Bering Sea Open Science Meeting
Program and Abstracts

Honolulu, HI, U.S.A.
February 22-23, 2014

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Bering Sea
Open Science Meeting

February 22 – 23, 2014
Honolulu, HI, U.S.A.

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MEETING PROGRAM

Saturday, Feb. 22 (18:00 - 22:00)
POSTER SESSION / RECEPTION
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Poster presenters are expected to be available to answer questions

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P-8 Simone **Vincenzi**, Will Satterthwaite and Marc Mangel

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Model-data synthesis and high resolution simulation of the Bering Sea

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ORAL PRESENTATIONS

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08:30	5 min	Introduction
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08:55	5 min	Discussion
09:00	20 min	**Calvin Mordy** Mechanisms that influence the magnitude, distribution and fate of primary production on the Bering Sea Shelf
09:20	20 min	**Rolf Gradinger** Contribution of sea ice biological processes to Bering Sea winter/spring carbon cycle
09:40	10 min	Discussion
09:50	30 min	Tea/Coffee Break
10:20	20 min	**Neil S. Banas** Temperature and ice influences on large zooplankton on interannual and multidecadal scales: Ecosystem and life-history modeling approaches
10:40	20 min	**George L. Hunt, Jr.** What controls the distribution and abundance of euphausiids over the southeastern Bering Sea shelf
11:00	10 min	Discussion
11:10	20 min	**Colleen M. Petrik** The effect of eastern Bering Sea climate variability on the distribution of walleye pollock early life stages during the BSIERP/BEST years
11:30	20 min	**Anne B. Hollowed** Fish distributions and ocean conditions
11:50	20 min	**Alan Haynie** Not just a march to the north: How climate variation affects the Bering Sea pollock trawl and Pacific cod longline fisheries
12:10	15 min	Discussion
12:25	1h 15min	Lunch (lunch box provided)

13:40	20 min	**Alexandre N. Zerbini** Baleen whale abundance and distribution in relation to environmental variables and prey abundance in the eastern Bering Sea
14:00	20 min	**Kathy Kuletz** Spatial and seasonal aspects of seabird diet and predator-prey relations across the Bering Sea shelf
14:20	20 min	**Andrew W. Trites** What drives the abundance of top predators? A comparative analysis of increasing and decreasing populations of fur seals and sea birds in the eastern Bering Sea
14:40	15 min	Discussion
14:55	30 min	Coffee/Tea Break
15:25	20 min	**Ivonne Ortiz** The benefits of hindsight: Examining results of the Bering Sea Project's vertically-integrated modeling effort from physics to fish
15:45	20 min	**Lee W. Cooper** A review of new insights on functioning and dynamics of the northern Bering Sea ecosystem
16:05	20 min	**Michael F. Sigler** An organism-centric view of subarctic productivity: Gas tanks, location matters and historical context
16:25	15 min	Discussion
16:40	10 min	Wrapup
16:50 18:00		Space remains available for conversation and informal discussion until 6 pm

Oral Presentations

February 23, 08:35 (BSOSM-9229)

It's not all about the ecosystem: Results and collaborations of the Local and Traditional Knowledge component of the Bering Sea Project

Henry P. **Huntington**[1], Bradley Benter[2], Nicholas A. Bond[3], Nicole M. Braem[4], Caroline L. Brown[4], James A. Fall[5], Taylor Hesselgrave[6], Eugene Hunn[7], Lisa B. Hutchinson-Scarbrough[5], David S. Koster[5], Theodore M. Krieg[8], Pamela Lestenkof[9], George Noongwook[10], Ivonne Ortiz[11], Martin Renner[12], Ann Fienup-Riordan[13], Kristen Sheeran[6], Michael F. Sigler[14], Jonathan A. Snyder[2], Francis K. Wiese[15], Phillip A. Zavadil[16] and Jinlun Zhang[17]

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10 Savoonga Whaling Captains Association, Native Village of Savoonga, Savoonga, AK, USA
11 School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA, USA
12 Tern Again Consulting, Homer, AK, USA
13 Calista Elders Council, Anchorage, AK, USA
14 Alaska Fisheries Science Center, NOAA, Juneau, AK, USA
15 North Pacific Research Board, Anchorage, AK, USA (now Stantec Consulting, St. John's, NL, Canada)
16 Aleut Community of St. Paul Island Tribal Government, St. Paul Island, AK, USA
17 Applied Physics Laboratory, University of Washington, Seattle, WA, USA

The Local and Traditional Knowledge (LTK) component of the Bering Sea Project started with an ambitious plan: to document a wide range of the ecosystem-related observations of residents of five of the region's indigenous communities, to document their interactions with the ecosystem particularly as reflected in subsistence harvests, and to explore the connections between our work and that of other Bering Sea Project researchers where possible. LTK documentation found high spatial variability in the changes observed around the Bering Sea, with one overall pattern of far greater change to date in the south than in the north. Documentation of subsistence harvests revealed various patterns of change over time, and the degree to which harvests are influenced by societal as well as ecological factors. Our "calorie-shed" collaboration demonstrated the vast spatial extent of human-environment interactions in the Bering Sea region, while our "cluster analysis" collaboration found large-scale patterns in harvest compositions by village. The "walrus-ice-wind" collaboration found evidence of the influence of wind and ice conditions on walrus harvest, but also that societal factors are likely a major component of harvest variability. A detailed collaborative look at the village of Emmonak underscored the importance of social and cultural understanding when examining change and its implications for communities. Common conclusions of these efforts are that the ecosystem is important, but not the whole story, and that many lines of inquiry and areas of expertise are needed to achieve "integrated" understanding at the ecosystem scale.

February 23, 09:00 (BSOSM-9278)

Mechanisms that influence the magnitude, distribution and fate of primary production on the Bering Sea Shelf

Phyllis J. Stabeno[1], Calvin W. **Mordy**[2], Michael W. Lomas[3] Lisa B. Eisner[4], Raymond N. Sambrotto[5] and Nancy B. Kachel[2]

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[3] Bigelow Laboratory for Ocean Science, East Boothbay, ME, USA
[4] NOAA Alaska Fisheries Science Center, Seattle, WA, USA
[5] Lamont Doherty Earth Observatory, Columbia University, Palisades, NY, USA

Factors that influence primary production and its fate on the Bering Sea shelf include timing of ice retreat, mixed layer depth, wind mixing, initial nitrate concentrations and regeneration. This synthesis effort utilized 20+ years of hydrographic and mooring results to examine the importance of each component. Every winter, strong winds and the break down of the frontal structure result in cross shelf flow and the replenishment of salts (including nutrients) on the southern (south of 60°N) Bering Sea shelf. Utilizing a simple box model, estimates of cross-shelf transport and its variability are made during fall and winter (before ice arrival). As salt is a good proxy for nitrate, estimates of pre-bloom nitrate can be made in the absense of nutrient data. There is year-to-year variability (~20%) in initial nutrient content. Utilization of the nutrient pool during production in spring and summer is related to the extent and timing of stratification and wind mixing, factors that are not necessarily forced by warm-cold conditions. Years are classified as warm, cold or average, from 1974 until the present using the sea-ice extent data. The variability of pre-bloom nitrate concentration, primary production and remineralization will be examined as a function of warm-cold years and winds.

February 23, 09:20 (BSOSM-9257)

Contribution of sea ice biological processes to Bering Sea winter/spring carbon cycle

Rolf **Gradinger**, Bodil Bluhm, Katrin Iken, Anna J. Szymanski and Jared Weems

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The Bering Sea shelf has the largest seasonal variation of sea ice extent in the Arctic. The large differences in associated biological factors, ranging from total marine biodiversity to sympagic-pelagic-benthic processes, have been largely unexplored for the Bering Sea. During three early spring expeditions (March to June) in 2008, 2009, and 2010, we explored the diversity of ice-associated flora and fauna (excluding bacteria) and determined ice algal primary production. In addition, we identified coupling to pelagic and benthic biological processes through vertical flux measurements under sea ice, stable isotopic composition of biota from all three habits, and experimental studies focusing on isotopic turnover rates.

Standing stock of sea ice algae were among the highest in the entire Arctic and exceeded concurrent phytoplankton concentrations substantially. The ice algal primary production was similar to phytoplankton productivity in the upper 20m of the water column. So far 47 diatom taxa have been identified in the Bering Sea ice. Sea ice meiofauna concentrations were low and differed in composition from high Arctic sites. No under-ice amphipods typical for the high Arctic were observed but krill, *Thysanoessa raschii,* appeared to feed on ice algae as indicated by *in situ* video observations and stable isotope data. Significant concentrations of ice algae were released during periods of advanced melt with April to June values exceeding 20 mg Chl *a* m^{-2} d^{-1} and may be available to pelagic and benthic consumers; however, isotopic assimilation rates in benthic clams were slow.

February 23, 10:20 (BSOSM-9227)

Temperature and ice influences on large zooplankton on interannual and multidecadal scales: Ecosystem and life-history modeling approaches

Neil S. **Banas**[1], Robert G. Campbell[2], Jinlun Zhang[3], Carin J. Ashjian[4], Evelyn J. Lessard[5], Alexei I. Pinchuk[6], Evelyn B. Sherr[7] and Barry F. Sherr[7]

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[7] College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR, USA

This talk describes results from three recent, linked model studies: 1) a high-resolution projection of ice cover and circulation under future climate, 2) a new planktonic nutrient-cycling model built using rich datasets from 9 BEST research groups, and 3) initial experiments in a new, trait-based model of copepod life history. In combination, these models allow us to test hypotheses regarding the mechanisms linking temperature and ice cover to the success of large crustacean zooplankton on both interannual and multidecadal scales. The planktonic ecosystem model reproduces both micro and macro features of Bering Sea primary production dynamics: on the micro scale, the time evolution of community structure and flux ratios during an intense ice-edge bloom observed in April 2009, and on the macro scale, observed relationships between ice-retreat timing and spring bloom timing for the northern and southern middle-outer shelves, 1978-2012. This multidecadal hindcast suggests that total spring-summer primary and secondary production are higher in warm years, and thus that observed interannual variability in LCZs occurs in spite of, not because of, spring-summer conditions. To estimate the sensitivity of LCZs to temperature and prey variability at other times of year, simple sensitivity experiments were performed using a new optimal-life-history model for Calanus spp. This model suggests that that temperature effects cannot explain the cold/warm year variance in LCZs, when winter and summer effects are taken together, but that even small changes in ice algal availability can.

