NOAA Technical Memorandum NMFS-AFSC-433

Bibliography: Northern Bering Sea

J. D. Stephens and R. A. McConnaughey (editors)

March 2022

U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center

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This document should be cited as follows:

Stephens, J. D., and R. A. McConnaughey (editors). 2022. Bibliography: Northern Bering Sea. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-433, 156 p.

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NOAA FISHERIES

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March 2022

Introduction

The northern Bering Sea (NBS) is a region in transition. Since 2008, much of the northern Bering Sea has been designated as a research area by the North Pacific Fishery Management Council. The Northern Bering Sea Research Area (NBSRA) is closed to non-pelagic bottom trawling in anticipation of ecosystem shifts in response to climate change. The NBSRA is to remain closed until the impacts of bottom trawling on this relatively undisturbed environment are understood.

This bibliography is part of an effort to gather existing data on the NBS to support future research in the NBSRA, and contains information on the biology, oceanography, geology, climate, and cultural heritage of the region. The rest of this introduction is designed to illustrate the types of information that can be found in the bibliography and is not intended to be a complete synthesis describing the region.

The NBS is defined as the part of the Bering Sea north of St. Matthew Island and Nunivak Island (Fig. 1). In the north, the Bering Strait forms the gateway between the Bering and Chukchi seas and provides the only outlet of Arctic waters into the Pacific. The NBS is also divided by a maritime boundary between U.S. and Russian waters.

St. Lawrence Island lies in the center of the NBS, and it is notable for several studies on its sea birds and an annual polynya (opening in sea ice) that occurs south of the island with considerable ecosystem effects. The Alaska coast features the Yukon-Kuskokwim Delta, which provides essential coastal habitat as well as the bulk of the terrigenous sediment inputs into the surrounding continental shelf.

The NBS region is inhabited by several Alaska Native communities, which are an important source of traditional knowledge on the area's climate and ecosystems. In particular, marine mammal subsistence hunting is deeply culturally important to these communities. Alaska Native tribes are federally recognized sovereign nations and have an elevated status in any decisions that affect tribal resources. This bibliography catalogues publications from several Alaska Native groups.

Climate change is a major concern in the NBS. Sea ice forms in the NBS each winter, but ice cover has been shrinking in recent years. This change is bringing a myriad of ecosystem effects on species, ranging from the spring plankton blooms to fish and marine mammals. Seals and walrus are particularly dependent on sea ice for birthing and haulouts, and they are projected to follow the ice as it retreats northward.

Warming waters in the southeast Bering Sea are shifting populations of fishes and crabs northward into the NBS. These changes are likely to have major impacts on commercially significant fisheries, but the full extent of these changes is still unknown and likely to vary from species to species. Whale populations (including bowhead, beluga, and gray whales) are

expected to change migratory patterns in response to the changing climate and shifting food supplies.

The information presented here is also available online in the Alaska Spatial bibliography at https://maps.coastalscience.noaa.gov/alaskaspatialbibliography/.

Figure 1. -- The focus area for the Northern Bering Sea Bibliography match the boundaries of the NBSRA and St. Lawrence Island Habitat Conservation Area as described by the Research Plan in NOAA-NMFS Alaska Fisheries Science Center (2012).

Bibliography

Aagaard, K., T. J. Weingartner, S. L. Danielson, R. A. Woodgate, G. C. Johnson, and T. E. Whitledge. 2006. Some controls on flow and salinity in Bering Strait. Geophysical Research Letters. 33(19):L19602. https://doi.org/10.1029/2006gl026612

***Keywords*:** currents; salinity; modelling; Bering Strait

***Abstract*:** During 1993–1994, steric forcing of flow through Bering Strait represented a northward sea level drop of ∼0.7 m from the Bering Sea Basin to the adjacent deep Arctic Ocean, of which ∼2/3 was due to the salinity difference between the basins. Seasonal variability of steric forcing appears small (<0.05 m), in contrast to large seasonal wind effects. Interannual changes in steric forcing may exceed 20%, however, and warm inflow from the North Atlantic, accumulation of freshwater in the southwest Canada Basin, and temperature and salinity changes in the upper Bering Sea have all contributed to recent changes. The mean salinity balance in Bering Strait is primarily maintained by large runoff to the Bering shelf, dilute coastal inflow from the Gulf of Alaska, and on-shelf movement of saline and nutrient-rich oceanic waters from the Bering Sea Basin. In Bering Strait, therefore, both the throughflow and its salinity are affected by remote events.

Ager, T. A., and R. L. Phillips. 2008. Pollen evidence for late Pleistocene Bering land bridge environments from Norton Sound, northeastern Bering Sea, Alaska. Arctic, Antarctic, and Alpine Research. 40(3):451-461. https://doi.org/10.1657/1523-0430(07-076)[AGER]2.0.CO;2

***Keywords*:** paleoenvironment; climate; glaciers; sea level

***Abstract*:** After more than half a century of paleoenvironmental investigations, disagreements persist as to the nature of vegetation type and climate of the Bering land bridge (BLB) during the late Wisconsin (Sartan) glacial interval. Few data exist from sites on the former land bridge, now submerged under the Bering and Chukchi seas. Two hypotheses have emerged during the past decade. The first, based on pollen data from Bering Sea islands and adjacent mainlands of western Alaska and Northeast Siberia, represents the likely predominant vegetation on the Bering land bridge during full-glacial conditions: graminoid-herb-willow tundra vegetation associated with cold, dry winters and cool, dry summer climate. The second hypothesis suggests that dwarf birch-shrub-herb tundra formed a broad belt across the BLB, and that mesic vegetation was associated with cold, snowier winters and moist, cool summers. As a step towards resolving this controversy, a sediment core from Norton Sound, northeastern Bering Sea was radiocarbon dated and analyzed for pollen content. Two pollen zones were identified. The older, bracketed by radiocarbon ages of 29,500 and 11,515 14C yr BP, contains pollen assemblages composed of grass, sedge, wormwood, willow, and a variety of herb (forb) taxa. These assemblages are interpreted to represent graminoid-herb-willow tundra vegetation that developed under an arid, cool climate regime. The younger pollen zone sediments were deposited about 11,515 14C yr BP, when rising sea level had begun to flood the BLB. This

younger pollen zone contains pollen of birch, willow, heaths, aquatic plants, and spores of sphagnum moss. This is interpreted to represent a late glacial dwarf birch-heath-willow-herb tundra vegetation, likely associated with a wetter climate with deeper winter snows, and moist, cool summers. This record supports the first hypothesis; that graminoid-herb-willow tundra vegetation extended into the lowlands of the BLB during full glacial conditions of the late Wisconsin.

Albrecht, G. T., A. E. Valentin, K. J. Hundertmark, and S. M. Hardy. 2014. Panmixia in Alaskan populations of the snow crab *Chionoecetes opilio* (Malacostraca: Decapoda) in the Bering, Chukchi, and Beaufort Seas. Journal of Crustacean Biology. 34(1):31-39. https://doi.org/10.1163/1937240x-00002197

Keywords**:** snow crab; population structure; ecosystem shifts

Abstract**:** Decreasing sea ice in the Arctic is expected to impact marine ecosystems, and to lead to increased human activity in the form of shipping traffic, fishing pressure, and mineral resource exploration and extraction. In the face of these pressures, we examine genetic population structure in the snow crab *Chionoecetes opilio* (Fabricius, 1788), throughout its distribution in Alaskan waters, to determine degrees of population connectivity between the Arctic and more southerly portions of the species' range. Snow crabs are widely distributed on the high-latitude continental shelves of North America, where they support a valuable commercial fishery in the United States and Canada. Fishing pressure in United States waters is currently concentrated in the Bering Sea, but large populations of snow crab also occur farther north in the Chukchi and Beaufort Seas. These northern stocks are not well studied, and not yet targeted by fisheries, although commercial-sized individuals were recently reported in areas of the Western Beaufort Sea. We used seven polymorphic microsatellite markers to examine tissue samples from 573 individual crabs collected at 12 sampling locations distributed across the Bering, Chukchi, and Beaufort Seas. These data indicate that Alaskan snow crabs constitute one large, panmictic population. Connectivity between fishery areas in the south and unexploited regions farther north thus appears to be substantial, perhaps due to a lengthy larval dispersal period and highly mobile adult population.

Alexander, V. 1995. The influence of the structure and function of the marine food web on the dynamics of contaminants in Arctic Ocean ecosystems. Science of the Total Environment. 160-161:593-603. https://doi.org/10.1016/0048-9697(95)04394-g

Keywords**:** pollution; arctic ecosystems; atmospheric transport; Arctic Ocean; airborne contaminants

Abstract**:** This paper examines some features of arctic marine ecosystems that may render them vulnerable to airborne pollutants. These features include the seasonal and spatial focus of primary productivity, the allocation of a relatively large proportion of the newly fixed carbon to the benthos, the prevalence of large mammals as apex consumers, and

relatively high lipid levels in many arctic species. Sea ice is an important factor, since pollutants falling onto the ice surface during the winter months can be concentrated in epontic particulate matter (at the ice/seawater interface), or, more likely, be released through melting of the ice and enter the planktonic system in spring, reaching the benthos via sedimentation. Two ecosystems are discussed in which these processes are likely to be important — the highly productive Chirikov Basin of the northern Bering Sea and the sea ice-associated community north of Svalbard. There is evidence that pollutants are accumulating in arctic marine ecosystems. However, our predictive ability is constrained by the inability to delineate the sites of deposition.

Atlas, R. M., M. I. Venkatesan, I. R. Kaplan, R. A. Feely, R. P. Griffiths, and R. Y. Morita. 1983. Distribution of hydrocarbons and microbial populations related to sedimentation processes in lower Cook Inlet and Norton Sound, Alaska. Arctic. 36(3):251-261. http://www.jstor.org/stable/40509517

Keywords**:** arctic marine ecosystems; sedimentation; microorganisms; hydrocarbons; lower Cook Inlet; Norton Sound

Abstract**:** In spring and summer 1978 and spring 1979 an integrated study was carried out to examine the interrelationships of physical (sediment deposition), chemical (organic carbon and hydrocarbon concentrations), and biological (microbial populations and activities) factors in the Cook Inlet and Norton Sound regions with respect to the probable sinks and fates of hydrocarbon contaminants within these ecosystems. Most of the fine-grained sediment entering Cook Inlet is transported out of the inlet into Shelikof Strait; however, significant sediment accumulation occurs within areas of Kamishak and Kachemak bays. In Norton Sound, sediment from the Yukon River is transported counterclockwise around the embayment and approximately 50% is deposited in the nearshore regions of the sound. In both regions, areas of high sediment accumulation are richer in organic carbon and hydrocarbon derived from land than are areas of low sediment accumulation. In general, areas with high sediment accumulation rates for fine-grained particles are also areas of relatively high microbial activity. Results suggest that these elevated microbial activities reflect biodegradation of detrital carbon associated with these particles. Also, the Cook Inlet and Norton Sound region were found to be free from petroleum hydrocarbon contamination (with the exception of one area in Cook Inlet). No evidence was found of hydrocarbon accumulation resulting from a gas seepage in Norton Sound, nor for accumulation of hydrocarbons in sediments of lower Cook Inlet and Shelikof Strait from oil well operations in upper Cook Inlet.

Baker, M. R., K. K. Kivva, M. N. Pisareva, J. T. Watson, and J. Selivanova. 2020. Shifts in the physical environment in the Pacific Arctic and implications for ecological timing and conditions. Deep Sea Research Part II: Topical Studies in Oceanography. 177:104802. https://doi.org/10.1016/j.dsr2.2020.104802

Keywords**:** US; Russia; Bering Sea; Chukchi Sea; marine system; sea ice; sea surface temperature; hydrography; water masses; wind; phenology; climate; international collaboration

Abstract**:** The northern Bering Sea and Chukchi Sea represent the gateway from the Pacific to the Arctic. This contiguous marine system encompasses one of the largest continental shelves in the world and serves as the sole point of connection between the North Pacific and Arctic Ocean. This region has unique attributes and complex dynamics, driven by the convergence of distinct water masses, dynamic currents, advection between Pacific and Arctic systems, and important latitudinal gradients relevant to stratification and water mass structure, water temperature, and seasonal ice cover. Many processes and interactions in the region appear to be changing with important implications for both hydrography and ecology. Our analyses access remote and local data sources in US and Russian waters to characterize oceanographic conditions and analyze the implications of dramatic shifts in recent years. Previously, this region appeared resistant to trends apparent elsewhere in the greater Arctic. Now, the Pacific Arctic also appears to be in rapid transition. The conditions observed in 2017–2019 are unprecedented. We note important shifts in the phenology and magnitude of physical variables, including sea-ice extent, concentration, and duration, as well as extreme reduction in the extent and intensity of the related Bering Sea cold pool. We also note distinct regional dynamics in sea surface temperature in the Bering-Chukchi system, distinguishing western, eastern and northern areas of the Bering Sea. Specifically, our analyses distinguish the northern Bering Sea as an important transition zone between the Pacific and Arctic with higher frequency variability in sea surface temperature anomalies. Our results suggest that the strength and position of the Aleutian Low may be linked to warm and cold phases in the Bering Sea and has an important role in large-scale circulation. While cold winds out of the north are necessary to form ice in the northern Bering Sea, strong winds may be associated with weak sea ice, as wind action may break ice and enhance vertical mixing, counteracting enhanced sea-ice production from the advection of cold air. Research in this important region is complicated by international borders but may be enhanced through international collaboration. This analysis represents an attempt to integrate data across Russian and US waters to more fully represent system-wide processes, to contrast regional trends, and to better understand physical interactions.

Baker, M. 2021. Contrast of warm and cold phases in the Bering Sea to understand spatial distributions of Arctic and sub-Arctic gadids. Polar Biology. 44:1083–1105. https://doi.org/10.1007/s00300-021-02856-x

Keywords**:** pacific cod; polar cod; saffron cod; walleye pollock; climate; sea ice; thermal tolerance; habitat

Abstract**:** The influence of climate on the dynamics of Arctic gadids is of increasing interest, particularly as research and survey effort expands in the Pacific Arctic. Understanding species-specific thermal tolerance may inform models of species distribution and projections of available habitat and also clarify implications of warming for ecological

communities. Analyzing shifts in species distribution in warm and cold periods, this study considers the effects of a warming climate on the distribution of two keystone Arctic gadids (polar cod, saffron cod) and two commercially important sub-Arctic gadids (walleye pollock, Pacific cod). Shifts in distribution were used to derive temperature tolerance thresholds and to project how these species might react to a warming Arctic. Significant shifts were noted in comparisons of warm (2002–2005, 2014–2016, 2017–2018) and cold (2006–2013) periods. Sub-Arctic species expanded and contracted their range as environmental conditions shifted. In contrast, Arctic species appeared constrained, such that population densities increased or decreased within the same core geographic area. Additionally, species with a demersal life history were able to tolerate a wider range of thermal conditions. These results provide important insights on relative thermal tolerance of each species, differential influence of temperature on pelagic versus demersal life histories, and depth as thermal refuge. This study demonstrates both the need to understand the spatial response of fish to changing ocean conditions in polar regions and the utility of distributional analyses to inform that effort.

Bakkala, R. G., K. Wakabayashi, K. Okada, J. J. Traynor, T. M. Sample, H. Yamaguchi, M. S. Alton, and M. O. Nelson. 1985. Results of cooperative U.S.-Japan groundfish investigations in the Bering Sea during May-August 1979. Bulletin No. 44. International North Pacific Fisheries Commission. Tokyo, Japan. 252 p. https://npafc.org/wp-content/uploads/Bulletin-44.pdf

Keywords**:** Fish populations; groundfish; Bering Sea; US; Japan

Abstract**:** From late May to late August, 1979, six research vessels from Japan and United States cooperatively surveyed the groundfish resources of the eastern Bering Sea. The major portion of the eastern Bering Sea continental shelf and slope were sampled with demersal trawls, and hydroacoustic-midwater trawling techniques were used to assess off-bottom concentrations of pollock (i.e. walleye pollock, *Theragra chalcogramma*) over the outer shelf and slope of the eastern Bering Sea and the population occupying upper layers of the deep water Aleutian Basin in the central Bering Sea. This report describes survey and analytical methods used and presents results on species encountered, distributions, abundances of major families and principal species in catches, and biological characteristics of principal species. Approximately 176 species from 37 families were identified from survey catches, including three new species of eelpouts (Zoarcidae). The total estimated biomass of groundfish in the eastern Bering Sea was 16.5 million t; 9.0 million t based on data from the demersal trawl survey; and 7.5 million t based on hydroacustic survey data. Pollock accounted for 11.1 million or 67% of the biomass in the eastern Bering Sea; an additional 1.3 million t of pollock were estimated to occupy pelagic waters of the Aleutian Basin. Other major species in the eastern Bering Sea were the flatfishes (Pleuronectidae) accounting for 3.1 million t (19%) of the biomass of which yellowfin sole (*Limanda aspera*) was the principal species (2.0 million t, 12%), Pacific cod (*Gadus macrocephalus*) 0.8 million t or 5%, eelpouts (Zoarcidae) 0.7 million t or 4%, and sculpins (Cottidae) 0.4 million t or 2%.

Bamberger, B., D. C. Callaway, M. A. Downs, M. S. Galginaitis, J. C. Russel, and D. Schug. 2008. Potential impacts of OCS activities on bowhead whale hunting activities in the Beaufort Sea. U.S. Dep. Interior, BOEM. OCS Study MMS 2007-062. Obligation No.: 31135. 380 p. https://espis.boem.gov/final%20reports/4529.pdf

***Keywords*:** potential impacts; bowhead whale; Beaufort Sea; marine mammal; oil and gas; exploration and development; North Slope; Barrow; Kaktovik; Nuiqsut; Savoonga

***Abstract*:** This study addresses the need for additional research regarding cultural, social, and economic impacts to Alaska Eskimo subsistence communities from ongoing arctic oil and gas exploration and production. The study is composed of three main parts: an overview of the project communities of Barrow, Kaktovik, Nuiqsut, and Savoonga in terms of geographical and historical background and contemporary demographic characteristics; four comprehensive profiles, one for each community, covering community background and history, community characterization, subsistence and cash economy, and the local nexus of whaling and OCS activities; and a presentation of findings from the survey data collection effort.

Basyuk, E., and Y. Zuenko. 2020. Extreme oceanographic conditions in the northwestern Bering Sea in 2017–2018. Deep Sea Research Part II: Topical Studies in Oceanography. 181-182:104909. https://doi.org/10.1016/j.dsr2.2020.104909

***Keywords*:** climate warming; ice cover; water temperature; water circulation; Bering Sea

***Abstract*:** Anomalous oceanographic conditions were observed in the northwestern Bering Sea in 2017–2018, including warmer air and water temperatures and reduced ice cover. Their effects on the water structure and circulation are considered. These conditions were formed on the background of warming tendency known in the Bering Sea since 2014, but the year 2018 was exceptional even relative to this background. In this year, deflections of some properties from their mean values exceeded two standard deviations (>2σ). The main reason for such abnormal conditions was southerly winds prevailed over the entire sea in winter because of a westward shift of the Aleutian Low; another factor was the strengthened advection of oceanic waters that still were abnormally warm after the period of extreme warming in the North-East Pacific in 2014–2016. As the result, the ice extent in winter and spring was below its mean value (more than twice lower in 2018), the air and water temperatures were above their mean values through the year (up to 15 and 3°C higher, respectively, in 2018), the cold water mass was not formed at the shelf bottom in winter and was absent in summer. Under this considerable redistribution of water density, the water circulation changed, the Navarin Current weakened and was even absent in fall 2018/ and the northward water transport toward the Bering Strait was realized through the eastern shelf and delivered the coastal waters from Alaska instead of the waters from the deep-water basins, as has been usual. The oceanographic conditions in 2018 were statistical outliers, atypical even for recent period of warming, but such conditions could be expected

if the warming continues. Thus, the phenomenon of 2017–2018 could be useful for understanding and predicting the reconstruction of the oceanographic regime in the near future.

Beatty, W. S., P. R. Lemons, S. A. Sethi, J. Everett, C. J. Lewis, J. B. Olsen, R. J. Lynn, G. M. Cook, J. L. Garlich-Miller, and J. K. Wenburg. 2019. Estimating pacific walrus abundance and demographic rates from genetic mark-recapture. U.S. Dep. Interior, BOEM. OCS Study 2019-059. 18 p. https://espis.boem.gov/final%20reports/BOEM_2019-059.pdf

Keywords**:** walrus; animal survey; Bering Sea; Chukchi Sea

Abstract**:** The U.S. Fish and Wildlife Service initiated a Pacific walrus genetic mark-recapture project in 2013 to estimate abundance, survival, and reproductive rates. We conducted research cruises in June of each year from 2013–2016 in the Bering and Chukchi Seas to sample juveniles and adult females, and this award partially funded the research cruise in 2017. We used a Horvitz-Thompson-type estimator to estimate the abundance of calves, juveniles, and adult females. We used age structure surveys to adjust this estimate for the estimated proportion of the population that were adult males. Addition of data from 2016 and 2017 did not substantially improve recapture rates. Thus, we only report preliminary results from 2013–2015. We estimated total population abundance as 283,213 with 95% credible interval 93,000–478,975. We are exploring alternative approaches such as integrated population models and close-kin mark-recapture to increase precision of parameter estimates.

Beatty, W. S., P. R. Lemons, S. A. Sethi, J. P. Everett, C. J. Lewis, R. J. Lynn, G. M. Cook, J. L. Garlich-Miller, and J. K. Wenburg. 2020. Panmixia in a sea ice-associated marine mammal: evaluating genetic structure of the Pacific walrus (*Odobenus rosmarus divergens*) at multiple spatial scales. Journal of Mammalogy. 101(3):755-765. https://doi.org/10.1093/jmammal/gyaa050

Keywords**:** walrus; animal survey; genetics; Bering Sea; Chukchi Sea

Abstract**:** The kin structure of a species at relatively fine spatial scales impacts broad-scale patterns in genetic structure at the population level. However, kin structure rarely has been elucidated for migratory marine mammals. The Pacific walrus (*Odobenus rosmarus divergens*) exhibits migratory behavior linked to seasonal patterns in sea ice dynamics. Consequently, information on the spatial genetic structure of the subspecies, including kin structure, could aid wildlife managers in designing future studies to evaluate the impacts of sea ice loss on the subspecies. We sampled 8,303 individual walruses over a 5-year period and used 114 single-nucleotide polymorphisms to examine both broad-scale patterns in genetic structure and fine-scale patterns in relatedness. We did not detect any evidence of genetic structure at broad spatial scales, with low FST values (≤ 0.001) across all pairs of putative aggregations. To evaluate kin structure at fine spatial scales, we defined a walrus group as a cluster of resting individuals that were less than one walrus body length apart.

We found weak evidence of kin structure at fine spatial scales, with 3.72% of groups exhibiting mean relatedness values greater than expected by chance, and a significantly higher overall observed mean value of relatedness within groups than expected by chance. Thus, the high spatiotemporal variation in the distribution of resources in the Pacific Arctic environment likely has favored a gregarious social system in Pacific walruses, with unrelated animals forming temporary associations.

Bédard, J. 1969. Feeding of the least, crested, and parakeet auklets around St. Lawrence Island, Alaska. Canadian Journal of Zoology. 47(5):1025-1050. https://doi.org/10.1139/z69-166

***Keywords*:** auklet; feeding habits; St Lawrence Island

***Abstract*:** The feeding habits of three plankton-feeding Alcidae, the least, crested, and parakeet auklets were studied on St. Lawrence Island, Alaska, between 1964 and 1966. The crested and the least auklets (*Aethia cristatella, A. pusilla*) exhibit similar patterns of dependence upon the food resources: both have, during early summer, a diversified diet consisting of mysids, hyperiids, gammarids, etc., but restrict themselves largely to one principal prey during the chick-rearing period. Then, *A. pusilla* eats mostly *Calanus* sp. while *A. cristatella* eats *Thysanoessa* spp. In all years, hatching coincided closely with the appearance of these prey items (copepods and euphausids) in the environment and it is argued that the timing of the auklets' breeding season has been adjusted to their cyclical abundance. *Cyclorrhynchus psittacula*, the parakeet auklet, maintains a diversified diet throughout the summer: *Parathemisto libellula*, a pelagic amphipod, is the dominant prey in its diet. The three species are found feeding together and are presumed to use the same depth range. Segregation in feeding between *A. cristatella* and *A. pusilla* is achieved by difference in bill size. This difference is sufficient to impose obligatory feeding upon different resources. Segregation between two possible competitors, *A. cristatella* and *Cyclorrhynchus*, seems to rest upon innate preferences for different prey types, minor structural differences in the feeding apparatus, and differences in foraging habits: the relative importance of each of these factors remains to be established. As a whole, the amount of overlap in feeding between the three species studied is very small.

Bering Sea Elders Advisory Group. 2011. The northern Bering Sea: Our way of life. Bering Sea Elders Advisory Group. Exchange for Local Observations and Knowledge of the Arctic. 60 p. https://eloka-arctic.org/communities/elders.html

***Keywords*:** community-based monitoring; wildlife observations; marine mammals; fish; birds; environmental features and use; marine conditions; sea ice; indigenous knowledge; food security and sovereignty

***Abstract*:** The purpose of *The Northern Bering Sea: Our Way of Life* is to show extensive areas where Alaska Native hunters and local fishermen harvest ocean resources, and the marine waters important to the resources we rely on. It illustrates that the whole northern Bering Sea is the storehouse that supports our way of life. The quotations from elders and

hunters are excerpted from interviews conducted for this project, other published material and oral history records. As we face threats to the northern Bering Sea, this report can support our leaders and inform outside decision-makers about how we depend on the ocean and how our way of life is inseparable from it. This project was not an in depth inquiry into traditional ecological knowledge of the natural history of species and their environment. However, indigenous knowledge of such things as where to hunt and fish, how to be a successful hunter and fisherman, seasonal patterns, weather, ocean conditions, how to process and preserve fish and game, uses for fish and game, and customs underlie information provided to generate the maps.

Bering Sea Elders Group. 2016. Northern Bering Sea and Bering Strait: Ecosystem and climate change. Bering Sea Elders Group. Exchange for Local Observations and Knowledge of the Arctic. 12 p. http://www.beringseaelders.org/wp-content/uploads/2016/11/N_Bering_Sea_Ecosystem-Climate-Change_med_res.pdf

Keywords**:** cultural issues; subsistence hunting; marine mammal; fish; climate change; Alaska Natives

Abstract**:** The cold, rich waters of the northern Bering Sea and Bering Strait form the foundation of culture, food security, and economy for coastal Yupik and Inupiaq peoples, who have relied on the abundant marine resources of this region for thousands of years. Cultural practices associated with hunting and fishing bind people to the sea, and tie families and communities together through the passing of knowledge from one generation to the next. Alongside ongoing traditional uses are small-scale commercial fisheries for salmon, crab, herring, and halibut, which are a vital component of regional employment and the cash economy. The seafloor and waters of this region are extraordinarily productive, and support a globally-significant diversity and abundance of marine mammals, seabirds, and other ocean life. One of the largest marine migrations on Earth moves through the northern Bering Sea and Bering Strait each spring to take advantage of the Arctic's burst of summer productivity, including thousands of bowhead and beluga whales, hundreds of thousands of walruses, an estimated one million ice seals, and millions of seabirds. But this unique ecosystem is vulnerable to ecological transformation and uncertainty due to climate change. For thousands of years, seasonal ice cover has structured ecological mechanisms underpinning marine life. Climate warming is leading to change in seasonal ice, altering the abundance, timing, and distribution of important species. The loss of sea ice is in turn causing a dramatic increase in ship traffic through these highly sensitive and important areas. Strengthening the role of tribal governance and utilizing precautionary management principles are tools that can address key concerns shared by tribes in the region.

Bering Sea Elders Group. 2016. Northern Bering Sea and Bering Strait: Food security. Bering Sea Elders Group. Exchange for Local Observations and Knowledge of the Arctic. 8 p. http://www.beringseaelders.org/wp-content/uploads/2016/11/N_Bering_Sea_food_security_med_res.pdf

***Keywords*:** cultural issues; subsistence fisheries; climate change; Alaska Natives

***Abstract*:** For thousands of years the coastal Yupik and Inupiaq peoples of the northern Bering Sea and Bering Strait have relied on marine mammals, seabirds, fish, shellfish, and other marine based resources for food. Hunting and fishing bind people to the sea, and tie families and communities together through the sharing of food and passing of knowledge and experience from one generation to the next.

Bluhm, B. A., K. O. Coyle, B. Konar, and R. Highsmith. 2007. High gray whale relative abundances associated with an oceanographic front in the south-central Chukchi Sea. Deep Sea Research Part II: Topical Studies in Oceanography. 54(23-26):2919-2933. https://doi.org/10.1016/j.dsr2.2007.08.015

***Keywords*:** gray whale; marine mammal; relative abundance; distribution; fronts; prey

***Abstract*:** We describe gray whale (*Eschrichtius robustus*) distribution in the south-central Chukchi Sea in relation to environmental factors during two 5-day surveys in June and September of 2003. Whale counts per 10-min scan (an index of relative abundance) ranged from 0 to 41 in June and from 0 to 28 in September. CTD data showed an ocean front around 67.8°N with strong horizontal gradients in temperature, salinity, chlorophyll-a concentration and water-column stability. Highest whale abundance indices occurred in or near the front in both periods. Preliminary qualitative assessment of biological communities in the study area suggests that infaunal clams, echinoderms, euphausids, chaetognaths and Arctic cod were common, while ampeliscid amphipods, the previously abundant infauna (and likely prey) in the nearby Chirikov Basin feeding area, were not dominant. Euphausids may be a prey for gray whales in this area. We suggest that frontal systems may play an important role in eastern North Pacific gray whale foraging grounds. Further study is needed to fully describe the role of frontal systems in gray whale foraging grounds.

Boveng, P. L., M. F. Cameron, P. B. Conn, and E. E. Moreland. 2016. Abundance estimates of ice-associated seals: Bering Sea populations that inhabit the Chukchi Sea during open-water period; Final report. U.S. Dep. Interior, BOEM and U.S. Dep. of Commerce, AFSC. OCS Study 2016-077. Obligation No.: M12PG00017. 122 p. 7600 Sand Point Way NE Seattle, WA 98115. https://espis.boem.gov/final%20reports/5578.pdf

***Keywords*:** bearded seal, *Erignathus barbatus*, ribbon seal, *Histriophoca fasciata*, ringed seal, *Phoca hispida*, spotted seal, *Phoca largha*, ice-associated seals, abundance, distribution, aerial survey, Bering Sea, Sea of Okhotsk, Chukchi Sea, Arctic

***Abstract*:** Aerial surveys were conducted in spring 2012 and 2013. In the United States and Russia combined, more than 47,000 nautical miles (nm) (87,000 km) of survey track was flown. The completion of this project marks the largest survey of ice-associated seals ever completed and will provide the first comprehensive estimates of abundance for bearded, spotted, ribbon, and ringed seals in the Bering Sea and Sea of Okhotsk.

Boveng, P. L., H. L. Ziel, B. T. McClintock, and M. F. Cameron. 2020. Body condition of phocid seals during a period of rapid environmental change in the Bering Sea and Aleutian Islands, Alaska. Deep Sea Research Part II: Topical Studies in Oceanography. 181-182:104904. https://doi.org/10.1016/j.dsr2.2020.104904

***Keywords*:** body conditions; length-weight relationships; food webs; trophic levels; sea ice; shelf edge

***Abstract*:** A warming climate has driven rapid physical changes in the Arctic environment, particularly in the Bering Sea. Biological changes are also increasingly evident in the Bering Sea and adjacent waters. The ecological results have been profound and relatively well documented for fishes and lower trophic levels. Upper trophic predators such as marine mammals, however, have been underrepresented in ecosystem surveys, models, and efforts to practice ecosystem-based fisheries management. We used multiple linear regression to model body condition (mass/length) as a function of species, age class, sex and year for ribbon and spotted seals in the Bering Sea, and harbor seals in the Aleutian Islands, from 2007 to 2018, for evidence of recent trends that might reflect trophic or bottom-up changes in the ecosystem. Model-averaged coefficients (in kg cm^{-1}, relative to the overall mean) indicated that body condition was lower for subadults (−0.063; 95% CI: −0.074 – −0.051) and pups (−0.120; 95% CI: −0.129 – −0.112) than for adults (0.183, the negative sum of the subadults and pups coefficients). Body condition for males (0.010; 95% CI: 0.002–0.019) was higher than for females (−0.010). Overall, body condition declined annually (−0.014 per year; 95% CI: −0.025 – −0.004), and there was an additive annual decline in body condition of seal pups across all species and sexes (−0.020; 95% CI: −0.030 – −0.011). An additive annual increase in body condition of spotted seals across all sexes and age classes (0.013; 95% CI: 0.004–0.022) mitigated the annual declines for this species. Model-averaged fitted values therefore indicated annual declines in body condition for ribbon and harbor seals of all sex and age classes, and for spotted seal pups. We relate these declines to the trend in Bering Sea ice extent and to recent, rapid changes brought on by the significant Northeast Pacific marine heat wave of 2014–2016 and its lingering effects through 2018 and 2019. The results indicate that these typically resilient, long-lived, generalist predators can be impacted by bottom-up forcing.

Bronson, M. T. 1989. Mercury in Alaska marine surface sediments: A review of the regional data. U.S. Dep. Interior, BOEM. OCS Environmental Assessment Program. 205-225 p. University of Rhode Island Kingston, Rhode Island 02881. https://espis.boem.gov/final%20reports/2872.pdf

***Keywords*:** mercury; heavy metals; sediment; Alaska

***Abstract*:** Mercury concentrations reported by eight studies of surface sediments varied significantly among regions of the Alaska shelf. Chukchi Sea data indicated the lowest mercury geometric means, .0121 ppm and .0127 ppm, for sand and mud, respectively. One

Beaufort Sea study reported the highest concentrations, with means of .0615 ppm and .0877 ppm, for sand and mud, respectively. Mercury levels did not differ significantly between the mud and sand fractions when data were combined among studies. Laboratory and collection methods differed among the studies and may have affected the mercury estimates, but no clear relationship emerged from a comparison of the reports.

Brown, Z. W., and K. R. Arrigo. 2013. Sea ice impacts on spring bloom dynamics and net primary production in the Eastern Bering Sea. Journal of Geophysical Research: Oceans. 118(1):43-62. https://doi.org/10.1029/2012jc008034

***Keywords*:** satellite; chlorophyll; sea ice

***Abstract*:** In the Eastern Bering Sea, changes in sea ice have been implicated in recent major upper-trophic level shifts. However, the underlying relationships between sea ice and primary producers have not been well tested. Here, we combine data from multiple satellite platforms, reanalysis model results and biophysical moorings to explore the dynamics of spring and summer primary production in relation to sea ice conditions. In the northern Bering Sea, sea ice consistently retreated in late spring, leading to ice-edge phytoplankton blooms in cold (0–1°C) waters. However, in the southeastern Bering Sea, sea ice retreat was far more irregular. Although this did not significantly alter bloom timing, late retreat led to blooms at the ice-edge while early retreat led to blooms in open waters that were warmer (≤5.4°C) and >70% more productive. Early sea ice retreat also led to higher productivity in summer, likely due to weaker thermal stratification. Overall, annual net primary production during warm years of early sea ice retreat was enhanced by 40–50% compared to years with late sea ice retreat in the southeastern Bering Sea. These findings suggest the potential for future sea ice loss to enhance overall carrying capacity of the southeastern Bering Sea ecosystem. Consistently warm blooms in the future may also channel more energy flow toward the pelagic, rather than benthic, environment. To date, however, neither sea ice extent nor the timing of its retreat have undergone long-term changes in the Eastern Bering Sea.

