Publications

Submitted

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.

TWEAK (Tsunami Warning and Environmental Observatory for Alaska): Tsunami Code Development

Roger Hansen, PI ***NOAA Goals: Serve Society's Needs for Weather and Water Information;***
Zygmunt Kowalik, Co-PI ***Safe, Efficient and Environmentally Sound Transportation***
and task lead
University of Alaska Fairbanks

Other investigators/professionals funded by this project:
James Beget, Tatiana Proshutinsky, Sathy Naidu, *University of Alaska Fairbanks;*
Galen Gisler, *Los Alamos National Laboratory;* ***Yoshinori Shigihara,*** *National Defense Academy, Japan*

CIFAR 10-074 (Task 3.1): This project is ongoing.

Primary objectives

The objective of the research plan is to improve the present numerical models and afterwards develop a comprehensive numerical model for tsunami generation, propagation and transformation to be used at the West Coast/Alaska Tsunami Warning Center (WC/ATWC). Although the current models have been successfully used, there is a need of actualization using the state-of-the-art approaches. To carry out this plan we closely cooperated with the WC/ATWC in model development, testing and implementation and with external institutions that are in the vanguard in specific fields of tsunami research, Los Alamos National Laboratory and the Tohoku University, amongst others.

Approach/methodology

We have approached the objective by developing particular tasks with the aim to improve the model components:

1) *Tsunami runup:* We have concentrated our efforts on developing a new runup code. The code was developed by Z. Kowalik (Institute of Marine Science, University of Alaska Fairbanks; IMS) in close cooperation with W. Knight (WC/ATWC) and J. Horrillo (IMS). The code was tested, calibrated and validated with analytical solutions as well as with laboratory experiments.
2) *2D/3D hybrid tsunami model*: We applied Full Navier-Stokes (FNS) equations to test the validity of the dynamics used in 2D. The model results obtained with hydrostatic tsunami model, Boussinesq (dispersive) model and FNS were compared in order to assess differences caused by vertical acceleration in FNS and identify the importance of dispersion for the global model. This investigation is a cooperative effort of J. Horrillo and Z. Kowalik (IMS) and Y. Shigihara (National Defense Academy, Japan).
3) *Interaction of tide and tsunami:* In the real ocean, the short-period tsunami wave rides on the longer-period tides. The question is whether these two waves can be superposed linearly for the purpose of determining the resulting sea level or rather in the shallow water they interact nonlinearly enhancing the total sea level and currents. The constructed model of nonlinear tsunami and tide interaction (preliminary we use only one tidal constituent) indicates that in Alaska, tsunami runup cannot be computed separately from tides. This investigation is a cooperative effort of A. T. Proshutinsky (WHOI/IMS) and Z. Kowalik (IMS).
4) *Tsunami generation by land and submarine slides:* Submarine slide model is in development by Z. Kowalik and J. Horrillo (IMS) and W. Knight (WC/ATWC) while scenarios are constructed by J. Beget (UAF) and S. Naidu (IMS).
5) *Construction of the comprehensive tsunami model:* The comprehensive model construction includes at the present time generation by earthquake, propagation and runup (Kowalik et al. 2004). This model was applied to test its skill in the simulation of the Indian Ocean tsunami case of 26 December 2004. The model domain covered the entire World Ocean extending from 80S to 69N. The model resolution was 1 minute and its domain had approximately 200 million grid points. In order to carry out this simulation, a parallel version of the model code was developed by T. Logan (ARSC) and run on a supercomputer.

Research accomplishments/highlights/findings

- The global tsunami model (GTM) developed by Kowalik et al. (2005a, 2005b) covers the entire World Ocean with spatial resolution less than 1 min. It describes new physics in the global tsunami propagation.
  a) The oceanic ridges act as ducts for tsunami waves, transferring energy for many thousands of kilometers without noticeable dissipation;
  b) Travel time computation based on Fermat's principle may lead to errors in the prediction of tsunami arrival time in tsunamis which propagate to other oceans;
  c) In passing through the straits between continents, a tsunami signal is reorganized from noisy into coherent motion (see Figure 1); and
  d) The Coriolis force plays an important role in the global tsunami propagation.

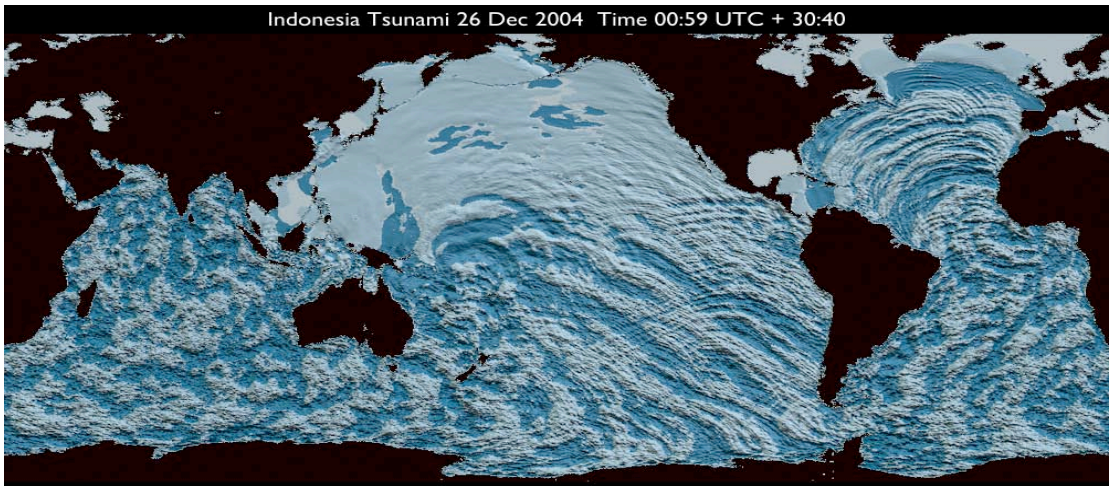


Figure 1. Sea level pattern generated by the Indian Ocean tsunami of 26 December 2004 at 30 h 40 min from the earthquake. Tsunami signals in Northern Atlantic and South Pacific have been reorganized into coherent waves after passing through the narrows between Africa and South America and Australia and Antarctica (Kowalik et al., 2005a, 2005b).