February 23, 10:40 (BSOSM-9249)

What controls the distribution and abundance of euphausiids over the southeastern Bering Sea shelf?

George L. **Hunt, Jr.**[1], Kerim Aydin, Hongsheng Bi, Alex DeRobertis, Georgina A. Gibson, Alexei I. Pinchuk and Patrick H. Ressler

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Euphausiids (*Thysanoessa* spp.) are a major component of crustacean zooplankton biomass over the southeastern Bering Sea shelf, and are an important trophic link between primary producers and large marine predators, such as seabirds, great whales, and walleye pollock (*Theragra chalcogramma*), with pollock accounting for 37% of predation on euphausiids. This high proportion of euphausiid consumption by pollock spurred interest in whether the distribution and biomass of euphausiids are controlled by pollock. As part of the BEST/BSIERP program, we examined the impact of pollock on euphausiids. Early work showed a negative relationship over five years between pollock biomass and euphausiid biomass, supporting the idea of top-down control. When bottom temperatures were included in the analysis, temperature was found to account for most of the variation in euphausiid distribution and biomass. New results show summer euphausiid biomass to be between 282 $mgCm^{-2}d^{-1}$ based on net surveys, 27,911 $mgCm^{-2}d^{-1}$ based on acoustic surveys and 3,289 $mgCm^{-2}d^{-1}$ based on an NPZ model. Summer euphausiid consumption by pollock based on model (FEAST) output (~2.6 $mgCm^{-2}d^{-1}$) and acoustic estimates (~6.5 $mgCm^{-2}d^{-1}$) when compared to summer productivity using the NPZ model (mean ~43.6 $mgCm^{-2}d^{-1}$) accounts for between 6% and 15% of euphausiid productivity, respectively. Thus, in toto, our results support bottom-up control of euphausiids. However, during the study period, age-3+ pollock biomass was about $5.4x10^6$ metric tons compared to a high in 1987 of $12.1x10^6$ metric tons. We caution that, in times when pollock are more abundant, they may exert top-down control.

February 23, 11:10 (BSOSM-9235)

The effect of eastern Bering Sea climate variability on the distribution of walleye pollock early life stages during the BSIERP/BEST years

Colleen M. **Petrik**[1], Janet T. Duffy-Anderson[2], Franz Mueter[3], Katherine S. Hedstrom[4], Seth L. Danielson[5] and Enrique N. Curchitser[6]

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[6] Institute of Marine and Coastal Sciences, Rutgers University, 71 Dudley Rd., New Brunswick, NJ, 08901, USA

During the BSIERP/BEST years, the eastern Bering Sea experienced a warm period followed by a prolonged cold period. Analyses of observational data indicated differences in the spatial distributions of walleye pollock early life stages, which were influenced by temperature more than wind, spawning stock biomass, and zooplankton biomass. Under warmer-than-average thermal conditions, distributions were shifted onshelf, suggesting a relationship with the predominant wind patterns over the shelf in these years. Additionally, egg abundance data indicated a spawning delay by as much as 40 d in the cold years, possibly related to the presence of sea ice and a cold pool and their greater extents on the shelf. We developed a coupled biological-physical model (ROMS-TRACMASS) to examine how variable physical forcing affects the transport and distribution of pollock early life stages in the eastern Bering Sea. The individual-based biophysical model was used to test the effects of atmospheric (wind), oceanographic (ice, water column temperature), and biological (time and location of spawning) conditions on the distribution, growth, and transport of walleye pollock eggs and larvae. Model results suggest that differences in adult spawning location between warm and cold years play a bigger role than differences in transport alone or differences in the time of spawning. The distributions of pollock larvae and juveniles may relate to survival depending on their spatial match-mismatch with prey on the shelf. We are investigating how transport pathways and the final distributions of juveniles overlap spatially with their prey in warm and cold years.

February 23, 11:30 (BSOSM-9240)

Fish distributions and ocean conditions

Anne B. **Hollowed**[1], M. Baker, S. Barbeaux, Edward D. Cokelet, S. Kotwicki, R.R. Lauth, Patrick H. Ressler, Sandra Parker-Stetter, John Horne, and Lorenzo Ciannelli

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Investigators designed, tested and implemented innovative new methods to collect oceanographic and biological data in the eastern Bering Sea. Water column profiles revealed a latitudinal gradient in the upper to lower density difference with stronger stratification north of 59°N. In spring, near surface chlorophyll a, oxygen and nutrient data exhibited relationships consistent with the classical Redfield ratios. Oceanographic conditions were cold throughout the study period which inhibited our ability to compare the strength of density gradients across the shelf in warm and cold years, however, we were able to show that the boundary of the well-mixed, inner shelf was not always located at the 50m isobath. Statistical analysis showed strong evidence of environmental influence on vertical and horizontal niche partitioning amongst forage fish, and juvenile and adult groundfish. Depth alone was not sufficient to explain observed spatial distributions; light, bottom temperature, prey availability (euphausiids) and predator abundance were also selected as explanatory variables. Comparison of acoustic estimates of euphausiid and pollock biomass showed pollock predation could be substantial, but overall water temperature was a much stronger predictor of euphausiid biomass than pollock biomass (a proxy for predation pressure), implying bottom-up control dominated. Frameworks for projecting future impacts of climate change on the spatial distribution and abundance allow a first order glimpse of future conditions under a changing climate.

February 23, 11:50 (BSOSM-9269)

Not just a march to the north: How climate variation affects the Bering Sea pollock trawl and Pacific cod longline fisheries

Alan C. **Haynie**[1] and Lisa Pfeiffer[2]

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How will changing climate impact commercial fisheries? The observed impacts of climate variation on the spatial distribution of Bering Sea fisheries are surprisingly different than the impacts on fish populations. In this paper, we integrate work that independently examined the impact of climate change on the Bering Sea pollock and Pacific cod catcher-processor fisheries. We examine how both fisheries have adjusted to variation in economic conditions, changes in abundance, and environmental conditions. For pollock, the mean location of winter fishing has varied little between warm and cold years, but there has been a northward shift in summer pollock biomass and fishing. However, contrary to the idea that this shift would be correlated directly with warming temperatures, this shift is contemporaneously correlated with the colder than average climate conditions in the latter part of the last decade. For Pacific cod, the mean location of fishing has not shifted significantly as a result of climate variation, but fishing trips have changed. Climate affects relative spatial catch-per-unit-effort (CPUE) in both fisheries by causing a cold pool (water less than 2°C that persists into the summer) that both species avoid. In the Pacific cod fishery, vessels make long-distance moves more often in warmer, low-CPUE years, leading to significantly higher fuel costs. We develop a general framework of the avenues through which climate affects fisheries; understanding the relationship among fishing location, climate variables, and economic factors is essential in predicting the effects of future warming on fisheries.

February 23, 14:00 (BSOSM-9245)

Spatial and seasonal aspects of seabird diet and predator-prey relations across the Bering Sea shelf

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Seabirds are highly mobile migrants that become central place foragers when breeding, after which they must replenish energy stores. In the Bering Sea, strong seasonal patterns in prey availability likely influence seabird distributions at sea, but foraging mode also affects seabird response to prey concentrations and habitat variables. During breeding, pursuit-diving murres (energetically costly flight) show more consistent interannual spatial patterns in distribution and in isotopic signatures than do surface foraging kittiwakes (low cost flight). In summer, spatial coherence was evident in a cross-shelf isotopic gradient from euphausiids to pollock to seabirds, especially murres. However, both kittiwakes and murres associated with age-1 pollock more often than with euphuasiids, which were more consistent in location over time, indicating that both seabird species preferred the energetically more valuable prey despite the additional search costs. Nocturnal foraging behavior and prey selection are not well quantified, but could be key to understanding seabird-prey relationships; both murres and kittiwakes exhibited different distributions and prey associations during night and day. In spring and summer, seabird densities were highest in the outer shelf and near shelf-edge canyons of both the southern and northern Bering Sea. In fall, seabirds were more dispersed and found farther north and on-shelf, where they associated with a variety of prey types, most often in shallow waters or where prey was above the pycnocline. Long-term (decadal) changes in prey distribution may partly explain the northward shift in the distribution of wide-ranging albatrosses and fulmars, and possibly the post-breeding dispersal of other species.

February 23, 13:40 (BSOSM-9276)

Baleen whale abundance and distribution in relation to environmental variables and prey abundance in the eastern Bering Sea

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The Bering Sea is one of the most productive marine ecosystems in the North Pacific and an important habitat for baleen whales. Because of its ecological and commercial importance and its sensitivity to climate change, the eastern Bering Sea (EBS) was the focus of a comprehensive study (The Bering Sea Project, BEST-BSIERP) developed to understand the processes that maintain this ecosystem. Because baleen whales consume large quantities of prey, recovery of populations from whaling has the potential to modify the ecosystem structure. Therefore, understanding how environmental variables and prey influence distribution and abundance is important for predicting how whales can impact the ecosystem and how they respond to environmental changes. In this study, line transect surveys were conducted to estimate abundance and to examine distribution of cetaceans in the eastern Bering Sea. Generalized additive models were used to model the abundance of fin, humpback, and minke whales in the EBS in 2008 and 2010 relative to physiographic, oceanographic, and biological variables. Phytoplankton chlorophyll-a concentration (Chl-a), distance from the 200m isobath, and euphausiid biomass were important predictors of minke and fin whale abundance. Abundance of humpback whales was correlated with sea surface temperature, euphausiid biomass, Chl-a, and depth. Results of this study provide a quantitative assessment of the relationship between baleen whale density and environmental variables and a basis to further understand habitat preferences and potential impact from climate change.

