Arctic through a New Eye: Integrating and Visualizing Arctic Data

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Scientific data collection in the Arctic has grown exponentially in recent years through initiatives led by government, the oil and gas industry, and academic institutions. This includes real-time data, forecast models, time-series monitoring, and project level data. Continued effort is needed to maintain and expand these efforts. However, there is a simultaneous need to integrate existing information to better understand the environment, promote safe operations, and inform decisions regarding human activities.

Integrating arctic data is challenging. Many data sets are housed in isolated and physically dispersed agencies, sometimes across borders. Technical barriers such as complex data formats, lack of standardization, and inadequate or nonexistent metadata have also made acquiring and using available scientific information a daunting task. As a result, existing data are often underused in current planning and decision-making processes.

To help address these needs, the Alaska Ocean Observing System is developing interactive web-based tools to assist scientists, regulators, coastal managers, spill responders, and citizens. This presentation will highlight the AOOS Arctic Portal—an online interactive mapping application that visualizes model output, real-time sensor measurements, satellite imagery, and GIS layers in a seamless interface. When completed, users will be able to choose from over 2,000 layer options including satellite imagery, ocean circulation and temperature models, habitat maps, environmental sensitivity indices, ice parameters, and other layers.

The goal of this tool is to improve access to existing data and benefit a wide spectrum of management efforts. Potential applications include marine shipping, offshore development, conservation, climate change, and community planning.

The Pacific Marine Arctic Regional Synthesis (PacMARS)

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PacMARS will assemble, by mid-year 2013, up-to-date documentation that contributes to understanding the Pacific-influenced arctic ecosystem from St. Lawrence Island through Bering Strait into the Chukchi and Beaufort seas. Our objective is to compile the best available knowledge from local communities and peer-reviewed social and natural sciences, as well as less readily available sources. As seasonal sea ice declines in the Arctic, reaching a record minima in 2012, oil and gas exploration is increasing as is ship traffic using the Bering Strait. Within this context of environmental and likely socio-economic changes, wildlife populations and human communities are adjusting to shifts in seasonal sea ice coverage and climatic warming that has been much more obvious than at lower latitudes. Subsistence hunting patterns in the Arctic are changing, and it is also clear that many organisms, from plankton to top predators, may be changing migration and foraging patterns; productivity within the food web may also be changing. We seek input from the scientific community, local residents, and other stakeholders in assembling the best current knowledge in a short time frame. Community based meetings in Nome, Kotzebue, and Barrow will be held in early 2013 to seek participation and knowledge of traditional Iñupiat and St. Lawrence Island Yupik communities. Written synthesis products will identify vulnerabilities, potential mitigation, and opportunities in the Arctic during a period of rapid environmental change.

Climate Induced Changes in Arctic Marine Ecosystem Diversity with Consequences for Indigenous Communities

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Global warming has dramatically affected physical conditions in the Arctic, including shifts from multiyear ice to thinner ice, shorter ice covered periods, and increased freshwater runoff. These, and other effects, profoundly affect the function and diversity of marine food webs, and their ability to support fishes, mammals, and related species, which in turn affects ability of indigenous communities to harvest at the top of the food chain.

Prediction of the structure and diversity of arctic marine ecosystems under climate change is difficult. High arctic marine ecosystems are generally of low productivity and minimal littoral productivity, while subarctic ecosystems are some of the most productive in the world, e.g., the Bering and Barents seas. Indigenous communities have strong, direct dependencies upon the marine ecosystems as currently known. It is well known that some arctic species migrate south for the winter; it is less well known that boreal species migrate into arctic ecosystems, complicating the prediction of the structure of arctic marine ecosystems and food webs into the future and their ability to support indigenous artisanal fisheries.

Movement through the Bering Strait is discussed relative to artisanal fisheries, and to prospective commercial fisheries, while noting the productive fisheries to the south, in the subarctic Bering Sea. Policy limitations following from the current Arctic Council's mandate are shown to limit the likelihood that arctic fisheries can be sustainably managed.

