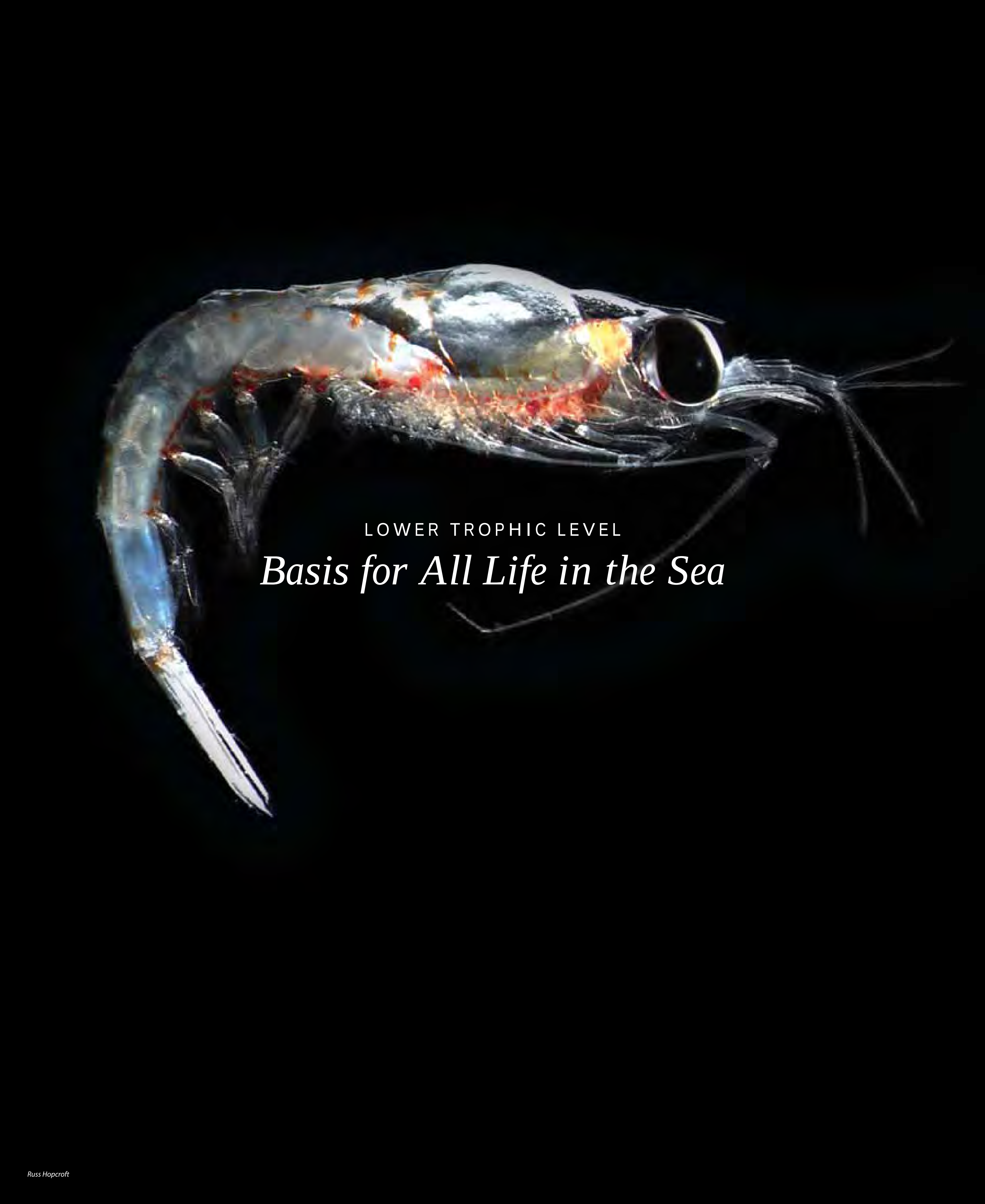


LOWER TROPHIC LEVEL

Basis for All Life in the Sea

Russ Hopcroft

LOWER TROPHIC LEVEL

While fishes, marine mammals, and seabirds are the most visible living marine resources at the top of the food chain upon which we depend, it is the tiniest organisms drifting and swimming with the currents that fuel all life in the sea. Scientists study these lower trophic levels (LTL) to improve our understanding of the overall ocean ecosystem, how it varies over time, and its response to climate change.

In the *Science Plan*, the National Research Council recommended that NPRB support fundamental studies of the basic structure and function of ecosystems to better understand the populations they support. The following LTL studies also address legislated priorities by specifically addressing needs for marine ecosystem information and pressing fishery management issues that help us better understand the impacts of the environment on upper trophic level species. To date, the Board has funded 31 LTL projects for a total of $5.1 million, of which 16 have been completed. This section discusses them in three main categories:

- oceanography
- phytoplankton ecology
- zooplankton ecology

Most LTL projects cover several levels, and often are termed nutrient-phytoplankton-zooplankton or NPZ studies, especially for modeling purposes. And many of the 31 projects are continuations of the same research, such as annual support of the Bering Sea moorings to service the hardware and extract the data.