February 23, 14:20 (BSOSM-9223)

What drives the abundance of top predators? A comparative analysis of increasing and decreasing populations of fur seals and sea birds in the eastern Bering Sea

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We undertook a comparative analysis of northern fur seals, thick-billed murres and black-legged kittiwakes that are thriving on Bogoslof Island (southern Bering Sea) and declining on St. Paul Island (Pribilof Islands – central Bering Sea) to elucidate the factors that drive the population dynamics of top predators in marine ecosystems. We assessed the abundance and distribution of prey around each breeding colony (Jul–Aug 2009), and concurrently determined diets, stress levels, and foraging locations of these three top predators. Birds and seals from the Pribilof Islands travelled further and for longer times to feed, and experienced higher stress levels compared to those from Bogoslof Island. Diets of fur seals and murres on St. Paul Island were dominated by juvenile pollock (low energy content), whereas diets on Bogoslof were dominated by high energy mesopelagic species (squids for murres; myctophids for

kittiwakes; squids and northern smoothtongue for seals). At-sea distributions of birds and mammals were relatively uniform across the Bering Sea, but distinct between breeding islands. Seal and seabird distributions corresponded with the broad scale distribution of widely dispersed shallow patches of prey—and not with the total biomass or numerical abundance of their dominant prey species. Quality of diets (*i.e.*, energy density) and their accessibility may drive reproductive success of birds and seals in the Bering Sea. Recovery of northern fur seals, thick-billed murres, and black-legged kittiwakes on the Pribilof Islands to numbers present prior to the 1975/76 regime shift will likely require a dietary increase in energy-rich cephalopods and mesopelagic fishes.

February 23, 15:25 (BSOSM-9268)

The benefits of hindsight: Examining results of the Bering Sea Project's vertically-integrated modeling effort from physics to fish

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The FEAST model is a vertically integrated model that couples high resolution oceanography, lower trophic levels and fish. The model was parameterized using both historical data analysis and field research stemming from The Bering Sea Project. We use the hindcast (1970-2005) and recent multiyear simulations (2004-2010) to gain insight into the annual sequence, magnitude and timing of biophysical processes and how fish respond to such processes across different regions of the Bering Sea shelf and slope throughout the year. The underlying sequence, timing and magnitude of biophysical processes follow a southwest-northeast, off-shelf – inner shelf gradient, where the interannual variability in magnitude of peak concentrations of either phytoplankton or zooplankton is greater than the variability of the timing for the different blooms. This allows general regional biophysical patterns to persist, despite annual variability. The general sequence of mesozooplankton blooms: copepods -> *Neocalanus* -> euphausiids, follow and are sequentially maintained by the large phytoplankton –> large microzooplankton –> small phytoplankton blooms. The timing of peak concentrations lag following an SW off-shelf to NE inner-shelf gradient, with the magnitude of phytoplankton peaks highest along the middle shelf. Likewise, fish response has a different timing and magnitude across space, from the degree of weight loss and dependence on alternative prey by newly hatched pollock, to the functional response to euphausiid abundance. We present a suite of fish responses to environmental conditions, highlighting their spatial, year round and interannual variability, with a focus on insights gained by comparison with the Bering Sea Project field years.

February 23, 15:45 (BSOSM-9258)

A review of new insights on functioning and dynamics of the northern Bering Sea ecosystem

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The region between St. Matthew and St. Lawrence Islands in the Bering Sea is a key late winter foraging area for Pacific walruses, bowhead whales, bearded seals and spectacled eiders. Species of concern, including Kittlitz's Murrelet, have also now been documented feeding south of St. Lawrence Island in leads and polynyas. Recent intensive studies include oceanographic cruises during sea ice melt blooms in May 2006 and 2007; late winter cruises in March 2008, 2009, 2010; and annual observational cruises utilizing the Canadian Coast Guard Service *Sir Wilfrid Laurier* that continue a July observational record dating back to 1998. This high density of sampling has documented the rapid, linked transition from sea ice algal blooms to open water algal production, the associated sedimentation processes, and the response of macrobenthic organisms on the sea floor. The most recent benthic surveys indicate changes in species assemblages and northerly biomass shifts in dominant infauna as well as declining benthic metabolism in locations that have been sampled for more than 25 years. There are also indications of shifts in sediment grain size on the northern Bering Sea seafloor. These changes are happening within the context of increased understanding of the distributions of upper trophic level organisms, which has benefited from advances in satellite telemetry. The overall ecosystem understanding that has emerged from recent studies is of an active biological system, even in late winter, with strong, but complex foodweb linkages that appear to be responding to environmental changes in the northern Bering Sea.

February 23, 16:05 (BSOSM-9230)

An organism-centric view of subarctic productivity: Gas tanks, location matters and historical context

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We present an organism-centric view of eastern Bering Sea production to understand the implications of seasonal and interannual variation for zooplankton and juvenile fish abundance. This description has four tenets: 1) stored lipids are important for survival and recruitment of zooplankton and fish; 2) multiple environmental conditions can fill (or deplete) energy stores; 3) whether favorable years occur intermittently or back-to-back matters; 4) in the southeastern Bering Sea, an ecotone between the Arctic and subarctic, it's not just spring that matters (the classic ecological view), and instead energy is required for maintenance and growth each season and thus resupply must occur each season. In addition, we argue that location matters for this story, most importantly because ice forms each winter in the Bering Sea with the large, annual variations in extent. In turn this variation affects annual levels of primary and secondary production, the spatial distributions of zooplankton and juvenile fish, and access to these forage species by their predators. Finally, we place our organism-centric view into a historical context, because it appears that whether production-favorable years occur as singletons or in succession determines community composition and when a shift occurs between bottom-up to top-down control.

Poster Presentations

BSOSM-9224
P-1

Top predators partition the Bering Sea

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We tracked the movements of seals and seabirds breeding on the Pribilof Islands (central Bering Sea) and Bogoslof Island (southern Bering Sea) to determine where these central place foragers feed relative to the constraints of distance from land, environmental conditions, and availability of food. A total of 115 northern fur seals, 128 thick-billed murres and 106 black-legged kittiwakes were equipped with GPS and activity tags in 2008 and 2009. At-sea locations showed no overlap in foraging areas for kittiwakes or murres breeding on the two Pribilof Islands despite the islands being within foraging distance of each other. Nor was there any overlap between the foraging areas for seabirds from Bogoslof Island compared to those from the Pribilofs. Foraging ranges of northern fur seals also showed segregation of feeding areas by breeding sites between and within islands. The distinct segregation of feeding areas by breeding colonies and the similarities in segregation between both groups of central place foragers implies a common set of selective mechanisms related to compass orientation of breeding colonies, competition within and between species, predation risk, and energetic constraints associated with distance, prey size and energy content. Our data suggest that immediate environmental conditions may have less effect on broad-scale habitat selection compared to colony orientation and the longer-term selective forces related to foraging costs and predictability of annual environmental conditions. This implies that existing breeding colonies in the Bering Sea may be poorly adapted and unable to respond favourably to global warming and environmental change.

BSOSM-9226
P-2

Mixotrophy in Arctic and sub-Arctic planktonic protists: Potential food web and ecosystem effects

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Many non-diatom phytoplankton and microzooplankton in polar food webs are mixotrophic; they are photosynthetic and phagotrophic. Mixotrophy has synergistic effects that can increase N, P and Fe availability to primary producers, reduce stoichometric imbalances and increase trophic efficiency. Large seasonal changes in light and nutrients may favor mixotrophs. In oligotrophic Arctic waters, the dominant phytoflagellates are bacterivorous. In the Bering Sea "cold pool" and Barents Sea in summer, bacterivorous *Dinobryon* colonies are important phytoplankton. In polar front and sub-polar waters, mixotrophic dinoflagellates are common. Mixotrophy may help keep phytoplankton in an active state during the polar night so they can take advantage of the short summer. Phagotrophy by phytoplankters permits primary production to occur when dissolved nutrients are limiting and can shorten the microbial food web, allowing more bacterial carbon to transfer to crustacean zooplankton. Mixotrophy among the microzooplankton is also common. Ciliates with acquired phototrophy are abundant in the Arctic Ocean (the Beaufort Gyre), Iceland, Greenland, Barents, Kara, and Bering Seas in summer and can account for 14-50% of the chlorophyll and up to 66% of the ciliate biomass. Both mixotrophic ciliates and dinoflagellates grow faster at sub-zero temperatures than their heterotrophic counterparts during the polar summer. Ciliates repackage phytoplankton carbon into larger size particles

and, because of mixotrophy, can increase the average GGE of the microzooplankton; thus increasing the primary production available as food to crustacean zooplankton. With the exception of the spring diatom bloom, mixotrophs appear to be important components of the Arctic planktonic food web.

BSOSM-9228
P-3

Potential mechanisms of climate influence on survival of large *Calanus* on the Eastern Bering Sea Shelf

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Climate over the Bering Sea during this century underwent a major shift from cold to warm to cold conditions. The shift to warmer temperatures was accompanied by declines in abundance and biomass of large zooplankton which recovered to previous levels when cold conditions returned. Using a stage specific model of *Calanus finmarchicus,* driven with temperature, currents and food fields from a regional ocean circulation model with embedded ecosystem model, we are testing the hypothesis that these changes are related to the presence and duration of sea ice over the middle shelf domain during spring. Preliminary results suggest that *Calanus* in the southeastern middle shelf domain can reach maximum size by May – July during both warm and cold years. However, in warm years lacking cold bottom water over the southern middle shelf, respiration rates increase and lipid stores may be exhausted as early as November 1st. Thus, sea ice may influence *Calanus* survival by generating a cold bottom layer which provides a thermal refuge for individuals that undergo diapause, increasing the likelihood of survival through the following spring.

BSOSM-9231
P-4

Dynamics of spatial and temporal change in the Western Aleutian Islands over decadal to millenial scales

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Understanding the complex dynamics of environmental change in northern latitudes is particularly critical for arctic avian communities, which are integral components that maintain biological teleconnections between the mid- and northern latitudes. We report on studies done 2009 - 2013 in the far Western Aleutians focused on the coastal dynamics related to climate change of marine bird communities. We use several data sources and analysis techniques, including diet data, stable isotopes, and Bayesian inference, and encompassing current, historical, and prehistorical time periods. Our preliminary results indicate that the community-wide spatial and temporal dynamics of marine bird ecosystems are far greater in our study period than has been evident over recent decades. We also find that the magnitude of change is lesser here in the low Arctic (*e.g.*, western Aleutian Islands 53°N) compared to High Arctic coastal marine ecosystems (*e.g.*, 78°N). In particular, we show that the ecological patterns observed within such widespread arctic species as puffins (*Fratercula* spp.), Northern Fulmar (*Fulmarus glacialis*), and Black-legged Kittiwake (*Rissa tridactyla*) indicate diets are strongly perturbed on small geographic and temporal scales of 10^1 km and subdecadal years. Moreover, we find that the variance in environmental and ecological parameters is increasing rapidly over time. We hypothesize that these fine-scale changes are related to mid-scale oceanographic and trophic-level changes, in addition to larger-scale perturbations possibly related to a cascade of climate-related factors.