NOAA relevance/societal benefits

Numerical models are required to assess expected coastal tsunami impact, both in amplitude and horizontal inundation distance, so that proper evacuation decisions can be made during tsunami warnings, as well as for long-term planning of coastal zone development. When the project is completed, the West Coast/Alaska Tsunami Warning Center will have the much-needed tsunami models for use in their warning procedures.

Research linkages/partnerships/collaborators and networking

The numerical modeling technique used by the West Coast/Alaska Tsunami Warning Center (WC/ATWC) which forms the present basis of the U.S. Tsunami Warning System's predictive technique was developed during the period 1984–1990 by the Institute of Marine Science, University of Alaska in cooperation with the Institute of Ocean Sciences, Sidney, BC, Canada through an NSF grant.

Several teams from institutions of the U.S.A. and Japan are involved in this project. For the continuing model development, the responsibility lies with the University of Alaska (Kowalik and Horrillo, Institute of Marine Science; Tom Logan, Arctic Region Supercomputing Center), W. Knight and P. Whitmore (WC/ATWC), Y. Shigihara (National Defense Academy, Japan) and T. and A. Proshutinsky (WHOI/IMS). Input to the project was also made by G. Gisler (Los Alamos), J. Beget (UAF) and S. Naidu (IMS); William Knight of the WC/ATWC coordinated research activities with implementation at the WC/ATWC.

We envision that many of the tsunami algorithms can be most effectively transported to and tested on the UAF supercomputers. Maintaining the codes and applications at UAF will enable the WC/ATWC to quickly generate new database entries as needed or to re-compute the old database entries. With a 3-D visualization laboratory in ARSC, it was a relatively simple task to develop animation techniques (R. Edberg, ARSC) that elucidated physics of the global tsunami propagation.

Education/outreach

Juan Horrillo is a Ph.D. graduate student in physical oceanography at the Institute of Marine Science, where Z. Kowalik chairs his advisory committee.

Publications

Peer-reviewed

Kowalik, Z., W. Knight, T. Logan and P. Whitmore. 2005a. Numerical Modeling of the global tsunami: Indonesian tsunami of 26 December 2004. *Science of Tsunami Hazards*, 23(1):40–56.

Non-peer-reviewed

Kowalik, Z., W. Knight, T. Logan and P. Whitmore. 2005b. The tsunami of 26 December 2004: Numerical Modeling and energy considerations. In: G.A. Papadopoulos and K. Satake, Eds. *Proceedings of the International Tsunami Symposium, Chania, Greece, 27–29 June 2005*, pp. 140–150.

Horrillo, J.J., Z. Kowalik and W. Knight. 2005c. Full Navier-Stokes approximation in tsunami investigation. In: G.A. Papadopoulos and K. Satake, Eds. *Proceedings of the International Tsunami Symposium, Chania, Greece, 27–29 June 2005*, pp. 77–88.

Kowalik, Z., J.J. Horrillo and E. Kornkven. 2004a. Tsunami runup onto a plane beach. The Third International Workshop on Long-wave Runup Models, Wrigley Marine Science Center, Catalina Island, California, 17–18 June 2004, 21 pp.

Kowalik, Z., J.J. Horrillo and E. Kornkven. 2004b. Tsunami generation and runup due to a 2D landslide. The Third International Workshop on Long-wave Runup Models, Wrigley Marine Science Center, Catalina Island, California, 17–18 June 2004, 10 pp.

TWEAK (Tsunami Warning and Environmental Observatory for Alaska): Earthquake Characteristics and Finite Fault Processes

Roger Hansen, PI *University of Alaska Fairbanks*

NOAA Goals: Serve Society's Needs for Weather and Water Information; Safe, Efficient and Environmentally Sound Transportation

Other investigators/professionals funded by this project:
Natasha Ruppert, *University of Alaska Fairbanks*

CIFAR 10-074 (Task 3.2): This project is ongoing.

Primary objectives

Implementation of the near-real-time moment tensor inversion and extended earthquake source inversion procedures at the Alaska Earthquake Information Center (AEIC).

Approach/methodology

The real-time earthquake detection system at AEIC is based on the Antelope software package from BRTT, Inc. Automatic earthquake locations are searched over a pre-calculated three-dimensional grid. Once an event is located, its magnitude is calculated. Location and magnitude along with the set of associated arrivals and other information are written into the real-time earthquake database. The moment tensor inversion program is triggered by a module that continuously watches the real-time earthquake database. When a new event above a certain magnitude level has been recorded, it triggers the execution of the moment tensor inversion module. The procedure consists of several steps. First, the waveforms are extracted from the broad-band stations. If the waveforms within a certain epicentral distance are available, then the moment tensor inversion is performed. The program generates a series of output files including a postscript graphics file with the actual and synthetic wave forms and the best fit moment tensor parameters, a map with the earthquake location and the focal mechanism obtained, and an ascii file with the moment tensor parametric data.

The automatic moment tensor information is available through the AEIC webpage:
http://www.aeic.alaska.edu/html_docs/moment_tensors.html
in three forms. Automatic moment tensors are reviewed on the following business day.

Research accomplishments/highlights/findings

- A total of 59 regional moment tensor solutions were calculated (Mw=3.9–5.9) for this time period (Figure 1).

- Ongoing expansion of the AEIC broadband network allows for more reliable calculations of the earthquake source parameters through inclusion of more waveform data into inversion. The most recent installation of 8 broadband stations in Wrangell–St. Elias National Park (a part of the ongoing St. Elias Erosion Tectonic Project, or STEEP) greatly expanded our detection capabilities in southern Alaska (Figure 2).
- Additional work was performed on refining velocity models for use in calculations of the synthetic seismograms.
- Work has been initiated on installation of the extended earthquake source inversion codes.