Russ Hopcroft

LOWER TROPHIC LEVEL PROJECTS

203	Continuation of long-term observations on Bering Sea shelf: Biophysical moorings at sites 2 and 4 *J. NAPP, P. STABENO, T. WHITLEDGE*
207	Detecting change in the Bering Sea ecosystem *A. HOLLOWED, J. OVERLAND, N. SOREIDE*
211	Sinking particles/pelagic food webs in the SE Bering Sea *S. HENRICHS*
302	A continuous plankton recorder survey of the North Pacific and southern Bering Sea *S. BATTEN, D. WELCH*
315	Continuation of long-term observations on the Bering Sea shelf: Biophysical moorings at sites 2 and 4 *J. NAPP, J. OVERLAND, P. STABENO, T. WHITLEDGE*
402	Evaluation of ocean circulation models for the Bering Sea and Aleutian Islands Region *A. HERMANN, D. MUSGRAVE*
406	Synthesis of marine biology and oceanography of Southeast Alaska *G. ECKERT*
410	Long-term observations on the Bering Sea shelf (2004-2005): Biophysical moorings at sites 2 and 4 as sentinels for ecosystem change *J. NAPP, P. STABENO, T.WHITLEDGE*
517	Sentinels for Bering Sea ecosystem change *J. NAPP, P. STABENO, T. WHITLEDGE*
520	Gulf of Alaska long-term observations *R. HOPCROFT*
536	A continuous plankton recorder survey of the North Pacific and southern Bering Sea *S. BATTEN, D. WELCH*
601	A continuous plankton recorder survey of the North Pacific and southern Bering Sea *S. BATTEN, D. MACKAS*
602	Sentinels for Bering Sea ecosystem change *J. NAPP, P. STABENO, T. WHITLEDGE*
603	Gulf of Alaska long-term observations *R. HOPCROFT*
607	Modeling study on the response of lower trophic level production to climate change *C. DEAL, M. JIN, J. WANG*
608	Response of the Bering Sea integrated circulation-ice-ecosystem to forcing by climate and the adjacent North Pacific and Arctic oceans 1955-2005 *R. BARBER, F. CHAI, Y. CHAO, A. DE CHARON, J. MCWILLIAMS, S.NGHIEM*
614	Optimization of a nutrient-phytoplankton-zooplankton ecological model for quantifying physical and biological interactions on the Gulf of Alaska shelf. *K. COYLE, A. HERMANN, S. HINCKLEY*
701	Sentinels for ecosystem change: long-term biophysical moorings on the Bering Sea shelf (2007-2008) *J. NAPP, P. STABENO, T. WHITLEDGE*
702	Development and testing of a real-time ocean data transmitting buoy for the Gulf of Alaska *T. WEINGARTNER*
705	Trends and variability in the Bering Sea/Bering Strait sea ice cover *S. DROBOT, C. FOWLER, J. MASLANIK*
706	Wind field over the Bering-Chukchi Shelf: The QUIKSCAT Perspective *T. WEINGARTNER*
707	Alaska ferry oceanographic monitoring in the Gulf of Alaska *N. BOND, E. COKELET, C. MORDY*
708	Gulf of Alaska long-term observations: The Seward line 2007 *R. HOPCROFT, T. WEINGARTNER, T. WHITLEDGE*
733	Pribilof Islands community-based ocean monitoring program *A. LESTENKOF, M. MALAVANSKY, B. ROBSON, P. ZAVADIL*
734	An updated hydrology model for the Gulf of Alaska *T. ROYER*
803	A continuous plankton recorder survey of the North Pacific and southern Bering Sea *S. BATTEN, D. MACKAS*
804	Seward line monitoring *R. HOPCROFT*
805	Modeling processes controlling the on-shelf transport of oceanic meso-zooplankton populations in the Gulf of Alaska and SE Bering Sea *K. COYLE, G. GIBSON, K. HEDSTROM*
806	Comparison of long-term laboratory estimates of fecundity of *Euphausia pacifica* from the Gulf of Alaska and the northern California Current *W. PETERSON*
828	Collaborative research: dynamicall consistent synthesis of in-situ and satellite measurements in the Aleutian passes *D. NECHAEV, G. PANTELEEV*
829	An important use for Aleutian Island indicators-hunting black swans *J. OVERLAND*

Matt Berman and Jay Clark

Oceanography

OUR UNDERSTANDING OF OCEAN DYNAMICS DEPENDS ON OUR ABILITY TO MAKE LONG-TERM OCEAN MEASUREMENTS. THE NRC IDENTIFIED OCEAN MONITORING AS POTENTIALLY ONE OF NPRB'S MOST VALUABLE LEGACIES.

Ocean measurements not only tell us about the current state of the ocean, they also provide an extremely valuable record for retrospective and modeling studies that shed light on how the ocean has changed over time and how it may change in the future.

Time-series measurements are not necessarily cutting-edge science. In fact, the National Science Foundation refers to "service" proposals when they seek to fund basic gathering of ocean data. However, this type of monitoring gives scientists the most synoptic picture of the ocean and its currents, vertical structure, and nutrient flux, all critically important drivers for primary and secondary production. Without these long-term observations, researchers would not be able to make comparisons among habitats and years, characterize seasonal and interannual variability, quantify regime shifts and climate changes, or create ecosystem models.

BERING SEA

The Board has invested over three-quarters of its LTL funds on basic oceanographic studies over the past eight years, with most going to the Bering Sea, as well as significant support for monitoring the northern Gulf of Alaska (see page 32). NPRB is now engaged in a ground-breaking $52 million partnership with the National Science Foundation to study the Bering Sea shelf ecosystem and create models that predict how it may change in response to projected climate conditions.

Phytoplankton Blooms and Cold Pools

Our perceptions of controlling factors largely derive from a host of measurements of temperature, salinity, currents, nutrients, ice cover, and fluorescence (a proxy for phytoplankton abundance) beginning in the mid-1990s when NOAA's Pacific Marine Environmental Laboratory deployed moored buoys at two key stations, M2 and M4, in about 70 meters of water on the southeastern Bering Sea shelf. Those measurements continue to enhance our understanding of the relationship of ice cover to the basic primary and secondary production of the overall ecosystem and whether energy flows mainly into the pelagic food web to provide forage for large fish populations, or rains down on the bottom and powers the benthic food web.

The measurements also inform about the formation of the cold pool (water less than 2°C) on the shelf, which may keep fish from migrating north. They tell us whether the Bering Sea is warmer or cooler than the long-term averages, and how winds and sea ice may reduce or enhance water column stability, with subsequent impacts on nutrient availability for primary production in the upper water column and timing of the spring phytoplankton bloom.