BSOSM-9232
P-5

Phytoplankton production and biomass, physical drivers and potential impacts on fisheries in the eastern Bering Sea

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The timing and magnitude of seasonal productivity in subarctic ecosystems can strongly influence the amount of energy that travels through the ecosystem from phytoplankton to zooplankton to fish. The timing of spring productivity (ice algae and phytoplankton) is related to sea ice coverage and retreat and set up of stratification, which in turn can impact zooplankton productivity and growth. Summer primary productivity sustains zooplankton productivity and can impact food resources for fisheries on the eastern Bering Sea shelf. Summer and fall productivity on the shelf is affected by vertical stability in the water column and wind events which impact vertical movement of nutrients to the surface waters. In fall the reduction of light due to vertical mixing of the water column marks the end of the growing season. To assess the relationship between primary production, physical drivers and potential impacts on fisheries, we compare available primary production and phytoplankton biomass data, length of winter (termed period when phytoplankton prey are unavailable for secondary producers), summer stratification and wind events, surface nutrient concentrations, zooplankton abundance and age 0 pollock size and energy content over recent years (2003-2011). Preliminary results suggest that high summer stratification and few wind mixing events can lead to lower primary production, lower silicate and reduced size for age-0 Pollock in the eastern Bering Sea.

BSOSM-9233
P-6

Persistent organic pollutants in organs of marine mammals from the Bering Sea

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Persistent Organic Pollutants (POPs) are harmful and toxic substances affected biota. HCHs and DDTs are used as pesticides in southern Hemisphere and may occur in polar regions due to atmospheric transfer. Marine mammals bio-magnify various pollutants may therefore be used as bioindicators in global monitoring of environmental contamination. While several studies have reported POPs accumulation in marine mammals in Subarctic regions, data for Russian areas of the Bering Sea is very scarce. HCHs and DDTs were detected in organs of marine mammals (grey whale *Eschrichtius robustus* and pacific walrus *Odobenus rosmarus divergens*) from the Bering Sea. The total concentration of pollutants in the adult grey whales was higher than in young individuals. POPs content in muscle and liver of the whales varied from 297 to 3581 ng/g lipids, and from 769 to 13808 ng/g lipids, respectively. The total concentration of POPs in muscles and liver of pacific walrus varied from 197 to 5659, and from 4856 to 90263 ng/g lipids, respectively. This fact may be caused by the differences in diets and specific positions in food web. Since no major local point sources of contamination exist in this region, the origin of many of these contaminants can be attributed to long-term transport via atmospheric processes and ocean currents.

BSOSM-9237
P-8

Integrating behavior, physiology and population dynamics to predict the effects of climate change on kittiwake colonies in the Bering Sea

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Climate change is predicted to affect the quality, abundance and spatial distribution of the prey base of top marine predators. A major finding of the BEST-BSIERP Bering Sea project has been that quality and accessibility of food drive reproductive success of top predators like fur seals and seabirds, and that existing breeding colonies may be unable to respond favorably to climate change.

Predicting the effects of changing climate and changing foraging conditions on colonies of seabirds is particularly challenging. Responses are likely to vary geographically even at fine scales, which may reflect different life history tradeoffs (*e.g.* survival and reproduction) being favored in different locations, *e.g.* in the eastern Bering Sea Bogoslof colonies are thriving while Pribilof colonies are declining.

We approach this challenge through a combination of theoretical and empirical methods: results of the empirical work on the interplay among diet, stress, and foraging location of seabirds in the Bering Sea carried out by the Patch Dynamics Team guides the theoretical constructs and the modeling identifies key pieces of empirical information that are required for advancing understanding.

We describe how we developed an overarching approach that links behavior, physiology, and population dynamics to understand and predict the effects of climate change on growth, feeding and breeding strategies of kittiwakes living in Bering Sea colonies. A common link across the life histories is the effect of environmental conditions on the stress that the birds experience, which affects their probability of survival and consequently other life history and demographic processes.

BSOSM-9238
P-9

Volume, heat and salt transport in the North-Eastern Bering Sea during 2007-2010 derived through the 4dvar data assimilation of *in situ* and satellite observation

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The circulation in the North-Eastern Bering Sea was reconstructed through 4Dvar data assimilation into two nested models with spatial resolution of 15km and 7km respectively. The variety of assimilated data includes both *in situ* (*e.g.*, temperature, salinity, velocity, surface drifters) and satellite (Sea Surface Height (SSH), Sea Surface Temperature (SST), ice concentration, velocity) observations. Our results that follow indicate significant intensification of the Bering Slope flow in winter and stronger variability of circulation over the Eastern Shelf during the summer and fall. Analysis of the obtained circulation patterns allows accurate estimates of major flows. Our analysis indicates that during 2007, 2008, and 2009, approximately 90% of the Bering Strait flow was from the Anadyr Strait, while flow through the Spanberg Strait contributed to only 10% of the Being Strait. This differs significantly from the previous (80% and 20%, respectively) estimates for these transports but agrees well with results of the Arctic Cap/HYCOM data assimilation system. We also present results of the adjoint sensitivity analysis and observing system simulation experiment with the goal to optimize velocity observations from high frequency radars and moorings in the Northern Bering Sea.

BSOSM-9239
P-10

Early reproduction by *Calanus glacialis* in the northern Bering Sea: The role of ice algae as revealed by molecular analysis

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Calanus glacialis initiated feeding and reproduction under extensive sea ice in the northern Bering Sea during late winter despite very low average water column chlorophyll a concentrations. Estimated egg production rates were between 0 and 12 eggs F⁻¹ Day⁻¹. Ingestion rates estimated from gut pigments were between 0.14 and 15.5 % Body C Day⁻¹ and were strongly correlated with surface chlorophyll. The dominant prey species in the guts of *C. glacialis,* the ice algal diatoms, *Fragilariopsis cylindrus*, *Fragilaria* sp. and *Pseudo-nitzschia* sp., were quantified by qPCR and species-specific ingestion rates estimated. The total of these was strongly correlated (r² =0.93) with, and similar to, those estimated from gut pigments. Feeding and reproduction was significantly related to air temperature lagged by 2 or 3 days and stimulated by a release of ice algae into the water column when air temperatures were warmer. The availability of ice algae over an extended period during colder winters will lead to a longer reproductive period and larger population sizes of *C. glacialis* compared with warmer years with less extensive ice cover.

BSOSM-9241
P-11

Internal tides over the Bering Sea slope and shelf

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Analyses of the 2-km resolution circulation model of the eastern Bering Sea suggest that semi-diurnal internal tides are energetic along the Bering Sea slope and over the outer shelf in summer. Surface current magnitudes associated with the internal tide may exceed 0.3 m/s in parts of the outer shelf. Some the internal tide energy is generated at the slopes of the Aleutian Island chain and propagated across the Bering Sea basin and some energy is generated locally along the Bering Sea slope, where the topographic barotropic to baroclinic energy conversion rate may be found in excess of 0.1 W/m2. The depth-integrated M2 baroclinic energy flux across the 200-m isobaths may in some places reach 100-700 W/m (for comparison, these values are 10 times as large as those on the Oregon). A large part of this energy dissipates at the outer shelf, contributing to mixing of the outer-shelf edge of the cold pool. Some part of that energy (on the order of 10 W/m) propagates over the strongly stratified cold pool and may contribute to its erosion on the inshore side. The energy flux is relatively intensified along the inner shelf edge of the pool. Further studies are needed to understand the role of internal tides in cross-slope material exchange and biological productivity in the Bering Sea.

BSOSM-9242
P-12

Integrated assessment of the carbon budget in the Southeastern Bering Sea

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During the primary field program for the Bering Ecosystem Study (2008 – 2010), independent seasonal estimates of net primary production (*NPP*), net community production (*NCP*), vertical export production (C_{exp}), and benthic carbon consumption (*BCC*) were used to construct a shelf-wide carbon budget for the southeastern Bering Sea. Here, we quantify the production, utilization, and transport of *NPP* on the annual scale for the southeastern shelf region of the Bering Sea (spatially partitioned into Outer, Middle, and Coastal Domains). We observed that lateral transport was the dominant mode of carbon export in the Outer Domain, exceeding C_{exp} by more than 30 g C m^{-2} yr^{-1}. In the Middle Domain, C_{exp} was more prominent than lateral transport (65 g C m^{-2} yr^{-1} and 46 g C m^{-2} yr^{-1}, respectively), and vertically exported carbon was more efficiently recycled in this Domain than in the Outer Domain (53% and 32% of C_{exp} respectively). In the Coastal Domain, lateral transport was a source of carbon to the bottom layer, with estimated input of carbon exceeding *NPP* by as much as 54 g C m^{-2} yr^{-1}. While the source of this additional carbon is unknown, one possible source is lateral transport from the Middle Domain during wind events that induce coastal convergence. The data presented here indicate a stronger pelagic character in the Outer Domain than previously estimated, and that the Middle Domain carbon budget is only balanced when including processes occurring in the Coastal Domain.

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P-13

Model-data synthesis and high resolution simulation of the Bering Sea

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We present results from several model-data synthesis projects for the Bering Sea. First, we discuss the result from the Bering Ecosystem STudy ice–ocean Modeling and Assimilation System (BESTMAS) over the period 1971–2013. We found that BESTMAS successfully captures the spatiotemporal variability of the trawl survey bottom temperature and water temperature variations at M2 mooring site. BESTMAS allows us to track how the Bering Sea ice-ocean system evolves in the past decades, including the observed warm and cold periods.

Second, we present results from the reconstruction of the ocean circulation in the Eastern Bering during the 2007-2010 through 4Dvar data assimilation. Analysis of the obtained circulation patterns allows for realistic estimation of major regional flows and temperature/salinity distributions. It indicates that 90% of the Bering Strait flow comes from the Anadyr Strait, while the Spanberg Strait flow contributes only 10% of the Being Strait flow. Results from the particle tracking and adjoint sensitivity analysis will be also discussed. Finally, the 2-km resolution ROMS model of the eastern Bering Sea, run for the ice-free period of July-October 2009, has explained ocean variability observed at shelf moorings, ARGO floats, and in satellite SST. This high-resolution solution has provided new insights about tidal and subtidal variability in the area, including fortnightly modulation in transports through Aleutian Island passes, irregular geometry of the cold pool edge, cross-shelf material transport by eddies, and internal tides.

