A HISTORIC PARTNERSHIP BETWEEN
THE NORTH PACIFIC RESEARCH BOARD AND
THE NATIONAL SCIENCE FOUNDATION

BEST-BSIERP Bering Sea PROJECT

Climate change and reduced ice cover significantly impact the Bering Sea ecosystem. We seek to understand the mechanisms that create and sustain this highly productive region, and how they may be altered over time.








UNDERSTANDING ECOSYSTEM PROCESSES IN THE BERING SEA 2007–2012

bsierp.nprb.org • January 2010

BERING ECOSYSTEM STUDY

BERING SEA INTEGRATED ECOSYSTEM RESEARCH PROGRAM

The North Pacific Research Board and the National Science Foundation are supporting a comprehensive, $52 million study of the eastern Bering Sea ecosystem from 2007–2012. More than one hundred federal, state, university, and private institution scientists are studying a range of issues in the Bering Sea—from atmospheric forcing and physical oceanography to humans and communities—including the attendant economic and social impacts of a changing ecosystem.

The scientific foundations for this large, innovative program are the National Science Foundation's 2005 Bering Ecosystem Study (BEST) Program Implementation Plan and the North Pacific Research Board's Bering Sea Integrated Ecosystem Research Program (BSIERP), which is based on NPRB's 2005 Science Plan. This foundation supports research to improve understanding of how the Bering Sea may respond to climate change, particularly as mediated through changes in seasonal sea ice cover.

Work supported by the National Science Foundation (NSF)

- **Climate, oceanography, and lower trophic levels:** Benthos, primary production near sea ice, nutrients, modeling, meso-zooplankton, micro-zooplankton, euphausiids, biophysical moorings, and physical oceanography
- **Social science research:** Relationships between a changing marine environment and Bering Sea communities

Work supported by the North Pacific Research Board (NPRB)

- **Climate, oceanography, and lower trophic levels:** Benthos, micro-zooplankton, biophysical moorings, and physical oceanography
- **Forage species:** Euphausiids, myctophids, and capelin
- **Fish:** Arrowtooth flounder, Pacific cod, and walleye pollock
- **Marine mammals:** Fur seals, walrus, and broad-scale whale distribution
- **Seabirds:** Thick-billed murres, black-legged kittiwakes, and broad-scale seabird distribution
- **Local and traditional knowledge (LTK):** Subsistence harvest and LTK ecosystem perspectives
- **Education, outreach, and communication**

Work supported by NSF and NPRB

- **Ecosystem modeling**
- **Data management**


Eli Gurarie


Todd Warshaw


Carrie Eischens


Tom Van Pelt

Why

Why Study the Bering Sea?

Alaska's Bering Sea fisheries provide nearly half of the seafood consumed in the U.S., forming a powerful economic engine for fishing communities and the core of an ocean-based subsistence lifestyle.

Whales, seals, and seabirds travel from afar to feed and mate here. Fur seals breed on island rookeries, while walrus haul out on sea ice to bear young. Whales and porpoises feast on huge schools of smaller fishes and tiny planktonic crustaceans. Orcas hunt other whales, seals, or salmon. Sea otters forage in kelp forests, plucking invertebrates from the seafloor.

Nearly half of Alaska's seabirds live in ten colonies in the Bering Sea. Some 36 million seabirds breed here, including shearwaters, fulmars, kittiwakes, albatrosses, storm-petrels, puffins, and murres.

Climate change and reduced ice cover could significantly impact the Bering Sea ecosystem. We seek to understand the mechanisms that create and sustain this highly productive ecosystem, and how they may be altered over time as our climate changes.