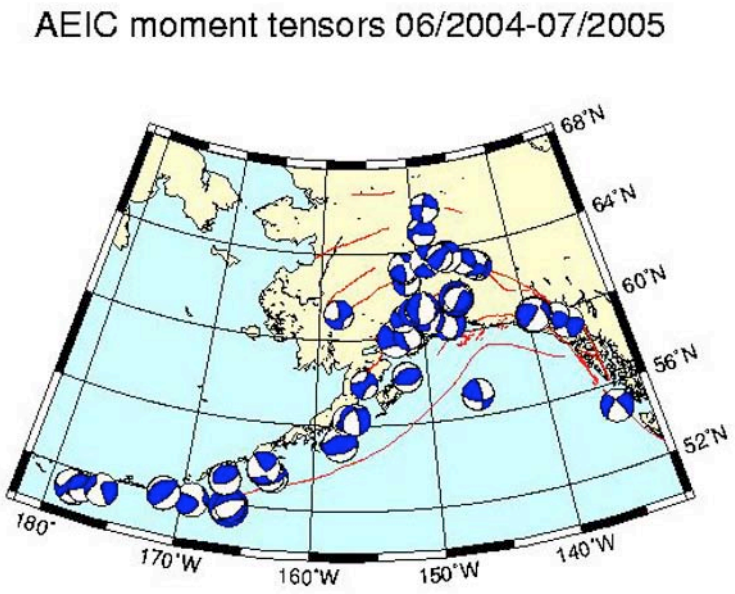


Figure 1.

NOAA relevance/societal benefits

Rapid calculation of earthquake source parameters through the moment tensor inversion allows scientists to determine sense of motion along the ruptured fault. While many other conditions determine whether an earthquake is capable of generating potentially destructive tsunamis, the foremost condition is the type of earthquake source (underthrusting vs. normal or strike-slip) and size.

The moment tensor inversion package at AEIC was installed in close cooperation with Dr. D. Dreger from Berkeley Seismic Laboratory. This cooperation is continuing as part of installation and tuning of the program package for extended source inversion at AEIC. All AEIC earthquake source data is available on-line through open-access web-pages. This information is available to scientists at the West Coast/Alaska Tsunami Warning Center (WC/ATWC) as well as many other institutions.

Research linkages/partnerships/collaborators and networking

This project is one of three research tasks identified under TWEAK (Tsunami Warning and Environmental observatory for Alaska) and share the linkages and partnerships outlined under the other tasks.

Education/outreach

Presentations

Stachnik, J.C., R.A. Hansen and N.A. Ratchkovski. Real-time processing and data exchange at the Alaska Earthquake Information Center. SSA 2005 Annual Meeting, 27–29 April 2005.

Publications

Peer-reviewed

Dreger, D., D.D. Oglesby, R. Harris, N. Ratchkovski and R. Hansen. 2004. Kinematic and dynamic rupture models of the November 3, 2002 Mw 7.9 Denali, Alaska, earthquake. *Geophysical Research Letters*, 31:L04605, doi:10.1029/2003GL018333.

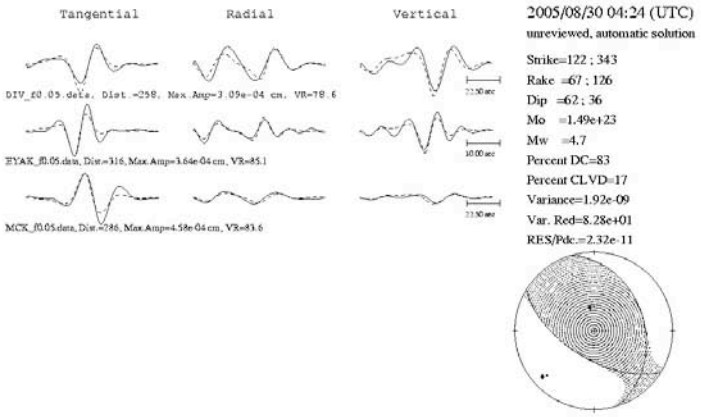
Oglesby, D.D., D.S. Dreger, R.A. Harris, N. Ratchkovski and R. Hansen. 2004. Inverse kinematic and forward dynamic models of the 2002 Denali fault earthquake, Alaska. *Bulletin of the Seismological Society of America*, 94(6B):S214–S233.

Ratchkovski, N.A., S. Wiemer and R.A. Hansen. 2004. Seismotectonics of the central Denali fault, Alaska and the 2002 Denali fault earthquake sequence. *Bulletin of the Seismological Society of America*, 94(6B):S156–S174.

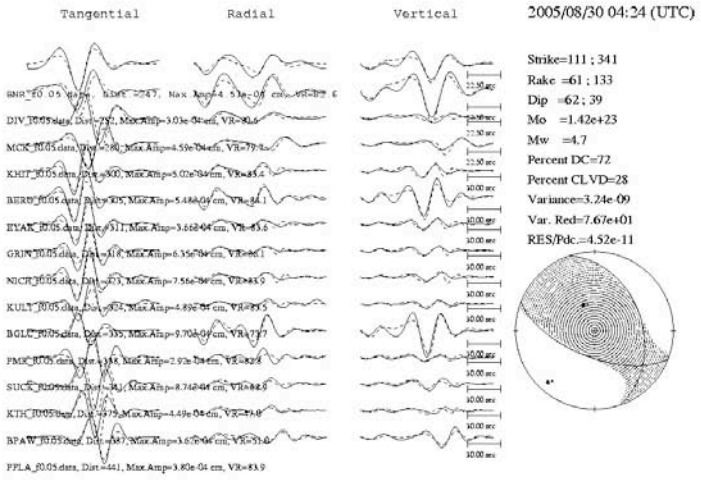
Ratchkovski, N.A. 2003. Change in stress directions along the central Denali fault, Alaska after the 2002 earthquake sequence. *Geophysical Research Letters*, 30, 2017, doi:10.1029/ 2003GL017905.