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P-14

Toward a reliable wave hind cast/forecast in the Bering Sea

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Climate change has affected the Bering Sea during the last decade including wave conditions. To better represent wave hindcast in the Bering Sea, we present modeling results of the WAM model configured for the Bering Sea forced buy different wave products and a novel way to assimilate wave information into the wave models using Reduced space 4Dvar (R4Dvar) data assimilation approach. The model results include the validation of several wind products for the region and comparison with satellite observation. The employed assimilation method does not require development of the tangent linear and adjoint codes for implementation. It is based on minimization of the cost function in a sequence of low-dimensional subspaces of the control space. The twin-data experiments show that assimilation of the wave data allows improved wave hindcast and forecast. Future plans are to extend this project to the Northern Pacific (including the Hawaii regions) and analyze the inter-connection between wave activity in different regions.

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P-15

Beyond the colonies: Seasonally important marine areas for seabirds in the northern Bering Sea

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The northern Bering Sea is undergoing rapid climate change and increased human activity. To guide research and management of marine birds in the region, we examined broad-scale distribution of birds from 60°N to 66.6°N (the Arctic Circle, north of Bering Strait). We tested for significant "hotspots" of seabird densities in spring (March–May; pre-breeding, sea-ice maximum), summer (June–August; breeding season, sea-ice retreat), and fall (September–November; post-breeding/migration, sea-ice minimum). We used ~50,000 km of shipboard survey data from 2007–2012 and standardized densities (birds/km^2) in 40-km grid cells. Most species showed seasonal shifts in distribution. In spring, bird densities were highest in the outer shelf near the ice edge (especially for surface-feeding birds) and in polynyas within the pack ice (especially south of St. Lawrence Island for benthic-feeding eiders and some diving piscivores). In summer, densities were highest near colonies and near the shelf break/Navarin Canyon. Migrant phalaropes and shearwaters became abundant in summer, with the former aggregated near Bering Strait and the latter near Navarin Canyon. Fall had the highest bird densities and species-richness, with multiple hotspots in the Chirikov Basin and north of Bering Strait (especially for diving planktivores and shearwaters). Hotspots were typically areas with strong physical forcing, and based on concurrent studies, had abundant euphausiids or fishes. Identifying important marine areas for birds will be complicated by seasonal dynamics and predicted changes in sea-ice coverage.

BSOSM-9247
P-16

Considering the potential importance of sediment feeding by krill in the Bering Sea: Insights from the Atlantic and Southern Oceans

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Euphausiids are an important component of the Bering Sea ecosystem, serving as prey for many of the region's predators including pollock and seabirds. Traditionally euphausiids have been considered planktivores, thought to feed mainly on phytoplankton and small zooplankton in the water column. However, recent work in the Gulf of Maine and Southern Ocean suggests that for at least some species of krill, feeding on the sediment may also be an important source of nutrition. Advances in molecular techniques for analysing krill gut contents have allowed detection of morphologically indistinct prey consumed by krill in-situ with minimal a-priori assumptions. These approaches detected sediment associated organisms in krill gut contents, and suggest this sediment feeding may form a large fraction of krill diet under some conditions. Sediment feeding may be important for krill species more broadly, particularly in relatively shallow and highly seasonal ecosystems such as the Bering Sea shelf. Krill potential feeding on the sediment in the Bering Sea would form an unexplored link between the benthic and pelagic realms with implications for carbon cycling, ecosystem modelling, and effects of a changing climate.

BSOSM-9248
P-17

Using imaging flow cytometry to examine phytoplankton assemblage structure in the Bering Sea

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The composition of phytoplankton assemblages in the Bering Sea was examined using an automated individual cell imaging approach on five cruises in 2010, 2011, and 2013. These cruises spanned a wide range of seasons including late spring, summer, late summer, and early winter. Early summertime phytoplankton assemblages were typically dominated by large biomass of diatoms whereas early winter assemblages, although considerably lower in terms of biomass, were dominated by dinoflagellates and some diatom taxa. In several cruises nanophytoplankton and picophytoplankton were also examined using standard flow cytometry. Such detailed taxonomic information on nano- and microplankton assemblage composition derived from imaging flow cytometry, coupled with concurrent sampling of smaller cells using standard flow cytometry, provides an unprecedented view into the spatial structure of phytoplankton communities in the Bering Sea. This insight helps to advance understanding of how the complex physics and chemistry of the Bering Sea controls the distribution and timing of phytoplankton production.

BSOSM-9250
P-18

Water masses of the Eastern Bering Sea Shelf

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The BEST-BSIERP Bering Sea Project mounted or supplemented several research cruises in the Eastern Bering Sea in spring-autumn 2007-2010, greatly enhancing previous coverage especially during ice-covered conditions. Water mass designations help to simplify the understanding and clarify the origins of ecosystem properties. Examining the T-S (temperature-salinity) diagrams from over 2000 CTD casts collected during 11 cruises, we identified 3 previously known water masses – Anadyr (AW), Bering Shelf (BSW) and Alaska Coastal Water (ACW) – and 3 water masses modified by brine rejected during sea-ice formation – Rejected Brine-AW, RB-BSW, RB-ACW – that comprise the core of the Cold Pool. Water-mass maps reveal AW on the outer shelf, BSW on the middle shelf and ACW on the inner shelf south of 59°N. North of there, RB-BSW and RB-ACW occupy the middle and inner shelf. In summer 2008, Mordy *et al*. (doi: 10.1016/j.dsr2.2012.02.012) noticed a sharp decrease in the nutrient content of the lower layer in the central portion of the 70-m transect. A horizontal slice at 50 m shows that transect intersected low-nutrient ACW there with richer BSW to the north and south.

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P-19

The spring fate of ice algae in the Bering Sea

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Sea ice algae are an essential part of Arctic marine food webs, particularly in early spring when phytoplankton growth is low. In the Bering Sea, the spring ice melt releases large quantities of ice algae into the water, where they can be grazed by zooplankton, sink to the bottom, or remain viable and contribute to the phytoplankton by “seeding” the ice-edge bloom. As early spring grazing in the Bering Sea is low, the majority of the algae will either sink or seed. This study seeks to determine a) the diversity of sea ice and planktonic algae in the Bering Sea and b) if certain ice algal species are more likely to sink or seed during the spring ice melt. Comparisons between the species composition in ice, water and sediment trap samples are used to assess algal fate. Results show a significant vertical flux beneath Bering Sea ice, peaking in late April and early May. Differences in the species composition in the ice and sediment traps suggest that while a large portion of the ice algae sink, this fate varies by species. Additional evidence will be required to determine if this difference is the result of seeding, or other factors such as grazing, silicate dissolution, lateral advection or resuspension. Similar species compositions in the ice and the water suggest that the algae released during ice melt could be seeding the phytoplankton.

BSOSM-9252
P-20

Examining the composition of dissolved organic matter in the Bering Sea

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Dissolved organic matter is a large reservoir of reduced carbon which is a carbon and energy source for marine microbes. Variability in the type and concentration of dissolved organic matter may impact its utilization by microorganisms and thereby alter its fate in marine ecosystems. In the present project, water and sea ice samples were collected in the Bering Sea during the winter of 2011. I used ultrahigh resolution mass spectrometry to examine variability in the molecular level composition of dissolved organic matter extracted from the samples. This information was combined with data on the concentration of organic matter. The analysis reveals differences in the organic matter in sea ice compared to what is observed in the underlying water column. The present project is the first molecular level assessment of the composition of dissolved organic matter in sea ice. The combination of data on organic matter in water and sea ice will be useful in assessing the biological and chemical sinks of organic matter in polar regions.

BSOSM-9253
P-21

Towards understanding cross-shelf exchange in the Bering Canyon

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Shelf-basin exchange is widely recognized as having an important influence on the ecosystem of the eastern Bering Sea. Shelf-basin exchange in the Bering Sea is highly heterogeneous, with enhanced cross-shelf transport associated with submarine canyons. Processes responsible for such enhancement include the interaction of ocean currents, tides, and eddies with bottom topography, but the relative importance and variability of these mechanisms are not well understood. We combine *in situ* measurements and numerical simulations to study shelf-basin exchange over Bering Canyon, the southernmost canyon along the eastern Bering Sea shelf-break. Bering Canyon sits adjacent to Unimak Pass, the only conduit between the shelves of the eastern Bering Sea and the Gulf of Alaska. Our goal is to identify key processes that control cross-isobath flow and how these processes vary episodically and seasonally.

Hydrographic data have been collected on more than ten occasions from a region enclosing Unimak Pass. These data are used to examine water properties indicative of shelf-basin exchange, information that can inform interpretation of model results. Preliminary results from ROMS indicate intrusions of high salinity basin water from Bering Canyon onto the shelf as the season progresses from spring through fall. Flow through Unimak Pass is predominantly northward from the Gulf of Alaska to the Bering Sea on the eastern side of the pass; while on the western side, flow alters directions on synoptic time scales. Using model output, we will discuss the influence of various processes (tides, Unimak Pass fluxes, *etc.*) influencing shelf-basin exchange in the region.

BSOSM-9254
P-22

Linking sea ice retreat to plankton community structure and function in the Bering Sea: Data integration and synthesis

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Our objective is to determine how climate change, and the accompanying earlier retreat in seasonal sea ice, warmer ocean temperatures, and reduced sea ice extent will alter the structure and function of the planktonic food web in the Bering Sea during spring, and thus the ultimate fate of algal production, the utilization and cycling of carbon, and the production and availability of zooplankton as prey for upper trophic levels. We are addressing this objective through data integration and synthesis and bio-physical modeling. Here we will present results from the data integration and synthesis component of the project. Biological and physical data including mesozooplankton abundance, size, ingestion and reproduction rates, chlorophyll and primary production, and temperature collected during the BEST-BSIERP spring and summer cruises (2008-2010) were integrated to produce estimates of total mesozooplankton biomass, grazing impacts, and secondary production on the Bering Sea shelf during spring for each of the three field years. The objectives of the analyses were to describe spatial patterns and interannual variability in the integrated biological rate estimates and to provide synthetic products for model validation. We found that mesozooplankton biomass increased significantly during spring across most regions of the shelf as a result of high growth and reproduction rates. However, grazing impacts were generally very low, mostly less than 10% of the chlorophyll standing stock was grazed, but tended to be greatest on the middle to outer shelf. Overall, secondary production rates were quite high, especially in areas associated with ice-edge blooms.