NOAA ECO-FICI Program

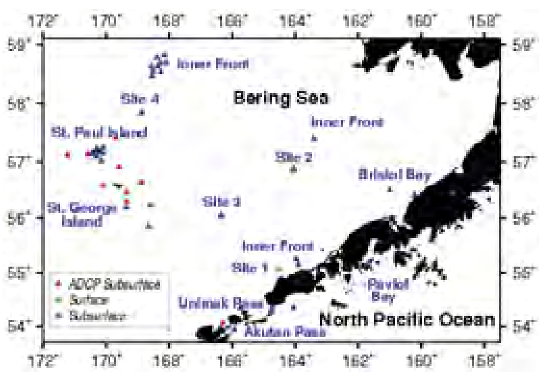
LOWER TROPHIC :: Oceanography :: Bering Sea

Ocean Observing Systems and Near Real-Time Data

Projects 203, 211, 315, 410, 517, 602, 701

MOORINGS ARE EXPENSIVE. THEY NEED SERVICING twice a year, spring and fall, for routine maintenance and data extraction. Starting in 2003, NPRB helped support those activities through funding for projects 203, 315, 410, 517, 602, and 701. The funds helped expand the array with two additional moorings at M5 and M8, thus nurturing a fledgling ocean observing system of four mooring sites, plus a hydrographic survey of about 200 stations.

With NPRB and NOAA support, researchers are making significant progress towards reporting near real-time data. In 2006, data from temperature, salinity, and zooplankton acoustics sensors were telemetered from a satellite mooring near M2 back to the Pacific Marine Environmental Laboratory in Seattle. In 2007, those data plus fluorescence were again transmitted in real time from the moorings. Scientists supplement the automated mooring data with shipboard collections of chlorophyll and zooplankton, as well as nitrates and other nutrients. Project 211 added a sediment trap to the M2 mooring in winter 2002-2003 to measure carbon, nitrogen, and selected lipids in organic material sinking down through the water column.



Location of biophysical moorings in the Bering Sea.

Warming or Cooling Seas?

Ocean monitoring tells us that the southeasern Bering Sea shelf warmed markedly by about 3°C during 2001–2005, closely associated with the decrease of sea ice. In 2006 and 2007, the Bering Sea cooled again, with ice extending farther south than in the previous five years and persisting well into May. In 2008, the sea was again very cool and the ice was the most extensive over the southern shelf since the mid-1970s. Scientists also learned that the maximum ice occurrences in spring in the Bering Sea appeared to be decoupled from the record-breaking low sea-ice concentrations in the Arctic Ocean summer.

Shifting of Spring Blooms

These changes in sea ice likely have major consequences for primary and secondary production. Over the southeastern shelf, the presence of sea ice determines the timing of the spring phytoplankton bloom. Conventional wisdom predicts that an early bloom will occur if ice is present after mid-March, but if there is no ice after mid-March, the bloom will occur later. Presumably the melting ice reduces salinity and sufficiently stabilizes the surface layer of seawater for phytoplankton to grow and multiply. It should be noted, however, that at least for the winter of 2003, which was relatively warm and ice-free near mooring M2, investigators were surprised to find a phytoplankton (diatom) bloom when they retrieved the sediment trap in March 2003. This very early production may have resulted from a lack of severe storms in mid- to late February. It may be that, at least in the shallower areas of the Bering Sea, late winter phytoplankton growth can occur even without sea ice meltwater-induced stabilization of the water column.

Dominance of Temperature versus Salinity

Overall, it appears that nutrient supply and summer salinity over the shelf have not significantly changed during the last three decades. Scientists noted an apparent decrease in the abundance of coldwater zooplankton species during the warm years of 2001–2005. They have increased in abundance during these last few cold years and provide important prey for fishes, seabirds, and marine mammals. Temperature dominates the structure of the water column over the southern shelf, while the northern shelf is dominated by salinity. In addition, the location of the boundary between the southern shelf (pelagic) and northern shelf (benthic) ecosystem appears to vary from one year to the next, with its location depending greatly upon maximum ice extent during the spring.

Partnerships in Monitoring the Bering Sea

Observations collected on the Bering Sea shelf give us critical information about how this ecosystem is responding to decadal shifts in climate. NOAA is one of the few entities monitoring the southeastern Bering Sea and support from NPRB has been critical to continuing the existing time series, expanding the locations where monitoring occurs, and expanding the number of variables monitored. These benchmark studies documented the rapid shifts from a warm to a cold regime, and how those shifts will change the timing of the spring phytoplankton bloom and the relative stability of nutrient concentrations over the southern shelf. The measurements will continue through 2009–2010 as part of the larger NPRB and NSF Bering Sea ecosystem study.

LOWER TROPHIC :: Oceanography :: Bering Sea

Detecting Regime Shifts Over Time

Project 207

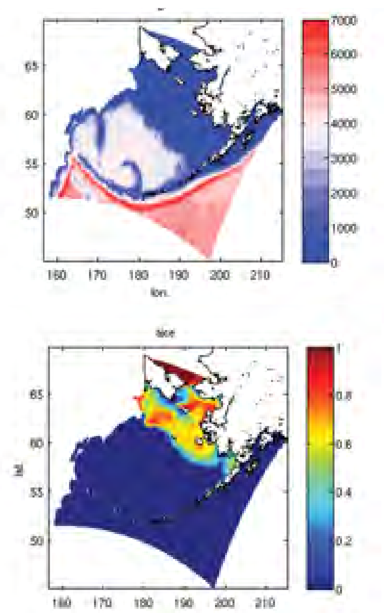
THREE OTHER BERING SEA PROJECTS BENEFITTED from the moorings data. Project 207 was a retrospective study to design a protocol for detecting and tracking change in the Bering Sea ecosystem. Resource managers need these formal indices of change for scientific and ecosystem-based management purposes. Measuring climate change in an area as large as the Bering Sea is a formidable challenge, and organizing and distributing the information can be equally as challenging. To confidently detect a regime shift, a long time series of data of at least ten years is needed from the moorings to develop a formal statistical test. However, by the time these data are available, scientists become uncertain whether the new regime is going to continue or is about to change its sign again. This project provided a tool for scientists to process incoming data in real time to signal the possibility of a regime shift as soon as possible and monitor how the magnitude of the shift may change over time. The investigators showed that regime shifts occurred in 1977, 1989, and 1998. The 1977 shift was strongest as related to atmospheric and oceanic indices for all observations stretching back to the beginning of the 20th century. They also noted shifts in fish stocks, salmon runs and catches of invertebrates. The regime of 1989–1997 was marked by relative winter cooling and reduced cyclonic activity. Researchers detected reductions in flathead sole and herring stocks, and classified large-scale atmospheric circulation patterns associated with warm and cold winters in the Bering Sea. Characteristic features of the 1998 shift have included a strong emphasis on spring-summer processes, an increase in winter cyclonic activity in the Bering Sea, earlier ice retreat, and lower runs of sockeye salmon beginning in 1997.