Ratchkovski, N.A., R.A. Hansen, J.C. Stachnik, T. Cox, O. Fox, L. Rao, E. Clark, M. Lafevers, S. Estes, J.B. MacCormack and T. Williams. 2003. Aftershock sequence of the Mw 7.9 Denali fault, Alaska, earthquake of 3 November 2002 from regional seismic network data. *Seismological Research Letters*, 74:743–752.

Automatic solution:



Reviewed solution:



Map:

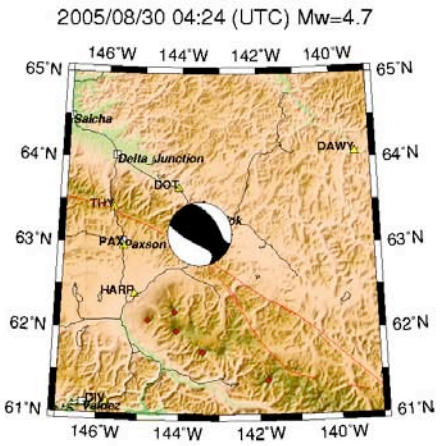


Figure 2.

TWEAK (Tsunami Warning and Environmental Observatory for Alaska): Tsunami Portal for Comparison of Tsunami Code

Roger Hansen, PI *University of Alaska Fairbanks*

NOAA Goals: Serve Society's Needs for Weather and Water Information; Safe, Efficient and Environmentally Sound Transportation

Other investigators/professionals funded by this project:
Barbara Horner-Miller (*Task lead****), Thomas Logan, Roger Edberg, Edward Kornkven, Elena Suleimani,*** *University of Alaska Fairbanks;* ***Cherri Pancake, Sara Cole, Tim Holt, Dylan Keon, Leanne Lai, Harry Yeh, Daehyun Yoon, Daphne Kagume, Wilson Mbugua, Javier Moncada****, Oregon State University*

CIFAR 10-074 (Task 3.3): This project continues into the next reporting period.

Primary objectives

The Tsunami Computational Portal will be a shared web portal for executing computational models of tsunami behavior. Researchers, operational staff and other interested parties will be able to input data for different scenarios to run on the available models. They will specify parameters for explicit scenarios, specify which of the available models to use to create computer runs, submit those runs for execution, access or download the results from the computational systems to the portal, and share comments on their results, issues and recommendations. The web portal will be built by an outsourced team and will include the necessary user interface/infrastructure to initially provide access to two prominent tsunami codes and professionally developed case studies.

Approach/methodology

The Tsunami Computational Portal is a shared website where computer models of tsunami behavior can be executed and compared against a series of benchmark data mimicking real-world coastal communities. The portal will allow researchers to collaboratively refine existing techniques for predicting the occurrence and effects of tsunamis and storm surge waves.

Computational models yielding relevant and useful predictive information about any particular natural hazard are hard to identify, access, or understand. In the case of tsunamis, a number of high-quality simulation and prediction models exist, but are in the hands of individual researchers located at various institutions throughout the world. To obtain critical predictive information (e.g., wave height and propagation estimates, run up effects), each model must be run with particular input data (specific coastline and underwater geography, historical water levels, tidal patterns, etc.). While much of the data is available online, it must be located and gathered from a variety of agencies, then converted to the appropriate formats for each model. Further, the computing resources for executing the models are scattered, with computer architecture, system availability, and access varying from one location to another. Expert computing knowledge is required to install the models, expert geographic information knowledge is required to convert and properly align the input data, and expert tsunami knowledge is required to accurately interpret simulation results. The Tsunami Computational Portal provides a collaborative forum where these areas of expertise come together in support of tsunami research and mitigation.

The Tsunami Computational Portal will provide a unique forum to expedite the development of new and enhanced methods for predicting tsunamis and mitigating their effects. Using the portal, researchers and tsunami warning operations staff will be able to collaboratively execute and analyze model behavior, comparing them to the observed effects of past tsunamis. Researchers who have developed computational models "contribute" them to the portal, where they are fully documented and made available for peer review by other tsunami experts. Portal users can select individual models and apply them to a variety of "scenarios," or collections of geographical and infrastructure data that mimic a variety of real-world coastal settings. The models are maintained at a supercomputer center (where they are kept up-to-date by IT professionals) and are executed on behalf of portal users; after execution, users can view or download their results. Most importantly, users can compare the results of running different models on the same "scenarios" and can exchange comments about issues and recommendations with the rest of the tsunami research community. This collaborative process of review and analysis will improve both our understanding of tsunami dynamics and the accuracy of tsunami models.

Research accomplishments/highlights/findings

- Two major tsunami models (the UAF Tsunami model and the COMCOT from Cornell) were ported to Arctic Region Supercomputing Center (ARSC) supercomputers to execute correctly and efficiently.

- These models were analyzed to identify those input parameters common to both models and those parameters specific to each of the models. A parameter definition document was created to define each identified parameter and the models were modified to accept input data as defined in that document.
- An easily extensible geospatial database, including bathymetry data, the topography data, the time series and maximum sea level files was created and populated with data from the areas of Cook Inlet (Alaska).
- The system architecture for the portal was defined and work began on the web-based interfaces that make up the portal.
- Work on the portal was leveraged to allow UAF to create a global tsunami model to study the effects of the Sumatra tsunami that occurred in December 2004.

NOAA relevance/societal benefits

The work done on this project was leveraged to extend the UAF tsunami model to become the first global tsunami model to model the Indonesian tsunami that occurred in December 2004. This provided new insights into the mechanism of propagation on a global scale.

Research linkages/partnerships/collaborators and networking

This project is leading to better collaborations between the Arctic Region Supercomputing Center and the West Coast and Tsunami Warning Center in Anchorage. William R. Knight, Physical Scientist at the Warning Center is utilizing the computational resources at ARSC working on the project sponsored by Zygmunt Kowalik (see earlier report on TWEAK task 3.1), IMS/UAF.

Education/outreach

Web portal under development: http://tsunamiportal.nacse.org/wizard.php

K–12 outreach

Visualization of results from these models are used in the ARSC Discovery Laboratory to present science to school children of all grades throughout the state of Alaska, making them more aware of tsunamis and their impacts on the world.