Burn, D. M., M. S. Udevitz, S. G. Speckman, and R. B. Benter. 2009. An improved procedure for detection and enumeration of walrus signatures in airborne thermal imagery. International Journal of Applied Earth Observation and Geoinformation. 11(5):324-333. https://doi.org/10.1016/j.jag.2009.05.004

***Keywords*:** airborne thermal imagery; Pacific walrus; aerial survey; Alaska; Bering Sea

***Abstract*:** In recent years, application of remote sensing to marine mammal surveys has been a promising area of investigation for wildlife managers and researchers. In April 2006, the United States and Russia conducted an aerial survey of Pacific walrus (*Odobenus rosmarus divergens*) using thermal infrared sensors to detect groups of animals resting on pack ice in the Bering Sea. The goal of this survey was to estimate the size of the Pacific walrus population. An initial analysis of the U.S. data using previously-established methods

resulted in lower detectability of walrus groups in the imagery and higher variability in calibration models than was expected based on pilot studies. This paper describes an improved procedure for detection and enumeration of walrus groups in airborne thermal imagery. Thermal images were first subdivided into smaller 200×200 pixel "tiles." We calculated three statistics to represent characteristics of walrus signatures from the temperature histogram for each tile. Tiles that exhibited one or more of these characteristics were examined further to determine if walrus signatures were present. We used cluster analysis on tiles that contained walrus signatures to determine which pixels belonged to each group. We then calculated a thermal index value for each walrus group in the imagery and used generalized linear models to estimate detection functions (the probability of a group having a positive index value) and calibration functions (the size of a group as a function of its index value) based on counts from matched digital aerial photographs. The new method described here improved our ability to detect walrus groups at both 2m and 4m spatial resolution. In addition, the resulting calibration models have lower variance than the original method. We anticipate that the use of this new procedure will greatly improve the quality of the population estimate derived from these data. This procedure may also have broader applicability to thermal infrared surveys of other wildlife species.

Burns, J. J. 1970. Remarks on the distribution and natural history of pagophilic pinnipeds in the Bering and Chukchi Seas. Journal of Mammalogy. 51(3):445-454. https://doi.org/10.2307/1378386

***Keywords*:** marine mammal; pinnipeds; sea ice; adaptation; Bering Sea; Chukchi Sea

***Abstract*:** Five species of pagophilic (ice-loving) pinnipeds live in the Bering and Chukchi seas: *Odobenus rosmarus, Phoca (Pusa) hispida, Phoca (Histriophoca) fasciata*, an ice-breeding population of *Phoca (Phoca) vitulina*, and *Erignathus barbatus*. Breeding adults of these species are mostly separated from each other during late winter and early spring, when, throughout the pupping and subsequent mating periods, *P. vitulina* and *P. fasciata* occupy the edge-zone of the seasonal pack ice, *E. barbatus* and *O. rosmarus* are mainly farther north within the heavier pack ice, and *P. hispida* occupies areas of extensive land-fast ice. This paper discusses differences in body structure, ecological adaptation, and behavior in relation to distribution of the five species.

Cacchione, D. A., and D. E. Drake. 1979. Bottom and near-bottom sediment dynamics in Norton Sound, Alaska. U.S. Dep of Interior, USGS. OCS Environmental Assessment Program. RU-430. 77-143 p. U.S. Geological Survey Menlo Park, California 94025. https://espis.boem.gov/final%20reports/1145.pdf

***Keywords*:** geomorphology; suspended sediment; hydrodynamics; shear stress; pollutant transport; erosion; Norton Sound; Bering Sea

***Abstract*:** An investigation of sediment dynamics in Norton Sound and other sections of the northern Bering Sea was conducted to define the principal pathways and mechanisms of bottom and suspended materials transport. A major topic of this research is the complicated interrelationships of sediment movement and hydrodynamic stresses that occur in the marine environment. Temporal contrasts like those caused by seasonal cycles and quiescent versus storm conditions are of particular interest. This research is pertinent to two major impact areas of petroleum development in the marine environment: (1) transport of materials including pollutants; and (2) hazardous sea floor conditions caused by wave and current erosion.

Cacchione, D. A., and D. E. Drake. 1982. Measurements of storm-generated bottom stresses on the continental shelf. Journal of Geophysical Research. 87(C3):1952-1960. http://pubs.er.usgs.gov/publication/70011782

***Keywords*:** geomorphology; suspended sediment; hydrodynamics; shear stress; erosion; Norton Sound; Bering Sea

***Abstract*:** Large values of bottom friction velocity, u., and roughness length, zo, determined from burst-averaged speed data taken on the continental shelf in outer Norton Sound, Alaska, with the GEOPROBE tripod during a storm are correlated with extremely large values of near-bottom concentration of total suspended particulate matter (TSM). The values obtained from the 'law of the wall' velocity-depth relationship are diminished substantially throughout the storm period when the turbulence-reducing effects of the vertical cncentration gradient of TSM are considered. The values are compared to those obtained from other workers.

Cacchione, D. A., D. E. Drake, and P. Wiberg. 1982. Velocity and bottom-stress measurements in the bottom boundary layer, outer Norton Sound, Alaska. Geologie en Mijnbouw. 61(1):71-78. http://pubs.er.usgs.gov/publication/70011704

***Keywords*:** geomorphology; shear stress; tides; hydrodynamics; shear stress; erosion; Norton Sound; Bering Sea

***Abstract*:** We have used long-term measurements of near-bottom velocities at four heights above the sea floor in Norton Sound, Alaska, to compute hourly values of shear velocity u., roughness and bottom-drag coefficient. Maximum sediment resuspension and transport, predicted for periods when the computed value of u. exceeds a critical level, occur during peak tidal currents associated with spring tides. The fortnightly variation in u. is correlated with a distinct nepheloid layer that intensifies and thickens during spring tides and diminishes and thins during neap tides. The passage of a storm near the end of the experiment caused significantly higher u. values than those found during fair weather.

Chen, C.-T. A. 1985. Preliminary observations of oxygen and carbon dioxide of the wintertime Bering Sea marginal ice zone. Continental Shelf Research. 4(4):465-483. https://doi.org/10.1016/0278-4343(85)90005-6

Keywords**:** marginal ice zone; oxygen; carbon dioxide; Bering Sea

Abstract**:** Wintertime oxygen and pH profiles across the marginal ice zone of the central and southeastern Bering Sea shelf are analyzed and compared with summer data. During the winter, at water depths shallower than 75 m, the water column is homogeneous and near freezing. Between the 75- and 200-m isobaths the structure is essentially two-layered, a cool and fresh upper layer overlying a warmer, more saline bottom layer. The oxygen concentration in the surface mixed layer is higher than the summer values, but the degree of saturation is lower because of the lower temperature in winter. The oxygen degree of saturation in the bottom mixed layer on the shelf in winter are higher than in the surface water in winter and the bottom water in summer. In summer the oxygen and carbon dioxide data show extreme variability governed primarily by biological processes. Winter oxygen and pH data, however, do not scatter as much as the summer data and indicate conservative mixing of several sub-surface water masses. The surface water is undersaturated in both oxygen and carbon dioxide and seems to absorb oxygen, but little carbon dioxide, from the atmosphere. Two stations were occupied in the Aleutian Basin. The homogeneous surface layer has the same oxygen and pH values as in the minimum temperature layer observed in the summer by other investigators at the same location. The result substantiates the hypothesis of early investigators that the summer minimum temperature layer is the remnant local winter water. All winter surface waters sampled are undersaturated with respect to oxygen, suggesting that the input of oxygen through the air-sea exchange does not keep up with the rate of upwelling and cooling, which reduces the degree of oxygen saturation. Surface carbon dioxide is also undersaturated because of cooling. The maximum temperature layer at these two Aleutian Basin stations is warmer, fresher, and contains more oxygen, but less carbon dioxide, than in the summer, suggesting advective input of some nonlocal seawater.

Chen, C.-T. A. 1993. Carbonate chemistry of the wintertime Bering Sea marginal ice zone. Continental Shelf Research. 13(1):67-87. https://doi.org/10.1016/0278-4343(93)90036-W

Keywords**:** marginal ice zone; carbon dioxide; cabonate; calcium; Bering Sea

Abstract**:** Winter titration alkalinity, total CO_2, pCO_2 and calcium profiles across the marginal ice zone of the central and southeastern Bering Sea shelf were obtained for the first time. The data indicate that Bering Sea Shelf Water was significantly affected by river runoff, and conservative mixing dominated the distribution of physical-chemical properties on the shelf. Low salinity waters had high normalized alkalinity, normalized total CO_2, and normalized calcium concentrations but low pCO_2. Total CO_2 data indicated organic carbon production rates of 2.9 ± 1.1 and 2.2 ± 1.1g C m^{-2} day^{-1}, respectively, on the shelf and in the Aleutian Basin between March and June. Calcium data suggested a vertical inorganic carbon flux of

0.075 μmol kg^{-1} y^{-1}, which represents approximately 35% of the total carbon flux in the Aleutian Basin. The entire Bering Sea Shelf Water was saturated by the anthropogenic CO_2, but excess CO_2 penetrates to no more than 1000 m in the Aleutian Basin and no excess CO_2 can be found in the Bering Sea Bottom Water. The entire Bering Sea contains 0.19 ± 0.05 × 10^{15}g anthropogenic carbon. The shelf water is now supersaturated with respect to calcite and aragonite, but could become undersaturated with a doubling of the current atmospheric CO_2 level. The carbonate deposits on the shelf could then begin to neutralize excess CO_2 and become an important excess CO_2 sink.

Christman, C. L., J. J. Citta, L. T. Quakenbush, J. T. Clarke, B. K. Rone, R. A. Shea, M. C. Ferguson, and M. P. Heide-Jørgensen. 2013. Presence and behavior of bowhead whales (*Balaena mysticetus*) in the Alaskan Beaufort Sea in July 2011. Polar Biology. 36(12):1851-1856. https://doi.org/10.1007/s00300-013-1395-4

Keywords**:** marine mammals; bowhead whale, *Balaena mysticetus*; Bering Sea; Chukchi Sea; Beaufort Sea

Abstract**:** The Western Arctic bowhead whale (*Balaena mysticetus*) is highly adapted to sea ice and annually migrates through the Bering, Chukchi, and Beaufort seas. While the overall distribution and seasonal movements of bowhead whales are mostly understood, information about their distribution in the Alaskan Beaufort Sea in early to mid-summer has not been well documented. In July 2011, we conducted an exploratory flight in the Alaskan Beaufort Sea, north of Camden Bay (71°N 144°W), near the location of a single satellite-tagged bowhead whale. Eighteen bowhead whales were observed, and behavior consistent with feeding was documented. To our knowledge, this is the first documentation of behavior consistent with feeding north of Camden Bay in mid-July. Few studies have focused on bowhead whale distribution in the Alaskan Beaufort Sea in early to mid-summer, and no long-term, region-wide surveys have been conducted during summer. Bowhead whales are already exposed to anthropogenic disturbance in the Canadian Beaufort Sea in summer, the Alaskan Beaufort Sea in fall, and the Chukchi and Bering seas from fall through spring. The presence of bowhead whale aggregations in the Alaskan Beaufort Sea in summer should be considered when assessing the cumulative effects of human-related activities.

Citta, J. J., L. T. Quakenbush, J. C. George, R. J. Small, M. P. Heide-Jørgensen, H. Brower, B. Adams, and L. Brower. 2012. Winter movements of bowhead whales (*Balaena mysticetus*) in the Bering Sea. Arctic. 65(1):13-34. https://doi.org/10.14430/arctic4162

Keywords**:** marine mammals; bowhead whale; *Balaena mysticetus*; Bering Sea; Chukchi Sea; Beaufort Sea

Abstract**:** Working with subsistence whale hunters, we tagged bowhead whales (*Balaena mysticetus*) with satellite-linked transmitters and documented their movements in the Bering Sea during two winters. We followed 11 whales through the winter of 2008 – 09 and

10 whales in 2009 – 10. The average date that bowhead whales entered the Bering Sea was 14 December in 2008 and 26 November in 2009. All but one tagged whale entered the Bering Sea west of Big Diomede Island. In the winter of 2008 – 09, whales were distributed in a line extending from the Bering Strait to Cape Navarin, whereas in 2009 – 10, the distribution shifted south of St. Lawrence Island, extending from Cape Navarin to St. Matthew Island. Bowhead whales were most likely to be found in areas with 90% – 100% sea-ice concentration and were generally located far from the ice edge and polynyas. The average date whales left the Bering Sea was 12 April in 2009 and 22 April in 2010. During the spring migration, all whales but one traveled north along the Alaska coast to summering grounds in the Canadian Beaufort. The remaining whale migrated a month later and traveled up the northern coast of Chukotka, where it was located when the tag stopped transmitting in August. It is unlikely that this whale migrated to the Beaufort Sea before returning south to winter within the Bering Sea, indicating the movements of bowhead whales are more complex than generally believed. Declining sea ice in the Bering Sea may result in the expansion of commercial fisheries and shipping; areas where such activities may overlap the winter range of bowhead whales include the Bering and Anadyr straits, the eastern edge of Anadyr Bay, and St. Matthew Island.

Citta, J. J., J. J. Burns, L. T. Quakenbush, V. Vanek, J. C. George, R. J. Small, M. P. Heide-Jørgensen, and H. Brower. 2014. Potential for bowhead whale entanglement in cod and crab pot gear in the Bering Sea. Marine Mammal Science. 30(2):445-459. https://doi.org/10.1111/mms.12047

Keywords**:** marine mammals; bowhead whale; crab; fisheries; *Balaena mysticetus*; Bering Sea

Abstract**:** Bowhead whales (*Balaena mysticetus*) of the western Arctic stock winter in ice-covered continental shelf regions of the Bering Sea, where pot fisheries for crabs (*Paralithodes* and *Chionoecetes spp.*) and Pacific cod (*Gadus macrocephalus*) pose a risk of entanglement. In the winter of 2008–2009 and 2009–2010 the spatial distribution of 21 satellite tagged bowhead whales partially overlapped areas in which pot fisheries for cod and blue king crab (*Paralithodes platypus*) occurred. However, these fisheries ended before whales entered the fishing areas, thus avoiding temporal overlap. A fishery for snow crab (*Chionoecetes opilio*) typically runs from January to May and provides the greatest potential for bowhead whales to encounter active pot gear. Tagged whales did not enter the area of the snow crab fishery during this study and generally remained in areas with >90% sea ice concentration, which is too concentrated for crab boats to penetrate. Pack ice sometimes overruns active fishing areas, resulting in lost gear, which is the most likely source of entanglement. The western Arctic stock of bowhead whales was increasing as of 2004; as such, incidental mortality from commercial pot fisheries is probably negligible at this time. Regardless, entanglement may increase over time and should be monitored.

Citta, J. J., L. T. Quakenbush, S. R. Okkonen, M. L. Druckenmiller, W. Maslowski, J. Clement-Kinney, J. C. George, H. Brower, R. J. Small, C. J. Ashjian, L. A. Harwood, and M. P. Heide-Jørgensen. 2015. Ecological characteristics of core-use areas used by Bering–Chukchi–Beaufort (BCB) bowhead whales, 2006–2012. Progress in Oceanography. 136:201-222. https://doi.org/10.1016/j.pocean.2014.08.012

Keywords**:** marine mammals; bowhead whale; *Balaena mysticetus;* Bering Sea; Chukchi Sea; Beaufort Sea

Abstract**:** The Bering–Chukchi–Beaufort (BCB) population of bowhead whales (*Balaena mysticetus*) ranges across the seasonally ice-covered waters of the Bering, Chukchi, and Beaufort seas. We used locations from 54 bowhead whales, obtained by satellite telemetry between 2006 and 2012, to define areas of concentrated use, termed "core-use areas". We identified six primary core-use areas and describe the timing of use and physical characteristics (oceanography, sea ice, and winds) associated with these areas. In spring, most whales migrated from wintering grounds in the Bering Sea to the Cape Bathurst polynya, Canada (Area 1), and spent the most time in the vicinity of the halocline at depths <75m, which are within the euphotic zone, where calanoid copepods ascend following winter diapause. Peak use of the polynya occurred between 7 May and 5 July; whales generally left in July, when copepods are expected to descend to deeper depths. Between 12 July and 25 September, most tagged whales were located in shallow shelf waters adjacent to the Tuktoyaktuk Peninsula, Canada (Area 2), where wind-driven upwelling promotes the concentration of calanoid copepods. Between 22 August and 2 November, whales also congregated near Point Barrow, Alaska (Area 3), where east winds promote upwelling that moves zooplankton onto the Beaufort shelf, and subsequent relaxation of these winds promoted zooplankton aggregations. Between 27 October and 8 January, whales congregated along the northern shore of Chukotka, Russia (Area 4), where zooplankton likely concentrated along a coastal front between the southeastward-flowing Siberian Coastal Current and northward-flowing Bering Sea waters. The two remaining core-use areas occurred in the Bering Sea: Anadyr Strait (Area 5), where peak use occurred between 29 November and 20 April, and the Gulf of Anadyr (Area 6), where peak use occurred between 4 December and 1 April; both areas exhibited highly fractured sea ice. Whales near the Gulf of Anadyr spent almost half of their time at depths between 75 and 100m, usually near the seafloor, where a subsurface front between cold Anadyr Water and warmer Bering Shelf Water presumably aggregates zooplankton. The amount of time whales spent near the seafloor in the Gulf of Anadyr, where copepods (in diapause) and, possibly, euphausiids are expected to aggregate provides strong evidence that bowhead whales are feeding in winter. The timing of bowhead spring migration corresponds with when zooplankton are expected to begin their spring ascent in April. The core-use areas we identified are also generally known from other studies to have high densities of whales and we are confident these areas represent the majority of important feeding areas during the study (2006–2012). Other feeding areas, that we did not detect, likely existed during the study and we expect core-use area boundaries to shift in response to changing hydrographic conditions.

Citta, J. J., P. Richard, L. F. Lowry, G. O'Corry-Crowe, M. Marcoux, R. Suydam, L. T. Quakenbush, R. C. Hobbs, D. I. Litovka, K. J. Frost, T. Gray, J. Orr, B. Tinker, H. Aderman, and M. L. Druckenmiller. 2017. Satellite telemetry reveals population specific winter ranges of beluga whales in the Bering Sea. Marine Mammal Science. 33(1):236-250. https://doi.org/10.1111/mms.12357

***Keywords*:** beluga whales; marine mammal; *Delphinapterus leucas*; Bristol Bay; Bering Sea; Gulf of Anadyr; Chukchi Sea; Beaufort Sea; satellite-linked transmitters; winter distribution

***Abstract*:** At least five populations (stocks) of beluga whales (*Delphinapterus leucas*) are thought to winter in the Being Sea, including the Bristol Bay, Eastern Bering Sea (Norton Sound), Anadyr, Eastern Chukchi Sea, and Eastern Beaufort Sea (Mackenzie) populations. Belugas from each population have been tagged with satellite-linked transmitters, allowing us to describe their winter (January–March) distribution. The objectives of this paper were to determine: (1) If each population winters in the Bering Sea, and if so, where? (2) Do populations return to the same area each year (i.e. are wintering areas traditional)? (3) To what extent do the winter ranges of different populations overlap? Tagged belugas from all five populations either remained in, or moved into, the Bering Sea and spent the winter there. Each population wintered in a different part of the Bering Sea and populations with multiple years of data (four or five) returned to the same regions in multiple years. When data were available from two populations that overlapped in the same year, they did not occupy the shared area at the same time. Although our sample sizes were small, the evidence suggests belugas from different populations have traditional winter ranges that are mostly exclusive to each population.

Citta, J. J., L. F. Lowry, L. T. Quakenbush, B. P. Kelly, A. S. Fischbach, J. M. London, C. V. Jay, K. J. Frost, G. O. C. Crowe, J. A. Crawford, P. L. Boveng, M. Cameron, A. L. Von Duyke, M. Nelson, L. A. Harwood, P. Richard, R. Suydam, M. P. Heide-Jørgensen, R. C. Hobbs, D. I. Litovka, M. Marcoux, A. Whiting, A. S. Kennedy, J. C. George, J. Orr, and T. Gray. 2018. A multi-species synthesis of satellite telemetry data in the Pacific Arctic (1987–2015): Overlap of marine mammal distributions and core use areas. Deep Sea Research Part II: Topical Studies in Oceanography. 152:132-153. https://doi.org/10.1016/j.dsr2.2018.02.006

***Keywords*:** Ringed seal; bearded seal; bowhead whale; pacific walrus; beluga whale; gray whale; Bering Sea; Chukchi Sea; Beaufort Sea; distribution; core area

***Abstract*:** We collated available satellite telemetry data for six species of ice-associated marine mammals in the Pacific Arctic: ringed seals (*Pusa hispida*; n = 118), bearded seals (*Erignathus barbatus*, n = 51), spotted seals (*Phoca largha*, n = 72), Pacific walruses (*Odobenus rosmarus divergens*, n = 389); bowhead whales (*Balaena mysticetus*, n = 46), and five Arctic and sub-arctic stocks of beluga whales (*Delphinapterus leucas*, n = 103). We also included one seasonal resident, eastern North Pacific gray whales (*Eschrichtius robustus*, n = 12). This review summarized the distribution of daily locations from satellite-linked

transmitters during two analysis periods, summer (May–November) and winter (December–April), and then examined the overlap among species. Six multi-species core use areas were identified during the summer period: 1) Chukotka/Bering Strait; 2) Norton Sound; 3) Kotzebue Sound; 4) the northeastern Chukchi Sea; 5) Mackenzie River Delta/Amundsen Gulf; and 6) Viscount Melville Sound. During the winter period, we identified four multi-species core use areas: 1) Anadyr Gulf/Strait; 2) central Bering Sea; 3) Nunivak Island; and 4) Bristol Bay. During the summer period, four of the six areas were centered on the greater Bering Strait region and the northwestern coast of Alaska and included most of the species we examined. The two remaining summer areas were in the western Canadian Arctic and were largely defined by the seasonal presence of Bering-Chukchi-Beaufort stock bowhead whales and Eastern Beaufort Sea stock beluga whales, whose distribution overlapped during both summer and winter periods. During the winter period, the main multi-species core use area was located near the Gulf of Anadyr and extended northwards through Anadyr and Bering Straits. This area is contained within the Bering Sea "green belt", an area of enhanced primary and secondary productivity in the Bering Sea. We also described available telemetry data and where they can be found as of 2017. These data are important for understanding ice-associated marine mammal movements and habitat use in the Pacific Arctic and should be archived, with appropriate metadata, to ensure they are available for future retrospective analyses.

Citta, J. J., S. R. Okkonen, L. T. Quakenbush, W. Maslowski, R. Osinski, J. C. George, R. J. Small, H. Brower, M. P. Heide-Jørgensen, and L. A. Harwood. 2018. Oceanographic characteristics associated with autumn movements of bowhead whales in the Chukchi Sea. Deep Sea Research Part II: Topical Studies in Oceanography. 152:121-131. https://doi.org/10.1016/j.dsr2.2017.03.009

Keywords**:** Chukchi Sea; Alaskan Coastal Current; Bering shelf water; Anadyr water; marine mammal; bowhead whale; *Balaena mysticetus*; resource selection; correlated random walk; behavioral state-space model

Abstract**:** Each fall, bowhead whales in the Bering-Chukchi-Beaufort (BCB) population migrate westward from summering grounds in the Beaufort Sea through the Chukchi Sea to the northern coast of Chukotka, Russia. Routes whales use when crossing the Chukchi Sea vary by year; in some years, whales migrate directly to the northern coast of Chukotka while in other years, whales may pause migration and linger, presumably to feed, in the central Chukchi Sea. To investigate how whale movements may be related to oceanographic variables we examined bowhead whale habitat selection within the Chukchi Sea in autumn (September-November) at two spatial scales. First, at the landscape scale (i.e. the Chukchi Sea), we compare oceanographic variables (e.g. temperature, salinity, and current velocity) at locations within used and randomly available tracks (i.e. paths of travel) to determine how oceanographic features are associated with where whales cross the Chukchi Sea in autumn. Second, at a local scale, we examine how directed travel or lingering within a whale's track is associated with oceanographic variables (e.g. temperature, salinity, and current velocity). Whale location data for 24 bowhead whales were paired with

oceanographic data from a pan-arctic coupled ice-ocean model for 2006–2009. At the landscape scale, we found that whales generally followed water of Pacific origin characterized by temperatures <0ºC and salinities between 31.5 and 34.25. Bowhead whales avoided Alaskan Coastal Water and Siberian Shelf Water, the latter of which defines the western limit of their range, likely due to lower intrinsic densities of zooplankton prey.

At the local scale, within their tracks, whales were more likely to interrupt directed movements and linger in areas characterized by stronger gradients in bottom salinity.

Citta, J. J., L. Quakenbush, and J. C. George. 2021. Chapter 4 - Distribution and behavior of Bering-Chukchi-Beaufort bowhead whales as inferred by telemetry, p. 31-56. ***In*** J. C. George and J. G. M. Thewissen (editor), The Bowhead Whale. Academic Press. Cambridge, MA. https://doi.org/10.1016/B978-0-12-818969-6.00004-2

Keywords**:** Bering-Chukchi-Beaufort stock; western Arctic stock; Bering Sea stock; bowhead whales; marine mammal; satellite telemetry; feeding behavior; dive behavior

Abstract**:** Over the last 30 years, the use of telemetry, especially satellite telemetry, has improved our understanding of bowhead whale movements and behavior of the Bering-Chukchi-Beaufort (BCB) stock. Here, we summarize the findings of a collaboration between the Alaska Department of Fish and Game, the Alaska Eskimo Whaling Commission, the North Slope Borough, and Fisheries and Oceans Canada that deployed satellite tags (n=77) on bowhead whales during 2006–18. This study refined our knowledge of the distribution of BCB bowhead whales, especially outside the boundaries of aerial surveys and away from whaling communities. We found that whale movements are much more complex and wide-ranging than originally thought; for example, some whales that initially migrate to the Canadian Beaufort may return west in midsummer, sometimes traveling all the way to Russia and back to Canada prior to the autumn migration. Based upon whale behavior (i.e., the timing of movements and dive behavior) and the colocation of whales and oceanographic features that help aggregate prey, bowhead whales of the BCB stock likely feed year-round. We think the distribution of BCB bowhead whales is largely driven by food availability and that whales have spatial memory of where food was located in past years. Much of the data we collected on the distribution of BCB bowhead whales is already out of date, as environmental changes are altering the distribution of bowhead prey and sea ice.

Clark, C. W., C. L. Berchok, S. B. Blackwell, D. E. Hannay, J. Jones, D. Ponirakis, and K. M. Stafford. 2015. A year in the acoustic world of bowhead whales in the Bering, Chukchi and Beaufort seas. Progress in Oceanography. 136:223-240. https://doi.org/10.1016/j.pocean.2015.05.007

Keywords**:** marine mammals; bowhead whale, *Balaena mysticetus*, Bering Sea; Chukchi Sea; Beaufort Sea

***Abstract*:** Bowhead whales, *Balaena mysticetus*, in the Bering–Chukchi–Beaufort (BCB) population, experience a variable acoustic environment among the regions they inhabit throughout the year. A total of 41,698h of acoustic data were recorded from 1 August 2009 through 4 October 2010 at 20 sites spread along a 2300km transect from the Bering Sea to the southeast Beaufort Sea. These data represent the combined output from six research teams using four recorder types. Recorders sampled areas in which bowheads occur and in which there are natural and anthropogenic sources producing varying amounts of underwater noise. We describe and quantify the occurrence of bowheads throughout their range in the Bering, Chukchi, and Beaufort seas over a 14-month period by aggregating our acoustic detections of bowhead whale sounds. We also describe the spatial–temporal variability in the bowhead acoustic environment using sound level measurements within a frequency band in which their sounds occur, by dividing a year into three, 4-month seasons (Summer–Fall 2009, August–November 2009: Winter 2009–2010, December 2009–March 2010: and Spring–Summer 2010, April–July 2010) and their home range into five zones. Statistical analyses revealed no significant relationship between acoustic occurrence, distance offshore, and water depth during Summer–Fall 2009, but there was a significant relationship during Spring–Summer 2010. A continuous period with elevated broadband sound levels lasting ca. 38 days occurred in the Bering Sea during the Winter 2009–2010 season as a result of singing bowheads, while a second period of elevated levels lasting at least 30 days occurred during the early spring–summer season as a result of singing bearded seals. The lowest noise levels occurred in the Chukchi Sea from the latter part of November into May. In late summer 2009 very faint sounds from a seismic airgun survey approximately 700km away in the eastern Beaufort Sea were detected on Chukchi recorders. Throughout the year, but most obviously during the November into May period, clusters of intermittent, nearly synchronized, high-level events were evident on multiple recorders hundreds of miles apart. In some cases, these clusters occurred over 2–5day periods and appear to be associated with high wind conditions.

Cline, J. D., and M. L. Holmes. 1977. Submarine seepage of natural gas in Norton Sound, Alaska. Science. 198(4322):1149-53. https://doi.org/10.1126/science.198.4322.1149

***Keywords*:** hydrocarbons; structural geology; bottom water; petroleum; Norton Sound

***Abstract*:** Unusual concentrations of dissolved two- to four-carbon alkanes were observed in the waters in Norton Sound in a localized area approximately 40 kilometers south of Nome, Alaska, in 1976. The hydrocarbons were identified in the near-bottom waters downcurrent for more than 100 kilometers from a sea-floor point source. Preliminary dynamic modeling estimates of the initial gas phase composition predict methanelethane and ethanelpropane ratios of 24 and 1.7, respectively, assuming the hydrocarbons were introduced by bubbles. The low ethanelpropane ratio is indicative of gas from a liquid petroleum source rather than from nonassociated or biogenic natural gas. Preliminary data on the structural geology of Norton Basin lend support to the interpretation based on the hydrocarbon plume. Unconformably truncated strata dip basinward from the seep locus; acoustic anomalies and numerous steeply dipping faults in the immediate vicinity of the

seep are corroborating evidence that shallow gas- or petroleum-charged sediments and strata coincide with avenues for migration of mobile hydrocarbons to the sea floor. These factors, taken in concert with the sedimentological regime, the recent revision (increase) of basin depth estimates, and the highly localized hydrocarbon source, strongly suggest a thermogenic rather than a recent biogenic origin for these gaseous compounds.

Clukey, E., D. A. Cacchione, and C. H. Nelson. 1980. Liquifaction potential of the Yukon prodelta, Bering Sea. ***In*** Offshore Technology Conference Houston, Texas. https://doi.org/10.4043/3773-ms

***Keywords*:** deposit; sediment; permeability; wave height; pore-water pressure; liquefy; undrained condition; loading; assessment; reservoir characterization

***Abstract*:** The Yukon prodelta is exposed to large storm waves propagating northward from the southern Bering Sea. Shallow water depths of the prodelta enhance the transfer of energy from the surface waves to the bottom. As the bottom deposits are cyclically loaded by large storm waves, potential decrease in their resistance to shear could ultimately cause liquefaction. A preliminary assessment of the engineering properties of Yukon sandy silt suggests that the prodelta deposits may be susceptible to wave induced liquefaction during severe storm events. In addition, erosion and are suspension of sediment in the prodelta may be intensified because of the liquefaction process.

Coachman, L. K., and K. Aagaard. 1988. Transports through Bering Strait: Annual and interannual variability. Journal of Geophysical Research: Oceans. 93(C12):15535-15539. https://doi.org/10.1029/JC093iC12p15535

***Keywords*:** currents; wind; model; Bering Sea; Bering Strait

***Abstract*:** Reanalysis of the 1976–1977 mean monthly transport estimates for Bering Strait of Coachman and Aagaard (1981) shows a considerably stronger wind dependence than was calculated by Aagaard et al. (1985). We find (1) a long-term mean transport of 0.8 Sv, (2) an annual transport cycle of amplitude 0.6 Sv, with the maximum in June, the minimum in February, and a secondary maximum in January probably associated with North Pacific blocking-ridge activity, and (3) an interannual variability marked by a number of low-flow years in the past two decades, including three of the four lowest-transport winter periods during this century. In a new current time series from 1984 to 1985 we find anomalously strong and persistent northerly flow during a 2-month period in which the current/wind correlation breaks down. This occurred during a prolonged period with southerly winds, and we believe the data point to an asymmetry in the dynamical response of the Bering Strait flow to major changes in wind direction.

Coachman, L. K. 1993. On the flow field in the Chirikov Basin. Continental Shelf Research. 13(5-6):481-508. https://doi.org/10.1016/0278-4343(93)90092-c

***Keywords*:** currents; wind; model; Bering Sea; Bering Strait

***Abstract*:** Current measurements from moorings in the Anadyr, Shpanberg and Bering straits and the Chirikov Basin each year from 1985 to 1988 over the summer production period (June–September) shed new light on the regional flow regime. Analyses focus on water conservation and residence times in the Chirikov Basin and the relationships between flows and regional wind field. The primary finding is the existence of two flow modes, a "Summer" mode lasting for 2–4 months each year, then a sharp transition about the middle of August each year to a "Fall" mode which prevails until the following April, May or June; periods of low flow variability as long as one month at other times of the year do not establish Summer flow conditions. All aspects of the flow field differ depending on which mode is active: north transport, coupling of flow to local winds, flow energy, incidence of flow reversals, and residence times. The cause for the modal behavior is marked differences in both the speed and direction of local winds and the degree of north-south wind divergence-convergence over the Bering Strait region. Analyses of flow reversals in one or more of the straits (there are four patterns) show how they are related to the regional winds.

Cooper, L. W., T. E. Whitledge, J. M. Grebmeier, and T. Weingartner. 1997. The nutrient, salinity, and stable oxygen isotope composition of Bering and Chukchi Seas waters in and near the Bering Strait. Journal of Geophysical Research: Oceans. 102(C6):12563-12573. https://doi.org/10.1029/97JC00015

***Keywords*:** nutrients; salinity; oxygen; Bering Sea; Chukchi Sea

***Abstract*:** Seawater nutrient, salinity, and oxygen 18 data collected from 1990 to 1993 in the Bering and Chukchi Seas were used to identify potential sources of nutrients and water masses that result in formation of the Arctic Ocean upper halocline and its associated nutrient maximum. Water matching the δ18O values of the Arctic Ocean upper halocline and containing sufficient, or a nearly sufficient, nutrient and salinity concentration was collected in subsurface waters in the summer in portions of the Bering Sea, particularly the Gulf of Anadyr. However, nutrient concentrations significantly declined in this north flowing water over the shallow continental shelf before it reached the Bering Strait, as a consequence of biological utilization, and dilution with nutrient-poor and oxygen 18-depleted fresh water. Therefore it does not appear likely that the flow of unaltered water through the Bering Strait in the summer plays a critical role in the formation of the Arctic Ocean upper halocline. The role of other mechanisms for contributing Pacific-derived waters to the Arctic Ocean nutrient maximum is considered.

Cooper, L. W., G. F. Cota, L. R. Pomeroy, J. M. Grebmeier, and T. E. Whitledge. 1999. Modification of NO, PO, and NO/PO during flow across the Bering and Chukchi shelves: Implications for use as Arctic water mass tracers. Journal of Geophysical Research: Oceans. 104(C4):7827-7836. https://doi.org/10.1029/1999jc900010

***Keywords*:** nutrients; currents; nitrogen; phosphorus; Arctic water

***Abstract*:** The NO and PO tracers (9[NO_3^-] + O2 and 135[PO_4^-] + O_2, respectively,) and their derivative NO/PO have found increasing use in Arctic water mass analyses for identifying the specific basin or shelf areas from which surface waters originate, based upon assumed differences in Pacific- and Atlantic-derived content and basin-to-basin differences within the Arctic. Following shipboard sampling in June-September 1993 and May-June 1994, both north and south of Bering Strait, we have found evidence that Pacific-derived waters flowing north to Bering Strait do not necessarily have any unique NO, PO, or NO/PO identity that would permit unequivocal use as a water mass tracer. In particular, NO/PO ratios in the Bering Sea continental shelf (<150 m) waters varied from 0.7 to 1.1, which encompasses ratios previously reported for Arctic continental shelf and Atlantic origin waters in the Arctic Ocean. The highest NO/PO ratios (∼1) in the Bering Sea were observed to the southwest of St. Lawrence Island, close to where high nutrient waters are first upwelled onto the shelf, and seasonally early in the biological production cycle. By contrast, later in the summer, north of Bering Strait, at the depth of the Arctic Ocean nutrient maximum, the highest concentrations of silica (∼60 μM) were associated with low NO/PO ratios (∼0.7). Apparent increases in the proportions of sea ice melt in these waters, inferred from 18O and salinity regressions, were associated with lower NO/PO ratios. This pattern, the potential for sea-air exchange, and a significant relationship between decreases in nitrate/phosphate ratios and both NO/PO ratios and silica concentrations indicate that biological and physical processes north and south of Bering Strait affect the fidelity of these nutrient-based tracers. These results indicate the need for consideration of shelf-based processes before NO/PO ratios and other nutrient-based tracers can be successfully applied as Arctic circulation tracers.