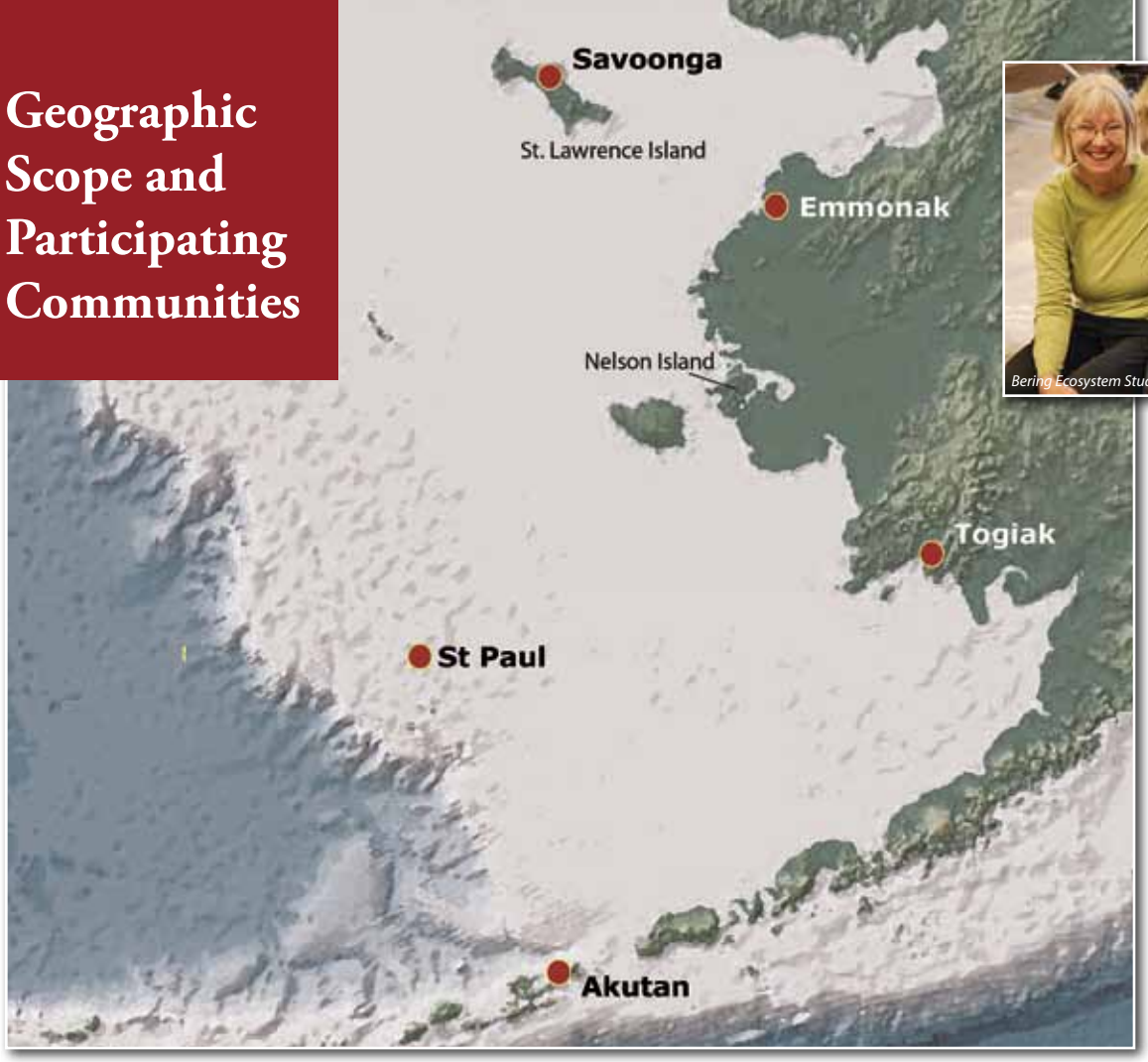
Background: Mark Rauzon / NPRB

John Piatt

Russ Hopcroft

Alaska Ocean Observing System / NOAA

Geographic Scope and Participating Communities




Bering Ecosystem Study

Research is taking place on the eastern Bering Sea shelf between the Aleutian Islands and St. Lawrence Island. Communities participating in this study are Savoonga, Emmonak, Togiak, St. Paul, and Akutan, as well as several communities in the Nelson Island area. All have a history of research on local and traditional knowledge and/or subsistence harvest surveys, which will provide useful information and a basis for identifying long-term trends and changes.

Local and traditional knowledge (LTK) involves information, understanding, and wisdom accumulated over time based on experience and often shared within a group. This knowledge forms the basis for people's beliefs and practices concerning their environment. In the Bering Sea, indigenous communities have thrived since time immemorial, based in large part on understanding where to find and how to use the resources provided by the ecosystem. Particularly for a region such as this, where scientific research is comparatively recent and access for such study is often difficult and expensive, LTK offers a substantial contribution to collective understanding of the ecosystem, its changes, and the implications for people and their environment.