TWEAK Element III: Tsunami Warning and Environmental Observatory for Alaska

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

NOAA Goals: Serve Society's Need for Weather and Water Information; Safe, Efficient and Environmentally Sound Transportation

CIFAR 06-028c: 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 Sensors *SeaSonde*) to map the surface velocity field at a resolution of ~3 km at 3 times/hour. The viewing field would cover approximately 80 km (subject to environmental constraints).

Research accomplishments/highlights/findings

- The HF Radar installation on Rugged Island and Middleton Island began in April 2005 when PI Dave Musgrave, technician Hank Statscewich and graduate student Jim Alanko traveled to Seward, Alaska. The Rugged Island research site installation and calibration of the HF radar equipment took from April 29 through May 8, 2005.
- On May 9, 2005, the three team members traveled to Middleton Island on a private charter and coordinated with Middleton Island FAA personnel to transport equipment from the runway to the proposed equipment

installation site approximately 2 miles away. The team spent the next three days installing and calibrating the equipment at this site.

- The HF Radar equipment at both sites operated from May 10, 2005 through May 28, 2005. Radial current vectors from each site produced during this three-week period were transferred in real-time to the University of Alaska Fairbanks. Upon reaching the UAF campus, the radial vectors were further processed into two-dimensional current vector maps (Figures 1 and 2).
- On May 28, 2005, a massive propane leak occurred at the Rugged Island site which caused a loss of all reserve propane fuel. Without fuel, the onsite generator could not run to charge up the onsite battery bank and the HF Radar equipment at the site was not operational. We were unable to immediately address the loss of the Rugged Island data stream because of prior field work commitments. On June 21, Hank Statscewich was able to travel to the Rugged Island site, where the propane leak was discovered. Because there were no leaks in the propane supply lines or generator fuel delivery system, we suspect an act of vandalism, where someone purposely opened the bleed valves on the propane bottles and let the 6-month supply of fuel escape into the air.
- In order to save the project from expensive vessel charters, an 18' Achilles inflatable boat, trailer and 50 HP motor were purchased on this grant. This vessel has made the round-trip travel to Rugged Island over 15 times and has essentially paid for itself in terms of saving the project charter expenses and more importantly allowing the team members the opportunity to travel to and from the site at their own schedule, an opportunity not afforded by the less expensive water-taxi services in the Seward area.

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. Although minimal salary support from the TWEAK project was used, funds provided from a NASA grant from the University of Massachusetts Dartmouth for $50,000 accounted for about half of the total amount spent for the Rugged and Middleton Island deployments.

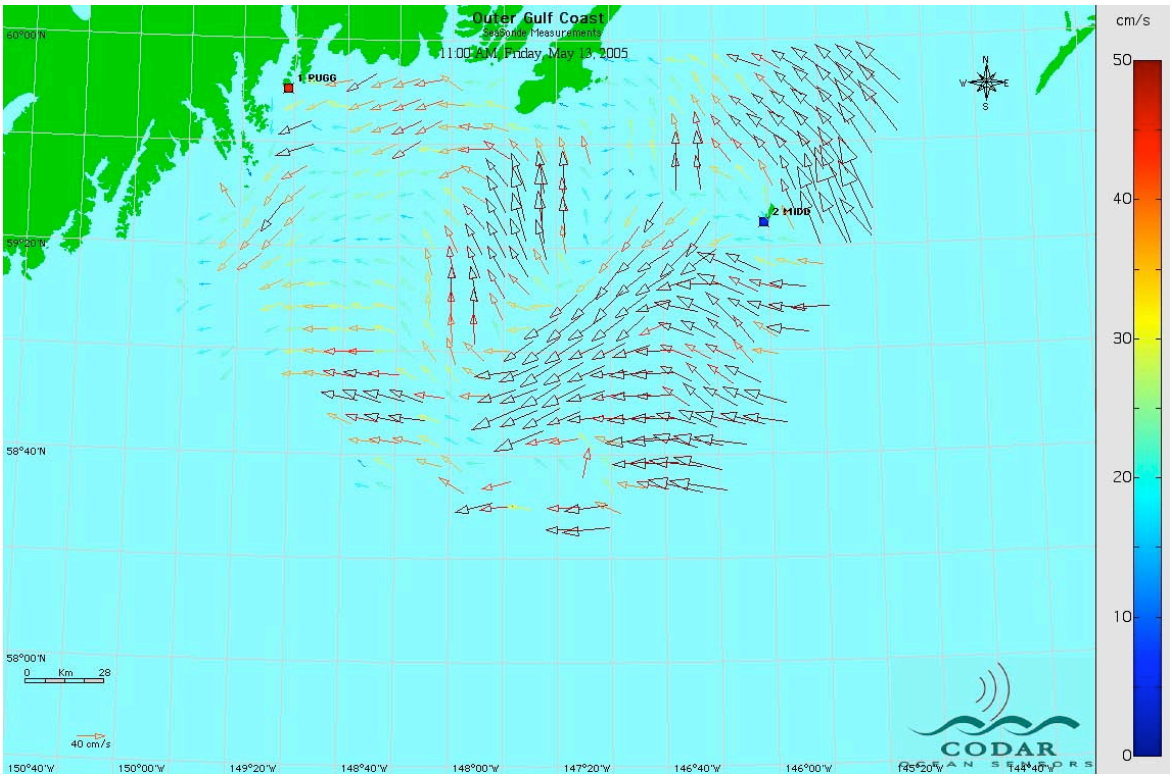


Figure 1. A two-dimensional current vector map collected at the start of the experiment.