Cooper, L. W., J. M. Grebmeier, I. L. Larsen, V. G. Egorov, C. Theodorakis, H. P. Kelly, and J. R. Lovvorn. 2002. Seasonal variation in sedimentation of organic materials in the St. Lawrence Island polynya region, Bering Sea. Marine Ecology Progress Series. 226:13-26. https://doi.org/10.3354/meps226013

***Keywords*:** Bering Sea; polynya; benthic-pelagic coupling; beryllium-7; ultraviolet radiation; carbon isotopes

***Abstract*:** A polynya that forms each winter south of St. Lawrence Island in the Bering Sea is located near very high standing stocks of macrobenthic invertebrates on this Arctic continental shelf. Sampling during or just after the ice melt in 1990, 1993, and 1994 revealed water-column, sediment particle and chemical distributions that were consistent with a high flux of organic materials to the sediments during the ice retreat. In contrast, lower phytoplankton biomass observed in late summer and fall of 1993, 1998, and 1999

was associated with seasonal declines in sedimentation indicators such as chlorophyll a in the water column and deposited on the surface sediments, lower occurrences of an atmospherically derived radionuclide beryllium-7 (7Be) in surface sediments, and lower sediment oxygen demand. Moreover, observations under late-winter conditions in April 1999 did not support a direct, continuous linkage between water-column production when the winter polynya is active and the very high benthic biomass and productivity observed on this shallow (30 to 60 m) shelf. For example, deposition of recent water-column production to the sediments in April was significantly lower than that during and just after the ice retreat in May and June. This lower rate of deposition in April was inferred from proxy indicators including photosynthetically-competent chlorophyll extractable from surface sediments, the presence of 7Be in surface sediments, and sediment oxygen demand. Despite high nutrient concentrations, water-column chlorophyll a concentrations were also uniformly lower (0.5 to 2 mg m^{-3}) in April than in May and June. Measurements of the underwater light and ultraviolet radiation field and analysis of DNA damage to dosimeters indicated that the low chlorophyll a biomass is probably not influenced by UV radiation in late winter and early spring. The stable carbon isotope composition of organic carbon in surface sediments suggests that open-water production in the polynya, relative to the adjacent production of sea-ice algae, is not large enough to influence the isotopic composition of organic materials in surface sediments near the polynya.

Cooper, L. W., M. A. Janout, K. E. Frey, R. Pirtle-Levy, M. L. Guarinello, J. M. Grebmeier, and J. R. Lovvorn. 2012. The relationship between sea ice break-up, water mass variation, chlorophyll biomass, and sedimentation in the northern Bering Sea. Deep Sea Research Part II: Topical Studies in Oceanography. 65-70:141-162. https://doi.org/10.1016/j.dsr2.2012.02.002

Keywords**:** sedimentation; Arctic zone; ice cover; ice breakup; Bering Sea

Abstract**:** The northern Bering Sea shelf is dominated by soft-bottom infauna and ecologically significant epifauna that are matched by few other marine ecosystems in biomass. The likely basis for this high benthic biomass is the intense spring bloom, but few studies have followed the direct sedimentation of organic material during the bloom peak in May. Satellite imagery, water column chlorophyll concentrations and surface sediment chlorophyll inventories were used to document the dynamics of sedimentation to the sea floor in both 2006 and 2007, as well as to compare to existing data from the spring bloom in 1994. An atmospherically-derived radionuclide, 7Be, that is deposited in surface sediments as ice cover retreats was used to supplement these observations, as were studies of light penetration and nutrient depletion in the water column as the bloom progressed. Chlorophyll biomass as sea ice melted differed significantly among the three years studied (1994, 2006, 2007). The lowest chlorophyll biomass was observed in 2006, after strong northerly and easterly winds had distributed relatively low nutrient water from near the Alaskan coast westward across the shelf prior to ice retreat. By contrast, in 1994 and 2007, northerly winds had less northeasterly vectors prior to sea ice retreat, which reduced the westward extent of low-nutrient waters across the shelf. Additional possible impacts on chlorophyll biomass include the timing of sea-ice retreat in 1994 and 2007, which occurred

several weeks earlier than in 2006 in waters with the highest nutrient content. Late winter brine formation and associated water column mixing may also have impacts on productivity that have not been previously recognized. These observations suggest that interconnected complexities will prevent straightforward predictions of the influence of earlier ice retreat in the northern Bering Sea upon water column productivity and any resulting benthic ecosystem re-structuring as seasonal sea ice retreats in the northern Bering Sea.

Cooper, L. W., M. G. Sexson, J. M. Grebmeier, R. Gradinger, C. W. Mordy, and J. R. Lovvorn. 2013. Linkages between sea-ice coverage, pelagic-benthic coupling, and the distribution of spectacled eiders: observations in March 2008, 2009 and 2010, northern Bering Sea. Deep-Sea Research Part II: Topical Studies in Oceanography. 94(October 2013):31-43. https://doi.org/10.1016/j.dsr2.2013.03.009

***Keywords*:** nutrients; chlorophyll; plankton; Spectacled Eider; sea ice; ecosystems; St Lawrence Island; Bering Sea

***Abstract*:** Icebreaker-based sampling in the northern Bering Sea south of St. Lawrence Island in March of 2008, 2009, and 2010 has provided new data on overall ecosystem function early in the annual productive cycle. While water-column chlorophyll concentrations (<25 mg m−2 integrated over the whole water column) are two orders of magnitude lower than observed during the spring bloom in May, sea-ice algal inventories of chlorophyll are high (up to 1 g m−3 in the bottom 2-cm of sea-ice). Vertical fluxes of chlorophyll as measured in sediment traps were between 0.3 to 3.7 mg m−2 d−1 and were consistent with the recent deposition (days to weeks time scale) of chlorophyll to the surface sediments (0–25 mg m−2 present at 0–1 cm). Sediment oxygen respiration rates were lower than previous measurements that followed the spring bloom, but were highest in areas of known high benthic biomass. Early spring release of sedimentary ammonium occurs, particularly southeast of St. Lawrence Island, leading to bottom-water ammonium concentrations of >5 µM. These data, together with other physical, biological, and nutrient data are presented here in conjunction with observed sea-ice dynamics and the distribution of an apex predator, the Spectacled Eider (*Somateria fischeri*). Sea-ice dynamics in addition to benthic food availability, as determined by sedimentation processes, play a role in the distribution of spectacled eiders, which cannot always access the greatest biomass of their preferred bivalve prey. Overall, the data and observations indicate that the northern Bering Sea is biologically active in late winter, but with strong atmospheric and hydrographic controls. These controls pre-determine nutrient and chlorophyll distributions, water-column mixing, as well as pelagic-benthic coupling.

Coyle, K. O., and R. C. Highsmith. 1994. Benthic amphipod community in the northern Bering Sea: analysis of potential structuring mechanisms. Marine Ecology Progress Series. 107(3):233-244. http://www.jstor.org/stable/24842680

***Keywords*:** ampeliscids; competition; predation; Bering Sea

***Abstract*:** The age class structure of ampeliscid populations is determined largely by competition for space. Population densities of the various ampeliscid species are regulated by a balance between required carbon flux rates to the seafloor, predation rates, competition for space and reproductive potential. The largest taxa require high organic matter input and low predation rates to mature and reproduce. Reductions in organic matter flux favor smaller taxa. Low predation rates favor larger taxa, which can out-compete the smaller taxa for available space. High predation rates favor smaller taxa, which have a higher reproductive rate and are therefore more effective colonizers. The above factors can explain the relative concentrations of *Ampelisca macrocephala*, *Ampelisca birulai* and *Byblis* spp., the most abundant ampeliscids in the northern Bering Sea. Elevated predation losses to gray whales will depress the density of the large-sized *A. macrocephala* populations and increase the density of the smallest species, *A. birulai*. Global warming should elevate ampeliscid food requirements, and may also lead to elevated predation rates, both selecting for smaller species.

Coyle, K. O., A. I. Pinchuk, L. B. Eisner, and J. M. Napp. 2008. Zooplankton species composition, abundance and biomass on the eastern Bering Sea shelf during summer: The potential role of water-column stability and nutrients in structuring the zooplankton community. Deep Sea Research Part II: Topical Studies in Oceanography. 55(16-17):1775-1791. https://doi.org/10.1016/j.dsr2.2008.04.029

***Keywords*:** zooplankton; hydrography; stability; nutrients; Alaska; Bering Sea

***Abstract*:** The southeastern Bering Sea sustains one of the largest fisheries in the United States, as well as wildlife resources that support valuable tourist and subsistence economies. The fish and wildlife populations in turn are sustained by a food web linking primary producers to apex predators through the zooplankton community. Recent shifts in climate toward warmer conditions may threaten these resources by altering productivity and trophic relationships in the ecosystem on the southeastern Bering Sea shelf. We examined the zooplankton community near the Pribilof Islands and on the middle shelf of the southeastern Bering Sea in summer of 1999 and 2004 to document differences and similarities in species composition, abundance and biomass by region and year. Between August 1999 and August 2004, the summer zooplankton community of the middle shelf shifted from large to small species. Significant declines were observed in the biomass of large scyphozoans (*Chrysaora melanaster*), large copepods (*Calanus marshallae*), arrow worms (*Sagitta elegans*) and euphausiids (*Thysanoessa raschii, T. inermis*) between 1999 and 2004. In contrast, significantly higher densities of the small copepods (*Pseudocalanus* spp., *Oithona similis*) and small hydromedusae (*Euphysa flammea*) were observed in 2004 relative to 1999. Stomach analyses of young-of-the-year (age 0) pollock (*Theragra chalcogramma*) from the middle shelf indicated a dietary shift from large to small copepods in 2004 relative to 1999. The shift in the zooplankton community was accompanied by a 3-fold increase in water-column stability in 2004 relative to 1999, primarily due to warmer

water above the thermocline, with a mean temperature of 7.3 °C in 1999 and 12.6 °C in 2004. The elevated water-column stability and warmer conditions may have influenced the zooplankton composition by lowering summer primary production and selecting for species more tolerant of a warm, oligotrophic environment. A time series of temperature from the middle shelf indicates that the warmer conditions in 2004 are part of a trend rather than an expression of interannual variability. These results suggest that if climate on the Bering Sea shelf continues to warm, the zooplankton community may shift from large to small taxa which could strongly impact apex predators and the economies they support.

Crain, D. D., S. A. Karpovich, L. Quakenbush, and L. Polasek. 2021. Using claws to compare reproduction, stress and diet of female bearded and ringed seals in the Bering and Chukchi seas, Alaska, between 1953–1968 and 1998–2014. Conservation Physiology. 9(1):1-14. https://doi.org/10.1093/conphys/coaa115

Keywords**:** sea ice; climate; marine mammals; seals; isotopes

Abstract**:** Rapid climate warming is decreasing sea ice thickness, extent and duration. Marine mammals such as bearded (*Erignathus barbatus*) and ringed (*Pusa hispida*) seals, which use sea ice for pupping, molting and resting, may be negatively affected. Claws from bearded and ringed seals store up to 14 and 12 years of sequential analyte data, respectively. These data can be used to compare reproduction, stress and diet across decades. In this study, we compare progesterone, cortisol and carbon and nitrogen stable isotopes in female bearded and ringed seals during 1953–1968 (pre-1968, a period prior to sea ice decline) to 1998–2014 (post-1998, a period during sea ice decline). When comparing these periods, bearded seals had statistically higher cortisol concentrations post-1998, and for both species δ13C was more negative post-1998, while progesterone and δ15N did not change. There was a positive relationship between progesterone and cortisol Z-scores for both species, except for ringed seals post-1998. There was a negative relationship between cortisol Z-scores and δ13C for bearded seals evident in post-1998 indicating that higher cortisol Z-scores are associated with more negative δ13C in bearded seals in recent years. This negative relationship between cortisol and δ13C in bearded seals suggests a shift to higher prey diversity, possibly due to changes in sea ice in the Pacific Arctic evident post 1998. Progesterone Z-scores corresponded to expected differences among non-pregnant, unimplanted, implanted and post-partum individuals. Using these data, pregnancy history was determined for reproductive years for each individual female sampled, which could allow for yearly pregnancy rates to be calculated given a large enough representative sample of the population. These results combine decades of observational studies with hormones and stable isotopes to infer changes in reproduction, stress and diet, as well as the connection between these life history parameters.

Crawford, J. A., L. T. Quakenbush, and J. J. Citta. 2015. A comparison of ringed and bearded seal diet, condition and productivity between historical (1975–1984) and recent (2003–2012) periods in the Alaskan Bering and Chukchi seas. Progress in Oceanography. 136:133-150. https://doi.org/10.1016/j.pocean.2015.05.011

Keywords**:** sea ice; climate; marine mammals; seals; Chukchi Sea; Beaufort Sea

Abstract**:** Reductions in summer sea ice in the Chukchi and Beaufort seas are expected to affect what has been an ice-adapted marine food web in the Pacific Arctic. To determine whether recent decreases in sea ice have affected ice-associated marine predators (i.e., ringed, *Pusa hispida*, and bearded seals, *Erignathus barbatus*) in the Bering and Chukchi seas we compared diet, body condition, growth, productivity, and the proportion of pups harvested (an index of weaning success) for seals of each species harvested by 11 Alaskan villages during two periods; a historical (1975–1984) and a recent period (2003–2012). We also examined how changes in indices of seal health may be correlated with the reduction of sea ice characteristic of the recent period. For ringed seals ⩾1year of age, the % frequency of occurrence (%FO) of Arctic cod (*Boreogadus saida*), walleye pollock (*Gadus chalcogramma*), rainbow smelt (*Osmerus mordax*), and Pacific herring (*Clupea pallasi*) increased from the historic to the recent period, while the %FO of invertebrates decreased for both pups and seals ⩾1year of age. For bearded seals ⩾1year of age, the %FO of Arctic cod, pricklebacks, and flatfish increased during the recent period, while the %FO of saffron cod (*Eleginus gracilis*) decreased for pups. Although invertebrates did not change overall for either age class, decreases occurred in 10 of 24 specific prey categories, for bearded seals ⩾1year of age; only echiurids increased. The %FO of gastropods and bivalves increased for pups while isopods and one species of shrimp and crab decreased in occurrence. During the recent period ringed seals grew faster, had thicker blubber, had no change in pregnancy rate, matured 2 years earlier, and a larger proportion of pups was harvested than during the historical period. Correlations with spring ice concentration showed that the growth and blubber thickness of seals ⩾1year of age, blubber thickness of pups, and the proportion of pups in the harvest all declined for ringed seals when ice concentrations were higher in the historic period. However, only the correlations between high ice concentrations and growth of ringed seals ⩾1year of age and the proportion of ringed seal pups in the harvest were statistically significant. Although growth of bearded seals ⩾1year of age was slower during the recent period, it was similar to the average over the entire time series, and blubber thickness increased. Pup growth and blubber thickness did not change between periods. There was no change in pregnancy rate, but females matured 1.6 years earlier, and a larger proportion of pups were harvested. Correlations with spring ice concentration showed that the growth of seals ⩾1year of age, the growth of pups, blubber thickness of pups, and proportion of pups in the harvest also declined for bearded seals when sea ice concentrations were higher. However, no relationships between bearded seals and sea ice were statistically significant. Overall, our results suggest that ringed seals in the Alaskan Bering and Chukchi seas have adjusted to changes in diet, are growing faster and possibly weaning more pups in the recent compared to the historic period. These patterns are less evident for bearded seals. Although the ringed and bearded seals we examined have not exhibited the declines in body condition, growth, or reproduction observed in other populations, continued monitoring and comparison among seal populations is vital to understanding the effects of changing environmental conditions in the Pacific Arctic region.

Cui, X., J. M. Grebmeier, and L. W. Cooper. 2012. Feeding ecology of dominant groundfish in the northern Bering Sea. Polar Biology. 35(9):1407-1419. https://doi.org/10.1007/s00300-012-1180-9

Keywords**:** Bering Sea; groundfish; feeding ecology; stomach content; prey overlap; arctic cod

Abstract**:** We investigated current diets of the six most abundant benthic fish in the northern Bering Sea. Our objective was to explore feeding strategies and potential competition with other top predators as ecosystem changes occur in the northern Bering Sea ecosystem. Our approach used stomach content data collected from field sampling during spring 2006 and 2007. Calanoid copepods and ampeliscid amphipods were important prey of Arctic cod (*Boreogadus saida*) but in different proportions depending upon fish size, feeding location, and local environmental conditions. Snailfish (Liparidae) occupied a broad niche and fed on a variety of benthic amphipods. Arctic alligatorfish (*Ulcina olrikii*) and Arctic staghorn sculpin (*Gymnocanthus tricuspis*) consumed ampeliscid amphipods predominantly. Shorthorn sculpin (*Myoxocephalus scorpius*) had a less-diverse diet, with snow crab (*Chionoecetes opilio*) most important by weight. Finally, all Bering flounder (*Hippoglossoides robustus*) sampled had empty stomachs. Our results indicate that ampeliscid amphipods, which have high biomass in the central region of the northern Bering Sea, are the most important prey for the dominant groundfish in the Chirikov Basin. Generally, all dominant benthic fish in the northern Bering Sea had narrow feeding niches, except snailfish. High diet overlap was found among many of the fish species, including Arctic cod and snailfish, snailfish and Arctic alligatorfish, and Arctic alligatorfish and Arctic staghorn sculpin. These findings are consistent with a relatively short food chain for benthic fish that are for the most part specialized feeders with narrow preferences for food and may be affected by changes in benthic prey distributions.

Danielson, S., E. Curchitser, K. Hedstrom, T. Weingartner, and P. Stabeno. 2011. On ocean and sea ice modes of variability in the Bering Sea. Journal of Geophysical Research: Oceans. 116(C12):C12034. https://doi.org/10.1029/2011JC007389

Keywords**:** sea ice; hindcast; climate; Bering Sea

Abstract**:** Results from a 35 year hindcast of northeast Pacific Ocean conditions are confronted with observational data collected over the Bering Sea shelf within the integration time period. Rotary power spectra of the hindcast currents near NOAA mooring site M2 site fall within the 95% confidence bounds for the observational spectra, except for a high bias in the counter-clockwise rotating component at 10 m depth in the high frequencies (periods <24 h). The model exhibits the most skill in reproducing anomalies of the integrated annual sea ice concentration and monthly subsurface (60 m depth) temperature fields, accounting for 85% and 50% of their observed variability. Analysis of the integrated ice concentration time series reveals evolution in the mean duration of ice-free waters (40 year trend of +6.8 days/decade) and changes in this parameter's variance with

time. Correlation and empirical orthogonal function (EOF) analyses reveal the primary temporal-spatial patterns of variability in the temperature and salinity fields over the Bering Sea and northern Gulf of Alaska for near-surface (0–20 m) and subsurface (40–100 m) depth layers. Correlation analysis between the EOF principal components and various climate index and observed time series shows that the Pacific Decadal Oscillation, the North Pacific Gyre Oscillation, and the Bering Sea annually integrated ice area anomalies are important indices of thermohaline variability; the spatial structures of these modes give insight to their potential impacts upon the ecosystem. We identify a number of ecologically and economically important species whose temporal variability is significantly correlated with the identified spatial patterns.

Danielson, S. L., T. J. Weingartner, K. S. Hedstrom, K. Aagaard, R. Woodgate, E. Curchitser, and P. J. Stabeno. 2014. 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. Progress in Oceanography. 125:40-61. https://doi.org/10.1016/j.pocean.2014.04.006

Keywords**:** currents; wind; model; Bering Sea; Bering Strait

Abstract**:** 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 using atmospheric reanalyses, current meter observations, satellite-based sea surface height (SSH) measurements, hydrographic profiles, and numerical model integrations. 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. While Ekman pumping controls Canada Basin dynamic heights (Proshutinsky et al., 2002), we do not find evidence for a strong relation between Beaufort Gyre sea surface height variations and the annually averaged Bering Strait throughflow. Over the western Chukchi and East Siberian seas easterly 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.

de la Vega, C., R. M. Jeffreys, R. Tuerena, R. Ganeshram, and C. Mahaffey. 2019. Temporal and spatial trends in marine carbon isotopes in the Arctic Ocean and implications for food web studies. Global Change Biology. 25(12):4116-4130. https://doi.org/10.1111/gcb.14832

***Keywords*:** carbon; sea ice; climate; ocean acidification; arctic marine ecosystems

***Abstract*:** The Arctic is undergoing unprecedented environmental change. Rapid warming, decline in sea ice extent, increase in riverine input, ocean acidification and changes in primary productivity are creating a crucible for multiple concurrent environmental stressors, with unknown consequences for the entire arctic ecosystem. Here, we synthesized 30 years of data on the stable carbon isotope (δ13C) signatures in dissolved inorganic carbon (δ13C-DIC; 1977–2014), marine and riverine particulate organic carbon (δ13C-POC; 1986–2013) and tissues of marine mammals in the Arctic. δ13C values in consumers can change as a result of environmentally driven variation in the δ13C values at the base of the food web or alteration in the trophic structure, thus providing a method to assess the sensitivity of food webs to environmental change. Our synthesis reveals a spatially heterogeneous and temporally evolving δ13C baseline, with spatial gradients in the δ13C-POC values between arctic shelves and arctic basins likely driven by differences in productivity and riverine and coastal influence. We report a decline in δ13C-DIC values (−0.011‰ per year) in the Arctic, reflecting increasing anthropogenic carbon dioxide (CO2) in the Arctic Ocean (i.e. Suess effect), which is larger than predicted. The larger decline in δ13C-POC values and δ13C in arctic marine mammals reflects the anthropogenic CO_2 signal as well as the influence of a changing arctic environment. Combining the influence of changing sea ice conditions and isotopic fractionation by phytoplankton, we explain the decadal decline in δ13C-POC values in the Arctic Ocean and partially explain the δ13C values in marine mammals with consideration of time-varying integration of δ13C values. The response of the arctic ecosystem to ongoing environmental change is stronger than we would predict theoretically, which has tremendous implications for the study of food webs in the rapidly changing Arctic Ocean.

DeMaster, D. P., L. F. Lowry, K. J. Frost, and R. A. Bengtson. 2001. The effect of sea state on estimates of abundance for beluga whales (*Delphinapterus leucas*) in Norton Sound, Alaska. Fishery Bulletin. (99):197-201. https://www.semanticscholar.org/paper/The-effect-of-sea-state-on-estimates-of-abundance-(-Demaster-Lowry/f3ec8eb5033a9791286ea001b91a7a8dd0b236f2

***Keywords*:** Beluga whale; marine mammal surveys

***Abstract*:** Beluga whales (*Delphinapterus leucas*) are relatively small odontocete cetaceans; standard lengths of newborn calves are about 160 cm and adults range from 300 to 450 cm (Doidge, 1990). At birth, calves are dark slate gray, and the color gradually lightens until they become pure white as adults (Brodie, 1989). When actively swimming or diving, their bodies break the surface only for brief periods. Frost et al. (1985) reported that the average length of surfacing intervals for two radio-tagged beluga whales were 0.9–2.2 seconds.

Aerial surveys are the most common method for estimating the abundance of beluga whales (e.g. Frost and Lowry, 1990; Richard et al., 1990; and Harwood et al., 1996). Beluga whales are readily seen from aircraft in calm, clear waters but become increasingly difficult to detect when the water is murky or when whitecaps are present. Although a reduction in detectability in higher sea states is expected, there have been no published reports to quantify this effect on beluga whale counts. Rather, researchers have usually restricted survey effort to conditions where whitecaps are uncommon to control the effect of sea state on estimates of abundance for beluga whales (*Delphinapterus leucas*) in Norton Sound, Alaska.

Derkachev, A. N., V. V. Ponomareva, M. V. Portnyagin, S. A. Gorbarenko, N. A. Nikolaeva, M. I. Malakhov, E. A. Zelenin, D. Nürnberg, and Y. Liu. 2018. Widespread tephra layers in the Bering Sea sediments: distal clues to large explosive eruptions from the Aleutian volcanic arc. Bulletin of Volcanology. 80(11):80. https://doi.org/10.1007/s00445-018-1254-9

Keywords**:** volcanism; volcanoes; tephra; marine sediment; Aleutian Islands; Bering Sea

Abstract**:** Tephra layers within marine sediments provide information on past explosive eruptions, which is especially important in the case of remote island arcs where data on proximal pyroclastic deposits can be scarce. Three Alaska-Aleutian tephras (labeled Br2, SR2, and SR4) were found in the late Pleistocene-Holocene sediments of the Bering Sea (north Pacific). We fingerprint glass from these tephras with the help of single-shard electron microprobe and LA-ICP-MS analyses and provide microprobe data on minerals from two of these tephras. The large compositional variability of the Alaska-Aleutian volcanoes permits the use of ratios of highly incompatible trace elements (Ba/Nb, Th/Nb, Th/La, La/Nb) for identification of distal tephra sources by comparison of these ratios in tephra glass and proximal bulk rock analyses. This method, along with mapped tephra dispersal, has allowed us to link tephras under study to Aniakchak, Semisopochnoi, and Okmok volcanoes, respectively. Our results indicate that tephra Br2 was derived from the ~ 3.6 ka Aniakchak II caldera-forming eruption (Alaska, USA). This is the first ever finding of the Aniakchak II tephra in Bering Sea sediments, which permits enlargement of its tephra volume and eruption magnitude to ~ 100 km^3 and 6.8, respectively. Tephra SR2, dated at ~ 12.2 ka, is likely associated with a post-glacial caldera on the Semisopochnoi Island, Aleutians (USA). Tephra SR4 (dated at ~ 64.5 ka), likely was derived from an earlier undocumented eruption from Okmok volcano (Aleutians). All three regionally spread tephra layers are valuable isochrones, which can be used for correlating and dating of Bering Sea sediments.

Dingier, J. R., and A. H. Sallenger. 1978. Coastal processes and morphology of the Bering Sea coast of Alaska. U.S. Dep. Interior, USGS. OCS Environmental Assessment Program. RU-431. 377-441 p. U.S. Geological Survey Menlo Park, California 94025. https://espis.boem.gov/final%20reports/1589.pdf

***Keywords*:** North Aleutian Basin; Norton Basin; Alaska; geology; coastal zone; geomorphology; transport; sediment; erosion; deposition; seasonality; model; intertidal; subtidal; wave height; Bering Sea; Nome; Norton Sound; Bristol Bay; Alaska region

***Abstract*:** Much of our effort during the first year of our study (FY 76) was involved in regional characterization of the physical environment of the Bering Sea coast of Alaska. This included determination of net longshore transport directions (for the entire study area), characterization of coastal morphology, and reconnaissance of beach morphology and sediment characteristics (for the northern Bering Sea coast of Alaska and the Bristol Bay coast of the Alaska Peninsula). In FY 77, these types of studies were extended to Pavlov Bay and Cold Bay on the Pacific coast of the Alaska Peninsula. These potential deep water ports may serve offshore petroleum exploitation of the Bristol Bay area in the future. The results of these types of studies can be used to obtain qualitative assessments of coastal stability, in preparing preliminary siting studies for coastal developments, and in the determination of the long-term directions of transport of particulate pollutants in the littoral system.

Drake, D. E., C. E. Totman, and P. L. Wi. 1979. Sediment transport during the winter on the Yukon prodelta Norton Sound, Alaska. SEPM Journal of Sedimentary Research. Vol. 49. https://doi.org/10.1306/212f78dd-2b24-11d7-8648000102c1865d

***Keywords*:** geomorphology; suspended sediment; hydrodynamics; shear stress; tides; Norton Sound; Bering Sea

***Abstract*:** Winter in the northern Bering Sea brings a drastic reduction in terrestrial runoff and a substantial decrease in air-sea momentum transfer (wind and waves) owing to the formation of shorefast and pack ice. Despite these changes, quantities of suspended silt and clay over the Yukon prodelta in the winter of 1978 were essentially the same as those observed during fair weather summer periods, when the sediment discharge of the Yukon River is at its maximum and there is no ice layer to inhibit surface waves. Furthermore, the regional transport pattern involving northward mean flow across the prodelta in Norton Sound remains unchanged in the winter. Bottom current and light scattering measurements obtained during the summer of 1977 showed that spring tides are capable of resuspending fine sediment at depths of about 18 m on the prodelta in the absence of significant surface wave action. We conclude that during the winter the suspended matter transport system is driven by tidal current reworking of sediments which were introduced by the Yukon River during the previous summer.

Drake, D. E., D. A. Cacchione, R. D. Muench, and C. H. Nelson. 1980. Sediment transport in Norton Sound, Alaska. Marine Geology. 36(1-2):97-126. https://doi.org/10.1016/0025-3227(80)90043-2

***Keywords*:** geomorphology; suspended sediment; hydrodynamics; shear stress; erosion; Norton Sound; Bering Sea

***Abstract*:** The Yukon River, the largest single source of Bering Sea sediment, delivers >95% of its sediment load at the southwest corner of Norton Sound during the ice-free months of late May through October. During this period, surface winds in the northern Bering Sea area are generally light from the south and southwest, and surface waves are not significant. Although wind stress may cause some transport of low-density turbid surface water into the head of Norton Sound, the most significant transport of Yukon River suspended matter occurs within advective currents flowing north across the outer part of the sound. The thickest accumulations of modern Yukon silt and very fine sand occur beneath this persistent current. We monitored temporal variations in bottom currents, pressure, and suspended-matter concentrations within this major transport pathway for 80 days in the summer of 1977 using a Geological Processes Bottom Environmental (GEOPROBE) tripod system. The record reveals two distinctive periods of bottom flow and sediment transport: an initial 59 days (July 8–September 5) of fair-weather conditions, characterized by tidally dominated currents and relatively low, stable suspended-matter concentrations; and a 21-day period (September 5–September 26) during which several storms traversed the northern Bering Sea, mean suspended-matter concentrations near the bottom increased by a factor of five, and the earlier tidal dominance was overshadowed by wind-driven and oscillatory wave-generated currents. Friction velocities (u*) at the GEOPROBE site were generally subcritical during the initial fair-weather period. In contrast, the 21-day stormy period was characterized by values that exceeded the critical level of 1.3 cm/s more than 60% of the time. The GEOPROBE data suggest that the very fine sand constituting about 50% of the sediment on the outer part of the Yukon prodelta is transported during a few late-summer and fall storms each year. A conservative estimate shows that suspended-matter transport during the storms in September 1977 was equal to four months of fair-weather transport.

Droghini, A., A. S. Fischbach, J. T. Watson, and J. P. Reimer. 2020. Regional ocean models indicate changing limits to biological invasions in the Bering Sea. ICES Journal of Marine Science. 77(3):964-974. https://doi.org/10.1093/icesjms/fsaa014

***Keywords*:** Alaska; climate envelope model; extreme temperatures; invasive species; North Pacific; non-native species; physiological thresholds; suitability modelling

***Abstract*:** Minimal vessel traffic and cold water temperatures are believed to limit non-indigenous species (NIS) in high-latitude ecosystems. We evaluated whether suitable conditions exist in the Bering Sea for the survival and reproduction of NIS. We compiled temperature and salinity thresholds of NIS and compared these to ocean conditions projected during two study periods: recent (2003–2012) and mid-century (2030–2039). We also explored patterns of vessel traffic and connectivity for US Bering Sea ports. We found that the southeastern Bering Sea had suitable conditions for the year-round survival of 80% of NIS assessed (n = 42). This highly suitable area is home to the port of Dutch Harbor, which received the most vessel arrivals and ballast water discharge in the US Bering Sea. Conditions north of 58°N that include sub-zero winter water temperatures were unsuitable for most NIS. While mid-century models predicted a northward expansion of suitable

conditions, conditions for reproduction remained marginal. Only 40% of NIS assessed (n = 25) had 6 or more weeks where conditions were suitable for reproduction. Our findings illustrate the potential vulnerability of a commercially important subarctic ecosystem and highlight the need to consider life stages beyond adult survival when evaluating limits to NIS establishment.

Druckenmiller, M. L., J. J. Citta, M. C. Ferguson, J. T. Clarke, J. C. George, and L. Quakenbush. 2018. Trends in sea-ice cover within bowhead whale habitats in the Pacific Arctic. Deep Sea Research Part II: Topical Studies in Oceanography. 152:95-107. https://doi.org/10.1016/j.dsr2.2017.10.017

Keywords**:** Bowhead whales; marine mammal; Arctic; sea ice; Beaufort Sea; Chukchi Sea; Bering Sea

Abstract**:** The range of the Bering-Chukchi-Beaufort (BCB) population of bowhead whales (*Balaena mysticetus*) extends across the seasonally ice-covered waters of the Pacific Arctic region. The majority of whales summer in the eastern Beaufort Sea and winter in the Bering Sea, migrating across the Chukchi Sea in fall and spring. As arctic sea-ice extent rapidly diminishes, the increasing length and variability of the open water season is changing bowhead habitat substantially, with many areas now regularly ice-free when whales are present. This study examines changes in the number of open water days (OWD) between 1979 and 2014 within annual bowhead whale core-use areas as defined by satellite tagging data, and within the western Beaufort Sea (140–157°W; to 72°N) sampled by fall aerial surveys. Ice cover has decreased more in the core-use areas in the northern extent of the range than in core-use areas in the southern extent. The numbers of OWD within the core-use areas near Point Barrow and along the northern Chukotka Coast during peak use have increased by 13 and 10 days/decade, respectively. The most dramatic reductions in sea-ice cover have taken place in the western Beaufort Sea where the number of OWD on the shelf and slope have increased by 20 and 25 days/decade, respectively. In contrast, sea-ice cover has not significantly changed within the winter core-use area near the Gulf of Anadyr. Using aerial survey data, we found that bowheads in the Beaufort Sea during the fall migration have a preference for being closer to shore than to the ice edge, and that their distance to shore decreases as the fraction of open water increases. This distribution may be due to increased feeding opportunities closer to shore as a result of greater upwelling along the shelf break when the ice cover is farther from shore. Furthermore, the aerial survey data also revealed a substantial shift westward toward Point Barrow in the whales' use of the western Beaufort Sea during fall in the period 1997–2014 compared to 1982–1996. The extent and timing of sea-ice coverage has changed relatively little over time in the Bering Sea. Bowheads typically migrate north prior to spring ice melt and retreat; therefore, large changes in the timing of the spring migration are not expected. We anticipate that bowheads will spend increasingly more time within summer and fall feeding areas, delaying their arrival to wintering areas in the Bering Sea. Reduced ice coverage and thickness in the southern Chukchi Sea may make wintering there more common in the future. Summer and fall movements may be more variable as productivity and zooplankton aggregations in

existing feeding areas are altered in response to sea ice thinning and retreat, and as new areas become available.

Drucker, R. 2003. Observations of ice thickness and frazil ice in the St. Lawrence Island polynya from satellite imagery, upward looking sonar, and salinity/temperature moorings. Journal of Geophysical Research. 108(C5):3149. https://doi.org/10.1029/2001jc001213

***Keywords*:** St. Lawrence Island; polynya; Bering Sea; polynya processes; remote sensing; studies of polynyas

***Abstract*:** For the 1999 winter, this paper examines the behavior of the Bering Sea St. Lawrence Island polynya using a combination of Advanced Very High Resolution Radiometer (AVHRR), RADARSAT synthetic aperture radar (SAR), meteorological data, over-winter moored upward looking sonars (ULS) and SeaBird salinity/temperature sensors. We define a thermal ice thickness from the AVHRR retrieval of ice surface temperature combined with meteorological observations and a heat flux model. South of the island, we compare the ULS and thermal thicknesses for congelation and frazil ice. When the satellites observe congelation ice over the ULSs, the ULS and thermal ice thicknesses generally agree. When SAR observes Langmuir plumes over the ULSs, which indicate frazil ice formation, the ULSs show scatterers at 5–20 m depths in the water column and the seawater temperatures are either within 0.01°C of freezing or are slightly supercooled. This suggests that during frazil events, crystals either nucleate at depth or are transported to depth by the Langmuir circulation. The combination of the SAR imagery and ULS observations also allow measurement of the pack ice advection velocity, the polynya width and the downwind frazil accumulation thickness, giving widths of 10 to 30 km and thicknesses of 0.1–0.2 m. Substitution of these observed values with the heat flux into the Pease polynya model yields polynya widths that approximately agree with the observed.