Arctic Oil and Fisheries: Divergent Approaches to Management in Light of Scientific Uncertainty

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The federal government must account for substantial scientific uncertainty in making choices about whether and under what conditions to allow industrial activities in the Arctic Ocean, such as oil and gas leasing and drilling, commercial fishing, and shipping. Rapidly changing conditions and missing baseline information, for example, make it difficult to evaluate and plan for the potential impacts of these industrial activities. Confronted with the same uncertainties, federal agencies have taken very different approaches to managing arctic fisheries and oil and gas. On the one hand, the National Oceanic and Atmospheric Administration has put in place an Arctic Fishery Management Plan that precludes commercial fishing until there is better information on which to base management decisions. One the other hand, the Department of the Interior has authorized sales that have resulted in more than three million acres of leases sold to oil companies and has moved forward to allow exploration drilling in both the Chukchi and Beaufort seas. This review explores these dichotomous approaches and their causes, focusing on how the applicable statutory standards were applied in deciding whether or not to take proactive, precautionary action. It concludes that, independent of political pressure and agency culture, important factors enabling proactive management include congressional leadership, community involvement, and a corporate stake in sustainable management decisions. As industrial pressures mount in the Arctic, these lessons can be applied to future decisions in an effort to reduce controversy and move toward comprehensive planning for the region.

Temporal Variations of Particulate Backscatter Coefficient of the Arctic Using CALIPSO Lidar Measurements from 2006 to 2012

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The CALIPSO satellite, launched in spring 2006 and likely to last beyond 2015, carries a lidar that produces 532 nm backscatter profiles of the atmosphere and the ocean. The cross polarization measurements of the CALIPSO lidar can be used for estimating particulate backscatter from phytoplankton.

The polar orbiting satellite CALIPSO has good coverage of arctic oceans for both day and night measurements. Particulate backscatter measurements of the ocean subsurface are derived directly from CALIPSO's depolarization ratio measurements from the ocean profiles. The depolarization ratio measurements from CALIPSO is highly accurate and stable (the accuracy of depolarization ratio measurements is better than 1%) and thus the temporal changes of the measurements are highly reliable for detecting changes.

Using the six year CALIPSO lidar observatons, we have created a global database of particulate backscatter. The focus of this presentation is the study of the temporal variations of particulate backscatter of the Arctic.

The Main Features of Spatial Variability of Nutrients in the Russian Part of the Arctic Basin

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The features of nutrient distribution observed during the Russian "Shelf-2010" expedition on board the R/V *Akademic Fedorov* in August-September 2010 are discussed. The low concentrations of mineral nitrogen, observed for the major part of arctic surface water, indicate that primary production is limited by nitrogen and not by phosphorus and silicon. The regions with a high concentration of silicate (8-11µM) and mineral phosphorus (0.7-0.9µM) in the surface layer were traced over the Mendeleev Ridge, proceeding over the east slope of Lomonosov Ridge, extending to the north over all polar parts of it, and continuing in the Eurasian basin near the North Pole. The area of high nitrate concentration on the surface (1.6-2.0µM) doesn't coincide with the area of high phosphorus and silicate, and it is relatively displaced to the west. Such an increase in nutrient content at the surface over the ridges can be caused by the general rise in Pacific waters and their mixing with surface waters, which might cause the rise of nutrient concentration in the photic layer of the North Pole area and over the Mendeleev Ridge. The waters of Pacific origin characterized by high nutrient values at 30-150 m depth are traced up to the North Pole area. During movement of Pacific waters from the Bering Strait to the north, the core of these waters rises from the depth of 100 m to 40 m. The thickness of this layer becomes more than two times thinner, although the values of nutrients decline not so noticeably.

Thermal Sensitivity of the Isopod *Saduria entomon* in Nushagak Bay, Southwestern Alaska