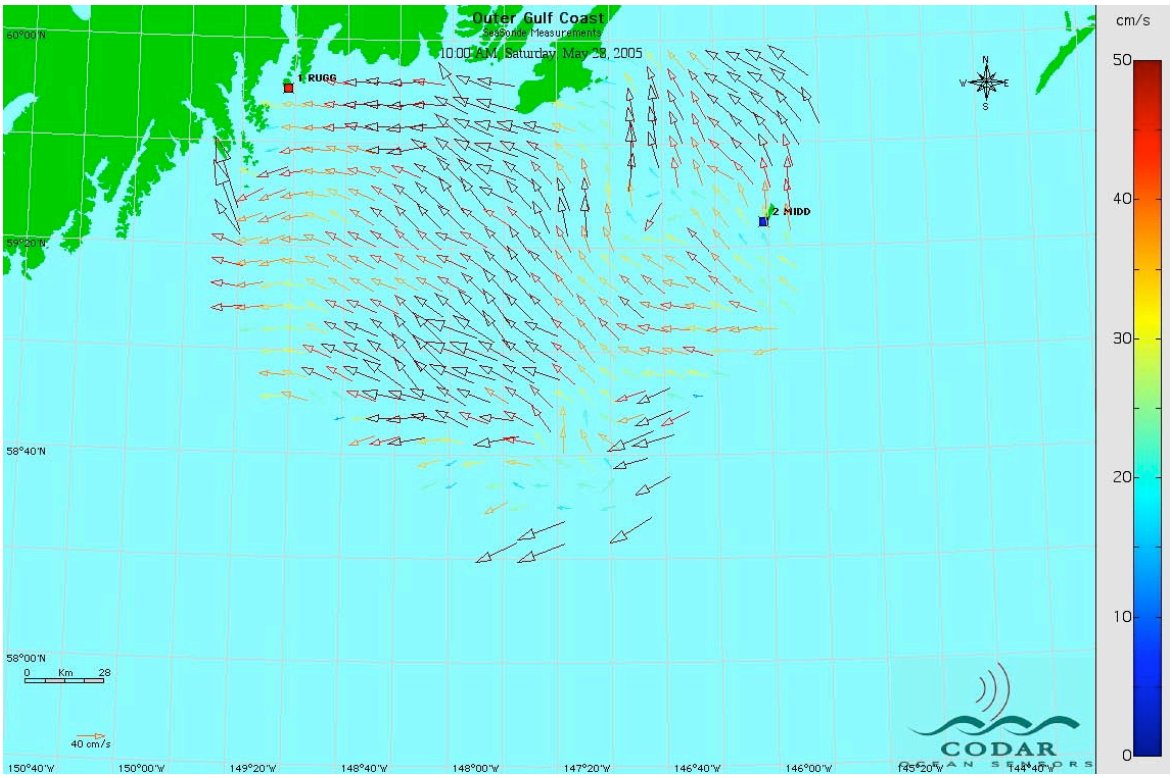


Figure 2. The last two-dimensional current vector map collected before the loss of propane at Rugged Island.

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: Understand Climate Variability and Change

CIFAR 10-059a: 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 three of four air sampling stations (Barrow, Denali Park and Poker Flat). The fourth sampling station on the Kenai Peninsula at Homer has had problems, first with lack of personnel to change the impactor sampler and second with the pump breaking and thirdly that the trailer facility which we are using is being abandoned by the Geophysical Institute's seismic group. To remedy these three problems, we are considering relocating this station to the Federal Building in Homer on Bishop's Beach, because the filters/impactor films are heavily impacted by fine grain loess that erodes away from the current cliff location. Though relocating the station in Homer, next to the shore, has some potential problems, namely from pollution from the small community, we think that this will be minor because the wind is predominantly from the west and south which brings air in from Kachemak Bay. Relocating has another advantage: the station will continually be within the marine boundary layer. The present sampling station is sometimes above the marine boundary layer in winter when the air mass around Homer becomes stable. Dr. Scott Pegau of NOAA Kachemak Bay Research Reserve has kindly offered to assist us in this project and has volunteered to change the impactor films on a weekly basis.
- We have recently moved highly specialized aerosol instruments to the Federal Building to help evaluate the new sampling site at Bishop's Beach. We are measuring the size distribution of the aerosols over the diameter range from 0.001 to 0.5 microns diameter with a Scanning Mobility Particle Sizer and automated Nolan Pollack counter loaned to us by Dr. John Gras in Australia. We are also measuring the aerosol optical scattering coefficient with a Weiss Nephelometer. These measurements should provide us with an idea of the strength and frequency of contamination that would affect this station and also provide some interesting information on the size and volume distribution of the aerosols we are sampling with our size-selective impactor system. It is believed that there is probably going to be an accumulation mode of aerosol, probably of diameter of a few tenths of a micron that is the major contributor to the fine stage of our chemical impactor.
- G. Shaw and P. Quinn have been working with the chemical data acquired in the network over the past two or three years. One goal is to prepare a paper that discusses the relative strength of chemical tracers at different seasons of the year and as a function of latitude. For example, we already are seeing evidence of a stronger sulfate component at Barrow than at Homer in spring during times of imported Arctic Haze. We are also seeing evidence of biologically produced sulfur from the marine system in summer, with the production being stronger in the Gulf of Alaska (and sampled by the Homer Station) than at the Barrow station. We see evidence of elevated potassium levels during times of wildfires, with the strongest signals at Poker Flat and Denali Park. Our goal is to combine all this data together, filter it and do interpretations. We have started this process and plan to submit publications on the interpretations in late 2005.
- We have had the opportunity to make a highly interesting comparison of data from two independent chemical data sources. During the years 2002 and 2003 air sampling systems operated by the Environmental Protection Agency (Clean Air Status and Trends Network, or CASTNET) were operated at Homer and at Poker Flat. These samplers are not impactors; they consist of filter packs and can collect information on gaseous components as well as particulate components, by using treated filters. However, the CASTNET stations also measure sulfate and nitrate and ammonium ion in parallel with the impactor samplers we run at the two stations on this project. It was therefore possible to intercompare the data. We are pleased to report that the intercomparison was excellent, for example the correlation between the sulfate concentration time series for two years was better than 95%. In this way, by using these parallel data sets, taken at slightly different locations on the sampling site, analyzed by different groups and with filters changed independently, we were able to verify that our lightly loaded, sensitive impactor films are evidently reporting good data and that contamination is not a problem. We were able to conclude this previously by taking and analyzing occasional blanks, but this direct comparison with independent data is a higher test of data quality.