LOWER TROPHIC :: Oceanography :: Bering Sea

Evaluating Ocean Circulation Models

Project 402

SINCE THE BOARD COULD NOT FUND EVERYTHING and was inundated with proposals for different types of models, it requested model evaluation proposals in the 2004 request for proposals to help determine where best to invest money over the long term. Project 402 evaluated ocean circulation models for the Bering Sea and Aleutian Islands region. A workshop in early 2005 included presentations by experts on existing models and related biological models, state-of-the-art data assimilations, and applications to the Bering Sea. Participants concluded that the ideal circulation model would adequately and simultaneously resolve all of the relevant scales of motion and phenomena in the Bering Sea and Aleutians, including flows through Aleutian passes, seasonal ice, and tidal mixing on the shelves. None of the present modeling approaches can rapidly and simultaneously capture all of those features for extended time periods, due in part to computing limits: fine-scale multi-decadal hindcasts require months of dedicated computer time. Progress in computer capacities and use of nested models may reduce computer time in the future. Data are also limiting, but this will improve as more monitoring information becomes available from the ocean moorings and other sources.



These 3D ROMS-NPZ models show depth (top) and ice cover (bottom).

LOWER TROPHIC :: Oceanography :: Bering Sea

Modeling Productivity with Changing Sea Ice

Project 607

A SECOND MODELING EFFORT, PROJECT 607, involved a coupled ice-ocean ecosystem model that included both pelagic and sea ice habitats. As noted above, climate-related trends in the Bering Sea, including warming waters and reduced ice cover, may have profound impacts on primary and secondary production. This modeling exercise suggested that the ice-associated blooms were seeded by sea ice algae released from melting sea ice. A run of the model over several decades, from 1960-2004, showed that before 1977, primary production was dominated by ice algae in icy cold water with only light grazing, favoring the benthic communities. After 1977, primary production was dominated by open-water species of diatom and flagellates in later and warmer water with higher grazing, which contributed more toward the upper ocean pelagic community. Nitrification rate may be an important control of dominant phytoplankton functional type and the amount of nitrate in summer bottom waters and in the winter water column. This study reflects the value of the monitoring moorings in the Bering Sea, which provide data of critical importance in determining long-term change.

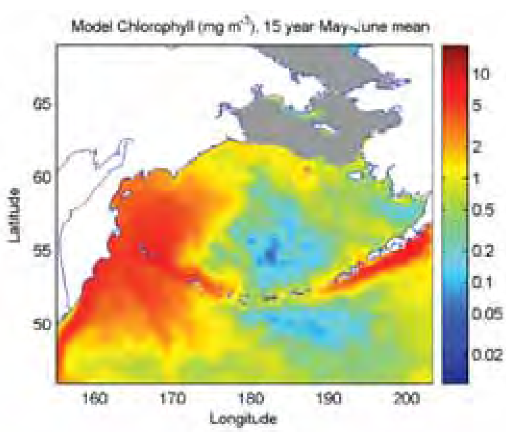
Thomas Van Pelt

LOWER TROPHIC :: Oceanography :: Bering Sea

Climate Change Response

Project 608

PROJECT 608 IS RETROSPECTIVELY ANALYZING THE ice ecosystem response of the Bering Sea to climate change and conditions in the adjacent North Pacific and Arctic oceans during 1955–2005. Researchers are identifying climatic, oceanic, and ice processes that regulate timing, quantity, and quality of the Bering Sea spring phytoplankton bloom, which is essential for recruitment of a strong year class of young fish that contribute to the valuable fisheries of the Bering Sea.



ROMS (model) simulated chlorophyll averaged over a four-year period (1997-2000).

LOWER TROPHIC :: Oceanography :: Bering Sea

Catching the Wind

Project 706

WE KNOW THAT WINDS AND WIND STRESSES FORCE ocean circulation, affect coastal sea levels, the wind-wave climate, air-sea heat fluxes, sea-ice extent, and provide energy for vertical mixing. Direct observations of marine winds are lacking, so marine scientists must rely on point measurements from coastal stations, marine buoys, and numerical weather models for broader application over larger scales of time and space. Project 706 is analyzing daily, satellite-derived scatterometer wind measurements to characterize their statistical properties on seasonal, monthly, and synoptic time scales, compare them with other wind measurements, and assess their value in driving nutrient-phytoplankton-zooplankton models.

LOWER TROPHIC :: Oceanography :: Bering Sea

Nearshore Monitoring

Project 733

ALTHOUGH THE MOORINGS AT M2–M8 COLLECT OCEAN data offshore, we also need more local measurements near shore. Project 733 supports a community-based, near-shore ocean monitoring program in the Aleut communities of St. Paul and St. George in the Pribilof Islands to augment measurements taken at M2-M8. Nearshore moorings will collect temperature and salinity to provide regional scientists with valuable time-series measurements to track climate-induced changes in the coastal zone of the Bering Sea.

Philip Zavadil

Monitoring equipment installed by the community of St. Paul Island.

LOWER TROPHIC :: Oceanography :: Bering Sea

Aleutian Pass Circulation

Project 828

THE ALEUTIAN PASSES ARE IMPORTANT CONDUITS for nutrient transport into the Bering Sea and up onto the shelf areas, even though relatively little is known about them. Project 828 is a comprehensive study of Aleutian pass circulation that will synthesize historical and contemporary hydrographic data, combined with drifter and current measurements, and satellite altimetry observations, to present a realistic circulation pattern and examine its variability. Researchers will reconstruct currents through the passes in 2002-2008, with a focus on silicate transport.