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The pan-arctic benthic isopod *Saduria* (*Mesidotea*) *entomon* is a euryhaline species found in cold water oceans, bays, and estuaries. In arctic and subarctic regions, *Sadurida* is an important species in coastal food webs as an opportunistic predator/carrion shredder and detritus feeder. In southwest Alaska, in the subarctic Nushagak estuary, a large population of *Saduria* has been observed feeding on spawned out salmon and salmon processing effluent. Because of its niche *Saduria* serves an important function in the Nushagak estuarine food web. Can *Saduria* survive in warmer water as water temperatures continue to increase in southwest Alaska? Temperature tolerance was tested for *Saduria* collected from Squaw Creek, a small tributary that drains into Nusahgak estuary. Specimens were equilibrated to lab conditions at 10°C for a minimum of 10 days. Studies were conducted for three hour periods using a 2 meter trough with a 0 to 20ºC temperature gradient. Results indicated that *Saduria* are positively correlated to temperatures between 3 and 10ºC and negatively correlated to temperatures above 15ºC. Tidbit temperature loggers at collection sites in Squaw Creek in 2008 and 2009 found that summer water temperatures of Squaw Creek fluctuated between 5 (May) and 15ºC (August). Since August water temperatures reach levels that isopods avoid, the distribution of *Saduria* may be temperature dependent. Future work is needed to investigate the biota thermal sensitivity in subarctic watersheds such as Nushagak. This research may help answer questions about the relationship between warming water temperature and changing ecosystem functions.

Lower Trophic Level of Arctic Waters in a Changing Climate

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Changes in sea ice cover, ocean temperatures, and freshwater input in the Arctic Ocean are occurring more rapidly than model predictions of its response to atmospheric warming. In particular, the lengthening of the ice-free season over shallow arctic shelves may substantially alter dominant benthic communities and ecosystem services; however, the effects of a changing climate on high arctic benthic communities are largely unknown because baseline data are limited. Benthic food webs contribute to overall production, carbon cycling, and remineralization of nutrients in arctic ecosystems and thus are critical to our understanding of ecosystem functioning and stability. The purpose of this study was to investigate regional benthic food webs on the Alaska Beaufort Sea shelf using stable carbon and nitrogen isotope ratios. Five regions were distinguished along the shelf to evaluate whether food web structure and food source characteristics varied among regions. Total food web length ranged from 4.1 to 5.2 TL (trophic level) for the regions sampled. Trophic structures were similar among west shallow and deep sites and among central shallow and east regions. The central deep region was distinct as several taxa occupied TL 5. Environmental structure was clearly distinct in the east with a marine δ13C signal (–20.6 to –23.3‰). A terrestrial δ13C signal was apparent at the mouth of the Colville River in the central shallow regions (–25.6 to –26.4‰). Even with variability of food source isotope signatures and environmental conditions within regions, food sources and environment predicted food web structure on the Beaufort Sea shelf.

Thermal Optimum and Upper Limits of Arctic Cod (*Boreogadus saida*)

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Arctic Ocean physicochemistry is rapidly changing and it is vital to acquire baseline thermal data for marine fish to predict arctic species survival. The keystone ectotherm species arctic cod (*Boreogadus saida*) was selected to quantify optimum conditions at different life stages including their range in thermal tolerance. This type of data is required to accurately forecast their chances of survival.

To quantify the potential impact these changes will have on arctic cod required a method that measures whole animal performance and is pragmatic enough to be applied in trying field conditions in the Arctic.

The aerobic scope concept, originally conceived by Fred Fry, one of Canada's pioneers in fish physiology, quantifies the amount of oxygen an animal has to carry out all activities above and beyond the oxygen needed for life support. It is a good measure of performance but unfortunately measuring aerobic scope accurately in fishes does not fall into the category of pragmatic in trying field conditions. Hence there has been a recent development of an indirect, high throughput index of temperature optimums (Topt) for aerobic scope in fishes, specifically simplified for field applications.

This method is based on measuring heart rate in active animals, and the Arrhenius plots generated highlight break points that represent Topt and upper thermal limits (Tmax). Results from 2 years of field trials and long-term temperature acclimation experiments will be presented, conducted on wild populations of arctic cod from Cambridge Bay, Nunavut.

Comparing the Feeding Ecologies of Three Abundant Fish Species the Chukchi and Beaufort Seas