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. Ms. Blakesley changes the impactor sampler once per week (all the stations impactor films are changed at the same time/date) and arranges for alternate personnel when she is on travel. She has been a loyal, long-term participant in this project and has always taken a high and active interest in the project and insures the highest quality of standards for this sampling program. She is donating approximately two hours per week to this project.
- Dr. Scott Pegau of the Kachemak Bay Research Reserve and NOAA operates the sampling station at Homer. Dr. Pegau has taken a great interest in the project and drives to the sampling location every week to change filters. Since early July, 2005, we have installed additional aerosol equipment to derive the aerosol size distribution spectrum and the optical scattering coefficient. Dr. Pegau is operating the equipment and is active in helping us locate an alternate sampling location for the southern station in the Gulf of Alaska. He is donating several hours a week to this project.
- Dr. John Ray of the National Park Service has helped maintain a meteorological system at the Poker Flat Research Station. The system is now permanently loaned to the University of Alaska and personnel at the Poker Flat Research range maintain this meteorological equipment that records wind direction and speed, temperature and temperature vertical gradient, solar radiation and humidity every 5 minutes.
- Mr. Brian Lawson from the office of Poker Flat Research Range is hired to change the impactor films every week. He has done a thorough and excellent job, spending about two hours per week on the project.

Education/outreach

A number of scientists and students have visited the air sampling site at Poker Flat in the past year.
Dr. Scott Pegau proposes to use our aerosol sampling instruments as demonstrations to public teaching programs carried out at the Kachemak Bay Research facility.

Publications

We anticipate submitting a peer-reviewed paper analyzing the chemical data from the four stations by the end of summer, 2005.
A publication summarizing trends and chemical signatures is under preparation.

Appendices 1–3

1. Projects Awarded 1 July 2004–30 June 2005

2. Personnel

3. Publication Activity

Appendix 1
CIFAR Projects Awarded in Cooperative Agreement NA17RJ1224
Year 4: 1 July 2004—30 June 2005

Last	First	Proposal Title	Proposal Budget	Sub F&A	Total Award	Task	Theme Description	Funding Source
Amendment 10								
Walsh	**John**	CIFAR Task I: Administration (Year 4)	$ 100,000	n/a	$ 100,000	I	Administration	OAR
Walsh	**John**	CIFAR Task I: Administration Supplement	$ 10,000	n/a	$ 10,000	I	Administration	OAR
Walsh	**John**	Arctic Climate Impact Assessment (ACIA): ACIA Secretariat Request for Additional Task I Support	$ 22,000	n/a	$ 22,000	I	Administration	OAR
Walsh	**John**	TASK I Administration - F&A rate change from 50.4% to 47.5% - expanded authority used to redirect (subawards only)	$ 1,450	n/a	$ 1,450	I	Administration	OAR
Cahill	**Cathy**	Atmospheric Aerosols over the Bering & Chukchi Seas	$ 24,405	n/a	$ 24,405	II	Contaminant Effects	OAR
Grebmeier	**Jackie**	Benthic Processes and Ecosystem Change in the Northern Bering and Chukchi Seas	$ 62,259	$ 11,875	$ 74,134	II	Marine Ecosystems	OAR
Hopcroft	**Russell**	A Census of Arctic Zooplankton Communities	$ 74,999	n/a	$ 74,999	II	Marine Ecosystems	OAR
Iken	**Katrin**	Arctic Epibenthic Community Structure and Benthic Food Web Structure	$ 61,637	n/a	$ 61,637	II	Marine Ecosystems	OAR
Norcross	**Brenda**	Fisheries Ecology of the Bering and Chukchi Sea	$ 74,448	n/a	$ 74,448	II	Fisheries Oceanography	OAR
Weingartner	**Thomas**	Bering Strait: The Pacific-Arctic Ocean Connection	$ 91,266	n/a	$ 91,266	II	Hydrographic & Sea Ice Studies	OAR
Whitledge	**Terry**	Interactions of Productivity and Nutrient Processes in the Northern Bering and Chukchi Seas	$ 74,844	n/a	$ 74,844	II	Marine Ecosystems	OAR
Adkison	**Milo**	Early Marine Growth and Survival of Bristol Bay Sockeye Salmon Smolt	$ 10,563	n/a	$ 10,563	III	Fisheries Oceanography	NMFS
Adkison	**Milo**	Relationship Between Growth and Survival of Coho Salmon Utilizing the Coastal Gulf of Alaska	$ 39,338	n/a	$ 39,338	III	Fisheries Oceanography	NMFS
Gharrett	**A.J.**	Species Composition and Spatial Distribution of GOA and BS Young-of-the-Year Rockfish Species. Phase II	$ 59,999	n/a	$ 59,999	III	Fisheries Oceanography	NMFS
Hansen	**Roger**	CREST CIFAR-Alaska Earthquake Information Center Seismic Station Upgrade and Installation	$ 268,204	n/a	$ 268,204	III	Tsunami Research	OAR
Hansen	**Roger**	RUNUP-CIFAR Alaska Tsunami Inundation Mapping Project	$ 224,000	n/a	$ 224,000	III	Tsunami Research	OAR
Hansen	**Roger**	Tsunami Warning and Environmental Observatory for Alaska - Year 3	$ 1,979,000	n/a	$ 1,979,000	III	Tsunami Research	NWS