Duffy-Anderson, J. T., P. Stabeno, A. G. Andrews III, K. Cieciel, A. Deary, E. Farley, C. Fugate, C. Harpold, R. Heintz, D. Kimmel, K. Kuletz, J. Lamb, M. Paquin, S. Porter, L. Rogers, A. Spear, and E. Yasumiishi. 2019. Responses of the northern Bering Sea and southeastern Bering Sea pelagic ecosystems following record-breaking low winter sea ice. Geophysical Research Letters. 46(16):9833-9842. https://doi.org/10.1029/2019GL083396

***Keywords*:** sea ice; stratification; crustaceans; zooplankton; seabirds; ecosystem shifts; Bering Sea

***Abstract*:** Bering Sea sea ice during winter 2017–2018 was the lowest ever recorded. Ecosystem effects of low ice have been observed in the southeastern Bering Sea, but never in the northern Bering Sea. Observations in both systems included weakened water column stratification, delayed spring bloom, and low abundances of large crustacean zooplankton. Summer Cold Pool presence was extremely limited. Young walleye pollock production and condition were similar to prior warm years, though catches of other pelagic forage fishes were low. Summer seabird die-offs were observed in the northern Bering Sea, and to lesser

extent in the southeastern Bering Sea, and reproductive success was poor at monitored colonies. Selected bottom-up responses to lack of sea ice in the north were similar to those in the south, potentially providing environmental indicators to project ecosystem effects in a lesser studied system. Results offer a potential glimpse of the broader Bering Sea pelagic ecosystem under future low-ice projections.

Eisner, L. B. 2013. The Bering Sea: Current status and recent trends. PICES Press. 21(1):29-31. https://meetings.pices.int/publications/pices-press

***Keywords*:** earth sciences; oceanography; ice precipitation; temperature science; energy management; meetings; ecosystems; cod; biomass; cold trends; climate change; fishing; plankton; United States; US; Arctic region; Japan

***Abstract*:** In the Bering Sea, winter-spring ocean temperatures in 2012 remained cold with lots of sea ice, similar to 2008 and 2010. This created the most extensive cold pool of the recent decade for summer 2012. Unlike a year ago, the summer of 2012 was relatively calm, and this resulted in a rather thin (-10 m) mixed layer that rapidly warmed in June through July, especially in the north, producing near-normal sea surface temperatures in summer. Given the relatively low heat content on the Bering Sea shelf at present, people are probably looking at a moderate to heavy ice year for 2013, although weather in late winter and early spring can change this prediction. Several fisheries oceanography surveys took place during summer and early fall 2012 in the Bering Sea. Hokkaido University's T/S Oshoro Maru conducted a survey in the Aleutian Islands and eastern Bering Sea shelf.

Eisner, L. B. 2015. The Bering Sea: Current status and recent trends. PICES Press. 23(1):33-35. https://meetings.pices.int/publications/pices-press

***Keywords*:** earth sciences; oceanography; fish; meteorology; birds; climate change; salmon

***Abstract*:** The sea surface temperatures over the eastern Bering Sea shelf were 2°C warmer than normal during the period of April through September 2014. This warmth can be attributed to the combination of the relatively mild winter of 2013-2014 and atmospheric forcing during the spring and summer of 2014. Mean sea level pressure was slightly above average for the period of interest, and the winds were anomalously weak in an overall sense, as illustrated by the time series of daily wind speeds at St. Paul in the Pribilof Islands. The return to warmer conditions featured a large coccolithophore bloom, small phytoplankton cells with plates composed of calcium carbonate, which give the water a milky aqua-colored appearance. This bloom started in July and persisted through September 2014, and was observed both in situ and in satellite images. In situ measurements of chlorophyll-α fluorescence and light attenuation indicated that the bloom occurred over approximately the top 20 m of the water column.

Eisner, L. B. 2016. The Bering Sea: Current status and recent trends. PICES Press. 24(1):42-45. https://meetings.pices.int/publications/pices-press

***Keywords*:** earth sciences; oceanography; cold; crustaceans; temperature; plankton; age; river; ecology; ecosystems; oceanography; biomass; minors; ice

***Abstract*:** The period of April through September 2015 featured positive sea surface temperature anomalies across much of the Bering Sea, with particularly warm water on the southeast portion of the shelf. The positive temperature anomalies represent a continuation of a warm period that began in 2014 after a relatively cold interval from 2007 into 2013. At the end of the summer of 2015, the depth-averaged temperature at Mooring 2 was at a maximum in a record extending back to 1995. The warmth can be attributed in part to the relatively mild winter of 2014-2015, especially on the Bering Sea shelf, where the ice did not extend as far south as usual, with the result being also a smaller cold pool. In other words, the extreme warmth during August to September 2015 on the Bering Sea shelf was not so much due to enhanced summer heating but rather due more to pre-existing positive temperature anomalies, especially at depth.

Eisner, L. B. 2017. The Bering Sea: Current status and recent trends. PICES Press. 25(1):46-49. https://meetings.pices.int/publications/pices-press

***Keywords*:** earth sciences; oceanography; temperature; birds; ecosystems; oceanography; summer; heat estimates; islands time series; Pribilof Islands; Anchorage; Alaska

***Abstract*:** The marine heat wave in the Bering Sea that began in 2014 continued through the interval of April 2016-September 2016. A map of the sea surface temperature anomaly distribution for the interval shows that it was especially warm on the southeastern Bering Sea shelf. The warm water was not just at the surface but rather, extended through the entire water column, with depth-averaged temperatures at Mooring 2 reaching a maximum in a record extending back to 1995. Remarkably, the vertically-integrated heat content at the end of the winter of 2016 was comparable to that during cold summers, such as 1999. The NOAA Ecosystem and Fisheries-Oceanography Coordinated Investigations group at the Alaska Fisheries Science Center conduct at-sea rapid assessments to provide a near real time index of zooplankton abundance. In 2016, abundance in the southeastern Bering Sea was dominated by small copepods < 2 mm.

Eisner, L. B. 2018. The Bering Sea: Current status and recent trends. PICES Press. 26(1):29-33. https://meetings.pices.int/publications/pices-press

***Keywords*:** earth sciences; oceanography; fish; meteorology; birds; climate change; salmon

***Abstract*:** Eisner provides details on current status and recent trends in the Bering Sea. The Bering Sea experienced moderate conditions during April-September 2017, relative to the anomalous warmth that prevailed from 2014 into early 2017. A map of the SST anomaly for April-September 2017 shows that conditions were still mostly warmer than normal. Anomalies exceeded 1°C across much of the northern portion of the Bering Sea, with +2°C

anomalies for some coastal areas. The southeastern shelf was only slightly warmer than normal. The anomalous warmth on the shelf was confined to a shallow layer near the surface. In particular, the depth-averaged temperatures at Mooring 2 (57°N, 164°W) were actually slightly cooler than normal, in part because the mixed layer was only about 10-15 m thick during much of the summer of 2017. The cooler water on the shelf as compared with the previous 3 years can be attributed in large part to the greater sea ice coverage during the preceding winter, again compared with recent years. Wintry weather that occurred in early April 2017 helped to cool and completely mix the waters over much of the southeastern shelf; the result was a cold pool during the summer in the middle shelf that extended much farther southeast than during the previous three summers.

Eisner, L. B. 2019. The Bering Sea: Current status and recent trends. PICES Press. 27(1):33-35,39. https://meetings.pices.int/publications/pices-press

***Keywords*:** earth sciences; oceanography; plankton; oceans; fisheries; trends; temperature; sea ice; winter; marine mammals; bottom water; ecosystems; summer; Oregon; Bering Sea; Canada; Alaska

***Abstract*:** During April through September 2018, Bering Sea ocean conditions reflected the unusual climate forcing of the previous winter as well of that of the period of review here. As reported in the previous edition of PICES Press, the winter of 2017-2018 was exceptionally warm, with a record low sea ice extent on the eastern shelf north of 60°N. The result was the smallest cold pool (near bottom water <2°C) on the Bering Sea shelf during the summer of 2018 since at least the early 1960s (P. Stabeno, personal communication). A map of the SST anomaly distribution for April-September 2018 shows warmer than normal temperatures for the entire region, with particularly high anomalies exceeding 2.5°C in Norton Sound and Kotzebue Sound. The temperatures in the southern portion of the Bering Shelf were not as extreme. Nevertheless, the depth-averaged temperatures at Mooring 2 (near 57°N, 164°W) were the second-highest in the observational record extending back to 1995 (the highest value was in 2016).

Eisner, L. B. 2020. The Bering Sea: Current status and recent trends. PICES Press. 28(1):60-64. https://meetings.pices.int/publications/pices-press

***Keywords*:** earth sciences; oceanography; polls & surveys; cod; summer; fisheries; weather patterns; sea ice; winter; biomass; ecosystems; ice; water temperature; salmon; fish; Bering Sea; Chukchi Sea; Arctic region; Alaska; Bering Strait

***Abstract*:** In what seems to be more the rule than the exception at the present time, the Bering Sea was considerably warmer than normal during the spring and summer of 2019, relative to historical norms. A map of the SST anomaly distribution for the months of April-September 2019 shows that it was particularly warm on the southeastern Bering Sea shelf, where the 6-month average temperatures were more than 3°C higher than their 1981-2010 averages. This constituted a virtual tie with 2016 for the warmest SST on record for the 6-

month period and that portion of the Bering Sea. The period considered here started off warm for the Bering Sea because the previous winter of 2018-19 was so unusual. In particular, that winter featured wind anomalies from the southwest, which meant more mild maritime air than usual and hence reduced southward advection and development of sea ice. The warm anomalies in the Bering Sea continued to increase during the spring and summer of 2019 due to the overall regional weather patterns that prevailed during that period.

Eisner, L. B., Y. I. Zuenko, E. O. Basyuk, L. L. Britt, J. T. Duffy-Anderson, S. Kotwicki, C. Ladd, and W. Cheng. 2020. Environmental impacts on walleye pollock (*Gadus chalcogrammus*) distribution across the Bering Sea shelf. Deep Sea Research Part II: Topical Studies in Oceanography. 181-182:104881. https://doi.org/10.1016/j.dsr2.2020.104881

Keywords**:** walleye pollock; Bering Sea; temperature; sea ice; cold pool

Abstract**:** Adult and juvenile (age-1) walleye pollock (*Gadus chalcogrammus*) were sampled by the US NOAA Alaska Fisheries Science Center summer bottom trawl survey in 2010, 2017, 2018, and 2019 in the northeastern and southeastern Bering Sea, with profiles of temperature collected concurrently. Similarly, the Russian Research Institute of Fisheries and Oceanography, Pacific branch, collected adult and juvenile pollock and temperature profiles on summer bottom trawl surveys in the northwestern Bering Sea. Results from these surveys show that adult pollock abundance in recent years (2017, 2018, 2019) has increased in northern regions of the Bering Sea shelf in both the US and Russian sectors. Lower abundances, compared to historic means, were observed in southern regions of the shelf, suggesting the pollock moved directionally from the south to the north. We relate changes in pollock distribution in recent intermediate (2017) and warm, low-ice years (2018–2019) to a prior cold, high-ice year (2010) and describe how these observations relate to our longer time series. We link temperature data from bottom trawl surveys (US and Russian), sea-ice indices (retreat timing and extent), as well as model-based estimates of ocean circulation to changes in pollock distribution and examine potential environmental factors driving the observed changes. Changes in sea-ice and bottom temperature (e.g., reductions in ice extent and shrinking of the cold pool), and changes in circulation (stronger northward currents over the northeastern shelf in warmer years, particularly in 2018) led to changes in distributions of adult and age-1 pollock. Adult pollock were concentrated north of St. Lawrence Island and had larger longitudinal distributions in warm years, 2017–2019; whereas they had a more southerly and narrow distribution over the outer shelf in the cold year, 2010. Age-1 pollock had higher densities over the inner eastern shelf in 2017–2019 compared to 2010. Northward flow around St. Lawrence Island (particularly in the spring) alternated between stronger flow on the west side of the island in 2010 and 2017 and stronger flow on the east side of the island in 2018 and 2019; variations in flow may have impacted the location of prey and movement of feeding pollock to the Chukchi Sea. Size structure comparisons between NW, NE and SE sections of the Bering Sea shelf suggest that movement of fish between US and Russian waters may have been highest in 2019, one of the two warmest years, and lowest in 2010, the coldest year. Spatial comparisons of

distributions and size structure across the Bering Sea help provide a comprehensive view of factors affecting the movement of this highly important commercial fish species.

Eisner, L. B. 2021. The Bering Sea: Current status and recent trends. PICES Press. 29(1):40-43. https://meetings.pices.int/publications/pices-press

***Keywords*:** earth sciences; oceanography; wind; fisheries; trends; river; ecology; pressure distribution; biomass; time series; acoustics; salmon; aquatic ecosystems; ocean temperature; Norton Sound; Bering Sea; Aleutian Islands; Yukon River; Alaska; Gulf of Alaska

***Abstract*:** The Bering Sea was warm during the spring and summer of 2020 relative to historical norms, but not to the extent of most of the past 5 years. The magnitude of the anomalous warmth in sea surface temperatures (SST) during 2020 from an area-average perspective was roughly one-half that during 2019. A map of the SST anomaly distribution for the months of April through September 2020 shows that it was especially warm over a broad band centered over the shelf break of the eastern Bering Sea, where the 6-month average temperatures were on the order of 1.5 degree C greater than their 1981-2010 averages. Positive temperature anomalies of lesser magnitude occurred in the western Bering Sea and in the vicinity of Bering Strait. Notably, the anomalies in the northern Bering Sea during 2020 were substantially weaker than those observed in that region during the same period of 2018 and 2019. The temperatures at depth appear to have been warmer than normal, but not to an extreme.

Erikson, L. H., R. T. McCall, A. van Rooijen, and B. Norris. 2015. Hindcast storm events in the Bering Sea for the St. Lawrence Island and Unalakleet Regions, Alaska. US. Dep. Interior, USGS. Open-File Report. 2015-1193. 57 p. Reston, VA. https://doi.org/10.3133/ofr20151193

***Keywords*:** model; climate; climate shifts; sea ice loss; coastal communities; storm surge; sea level; flooding

***Abstract*:** This study provides viable estimates of historical storm-induced water levels in the coastal communities of Gambell and Savoonga situated on St. Lawrence Island in the Bering Sea, as well as Unalakleet located at the head of Norton Sound on the western coast of Alaska. Gambell, Savoonga, and Unalakleet are small Native Villages that are regularly impacted by coastal storms but where little quantitative information about these storms exists. The closest continuous water-level gauge is at Nome, located more than 200 kilometers from both St. Lawrence Island and Unalakleet. In this study, storms are identified and quantified using historical atmospheric and sea-ice data and then used as boundary conditions for a suite of numerical models. The work includes storm-surge (temporary rise in water levels due to persistent strong winds and low atmospheric pressures) modeling in the Bering Strait region, as well as modeling of wave runup along specified sections of the coast in Gambell and Unalakleet. Modeled historical water levels are used to develop return periods of storm surge and storm surge plus wave runup at key locations in each

community. It is anticipated that the results will fill some of the data void regarding coastal flood data in western Alaska and be used for production of coastal vulnerability maps and community planning efforts.

Fall, J., N. Braem, C. Brown, L. Hutchinson-Scarbrough, D. Koster, and T. Krieg. 2013. Continuity and change in subsistence harvests in five Bering Sea communities: Akutan, Emmonak, Savoonga, St. Paul, and Togiak. Deep Sea Research Part II: Topical Studies in Oceanography. 94:274-291. https://doi.org/10.1016/j.dsr2.2013.03.010

***Keywords*:** climate change; sea ice; marine mammals; fisheries; Alaska Natives; traditional knowledge; Arctic; subsistence

***Abstract*:** To document and quantify subsistence harvests of fish and wildlife resources, and provide topics for subsequent key respondent interviews to collect local and traditional knowledge (LTK) about the Bering Sea ecosystem, comprehensive household harvest surveys were conducted in four Bering Sea Alaska Native communities: Akutan, Emmonak, Savoonga, and Togiak. In a fifth community, St. Paul, annual programs to document two key subsistence resources, fur seals and sea lions, continued. Surveys documented relatively high and diverse subsistence harvests, consistent with earlier research that demonstrated the continuing economic, social, and cultural importance of subsistence uses of wild resources. The research also found differences in subsistence use patterns compared to previous years' studies, such as harvest levels, harvest composition, and diversity of resources used, although differences between study years were not uniform across communities. Survey respondents, as well as key respondents in subsequent interviews, identified a complex range of personal, economic, and environmental factors when comparing subsistence uses in the study year with other years, such as increasing costs of fuel and purchased food, commercial fisheries harvests and bycatch, more persistent storms and less predictable winds, and reduced sea ice. Such conditions affect resource abundance and locations as well as access to fish and wildlife populations, and may shape long-term trends. So far, as in the past, families and communities have adapted to changing economic, social, and environmental conditions, but the future is less clear if such changes intensify or accelerate. Local community residents should be essential partners in future efforts to understand these complex processes that affect the natural resources of the Bering Sea.

Fedewa, E. J., T. M. Jackson, J. I. Richar, J. L. Gardner, and M. A. Litzow. 2020. Recent shifts in northern Bering Sea snow crab (*Chionoecetes opilio*) size structure and the potential role of climate-mediated range contraction. Deep Sea Research Part II: Topical Studies in Oceanography. 181-182:104878. https://doi.org/10.1016/j.dsr2.2020.104878

***Keywords*:** Climate change; snow crab; Bering Sea; cold pool; spatial distribution; loss of sea ice; demography

***Abstract*:** Recent historic lows in sea ice and cold pool extent in the Bering Sea have been linked to large-scale biogeographic shifts in many demersal taxa. Snow crab (*Chionoecetes opilio*) are associated with the cold pool and thus may be especially prone to northward range contraction with continued warming. Data from the 1988–2019 National Marine Fisheries Service eastern Bering Sea (EBS) bottom trawl surveys were used to examine the effect of climate warming on snow crab thermal habitat use and spatial distributions. The northern Bering Sea (NBS) was also surveyed in 2010 and 2017–2019, allowing us to examine NBS snow crab demographic structure relative to potential climate-driven range contraction into the NBS. Across the time series, trends in temperatures occupied by snow crab were tightly coupled with average bottom temperatures in the EBS despite extreme temperatures in 2018–2019 that exceeded cold-water thermal preferences of juvenile snow crab. Furthermore, we found that increased temperatures and a reduced, more northerly cold pool extent resulted in a smaller area occupied by snow crab across different ontogenetic stages, although there was no evidence for a northward shift in centers of distribution within the EBS. These findings suggest that the spatial extent and average temperature of snow crab distribution are likely constrained by the availability of cold water habitat in the EBS, and dramatic declines in juvenile snow crab abundance observed in 2019 may be attributed to potential direct or indirect temperature effects on survival of highly stenothermic early benthic stages of snow crab. Despite limited support for a directional range shift, survey abundance estimates indicated a ~600% increase in abundance of larger size classes of male snow crab (≥61 mm carapace width) in the NBS between 2018 and 2019. Substantial shifts in juvenile abundances and NBS snow crab size structure in 2019 may have important management implications for the stock. While the increase in NBS mature male biomass may suggest the potential for a commercial fishery in more northern latitudes, concurrent declines in juvenile abundance suggest caution concerning the sustainability of the stock with continued warming.

Field, M. E., C. H. Nelson, D. A. Cacchione, and D. E. Drake. 1981. Sand waves on an epicontinental shelf: Northern Bering Sea. Marine Geology. 42(1-4):233-258. http://pubs.er.usgs.gov/publication/70012029

***Keywords*:** geomorphology; suspended sediment; hydrodynamics; shear stress; sand; bedforms; Bering Sea

***Abstract*:** Sand waves and current ripples occupy the crests and flanks of a series of large linear sand ridges (20 km x 5 km x 10 m high) lying in an open-marine setting in the northern Bering Sea. The sand wave area, which lies west of Seward Peninsula and southeast of Bering Strait, is exposed to the strong continuous flow of coastal water northward toward Bering Strait. A hierarchy of three sizes of superimposed bedforms, all facing northward, was observed in successive cruises in 1976 and 1977. Large sand waves (height 2 m; spacing 200 m) have smaller sand waves (height 1 m; spacing 20 m) lying at a small oblique angle on their stoss slopes. The smaller sand waves in turn have linguoid ripples on their stoss slopes. Repeated studies of the sand wave fields were made both years with high-resolution seismic-reflection profiles, side-scan sonographs, underwater

photographs, current-meter stations, vibracores, and suspended-sediment samplers. Comparison of seismic and side-scan data collected along profile lines run both years showed changes in sand wave shape that indicate significant bedload transport within the year. Gouge marks made in sediment by keels of floating ice also showed significantly different patterns each year, further documenting modification to the bottom by sediment transport. During calm sea conditions in 1977, underwater video and camera observations showed formation and active migration of linguoid and straight-crested current ripples. Current speeds 1 m above the bottom were between 20 and 30 cm/s. Maximum current velocities and sand wave migration apparently occur when strong southwesterly winds enhance the steady northerly flow of coastal water. Many cross-stratified sand bodies in the geologic record are interpreted as having formed in a tidal- or storm-dominated setting. This study provides an example of formation and migration of large bedforms by the interaction of storms with strong uniform coastal currents in an open-marine setting.

Fienup-Riordan, A., C. Brown, and N. M. Braem. 2013. The value of ethnography in times of change: The story of Emmonak. Deep Sea Research Part II: Topical Studies in Oceanography. 94:301-311. https://doi.org/10.1016/j.dsr2.2013.04.005

***Keywords*:** Bering Sea; local and traditional knowledge; Alaska Natives; subsistence; ethnography

***Abstract*:** This paper considers the connections between the social science components of two major multidisciplinary research projects recently carried out in the Eastern Bering Sea: The Bering Ecosystem Study Program (BEST) and the Bering Sea Integrated Ecosystem Research Program (BSIERP). Although the primary concern of the larger Integrated Bering Sea Project was oceanographic, a significant effort was made to understand the impacts of changes in the Eastern Bering Sea on coastal communities. We describe our complementary research in Emmonak in order to put the local and traditional knowledge (LTK) survey and interview data gathered during the BSIERP study into ethnographic and historical context to show how important time depth is in the interpretation of LTK. Taking examples from salmon fishing, seal harvesting, and local understandings of place, we argue that a comprehensive ethnographic approach, including both LTK and cultural history, is essential in understanding contemporary Bering Sea coastal communities.

Frey, K. E., G. W. K. Moore, L. W. Cooper, and J. M. Grebmeier. 2015. Divergent patterns of recent sea ice cover across the Bering, Chukchi, and Beaufort seas of the Pacific Arctic Region. Progress in Oceanography. 136:32-49. https://doi.org/10.1016/j.pocean.2015.05.009

***Keywords*:** sea ice; hindcast; model; climate; climate shifts; sea ice loss; Bering Sea; Chukchi Sea; Beaufort Sea

***Abstract*:** Over the past three decades of the observed satellite record, there have been significant changes in sea ice cover across the Bering, Chukchi, and Beaufort seas of the Pacific Arctic Region (PAR). Satellite data reveal that patterns in sea ice cover have been

spatially heterogeneous, with significant declines in the Chukchi and Beaufort seas, yet more complex multi-year variability in the Bering Sea south of St. Lawrence Island. These patterns in the Chukchi and Beaufort seas have intensified since 2000, indicating a regime shift in sea ice cover across the northern portion of the PAR. In particular, satellite data over 1979–2012 reveal localized decreases in sea ice presence of up to −1.64 days/year (Canada Basin) and −1.24 days/year (Beaufort Sea), which accelerated to up to −6.57 days/year (Canada Basin) and −12.84 days/year (Beaufort Sea) over the 2000–2012 time period. In contrast, sea ice in the Bering Sea shows more complex multi-year variability with localized increases in sea ice presence of up to +8.41 days/year since 2000. The observed increases in sea ice cover since 2000 in the southern Bering Sea shelf region are observed in wintertime, whereas sea ice losses in the Canada Basin and Beaufort Sea have occurred during summer. We further compare sea ice variability across the region with the National Centers for Environmental Prediction (NCEP) North American Regional Reanalysis (NARR) wind and air temperature fields to determine the extent to which this recent variability is driven by thermal vs. wind-driven processes. Results suggest that for these localized areas that are experiencing the most rapid shifts in sea ice cover, those in the Beaufort Sea are primarily wind driven, those offshore in the Canada Basin are primarily thermally driven, and those in the Bering Sea are influenced by elements of both. Sea ice variability (and its drivers) across the PAR provides critical insight into the forcing effects of recent shifts in climate and its likely ultimate profound impacts on ecosystem productivity across all trophic levels.

Frost, K. J., and L. F. Lowry. 1980. Feeding of ribbon seals (*Phoca fasciata*) in the Bering Sea in spring. Canadian Journal of Zoology. 58(9):1601-1607. https://doi.org/10.1139/z80-219

***Keywords*:** marine mammal; seals; sea ice; ecosystems; climate

***Abstract*:** Digestive tracts of 61 ribbon seals (*Phoca fasciata*) collected in the seasonal pack ice of the Bering Sea during March to June 1976–1979 were examined. Very little fresh food was found in stomachs; however, hard parts of prey, particularly fish otoliths, were found in stomachs and (or) intestines of 28 seals. Based on counts of otoliths, the main prey were pollock in south-central and central Bering Sea, and arctic cod in northern Bering Sea. Weights and lengths of fishes consumed by seals were estimated from measurements of otoliths. On the basis of estimated whole weight of prey consumed, eelpout were a major food of these seals in south-central and central Bering Sea. Comparison of the species composition of fishes caught in trawls and eaten by seals suggests that seals in central and northern Bering Sea select for pollock and arctic cod, and against sculpins and capelin. In contrast, in south-central Bering Sea pollock was the most abundant fish in both seals and trawls. Seals were nonselective with regard to size of pollock consumed but appeared to select for large arctic cod. Our data suggest feeding conditions may be more favorable for ribbon seals in south-central Bering Sea than in more northern areas.

Fukai, Y., Y. Abe, K. Matsuno, and A. Yamaguchi. 2020. Spatial changes in the summer diatom community of the northern Bering Sea in 2017 and 2018. Deep Sea Research Part II: Topical Studies in Oceanography. 181-182:104903. https://doi.org/10.1016/j.dsr2.2020.104903

***Keywords*:** northern Bering Sea; phytoplankton community; diatoms; year-to-year changes

***Abstract*:** In recent years, the northern Bering Sea has experienced changes in the timing of sea-ice retreat and in hydrographic conditions during the summer. The influence of these environmental changes on the diatom community has not been examined. In this study, we investigated the spatial changes in the diatom community of the northern Bering Sea during the summers of 2017 and 2018, and evaluated the effects of environmental variability on these communities. We found that the diatom cell density and diversity varied with water masses. A cluster analysis based on cell density revealed that the diatom communities were separated into four groups, and that the distributions of three of these groups were different spatially between 2017 and 2018. In the Bering Strait and the Chirikov Basin regions, the diatom communities differed between 2017 and 2018. In 2017, these diatom communities were dominated by cold-water species such as *Chaetoceros gelidus* and *Chaetoceros* spp. (subgenus *Hyalochaetae*), while in 2018, the community was dominated by cosmopolitan species such as *Thalassionema nitzschioides* and *Chaetoceros* spp. (subgenus *Phaeoceros*). NMDS and multiple regression analysis indicated that the timing of the sea-ice retreat was the most important contributor to the differences in the diatom community. In contrast, there was no year-to-year difference south of St. Lawrence Island, possibly because nutrients were depleted and phytoplankton types other than diatoms were dominant.

Fukuchi, M., H. Sasaki, H. Hattori, O. Matsuda, A. Tanimura, N. Handa, and C. P. McRoy. 1993. Temporal variability of particulate flux in the northern Bering Sea. Continental Shelf Research. 13(5):693-704. https://doi.org/10.1016/0278-4343(93)90100-C

***Keywords*:** carbon; sediment; sediment transport; Bering Sea

***Abstract*:** Observations of downward particulate flux were carried out in the main depocenter of the Chirikov Basin in the northern Bering Sea between 20 June and 24 September 1988 using a time series sediment trap. A total of 12 samples, each representing an 8 day period, were collected at the mooring depth of 36 m where the bottom depth was 49 m. Total POC flux varied between 253 and 654 mg C m^{-2} day^{-1}. Relatively low C/N ratios (4.9–7.4) indicated a fresh organic matter supply to benthic communities. The mean organic carbon flux (501 mg m^{-2} day^{-1}) is comparable to the estimated organic carbon utilization (464 mg m^{-2} day^{-1}) at the sediment surface (Grebmeier and McRoy, 1989 Marine Ecology Progress Series, 53, 79–91), suggesting a close correspondence between the particulate flux and the benthic demand of the Chirikov depocenter.

Fukuyama, A. K., and J. S. Oliver. 1985. Sea star and walrus predation on bivalves in Norton Sound, Bering Sea, Alaska. Ophelia. 24(1):17-36. https://doi.org/10.1080/00785236.1985.10426616

***Keywords*:** walrus; animal survey; sea stars; Bering Sea; Norton Sound

***Abstract*:** Pacific walruses (*Odobenus rosmarus divergens*) and sea stars (*Asterias amurensis*) are the primary predators on bivalve mollusks in Norton Sound and probably in most of the Bering and Chukchi Seas. Secondary predators in these areas include starry flounder (*Platichthys stellatus*) and king (*Paralithodes* spp.) and Tanner (*Chionoecetes* spp.) crabs. Walruses and sea stars consume the same species, but not the same sizes of bivalves. The primary walrus prey are large individuals of several bivalve species, which have no refuge from walrus predation. Sea stars feed on smaller species and on smaller individuals of the large bivalve species. Laboratory experiments and field observations indicate that large bivalves have refuges from sea stars. Large *Serripes groenlandicus* escape sea star predation by leaping, large *Yoldia hyperborea* by rapid burrowing into the sediment. Large *Mya truncata* and *Macoma calcarea* live too deep in the sediment (>15 cm) for capture by the shallow digging (<10 cm) *Asterias amurensis*. Since behavior and depth refuges are less effective for smaller bivalves, sea stars forage intensively on intermediate sizes and probably maintain the bimodal size distribution in some large bivalve species. Intense walrus predation on large clams probably produces the unimodal distribution of primarily small sizes in some local populations of *M. calcarea* and *S. groenlandicus*. Intense walrus or sea star predation may have important effects on the availability of bivalve prey for each other and for other predators.

Gemery, L., T. M. Cronin, L. W. Cooper, and J. M. Grebmeier. 2013. Temporal changes in benthic ostracode assemblages in the Northern Bering and Chukchi Seas from 1976 to 2010. Deep Sea Research Part II: Topical Studies in Oceanography. 94:68-79. https://doi.org/10.1016/j.dsr2.2013.03.012

***Keywords*:** Bering Sea; Chukchi Sea; benthic; ecosystem change; ostracodes; meiofauna

***Abstract*:** We analyzed living ostracode assemblages from the northern Bering Sea, collected between 1976 and 2010, and from the Chukchi Sea, collected in 2009 and 2010, to examine how climatic and oceanographic changes are affecting modern ostracode species distributions. Totals of 21 and 28 ostracode species were identified, respectively, from Bering and Chukchi Sea surface sediment samples. The Bering Sea assemblage is largely transitional in species composition between those inhabiting western Arctic continental shelves and the subarctic Gulf of Alaska. Temporal changes in the Bering Sea assemblage provide evidence that decadal temperature changes have affected species composition. For example, the proportion of *Normanicythere leioderma*, a predominantly Arctic species, decreased from 70% of the total assemblage population in 1999 to 15% by 2006. This decrease coincided with a shift in the Arctic Oscillation toward a positive mode and warmer Bering sea-surface temperatures (SST) beginning in the early 2000s. In contrast, the more temperate species, *Pectocythere janae* (also known as *Kotoracythere arctoborealis*) made up less than 4% of the Bering assemblage prior to 2000 but increased in abundance to as much as 30% as Bering Sea temperatures rose from 2001 to 2006. This pattern has reversed since 2006 when cooler temperatures led to a decline in *P. janae* and return in the prominence of *N. leioderma*. Our results support the idea that recent ocean temperature

changes and a reduced sea ice season in the Bering–Chukchi Sea region are changing species composition in benthic ecosystems.

Georgette, S., M. Coffing, C. Scott, and C. Utermohle. 1998. The subsistence harvest of seals and sea lions by Alaska Natives in the Norton Sound-Bering Strait Region, Alaska, 1996-97. Alaska Department of Fish and Game. Technical Paper No. 242. 87 p. Juneau, Alaska. http://www.adfg.alaska.gov/techpap/tp242.pdf

***Keywords*:** climate change; sea ice; marine mammals; Alaska Natives; traditional knowledge; Arctic; subsistence

***Abstract*:** This report describes the subsistence takes of bearded seal (*Erignathus barbatus*), ringed sea (*Phoca hispida*), spotted seal (*Phoca largha*), ribbon seal (*Phoca fasciata*), and Stellar sea lion (*Eumetopias jubatus*) by Alaska Natives in selected communities in the Norton Sound-Bering Strait region of northwest Alaska during the 12-month period February 1996 through January 1997. The information, including size of take, seasons, geographic distribution, and age and sex of the harvest derives from systematic interviews with hunters and users of marine mammals in 319 households in six of 16 communities in the Norton Sound-Bering Strait area (Brevig Mission, Gambell, Golovin, Savoonga, Shaktoolik, and Stebbins). The research was conducted cooperatively by Kawerak, Inc., a non-profit, regional Native organization, and the Division of Subsistence, Alasaka Department of Fish and Game, under contract with the National Marine Fisheries Service. Local research assistants trained as part of the project assisted in the collection of information.

Giesbrecht, K. E., D. E. Varela, J. Wiktor, J. M. Grebmeier, B. Kelly, and J. E. Long. 2019. A decade of summertime measurements of phytoplankton biomass, productivity and assemblage composition in the Pacific Arctic Region from 2006 to 2016. Deep Sea Research Part II: Topical Studies in Oceanography. 162:93-113. https://doi.org/10.1016/j.dsr2.2018.06.010

***Keywords*:** phytoplankton; nutrients; chlorophyll a; carbon utilization; nitrate utilization; new production; time series; Bering Shelf; Chukchi Sea

***Abstract*:** We present phytoplankton and nutrient observations from a period of ten years within five biological 'hotspots' in the Bering and Chukchi Seas, as identified by the Distributed Biological Observatory (DBO). Nitrate (NO_3^-) and total and size-fractionated (< and >5 μm) chlorophyll a (Chl a) concentrations, and rates of carbon (ρC, 'primary productivity') and NO_3^- utilization (ρNO_3) were measured throughout the euphotic zone during eight cruises in July 2006, 2008 and yearly from 2011 to 2016. Samples were collected at one station within each of these five hotspots, which were located south of St. Lawrence Island (DBO1), south of the Bering Strait in the Chirikov Basin (DBO2), in the southeastern (DBO3) and northeastern (DBO4) Chukchi Sea, and in Barrow Canyon (DBO5).