LOWER TROPHIC :: Oceanography :: Bering Sea

Early Warning of Catastrophic Events

Project 829

PROJECT 829 IS EXPLORING THE NATURE OF DRAMATIC shifts and developing ecosystem indicators that may provide early warning of potential catastrophic ecosystem events, and thus help guard against them. The large shifts are unexpected large events in complex, non-linear systems, such as large stock market moves, dramatic changes in Arctic sea ice cover, or large swings in fish populations.

Erika Acuna

MONITORING THE GULF OF ALASKA

The North Pacific has varied significantly over the past decade, due partly to variations in climate as reflected in indices such as El Niño and the Pacific Decadal Oscillation. Changes in these indices suggested that the 1997 El Niño represented a transition to a new regime, or regime shift, which portends a fundamental change in ecosystem structure and function similar to the large change that occurred in 1976 when the Gulf of Alaska fishery changed from being dominated by shrimp to pollock, salmon, and halibut. As in the Bering Sea, researchers need long-term measurements to characterize changes in the ecosystem.

LOWER TROPHIC :: Oceanography :: Monitoring the Gulf of Alaska

Observations from the Seward Line Transect

Projects 520, 603, 702, 708, 804

THE SEWARD LINE IS A 150-MILE TRANSECT ACROSS the Gulf of Alaska shelf to the south of Seward, Alaska. The Board supported monitoring along the Seward Line in the Gulf of Alaska in 2005 with Project 520 and continued those measurements through projects 603, 708, and 804. The observations build on earlier data collected under the Global Ocean Ecosystems Dynamics (GLOBEC) program from 1998–2004. Apart from the Canadian Line-P sampling program to the south, no other program in the Alaska Gyre allows observation of long-term changes in the oceanography of a region that is so critical to Alaska's fisheries, subsistence, and tourist economies. The long-term data will help us distinguish patterns and causes from seasonal and interannual variability. Cruises in May and September capture spring phytoplankton blooms and summer conditions along the transect.

Cold Years

Researchers compared observations of physical-chemical structure, primary (algal) production and the distribution and abundance of zooplankton, along with their seasonal and interannual variations to historical datasets to understand how different climatic conditions influence the biological conditions during those years. Average May temperature and salinity over the upper 100 meters across the Seward Line in 2005 and 2006 were comparable to other years, but it was anomalously cold in 2007. In fact, spring temperatures in 2007 were colder than any year since the early 1970s.

Zooplankton and Pink Salmon

The early spring 2007 water column was less stratified than normal, suggesting low winter freshwater runoff, strong winter mixing and anomalously high salinities at the surface and low salinities at depth. Spring zooplankton biomass was often low in extremely warm years and often high during extremely cold years. There also was a seasonal invasion of more southern species during warm years. Changes in zooplankton abundance and community composition could impact pink salmon survival in this region. Zooplankton collection during 2005-2007 remain consistent with the belief that years of high springtime *Neocalanus* copepod abundance often result in higher pink salmon survival at the critical periods of ocean entry.

Researchers conclude from these studies, and others begun in 1998, that the relationship between climate indices and conditions in the Gulf of Alaska is much more complicated than previously thought. Projects 708 and 804 will continue monitoring along the Seward Line through 2009. Project 702 supports development and testing of real-time ocean data transmission from the GAK-1 mooring. The Board anticipates ongoing support for ocean monitoring in the Gulf of Alaska within the context of its developing integrated ecosystem research program in that region.

Mark Kelley

FEATURE PROJECT

LOWER TROPHIC :: Oceanography :: Monitoring the Gulf of Alaska

Zooplankton in the Gulf of Alaska

STUDIES ALONG THE SEWARD LINE, A PROMINENT MONITORING PROGRAM taking the pulse of the northern Gulf of Alaska, revealed a mix of zooplankton species living in these waters.

In May, communities of *Neocalanus* spp., *Metridia pacifica*, and *Calanus marshallae* dominate the waters at night, while in September, researchers found *Metridia pacifica, Calanus* spp., *Eucalanus bungii*, and euphausiids.

During the day, finer mesh collections in May showed more *Oithona similis* and *Pseudocalanus* spp., but *Neocalanus* species and *Calanus marshallae* still dominated the biomass. *Oithona* and *Pseudocalanus* also continued to numerically dominate September daytime collections.

As in other biological communities, researchers noted changes in the abundance of certain species between years, although the largest copepods that dominate the spring bloom, *Neocalanus cristatus*, showed no significant pattern across years. Abundance of slightly smaller N. plumchrus/fleminger shifted significantly.

Swings in abundance may not always be related to water temperature, but temperature does affect growth rates and passage of copepod stages through the ecosystem. The physical environment influences how long various species remain in the upper water column and are more available to predators, such as salmon. These changes in prey availability could have a large impact on the survival of juvenile pink salmon, giving zooplankton studies a direct application to fisheries ecology.

Long-Term Observation Program (LTOP) stations. In addition to basic sampling, purple stations have primary production and zooplankton growth or reproduction incubations.

Zooplankton studies are vitally important to fisheries ecology since changes in prey availability affect survival of juvenile fishes.

Russ Hopcroft

LOWER TROPHIC :: Oceanography :: Monitoring the Gulf of Alaska

Freshwater Discharge and the Alaska Coastal Current

Project 734

THE ALASKA COASTAL CURRENT FLOWS ALONG SHORE AS IT SWEEPS THE COAST OF THE NORTHEASTERN PACIFIC Ocean from the Columbia River to the Aleutian Island chain and into the Bering Sea through Unimak Pass. The current influences the advection of heat, salt, and nutrients in the Bering Sea and Arctic Ocean. Project 734, while not a monitoring project per se, did provide an updated hydrology model that will let scientists incorporate freshwater discharge along the coasts of Alaska and British Columbia into models and estimations of the current. The new model incorporates discharges from glacial melting and rivers, which are accelerating as coastal mountain glaciers melt.