Michael Downs

Jennifer Sepez

LEARNING ABOUT CHANGES

In these communities, the LTK component is documenting existing knowledge, fostering collaborative analysis, generating research hypotheses, collaborating with other projects in the program, and recording observations.

This project examines all animal species harvested by residents of the partner communities. In particular, this focus is on species that are significant subsistence resources (nutritionally, culturally, or otherwise) and that are also focal species for other program components. For example, we plan to examine the cultural and subsistence practices regarding walrus in Savoonga, fur seals in St. Paul, and seabirds in all communities, as well as other species or environmental parameters identified through discussion with other program researchers.


Aleut Native Community of St. Paul


Astrid Scholz


Bering Ecosystem Study

Community and Regional Advisory Boards

In each community, local research coordinators are assisting in studies on recent changes in subsistence, and on understanding traditional knowledge of elders and experienced hunters about environment and species, such as marine mammals and birds. Community advisory boards work closely with a regional advisory board for the project to help guide LTK research.


Deborah Mercy/UAF MAP


Deborah Mercy/UAF Marine Advisory Program

Savoonga (St. Lawrence Island)
Population: 786; Language/culture group: St. Lawrence Island Yup'ik

Emmonak (Yukon-Kuskokwim Delta)
Population: 900
Language/culture group: Central Yup'ik

Togiak (Bristol Bay)
Population: 987
Language/culture group: Central Yup'ik

St. Paul (Pribilof Islands)
Population: 470
Language/culture group: Unangan (Aleut)

Akutan (Aleutians)
Population: 80; Language/culture group: Unangan (Aleut)

Nelson Island (Yukon-Kuskokwim Delta)
Population 1,065 (total of Nightmute, Toksook Bay, and Tununak);
Language/culture group: Central Yup'ik

Focal Areas of Research

We are studying the Bering Sea ecosystem from atmospheric forcing and physical oceanography to humans and communities, as well as the socio-economic impacts of a changing marine ecosystem. Innovative ecosystem modeling, sound data management, and exciting education and outreach activities will unite the program.

Contribution to fisheries management

We hypothesize that changing climate-ocean conditions will affect the abundance and distribution of commercially important fish, and thus impact the fisheries that depend upon them. For commercial fishermen, this could lead to a change in home ports. Vessels may also have to travel further, incurring greater fuel costs and peril at sea.

Our goal is to provide a better understanding of how fish abundance and distribution will change. Such knowledge should enable commercial fishermen to more successfully prepare for and adapt to anticipated changes with minimal income loss, and ensure continued safety at sea.

Humans

- Interview community residents to conceptualize ecosystem in Native Alaskan terms
- Study subsistence and use patterns

Investigators: Jim Fall, Ann Fienup-Riordan, Eugene Hunn, Henry Huntington, Mark John, Sarah Kruse, George Noongwook, Astrid Scholz, Jennifer Sepez, Josh Wisniewski, Phil Zavadil

Marine Mammals

- Broad-scale visual surveys
- Patch Dynamics: Foraging studies of fur seals, walrus, and their prey
- Retrospective analyses

Investigators: Phil Clapham, Nancy Friday, Chad Jay, Sue Moore, Franz Mueter, Andrew Trites, Alex Zerbini

Seabirds

- Broad-scale visual surveys
- Patch Dynamics: Foraging studies of thick-billed murres, black-legged kittiwakes, and their prey
- Chick diet and condition studies
- Retrospective analyses

Investigators: Vernon Byrd, David Irons, Sasha Kitaysky, Kathy Kuletz, Franz Mueter, Heather Renner, Daniel Roby

Fishes, Forage Species, and Trophic Interactions

- Acoustic surveys
- Fish stomach analysis
- Surface and bottom trawl surveys
- Forage species and trophic interactions
- Retrospective analysis of pollock, seabird, and fur seal productivity
- Persistence of foraging "hotspots"
- Seasonal bioenergetics

Kerim Aydin, Kevin Bailey, Kelly Benoit-Bird, Steve Barbeaux, Lorenzo Ciannelli, Ned Cokelet, Alex DeRobertis, Scott Heppell, Anne Hollowed, John Horne, Ed Farley, Stan Kotwicki, Gordon Kruse, Kathy Kuletz, Robert Lauth, Franz Mueter, Sandra Parker-Stetter, Patrick Ressler, Mike Sigler, Phyllis Stabeno, Chris Wilson