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Assessing the importance of advective vs. *in-situ* processes to Euphausiid production in the Eastern Bering Sea

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In agreement with observations, the *BEST-NPZ* lower trophic level ecosystem model predicts a reduction in euphausiid biomass during warm periods. The model also predicts a reduction in secondary production of euphausiids on the shelf break and southern shelf with warmer temperature. No significant change in euphausiid production was predicted for the historic warm years (2001-2005) in the northern middle shelf. This heterogeneity in response to climate is likely due to the heterogeneity in the shelf environment; the northern shelf is generally colder with consistent winter/spring ice cover while the southern shelf and shelf break regions tend to be warmer and have a much greater intra and inter-annual variability in sea ice. Taking a regional approach to examining this spatial heterogeneity, we correlate the euphausiid production with temperature and ice cover in multiple Bering Sea bio-physical domains. We compare the magnitude of the horizontal flux of euphausiid biomass into each region to the in-situ production occurring within the region, in order to assess the relative importance of each process throughout the shelf.

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P-24

Timing and location of nitrate flux in the Eastern Bering Sea and its importance to primary production

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The Eastern Bering Sea shelf is one of the most productive regions in the world but shelf primary production is limited by both light and nutrient availability. Surface shelf waters are depleted of nutrients during the spring bloom, and subsequent primary production is dependent on nutrient re-supply via horizontal or vertical flux of nutrients to the upper mixed layer. Shelf nutrients are seasonally replenished by on-shelf flux of nutrient rich waters from the deep basin. Simulations with the *BEST-NPZ* lower trophic level ecosystem model suggest that the on-shelf flux of nitrate is generally greater on the southern half of the shelf and in the middle shelf around St Mathews Island. The on-shelf flux is greater during winter months and generally larger in warm years than cold years. Correlations between the horizontal and vertical nutrient flux into multiple Bering Sea bio-physical domains and the in-situ primary production with a region enable assessment of the relative importance of each process to productivity throughout the shelf, and determination of the critical periods of nutrient re-supply to Eastern Bering Sea primary production.

BSOSM-9259
P-25

How many euphausiids are there (really) in the eastern Bering Sea?

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Euphausiids are a key zooplankton taxon in the eastern Bering Sea (and in many other ecosystems), linking lower trophic levels to top predators. Despite their ubiquity, the absolute magnitude of euphausiid standing stock in the Bering Sea (principally *Thysanoessa* spp.) is not well known. Plankton nets provide a physical sample and high taxonomic precision, but since euphausiids are good at avoiding capture, nets probably underestimate euphausiid density. Acoustic-trawl methods have been used for high-resolution, large-scale surveys of euphausiids, but uncertainty in target strength (TS, the backscatter from a single euphausiid) values propagates to computations of derived density and biomass. In comparisons of net capture and acoustic density estimates in the literature, acoustic estimates are nearly always much higher; acoustic estimates of summer standing stock are nearly 70-fold higher in this data set. Finally, ecosystem (nutrients-phytoplankton-zooplankton or NPZ) models estimate euphausiid standing stocks, but incomplete knowledge of parameters and processes within these models can lead to large uncertainties in their output, as well. Here, we compare estimates of eastern Bering Sea euphausiid standing stock from nets, acoustics, ecosystem models, and the literature, and attempt to reconcile the differences. Applying 1) literature estimates of the magnitude of net avoidance by euphausiids and 2) an independent empirical estimate of TS from regressing net catch on measured backscatter indicates that revised net sample and acoustic estimates may be of the same order. The biases in absolute magnitude proposed here would not change the relative temporal or spatial patterns in these data sets.

BSOSM-9260
P-26

Imprint of ice edge phytoplankton production on summer macrozooplankton and fish populations in the eastern Bering Sea

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In the eastern Bering Sea, planktonic productivity was low under sea-ice but increased significantly along many regions of the marginal ice zone (MIZ) where new productivity exceeded 30 mmols m-2 d-1 and nitrogen f-ratios exceeded 0.8 over 4 field seasons (2007-10). The position of the bloom along the western edge of the MIZ in April-May in the outer part of the northern shelf was one of the most consistent features during the study. Its timing and intensity varied with the extent and timing of ice cover however, and was delayed in 2008 relative to 2007 and 2009. We compare the variations in ice edge productivity with parallel measurements of fish and macrozooplankton from acoustic surveys of the region in both spring and summer. Both the timing and the spatial extent of the phytoplankton bloom may be related to the trophic response observed in the acoustic data in that from year to year, the variation of the intensity of the bloom can be related to the subsequent macrozooplankton biomass, and to a lesser extent the young of the year fish. These relationships and their underlying mechanisms will be discussed.

BSOSM-9261
P-27

The legacy of the Bering Sea Project: Archival and preservation of the project data for current and future research

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The Bering Sea Integrated Ecosystem Research Program (BSIERP) developed and supported by North Pacific Research Board, and the Bering Sea Ecosystem Study (BEST) supported by the National Science Foundation addressed changes in the critical marine ecosystem of the Northern Pacific Bering Sea. More than one hundred scientists over a six year period engaged in field data collection, original research, and ecosystem modeling. The resulting 359 datasets set a new paradigm for critical information needed to answer key questions about these changes. The Earth Observing Laboratory (EOL) of the National Center for Atmospheric Research provided data management support to the BEST and BSIERP investigators, bringing their efforts together for archival into the Bering Sea Project Data Archive.

This poster gives an overview of the comprehensive data management support strategy that EOL provided for the Bering Sea Project: from early involvement with the science team in order to determine their requirements; to developing a specification for metadata and documentation; from the onboard ship support and implementation of the cruise Field Catalogs on ten different ships over four years; and developing online tools for submitting metadata and data; to geolocating Local and Traditional Knowledge stories with place names on a map. The lasting legacy is a database that cross references each unique investigator dataset, providing easy access to the metadata and data. EOL will assume long term stewardship of this unique data archive, and the poster will serve as a resource for how the archive has been conceptualized and organized.

BSOSM-9262
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Circulation in the Eastern Bering Sea: Inferences from a 2-kilometer-resolution model

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A 2 kilometer-resolution model of the Eastern Bering Sea is developed to capture dynamical processes on the scale of the Rossby radius of deformation on tidal to seasonal time scales. The high-resolution throughout ensures that the mesoscale dynamics of significant subregions of the domain, such as the Aleutian Island passes, Bering Sea slope, and the Bering Shelf canyons are captured simultaneously without concern for loss of interconnectivity between regions. Simulations are performed for the ice-free season (June-October) of 2009 forced with tides and atmospheric forcing. The model compares favorably with observations from AVHRR, Argo drifters and Bering Sea Shelf moorings. It captures mesoscale dynamics with diurnal and two-week variability through the eastern Aleutian Island passes. The two week oscillation (associated with the K1 and O1 tides) in volume flux through the largest of these passes (Amukta Pass) is found to be out of phase with the transport through the neighboring passes (*e.g.* Seguam Pass, Samalga Pass). Eddy formation, also with two-week periodicity, is noted over Bering Canyon where the Aleutian North Slope Current transitions into the Bering Slope Current. On the shelf, mesoscale structure is found to be ubiquitous along the mixing front of the cold pool. Structures at the scale of O(20 km) persist and play a role in determining the pattern of erosion of the water mass as the shelf warms and mixes.

BSOSM-9263
P-29

Multiple realizations of future biophysical states in the Bering Sea

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There is considerable uncertainty in projections of global climate over the coming decades; this uncertainly derives from both fundamental limits to predictability of the atmospheric/oceanic system, and our incomplete knowledge of future anthropogenic emissions of greenhouse gases. By extension, there is considerable uncertainty regarding future regional conditions in the Bering Sea. In order to assess probable mean conditions and their uncertainty in the Bering Sea, dowscaling simulations were carried out with a 10-layer regional biophysical model of the area. Regional hindcasts were driven by atmospheric forcing and oceanic boundary conditions derived from reanalyses of past conditions (chiefly CORE, SODA and NOAA's Climate Forecast System Reanalysis [CFSR]). Regional forecasts were driven by three CMIP3 global atmosphere/ocean models (CGCM3, MIROC, and ECHO-G). Results were averaged into the standard biophysical domains used in the BEST/BSIERP program. Decadal means of these results indicate a range of 0.5-1.5 C increase over present conditions by 2040 for the south middle shelf domain. On the mid-north middle shelf, a similar increase is observed, with somewhat larger uncertainty. Ice coverage on the southern middle shelf exhibits substantial interannual variability in 2010-2030, but reduced variability thereafter as the mean ice cover disappears. The ECHO-G model, which exhibits the coldest forecast, also exhibits the largest ice cover. Throughout these 10-layer runs, an inverse correlation was observed between spring temperatures and fall production of large crustacean zooplankton (neocalanus and euphausiids). Substantial decadal trends in this production were not observed, however.

BSOSM-9264
P-30

Seasonal variability of Net Community and Gross Photosynthetic Production (NCP and GPP) and the role of spring water column stratification in controlling ecosystem export efficiency on the Eastern Bering Sea shelf

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Using simultaneous measurements of O_2/Ar and Oxygen Triple Isotopes of dissolved O_2, we examined the seasonal variability of NCP and GPP, and NCP/GPP ratios, a measure of potential ecosystem carbon supply to the benthos or higher trophic levels. Data were collected in spring (April-May 2007 and 2008) and summer (July 2008) on the Eastern Bering Sea shelf. Summer NCP, integrated over the June-September period, was 3.6±1.2 mol-Cm^{-2}. A similar NCP estimate, 3.3±1.2 mol-Cm^{-2}, was determined by integrating the NCP rates over a month-long period of a spring bloom, developing in late April-May within the Marginal Ice Zones (MIZ).

Strong seasonal variability was observed in daily NCP, GPP and instantaneous NCP/GPP ratios. Within the spring blooms, average NCP was 110±40 mmol-$Cm^{-2}d^{-1}$, with daily fluxes increasing from ≤1 to >600 mmol-$Cm^{-2}d^{-1}$ through the progression of the bloom. Summer NCP rates averaged 30±11 mmol-$Cm^{-2}d^{-1}$. Shelf-averaged NCP/GPP ratios of 0.32±0.07 within the MIZ blooms exceeded by a factor of ~3 the average summer NCP/GPP ratios of 0.12±0.02. Statistically significant correlations between the NCP/GPP ratios and mixed layer depth, as well as water column stratification, was documented in spring, identifying stabilization of the water column by the melting ice as a main factor, driving exceptionally high export efficiency of late-spring blooms on the Eastern Bering Sea shelf. As both 2007 and 2008 were "cold" years, our results highlight the role of the ice extent and duration in stabilizing the water column, and thus regulating the extent of the benthic-pelagic shelf ecosystem coupling.