LOWER TROPHIC :: Oceanography :: Monitoring the Gulf of Alaska

NPZ Model

Project 614

DUE FOR COMPLETION IN 2010, PROJECT 614 SUPPORTS DEVELOPMENT of a nutrient-phytoplankton-zooplankton ecological model that will incorporate quantitative relationships between the physical and biological data collected during field observations along the Seward Line.

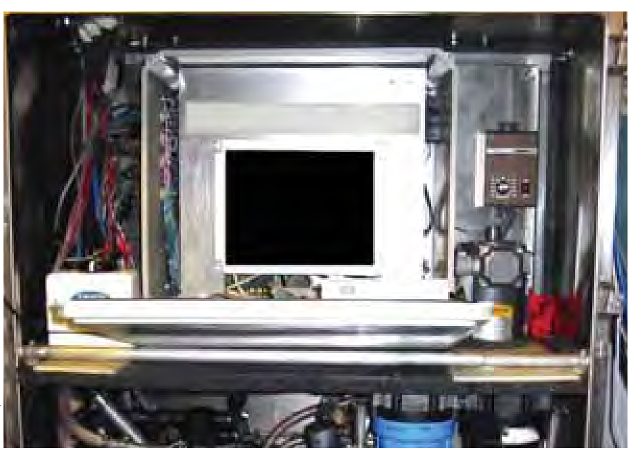
Russ Hopcroft

LOWER TROPHIC :: Oceanography :: Monitoring the Gulf of Alaska

Ferry Boxes

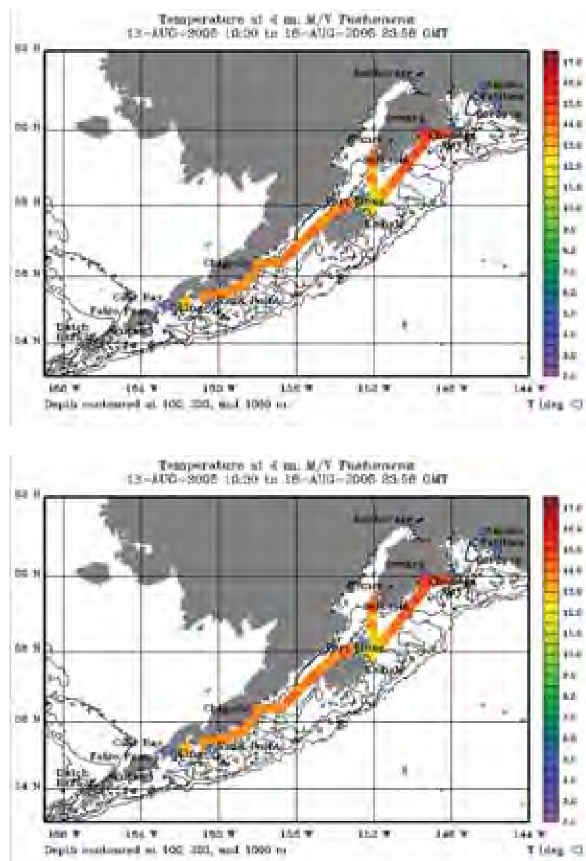
Project 707

THE BOARD ALSO IS SUPPORTING OCEAN MONITORING using a unique observation system on Alaska marine ferries called "ferry boxes." Project 707 installed these boxes on ferries to record water temperature, salinity, phytoplankton nutrients and biomass, freshwater influence, and water clarity along the ferry route between Homer, Kodiak, and Dutch Harbor. This work supports a dataset that, if maintained, may reveal long-term developmental, climatic, and anthropogenic changes.



Russ Hopcroft

The primary instrument box on the *Tustumena* containing temperature, salinity, nitrate, chlorophyll and CDOM fluorescence, and optical transmittance sensors.



Temperature along the *Tustumena's* route in the Alaska Coastal Current to Dutch Harbor in August 2005 (top) and August 2006 (bottom).

Phytoplankton Ecology

TINY DRIFTING OCEAN PLANTS CALLED PHYTOPLANKTON FUEL ALL LIFE IN THE SEA, FORMING THE FOUNDATION OF THE FOOD WEB.

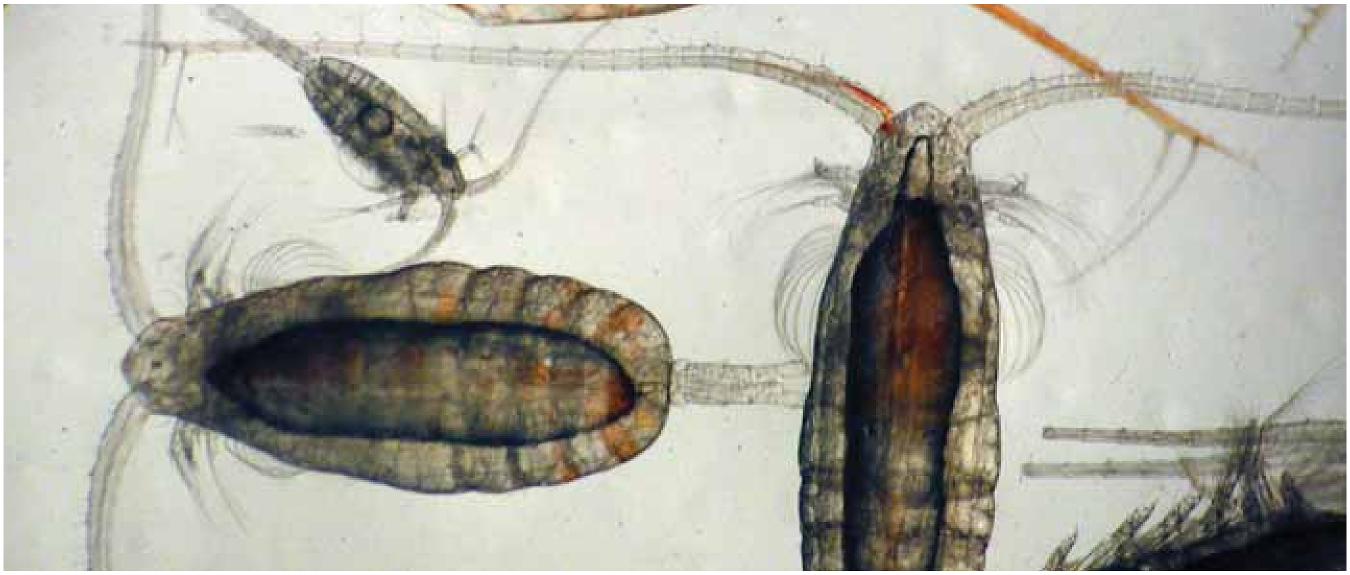
While the Board has not funded projects that focus solely on phytoplankton ecology, it has funded projects that measure phytoplankton abundance through fluorescence and relate it to changes in the surrounding ocean environment, such as the southeastern Bering Sea moorings and along the Seward Line. These studies improve our understanding of the timing of the spring bloom and in the case of the Bering Sea moorings, how the initial onset of phytoplankton production relates to the presence or absence of sea ice on the Bering Sea shelf. The timing of these blooms is important to the Bering Sea's food web.