updated: 9/19/2005

Last	First	Proposal Title	Proposal Budget	Sub F&A	Total Award	Task	Theme Description	Funding Source
Hillgruber	**Nicola**	Energy, Diet, and Condition of Juvenile Pink Salmon, Oncorhynchus gorbuscha, in the Gulf of Alaska	$ 7,555	n/a	$ 7,555	III	Fisheries Oceanography	NMFS
Melling	**Humfrey**	Monitoring Sea Ice Thickness in the Arctic Ocean Using Seafloor-Moored Ice Profiling Sonar	$ 62,400	$ 11,875	$ 74,275	III	Hydrographic & Sea Ice Studies	OAR
Naidu	**A. Sathy**	Grain Size Distributions, and Concentrations and Stable Isotope Ratios of Organic Carbon and Nitrogen in Marine Sediments near the Islands of Four Mountains, Aleutian Chain, Southeastern Bering Sea	$ 24,487	n/a	$ 24,487	III	Fisheries Oceanography	NMFS
Norcross	**Brenda**	Reproduction Potential of Pacific Cod	$ 52,310	n/a	$ 52,310	III	Fisheries Oceanography	NMFS
Quinn II	**Terrance**	University of Alaska Fairbanks Graduate Student Stipend for Stock Assessment Training and Improvement	$ 46,500	n/a	$ 46,500	III	Fisheries Oceanography	NMFS
Reiersen	**Lars-Otto**	Arctic Monitoring and Assessment Programme (AMAP)	$ 58,000	n/a	$ 58,000	III	Contaminant Effects	OAR
Reynolds	**Jennifer**	Habitat Analysis of Major Fishing Grounds on the Kodiak Shelf, Alaska	$ 77,001	n/a	$ 77,001	III	Fisheries Oceanography	NMFS
Reynolds	**Jennifer**	Bogoslof Island Mapping for Invertebrate Colonization Study	$ 16,359	n/a	$ 16,359	III	Marine Ecosystems	NMFS
Shaw	**Glenn**	NETWORK Long-Term Trends & Spatial Variability in Arctic Haze at Four Sites in Western Alaska	$ 10,000	n/a	$ 10,000	III	UV and Arctic Haze	OAR
Weingartner	**Thomas**	ALPHA HELIX for GLOBEC	$ 314,500	n/a	$ 314,500	III	Fisheries Oceanography	NOS
Whitledge	**Terry**	GLOBEC-NEP: Topographic Control of Mesoscale Variability in the Gulf of Alaska	$ 124,353	n/a	$ 124,353	III	Fisheries Oceanography	NOS
			$ 3,971,877	$ 23,750	$ 3,995,627			

updated: 9/19/2005

Appendix 2. Summary of CIFAR-funded Personnel

Category	Number	B.S.	M.S.	Ph.D.
Research Scientist	3		2	1
Visiting Scientist				
Postdoctoral Fellow	1			1
Research Support Staff				
Administrative	2	2		
Total (≥ 50% NOAA Support)	**6**			
Undergraduate Students	9			
Graduate Students	24	11	13	
Total Students	**33**			
Employees (< 50% NOAA Support)	73	11	10	52
Located in NOAA Lab	10	ABL (2)	ABL(5), AFSC (3)	
Obtained NOAA employment within last year	2			2

Appendix 3. Publication Activity

Work from projects funded under the current cooperative agreement (NA17RJ1224) that was published, accepted, or in press during the reporting period (or published during previous reporting periods but not reported earlier).

Berman, M. Modeling effects of habitat closures in ocean fisheries. In: *Proceedings of the North American Association of Fisheries Economists (NAAFE) Forum 2005: Fisheries Benefits for All Generations*, Vancouver, BC, in press. (To be submitted to a special issue of Marine Resource Economics, August 2005.)

Briscoe, R.J. 2004. Factors Affecting Growth and Survival of Auke Creek, Alaska Coho Salmon (*Oncorhynchus kisutch*). M.S. thesis, University of Alaska Fairbanks, 57 pp.

Briscoe, R.J., M.D. Adkison, A. Wertheimer and S.G. Taylor. 2005. Biophysical factors associated with the marine survival of Auke Creek, Alaska coho salmon. *Transactions of the American Fisheries Society*, in press.

Bromwich, D.H. and R.L. Fogt. 2005. Strong trends in the skill of the ERA-40 and NCEP/NCAR reanalyses in the high and middle latitudes of the Southern Hemisphere, 1958–2001. *Preprints, Eighth Conference on Polar Meteorology and Oceanography*, San Diego, California, 9–13 January 2005, American Meteorological Society, CD-ROM.

Burns, J.M., C.A. Clark and J.P. Richmond. 2004. The impact of lactation strategy on physiological development of juvenile marine mammals: Implications for the transition to independent foraging. *Comparative Physiology and Biochemistry, International Congress Series*, 1275:341–350.

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Dreger, D., D.D. Oglesby, R. Harris, N. Ratchkovski and R. Hansen. 2004. Kinematic and dynamic rupture models of the November 3, 2002 Mw 7.9 Denali, Alaska, earthquake. *Geophysical Research Letters*, 31:L04605, doi:10.1029/2003GL018333.

Fan, X. and J.S. Tilley. Dynamic assimilation of MODIS-retrieved humidity profiles within a regional model for high latitude forecast applications. *Monthly Weather Review*, conditionally accepted after minor revisions.

Fan, X., J.S. Tilley and J.E. Walsh. 2004. Application of MM5/3DVAR at high latitude: Resolution sensitivity. *Preprints, Fifth WRF/14th MM5 User's Workshop*, NCAR, 22–25 June 2004, Boulder, Colorado, 5.10.

Fan, X., J.R. Krieger, X. Meng, R.W. Smith and J.E. Walsh. 2005. Assimilation of MODIS retrievals with the MM5/3DVAR system in an Arctic extreme rain event. *Preprints, Eighth Conference on Polar Meteorology and Oceanography*, AMS, San Diego, California, 9–13 January 2005, P3.19.

Francis, J.A., E. Hunter and C.-Z. Zou. Arctic tropospheric winds derived from TOVS satellite retrievals. *Journal of Climate*, in press.

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(See next page for summary table.)

Summary table of publications during the current cooperative agreement (projects funded under NA17RJ1224).

	JI (subgrantee) lead				NOAA lead				Other lead			
	FY02	FY03	FY04	FY05	FY02	FY03	FY04	FY05	FY02	FY03	FY04	FY05
P-R	0	9	10	12	0	0	0	0	0	4	4	3
N-P-R	0	1	13	12	1	0	1	1	0	1	0	0