Benthos and NPZ*

*nutrients-phytoplankton-zooplankton

- Benthic studies
- Ichthyoplankton (larval fish)
- Energetics of juvenile fish
- Nutrients
- Micro- and meso-zooplankton; euphausiids
- Primary production
- Sea ice studies

Investigators: Carin Ashjian, Robert Campbell, Lee Cooper, Ken Coyle, Allan Devol, Janet Duffy-Anderson, Ted Durbin, Lisa Eisner, Rolf Gradinger, Jackie Grebmeier, Ron Heintz, Rodger Harvey, Nicola Hillgruber, Tom Hurst, Ben Laurel, Evelyn Lessard, Michael Lomas, Ann Matarese, Brad Moran, Jeff Napp, Alexei Pinchuk, Ray Sambrotto, Barry Sherr, Evelyn Sherr, David Shull, Dan Sigman, Rolf Sonnerup, Dean Stockwell, Diane Stoecker, Terry Whitledge

Atmosphere, Ice, and Ocean

- Year-round biophysical oceanographic moorings
- Sea ice studies
- Stratification and circulation
- Spring and summer ocean conditions
- Retrospective analyses of sea ice and ocean processes

Investigators: Knut Aagaard, Carin Ashjian, Bodil Bluhm, Robert Campbell, Rolf Gradinger, Katrin Iken, Calvin Mordy, Jeff Napp, Jim Overland, Barry Sherr, Evelyn Sherr, Rolf Sonnerup, Phyllis Stabeno, Dean Stockwell, Tom Weingartner, Terry Whitledge, Rebecca Woodgate, Jingfeng Wu, Jinlun Zhang

Ecosystem Modeling

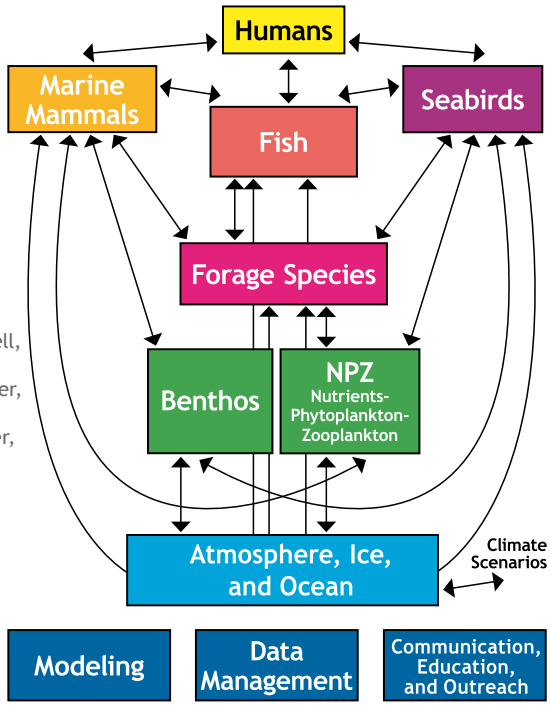
Investigators: Kerim Aydin, Nicholas Bond, Enrique Curchitser, Michael Dalton, Georgina Gibson, Alan Haynie, Kate Hedström, Albert Hermann, Jim Ianelli, Gordon Kruse, Marc Mangel, Franz Mueter, Andre Punt, Mike Sigler, Rebecca Woodgate, Jinlun Zhang

Data Management

Investigators: Ken Coyle, James Moore, Gregory Stossmeister, Steve Williams

Communication, Education, and Outreach

Investigator: Nora Deans



What is patch dynamics?

We will use fine-scale studies of birds, mammals, and their forage base to determine how spatial patterns (patches) affect interactions of predators and prey.

We seek to learn what controls the abundance, distribution and population trends of some of the Bering Sea's top predators, and to provide models with data to predict how and why these species will respond to environmental changes.

What are forage species?

"Forage" species form the middle of the food web and include fishes and invertebrates such as capelin *(Mallotus villosus)*, euphausiids (krill), eulachon *(Thaleichthys pacificus)*, Pacific sand lance *(Ammodytes hexapterus)*, and juvenile Pacific herring *(Clupea pallasii)*, salmon *(Onchorhynchus* sp.*)*, and walleye pollock *(Theragra chalcogramma)*.