Nitrate concentrations averaged over the 10 years increased with depth and euphotic-zone integrated values were highest in the Chirikov Basin. Subsurface maxima in Chl a were present at about 30 m depth at most locations during every cruise, although the maximum ρC and ρNO_3 rates were shallower, within the top 10 m of the water column. The f-ratio (calculated as $\rho NO_3/\rho C$) averaged for all DBO regions and for the 10-year study-period was 0.41 (± 0.24). Similarly, phytoplankton > 5 µm in size accounted for 65 (± 23) % of total Chl a for all regions over the 10 years. Taxonomic analysis done in 2013 showed that diatoms were the dominant taxa throughout all of the DBO regions, with the exception of areas influenced by low-nutrient waters on the eastern side of the Chukchi shelf near the Alaska coast. These coastal waters were dominated by coccolithophores and small (< 7 µm) flagellates and had much lower Chl a concentrations, ρC and ρNO_3 than farther west. In addition, the proportion of pennate diatoms to total diatom abundance was found to be elevated relative to centric diatoms when sea-ice was present. Our measurements of phytoplankton biomass and ρC indicated that the higher abundance of pennate diatoms in the euphotic zone was the result of phytoplankton blooms happening below the ice, rather than pennate diatoms being supplied by a sea-ice diatom bloom. The dynamic nature of the Pacific Arctic Region (PAR) resulted in strong interannual variability within each DBO region for all parameters, with no clear increasing or decreasing trends from 2006 to 2016. Spatial variations were more consistent, with the highest rates of ρC and ρNO_3 occurring in the nutrient-rich waters of the southeastern Chukchi Sea (away from shore), and decreasing in regions further north as NO_3^- concentrations were lower. An east-west gradient in phytoplankton biomass and productivity was also observed in the southeastern Chukchi Sea, which can be attributed to differences in the nutrient content of the water masses along the gradient. This study shows that the observed strong interannual variability in phytoplankton biomass and productivity cannot be attributed to differences in methodology or sampling time. It also highlights the need for better temporal and spatial sampling resolution such that the long-term effects of climate-induced changes can be identified against the backdrop of the naturally-strong interannual variability in the PAR.

Givens, G. H., R. M. Huebinger, J. C. Patton, L. D. Postma, M. Lindsay, R. S. Suydam, J. C. George, C. W. Matson, and J. W. Bickham. 2010. Population genetics of bowhead whales (*Balaena mysticetus*) in the western Arctic. Arctic*.* 63(1):1-12. http://www.jstor.org/stable/40513365

Keywords**:** gray whale; marine mammal; relative abundance; distribution; whaling; subsistence hunting; Alaska Natives; cultural issues

Abstract**:** Bowhead whales (*Balaena mysticetus*) in the Bering, Chukchi, and Beaufort seas experienced a severe reduction as a result of commercial whaling in the 19th century. Since the cessation of commercial whaling, the population has recovered to a size that is approaching pre-whaling estimates. Inupiat and Yupik communities in northern and western Alaska hunt these Western Arctic (WA) bowheads along their migratory path during spring and fall. This hunting is regulated by the International Whaling Commission. Recent but preliminary analysis of available genetic data (207 whales and 10 microsatellite markers) raised the question of the presence of multiple, genetically distinct populations

within the WA bowheads. Here we re-examined this question on the basis of a study of 414 whales and 22 newly developed microsatellite loci. We identified widespread departures from Hardy-Weinberg equilibrium; however, we were unable to detect significant evidence of multiple genetic populations within the WA bowheads that could explain this Hardy-Weinberg disequilibrium, particularly when compared to the strength of evidence for differentiation between WA bowheads and other populations from distant regions such as the Okhotsk Sea and eastern Canada. There was conclusive evidence of genetic differentiation among the three regions. The statistical rejection of panmixia within the WA improves our understanding of bowhead whale biology, and the lack of evidence for multiple populations within the WA enables risk-averse management of aboriginal hunting of Western Arctic bowhead whales.

Glubokov, A. I., S. V. Novikova, and P. K. Afanasiev. 2018. Recent data on northern rock sole *Lepidopsetta polyxystra* from the northwestern part of the Bering Sea. Journal of Ichthyology. 58(5):761-764. https://doi.org/10.1134/S0032945218050077

***Keywords*:** bottom trawl; rock sole; fisheries; stock assessment; Bering Sea

***Abstract*:** The features of the biology and spatial distribution of northern rock sole *Lepidopsetta polyxystra* are described based on the analysis of samples from bottom trawlings in the northwestern part of the Bering Sea at depths of 57−440 m in June–August 1996–2001.

Grebmeier, J. M., C. P. McRoy, and H. M. Feder. 1988. Pelagic-benthic coupling on the shelf of the northern Bering and Chukchi Seas. I. Food supply source and benthic biomass. Marine Ecology Progress Series. 48:57-67. https://doi.org/10.3354/meps048057

***Keywords*:** nutrients; biomass; sediment; carbon; nitrogen; Alaska Costal Water

***Abstract*:** The shelf waters of the northern Bering and Chukchi Seas are ice-covered for 7 mo of the year, but despite this harsh environment, they are characterized by high benthic biomass. Coupling between water column primary production and the benthos was investigated in summers 1984 to 1986 by measurements of sediment characteristics in relation to those of the water column. Low surface sediment C/N ratios (5.8 to 7.6) suggested a higher quality, nitrogen-rich marine carbon supply to the benthos in the highly productive (ca 250 to 300 g C m^{-1} yr^{-1}) Bering Shelf-Anadyr Water (BSAW) compared to lower quality, higher C/N ratios (7.7 to 14.0) in sediment under the less productive (ca 50 g C m^{-1} yr-1) Alaska Coastal Water (ACW). Stable carbon isotope ratios suggested a marine origin for organic matter in BSAW compared to a mixture of marine and terrestrial input in ACW. Mean benthic biomass was significantly different between water locations, with mean benthic biomass decreasing from 20.2 g C m^{-2} under BSAW to 6.3 g C m^{-2} under ACW Summer benthic biomass remained seasonally constant for the 3 yr. Benthic communities underlying BSAW received a high quality marine food supply on a regular basis interannually, while those in ACW received an interannually variable amount of terrigenous

organic matter in addition to marine organic matter. We conclude that the quality and quantity of organic carbon deposited to the benthos directly influence benthic biomass.

Grebmeier, J. M., H. M. Feder, and C. P. McRoy. 1989. Pelagic-benthic coupling on the shelf of the northern Bering and Chukchi Seas. II. Benthic community structure Marine Ecology Progress Series. 51:253-268. https://doi.org/10.3354/meps051253

***Keywords*:** ecosystem dynamics; pelagic–benthic coupling; benthos

***Abstract*:** Benthic fauna abundance, biomass and diversity were investigated in the northern Bering and Chukchi Seas to determine factors influencing faunal distribution in this polar region. The hypothesis tested whether sediment grain size and water mass characteristics, such as organic carbon supply to the benthos and temperature, are regulating factors in benthic community structure. Benthic communities under the cold, highly productive (-250 to 300 g C m^{-2} yr^{-1}) Bering Shelf-Anadyr Water (BSAW) are dominated by a high biomass of amphipods (F. Ampeliscidae and F. Isaeidae) and bivalves (F. Nuculidae and F. Tellinidae). A diverse, low biomass fauna exists in benthic communities under the warmer, less productive (-50 g C m^{-1} yr^{-1}) Alaska Coastal Water (ACW), including amphipods (F. Isaeidae and F. Ampeliscidae), bivalves (F Tellinidae and F. Thyasiridae), polychaetes (F. Maldanidae and Nephtyidae), and sand dollars (F. Echinarachniidae). Faunal diversities are lowest for stations under BSAW, characterized by high food supply and moderately homogeneous (well-sorted), sandy sediments. Highest diversities occur at stations in ACW, which is characterized by low food supply and a more heterogeneous (poorly-sorted) mixture of silt and clay, sand and gravel sediments. Faunal diversity also increased to the north in the Chukchi Sea, where food availability in the bottom water and surface sediments was greater and more heterogeneous, finer-grain sediments occur. The findings indicate that sediment heterogeneity, silt and clay fractions, and temperature are major regulating factors on benthic community structure, with each positively influencing faunal diversity. Lower diversity was correlated to an increase in fine sand fractions. Food supply, both in the bottom water and surface sediments, has a more variable Influence on benthic community structure, although it has a direct positive influence on benthic biomass.

Grebmeier, J. M., and C. P. McRoy. 1989. Pelagic-benthic coupling on the shelf of the northern Bering and Chukchi Seas. III. Benthic food supply and carbon cycling. Marine Ecology Progress Series. 51:253-268. https://doi.org/10.3354/m053p079

***Keywords*:** carbon; sea ice; climate; arctic marine ecosystems; biomass

***Abstract*:** Benthic carbon cycling in the northern Bering and Chukchi Seas was hypothesized to be regulated by variable primary production regimes in the overlying water: the highly productive (-250 to 300 g C m^{-2} yr^{-1}) Bering Shelf-Anadyr Water (BSAW) and the less productive (-50 g C m^{-2} yr^{-1}) Alaska Coastal Water (ACW). Sediment oxygen uptake was correlated with water column parameters and surface sediment C/N ratios characteristic of

each water type. Total sediment oxygen uptake rates decreased from a mean 19.2 mmol O2 m^{-2} d^{-1} in BSAW to a mean 8.7 mmol O2 m^{-1} d^{-1} in ACW. Mean benthic aerobic respiration rates significantly varied interannually in BSAW, although they were consistently 2 to 3 times greater in BSAW than in ACW within any one year, indicating that interannual variability in water column primary production may have a direct influence on the availability of organic carbon to the benthos. The explanation for higher respiration rates in the benthos beneath BSAW negates an expected reduction due to colder temperatures. A reduction in organic matter to the benthos in ACW apparently limits benthic metabolism even at higher temperatures. Macrofaunal respiration and bioturbation in high benthic biomass regions were important components in benthic carbon cycling.

Grebmeier, J. M. 1993. Studies of pelagic-benthic coupling extended onto the Soviet continental shelf in the northern Bering and Chukchi seas. Continental Shelf Research. 13(5-6):653-668. https://doi.org/10.1016/0278-4343(93)90098-i

***Keywords*:** sediment; biomass; organic carbon; hydrodynamics; Bering Sea; Chukchi Sea

***Abstract*:** Studies of pelagic-benthic coupling and benthic carbon cycling in the northern Bering and Chukchi seas were extended onto the Soviet continental shelf as part of the third U.S.A.-U.S.S.R. Oceanographic Expedition to the Bering and Chukchi seas in 1988. High sediment oxygen uptake rates (an indicator of food supply to the benthos) and benthic biomass were observed in the western shelf regions of the Gulf of Anadyr, Chirikov Basin and southern Chukchi Sea. Low sediment respiration and faunal biomass were observed in the central and slope areas of the Gulf of Anadyr and near the Alaska coastline. Both high sediment respiration and benthic biomass were related to regions of high carbon deposition to the benthos and sediment organic carbon content. Preliminary studies of sediment accumulation, measured using organic carbon content and atmospherically-derived 210 Pb values in surface sediments, were low in the sandy regions of the northern Bering Sea, with higher sediment accumulation zones occurring in the silt and clay regions in the central Gulf of Anadyr and southern Chukchi Sea. Hydrodynamics have a major influence on organic carbon loading and sediment composition, which in turn influences benthic community structure, biomass and sediment respiration in this Arctic region.

Grebmeier, J. M., and L. W. Cooper. 1995. Influence of the St. Lawrence Island polynya upon the Bering Sea benthos. Journal of Geophysical Research. 100(C3):4439-4460. https://doi.org/10.1029/94jc02198

***Keywords*:** sea ice; currents; climate shifts; sea ice loss; sediment; nutrients; Bering Sea

***Abstract*:** The influence of a polynya, a persistent ice-free region, on water column production and subsequent transport to the shallow continental shelf benthos of the Bering Sea was evaluated by studying spatial patterns of organic material deposition, benthic biomass, community sediment metabolism, benthic population structure, and other potential indicators of enhanced organic carbon transport to benthic communities

underlying the St. Lawrence Island Polynya. Despite suggestions that polynyas may be important localized centers of primary production in polar waters, we found that the St. Lawrence Island Polynya does not obviously enhance the biomass of benthic communities directly below the polynya. However, southward flowing, baroclinic currents generated as a result of brine injection at the polynya edge do appear to have an influence on the biomass and ecological structure of Bering Sea benthic communities south of St. Lawrence Island. These currents appear to affect mean sediment oxygen consumption, surface organic carbon/nitrogen ratios, total organic content, and bottom water ammonia by sweeping phytodetrital matter south and to the west of the island. A particle-reactive, short-lived, natural radioisotope, 7Be, used as an indicator of rapid (days to weeks) deposition of particulate material from the water column, was detected only in surface sediments to the southwest of the island, indicating enhancement of particle deposition to the southwest of the island. Finally, the 18O content of tunicate cellulose was highest in the polynya region, consistent with increased filter feeding in the late winter when the polynya is present, and presumably promoting primary production in the open water. The Anadyr Current, consisting of nutrient-rich, deeper Bering Sea water that is upwelled onto the shelf in the Gulf of Anadyr, flows west to east in the region south of St. Lawrence Island throughout the year and is the major forcing function for high production in the region. The interaction of Anadyr Water with the winter/spring ephemeral polynya and associated baroclinic currents combine to positively influence benthic communities.

Grebmeier, J. M., L. W. Cooper, H. M. Feder, and B. I. Sirenko. 2006. Ecosystem dynamics of the Pacific-influenced Northern Bering and Chukchi Seas in the Amerasian Arctic. Progress in Oceanography. 71(2-4):331-361. https://doi.org/10.1016/j.pocean.2006.10.001

Keywords**:** ecosystem dynamics; pelagic–benthic coupling; benthos

Abstract**:** The shallow continental shelves and slope of the Amerasian Arctic are strongly influenced by nutrient-rich Pacific waters advected over the shelves from the northern Bering Sea into the Arctic Ocean. These high-latitude shelf systems are highly productive both as the ice melts and during the open-water period. The duration and extent of seasonal sea ice, seawater temperature and water mass structure are critical controls on water column production, organic carbon cycling and pelagic–benthic coupling. Short food chains and shallow depths are characteristic of high productivity areas in this region, so changes in lower trophic levels can impact higher trophic organisms rapidly, including pelagic- and benthic-feeding marine mammals and seabirds. Subsistence harvesting of many of these animals is locally important for human consumption. The vulnerability of the ecosystem to environmental change is thought to be high, particularly as sea ice extent declines and seawater warms. In this review, we focus on ecosystem dynamics in the northern Bering and Chukchi Seas, with a more limited discussion of the adjoining Pacific-influenced eastern section of the East Siberian Sea and the western section of the Beaufort Sea. Both primary and secondary production are enhanced in specific regions that we discuss here, with the northern Bering and Chukchi Seas sustaining some of the highest water column production and benthic faunal soft-bottom biomass in the world ocean. In

addition, these organic carbon-rich Pacific waters are periodically advected into low productivity regions of the nearshore northern Bering, Chukchi and Beaufort Seas off Alaska and sometimes into the East Siberian Sea, all of which have lower productivity on an annual basis. Thus, these near shore areas are intimately tied to nutrients and advected particulate organic carbon from the Pacific influenced Bering Shelf-Anadyr water. Given the short food chains and dependence of many apex predators on sea ice, recent reductions in sea ice in the Pacific-influenced sector of the Arctic have the potential to cause an ecosystem reorganization that may alter this benthic-oriented system to one more dominated by pelagic processes.

Grebmeier, J. M., J. E. Overland, S. E. Moore, E. V. Farley, E. C. Carmack, L. W. Cooper, K. E. Frey, J. H. Helle, F. A. McLaughlin, and S. L. McNutt. 2006. A major ecosystem shift in the northern Bering Sea. Science. 311(5766):1461-4. https://doi.org/10.1126/science.1121365

Keywords**:** animals; arctic regions; ducks; ecosystem; fishes; geologic sediments; geologic chemistry; ice cover; oxygen analysis; Pacific Ocean; population dynamics; temperature; walruses; whales

Abstract**:** Until recently, northern Bering Sea ecosystems were characterized by extensive seasonal sea ice cover, high water column and sediment carbon production, and tight pelagic-benthic coupling of organic production. Here, we show that these ecosystems are shifting away from these characteristics. Changes in biological communities are contemporaneous with shifts in regional atmospheric and hydrographic forcing. In the past decade, geographic displacement of marine mammal population distributions has coincided with a reduction of benthic prey populations, an increase in pelagic fish, a reduction in sea ice, and an increase in air and ocean temperatures. These changes now observed on the shallow shelf of the northern Bering Sea should be expected to affect a much broader portion of the Pacific-influenced sector of the Arctic Ocean.

Grebmeier, J. M., S. E. Moore, J. E. Overland, K. E. Frey, and R. Gradinger. 2010. Biological response to recent pacific Arctic sea ice retreats. Eos, Transactions American Geophysical Union. 91(18):161-168. https://doi.org/10.1029/2010eo180001

Keywords**:** sea ice; model; climate; climate shifts; sea ice loss; ecosystem shifts; nutrients; chlorophyll

Abstract**:** Although recent major changes in the physical domain of the Arctic region, such as extreme retreats of summer sea ice since 2007, are well documented, large uncertainties remain regarding responses in the biological domain. In the Pacific Arctic north of Bering Strait, reduction in sea ice extent has been seasonally asymmetric, with minimal changes until the end of June and delayed sea ice formation in late autumn. The effect of extreme ice retreats and seasonal asymmetry in sea ice loss on primary production is uncertain, with no clear shift over time (2003–2008) in satellite-derived chlorophyll concentrations. However, clear changes have occurred during summer in species ranges for zooplankton,

bottom-dwelling organisms (benthos), and fish, as well as through the loss of sea ice as habitat and platform for marine mammals.

Grebmeier, J. M., L. W. Cooper, C. A. Ashjian, B. A. Bluhm, R. B. Campbell, K. E. Dunton, J. Moore, S. Okkonen, G. Sheffield, J. Trefry, and S. Y. Pasternak. 2015. Pacific marine Arctic regional synthesis (PacMARS) final report. North Pacific Research Board. 259 p. http://pacmars.cbl.umces.edu/

***Keywords*:** ecosystems; benthic; coastal; communities; fisheries; contaminants; seasons; sea ice; climate; physical conditions; zooplankton; nearshore; literature reveiw; Arctic

***Abstract*:** The Pacific Marine Arctic Regional Synthesis (PacMARS) is a research synthesis effort funded by Shell Exploration & Production Company and ConocoPhillips, and administered and managed by the North Pacific Marine Research Institute through the North Pacific Research Board in consultation with the U.S. National Science Foundation Division of Polar Programs. The goal of the Pacific Marine Arctic Regional Synthesis (PacMARS) effort is to facilitate new and cross-disciplinary synergies in our understanding of the marine ecosystem of the greater Bering Strait region, including the northern Bering, Chukchi and Beaufort seas. The specific objectives of the PacMARS research team and collaborators are as follows: (1) identify and synthesize existing data sets that are critical for evaluating the current state of knowledge of this marine ecosystem, including human dimensions, and (2) define the high-priority, overarching scientific themes and research needs for the next decade or more of marine ecosystem studies in the Pacific Arctic Region.

Grebmeier, J. M., K. E. Frey, L. W. Cooper, and M. Kędra. 2018. Trends in benthic macrofaunal populations, seasonal sea ice persistence, and bottom water temperatures in the Bering Strait region. Oceanography. 31(2):136-151. https://doi.org/10.5670/oceanog.2018.224

***Keywords*:** sea ice; model; climate; climate shifts; sea ice loss; biomass; ecosystems; Bering Sea; Chukchi Sea

***Abstract*:** Recent declines in sea ice extent and warming seawater temperatures in the Arctic have the potential to impact regional and pan-Arctic marine ecosystems. To investigate marine biological response to these key drivers and other environmental factors, we undertook a robust trend analysis of benthic macrofaunal populations and environmental drivers in the Bering Strait region. Our focus was on the waters of the northern Bering and southern Chukchi Seas, which are shallow (<100 m) and seasonally productive, with strong pelagic-benthic coupling between water-column-derived organic matter and the seafloor. Studies indicate that both in situ production and advection of upstream phytodetritus support persistent biologically productive regions, termed hotspots, in the greater Bering Strait region. The benthic marine ecosystem is dominated by macroinvertebrates (e.g., clams, polychaetes, and amphipods) that in turn serve as food resources for diving mammals and seabirds, thus allowing for changes to cascade strongly

through the food web from prey to predator. During our study, the persistence of seasonal sea ice significantly declined; trend analyses indicate both earlier sea ice breakup and later fall freeze-up in recent years. When combined with warming sea-water temperatures in the region, these changes have ramifications for water column processes that influence benthic faunal biomass and composition, which can transfer to upper trophic level predators. We studied these changes by evaluating time series sites in three benthic biomass hotspots starting in 1998 (Southeast Chukchi Sea region), 1999 (Chirikov Basin region), and 2000 (St. Lawrence Island Polynya region). We present these data within a broader evaluation of benthic biomass results from prior cruises dating as early as the 1970s. The current study focuses on the period 1998–2015 at sites occupied annually each July using CCGS Sir Wilfrid Laurier. Since 2010, these time series sites have become part of the international Distributed Biological Observatory (DBO), a network of standard time series stations and transect lines in the Pacific Arctic that is used for evaluating changes within the biological system. We found that these regions have experienced northward shifts in high benthic biomass and changes in dominant macrofaunal composition that are coincident with recent reduced sea ice cover and variable warming of seasonal water column temperatures. Hydrographic changes can influence chlorophyll a inventories in surface sediments and total organic carbon content, both of which are indicators of food supply to the benthos. In addition, sediment grain size reflects variable current flow that in turn influences faunal composition. Time series studies are essential for evaluating whether this region is transitioning or even reaching a “tipping point” that could shift the benthic-dominated system to a pelagic one, with large-scale ramifications for ecosystem structure in this highly productive Pacific Arctic ecosystem.

Hamazaki, T., L. Fair, L. Watson, and E. Brennan. 2005. Analyses of Bering Sea bottom-trawl surveys in Norton Sound: absence of regime shift effect on epifauna and demersal fish. ICES Journal of Marine Science. 62(8):1597-1602. https://doi.org/10.1016/j.icesjms.2005.06.003

Keywords**:** Bering Sea; demersal fishes; epifauna; Norton Sound; regime shift

Abstract**:** This study retrospectively examined evidence of ocean climate regime shift effects on epifauna and demersal fish of Norton Sound, Alaska, northeast Bering Sea, based on triennial bottom-trawl surveys from 1976 to 2002. Throughout the period, benthic fauna was dominated by sea stars (48–78%), followed by cods (5–19%), flatfish (5–15%), sculpins (1.5–7%), and crabs (2–6%). From 1976 to 2002, the cpue index of total species increased exponentially (4.5% y−1) by threefold with some declines in 1991 and 1999. The increase was also observed in sea stars (5.1% y−1), flatfish (6.1% y−1), and crabs (2.5% y−1). However, trends of cods and sculpins were mixed. Regression analysis showed the cpue index of total species to be positively correlated with survey years and bottom-water temperature. However, bottom-water temperature, when considered by itself, was not significant. Results suggest that regime shifts caused biomass increases of Norton Sound epifauna and demersal fish.

Haney, J. C. 1988. Foraging by northern fulmars (*Fulmarus glacialis*) at a nearshore, anticyclonic tidal eddy in the northern Bering Sea, Alaska. Colonial Waterbirds. 11:318-321. https://doi.org/10.2307/1521017

Keywords**:** seabird; Northern Fulmar; climate change; sea ice; ecosystems; seasonality

Abstract**:** Northern Fulmars (*Fulmar glacialis*) fed on ice-associated macrofauna (probably gammarid amphipods) and pinniped offal concentrated by convergent flow at an eddy boundary near Northwest Cape on St. Lawrence Island, Alaska. The eddy was anticyclonic, measured approximately 1.5 by 2.25 km, and was generated by nearshore streaming induced by the cape's topography during lesser flood stage of the tidal cycle. These favorable feeding conditions persisted only for a few hours on a single day (22 May 1987). Like man-assisted scavenging, this observation suggests that natural feeding by fulmars can be highly opportunistic and time-dependent.

Haney, J. C., and A. E. Stone. 1988. Littoral foraging by red phalaropes during spring in the northern Bering Sea. The Condor. 90(3):723-726. https://doi.org/10.2307/1368368

Keywords**:** seabird; Red Phalarope; ecosystems; foraging

Abstract**:** Phalaropes demonstrate considerable plasticity in their choice of foraging habitats. The Red Phalarope (*Phalaropus fulicaria*) alternates use of pelagic environments in winter and migration (Taning 1933, Stanford 1953, Briggs et al 1984) with wet tundra habitats during the breeding season (Kistchinski 1975, Mayfield 1979, Ridley 1980). Foods available and taken in littoral zones of the Arctic Ocean in fall have been identified (Conners and Risebrough 1978, Johnson and Richardson 1980), but otherwise little attention has been devoted to the transition between the marine and terrestrial periods of the Red Phalarope's life history. We report phalarope use of littoral areas during spring in the northern Bering Sea and Kongkok Bay, St. Lawrence Island, Alaska. In addition, we describe phalarope foraging tactics and foods available in the sur zone, emphasizing this form of littoral foraging as an opportunistic and facultative feeding strategy.

Haney, J. C. 1991. Influence of pycnocline topography and water-column structure on marine distributions of alcids (Aves: Alcidae) in Anadyr Strait, Northern Bering Sea, Alaska. Marine Biology. 110(3):419-435. https://doi.org/10.1007/BF01344361

Keywords**:** seabird; auklet; climate change; sea ice; ecosystem shifts; Bering Sea; Chukchi Sea; Beaufort Sea; St Lawrence Island

Abstract**:** Systematic ship-board surveys were used to simultaneously record seabird abundances and resolve coarse-scale (3 to 10 km) horizontal and fine-scale (1 to 10 m) vertical variability in water-column structure and bathymetry for portions of the coastal zone in Anadyr Strait near western St. Lawrence Island, northern Bering Sea, Alaska, during August and September 1987. Three plankton-feeding alcids, parakeet (*Cyclorrhynchus*

psittacula), crested (*Aethia cristatella*) and least (*A. pusilla*) auklets, each exhibited distinct associations for different pycnocline characteristics. Least auklets were more abundant in mixed water, but they also occurred within stratified water where the pycnocline and upper-mixed layer were shallow (≤8 m) and thin (≤10 m), respectively. Low body mass (85 g), high buoyancy, and relatively poor diving ability may have restricted this auklet to areas where water-column strata nearly intersected the surface, or to areas from which strata were absent altogether due to strong vertical mixing. Parakeet and crested auklets, which are larger-bodied (ca. 260 g) planktivores with presumably greater diving ability, were more abundant in stratified water, and both species exhibited less specific affinities for water-column characteristic at intermediate and shallow levels. All three auklets avoided locations with strong pycnocline gradients (≤0.22 σtm − 1), a crude index of the strong, subsurface shear in water velocities characteristic of this region. Auklet distributions in Anadyr Strait were consistent with: (1) strata accessibility, as estimated from relationships between body mass and relative diving ability, (2) possible avoidance of strong subsurface water motions, and (3) habits and distributions of plankton prey. In contrast, largebodied (>450 g) alcids [i.e., common (*Uria aalge*) and thick-billed (*U. lomvia*) murres, pigeon guillemots (*Cephus columba*), tufted (*Fratercula cirrhata*), and horned (*F. corniculata*) puffins feeding on fish or benthic invertebrates] showed no consistent relationships with either the pycnocline or upper-mixed layers. All large alcids were more common in stratified than in vertically-mixed waters, but differences in abundance between mixing regimes were small or equivocal. The only measured variable with which all large alcids were associated was total water-column depth: murres, guillemots, and puffins each used areas with shallow sea floors and avoided areas with deeper sea floors. Failure of large alcids to discriminate among foraging areas in Anadyr Strait as a function of pycnocline topography and strength may be attributable to: (1) greater reliance on large pelagic and benthic prey not associated with the pycnocline; (2) higher body mass, lower buoyancy, and greater diving ability; (3) foraging over a uniquely shallow continental shelf where all vertical strata, including the sea floor, are potentially accessible from the ocean surface.

Haney, J. C., and A. E. S. Schauer. 1994. Environmental variability facilitates coexistence within an alcid community at sea. Marine Ecology Progress Series. 103:221-237. http://pubs.er.usgs.gov/publication/70184357

Keywords**:** seabird; environmental changes; ecosystems; seasonality

Abstract**:** We examined coexistence at sea among 7 taxa of diving, wing-propelled seabirds (*Alcidae*) in the genera *Aethia*, *Uria*, *Cepphus*, and *Fratercula*. Species abundances were measured simultaneously with a suite of environmental factors in the northern Bering Sea, Alaska, USA; data from 260 adjacent and non-adjacent sites occupied by alcids foraging offshore near breeding colonies were then subjected to principal component analysis (PCA). We used PCA to group redundant environmental descriptors, to identify orthogonal axes for constructing a multi-dimensional niche, and to differentiate species associations within niche dimensions from species associations among niche dimensions. Decomposition of the correlation matrix for 22 environmental and 7 taxonomic variables with PCA gave 14

components (10 environmental and 4 species interactions) that retained 90% of the original available variance. Alcid abundances (all species) were most strongly correlated with axes representing tidal stage, a time-area interaction (due to sampling layout), water masses, and a temporal or intra-seasonal trend partially associated with weather changes. Axes representing tidal stage, 2 gradients in macro-habitat (Anadyr and Bering Shelf Water masses), the micro-habitat of the sea surface, and an air-sea interaction were most important for detecting differences among species within niche dimensions. Contrary to assumptions of competition, none of 4 compound variables describing primarily species-interactions gave strong evidence for negative associations between alcid taxa sharing similar body sizes and feeding requirements. This exploratory analysis supports the view that alcids may segregate along environmental gradients at sea. But in this community, segregation was unrelated to foraging distance from colonies, in part because foraging 'substrate' was highly variable in structure, location, and areal extent. We contend that coexistence within this seabird group is facilitated via expanded niche dimensions created from a complex marine environment.

Hans, N. C., D. R. Thor, M. W. Sandstrom, and K. A. Kvenvolden. 1979. Modern biogenic gas-generated craters (sea-floor “pockmarks”) on the Bering Shelf, Alaska. GSA Bulletin. 90(12):1144-1152. https://doi.org/10.1130/0016-7606(1979)90<1144:MBGCSP>2.0.CO;2

***Keywords*:** hydrocarbons; submarine structures; geology; Norton Sound; Bering Sea

***Abstract*:** As many as 1,340 small craters per square kilometre cover the sea floor of Norton Sound in the northeastern Bering Sea. The craters are circular pits, 1 to 10 m in diameter and less than 1 m deep, observed on sonographs over 20,000 km^2 of northern Norton Sound sea floor. Craters typically are associated with acoustic anomalies, near-surface peaty mud, and gas-charged sediment. The peaty mud is a thick (>1.5 m), nonmarine pre-Holocene deposit that is now covered by a 1- to 3-m-thick layer of Holocene marine mud in the area of the craters. The peaty mud (2% to 8% organic carbon) contains abundant biogenic methane [C1/(C2 + C3) = 256 to 7,669] with carbon isotope (δ13C) values of −69‰ to −75‰- Decomposition of organic debris in the peaty mud apparently charges the mud with gas. The peaty and gassy zones attenuate sound waves and cause acoustic anomalies on high-resolution seismic profiles in the area with craters. The craters are forming now, as shown by the disruption of modern ice gouges by the craters. In the absence of storms, the gas apparently is trapped in the peaty mud in a saturated state by the cover of Holocene mud. Periodically, possibly during storms, the gas escapes through the thin Holocene cover and forms craters.

Hardy, S. M., M. Lindgren, H. Konakanchi, and F. Huettmann. 2011. Predicting the distribution and ecological niche of unexploited snow crab (*Chionoecetes opilio*) populations in Alaskan waters: A first open-access ensemble model. Integrative and Comparative Biology. 51(4):608-622. https://doi.org/10.1093/icb/icr102

***Keywords*:** snow crab; population genetics; connectivity

***Abstract*:** Populations of the snow crab (*Chionoecetes opilio*) are widely distributed on high-latitude continental shelves of the North Pacific and North Atlantic, and represent a valuable resource in both the United States and Canada. In US waters, snow crabs are found throughout the Arctic and sub-Arctic seas surrounding Alaska, north of the Aleutian Islands, yet commercial harvest currently focuses on the more southerly population in the Bering Sea. Population dynamics are well-monitored in exploited areas, but few data exist for populations further north where climate trends in the Arctic appear to be affecting species' distributions and community structure on multiple trophic levels. Moreover, increased shipping traffic, as well as fisheries and petroleum resource development, may add additional pressures in northern portions of the range as seasonal ice cover continues to decline. In the face of these pressures, we examined the ecological niche and population distribution of snow crabs in Alaskan waters using a GIS-based spatial modeling approach. We present the first quantitative open-access model predictions of snow-crab distribution, abundance, and biomass in the Chukchi and Beaufort Seas. Multi-variate analysis of environmental drivers of species' distribution and community structure commonly rely on multiple linear regression methods. The spatial modeling approach employed here improves upon linear regression methods in allowing for exploration of nonlinear relationships and interactions between variables. Three machine-learning algorithms were used to evaluate relationships between snow-crab distribution and environmental parameters, including TreeNet, Random Forests, and MARS. An ensemble model was then generated by combining output from these three models to generate consensus predictions for presence–absence, abundance, and biomass of snow crabs. Each algorithm identified a suite of variables most important in predicting snow-crab distribution, including nutrient and chlorophyll-a concentrations in overlying waters, temperature, salinity, and annual sea-ice cover; this information may be used to develop and test hypotheses regarding the ecology of this species. This is the first such quantitative model for snow crabs, and all GIS-data layers compiled for this project are freely available from the authors, upon request, for public use and improvement.

Helle, J., E. Farley, J. Murphy, A. Feldmann, Kris Cieciel, J. Moss, L. Eisner, J. Pohl, and M. Courtney. 2007. The Bering-Aleutian salmon international survey (BASIS). AFSC quarterly report Jan-Mar 2007. U.S. Dep. Commerce, NOAA. AFSC Quarterly Report. 5 p. 7600 Sand Point Way NE, Seattle WA 98115. http://www.afsc.noaa.gov/Quarterly/jfm2007/jfm07feat.pdf.

***Keywords*:** fisheries; salmon; stock assessment; BASIS

***Abstract*:** The fisheries oceanography survey of the Bering Sea, known as BASIS, is made possible by the international treaty that led to the organization of the North Pacific Anadromous Fish Commission (NPAFC). The NPAFC was established under the Convention for the Conservation of Anadromous Stocks in the North Pacific Ocean effective February 1993 and includes Canada, Japan, Republic of Korea, the Russian Federation, and the United States. The NPAFC Convention Area forms the world's largest marine conservation area for seven species of Pacific salmon. Drastic changes in physical and biological conditions in the

Bering Sea during the 1990s in conjunction with extreme fluctuations in the abundance and growth of both North American and Asian salmon stocks prompted managers to call for more information on marine ecology of Pacific salmon. The coincidence of changes in the environment and salmon abundance and growth led to cooperative research on the mechanisms that link these changes. The response of NPAFC scientists was to develop an unprecedented and ambitious plan to sample the entire epipelagic ecosystem of the Bering Sea. This plan, the Bering-Aleutian Salmon International Survey, was designed to understand the biological response of salmon within an ecological context during a period of climate change. The Alaska Fisheries Science Center's Ocean Carrying Capacity Program, established in 1994, is responsible for BASIS research in U.S. waters.