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Climate change in arctic marine environments could alter the current structure of food webs. Arctic cod (*Boreogadus saida*), arctic staghorn sculpin (*Gymnocanthus tricuspis*), and shorthorn sculpin (*Myoxocephalus scorpius*) are abundant in the Chukchi and Beaufort seas and are important forage for marine mammals, birds, and other fishes. While the distribution and trophic importance of these species is well documented, less is known about their feeding ecology. This study compares the diets of these three species across both seas to highlight differences in resource use. Diet differences were examined by percent weight (%W), percent occurrence (%O), and multi-dimensional scaling (MDS) techniques. Preliminary results across both seas indicate calanoid copepods (mostly *Calanus* sp.) were very important to *B. saida*, but not to sculpins in this study. Hyperiid amphipods (*Themisto* sp.) were important across both seas to *B. saida* and *M. scorpius* only, with a larger %W and %O for both species in the Beaufort Sea. Gammaridean amphipods were important contributors across all species and seas except for *B. saida* in the Beaufort Sea. *G. tricuspis* diets were dominated by gammaridean amphipods in the Chukchi Sea and polychaetes in the Beaufort Sea. Overall, there appears to be a difference in resource use within species across both seas. The intent of this research is to advance our understanding of present day trophic structure in the Arctic. As the climate continues to change, knowledge of the current role of fishes in arctic food webs will be valuable in evaluating any changes in feeding ecology.

Trophic Relationships of Five Species of Demersal Fishes in the Northeastern Chukchi Sea, 2009-2010

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Fishes in the Arctic are important components of the ecosystem, both as predators and as prey. As the Arctic warms and sea ice decreases, prey availability for fishes and other predators is expected to change. Consistent records of marine trophic structure are important to scientists as climate change occurs. This study examined stomach contents and stable isotopes of five fish species collected in 2009-2010 in the Chukchi Sea. These species were selected for diet and stable isotope analyses based on their prevalence on the sampling grounds and because they represented major taxonomic families of the Chukchi Sea. The selected species were arctic cod (*Boreogadus saida*, family Gadidae, cods); arctic staghorn sculpin (*Gymnocanthus tricuspis*, family Cottidae, sculpins); polar eelpout (*Lycodes polaris*, family Zoarcidae, eelpouts); stout eelblenny (*Anisarchus medius*, family Stichaeidae, pricklebacks); and Bering flounder (*Hippoglossoides robustus*, family Pleuronectidae, flatfishes). Differences in diet were found among species and among size classes within species. Stable isotope analysis showed differences among species in both trophic level and benthic versus pelagic foraging strategy. Diet analysis results supported the stable isotope results. Arctic cod consumed pelagic prey at the lowest trophic level, while polar eelpout fed on benthic prey at the highest trophic level. Bering flounder, arctic staghorn sculpin, and stout eelblenny fell in between arctic cod and polar eelpout in terms of trophic placement and foraging strategies. These observed differences may indicate that climate change could differentially impact arctic fishes, potentially affecting other predators in the arctic food web.

Richness and Diversity of Demersal Fishes in the Chukchi Sea over 50 Years

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Because of potential climate change and oil exploration, it is necessary to examine historical fish collections in the eastern Chukchi Sea. We analyzed the fish catches of 14 cruises in 13 years over the 50-year period from 1959 through 2008. Eight different configurations of trawl gears were used for 501 unique bottom hauls at 406 stations. Cruises were in the ice-free months June-September, though most were in August and September. Approximately 169,000 fishes were collected of 59 species and 80 taxa. Smaller-mesh nets retained more fish and produced greater richness and diversity indices. There was an apparent increase in fish diversity in recent years. Richness and diversity indices were high, indicating stable community structures, at and straight north of Bering Strait, including the southwest part of Lease Sale 193. In contrast, richness and diversity were low, indicating low stability, in the northern parts of Lease Sale 193. Variability in year, month, and location of collections over 50 years confounded interpretation of effects of physical environment factors on fish in this study, i.e., temperature, salinity, depth, and water mass. Use of multiple gears further confounded interpretation of the results. Consistent monitoring of fish and associated oceanographic variables in Lease Sale 193 should be conducted with the same trawl gear, in late August every 3 or 4 years, to establish a foundation for evaluating distributional shifts of fishes in the eastern Chukchi Sea. The apparent increases in diversity could as easily be due to increased knowledge of the identity of the arctic fishes and increased density and timing of sampling, as to any actual change in number of species present.