Forage species are distinguished by schooling behavior, relatively short life spans, and local abundance. They are both prey for larger fish and marine mammals, as well as predators of ichthyoplankton (larval fish) and zooplankton.

Photos, left to right: Rolf Gradinger coring ice (Christian Morel); pollock (NPRB); Francis Wiese, Vernon Byrd, and Mike Sigler in fog (Nikolai Konyukhov); Sue Moore listening (Andrew Trites); fur seals (Carrie Eischens); Alexei Pinchuk with zooplankton sample (Tom Van Pelt); black-legged kittiwake (Carrie Eischens).

Modeling and Data Management

Ecosystem modeling will link climate, physical oceanography, lower and upper trophic levels, and economic outcomes, and attempt to predict the impacts of climatic change on the Bering Sea ecosystem.

The goal of ecosystem modeling is to improve our ability to predict the production and spatial distributions of lower trophic level and forage species, fishes, seabirds, and marine mammals, as well as local impacts on communities and the economy.

Vertically linked models allow two-way coupling between ecosystem components and allow forecasts of economic effects for fisheries contingent on climate scenarios (e.g., increased operating costs for pollock vessels due to ocean warming effects on the southeast Bering Sea pollock population). Models also allow the depiction of uncertainty in forecasts. Rigorous model validation, continuous full-model feedbacks, and a variety of model comparisons will help ensure reality-based results.

DATA MANAGEMENT, SECURE DELIVERY, AND STORAGE

Management of large and diverse datasets generated by investigators from multiple institutions and backgrounds poses huge challenges for large research projects.

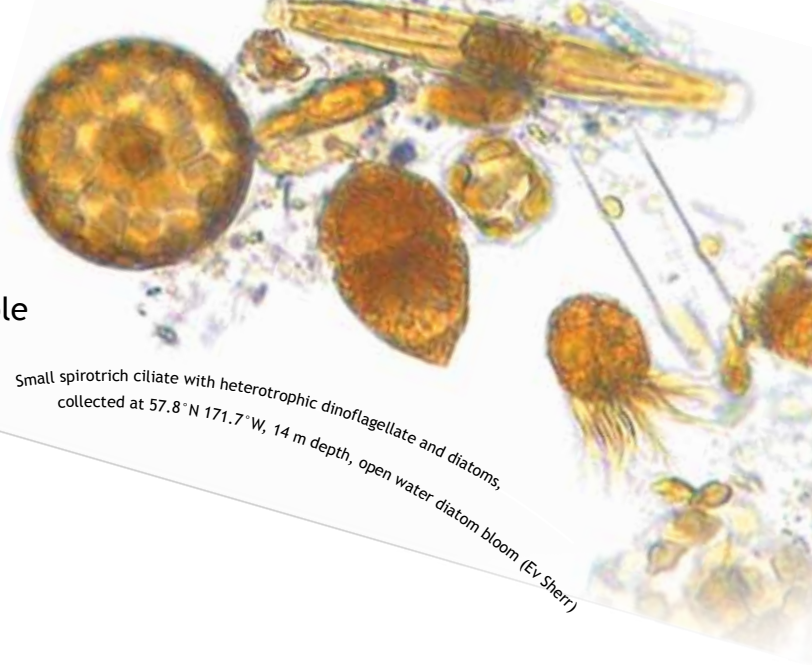
The vision of this data management program is to ensure consistency of data access, data retention, awareness by researchers of data availability, secure access and analysis platforms, and short delays between data acquisition and dissemination.

Data managers will provide tools and security for data perusal, access and documentation of project activities. Tools include the Earth Observing Laboratory data and metadata archival and distribution system, an online field catalog aboard the USCGC *Healy,* and a GIS mapserver application to provide an interactive map with links to data and other information.

Managers will also collect preliminary and final datasets from investigators for interim archival, with final datasets and metadata staged to a long-term archive center; and collect and archive supplementary data from other shipboard instruments.

Photos, top to bottom: Sun supercomputer "Midnight", Arctic Region Supercomputing Center; Georgina Gibson and Kate Hedström, Rachel Potter; St. Paul coastline, Sarah Kruse.