Henriksen, K., T. H. Blackburn, B. A. Lomstein, and C. P. McRoy. 1993. Rates of nitrification, distribution of nitrifying bacteria and inorganic N fluxes in northern Bering-Chukchi shelf sediments. Continental Shelf Research. 13(5-6):629-651. https://doi.org/10.1016/0278-4343(93)90097-h

Keywords**:** sediment; nitrogen; nutrients; biomass; ammonium; nitrate; Bering Sea; Chukchi Sea

Abstract**:** Spatial distribution of sediment nitrification rates and fluxes of ammonium and nitrate were measured in shelf sediments of the northern Bering and Chukchi seas. The sediments could be divided into three main areas depending on macrofaunal activity and input of organic nitrogen. Sediments underlying the highly productive Bering Shelf-Anadyr water (BSAS) were characterized by a high macrofaunal biomass and a high input of nitrogen-rich organic material. Tube-dwelling amphipods dominated in the sandy sediments of the northern Bering Sea, while bivalves dominated in the fine textured sediments of the Chukchi Sea. Sediments underlying the low productive Alaska Coastal Water (ACS) were characterized by low macrofaunal biomass and an input of lower quality organic material. Generally nitrification rates and nutrification potentials (NP) were highest in BSAS and lower in ACS. Nitrification rates of surface sediment, calculated from NP, accounted for 90% of the measured rates in ACS, but only 35–75% in BSAS. These data together with the distribution patterns of NP and pore water nitrate profiles implied, that most sediment nitrification was confined to the sediment surface in ACS and in BSAS bivalve sediments, while most sediment nitrification took place in the ventilated burrow walls of BSAS amphipod sediments. The NH^{4+} efflux was five-fold greater from BSAS compared to ACS, whereas the estimated sediment net NH^{4+} production was three-fold greater. The increase in NH^{4+} efflux relative to net NH^{4+} production could mostly be attributed to macrofaunal excretion. The NO^{3-} flux between sediment and water column was correlated with NO^{3-} concentrations in the bottom water. At concentrations higher than 10 µM NO^{3-}, the flux was directed into the sediment and at lower concentrations out of the sediment. Spatial distribution of high bottom water NO^{3-} concentrations correlated with high NH^{4+} fluxes out of the sediment. This resulted in a lower net efflux of inorganic nitrogen from these sediments.

Hermann, A. J., G. A. Gibson, N. A. Bond, E. N. Curchitser, K. Hedstrom, W. Cheng, M. Wang, E. D. Cokelet, P. J. Stabeno, and K. Aydin. 2016. Projected future biophysical states of the Bering Sea. Deep Sea Research Part II: Topical Studies in Oceanography. 134:30-47. https://doi.org/10.1016/j.dsr2.2015.11.001

Keywords**:** USA; Alaska; Bering Sea; modelling

Abstract**:** Three global climate simulations from the Intergovernmental Panel on Climate Change Fourth Assessment (AR4) were used as physical forcing to drive a regional model that includes both physical and biological elements of the Bering Sea. Although each downscaled projection indicates a warming of 1–2°C between 2010 and 2040 on the Bering Sea shelf, the interannual and interdecadal details of this trend vary considerably among the three realizations. In each case, the magnitude of presently observed interannual variability of bottom temperatures and ice cover is found in the models to be maintained out to at least 2040, but with a steadily increasing probability of warm years with less ice on the southern shelf. The overall trends indicate warmer temperatures and the retreat of ice in the southeastern Bering Sea, but continued ice cover in the northeastern Bering Sea. Sensitivity analyses suggest both increasing air temperature and northward wind stress as primary drivers of higher water-column temperatures. Based on currently available models, changes in shortwave radiation are not likely to have a significant role in this warming. Warming trends on the outer shelf may lead to decreased production of large crustacean zooplankton at that location, but could increase such production on the inner shelf.

Hermann, A. J., G. A. Gibson, W. Cheng, I. Ortiz, K. Aydin, M. Wang, A. B. Hollowed, K. K. Holsman, and S. Sathyendranath. 2019. Projected biophysical conditions of the Bering Sea to 2100 under multiple emission scenarios. ICES Journal of Marine Science. 76(5):1280–1304. https://doi.org/10.1093/icesjms/fsz043

Keywords**:** Bering Sea, biophysical modelling, climate change, regional modelling

Abstract**:** A regional biophysical model is used to relate projected large-scale changes in atmospheric and oceanic conditions from CMIP5 to the finer-scale changes in the physical and biological structure of the Bering Sea, from the present through the end of the twenty-first century. A multivariate statistical method is used to analyse the results of a small (eight-member) dynamically downscaled ensemble to characterize and quantify dominant modes of variability and covariability among a broad set of biophysical features. This characterization provides a statistical method to rapidly estimate the likely response of the regional system to a much larger (63-member) ensemble of possible future forcing conditions. Under a high emission [Representative Concentration Pathway 8.5 (RCP8.5)] scenario, results indicate that decadally averaged Bering Sea shelf bottom temperatures may warm by as much as 5°C by 2100, with associated loss of large crustacean zooplankton on the southern shelf. Under a lower emission scenario (RCP4.5), these effects are predicted to be approximately half their calculated change under the high emission scenario.

Highsmith, R. C., and K. O. Coyle. 1992. Productivity of arctic amphipods relative to gray whale energy requirements. Marine Ecology Progress Series. 83(2/3):141-150. http://www.jstor.org/stable/24827599

***Keywords*:** gray whale; marine mammal; relative abundance; distribution; fronts; prey; crustacean; amphipod

***Abstract*:** Amphipod crustaceans dominate the benthic community in vast areas of the northern Bering Sea; they are the major prey of the California gray whale *Eschrichtius robustus*. The protected whale population is growing steadily and may be approaching the carrying capacity of the amphipod community, one of the most productive benthic communities in the world. The abundance and biomass of the amphipod community decreased during the 3 yr period 1986 to 1988, resulting in a 30 % decline in production. High-latitude amphipod populations are characterized by low fecundity and long generation times. Large, long-lived individuals are responsible for the majority of amphipod secondary production. A substantial reduction in the density of large individuals in the population will result in a significant, long-term decrease in production.

Hill, V., M. Ardyna, S. H. Lee, and D. E. Varela. 2018. Decadal trends in phytoplankton production in the Pacific Arctic Region from 1950 to 2012. Deep Sea Research Part II: Topical Studies in Oceanography. 152:82-94. https://doi.org/10.1016/j.dsr2.2016.12.015

***Keywords*:** polar waters; primary production; climate changes; measurements

***Abstract*:** This paper provides a synthesis of available in situ primary production (PP) measurements from the Pacific Arctic Region (PAR), collected between 1950 and 2012. Seasonal integrated primary production (IPP) across the PAR was calculated from 524 profiles, 340 of which were also analyzed to determine the average vertical distribution of PP rates for spring, summer and fall months. The Chirikov Basin and Chukchi Shelf were the most productive areas, with the East Siberian Sea, Chukchi Plateau and Canada Basin the lowest. Decadal-scale changes were indicated in the southern Chukchi Sea, and across Hanna Shoal. In the southern Chukchi Sea in August, IPP increased significantly from 113±35 mgC m^{-2} d^{-1} in 1959 and 1960 to 833±307 mgC m^{-2} d^{-1} in the 2000s. Increases in the magnitude of IPP were accompanied by variations in the vertical distribution, the subsurface peak observed in the 1959/60 was not present in the 2000s. The mechanism behind this change was undetermined but could have included changes in stratification, mixing or surface distribution of water masses as well as methodological differences. Over Hanna Shoal, the phytoplankton surface bloom now occurs earlier by several weeks compared to 1993, linked to increases in light due to earlier sea- ice retreat. In 1993 with sea ice still present in the region the surface bloom occurred in August, in 2002 and 2004 this same period was characterized by open water and low surface PP and strong subsurface production. This dataset provides a region-wide quantification of IPP and decadal trends and highlights the need for a cooperative monitoring program to observe the long-term impacts of climate change in the Arctic ecosystem.

Hirawake, T., and G. L. Hunt. 2020. Impacts of unusually light sea-ice cover in winter 2017-2018 on the northern Bering Sea marine ecosystem – An introduction. Deep Sea Research Part II: Topical Studies in Oceanography. 181-182:104908. https://doi.org/10.1016/j.dsr2.2020.104908

Keywords**:** climate change; loss of sea ice; sub-Arctic seas

Abstract**:** This paper serves as an introduction to the Deep-Sea Research II special issue on the impacts of a severe lack of sea ice in the northern Bering Sea (NBS) in the winter of 2017-2018. To complement the papers in this volume, we provide a brief synopsis of the physical oceanography of the NBS, including information on the characteristics of the dominant water masses, and the patterns of sea-ice formation and duration in years past. The 17 papers in this volume provide a series of snapshots of the northern Bering Sea in the spring and summer of 2018, which followed an unusual warming in February 2018 and record-breaking low sea-ice concentrations. The lack of ice in spring affected the temperatures and structure of the water column, impacted the timing of the spring bloom, and affected the marine food webs from the amounts and kinds of phytoplankton and zooplankton, to the distribution of fish and the reproduction and survival of marine birds and mammals. As the Arctic and sub-Arctic warm, events like those observed in 2018 may well become the norm. If so, we may anticipate major changes in the NBS marine ecosystem and those dependent upon its resources.

Hirawake, T., J. Oida, Y. Yamashita, H. Waga, H. Abe, J. Nishioka, D. Nomura, H. Ueno, and A. Ooki. 2021. Water mass distribution in the northern Bering and southern Chukchi seas using light absorption of chromophoric dissolved organic matter. Progress in Oceanography. 197:102641. https://doi.org/10.1016/j.pocean.2021.102641

Keywords**:** chromophoric dissolved organic matter; absorption coefficient; water mass; T-S diagram; Anadyr water

Abstract**:** The northern Bering Sea (NBS) and southern Chukchi Sea (SCS) contain several water masses with different characteristics that have been conventionally classified using temperature and salinity data. However, recent warming and sea ice decline can change these water properties, which suggests that classifying water masses using temperature–salinity diagrams could be problematic for this region. We used the light absorption coefficient of chromophoric dissolved organic matter (CDOM), aCDOM, as an alternative way to classify water masses. The aCDOM spectra of several water depths were measured in the NBS, the Gulf of Anadyr included, and SCS in July 2017 and 2018, and August 2018. Optical parameters that indicate CDOM quantity and quality, aCDOM(350) and spectral slopes (S275–295 and S350–400), were calculated for each sample; water masses were classified using cluster analysis. When surface waters in the NBS and SCS are classified on the basis of the conventional method using a temperature–salinity diagram, they are mistakenly identified as Alaskan Coastal Water because of warmer temperatures. However,

our cluster analysis using CDOM parameters evenly classified seven water masses with reasonable distributions. A water mass with the highest aCDOM(350) and lowest S275–295 was found along the coast of the Gulf of Anadyr and Alaska mainland, which suggests that freshwater originates from the Anadyr and Yukon rivers and is transported by the Anadyr Current and Alaskan Coastal Current, respectively. A CDOM-based water mass with high S275–295, indicating CDOM degradation by ultraviolet radiation, was present at the sea surface. A water mass with low S275–295 was found at deeper water depths and river mouths. These results suggest that classification with CDOM parameters is consistent with geographical features. In addition, we recognized a water mass with high nitrate concentrations, which is likely Anadyr Water that originates in the region from the Bering Slope to the Gulf of Anadyr. Overall, this study reveals that water mass classification using CDOM parameters is useful in coastal sea areas in which water mass mixing is complex.

Holland, M. M., C. M. Bitz, and B. Tremblay. 2006. Future abrupt reductions in the summer Arctic sea ice. Geophysical Research Letters. 33(23):L23503. https://doi.org/10.1029/2006gl028024

***Keywords*:** sea ice; model; climate; climate shifts; sea ice loss

***Abstract*:** We examine the trajectory of Arctic summer sea ice in seven projections from the Community Climate System Model and find that abrupt reductions are a common feature of these 21st century simulations. These events have decreasing September ice extent trends that are typically 4 times larger than comparable observed trends. One event exhibits a decrease from 6 million km^2 to 2 million km^2 in a decade, reaching near ice-free September conditions by 2040. In the simulations, ice retreat accelerates as thinning increases the open water formation efficiency for a given melt rate and the ice-albedo feedback increases shortwave absorption. The retreat is abrupt when ocean heat transport to the Arctic is rapidly increasing. Analysis from multiple climate models and three forcing scenarios indicates that abrupt reductions occur in simulations from over 50% ofthe models and suggests that reductions in future greenhouse gas emissions moderate the likelihood of these events.

Holmes, M. L., and D. R. Thor. 1982. Distribution of gas-charged sediment in Norton Sound and Chirikov Basin. Geologie En Mijnbouw. 61(1):79-89. https://doi.org/10.1016/0198-0254(82)90240-0

***Keywords*:** Norton Sound; seismic surveys; reflection methods; acoustical surveys; gases; marine sediments; Bering Sea; marine geology; geology; earth sciences; west Pacific; Pacific Ocean

***Abstract*:** Numerous zones of anomalous acoustic responses caused by gas in the subsurface sediment layers have been detected on seismic reflection records from Norton Sound and Chirikov Basin. The frequency and distribution of these zones suggest that as much as 7000 km^2 of the northeastern Bering Sea may be underlain by gas-charged

sediment. Much of the gas is of shallow biogenic origin, having been generated in buried peat deposits. Seismic velocity beneath a large gas seep south of Nome decreases in the interval from 250 to 440 m below the seafloor, where thermogenic gases of deeper origin are migrating upward along a system of basin margin faults.

Huang, D., J. Lin, J. Du, and T. Yu. 2020. The detection of Fukushima-derived radiocesium in the Bering Sea and Arctic Ocean six years after the nuclear accident. Environmental Pollution. 256:113386. https://doi.org/10.1016/j.envpol.2019.113386

***Keywords*:** radiocesium; seawater; Fukushima accident; Arctic

***Abstract*:** After the Fukushima Daiichi Nuclear Power Plant (FDNPP) accident, radionuclides released by this event were observed in the Pacific Ocean. Models predicted that these radionuclides would be transported to the Bering Sea; however, limited evidence currently reveals the transportation of these radionuclides to the Arctic Ocean. Here, we provide the first direct observation showing that FDNPP-derived 134Cs and 137Cs were present in subarctic regions and the Arctic Ocean (Chukchi Sea) in 2017. Furthermore, we conclude that these radionuclides were transported from the Pacific Ocean into the Bering and Chukchi Seas by ocean currents. Additionally, the 137Cs activity concentrations in the Bering Sea exceed those in all previous reports. Due to the continuous leaking of radionuclides from the FDNPP, we hypothesize that FDNPP-derived radionuclides will be continuously transported to the Arctic Ocean in the next several years. Our results suggest that though far away from Fukushima, the accident-derived anthropogenic radionuclides also influenced the Arctic Ocean by ocean currents.

Hunt, G. L., K. O. Coyle, L. B. Eisner, E. V. Farley, R. A. Heintz, F. Mueter, J. M. Napp, J. E. Overland, P. H. Ressler, S. Salo, and P. J. Stabeno. 2011. Climate impacts on eastern Bering Sea foodwebs: a synthesis of new data and an assessment of the oscillating control hypothesis. ICES Journal of Marine Science. 68(6):1230-1243. https://doi.org/10.1093/icesjms/fsr036

***Keywords*:** Bering Sea; climate change; crustacean zooplankton; Oscillating Control Hypothesis; sea ice cover; *Theragra chalcogramma*; walleye Pollock; year-class strength

***Abstract*:** Walleye pollock (*Theragra chalcogramma)* is an important component of the eastern Bering Sea ecosystem and subject to major fisheries. The Oscillating Control Hypothesis (OCH) predicted that recruitment of pollock year classes should be greatest in years with early ice retreat and late blooms in warm water, because more energy would flow into the pelagic (vs. benthic) community. The OCH further predicted that, with pollock population growth, there should be a shift from bottom-up to top-down regulation. New data support the predictions that in those years with early ice retreat, more primary production accrues to the pelagic compartment and that large numbers of age-0 pollock survive to summer. However, in these years, production of large crustacean zooplankton is reduced, depriving age-0 pollock of lipid-rich prey in summer and autumn. Consequently, age-0 pollock energy reserves (depot lipids) are low and predation on them is increased as

fish switch to age-0 pollock from zooplankton. The result is weak recruitment of age-1 recruits the following year. A revised OCH indicates bottom-up constraints on pollock recruitment in very warm periods. Prolonged warm periods with decreased ice cover will likely cause diminished pollock recruitment and catches relative to recent values.

Huntington, H. P., N. M. Braem, C. L. Brown, E. Hunn, T. M. Krieg, P. Lestenkof, G. Noongwook, J. Sepez, M. F. Sigler, F. K. Wiese, and P. Zavadil. 2013. Local and traditional knowledge regarding the Bering Sea ecosystem: Selected results from five indigenous communities. Deep Sea Research Part II: Topical Studies in Oceanography. 94:323-332. https://doi.org/10.1016/j.dsr2.2013.04.025

Keywords**:** climate change; sea ice; fisheries; Alaska Natives; traditional knowledge; Arctic; observation

Abstract**:** We documented local and traditional knowledge (LTK) about the Bering Sea ecosystem through interviews with Alaska Native elders, hunters, and fishers in the coastal communities of Akutan, St. Paul, Togiak, Emmonak, and Savoonga. Their observations describe a complex and changing ecosystem, with indications of divergent impacts of change in the south (many species in decline) and the north (a productive ecosystem). Observed changes in species abundance suggest that the marginal zone of maximum (March) sea-ice extent is experiencing the most rapid directional changes, including shifts in distribution of ice-associated species such as bearded seal (*Erignathus barbatus*). Causes of declines in other species such as northern fur seals (*Callorhinus ursinus*) and murres (*Uria* spp.) are harder to identify, and seabird abundance trends appear to vary greatly with location. Connections between the LTK findings and other research under the North Pacific Research Board and National Science Foundation's Bering Sea Project were modest due to mismatches in temporal and spatial scales of reference and the fact that LTK observations were not initially made with scientific relevance in mind. We found, however, the overall observations to be consistent with the emerging picture of high spatial variability in the Bering Sea ecosystem.

Huntington, H. P., G. Noongwook, N. A. Bond, B. Benter, J. A. Snyder, and J. Zhang. 2013. The influence of wind and ice on spring walrus hunting success on St. Lawrence Island, Alaska. Deep Sea Research Part II: Topical Studies in Oceanography. 94:312-322. https://doi.org/10.1016/j.dsr2.2013.03.016

Keywords**:** Pacific walrus; hunting; St. Lawrence Island; Bering Sea; winds; sea ice; Generalized additive model (GAM)

Abstract**:** St. Lawrence Island Yupik hunters on St. Lawrence Island, Alaska, take hundreds of Pacific walrus (*Odobenus rosmarus divergens*) each year. The harvest and associated effort (hunting trips taken), however, are variable from year to year and also from day to day, influenced by physical environmental factors among other variables. We used data from 1996 to 2010 to construct generalized additive models (GAMs) to examine several

relationships among the variables. Physical factors explained 18% of the variability in harvest in Savoonga and 25% of the variability in effort; the corresponding figures for Gambell were 24% and 32%. Effort alone explained 63% of the harvest in Savoonga and 59% in Gambell. Physical factors played a relatively smaller role in determining hunting efficiency (walrus taken per hunting trip), explaining 15% of the variability in efficiency in Savoonga and 22% in Gambell, suggesting that physical factors play a larger role in determining whether to hunt than in the outcome of the hunt once undertaken. Combining physical factors with effort explained 70% of the harvest variability in Savoonga and 66% in Gambell. Although these results indicate that other factors (e.g. fuel prices, socioeconomic conditions) collectively cause a greater share of variability in harvest and effort than ice and wind, at least as indicated by the measures used as predictors in the GAMs, they also suggest that environmental change is also likely to influence future harvest levels, and that climate models that yield appropriately scaled data on ice and wind around St. Lawrence Island may be of use in determining the magnitude and direction of those influences.

Huntington, H. P., I. Ortiz, G. Noongwook, M. Fidel, D. Childers, M. Morse, J. Beaty, L. Alessa, and A. Kliskey. 2013. Mapping human interaction with the Bering Sea ecosystem: Comparing seasonal use areas, lifetime use areas, and "calorie-sheds". Deep Sea Research Part II: Topical Studies in Oceanography. 94:292-300. https://doi.org/10.1016/j.dsr2.2013.03.015

Keywords**:** calorie-shed; subsistence use area; Bering Sea; hunting; fishing; development

Abstract**:** Alaska Native coastal communities interact with the marine environment in many ways, especially through the harvest of fish, marine mammals, and seabirds. The spatial characteristics of this interaction are often depicted in terms of subsistence use areas: the places where harvests and associated travel occur. Another way to consider the interaction is to examine the areas where harvested species range during their lifecycle or annual migratory path. In this paper, we compare seasonal subsistence use areas, lifetime subsistence use areas, and "calorie-sheds," or the area over which harvested species range. Each perspective offers useful information concerning not only the nature of human–environment interactions but also the scope for potential conflict with other human activity and the means by which such conflicts could be reduced, avoided, or otherwise addressed. Seasonal subsistence use areas can be used to manage short-term activities, such as seasonal vessel traffic during community re-supply. Lifetime subsistence use areas indicate the area required to allow hunters and fishers the flexibility to adjust to interannual variability and perhaps to adapt to a changing environment. Calorie-sheds indicate the areas about which a community may be concerned due to potential impacts on the species they harvest.

Huntington, H. P., L. T. Quakenbush, and M. Nelson. 2016. Effects of changing sea ice on marine mammals and subsistence hunters in northern Alaska from traditional knowledge interviews. Biol Lett. 12(8):20160198. https://doi.org/10.1098/rsbl.2016.0198

***Keywords*:** Alaska; animals; Arctic regions; Cetacea; ecosystem; humans; ice cover; North Sea; Alaska; Arctic; marine mammals; indigenous communities; sea ice; traditional knowledge

***Abstract*:** Marine mammals are important sources of food for indigenous residents of northern Alaska. Changing sea ice patterns affect the animals themselves as well as access to them by hunters. Documenting the traditional knowledge of Inupiaq and Yupik hunters concerning marine mammals and sea ice makes accessible a wide range of information relevant to understanding the ecosystem to which humans belong. We interviewed hunters in 11 coastal villages from the northern Bering Sea to the Beaufort Sea. Hunters reported extensive changes in sea ice and weather that have affected the timing of marine mammal migrations, their distribution and behaviour and the efficacy of certain hunting methods. Amidst these changes, however, hunters cited offsetting technological benefits, such as more powerful and fuel-efficient outboard engines. Other concerns included potential impacts to subsistence hunting from industrial activity such as shipping and oil and gas development. While hunters have been able to adjust to some changes, continued environmental changes and increased disturbance from human activity may further challenge their ability to acquire food in the future. There are indications, however, that innovation and flexibility provide sources of resilience.

Huntington, H. P., L. T. Quakenbush, and M. Nelson. 2017. Evaluating the effects of climate change on indigenous marine mammal hunting in northern and western Alaska using traditional knowledge. Frontiers in Marine Science. 4(319). https://doi.org/10.3389/fmars.2017.00319

***Keywords*:** climate change; sea ice; marine mammals; Alaska Natives; traditional knowledge; Arctic; subsistence

***Abstract*:** Iñupiaq, Yup'ik, and Cup'ik hunters in 14 Alaska Native communities described a rapidly changing marine environment in qualitative traditional knowledge interviews conducted over the course of a decade with 110 individuals. Based on their observations, sea ice conditions are the most notable change, with later freeze-up, thinner and less reliable ice, and earlier and more rapid break-up. Marine mammal populations in northern and western Alaska have been affected by changes in the physical environment, with alterations to migratory timing and routes, distribution, abundance, health, and behavior. Despite these changes, marine mammal populations in the region remain generally healthy and abundant. For hunters, access is the biggest challenge posed by changing conditions. Sea ice is less safe for travel, particularly for more southerly communities, making hunting more dangerous or impossible. Rapid break-up has reduced the time available for hunting amid broken ice in spring, formerly a dependable and preferred season. Social change also affects the ways in which hunting patterns change. Increased industrial development, for example, can also alter marine mammal distribution and reduce hunting opportunity. Reduced use of animal skins for clothing and other purposes has reduced demand. More powerful and reliable engines make day trips easier, reducing the time spent camping. An essential component of adjustment and adaptation to changing conditions is the retention

of traditional values and the acquisition of new information to supplement traditional knowledge. Our findings are consistent with, and add detail to, what is known from previous traditional knowledge and scientific studies. The ways in which hunters gather new information and incorporate it into their existing understanding of the marine environment deserves further attention, both as a means of monitoring change and as a key aspect of adaptation. While the changes to date have been largely manageable, future prospects are unclear, as the effects of climate change are expected to continue in the region, and ecological change may accelerate. Social and regulatory change will continue to play a role in fostering or constraining the ability of hunters to adapt to the effects of climate change.

Ice Seal Committee. 2016. The subsistence harvest of ice seals in Alaska— a compilation of existing information, 1960–2014. Ice Seal Committee. Committee Reports. 76 p. http://www.north-slope.org/assets/images/uploads/SHOISiA_2016_approved.pdf

Keywords**:** seal; marine mammal; subsistence hunting; Alaska Natives; cultural issues

Abstract**:** Bearded (*Erignathus barbatus*), ringed (*Pusa hispida*, also *Phoca hispida*), spotted (*Phoca largha*), and ribbon seals (*Histriophoca fasciata*) are the species of Alaska's seals collectively called ice seals because of their association with sea ice for feeding, resting, and pupping. Ice seals are an important component in maintaining Alaska Native subsistence culture because seals are a source of food and skins are used for clothes, boats, and crafts. Hunting, processing, and using seals is an important part of Alaska Native culture and heritage. To document subsistence needs and to show that harvests are sustainable, the number of seals used by a community should be determined and reported annually. Reporting subsistence seal harvest by community shows how important seals are to communities and how many are needed. This information will become more important if climate change or other factors reduce the number of seals in a population or changes where they are found. In situations where no is data available more conservative decisions are often made to conserve the resource than would be necessary if good harvest data were available. Reliable estimates of the numbers of seals in each population do not exist because it is difficult to count them. Aerial surveys are the best tool but they are expensive and dangerous and although some seals are counted, the number in the water and not counted is unknown. Learning more about the current level of subsistence harvest of ice seals, which is thought to be sustainable, could also provide valuable information about the size of seal populations where little information is available. The Ice Seal Committee (ISC), originally called the Ice Seal Working Group, was formed in December of 2004 and consisted of five delegates, one from each of the five regions where ice seals occur in Alaska (Fig. 1). The purpose of the Ice Seal Committee as stated in the bylaws is "to preserve and enhance the marine resources of ice seals including the habitat; to protect and enhance Alaska Native culture, traditions, and especially activities associated with subsistence uses of ice seals; to undertake education and research related to ice seals." The ISC has identified the collection of harvest information as a priority. Collecting and reporting harvest information demonstrates concern for the resource and is an important contribution to management. This report serves to compile existing ice seal harvest information for the

years 1960–2013 to determine where and how often harvest information is being collected and where efforts need to be focused in the future.

Jay, C. V., M. S. Udevitz, R. Kwok, A. S. Fischbach, and D. C. Douglas. 2010. Divergent movements of walrus and sea ice in the northern Bering Sea. Marine Ecology Progress Series. 407:293-302. https://doi.org/10.3354/meps08575

***Keywords*:** walrus; marine mammal; sea ice; telemetry; Bering Sea; Chukchi Sea

***Abstract*:** The Pacific walrus *Odobenus rosmarus divergens* is a large Arctic pinniped of the Chukchi and Bering Seas. Reductions of sea ice projected to occur in the Arctic by mid-century raise concerns for conservation of the Pacific walrus. To understand the significance of sea ice loss to the viability of walruses, it would be useful to better understand the spatial associations between the movements of sea ice and walruses. We investigated whether local-scale (~1 to 100 km) walrus movements correspond to movements of sea ice in the Bering Sea in early spring, using locations from radio-tracked walruses and measures of ice floe movements from processed synthetic aperture radar satellite imagery. We used generalized linear mixed-effects models to analyze the angle between walrus and ice floe movement vectors and the distance between the final geographic position of walruses and their associated ice floes (displacement), as functions of observation duration, proportion of time the walrus was in water, and geographic region. Analyses were based on 121 walrus-ice vector pairs and observations lasting 12 to 36 h. Angles and displacements increased with observation duration, proportion of time the walrus spent in the water, and varied among regions (regional mean angles ranged from 40° to 81° and mean displacements ranged from 15 to 35 km). Our results indicated a lack of correspondence between walruses and their initially associated ice floes, suggesting that local areas of walrus activities were independent of the movement of ice floes.

Jay, C. V., J. M. Grebmeier, A. S. Fischbach, T. L. McDonald, L. W. Cooper, and F. Hornsby. 2014. Pacific walrus (*Odobenus rosmarus divergens*) resource selection in the northern Bering Sea. PLoS One. 9(4):E93035. https://doi.org/10.1371/journal.pone.0093035

***Keywords*:** animals; biomass; ecosystem; geography; ice cover; models, biological; oceans and seas; Pacific Ocean; probability; walruses; physiology

***Abstract*:** The Pacific walrus is a large benthivore with an annual range extending across the continental shelves of the Bering and Chukchi Seas. We used a discrete choice model to estimate site selection by adult radio-tagged walruses relative to the availability of the caloric biomass of benthic infauna and sea ice concentration in a prominent walrus wintering area in the northern Bering Sea (St. Lawrence Island polynya) in 2006, 2008, and 2009. At least 60% of the total caloric biomass of dominant macroinfauna in the study area was composed of members of the bivalve families Nuculidae, Tellinidae, and Nuculanidae. Model estimates indicated walrus site selection was related most strongly to tellinid bivalve caloric biomass distribution and that walruses selected lower ice concentrations from the

mostly high ice concentrations that were available to them (quartiles: 76%, 93%, and 99%). Areas with high average predicted walrus site selection generally coincided with areas of high organic carbon input identified in other studies. Projected decreases in sea ice in the St. Lawrence Island polynya and the potential for a concomitant decline of bivalves in the region could result in a northward shift in the wintering grounds of walruses in the northern Bering Sea.

Jeffers, J. 2010. Climate change and the Arctic: adapting to changes in fisheries stocks and governance regimes. Ecology Law Quarterly. 37(3):917-977. http://www.jstor.org/stable/43920934

Keywords**:** climate change; marine ecosystem; fisheries; cultural issues; Bering Sea; sea ice

Abstract**:** This Note analyzes climate change impacts on Arctic fisheries and governance structures, and examines the role of science, policy, and law in minimizing future repercussions of such impacts. The Arctic is currently undergoing unprecedented shifts in marine species, and climatic conditions in the region are changing at a rate nearly twice as fast as those at lower latitudes. In addition, long-term climatic changes present entirely new challenges. These ecological and socioeconomic alterations will have a significant effect on fisheries governance structures and interactions between Arctic countries and could potentially destabilize existing management regimes. Positive changes to fishery stock compositions and distributions may also lead to conflicts between Arctic nations due to overlapping jurisdictional claims, unregulated fishing, and a lack of multiregional agreements. The current Arctic regulatory and governance framework is not sufficient in scope and flexibility to adequately address future fishery changes brought on by climate change. This Note suggests that the region needs a new, dynamic management regime in order to successfully negotiate the uncertainties inherent in climate change predictions and anticipate the effects such climatic changes will have on fisheries stocks. I propose four primary components of such a regime: (1) increased overlap of nation-state actors and scientists, (2) institutional nesting, (3) division and management of resources (both in terms of jurisdictional concerns, as well as conservation and utilization principles), and (4) non-political measures. I integrate these components into specific governance options for the future, including the creation of an Arctic regional treaty, an overhaul of the Arctic Council, and the formation of an Arctic-wide Regional Fisheries Management Organization. This Note concludes that although a regional treaty or agreement is currently unrealistic, overhauling the Arctic Council and establishing a new Arctic Ocean Regional Fisheries Management Organization may be feasible options to create an effective governance regime.

Jensen, D., A. Mahoney, and L. Resler. 2020. The annual cycle of landfast ice in the eastern Bering Sea. Cold Regions Science and Technology. 174:103059. https://doi.org/10.1016/j.coldregions.2020.103059

***Keywords*:** landfast; sea ice; subarctic; Bering Sea

***Abstract*:** Seasonal sea ice – ice which freezes in late fall and melts completely the following summer – is a central feature in the ecology, geomorphology, and climatology of the eastern Bering Sea. In this region's coastal zones, sea ice becomes locked in a stationary position against coastlines and influences interactions among land, ocean, and atmospheric processes. A thorough understanding of how this stationary ice, known as landfast ice, affects unique biogeophysical processes in the eastern Bering Sea region is limited by a lack of data on its areal coverage and seasonal duration. Here, we present the most comprehensive landfast ice dataset created to date for the Alaska Bering Sea region, derived using satellite imagery dated 1996–2008. This study provides a baseline set of observations regarding the landfast ice regime by identifying patterns in spatial distribution and interannual change. Our results show that spatial distribution and interannual change vary by regional geography in the eastern Bering Sea. Landfast ice widths averaged approximately 4.2 km on Northern Section, 18.8 km on the Central Section coastlines, and 8.9 km on the Yukon-Kuskokwim Delta. Modal water depths at the landfast ice edge varied by the Northern, Central, and Southern Section coastlines as well, with respective modal values of −13 m, −7 m, and − 8.5 m. We attribute these regional variations in width and water depth to differing conditions in near-shore bathymetry and coastal morphology. On an interannual basis, landfast ice formed 5 days later in the year, and broke up 4 days earlier on average in the eastern Bering Sea region from 1996 to 2008. Notably, ice-free conditions occurred 15 days later on the Central Section coastlines. The spatial distribution and interannual change of landfast ice is of importance to associated environmental changes in the eastern Bering Sea region, including accelerated coastal erosion, difficulties surrounding subsistence activities, diminishing wildlife habitat, and seasonal shifts in sediment transport into marine food webs from rivers.

Johnson, K. R., C. H. Nelson, and J. John H. Barber. 1983. Assessment of gray whale feeding grounds and sea floor interaction in the northeastern Bering Sea. U.S. Dep. Interior, USGS. Open-File Report 83-727. 112 p. U.S. Geological Survey Menlo Park, California 94025. https://doi.org/10.3133/ofr83727

***Keywords*:** gray whale; marine mammal; relative abundance; distribution; fronts; prey; amphipod

***Abstract*:** A dense ampeliscid amphipod community in Chirikov Basin and around St. Lawrence Island in the northeastern Bering Sea has been outlined by summarizing biological studies, analyzing bioturbation in sediment samples, and examining sea floor photos and videotapes. The amphipod population is associated with a homogeneous, relict fine-grained sand body 0.10-1.5 m thick that was deposited during the marine transgression over the Bering land bridge 8,000-10,000 yr B.P. Modern current and water mass movements and perhaps whale feeding activity prevent modern deposition in this area. The distribution of the transgressive sand sheet, associated amphipod community and feeding gray whales mapped by aerial survey correlate closely with three types of sea-floor pits observed on

high (500 kHz) and low (105 kHz) resolution side-scan sonar; they are attributed to gray whale feeding traces and their subsequent current scour modification. The fresh and modified feeding pits are present in 22,000 km of the basin and they cover a total of 2 to 18% of the sea floor in different areas of the feeding region. The smallest size class of pits approximates whale mouth gape size and is assumed to represent fresh whale feeding pits. Fresh feeding disturbance of the sea floor is estimated to average about 5.7% for a full feeding season. Combined with information that 34% of the measured benthic biomass is amphipod prey species, and calculating the number of gray whale feeding days in the Alaskan waters plus amount consumed per day, it can be estimated that Chirikov Basin, 2% of the feeding area, supplies a minimum of 5.3 to 7.1% of the gray whale's food resource in the Bering Sea and Arctic Ocean. If a maximum of 50% of the fresh feeding features are assumed to be missed because they parallel side-scan beam paths, then a maximum whale food resource of 14.2% is possible in northeastern Bering Sea. Because of side-scan techniques and possible higher amphipod biomass estimates, a reasonable minimum estimate of the total whale food resource in northeastern Bering Sea is 10%. These data show that side-scan sonar is a powerful new technique for analyzing marine mammal benthic feeding grounds. Sonographs reveal that the gray whales profoundly disturb the substrate and initiate substantial further erosion by bottom currents, all of which enhances productivity of the prey species and results in a "farming of the sea floor". In turn, because of the high concentration of whale prey species in a prime feeding ground that is vulnerable to the development of petroleum and mining for sand, great care is required in the exploitation of these resources in the Chirikov Basin.