Sourcing Fatty Acids to Juvenile Arctic Cod (*Boreogadus saida*) in the Beaufort Sea Using Compound Specific Stable Carbon Isotope Analyses

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Arctic warming has resulted in the reduction of both the extent and thickness of sea ice in seasonally ice-covered waters. Sea ice is a defining feature of the arctic marine ecosystem and serves as important habitat for microalgae and fish. Continued reduction in sea ice coverage could cause a decrease in sea ice algae, which is a potentially important source of primary production (including fatty acids, FA) for higher trophic levels. Arctic cod (*Boreogadus saida*), particularly juveniles, are often found in close association with sea ice and represent an important trophic link in the arctic food web. However, the proportional contribution of sea ice algal production via the sympagic food web to the diet of arctic cod is unknown. We used compound-specific stable carbon isotope analysis of individual FA in juvenile arctic cod collected from three regions in the Beaufort Sea (2011, n = 33) to estimate the proportional contribution of these compounds from sea ice particulate organic matter (iPOM) relative to pelagic POM (pPOM). The δ13C values (mean ±1std) of the FA 14:0 (–31.6‰ ±0.6); 16:4n–1 (–32.6‰ ±1.7); 18:0 (–30.1‰ ±0.7); 20:5n–3 (–31.2‰ ±0.6); 22:6n–3 (–31.6‰ ±0.7) in the arctic cod were compared with those from the same FA in iPOM and pPOM and resemble pPOM. Our data provide no evidence of the FA in these juvenile arctic cod having being derived from iPOM. The small variability in δ13C values for these FA in arctic cod indicates a narrow feeding niche for these juvenile fish across the Beaufort Sea.

The Effects of Climate Variability on Juvenile Pink and Chum Salmon Growth and Condition in the Northeastern Bering and Chukchi Seas

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The Arctic is warming at an unprecedented rate. Associated with rising temperatures are decreases in thickness and coverage of summer snow and ice. These changes in temperature and summer sea-ice extent are resulting in a notable shift in the northeastern Bering Sea and Chukchi Sea (NEBS/CS) systems from arctic to more subarctic conditions. Increases in the abundance of juvenile chum (*Oncorhynchus keta*) and pink salmon (*O. gorbuscha*) might be expected in the Arctic; however, to date, there is limited information on salmon distribution in the Chukchi Sea. This project will focus on the ability of the NEBS/CS regions to support juvenile pink and chum salmon growth by measuring insulin-like growth factor-I (IGF-I) levels, energy content, and analyzing diet from sampling in 2012 and 2013. IGF-I is a growth hormone that stimulates muscle and cartilage growth and is an accurate measure of relative growth rate in many teleost species. In addition to data collected during scheduled 2012 and 2013 surveys, this project will use diet and energetic data collected by the Bering-Aleutian Salmon International Surveys (BASIS) to make a comparison between warm (2001-2005) and cold (2006-present) regimes. The possibility of increasing utilization of the Arctic for summer feeding grounds by juvenile salmon requires an assessment of these arctic regions to determine whether the habitats are conducive to early developmental growth and condition of salmon species. Understanding the relationships between diet, growth, and temperature are necessary in order to benefit fisheries managed salmon returns and assist in adaptation of fishery management to increasing climate variability.

Trophic Dynamics of Chukchi Sea Fishes

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With declining sea-ice extent, and longer open-water seasons, there is an increasing interest in shipping, oil exploration, and commercial fishing in the Arctic. Anticipated natural and anthropogenic changes are expected to alter the ecosystem of the Chukchi Sea, including its fish communities. As a component of the Arctic Ecosystem Integrated Study, this project presents a unique opportunity to collect baseline C and N stable isotope data to assess the ontogenetic, spatial, and temporal variability of the trophic roles (trophic level and diet source) of key fish species in the Chukchi Sea in a relatively pristine system and in the absence of a commercial fishery. Unlike diet analysis, stable isotope analysis integrates only food items assimilated by consumers, accurately representing a transfer of energy between trophic levels, and integrates diet over a longer time-scale. During August and September of 2012 and 2013, 16 fish species and 4 baseline invertebrate species will be collected from surface, midwater, and bottom (only 2012) trawls within the Chukchi Sea. We will outline our project goals, provide a general overview of the Chukchi Sea food web, and present preliminary data on the length and spatial distributions of the samples collected in the 2012 field season. Additionally, we hope to include preliminary analysis of stable isotope results for saffron cod (*Eleginus gracilis*) and chum salmon (*Oncorhynchus keta*).