Program Management



Small spirotrich ciliate with heterotrophic dinoflagellate and diatoms, collected at 57.8°N 171.7°W, 14 m depth, open water diatom bloom (Ev Sherr)

The Bering Sea Project program office is responsible for program coordination and communication, website development, and meeting planning.

Science Advisory Board

The Science Advisory Board meets regularly and provides scientific leadership, encouragement, and oversight in program integration, data exchange, and synthesis. It also provides scientific input to the respective program offices and helps with dispute resolution. This group is composed of six members, three each from BSIERP and BEST, elected by the respective principal investigators.

Current members

- Jeff Napp (BSIERP)
- Mike Lomas (BEST)
- Phyllis Stabeno (BSIERP)
- Carin Ashjian (BEST)
- Rodger Harvey (co-chair, BEST)
- Mike Sigler (co-chair, BSIERP)

Principal investigator meetings

Annual principal investigator meetings allow investigators to share results; plan cruises, community visits, and other fieldwork. The meetings also allow investigators to make small adjustments to methods and schedules, and provide everyone with a "big-picture" look at the progress and integration of the program.

In addition, BSIERP and BEST lead investigators meet monthly via teleconferences to communicate the progress of each project and to highlight recent results.

Left: Principal investigators and program managers gather at the 2008 Annual Meeting in Girdwood (Tom Van Pelt).

Program organization

Background: Deborah Mercy / UAF Marine Advisory Program

Scientific Cruises

Many collaborative research cruises to the eastern Bering Sea are planned during the course of the program. Offshore travel in the Bering Sea and Aleutian Islands regions is a tremendously expensive logistical effort. The areas of interest are remote, and storms, winds and large waves make for challenging working conditions. Sea ice, present in winter and early spring, calms the waves, but presents its own challenges for research operations.


Tom Van Pelt

Oceangoing vessels must be large and sturdy enough to withstand tempestuous seas and sea ice. The U.S. Coast Guard icebreaker *Healy* is instrumental in this research. Designed to conduct a wide range of research activities in the unforgiving conditions of Arctic waters, she can break 4½ feet of ice continuously at a speed of three knots and can operate in temperatures as low as -50˚F.

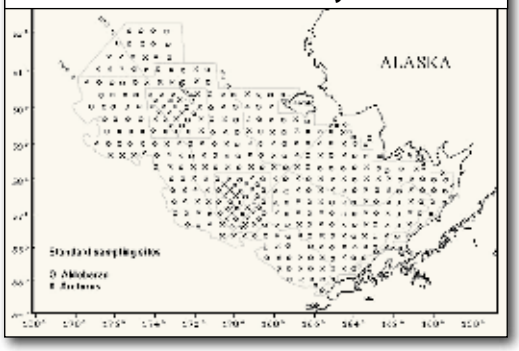
Other vessels, such as NOAA's *Oscar Dyson* and *Miller Freeman,* the USFWS *Tiĝlax̂*, and chartered fishing boats such as the *Frosti* and the *Aldebaran* are also being deployed to conduct oceanic work.


Jillian Worssam/ PolarTREC

Surface trawl survey area

Objective: To monitor the condition of eastern Bering Sea continental shelf fishes living in the top layers of the ocean.

Bottom trawl survey area

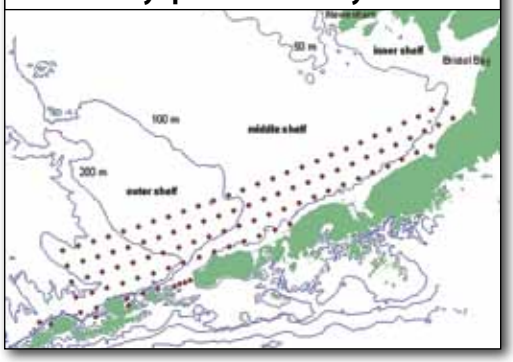


Objective: To monitor the condition of the eastern Bering Sea continental shelf fauna immediately above the seafloor.

Acoustic-midwater trawl survey area

Objective: To identify processes influencing the distribution of forage fish, their predators, and competitors relative to ocean habitat conditions; and to evaluate how climate change may impact forage fish movement and seasonal distribution.

Ichthyoplankton survey area



Objective: To examine interactions among climate, weather, and the recruitment of fishes in the eastern Bering Sea by describing larval fish assemblages and determining how physical and biological factors affect transport and survival of fish larvae.