Johnson, W. R., and Z. Kowalik. 1986. Modeling of storm surges in the Bering Sea and Norton Sound. Journal of Geophysical Research. 91(C4):5119-5128. https://doi.org/10.1029/JC091iC04p05119

Keywords**:** sea ice; model; climate; climate shifts; sea ice loss; biomass; ecosystems; Bering Sea; Chukchi Sea

Abstract**:** Sea level, currents, and ice distribution are studied in the Bering Sea during storm events. The ice and ice edge are incorporated into storm surge model. The interaction of wind, ice, and water is expressed by the normal and tangential stresses. A numerical grid is established for the Bering Sea, and a second refined grid is constructed for Norton Sound. Construction of open boundary conditions for the water and ice motion and numerical questions related to the application of a large frictional coefficient for ice are also discussed. Storm events from February and March 1982 are analyzed and compared with observations of bottom pressure and ice motion made by NOAA Pacific Marine Environmental Laboratory in the Bering Sea and sea level observations at Stebbins, Alaska. The influence of the ice on the storm surge propagation is shown, particularly that of the fast ice in Norton Sound. The model reproduces several observed features of the ice distribution in the Bering Sea, including the “race track” region off Nome, the polynya south of Saint Lawrence Island, and the movement of the ice edge.

Jones, M. C., M. Berkelhammer, K. J. Keller, K. Yoshimura, and M. J. Wooller. 2020. High sensitivity of Bering Sea winter sea ice to winter insolation and carbon dioxide over the last 5500 years. Science Advances. 6(36):EAAZ9588. https://doi.org/10.1126/sciadv.aaz9588

Keywords**:** sea ice; model; climate; climate shifts; oxygen

Abstract**:** Anomalously low winter sea ice extent and early retreat in CE 2018 and 2019 challenge previous notions that winter sea ice in the Bering Sea has been stable over the instrumental record, although long-term records remain limited. Here, we use a record of peat cellulose oxygen isotopes from St. Matthew Island along with isotope-enabled general circulation model (IsoGSM) simulations to generate a 5500-year record of Bering Sea winter sea ice extent. Results show that over the last 5500 years, sea ice in the Bering Sea decreased in response to increasing winter insolation and atmospheric CO_2, suggesting that the North Pacific is highly sensitive to small changes in radiative forcing. We find that CE 2018 sea ice conditions were the lowest of the last 5500 years, and results suggest that sea ice loss may lag changes in CO_2 concentrations by several decades.

Kikuchi, G., H. Abe, T. Hirawake, and M. Sampei. 2020. Distinctive spring phytoplankton bloom in the Bering Strait in 2018: A year of historically minimum sea ice extent. Deep Sea Research Part II: Topical Studies in Oceanography. 181-182:104905. https://doi.org/10.1016/j.dsr2.2020.104905

Keywords**:** Bering Strait; sea ice; ice-edge bloom; open-water bloom; Aleutian low

Abstract**:** Under climate change, the Bering–Chukchi continental shelves have experienced drastic sea ice loss, breaking the minimum sea ice extent record in 2018. In this paper, we report a distinctive spring phytoplankton bloom in the Bering Strait based on year-round mooring observations during 2016–2018. A near-bottom fluorescence sensor mounted on a mooring and satellite observations indicate that, despite the early sea ice retreat in spring of 2018 (mid-April), the spring phytoplankton bloom was not observed for more than 20 days after sea ice retreat. In contrast, in 2017 when sea ice retreat did not occur as early as it did in 2018 (early May), the bloom and sea ice retreat occurred in tighter synchrony. Mooring (2016–2018) and satellite observations (2003–2011, 2013–2018) suggest that an open-water bloom rather than an ice-edge bloom occurred in the Bering Strait in the spring of 2018. Early sea ice retreat apparently provided unfavorable conditions for an ice-edge bloom due to weak sunlight and winter-like weather. Mid-winter sea ice loss was promoted by unusual southerly winds, bringing in warm water from the south. For the Bering Strait, the end of April is a reference date for sea ice retreat that distinguishes between an open-water bloom and an ice-edge bloom, which is approximately one month later than that in the southeastern Bering Sea.

Kimura, F., Y. Abe, K. Matsuno, R. R. Hopcroft, and A. Yamaguchi. 2020. Seasonal changes in the zooplankton community and population structure in the northern Bering Sea from June to September, 2017. Deep Sea Research Part II: Topical Studies in Oceanography. 181-182:104901. https://doi.org/10.1016/j.dsr2.2020.104901

***Keywords*:** northern Bering sea; seasonal changes; zooplankton community; population structure; copepods; chaetognaths; appendicularians

***Abstract*:** Zooplankton community structure in the northern Bering Sea may change significantly over relatively short periods due to the inflow of different water masses and the seasonal release of meroplankton, although details of these changes are still unclear. We studied the zooplankton community in the northern Bering Sea from June to September of 2017 and examined seasonal changes in the community structure and stage structure of the dominant species. Zooplankton abundance ranged from 41,000 to 928,000 ind. m−2, with the greatest abundances near 174°W during July. Copepods were the dominant taxa, comprising 10–98% of zooplankton abundance, with benthic larvae such as bivalves dominant at some stations during July and August. Cluster analysis of abundances divided the station/zooplankton communities into seven groups. West of 172°W, clear seasonal changes were not observed, because the Bering Chukchi Winter Water persisted in the deep layer and sampling was only conducted in this region in July and August. In contrast, the community structures east of 172°W differed every month due to water masses changes, meroplankton release, and copepod production associated with the phytoplankton bloom. Despite the changes of water mass, development for the dominant large copepods (*Calanus glacialis/marshallae*, *Eucalanus bungii* and *Metridia pacifica*) was revealed from their population stage structures. Seasonal shifts in species within *Neocalanus* and appendicularians were driven by water mass exchanges. This study demonstrates that zooplankton community in the northern Bering Sea varies substantially on a monthly time scale. Therefore, to evaluate the impact of climate change on zooplankton, it is important to consider both the seasonal period and the dominant water masses present.

King, E. R. 1961. An aeromagnetic profile from Anchorage to Nome, Alaska. Geophysics. 26(6):716-726. https://doi.org/10.1190/1.1438945

***Keywords*:** aeromagnetic; tectonics; gamma anomaly; geology

***Abstract*:** A total-intensity profile was obtained on a 500-mile flight by a U. S. Geological Survey airplane from Anchorage to Nome, Alaska, on May 4, 1954. The average flight altitude was 6,000 ft above sea level except over the Alaska Range where the flight altitude was 9,000 ft. This profile crossed eight of the major tectonic elements of Alaska at right angles to their trend and gives valuable regional information in an area where other geophysical and geological information is scarce or lacking. The profile has a net gradient downward to the northwest, most of which is ascribed to the component of the earth's main magnetic field along the flight traverse. The great variety of magnetic anomalies which

are superimposed on this gradient originate from variations in lithology along the traverse. All the magnetic anomalies, except a large one over the Yukon River, are caused by magnetic rocks at or near the surface. The magnetic profile may be divided into four major segments and nine subsegments, each having a characteristic magnetic pattern. Most of these can be related to a tectonic unit. The large plutons of the Talkeetna geanticline are clearly defined by a group of anomalies having the highest amplitudes of any on the profile. The Matanuska geosyncline to the east is represented by a 25-mile section of sloping profile consistent with a thick sedimentary section but indicating that the geosyncline is comparatively narrow near Anchorage. The 200-mile central magnetic segment is relatively free from all but very minor anomalies. This segment includes the Alaska Range geosyncline, the Tanana geanticline, and the Kuskokwim geosyncline; showing only slight magnetic contrasts between each of these elements. The two geosynclines either have thick Mesozoic sedimentary sections or have underlying crystalline rocks which are low in magnetic susceptibility at shallow depths. The rocks of the geanticline have a low but not negligible magnetic susceptibility and are predominantly Paleozoic sedimentary rocks. A single 300-gamma anomaly on the west edge of the central segment is caused by a small, mafic intrusive body in the Paleozoic metamorphic rocks of Mt. Hurst. West of this anomaly the profile consists of a series of small sharp anomalies which are probably caused by Paleozoic metavolcanic rocks of the Ruby geanticline. The second largest anomaly on the profile is in the Koyukuk geosyncline over the Yukon River. The source is calculated to be more than a mile deep and may be an intrusive body at least 15 miles wide. This anomaly is flanked by 20-mile sections of flat or sloping profile which indicate areas of thick sedimentary rocks, particularly in the region west of the Yukon River. The 150-mile Norton Sound magnetic segment on the western end of the profile consists of many closely spaced anomalies produced by rocks which are either volcanic or similar to the Seward complex. Of the four Cenozoic basins or lowlands crossed by the profile, three are underlain by rocks of moderate to high magnetic susceptibility at shallow depths. These are the Cook Inlet basin, part of which overlaps rocks of the Talkeetna geanticline, the Innoko basin of central Alaska which overlies the rocks of the Ruby geanticline, and the Norton basin, in which sedimentary deposits are thin or absent. The fourth, the Minchumina basin, is underlain by the low-susceptibility rocks at the Tanana geanticline, which are also probably close to the surface.

Kolts, J. M., J. R. Lovvorn, C. A. North, J. M. Grebmeier, and L. W. Cooper. 2013. Effects of body size, gender, and prey availability on diets of snow crabs in the northern Bering Sea. Marine Ecology Progress Series. 483:209-220. https://doi.org/10.3354/meps10292

Keywords**:** essential fish habitat; decapod diets; prey size selection; *Chionoecetes opilio*; crustacean stomach contents; benthic prey availability; Bering Sea

Abstract**:** In efforts to maintain or restore populations of snow crabs *Chionoecetes opilio*, identifying important habitats requires knowing prey preferences and availability for different sexes and life stages. We analyzed the diets of juvenile, adolescent, and adult snow crabs of both sexes relative to available prey throughout a large area of the northern

Bering Sea. Snow crabs of all sizes consumed a wide variety of prey including bivalves, gastropods, polychaetes, ophiuroids, and crustaceans. The proportions of different taxa in snow crab diets corresponded closely to the relative abundance of those taxa in different areas; thus, in this region, diets of respective sexes and ages can be predicted fairly accurately from the local abundance of different prey. The only apparent differences in diet between sexes were related to the larger and stronger claws of adult males. Larger crabs consumed larger prey that required greater handling ability and claw strength, such as harder-shelled bivalves and gastropods, larger polychaetes, and other snow crabs. Juvenile crabs consumed softer, more easily manipulated prey, such as amphipods and small bivalves with thin or incompletely calcified shells. Areas of high abundance of juvenile snow crabs, previously not recognized in designating essential habitat in this region, were characterized by high abundance of amphipods and small bivalves. Quality and importance of habitat for snow crabs appeared to depend jointly on several factors: hydrographic patterns that determine locations of larval settlement and subsequent ontogenetic migration, the combined abundance of all prey taxa, and ontogenetic capabilities for handling different sizes of prey.

Kolts, J. M., J. R. Lovvorn, C. A. North, and M. A. Janout. 2015. Oceanographic and demographic mechanisms affecting population structure of snow crabs in the northern Bering Sea. Marine Ecology Progress Series. 518:193-208. https://doi.org/10.3354/meps11042

Keywords**:** population structure; larval advection; larval settlement; Ontogenetic migration; dispersion; reproduction; *Chionoecetes opilio*

Abstract**:** Snow crabs *Chionoecetes opilio* are quite productive at suitable temperatures, but can also be abundant in water cold enough to depress settlement of larvae, growth, and reproduction. In much of the northern Bering Sea, bottom water temperatures are below -1°C for most or all of the year. Crab pelagic larvae prefer to settle at temperatures above 0°C, so we found high densities of juveniles only where intruding warm currents deposited larvae in localized areas. After settlement, maturing crabs appeared to exhibit ontogenetic migration toward deeper, warmer water. Cold temperatures excluded key predators, but decreased fecundity by restricting females to small body size (with associated small clutches) and to breeding every 2 yr. Migration to warmer water may allow females to breed annually and to encounter more adult males needed to fertilize subsequent clutches. Because older males also emigrate, remaining adolescent males probably inseminate newly maturing females. Without localized intrusion of warmer currents, snow crabs might not persist at high densities in such cold waters. However, they are currently very abundant, and export many pelagic larvae and adults.

Kotwicki, S., and R. R. Lauth. 2013. Detecting temporal trends and environmentally-driven changes in the spatial distribution of bottom fishes and crabs on the eastern Bering Sea shelf. Deep Sea Research Part II: Topical Studies in Oceanography. 94:231-243. https://doi.org/10.1016/j.dsr2.2013.03.017

Keywords**:** spatial distribution; population shift; cold pool; bottom fish; crab; Bering Sea shelf

Abstract**:** This study uses a 30-year time series of standardized bottom trawl survey data (1982–2011) from the eastern Bering Sea shelf to model patterns of summer spatial distribution for various bottom fishes and crabs in response to changes in the areal extent of the cold pool, time lag between surveys, and fluctuations in population abundance. This investigation is the first to include data for the 2006–2010 cold period and to use between-year comparisons of local and shelf-wide spatial indices to test specific responses to three different isothermal boundaries within the cold pool. Distributional shifts in population varied considerably among species and directional vectors for some species were greater in magnitude to the east or west than to the north or south; however, in general, eastern Bering Sea shelf populations shifted southward in response to the increasing cold pool size, and after accounting for differences in temperature and population abundance, there was still a temporal northward shift in populations over the last three decades despite the recent cooling trend. Model results for local and shelf-wide indices showed that survey time lag and cold pool extent had a greater effect on spatial distribution than population abundance, suggesting that density-independent mechanisms play a major role in shaping distribution patterns on the eastern Bering Sea shelf. The area enclosed by the 1°C isotherm most commonly affects both local and shelf-wide spatial indices suggesting that 1°C is a more important boundary for describing temperature preferences of eastern Bering Sea bottom fishes and crabs than is the 2°C isotherm used for designating the physical boundary for the cold pool.

Krenz, C., L. Gadamus, and J. Raymond-Yakoubian. 2014. Bering Strait: Marine life and subsistence use data synthesis. Oceana and Kawerak, Inc. Oceana and Kawerak Report. 499 p. http://oceana.org/publications/reports/the-bering-strait-marine-life-and-subsistence-data-synthesis

Keywords**:** climate change; sea ice; marine mammals; ecosystem shifts; benthic habitat; fisheries; Alaska Natives; traditional knowledge; Arctic; subsistence

Abstract**:** Oceana and Kawerak, Inc. recently completed the Bering Strait Marine Life and Subsistence Data Synthesis, which portrays areas of importance and high abundance for marine species such as ice seals, walrus, polar bears, and whales, as well as other marine ecosystem components like benthic habitat and sea ice. This synthesis uses both western science and Alaska Natives' Local and Traditional Knowledge to create a synthesis that decision makers can use to help protect valuable and vulnerable marine areas from human threats such as shipping, and large-scale commercial fishing.

Kruege, C. C., and C. E. Zimmerman. 2009. Pacific Salmon: Ecology and management of western Alaska's populations. AFS Symposium 70. American Fisheries Society. Bethesda, MD. 1235 p. https://doi.org/10.47886/9781934874110

***Keywords*:** marine ecology; freshwater ecology; subsistence fisheries; commercial fisheries; sport fisheries; economics, governance; cultural issues

***Abstract*:** This timely book examines the sustainability of salmon fisheries in the Arctic-Yukon Kuskokwim (AYK) region of Alaska. With more than fifty chapters, the book assesses the ecological processes that cause change in salmon populations; describes the effects of varying salmon runs on rural communities; reviews state, Federal, and international management of salmon fisheries in the region; and examines emerging themes at the nexus of salmon ecology and management in the AYK region.

Kuletz, K., D. Cushing, and E. Labunski. 2020. Distributional shifts among seabird communities of the northern Bering and Chukchi seas in response to ocean warming during 2017–2019. Deep Sea Research Part II: Topical Studies in Oceanography. 181-182:104913. https://doi.org/10.1016/j.dsr2.2020.104913

***Keywords*:** seabird; climate change; sea ice; ecosystems; seasonality

***Abstract*:** In the northern Bering Sea and eastern Chukchi Sea, 2017–2019 were record-breaking years for warm ocean temperatures and lack of sea ice. The region supports millions of seabirds that could be affected by shifts in prey distribution and availability caused by changing environmental drivers. However, seabirds are highly mobile and often flexible in diet, and might alter their foraging distributions accordingly. To determine if there was evidence of long-term changes in abundance of seabirds, or if seabirds used the offshore habitat differently during recent warm years, we compared species richness, community composition, and distribution and abundance of selected species and total seabirds (all species combined) between two periods, 2007–2016 and 2017–2019. We also evaluated annual changes in abundance during 2007–2019. We used 79,426 km of transects from vessel-based surveys conducted July through September. Total seabird density for the entire study area increased by ~20% during 2017–2019, but changes were not consistent across the study area, nor among species, and species richness declined except for a slight increase in the northern Chukchi Sea. Total seabird density declined most in the northern Bering Sea (−27%), although it increased in the Chirikov Basin by 73%. During 2017–2019, abundance of piscivorous murres (*Uria* spp.) decreased everywhere, whereas planktivorous Aethia auklet density increased by 70% in Chirikov Basin; auklets apparently abandoned their post-breeding migration to the Chukchi Sea. Short-tailed shearwaters (*Ardenna tenuirostris*) expanded farther into the northern Chukchi Sea, with nearly twice the density of the previous decade. We identified five seabird community types, three of which (all dominated by an alcid species) contracted spatially in the later period, and shifted south or near colonies. In contrast, a short-tailed shearwater dominated community expanded northward, and a community defined by low seabird density expanded throughout the eastern portion of both the northern Bering and Chukchi seas, suggesting higher-density communities had shifted westward. The variable responses among species correspond to documented changes in the environment as well as their natural history.

Kvenvolden, K. A., C. H. Nelson, D. R. Thor, M. C. Larsen, G. D. Redden, J. B. Rapp, and D. J. Des Marais. 1979. Biogenic and thermogenic gas in gas-charged sediment of Norton Sound, Alaska. ***In*** Offshore Technology Conference Houston, Texas. https://doi.org/10.4043/3412-ms

Keywords**:** methane; upstream oil & gas; reservoir characterization; water column; vent; carbon isotopic composition; gas-charged sediment; composition; thermogenic gas; Norton Sound

Abstract**:** Chemical and isotopic compositions of sediment gas from Norton Sound have been determined for near-surface, gas-charged sediments at two sites identified in acoustic profiles and bottom observations. At one site our air-driven vibracorer penetrated sediment saturated with methane that has a carbon isotopic composition (δ13 C_{PDB}) of -80%. This isotopic value suggests that the methane originated from active biological processes operating on peat in the top 4 m of sediment. At the other site, characterized by a large subsurface acoustic anomaly, smaller near-surface acoustic anomalies and active seepage of gas, our vibracorer obtained sediment saturated with gas composed of 98% CO_2 which had a δ13 C_{PDB} value of -2.7%. Associated with the CO_2 are minor concentrations of petroleum-like light hydrocarbons. Methane in this mixture has a δ13 C_{PDB} value of -36%. The carbon isotopic compositions of CO_2 and methane along with the chemical distribution of gaseous hydrocarbons indicate that at this site these gases are derived from thermal processes operating at depth in Norton Basin. Apparently CO_2 from the decarbonation of marine limestone acts as a carrier for hydrocarbon gases that have been generated from organic matter buried in the basin. The gases reach the surface by faults and escape at the seafloor as a submarine seep. The presence of near-surface gas charged sediment in Norton Sound reduces the stability of the seafloor. Areas where sediments are charged with gas may pose potential hazards for engineering developments.

Ladd, C., S. W. Bell, D. G. Kimmel, C. W. Mordy, P. J. Stabeno, and S. Stalin. 2020. Eddy-like features near St. Matthew Island, eastern Bering Sea shelf: Observations from the Oculus coastal glider. Geophysical Research Letters*.* 47(23):E2020GL089873. https://doi.org/10.1029/2020gl089873

Keywords**:** glider observations; eddy; chlorophyll; St. Matthew Island; Bering Sea Shelf

Abstract**:** The eastern Bering Sea Shelf is characterized by high biological productivity, seasonal sea ice, and commercially important fisheries. Enhanced productivity is often associated with small-scale oceanographic features. Our objective was to use an autonomous underwater vehicle to examine features typically missed by ~20-km spaced shipboard sampling. A coastal glider (Oculus) sampled ~3 dives hr−1 with horizontal spacing of ~300 m per dive in August/September 2017. In the north-south transition zone near St. Matthew Island, the glider sampled four eddy-like features associated with weaker vertical stratification. These features had diameters of 15–20 km and were associated with higher

surface chlorophyll. Shipboard data collected in the same region approximately a month later showed that a similar feature was associated with high concentrations of small copepods. Incorporating higher resolution sampling available with gliders into the Bering Sea observing network will improve our understanding of ecosystem response to patchiness in the system.

Lalande, C., J. M. Grebmeier, A. M. P. McDonnell, R. R. Hopcroft, S. O'Daly, and S. L. Danielson. 2021. Impact of a warm anomaly in the Pacific Arctic region derived from time-series export fluxes. PLOS ONE. 16(8):E0255837. https://doi.org/10.1371/journal.pone.0255837

***Keywords*:** carbon; chlorophyll; suspended sediment; sediment; sediment transport; Bering Sea; Chukchi Sea

***Abstract*:** Unusually warm conditions recently observed in the Pacific Arctic region included a dramatic loss of sea ice cover and an enhanced inflow of warmer Pacific-derived waters. Moored sediment traps deployed at three biological hotspots of the Distributed Biological Observatory (DBO) during this anomalously warm period collected sinking particles nearly continuously from June 2017 to July 2019 in the northern Bering Sea (DBO2) and in the southern Chukchi Sea (DBO3), and from August 2018 to July 2019 in the northern Chukchi Sea (DBO4). Fluxes of living algal cells, chlorophyll a (chl a), total particulate matter (TPM), particulate organic carbon (POC), and zooplankton fecal pellets, along with zooplankton and meroplankton collected in the traps, were used to evaluate spatial and temporal variations in the development and composition of the phytoplankton and zooplankton communities in relation to sea ice cover and water temperature. The unprecedented sea ice loss of 2018 in the northern Bering Sea led to the export of a large bloom dominated by the exclusively pelagic diatoms *Chaetoceros* spp. at DBO2. Despite this intense bloom, early sea ice breakup resulted in shorter periods of enhanced chl a and diatom fluxes at all DBO sites, suggesting a weaker biological pump under reduced ice cover in the Pacific Arctic region, while the coincident increase or decrease in TPM and POC fluxes likely reflected variations in resuspension events. Meanwhile, the highest transport of warm Pacific waters during 2017–2018 led to a dominance of the small copepods *Pseudocalanus* at all sites. Whereas the export of ice-associated diatoms during 2019 suggested a return to more typical conditions in the northern Bering Sea, the impact on copepods persisted under the continuously enhanced transport of warm Pacific waters. Regardless, the biological pump remained strong on the shallow Pacific Arctic shelves.

Larsen, B. R., C. H. Nelson, C. Heropolous, and J. J. Patry. 1980. Distribution of trace elements in bottom sediment of the northern Bering Sea. U.S. Dep of Interior, USGS. OCS Environmental Assessment Program. RU-413. 193-314 p. U.S. Geological Survey Menlo Park, California 94025. https://espis.boem.gov/final%20reports/760.pdf

***Keywords*:** elements; heavy metals; metals; sediment; trace metals; geochemistry; Norton Basin; St Matthewhall; Navarin Basin

***Abstract*:** This study was conducted to develop a geochemical data set of the distribution and concentration of major and trace elements in sediments of the northern Bering Sea. The mapped data serve as baseline data against which future changes, resulting from potential development in the region, can be monitored. Anomalously high concentrations of some elements in the Bering Sea sediments are related to land-based mineral sources.

Lauth, R. R. 2011. Results of the 2010 eastern and northern Bering Sea continental shelf bottom trawl survey of groundfish and invertebrate fauna. U.S. Dep. Commerce. NOAA Tech. Memo. NMFS-AFSC-227. 256 p. 7600 Sand Point Way N.E., Seattle, WA 98115. https://repository.library.noaa.gov/view/noaa/3852

***Keywords*:** groundfish; invertebrates; bottom trawl; fisheries; Bering Sea

***Abstract*:** From June to August 2010, the National Marine Fisheries Service's Alaska Fisheries Science Center, Resource Assessment and Conservation Engineering Division, conducted its 29th annual eastern Bering Sea (EBS) continental shelf bottom trawl survey of groundfish and invertebrate fauna. In addition, the 2010 survey coverage was expanded to include the northern Bering Sea (NBS). The expanded study area covered the entire Bering Sea continental shelf from 20 to 200 m bottom depth to the U. S. -Russian Convention Line between the Alaska Peninsula and the Bering Strait, including Norton Sound. Three stern trawlers, the 43.5-m FV Alaska Knight, the 40-m FV Aldebaran, and the 38-m FV Vesteraalen were chartered to sample this survey area. Demersal populations of fishes and invertebrates were sampled by trawling for 30 minutes at stations centered within a stratified sytematic grid consisting of a total of 376 stations in the EBS and 145 stations in the NBS. At each station, species composition of the catch was determined, and length distributions and age structure samples were collected from ecologically and commercially important species. All survey stations were sampled successfully in the EBS, and all but three stations were sampled successfully in the NBS. For the fifth consecutive year, average surface (5.4 degrees C) and bottom (1.4 degrees C) water temperatures for the EBS shelf were well below the long-term means from 1982 to 2009 for the surface (6.6 degrees C) and for the bottom (2.3 degrees C). A total of 120 species of fishes representing 23 families and 74 genera, as well as 199 species of invertebrates representing 14 phyla, were identified in the catches from both the EBS and NBS. Fish taxa accounted for only 38% of the total CPUE. In the EBS, walleye pollock (*Theragra chalcogramma*), Pacific cod (*Gadus macrocephalus*), yellowfin sole (*Limanda aspera*), and rock sole (*Lepidopsetta* spp.) comprised 77% of the total fish biomass, and in the NBS, yellowfin sole and Alaska plaice (*Pleuronectes quadrituberculatus*) comprised 61% of the total fish biomass. The majority of invertebrate biomass in both the EBS (67%) and NBS (67%) consisted of echinoderms and crustaceans. Survey results persented herein include abundance estimates for fishes and invertebrates, geographic distributions and abundance-at-length of the more common fish species, and summary surface and bottom temperature data during the summer survey period. Appendices provide station data, summarized catch data by station, species listings, and detailed analyses of abundance and biological data of the sampled populations.

Lauth, R. R., E. J. Dawson, and J. Conner. 2019. Results of the 2017 eastern and northern Bering Sea continental shelf bottom trawl survey of groundfish and invertebrate fauna. U.S. Dep. Commerce. NOAA Tech. Memo. NMFS-AFSC-396. 270 p. 7600 Sand Point Way N.E., Seattle, WA 98115. https://repository.library.noaa.gov/view/noaa/3852

***Keywords*:** fish; crab; fisheries; biomass; surveys; Bering Sea

***Abstract*:** Between 2010 and 2017, there were noticeable changes in the benthic community of the NBS. Total CPUE values for many of the animals in the NBS shifted from being low in 2010 to being much higher in 2017. The total estimated animal biomass in the NBS increased from 3.0 million t in 2010 to 4.5 million t in 2017 driven primarily by increases in walleye pollock and Pacific cod. Major distributional shifts by these two species and others were likely in response to the warmer conditions resulting from diminished sea ice during the recent warm stanza that began in 2014. The dramatically different and unexpected results underscore the need for continuing NEBS surveys on a regular basis to learn more about the environmental variability and how fish and crab populations are responding to a dynamic and changing environment. Moreover, many of the design-based estimates of survey abundance currently used in Bering Sea and Aleutian Island (BSAI) stock assessments are biased because they do not account for the dynamic biological and physical process errors such as those readily apparent for pollock and Pacific cod in the NEBS surveys. Hence, new methods for model-based estimates of survey abundance that incorporate as well as propagate uncertainty in the stock assessment models are also needed.

Lefebvre, K. A., L. Quakenbush, E. Frame, K. B. Huntington, G. Sheffield, R. Stimmelmayr, A. Bryan, P. Kendrick, H. Ziel, T. Goldstein, J. A. Snyder, T. Gelatt, F. Gulland, B. Dickerson, and V. Gill. 2016. Prevalence of algal toxins in Alaskan marine mammals foraging in a changing arctic and subarctic environment. Harmful Algae. 55:13-24. https://doi.org/10.1016/j.hal.2016.01.007

***Keywords*:** climate; algae; algal toxins; marine mammals

***Abstract*:** Current climate trends resulting in rapid declines in sea ice and increasing water temperatures are likely to expand the northern geographic range and duration of favorable conditions for harmful algal blooms (HABs), making algal toxins a growing concern in Alaskan marine food webs. Two of the most common HAB toxins along the west coast of North America are the neurotoxins domoic acid (DA) and saxitoxin (STX). Over the last 20 years, DA toxicosis has caused significant illness and mortality in marine mammals along the west coast of the USA, but has not been reported to impact marine mammals foraging in Alaskan waters. Saxitoxin, the most potent of the paralytic shellfish poisoning toxins, has been well-documented in shellfish in the Aleutians and Gulf of Alaska for decades and associated with human illnesses and deaths due to consumption of toxic clams. There is little information regarding exposure of Alaskan marine mammals. Here, the spatial patterns and prevalence of DA and STX exposure in Alaskan marine mammals are

documented in order to assess health risks to northern populations including those species that are important to the nutritional, cultural, and economic well-being of Alaskan coastal communities. In this study, 905 marine mammals from 13 species were sampled including; humpback whales, bowhead whales, beluga whales, harbor porpoises, northern fur seals, Steller sea lions, harbor seals, ringed seals, bearded seals, spotted seals, ribbon seals, Pacific walruses, and northern sea otters. Domoic acid was detected in all 13 species examined and had the greatest prevalence in bowhead whales (68%) and harbor seals (67%). Saxitoxin was detected in 10 of the 13 species, with the highest prevalence in humpback whales (50%) and bowhead whales (32%). Pacific walruses contained the highest concentrations of both STX and DA, with DA concentrations similar to those detected in California sea lions exhibiting clinical signs of DA toxicosis (seizures) off the coast of Central California, USA. Forty-six individual marine mammals contained detectable concentrations of both toxins emphasizing the potential for combined exposure risks. Additionally, fetuses from a beluga whale, a harbor porpoise and a Steller sea lion contained detectable concentrations of DA documenting maternal toxin transfer in these species. These results provide evidence that HAB toxins are present throughout Alaska waters at levels high enough to be detected in marine mammals and have the potential to impact marine mammal health in the Arctic marine environment.

Lovvorn, J. R., A. R. Rocha, S. L. Danielson, L. W. Cooper, J. M. Grebmeier, and K. S. Hedstrom. 2020. Predicting sediment organic carbon and related food web types from a physical oceanographic model on a subarctic shelf. Marine Ecology Progress Series. 633:37-54. https://www.int-res.com/abstracts/meps/v633/p37-54/

Keywords**:** suspended sediment; bottom-feeding; bottom type; ocean modeling; bottom flow; organic carbon

Abstract**:** In changing environments, conservation planning for bottom-feeding marine predators requires estimating the present and future spatial patterns of benthic communities. In the northern Bering Sea, we used the Regional Ocean Modeling System (ROMS) to hindcast near-bottom flows that redistribute settled phytodetritus and organic sediments, which in turn strongly affect the dispersion of 3 food web types that differentially favor spectacled eiders *Somateria fischeri*, walruses *Odobenus rosmarus*, or gray whales *Eschrichtius robustus*. Using data collected between 1994 and 2010, we interpolated spatial patterns of sediment organic carbon from field samples and correlated them with water depths and modeled flow velocities, temperatures, and salinities. In the deeper (mean 63 m) southern study area with weak net flows, hindcast near-bottom currents had negligible effects on patterns of sediment longer-term organic carbon (LTOC); instead, regional depth gradients and local bathymetry were the best predictors (r^2 = 0.72-0.85 among 7 years). In that area, climatic variations in total primary production would affect the areal extent of different LTOC levels, but not the core locations of persistent patches defined by depth. In the shallower (mean 39 m) northern study area with much faster flows, seafloor depth had negligible effects, and patterns of LTOC depended mainly on currents (r^2 = 0.48-0.55 over 2 years) that are subject to climatic changes in winds. Based

on ranges of LTOC for different food web types, substantial portions of both areas must be conserved to ensure annual availability of all 3 types. Regional ocean circulation models driven by downscaled climate models provide important opportunities for projecting spatial patterns of key benthic habitats in this region.

Maekakuchi, M., K. Matsuno, J. Yamamoto, Y. Abe, and A. Yamaguchi. 2020. Abundance, horizontal and vertical distribution of epipelagic ctenophores and scyphomedusae in the northern Bering Sea in summer 2017 and 2018: Quantification by underwater video imaging analysis. Deep Sea Research Part II: Topical Studies in Oceanography. 181-182:104818. https://doi.org/10.1016/j.dsr2.2020.104818

Keywords**:** Ctenophores; Scyphomedusae; northern Bering Sea; vertical distribution; horizontal distribution; imaging analysis

Abstract**:** We examined the abundance and horizontal and vertical distributions of epipelagic ctenophores and scyphomedusae in the northern Bering Sea using an underwater video camera during July of 2017 and 2018. The effects of environmental and biological parameters on the distribution of these species were evaluated by generalized additive modelling (GAM). In 2017, the dominant ctenophore, *Bolinopsis infundibulum*, was mainly distributed in the north and west of St. Lawrence Island (SLI), and their vertical distribution varied with the region but not by the time of day. We found that *B. infundibulum* was distributed in the upper pycnocline north of SLI, but below the pycnocline west of SLI. Biological interactions with other gelatinous zooplankton may explain these regional differences in vertical distribution; GAM analysis revealed a negative interaction between *B. infundibulum* and the large scyphomedusa, *Chrysaora melanaster*, which occurred in the upper layer in the west of SLI. *B. infundibulum* may avoid that layer to reduce feeding competition. For the ctenophore, *Beroe* sp., vertical and horizontal distributions were similar to those of *B. infundibulum*, and GAM analysis also revealed a positive interaction for both species. As *B. infundibulum* is an important prey of *Beroe* sp., a prey-predator interaction may result from their similar horizontal and vertical distributions. Standing stocks of epipelagic ctenophores and scyphomedusae in 2018 were low compared to those in 2017, by a factor of 1/20 (*C. melanaster*) and1/90 (*Beroe* sp.). This might be due to annual differences in water mass in this region, in that the thermal conditions characterized by a high abundance of the dominant *B. infundibulum* in 2017 (<2 and >8°C) were absent in 2018. As this drastic decrease in standing stock in 2018 was apparent for both ctenophores and scyphomedusae, food availability was hypothesized to be poor that year.

Marsh, J. M., and F. J. Mueter. 2019. Influences of temperature, predators, and competitors on polar cod (*Boreogadus saida*) at the southern margin of their distribution. Polar Biology. 43(8):995-1014. https://doi.org/10.1007/s00300-019-02575-4

Keywords**:** *Boreogadus saida*; Bering Sea; Labrador Sea; interspecific interactions; climate change; spatial distribution

***Abstract*:** Polar cod (*Boreogadus saida*) is the most abundant and ubiquitous fish species throughout the Arctic Ocean. As such, they serve an important ecosystem role linking upper and lower trophic levels and transferring energy between the benthic and pelagic realms. Our objective is to explore what limits the southern distribution of polar cod in Pacific and Atlantic sectors by examining time series of survey and oceanographic data. We quantify the variability in the southern extent of the polar cod distribution in the Bering and Labrador Seas, and determine mechanisms (bottom temperature and potential predators: Pacific cod *Gadus macrocephalus*, Atlantic cod *Gadus morhua*, and Greenland halibut *Reinhardtius hippoglossoides* and competitors: capelin *Mallotus villosus* and walleye pollock *Gadus chalcogrammus*) driving the variability. When temperatures were lower, polar cod occupied larger areas and had higher abundances in both regions, suggesting that as temperatures increase with climate warming the range of polar cod is likely to contract. Temperature had a much larger impact on polar cod abundance than competitor abundance and predator abundance, especially in the eastern Bering Sea. However, when we included data from northern and eastern Bering Sea in 2010 and 2017, polar cod were less likely to occur in warmer waters when either Pacific cod or walleye pollock were present. Northward range expansions of subarctic Pacific cod and walleye pollock may further restrict polar cod distributions.