The Spatial-Temporal Distribution of Arctic Cod (*Boreogadus saida*) in the Western Arctic Ocean and Its Response to Climate Change

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A generalized additive model (GAM) was applied to multi-approach survey data to reveal the influences of environmental factors on the abundance of arctic cod (*Boreogadus saida*). The abundance data came from the "Data Warehouse" of the School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, and the climate change data were derived from the NOAA Earth System Research Laboratory. The result showed that the abundance of arctic cod had a significant decadal variation, and the abundance in the 1980s was about 3 times higher than in the 1960s. The average abundance was very low from January to May and higher abundance occurred in August, September, and December. Monthly abundances also varied significantly. Higher abundances were distributed in the waters off Barrow and in the Gulf of Anadyr in the 1950s, in the waters off Inuvik and in the Dease Strait in the 1960s, in the Chukchi Sea and Beaufort Sea in the 1970s, in the Beaufort Sea in the 1980s, in the Bering Sea (southern St. Lawrence Island) in the 1990s, and in the Bering Strait and Chukchi Sea in 2000-2007. The results indicated nonlinear responses of abundance to the environmental covariates. The total deviance level in the GAM model attributed to abundance was 26.60%, the largest contribution was derived from the item "year" at 8.69%, and the next contribution levels were the Arctic Oscillation (AO) index (2.79%), Western Hemisphere Warm Pool (WHWP) index (2.46%), and longitude (2.42%).

Ichthyoplankton Collected on the 2004 and 2009 Russian-American Long-Term Census of the Arctic Research Cruises

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We present results on the taxonomic diversity, abundances, distributions, and lengths of ichthyoplankton sampled during the second biological survey of the Russian-American Long-Term Census of the Arctic (RUSALCA) Program. A 60 cm bongo net with 505 μm mesh towed at 2 knots was used to collect samples at 31 stations in the Chukchi Sea 4-29 September 2009. Thirty-four larval and juvenile fishes were collected, composed of 10 species in seven families. Arctic cod (*Boreogadus saida*) was the dominant species accounting for nearly half of the larvae and juvenile fishes caught. Abundances and taxonomic diversity of ichthyoplankton caught in 2009 were considerably lower than was observed in the first RUSALCA survey (10-22 August 2004), which used the same sampling methods at 18 stations in a smaller geographic area. At 13 stations sampled in both surveys, no arctic cod were collected in 2009 while 101 individuals were caught at eight stations in 2004. Mean standard length (SL) of arctic cod caught in 2009 (26.7 mm) was significantly greater than in 2004 (16.4 mm). Possible explanations for the lower abundance and greater lengths of arctic cod observed in 2009 include a one month later survey date, gear avoidance by larger individuals, and a shift in distribution related to oceanographic conditions. We suggest that a net with larger mesh size and mouth opening that can be towed at greater speed may be more effective at catching larval and juvenile fish during late summer in the Chukchi Sea.

Physical-Biological Interactions Governing Spatial Distributions and Abundance of Beluga Whales in Cook Inlet, Alaska

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Annual abundance estimates of the endangered beluga whales (*Delphinapterus leucas*) in Cook Inlet, Alaska, have indicated a decline in the population over the past decades, but no convincing explanation has been offered so far for this trend. However, spatial data from annual aerial surveys of Cook Inlet, compared with corresponding flow rates during May from six indicator rivers, indicated strong relationships between rates of river discharge and beluga distributions and abundance in the Upper Cook Inlet. Thus, belugas moved away from the Susitna Delta when flow rate from the Susitna River was low relative to rivers draining into the Knik Arm and Turnagain Arm. River discharge during May explained 86% of the interannual variability in survey abundances recorded in the Susitna Delta, and 56% of the variability in the overall Abundance Index. Moreover, statistically significant correlations were found between seasonal movements of belugas tracked by satellite and the timing of peak flows at different rivers. Interannual variation in seasonal movements was also found to relate to year-to-year variations in water temperature and the time of ice melt/freezing, while population estimates showed a 3-4 year cycle of interannual variation resembling the Pacific Decadal Oscillation index. Although the exact mechanism by which large-scale climate variation impacts belugas is not yet clear, these relationships suggest that climate influences on highly dynamic habitat availability determine beluga spatial distributions, and interannual changes in these distributions may have an important effect on population estimates for Cook Inlet.

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