SEASONAL RESEARCH CRUISES, 2008-2010

Vessel	Scientific Survey / Fishing
F/V *Aldebaran*[1]	Winter Pollock A season fishing
NOAA R/V *Miller Freeman*	Winter climate-modulated fishery recruitment cruise (winter ichthyoplankton survey)
USCGC *Healy*, USCGC *Polar Sea*	Spring cruise concentrating on benthic studies south of St. Lawrence Island and walrus tagging and tracking
USCGC *Healy*, R/V *Thompson*	Spring cruise measuring ocean conditions and food web productivity on eastern Bering Sea shelf
NOAA R/V *Oscar Dyson*	Spring climate-modulated fishery recruitment cruise (spring ichthyoplankton survey)
F/V *Arcturus*[1], F/V *Aldebaran*[1]	Spring-summer Eastern Bering Sea crab and groundfish survey (bottom trawl survey)
NOAA R/V *Oscar Dyson*	Spring-summer NOAA acoustic survey in eastern Bering Sea
M/V *Tiĝlax̂*[1]	Bogoslof Island seabird and fur seal summer fieldwork support
USCGC *Healy*, R/V *Thompson*, R/V *Knorr*	Summer cruise measuring productivity on eastern Bering Sea shelf
F/V *Frosti*[1]	Summer cruise examining the distribution and composition of forage fish patches around the Pribilof Islands
NOAA R/V *Melville*, NOAA R/V *Miller Freeman*	NOAA EcoFOCI fall hydrography and plankton survey
F/V *Sea Storm*[1] NOAA R/V *Oscar Dyson*	Fall NOAA surface trawl survey (BASIS)
NOAA R/V *Miller Freeman*	NOAA EcoFOCI fall ichthyoplankton and juvenile fish survey

[1]or equivalent contract vessel
*See the most current cruise calendar at **bsierp.nprb.org.**

Background: Nora Deans

Typical Bering Sea Cruise Track of the USCGC *Healy*

Background: Carin Ashjian

Education, Outreach, and Communication

Education, outreach, and communication strategies for the Bering Sea project focus on sharing information with diverse regional and national audiences about how scientists and local communities are learning about changes in the vital Bering Sea ecosystem.

Communicating about science

The multi-layered website (left) changes with each new report from the field. Chief scientists, PolarTREC educators-at-sea, radio journalists and NPRB staff all help to tell the story of this innovative field science and ecosystem modeling partnership through blogs, photographs and cruise reports.

Researchers give community presentations, radio interviews, participate in "webinars" with college and elementary classes from ships far out in the ice, and later send in maps that show where tagged walrus, fur seals and kittiwakes go in search of food.

PolarTREC teacher Craig Kasemodel (above right) gave students and teachers across the country a glimpse of his experiences helping researchers aboard the icebreaker Healy.

Bering Sea in schools

Middle school teachers updating the Alaska's Seas and Rivers curriculum are incorporating aspects of the Bering Sea Project into their case studies, which are featured online at **seagrant.uaf.edu/marine-ed/curriculum/.**

Broadening our reach

Researchers and program staff use posters, brochures, and other media to share overviews of program activities with colleagues at conferences and in communities.

Carrie Eischens

Background: Carrie Eischens

Nora Deans

Carrie Eischens

Radio journalist Elizabeth Arnold records sounds of fur seals on St. Paul Island (this page) and waits with field biologist Alexis Will for tagged thick-billed murres to return to the colony (far left).

Principal Investigators

This research would not be possible without the efforts of more than 100 principal investigators from the U.S. and Canada, most of whom are pictured here.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NOAA


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NOAA


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Alex Zerbini
NOAA

Jinlun Zhang
Univ of Washington

We also want to acknowledge the host of several hundred collaborators, postdocs, graduate students, research assistants, lab technicians, programmers, field and ship crews, and others who are working year-round to move this ambitious project forward.

No photos available for Rolf Sonnerup (UW), Greg Stossmeister (NCAR)

Phytoplankton (segmented) and microzooplankton (round) (Diane Stoecker)

BERING SEA INTEGRATED ECOSYSTEM RESEARCH PROGRAM

BERING ECOSYSTEM STUDY

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