BSOSM-9265
P-31

Long term observations of currents on the middle shelf of the eastern Bering Sea

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Although the long term means of currents on the middle shelf of the Bering Sea (measured at M2, M4, M5, and M8) are very weak (~1cms-1), there are significant, different patterns on both seasonal and storm scales. These patterns differ among moorings and between top and bottom currents. At M2, summer surface currents are largely wind-driven. However, during the winter, bottom currents significantly modify the current structure of the whole water column. Winter currents, which provide paths of advection for nutrients, zooplankton and larval fish tend to parallel the Alaska peninsula. When ice is present, the directional response of currents to wind directions is restricted further. At M4 in summer significant southward bottom flow dominates the flow top to bottom. This southward flow is likely related to the cyclonic flow observed around the Pribilof Islands. At M5 mean bottom currents shift from southward in the summer to east-southeastward during the ice-covered winter. Summer currents at M8 are very weak. In winter, before ice covers the vicinity currents are strongly baroclinic, with dominantly westward flow, unrelated to winds. Only after ice covers M8 do the winds dominate the currents. Just as water properties differ from north to south on the middle shelf, there are differences in both speed and direction of mean and seasonal currents between the north and south, top and bottom. These differences define the location and intensity of replenishment of water properties, zooplankton, and larval fish.

BSOSM-9266
P-32

A nutrient flux budget among time-variable biophysical domains on the Bering Sea shelf

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The eastern Bering Sea shelf is highly productive. Historically this area has been classified into three or more biophysical domains, resulting primarily from the interaction of sloping bathymetry, tidal mixing, and surface forcing: 1) a nearshore region with a uniformly mixed water column; 2) a mid-shelf region with well-mixed surface and bottom layers, separated by intense stratification; 3) an outer-shelf region with surface and bottom mixed layers, separated by a thick stratum of moderately stratified water. The boundaries between these domains are broadly coincident with the local bathymetry; however, periodic fluctuations in tidal strength, as well as the variability of advection and wind-driven mixing, can modulate the boundaries through time. Using a multiyear biophysical model of circulation, nutrients and production in the Bering Sea, we classify the shelf waters into each of the domains on a weekly basis, and explore the time-varying advective and entrainment flux of nutrients across the domain boundaries. These results are contrasted with nutrient flux budgets based on geographically stationary boundaries (*e.g.* cross-isobath flux).

BSOSM-9267
P-33

Evaluation of extreme events over the Bering Sea simulated by the Community Climate System Model, Version 4

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Biological production in the Bering Sea not only supports several species of seabirds and marine mammals, but also supplies half of the marine harvest in United States waters. However, the Bering Sea ecosystem may be vulnerable to extreme events and long-duration anomalies, which are expected to increase in both duration and intensity with the changing climate (IPPC Special Report, 2012). Evaluation of multi-decadal Earth System Model simulations that include a coupled representation of ecosystems can improve our understanding of extreme events and their impact on high latitude marine ecosystems. This project evaluates the fourth version of the Community Climate System Model's ability to simulate extreme events relevant to critical components of the Bering Sea ecosystem. A comparison of the frequency of observed and simulated extreme atmospheric and oceanic events will be presented, along with a discussion of the extent and time frame of resultant biological responses.

BSOSM-9270
P-34

Modeling seasonal to multi-decadal dynamics of the Bering Sea using the Regional Arctic System Model

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Understanding the dynamics of the Bering Sea requires knowledge of the mean circulation, its upstream forcing, downstream linkages and their variability at seasonal to multi-decadal time scales. Such information is not readily available, as the region presents a number of challenges to both observational and modeling studies. While interdisciplinary and coordinated field programs, such as the BEST-BSIERP Bering Sea Project, add substantial amount of new observational data, climate models commonly are limited in realistic simulation of this region. This is in part due to the requirement of high spatial resolution needed to realistically simulate exchanges through narrow and/or shallow passages and mesoscale processes, such as eddies, coastal and slope currents controlling inter- and shelf-basin volume and property exchange. In addition, climate model representation of air-ice-ocean interactions and feedbacks in the Bering Sea is also incomplete, which affects their climate change prediction and impact assessment for the region.

To advance such model limitations we use a version of the Regional Arctic System Model (RASM), forced with the Coordinated Ocean-ice Reference Experiments version 2 (CORE2) atmospheric and hydrological reanalysis data for 1948-2007. Model results are analyzed to examine the sea ice and ocean states in the Bering Sea at seasonal to multi-decadal time scales. The overarching goal of this research is to quantify the long-term and seasonal means and variability of the circulation and water mass exchanges over multiple time scales across the Bering Sea using RASM.

BSOSM-9271
P-35

Combining shipboard data and a vertically generalized productivity model to resolve fine temporal and spatial scale variability in primary production on the Eastern Bering Sea Shelf

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The Eastern Bering Sea represents one of the most important commercial fisheries in the U.S. The Bering Sea shelf is expansive, and is physically partitioned into distinct cross-shelf and north/south domains, with each domain having unique ecosystem characteristics including seasonal nutrients, phytoplankton primary production (PP), benthic carbon flux, zooplankton and fish speciation and production. Springtime PP dominates annual PP, at least on the southern shelf, and the timing and magnitude of spring production varies, at least in part, with the extent of sea-ice, stratification and wind mixing. However, the interaction between timing, magnitude and spatial variability of PP and its fate within the Bering Sea ecosystem (*e.g.*, partitioning between pelagic and benthic fisheries), and how it might change with climate, remain largely open questions.

We combined the structure of a vertically generalized productivity model (VGPM) with the direct shipboard measurements of euphotic zone chlorophyll, temperature and daily insolation to estimate primary production on a station by station basis for multiple cruises over the period 2008-2010. Shipboard data were collected on 24 cruises each covering large areas of the Bering Sea shelf, and collectively covering over half of the ice-free growing season as well as periods of ice cover in spring. These results highlight the high spatial and temporal variability in the magnitude of primary production on the shelf that otherwise are smoothed over when using satellite based production estimates that average over much larger spatial areas and longer time scales.

BSOSM-9272
P-36

Dinoflagellate cysts in recent marine sediments of Russian coastal waters of the Bering Sea

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The quantitative and qualitative composition of live dinoflagellate cysts was studied in the upper two-centimeter layer of recent marine sediments, collected at 19 stations in Russian coastal waters of the Bering Sea. A total of 28 types of identified cysts belonged to 11 genera: *Alexandrium*, *Diplopsalis*, *Ensiculifera*, *Gonyaulax*, *Gyrodinium*, *Pentapharsodinium*, *Polykrikos*, *Preperidinium*, *Protoceratium*, *Protoperidinium*, and *Scrippsiella*. Cysts of the species *Gonyaulax spinifera*, *Pentapharsodinium dalei*, *Protoceratium reticulatum*, *Protoperidinium americanum*, *P. conicoides*, *P. subinerme*, *Scrippsiella crystallina*, and *S. trochoidea* were the most spread. The ones of the potentially toxic species *Alexandrium tamarense* were also widely distributed and prevailed in the studied area. Their concentration varied from 0 to 25, 860 cells/cm^3; the maximum concentration was recorded in Pavel Bay (Koryak Okrug, Kamchatka). Clonal cultures of *Alexandrium tamarense* were established by isolation and germinations of cysts. Some clones from Bering Sea produced almost 2.5 times more toxin (175.8 fmol cell^{-1}) and were 2/8 times more toxic (55,188.6 fg equiv. cell^{-1}) than any of other clones from Rusiian Far Eastern seas.

BSOSM-9273
P-37

Temporal shifts in seabird populations and spatial coherence with their prey in the southeastern Bering Sea

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Summer and fall can be energetically demanding periods for seabirds. In summer, breeding seabirds are central-place foragers and need to acquire enough prey within a radius of their breeding colony to feed rapidly growing chicks and for self maintenance. In fall, seabirds are non-central place foragers and many need to replenish depleted fat reserves reduced during the breeding season, undergo feather molt and replacement, and prepare for migration. We used 32,000 km of vessel-based surveys to examine annual and seasonal changes in seabird communities and spatial relationships with concurrently sampled prey in the southeastern Bering Sea. We compared seabird and prey densities during summer (June-July) and fall (late August-October) of 2008-2010 within a 400,000 km^2 study area. Prey sampled with hydroacoustics and nets were classified as age-0 and age-1 walleye pollock (*Theragra chalcogramma*) and Pacific cod (*Gadus macrocephalus*), other forage fishes, and euphausiids (*Thysanoessa* spp.). Diving piscivores and shearwaters (*Puffinus* spp.) dominated summer and fall seabird communities. Species richness and densities of all seabird foraging guilds tended to increase in fall *vs.* summer, most dramatically for surface feeding planktivores. Fall seabird densities showed little interannual variation, whereas summer densities were considerably lower in 2010. Seabirds and prey exhibited species-specific spatial patterns that were often consistent across years. In summer, breeding birds were concentrated around colonies and along the shelf break, then dispersed to the mid and inner shelf in the fall. Middle and inner shelf prey appear to be a particularly important fall resource for seabirds in the southeastern Bering Sea.

BSOSM-9274
P-38

Fatty acid and stable isotope characteristics of sea ice and pelagic particulate organic matter in the Bering Sea: Tools for estimating sea ice algal contribution to Arctic food web production

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We determined fatty acid (FA) profiles and carbon stable isotopic composition of individual FAs ($\delta^{13}C_{FA}$ values) from sea ice particulate organic matter (i-POM) and pelagic POM (p-POM) in the Bering Sea during maximum ice extent, ice melt, and ice-free conditions in 2010. Based on FA biomarkers, differences in relative composition of diatoms, dinoflagellates, and bacteria were inferred for i-POM versus p-POM and for seasonal succession stages in p-POM. Proportions of diatom markers were higher in i-POM (16:4n-1: 6.6 to 8.7%, 20:5n-3: 19.6 to 25.9%) than in p-POM (16:4n-1: 1.2 to 4.0%, 20:5n-3: 5.5 to 14.0%). The dinoflagellate marker 22:6n-3/20:5n-3 was highest in p-POM. Bacterial FA concentration was higher in the bottom 1 cm of sea ice (14 to 245 mg L^{-1}) than in the water column (0.6 to 1.7 mg L^{-1}). Many i-POM $\delta^{13}C_{FA}$ values were higher (up to ~10‰) than those of p-POM, and i-POM $\delta^{13}C_{FA}$ values increased with day length. The higher i-POM $\delta^{13}C_{FA}$ values are most likely related to the reduced dissolved inorganic carbon (DIC) availability within the semi-closed sea ice brine channel system. Based on a modified Rayleigh equation, the fraction of sea ice DIC fixed in i-POM ranged from 12 to 73%, implying that carbon was not limiting for primary productivity in the sympagic habitat. These differences in FA composition and $\delta^{13}C_{FA}$ values between i-POM and p-POM will aid efforts to track the proportional contribution of sea ice algal carbon to higher trophic levels in the Bering Sea and likely other Arctic seas.