A current scientific paradigm suggests that water column grazing by mesozooplankton has very little impact on ice-edge blooms in the northern Bering Sea. Most of the primary production sinks and becomes an important food source for the benthos. In the southern Bering Sea, later blooms feed the pelagic system. It also appears that middle shelf blooms in the Bering Sea are grazed less than those on the outer shelf, thus enhancing the benthic food supplies. Nutrient measurements have shown that both the ice-associated bloom and the more typical spring bloom strip the upper water column of nutrients. In November, when the strong summer thermocline breaks down, a fall bloom is signaled by an increase in fluorescence.

Zooplankton Ecology

MINUTE ANIMALS KNOWN AS ZOOPLANKTON REPRESENT THE SECONDARY PRODUCTION LEVEL AT THE BASE OF THE FOOD WEB.

Because they have relatively short life spans, mostly a year or less, and have varying degrees of control over where they drift, zooplankton respond very quickly to changes in their environment. Poor conditions for zooplankton mean less food is available for larger animals. As a result, larger animals also have a poor year, go somewhere else or eat whatever else is available. We need to know more about how zooplankton species respond to variability in ocean conditions. The Board has responded to this need in several ways – the zooplankton collections along the Seward Line; continuous plankton recorder studies across the North Pacific; and zooplankton studies within the NPRB-NSF Bering Sea Integrated Ecosystem Research Program. The Board also funded several other smaller studies.



Matt Berman and Jay Clark

LOWER TROPHIC :: Zooplankton Ecology

Continuously Recording Where Zooplankton Live

Projects T0004, 302, 536, 601, 803

RESEARCHERS OFTEN USE DEDICATED RESEARCH vessels to collect zooplankton. These expeditions may be very expensive and short in duration, offering only selected snapshots of the plankton communities off Alaska. An alternative program relies on volunteer commercial ships that tow a Continuous Plankton Recorder (CPR) along their regular routes. The CPR needs no accompanying scientist, making it relatively inexpensive to operate.

CPR studies off Alaska commenced in 2000 with funding made available under the North Pacific Marine Research (NPMR) Program. The Board added its support in 2002, using North Pacific Marine Research Institute research funds to continue an NPMR project (Project T0004 administered by the Alaska SeaLife Center). NPRB supported CPR deployments through 2009 by funding projects 302, 536, 601, and 803.

Project 803 continued CPR activities through 2008 (although data are not yet available) and into 2009. In September 2008, the Board approved setting aside $50,000 annually for five years to contribute to a CPR funding consortium coordinated by the North Pacific Marine Science Organization (PICES). Depending on funds made available from other sources, the CPR program may or may not be maintained at its past activity levels.

Great Circle Route

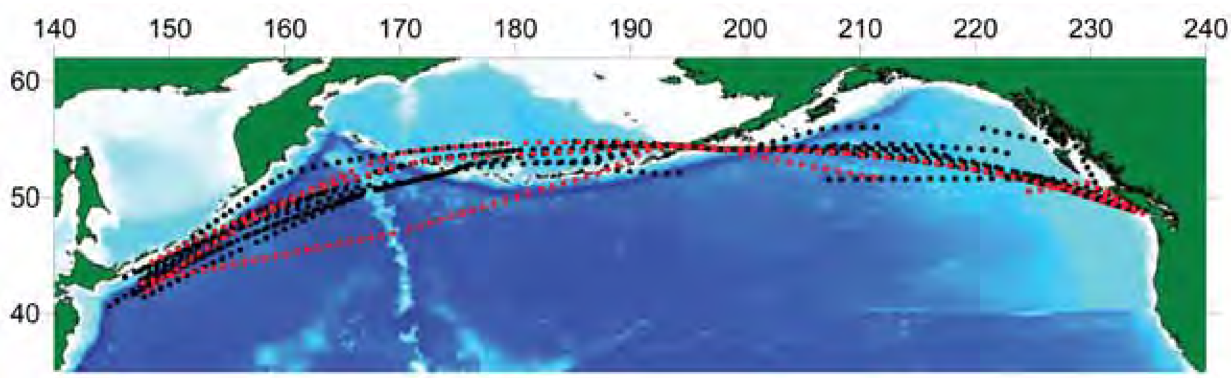
Commercial vessels tow a CPR for more than 6,500 kilometers across the Pacific, following the "Great Circle Route" from British Columbia to Japan. The sampling complements similar activities in the North Atlantic that have gone on for more than 60 years. Samplers collect zooplankton and data on temperature, salinity, and chlorophyll *a* (measured as fluorescence) down to a depth of about six meters. More than 3,000 plankton samples have been collected from crossings made mainly in April, June, and September/October, under funding provided by NPRB. So far, researchers have identified nearly 290 plankton species in the samples, including about 130 phytoplankton and 160 zooplankton species.

Distinct Neighborhoods

Transects pass through many different water masses and regions across the North Pacific, some more offshore than others. Scientists are starting to see some patterns, albeit highly variable ones, emerge from these past seven years of collections. There seem to be some ten distinct plankton communities (termed "mesoscale marine ecosystems") across the North Pacific, relating primarily to bathymetry and current systems. Many zooplankton species are common to all regions, but other species characterize just a few regions. For example, small copepods dominate in shelf regions and large subarctic copepods dominate in oceanic regions. Biomass also tends to be higher in shelf regions than in oceanic regions.

Some Like It Hot

Zooplankton appear to be strongly influenced by temperature, which has a strong influence on their metabolic and developmental rates, and probably on their survival rates. Water temperature thus may influence the presence of certain species. In warmer years, southern species may occur further north, expanding their range and abundance in the northern Gulf of Alaska, and thereby changing community composition. The western Gulf does not show the same temperature/zoogeographic relationship, possibly because eddies spinning off the Alaskan Stream add coastal water to the offshore region. Relating various zooplankton species to warm or cool conditions may provide greater understanding of why certain predator species, such as pink salmon, are more successful in some years than others, especially as their forage base relates to the prey quality, availability, and abundance of certain zooplankton species.



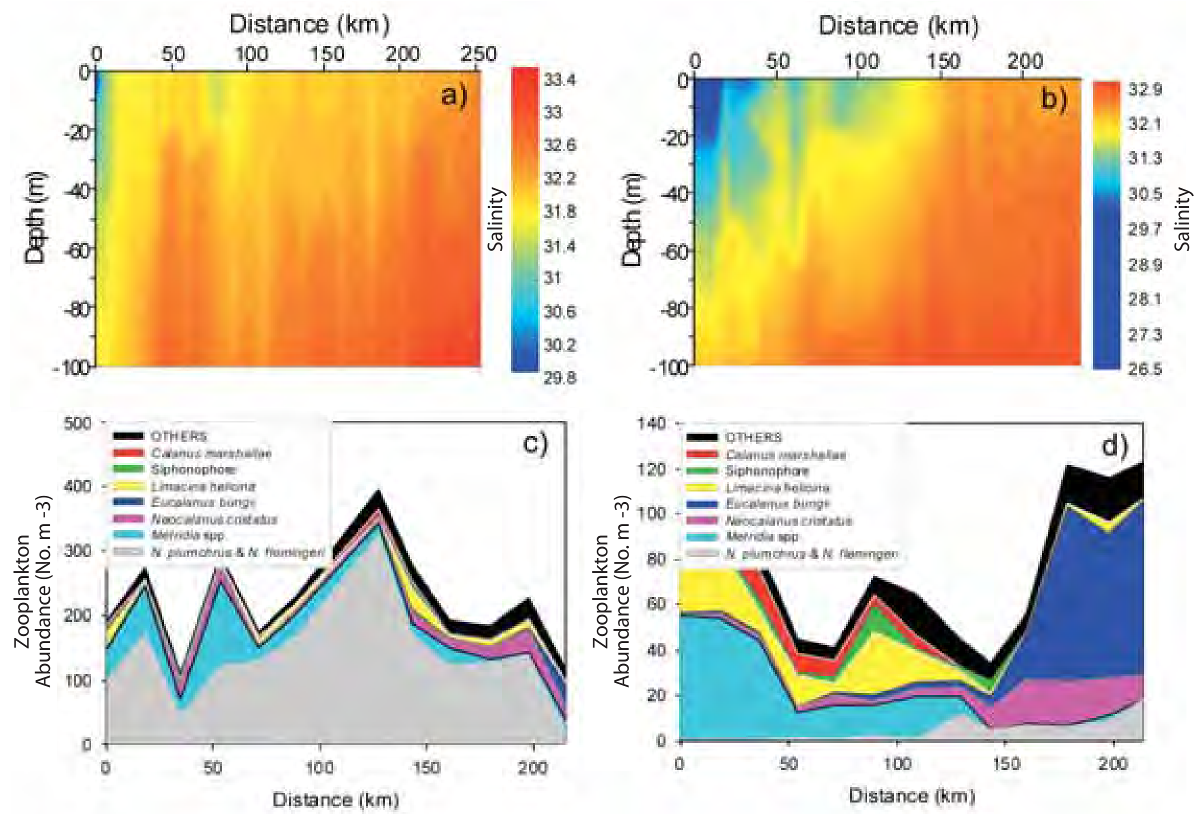
Position of samples that have been processed. Samples processed under Project 536 are shown in red. The typical great circle route shows a high density of samples, but the Sept 2005 route crossed the Gulf of Alaska further south than normal and the May 2006 route avoided a storm in the Bering Sea and traversed the western Pacific much further south than normal.

LOWER TROPHIC :: Zooplankton Ecology

Modeling Where Zooplankton Go in the Gulf

Project 805

PROJECT 805 IS A MODELING STUDY THAT FOCUSES ON BIOLOGICAL AND PHYSICAL PROCESSES INFLUENCING transport of oceanic zooplankton onto the southeast Bering Sea and Gulf of Alaska shelves under a variety of climate scenarios. Based on these models, field studies can be targeted in time and space on key transport events to eventually provide quantitative information on potential physical-biological mechanisms that influence variability in year-class strength of forage and commercial fish stocks.



Salinity and zooplankton abundance across the Gulf of Alaska shelf during a period with no notable frontal structure (a and c) and during a period with a strong frontal structure (b and d). Image from project statement of work.

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A Closer Look at Euphausiids

Project 806

STUDIES OF KEY SECONDARY PRODUCERS LIKE *EUPHAUSIIDS* will help us understand their role in the food web and how they may be influencing upper-level predators—salmon, pollock, herring, and rockfish, as well as seabirds and marine mammals. Project 806 will provide information about *Euphausia pacifica* from the Gulf of Alaska by exploring the range of reproductive and growth behaviors exhibited by individual females maintained over several months in a controlled laboratory setting.

Russ Hopcroft