BSOSM-9275
P-39

Decadal variability and predictability of ecosystem changes in the Bering Sea

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Internal atmospheric variability is one of the main drivers for ocean dynamical changes in the North Pacific with subsequent impacts on marine ecosystems and their productivity. Using the Community Earth System Model (CESM), version 1.0.3 with marine ecosystem and biogeochemical components we study the effects of atmospheric circulation changes on primary production in the Bering Sea. Our results suggest that wind-driven current and subsequent nutrient changes on decadal timescales play an important role in pre-conditioning shifts in ecosystems in the Bering Sea; but that the actual changes are much more controlled by combinations of high frequency variability in local mixing, light availability and zooplankton grazing. Implications of these results for the potential interannual to decadal predictability of plankton biomass variations are discussed.

BSOSM-9279
P-41

Nitrogen cycling on the Inner Shelf of the Eastern Bering Sea

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Portions of the inner shelf in the southern Bering Sea have little reactive nitrogen (relatively low advective flux and high rates of denitrification), but appreciable concentrations of chlorophyll. This raises the question: what are the sources of reactive nitrogen species to this region and how efficiently is N recycled? In this study, the flux of nitrogen on the inner shelf was explored using hydrographic observations (water properties, currents, nutrients, chlorophyll), rate measurements of nitrogen and carbon assimilation and sedimentary denitrification, respiration, and nitrogen efflux, and modeling of cross-shelf exchange at the inner front. These data were collected in 2007-2010 as part of the Bering Sea Ecosystem Study (BEST) – a multidisciplinary investigation of the regional ecosystem. Results show that in summer, new production at the inner front and regenerated production on the inner shelf are measurable despite the near absence of a dissolved nitrogen pool. Estimates of the cross shelf nutrient flux from ROMS simulations (with similar setups) at 10 km and 2 km resolution, were comparable, and used with rates of assimilation, sedimentary loss and efflux to create a nitrogen mass balance for the inner shelf.

BSOSM-9280
P-42

Coupled wind-forced controls of the Bering-Chukchi shelf circulation and the Bering Strait throughflow: Ekman transport, continental shelf waves, and variations of the Pacific-Arctic sea surface height gradient

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We develop a conceptual model of the closely co-dependent Bering shelf, Bering Strait, and Chukchi shelf circulation fields by evaluating the effects of wind stress over the North Pacific and western Arctic. This conceptual model suggests Bering Strait transport anomalies are primarily set by the longitudinal location of the Aleutian Low, which drives oppositely signed anomalies at synoptic and annual time scales. Synoptic time scale variations in shelf currents result from local wind forcing and remotely generated continental shelf waves, whereas annual variations are driven by basin scale adjustments to wind stress that alter the magnitude of the along-strait (meridional) pressure gradient. In particular, we show that storms centered over the Bering Sea excite continental shelf waves on the eastern Bering shelf that carry northward velocity anomalies northward through Bering Strait and along the Chukchi coast. The integrated effect of these storms tends to decrease the northward Bering Strait transport at annual to decadal time scales by imposing cyclonic wind stress curl over the Aleutian Basin and the Western Subarctic Gyre. Ekman suction then increases the water column density through isopycnal uplift, thereby decreasing the dynamic height, sea surface height, and along-strait pressure gradient. Storms displaced eastward over the Gulf of Alaska generate an opposite set of Bering shelf and Aleutian Basin responses. Over the western Chukchi and East Siberian seas prevailing winds promote coastal divergence, which also increases the along-strait pressure head, as well as generates shelf waves that impinge upon Bering Strait from the northwest.

BSOSM-9281
P-43

Using multi-species models to evaluate climate and trophic impacts on recommended harvest rates of groundfish in the Bering Sea (AK)

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Climate change has already altered marine ecosystems around the world and is postulated to cause a 2-4°C increase in SST for the Bering Sea (AK). Here we use multi-species food-web and assessment models (MSM) to link climate-driven changes in physical and trophodynamic conditions to recruitment and survival in order to distinguish fishery impacts from large-scale climate pressures. MSM simultaneously runs age-structured stock assessment models and links the models through estimates of predation mortality based on predator abundances in the model. In this study, we modified an existing MSM for three species of fish from the Bering Sea (walleye pollock, Pacific cod, and arrowtooth flounder) to incorporate temperature dependent predator rations estimated using Wisconsin bioenergetics models (*i.e.*, TMSM). We fit the model to hindcast-extracted time series then used downscaled IPCC scenario-driven ROMS/NPZ model estimates of temperature, circulation, and zooplankton abundance to project MSM forward to 2040 and derive multi-species biological reference points (MBRPs) for various harvest control rule approaches. Initial results indicate that TMSM estimates of recruitment are higher than those from analogous single species models, whereas harvestable biomass is lower. MBRPs are strongly influenced by harvest rates of predator populations and climate-driven changes to metabolic demand and recruitment. When fishing pressure on predators is attenuated, predation mortality increases and reduces unfished biomass of prey species. Our results demonstrate that prey species populations are strongly influenced by the interacting effects of climate and predator harvest rates, underscoring the importance of considering the interaction of both factors in fisheries management.

BSOSM-9308
P-44

Using vessel monitoring system (VMS) data to estimate spatial effort for unobserved trips in Bering Sea fisheries

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The primary characteristics of fishing effort - how much, how often, when, and where - are critical components for estimating the impacts of commercial fishing on target and non-target species, as well as on their habitats. For vessels that target a number of North Pacific species including pollock and Pacific cod, vessel monitoring systems (VMS) transmit fishing vessel locations and times at regular intervals, capturing vessel movement behaviors (*e.g.*, speed and turn angles). Thus, they offer an opportunity to resolve many of the uncertainties surrounding fishing effort in the absence of fishery observers. We used the eastern Bering Sea pollock catcher vessel fleet as a test case for utilizing VMS data to predict when fishing occurred. We combined VMS and 100% fishery observer coverage data from 2011 - 2013 to build generalized additive models of fishing effort. Out-of-sample model predictions of fishing and non-fishing behaviors yielded a high degree of accuracy both within and across years. Models were extended to data from 2003 - 2010 for which fishery observer coverage was 100% for a portion of the fleet and 30% for the remainder. Out-of-sample predictions for the 100% coverage vessels and for the observed portion of the 30% coverage vessels yielded similar prediction accuracies to those from 2011 - 2013. Models were then extended to the remainder of the fleet to predict fishing effort for the unobserved fishing trips. We also compared these models to speed filters that have been employed

in some cases to estimate fishing effort from VMS data, finding that speed filters commonly over-estimate the likelihood that fishing occurred. We are utilizing a similar methodology to estimate unobserved fishing effort for the Pacific cod fishery in the Bering Sea and the pollock and cod fisheries in the Gulf of Alaska. Our approach demonstrates an under-utilized opportunity for VMS data, providing probabilistic estimates of fishing behavior through a framework that is applicable across multiple gear types, target species, years, and management areas.

BSOSM-9314
P-45

Linking climate to Bering Sea fisheries via a new, trait-based copepod life-history model

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Interannual variability in recruitment of Bering Sea pollock has been linked to variability in large crustacean zooplankton (LCZs), which have greater success in cold years. A new life history model of *Calanus* spp. is helping identify the mechanisms behind this pattern. The model resolves structural biomass and lipid reserves for each life stage, and links growth, development, egg production, and mortality rates via individual size. Four stage-dependent parameters define life history and lipid strategy: activity level, fraction of prey assimilation stored as lipids, and egg production from assimilation and reserves. Results suggest that direct temperature effects cannot explain the increased success of LCZs in cold years: warmer winter temperatures cause faster depletion of lipid reserves, but the positive effect of warmer spring-summer temperatures outweighs it. Instead, *Calanus* success is found to be extremely sensitive to winter prey concentration (via reproductive timing), and thus to the production and release of ice algae before the spring bloom. Preliminary projections are presented for the 2040s, using the *Calanus* model in combination with regional biophysical projections.

BSOSM
P-46

Spatial and temporal variability in Bering and Chukchi Sea ostracodes from 1970 to 2013

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We investigated geographic distributions of benthic ostracode assemblages from Bering and Chukchi Sea surface sediments collected during the past 43 years to document benthic meiofaunal community structure and understand the influence of climatic and oceanographic changes. The study region includes continental shelf regions influenced by the Alaska Coastal Current and the Bering Sea Shelf Current. A total of 37 species were identified in the Chukchi Sea and 21 in the northern Bering Sea representing a diverse mixture of species characteristic of Arctic and sub-Arctic continental shelves. The dominant taxa are *Paracyprideis pseudopunctillata*, *Sarsicytheridea bradii*, and *Normanicythere leioderma* with secondary species *Semicytherura complanata*, *Cluthia cluthae*, *Cytheropteron elaeni*, *Heterocyprideis fascis*, *Robertsonites tuberculatus, Pectocythere janae*, and *Acanthocythereis dunelmensis*.

Results show temporal (decadal and interannual) and spatial variability in ostracode species assemblages and preliminary evidence for a decline in cryophilic species and an increase in temperate taxa most notable during the last decade. For example, the cold-water species *Normanicythere leioderma* provides evidence for changing ostraocde faunal composition. In the Chukchi Sea in 1970, it comprised 63% of the ostracode fauna in coastal and mid-shelf samples at depths averaging 20-40m. In the Hanna Shoal region, during 2002 and 2004, it represented 12% and 28% of the fauna. During the last decade, *N. leioderma* has declined to 1-2% of the assemblage in 2012 and 2013. However, in the northern Bering Sea, *N. leioderma* was the dominant species in the 1990s, with abundances between 49 to 80% and more recently between 17-36% in 2009 and 2010.

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