Martin, D. J., C. J. Whitmus, and L. E. Hachmeister. 1987. Distribution and seasonal abundance of juvenile salmon and other fishes in the Yukon Delta. U.S. Dep of Interior, USGS. OCS Environmental Assessment Program. Obligation No.: 14-12-0001-30133 RU-660. 152 p. U.S. Geological Survey Menlo Park, California 94025. https://espis.boem.gov/final%20reports/86.pdf

***Keywords*:** Yukon–Kuskokwim delta; fish habitat; oil spill; chinook salmon; chum salmon; coregonid fishes; juvenile fishes; shellfish; ecosystem

***Abstract*:** The purpose of this study was to identify the importance of aquatic habitats in the Yukon River Delta for juvenile salmon and other fishes, and to determine the vulnerability of these fish to the potential impacts of an oil spill. An investigation was conducted of the distributary channels, nearshore, and shallow offshore habitats to determine the outmigration timing , distribution, and seasonal abundance of juvenile salmon and other fishes in the Yukon River Delta. Fisheries and oceanographic data were collected from three surveys that began immediately following ice breakup (i.e., early June) and ended in mid-August 1986.

McGregor, R. C. 1902. A list of birds collected in Norton Sound, Alaska. The Condor. 4(6):135-144. https://doi.org/10.2307/1360889

***Keywords*:** seabird; Norton Sound; birding; species observations

***Abstract*:** No abstract available.

McKinnell, S. 2011. The state of the Bering Sea in 2010. PICES Press. 19(1):35-37. https://www.proquest.com/docview/884233054

***Keywords*:** earth sciences; oceanography; sea surface temperature

***Abstract*:** No abstract available.

McManus, D. A., and K. Venkatarathnam. 1974. Yukon River sediment on the northernmost Bering Sea shelf. SEPM Journal of Sedimentary Research. 44:1052-1060. https://doi.org/10.1306/212f6c2b-2b24-11d7-8648000102c1865d

***Keywords*:** age; Alaska; Arctic Ocean; Bering Sea; Cenozoic; Chukchi Sea; continental shelf; distribution; environment; granulometry; heavy minerals; Holocene; interpretation; marine mineral; composition; North America; North Pacific; oceanography; Pacific Ocean; provenance; Quaternary; sedimentation; sediments; United States; Yukon River; Chirikov Basin

***Abstract*:** Although modern very fine-grained sands and silts are deposited seaward of the delta of the Yukon River, sediment derived from the Yukon today is a more dominant component of bottom sediments in the Chukchi Sea than in the Bering Sea where the river debouches. Between the area of the delta and the Bering Strait entrance to the Chukchi Sea is the Chirikov Basin, which is floored by relict sands and has a pattern of bottom topography leading into the Chuckchi Sea that suggests a former route of the Yukon. Analyses of bottom-sediment texture and mineralogy, however, indicate that the Holocene Yukon sand has not reached the Chirikov Basin. Only after the opening of Shpanberg Strait approximately 11,800 B.P. did Yukon-derived sediment enter the northernmost Bering Sea. From 11,800 to 5,000 B.P. fine-grained sand was carried onto Norton Plain by the recently strengthened coastal current. This sand is now relict. Since nearly 5,000 B.P. the modern Yukon very fine sand and silt have been accumulating near the delta. Future studies may show that the opening of Shpanberg Strait represents a more marked change in the sedimentary history of the adjacent parts of the Bering and Chuckchi seas than does the earlier opening of Bering Strait and the Strait of Anadyr that formed the initial connection of the seas.

McManus, D. A., K. Venkatarathnam, D. M. Hopkins, and C. H. Nelson. 1977. Distribution of bottom sediments on the continental shelf, northern Bering Sea. U.S. Dep of Interior, USGS. Geological Survey Professional Paper 759-C. 38 p. U.S. Goverment Printing Office, Washington. https://pubs.usgs.gov/pp/0759c/report.pdf

***Keywords*:** geomorphology; suspended sediment; hydrodynamics; shear stress; erosion; Norton Sound; Bering Sea; Chukchi Sea

***Abstract*:** Most of the sediment contributed to the northern Bering Sea today (modern sediment) is associated with the Yukon River runoff and the high-speed currents (30-40 cm/sec near the bottom) within the Alaskan Coastal Water, which sets northward along the coast through Bering Strait into the Chukchi Sea. Most sediment is silt sized but includes some very fine grained sand and clay-sized material. The very fine sand extends northward across the mouth of Norton Sound, where it mixes on the west with relict Yukon fine sand to form a palimpsest sand, thence grades eastward into Yukon silt that covers southern Norton Sound. Much of the Yukon silt enters Norton Sound, but there is only a thin accumulation there, except near the delta. The silt issues from the sound along the north side, where a silt deposit is in presumed dynamic equilibrium, thereby marking the dispersal path through a depression into the coastal current. The modern silt associated with the coastal current is considered a dynamic component of the bottom sediment, which otherwise consists of relict sand and gravel. The net transport of the silt is through the Bering Strait and into the Chukchi Sea. Impressed on the steady north ward -setting current are irregular large-velocity fluctuations produced partly by tidal currents and partly by the wind regime. For the area as a whole, tidal currents and wind drift are believed to be more significant than wave drift or estuarine-type density circulation. Where the coastal current is strongest, the sediment is a relict or residual lag sand and gravel derived from glacial material or from metamorphic bedrock of Seward Peninsula. Under the slower Modified Shelf Water offshore of the coastal water, the bottom sediment also is relict, in part relict Yukon sand, in part derived from glacial moraines. Modern sediments do not accumulate beneath the Modified Shelf Water, as they do beneath the coastal water. Northern Bering Sea was subaerially exposed during the period of eustatically lowered sea level that coincided with the last glaciation. However, the surface sediments provide no indication that the Yukon River has ever drained northward into the Arctic Ocean. Until relatively recent time, the Yukon drained southward into southern Bering Sea. The river mouth has been in its present northern position for only a geologically brief period. Seaward size grading in relict sands is ascribed to the present day strong current paralleling the isobaths.

Menard, J., J. Soong, J. Bell, L. Neff, and J. M. Leon. 2020. 2018 annual management report Norton Sound, Port Clarence, and Arctic, Kotzebue areas. Alaska Department of Fish and Game. Fishery Management Report. No. 20-05. 1-240 p. Anchorage, Alaska. https://www.adfg.alaska.gov/FedAidPDFs/FMR20-05.pdf

***Keywords*:** Chinook salmon; *Oncorhynchus tshawytscha*; chum salmon; *Oncorhynchus keta*; coho salmon; *Oncorhynchus kisutch*; pink salmon; *Oncorhynchus gorbuscha*; sockeye (red) salmon; *Oncorhynchus nerka*; red king crab; *Paralithodes camtschaticus*; Pacific herring; *Clupea pallasii*; inconnu (sheefish) *Stenodus leucichthys*; whitefish *Coregonus laurettae*; *Coregonus pidschian*; *Coregonus sardinella*; *Coregonus nasus*; Dolly Varden; *Salvelinus malma*; saffron cod; *Eleginus gracilis*; subsistence; commercial fishery; management; escapement; Norton Sound; Port Clarence; Kotzebue Sound; Arctic; Annual Management Report (AMR); Fishery Management Report (FMR)

***Abstract*:** This report provides information about the 2018 commercial and subsistence fisheries of Norton Sound, Port Clarence, Arctic, and Kotzebue management areas of the Arctic, Yukon, and Kuskokwim (AYK) Region of the Alaska Department of Fish and Game, Division of Commercial Fisheries. The management areas consist of all waters from Point Romanof north of the Yukon River and west of 141 degrees W longitude and those waters draining into the Bering Sea north of Yukon River; the Chukchi Sea, Beaufort Sea and Arctic Ocean. Commercial and subsistence fisheries target 5 species of salmon (Chinook *Oncorhynchus tshawytscha*, sockeye *O. nerka*, chum *O. keta*, coho *O. kisutch*, and pink *O. gorbuscha* salmon), Pacific herring *Clupea pallasii*, red king crab *Paralithodes camtschaticus,* and miscellaneous species such as inconnu (sheefish) *Stenodus leucichthys,* whitefish *Coregonus laurettae*, Dolly Varden *Salvelinus malma*, and saffron cod *Eleginus gracilis*.

Meyers, T. R., J. Ferguson, C. Bentz, and T. Burton. 2019. Opportunistic phaeohyphomycoses in wild saffron cod *Eleginus gracilis* from waterways of Norton Sound and Toksook Bay, Alaska, USA. Diseases of Aquatic Organisms*.* 135(3):211-226. https://doi.org/10.3354/dao03393

***Keywords*:** Alaska; animals; Ascomycota; bays; *Crocus*; humans; Phaeohyphomycosis; Ascomycete; black mycoses; *Cadophora*; *Chaetomium*; *Pseudophacidium*; saffron cod; *Valsa*

***Abstract*:** These case reports describe locally invasive black pigmented mycotic infections of the skin and gills of saffron cod *Eleginus gracilis* associated with 8 different opportunistic ascomycete fungi: *Alternaria* sp., *Cladosporium herbarum*, *Chaetomium globosum*, *Cadophora luteo-olivacea*, *Penicillium* sp., *Phoma herbarum*, *Pseudophacidium ledi* and *Valsa sordida*. These fungi were isolated on conventional media, identified according to morphological structures and confirmed by genetic sequencing. Several of these fungi are primary plant pathogens as well as opportunistic human pathogens in immunocompromised individuals. Several have also been described as causing opportunistic infections of fish. This case material represents the first report of *C. luteo-olivacea*, *C. globosum*, *P. ledi* and *V. sordida* as likely opportunistic fish pathogens in Alaskan watersheds of Norton Sound and south in Toksook Bay and possibly elsewhere.

Miles, A. K., and S. Hills. 1994. Metals in diet of Bering Sea walrus: *Mya* sp. as a possible transmitter of elevated cadmium and other metals. Marine Pollution Bulletin*.* 28(7):456-458. https://doi.org/10.1016/0025-326X(94)90133-3

***Keywords*:** walrus; seals; marine mammals; heavy metal; cadmium; health; subsistence hunting; Bering Sea

***Abstract*:** Elevated levels of cadmium in Pacific walrus (*Odobenus rosmarus divergens*) and northern fur seals (*Callorhinus ursinus*) have been reported in populations from the Bering Sea (Goldblatt & Anthony, 1983; Taylor et al., 1989). Russian and US authorities are concerned because of the possible health hazards from consuming pinniped meat harvested for subsistence peoples. The effects of cadmium on marine mammals have not been determined, but high concentrations of this element in humans and laboratory

animals have been correlated with renal, skeletal, and biochemical dysfunctions (Friberg et al., 1986).

Miszaniec, J. I., J. Darwent, and C. M. Darwent. 2019. Small game, estuaries, and nets: New perspectives on Norton culture coastal adaptations from a shell midden in Norton Sound, Alaska. The Journal of Island and Coastal Archaeology.1-25. https://doi.org/10.1080/15564894.2019.1701148

***Keywords*:** Alaska; zooarcheology; Norton; fishing; netting; coastal

***Abstract*:** Norton culture (ca. 740 BC–AD 1000) sites are ubiquitous across the western Arctic. Based on artifact and settlement data, it is generally agreed that Norton culture south of Seward Peninsula possessed a mixed marine-focused economy dominated by seasonally available Pacific salmon. However, the few direct studies of Norton subsistence, thus far, have suggested an emphasis on marine mammals rather than salmon. We present the results of a zooarchaeological midden analysis from the large Norton site of Difchahak (49-NOB-005) near Shaktoolik on Norton Sound, Alaska. We argue the faunal remains recovered from this site reflect its local estuarine system. Inhabitants were able to maintain year-round occupation of the region through an expansion of netting technology to non-salmon prey species. The economic focus at Difchahak was on mass capture of several seasonally available taxa, including salmon, mussels, saffron cod, ptarmigan, ducks, geese, and seal. Comparison of these faunal remains to those from Norton culture deposits at the neighboring site of Iyatayet suggests that differences between the localities are largely driven by geographically dependent prey-species distributions, and these two sites may represent complementary parts to a broad logistical foraging system.

Moore, S. E., J. M. Grebmeier, and J. R. Davies. 2003. Gray whale distribution relative to forage habitat in the northern Bering Sea: current conditions and retrospective summary. Canadian Journal of Zoology. 81(4):734-742. https://doi.org/10.1139/z03-043

***Keywords*:** gray whale; marine mammal; distribution; mortality events; amphipod; prey; climate

***Abstract*:** Hundreds of gray whales (*Eschrichtius robustus*) stranded dead along beaches from Mexico to Alaska in 1999 and 2000. The cause of the mortalities remains unknown, but starvation resulting from a reduction in prey, especially in the Chirikov Basin, was suggested as the cause. In the 1980s, the Chirikov Basin was considered a prime gray whale feeding area, but there has been no recent comprehensive assessment of whale or prey distribution and abundance. In 2002, a 5-day survey for gray whales revealed restricted distribution in the basin and a 3- to 17-fold decline in sighting rates. To put these data in context, a retrospective summary of gray whale and benthic fauna distribution and abundance was undertaken. During the 1980s, gray whale sighting rates in the Chirikov Basin were highly variable. Ampeliscid amphipods dominated the benthos where gray whale sighting rates were highest. Available measures of biomass suggest a downturn in

amphipod productivity from 1983 to 2000, when estimates of gray whale population size were increasing, suggesting that the whales simply expanded their foraging range. We encourage long-term study of the Chirikov Basin as a location where predator–prey responses to changing ocean climate can be researched, because decadal time series data are available.

Moore, S. E., and P. J. Stabeno. 2015. Synthesis of Arctic Research (SOAR) in marine ecosystems of the Pacific Arctic. Progress in Oceanography. 136:1-11. https://doi.org/10.1016/j.pocean.2015.05.017

***Keywords*:** Pacific Arctic, physics, oceanography, sea ice, ecosystem, management, marine birds and mammals, benthos, Arctic, synthesis, Chukchi, Beaufort, Bering

***Abstract*:** A study was designed to facilitate the synthesis of scientific information from interdisciplinary biological and oceanographic research in the Pacific Arctic region. A workshop was held to refine the science themes and questions, form research teams to undertake analysis and development of manuscripts, and develop short proposals for a series of synthesis projects. This resulted in 33 multi-author papers in two special volumes of peer-reviewed journals, synthesizing information collected by BOEM, other federal and state agencies (e.g. NOAA, USGS, NSF), and the oil and gas industry. The findings from these studies included enhanced scientific understanding of the relationships among oceanographic conditions, benthic organisms, lower trophic prey species (forage fish and zooplankton), and marine mammal distribution and behavior in the region, with particular emphasis on the northeastern Chukchi Sea. The outcomes also included enhanced capability to predict future changes in oceanographic features, such as currents, upwelling, and ice leads, and associated changes in the behavior of marine mammals and their prey in the region. Further, the results of these synthesis activities were effectively transmitted to resource managers, local Arctic residents, national and international science societies, and the general public.

Mueter, F. J., and M. A. Litzow. 2008. Sea ice retreat alters the biogeography of the Bering Sea continental shelf. Ecological Applications. 18(2):309-320. https://doi.org/10.1890/07-0564.1

***Keywords*:** Arctic regions; conservation of natural resources; ecosystem; greenhouse effect; ice; oceanography; oceans and seas; seawater; temperature; time factors

***Abstract*:** Seasonal ice cover creates a pool of cold bottom water on the eastern Bering Sea continental shelf each winter. The southern edge of this cold pool, which defines the ecotone between arctic and subarctic communities, has retreated approximately 230 km northward since the early 1980s. Bottom trawl surveys of fish and invertebrates in the southeastern Bering Sea (1982-2006) show a coincident reorganization in community composition by latitude. Survey catches show community-wide northward distribution shifts, and the area formerly covered by the cold pool has seen increases in total biomass, species richness, and average trophic level as subarctic fauna have colonized newly

favorable habitats. Warming climate has immediate management implications, as 57% of variability in commercial snow crab (*Chionoecetes opilio*) catch is explained by winter sea ice extent. Several measures of community distribution and structure show linear relationships with bottom temperature, suggesting warming climate as the primary cause of changing biogeography. However, residual variability in distribution not explained by climate shows a strong temporal trend, suggesting that internal community dynamics also contribute to changing biogeography. Variability among taxa in their response to temperature was not explained by commercial status or life history traits, suggesting that species-specific responses to future warming will be difficult to predict.

Mueter, F. J., J. Weems, E. V. Farley, and M. F. Sigler. 2017. Arctic Ecosystem Integrated Survey (Arctic EIS): Marine ecosystem dynamics in the rapidly changing Pacific Arctic Gateway. Deep Sea Research Part II: Topical Studies in Oceanography. 135:1-6. https://doi.org/10.1016/j.dsr2.2016.11.005

***Keywords*:** Arctic; northern Bering Sea; Chukchi Sea; fish; zooplankton

***Abstract*:** This study on the Distribution of Fish, Crab, and Lower Trophic Communities in the Northeastern Bering Sea and Chukchi Sea formed a large part of the broader Arctic Ecosystem Integrated Survey, the first comprehensive fisheries ecosystem assessment of the Northern Bering Sea and Chukchi Sea. Surveys were conducted in the summers of 2012 and 2013 from several platforms to sample demersal as well as pelagic fish communities. Oceanographic and biological samples collected during these surveys provided a trove of new information on the distribution, abundance, biology and population dynamics of pelagic and demersal fish and invertebrate populations in the Northern Bering Sea and Chukchi Sea, in addition to new insights into the physical forcing and plankton dynamics of the system. Scientific highlights include: (1) Large differences in oceanographic conditions between 2012 and 2013, associated with differences in local winds and in the flow of water through Bering Strait and its advection in the Chukchi Sea; (2) High densities of larval and young-of-year Arctic cod (*Boreogadus saida*) observed in the northeast Chukchi Sea in both survey years; (3) Plankton, fish and invertebrate species of Pacific origin dominated demersal and pelagic communities throughout the region, but distinct Arctic populations of some species were associated with Arctic water masses on the northeast Chukchi Sea shelf; (4) Juvenile salmon of western Alaska origin, in particular chum (*Oncorhynchus keta*), pink (*O. gorbuscha*), and Chinook salmon (*O. tshawytscha*), were widespread and abundant in the northern Bering Sea, extending into the Chukchi Sea and mixing with local populations from Kotzebue Sound; (5) the Chukchi Sea populations of Arctic cod and snow crab (*Chionoecetes opilio*) are continuous with and directly connected to populations in the Bering Sea.

Murphy, E. C., A. M. Springer, and D. G. Roseneau. 1991. High annual variability in reproductive success of Kittiwakes (*Rissa tridactyla L*.) at a colony in western Alaska. Journal of Animal Ecology. 60(2):515-534. https://doi.org/10.2307/5295

***Keywords*:** St Matthew Hall; Norton Basin; Hope Basin; Chukchi Sea; Alaska; biology; seabirds; Bering Strait; behavior; distribution; breeding; nesting; feeding; St Lawrence Island; Norton Sound; survey; aerial observations; diversity; abundance; shorebirds; birds; murre; kittiwake; auklet; puffin; cormorant; Alaska Region

***Abstract*:** All aspects of reproductive performance of kittiwakes (*Rissa tridactyla L.*) fluctuated markedly in 1975-89 at a colony of about 10 000 nesting pairs in the north-eastern Bering Sea, Alaska. In breeding seasons following cold springs, breeding was delayed, fewer nests were built, fewer nests contained eggs, and clutch size, hatching success and the number of chicks fledging per nest were reduced. Complete reproductive failures followed the three coldest springs in the 15-year period. Reproductive success (chicks fledged per nest) was highest following moderately warm springs; however, growth rates of chicks and fledging success were extremely low following the warmest spring on record. Spring air temperatures were highly correlated with break-up of sea ice and these factors probably influenced seasonal warming trends in the sea water and the consequent availability of prey such as sandeels (*Ammodytes hexapterus* Pallas) near the colony. During this 15-year period, interannual variability in spring air temperature was pronounced in comparison to that during the previous 68-year period; however, simulations using May temperature as a predictor of reproductive success suggested that high annual variability in reproduction has occurred throughout this century. Numbers of adult-plumaged birds on the cliffs in mid-season were markedly lower and more variable in years when few nests were built, suggesting that relatively few experienced adults breed and consistently are present at the colony in years when overall reproductive performance is poor.

Murphy, J. M., K. G. Howard, J. C. Gann, K. C. Cieciel, W. D. Templin, and C. M. Guthrie. 2017. Juvenile Chinook Salmon abundance in the northern Bering Sea: Implications for future returns and fisheries in the Yukon River. Deep Sea Research Part II: Topical Studies in Oceanography. 135:156-167. https://doi.org/10.1016/j.dsr2.2016.06.002

***Keywords*:** Chinook salmon; northern Bering Sea; Yukon River

***Abstract*:** Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) abundance in the northern Bering Sea is used to provide insight into future returns and fisheries in the Yukon River. The status of Yukon River Chinook Salmon is of concern due to recent production declines and subsequent closures of commercial, sport, and personal use fisheries, and severe restrictions on subsistence fisheries in the Yukon River. Surface trawl catch data, mixed layer depth adjustments, and genetic stock mixtures are used to estimate juvenile abundance for the Canadian-origin stock group from the Yukon River. Abundance ranged from a low of 0.62 million in 2012 to a high of 2.58 million in 2013 with an overall average of 1.5 million from 2003 to 2015. Although abundance estimates indicate that average survival is relatively low (average of 5.2%), juvenile abundance was significantly correlated ($r=0.87$, $p=0.005$) with adult returns, indicating that much of the variability in survival occurs during early life-history stages (freshwater and initial marine). Juvenile abundance in the northern Bering Sea has increased since 2013 due to an increase in early life-history survival (average

juveniles-per-spawner increased from 29 to 59). The increase in juvenile abundance is projected to produce larger runs and increased subsistence fishing opportunities for Chinook Salmon in the Yukon River as early as 2016.

Nagel, P. A. 1992. Results of the third joint US-USSR Bering & Chukchi Seas expedition (BERPAC). U.S. Fish and Wildlife Service Biological Reports. US Department of Interior. Washington, D.C. 444 p. http://babel.hathitrust.org/cgi/pt?id=uc1.31822007899610

***Keywords*:** Bering Sea; Joint U.S.-U.S.S.R. Bering Sea Expedition; marine pollution; scientific expeditions; testing

***Abstract*:** No abstract available.

Napp, J. 2011. The Bering Sea: Current status and recent events. PICES Press. 19(2):35-37. https://meetings.pices.int/publications/pices-press

***Keywords*:** earth sciences; oceanography; sea surface temperature

***Abstract*:** No abstract available.

Nelson, H., and J. S. Creager. 1977. Displacement of Yukon-derived sediment from Bering Sea to Chukchi Sea during Holocene time. Geology. 5(3):141-146. https://doi.org/10.1130/0091-7613(1977)5<141:Doysfb>2.0.Co;2

***Keywords*:** geomorphology; sea level; transgression; sediment dynamics; sediment; Norton Sound; Bering Sea; Chukchi Sea

***Abstract*:** Since Shpanberg Strait was opened by sea-level transgression about 12,000 B.P., one-third to one-half of the sediment load of the Yukon River has bypassed the northern Bering Sea to accumulate in the thick blanket of Holocene sediment in the southern Chukchi Sea. Prior to the transgression of Norton Sound about 9500 B.P., more than half of the Yukon River sediment may have been bypassed to the Chukchi Sea. After about 5000 B.P., deposition of Yukon sediment significantly increased in the Bering Sea when the present Yukon subdelta was apparently formed in the southern part of Norton Sound. Even now, one-third of the Yukon load may be carried to the Chukchi Sea, because the continual strong northward circulation of the Alaskan Coastal Water advects some of the Yukon sediment plume, along with masses of sediment intermittently resuspended by storms.This major displacement of sediment 500 to 1,000 km from a river source has important implications for models of advective transport over shelves, paleogeographic reconstructions of sedimentary environments in epicontinental seas, and development of nonsubsiding deltas, such as the Yukon.

Nelson, H., K. A. Kvenvolden, and E. C. Clukey. 1978. Thermogenic gases in near-surface sediments of Norton Sound, Alaska. ***In*** Offshore Technology Conference Houston, Texas. https://doi.org/10.4043/3354-ms

Keywords**:** geomorphology; bottom type; sediment; hydrodynamics; seismic; hydrocarbons; Norton Sound; Bering Sea

Abstract**:** A plume of hydrocarbon gases, assumed to be of thermogenic origin based on chemical compositions, has been noted by others in the water column of Norton Sound about 40 km south of Nome, Alaska. We used detailed geophysical transects, side-scan sonar, underwater television, and chromatographic analyses of gases in near-surface sediments to define a probable source area of hydrocarbon gases at the southern apex of the water plume epicenter. Geophysical, geotechnical, and geochemical evidence together indicate that hydrocarbon gases of subsurface, thermogenic origin apparently migrate into the near surface sediments along a fault zone. Subbottom reflector terminations on continuous seismic profiles outline a large zone of anomalous acoustic responses about 9 km in diameter and at 100-m depth that may be caused by a subsurface accumulation of gas. Gas migration from the accumulation to the surface sediment is indicated by smaller zones of reflector terminations observed in high-resolution profiles and by seafloor craters seen on underwater television at one station. The presence of gas-charged surface sediment also is suggested by low percent pore water saturation, greater penetration of the penetrometer, and more rapid penetration of the vibracorer in sediment at the station with near-surface acoustic anomalies and seafloor craters. Analyses of hydrocarbon gases in sediments from a 1.6-m vibracore taken at this station showed unusually high concentrations of hydrocarbon gases heavier than methane; the ethane, propane, n-butane, and isobutane were 76, 4, 6, and 52 times greater than in other near-surface sediments in this region, and also significant quantities of gasoline-range hydrocarbons were present. The gas composition and presence in near-surface sediments above a thick underlying section with acoustic anomalies points to the possibility of petroleum at depth in this region. Our work indicates that surface and near-surface studies of the continental shelf may contribute significantly to petroleum-resource evaluations in addition to defining areas of potential hazard from gas-charged sediment.

Nelson, C. H., F. Michael E, D. A. Cacchione, D. E. Drake, and T. H. Nilsen. 1980. Ripples and sand waves in Norton basin: bed-form activity and scour potential. U.S. Dep of Interior, USGS. USGS Numbered Series 80-659. 20 p. https://doi.org/10.3133/ofr80659

Keywords**:** sediment; hydrodynamics; shear stress; sand; bedforms; Norton sound; Bering Sea

Abstract**:** Strong currents are present throughout much of the northern Bering Sea, particularly where westward land projections interject into the prevailing northward flow, such as in the eastern Bering Strait area (see fig 1, Nelson, Holocene transgression article this volume) (Fleming and Heggarty, 1966). In such regions large bedforms develop and

migrate to form an unstable sea floor that can be a potential hazard to platform foundations and pipelines. Such potentially hazardous areas must be identified, their history assessed, and magnitude of future problems predicted. This paper outlines regions of mobile bedforms (fig, 1) and presently known aspects of their activity.

Nelson, C. H. 1982. Modern shallow-water graded sand layers from storm surges, Bering Shelf: a mimic of Bouma sequences and turbidite systems. Journal of Sedimentary Petrology. 52(2):537-545. http://pubs.er.usgs.gov/publication/70011633

***Keywords*:** sediment; sand; bedforms; delta; Yukon Delta; Bering Sea

***Abstract*:** A sequence of graded sand layers, interbedded with mud, extends offshore over 100 km from the Yukon Delta shoreline across the flat, shallow epicontinental shelf of the northern Bering Sea, Alaska. Proximal graded sand beds on the delta-front platform near the shoreline are coarser, thicker and contain more complete vertical sequences of sedimentary structures than distal beds. The sequence of graded sands appears to be related to the major storm surges that occur every several years. The major storms increase the average 10 m water depth in southern Norton Sound as much as 5 m and cause fluctuations in pore pressure from wave cyclic loading that may liquefy the upper 2 to 3 m of sediment.

Nelson, C. H., K. R. Johnson, and J. H. Barber. 1987. Gray whale and walrus feeding excavation on the Bering Shelf, Alaska. Journal of Sedimentary Research. 57(3):419-430. https://doi.org/10.1306/212f8b4d-2b24-11d7-8648000102c1865d

***Keywords*:** walrus; gray whale; marine mammals; amphipods; feeding; benthic furrows; ecosystems

***Abstract*:** Sidescan sonar has been used to delineate benthic feeding structures of the California gray whale (*Eschrichtius robustus*) and Pacific walrus (*Odobenus rosmarus divergens*) on the northeastern Bering Shelf. The gray whales (average mouth length, 2.0 m), when suction feeding on infaunal amphipods, create shallow pits in the sea floor, typically 2.5 m x 1.5 m x 10 cm deep, which are distinct and mappable on sidescan sonographs. Similarly, walrus, when foraging for shallow clams, create long, linear feeding furrows that average 47 x 0.4 x 0.1 m (length-width-depth). The distribution of the whale pits over 22,000 km^2 of the Bering Shelf closely matches 1) sightings of feeding whales identified by mud plumes; 2) the distribution of ampeliscid amphipods, the gray whale's main prey; and 3) the distribution of a transgressive inner-shelf fine sand that serves as a substrate for the amphipods. The walrus' furrows are recognized over 6,600 km^2 of variable muddier or coarser-grained substrate with clam-rich benthic communities that surround the fine sand substrate of whale feeding areas. The whale feeding pits are commonly enlarged and oriented by seasonal storm-related scour. Nonenlarged pits (less than 5.3 m^2 in area) form a discrete statistical population that we define as fresh. We estimate that a minimum of 5.6 percent (1,200 km^2) of the feeding area of the northeastern Bering Shelf (22,000 km^2)

was covered by fresh pits made by whales during the 1980 feeding season. Assuming that the average pit depth is 10 cm, a minimum of 120 x 10^6 m^3 (172 x 10^6 metric tons) of sediment, equivalent to about three times the yearly sediment load of the Yukon River, is excavated and injected into the water column by as many as 16,000 gray whales feeding in northeastern Bering Sea each season. As a result of 1) sediment resuspension by whales, 2) average current speeds of 10.7 cm/s northward during the feeding season, and 3) enhanced post-feeding current scour because of bottom roughening, the following occur: the majority of the clay fraction (4.3 x 10^6 metric tons) of resuspended sediment is advected to the Chukchi Sea each year; sand gradually is transported northward and fills old feeding pits; modern mud does not accumulate in this region; and the whale-disturbed sand lacks physical sedimentary structures and matrix mud. Walrus feeding features are smaller, formed in higher-energy environments, and modified more rapidly than whale feeding pits. The amount of sediment reworking by walrus feeding may nearly equal that of whale feeding, but this cannot be quantified accurately.

Nelson, M. A., L. T. Quakenbush, B. D. Taras, and Ice Seal Committee. 2019. Subsistence harvest of ringed, bearded, spotted, and ribbon seals in Alaska is sustainable. Endangered Species Research. 40:1-16. https://doi.org/10.3354/esr00973

Keywords**:** *Erignathus barbatus; Pusa hispida; Phoca hispida; Phoca largha; Histriophoca fasciata;* ice seal; potential biological removal; struck and lost

Abstract**:** In 2012, climate-warming related decreases in sea ice led to listings of ringed *Pusa hispida* and bearded seals *Erignathus barbatus* as threatened under the United States Endangered Species Act (ESA) prior to evidence of population declines. These and 2 other ice-associated species (spotted *Phoca largha* and ribbon seals *Histriophoca fasciata*) are vital subsistence resources to coastal Alaska Native communities. ESA-related assessments concluded that subsistence removals (seals that were harvested as well as those that were struck and lost) were sustainable; however, limited data precluded a quantitative evaluation. Potential biological removal (PBR), defined as the maximum number of animals that can be removed from a stock while allowing the stock to reach or maintain its optimal sustainable size, is typically used to determine whether human-caused mortality is sustainable. Although developed to address commercial fisheries bycatch, PBR serves as a conservative measure of sustainability. We compiled annual subsistence removal of ice seals in Alaska between 1992 and 2014 for 41 of 55 ice seal hunting communities and used per capita (based on the 2015 human population) removal estimates from surveyed communities to estimate regional and statewide average removals. We used average per capita values of harvest, combined with struck and lost, for surveyed communities (average removals) to extrapolate to unsurveyed communities. To account for underreported harvest, we also extrapolated using maximum harvest values, providing a liberal estimate. Both the average and liberal estimates of removals were below PBR for all 4 species. Thus, the best available data indicate that subsistence hunting is currently sustainable for all 4 species of ice seals.

Niebauer, H. J., V. Alexander, and S. Henrichs. 1990. Physical and biological oceanographic interaction in the spring bloom at the Bering Sea marginal ice edge zone. Journal of Geophysical Research. 95(C12):22229–22241. https://doi.org/10.1029/JC095iC12p22229

Keywords**:** sea ice; salinity; phytoplankton; zooplankton; chlorophyll; meltwater

Abstract**:** At the edge of the melting sea ice pack in the Bering Sea in spring, physical, biological, and chemical oceanographic processes combine to generate a short-lived, intense phytoplankton bloom that is associated with the retreating ice edge. The bloom begins a week or so before the first of May triggered by insolation and by the low-salinity meltwater stratification in the presence of high nitrate concentrations (~ > 25 μM). Meltwater (salinity) stratification delineates ice edge blooms from open water blooms where temperature gradients generate the stratification. Five cross-ice sections of temperature, salinity, σt, chlorophyll, and nitrate are presented as a time series from April 27 to May 5 illustrating the bloom. Evidence of two separate but concurrent blooms in the ice edge zone are presented. In addition, meteorological and oceanographic conditions were observed that should have been conducive to ice edge up welling. While significant ice and water movement occurred, upwelling was not observed. Finally, the Bering Sea ice edge spring bloom is compared with other ice edge systems in both hemispheres, showing that initial Bering Sea nitrate concentrations are among the highest observed but quickly become limiting owing to the rapid build up of phytoplankton populations. This primary production is not coupled to the pelagic Zooplankton because Zooplankton are largely absent on account of the cold temperatures. Observed maximum chlorophyll concentrations in the bloom are several times greater than those observed in other systems.

Niebauer, H. J., V. Alexander, and S. M. Henrichs. 1995. A time-series study of the spring bloom at the Bering Sea ice edge I. Physical processes, chlorophyll and nutrient chemistry. Continental Shelf Research. 15(15):1859-1877. https://doi.org/10.1016/0278-4343(94)00097-7

Keywords**:** sea ice; model; climate; climate shifts; sea ice loss; spring melt; salinity; plankton; nutrients; bloom

Abstract**:** An intense but short-lived phytoplankton bloom develops in the low-salinity melt waters at the edge of the Bering Sea ice as the ice melts and retreats each spring. In spring 1988 we followed the development of this bloom by sampling every 3 h while following a freely drifting drogue in the marginal ice-edge zone for two four-day periods. The first period (29 April–3 May) was at an early stage of the bloom while the second period (10–13 May) was at the peak of the bloom. Early in the bloom, the phytoplankton consumed all the nitrate (~400 mmoles m^{-2}) initially present in the surface water producing large accumulations of particulate carbon (>1000 mmoles C m^{-2}). By the time of peak chlorophyll concentrations (~35 mg M^{-3}), nitrate concentrations had been depleted so that the sustained high productivity depended on either recycled or imported nutrients. After this

point, there was little net additional accumulation of biomass. From these data plus cruise data from previous years, we find that the Bering Sea ice-edge bloom typically begins in the last week of April and appears to precede blooms in the adjacent ice-free waters by days to weeks. The variability in bloom onset observed over several years is not linked very closely to the large scale climatic variations found in this region, but rather appears to be related to local weather during the end of April and the first part of May, with calm, sunny weather being required to initiate the blooms.

Nishio, S., H. Sasaki, H. Waga, and O. Yamamura. 2020. Effects of the timing of sea ice retreat on demersal fish assemblages in the northern Bering and Chukchi Seas. Deep Sea Research Part II: Topical Studies in Oceanography. 181-182:104910. https://doi.org/10.1016/j.dsr2.2020.104910

Keywords**:** sea ice; model; climate; climate shifts; sea ice retreat; fish; walleye pollock; flounder; St Lawrence Island; Arctic

Abstract**:** The structure of demersal fish assemblages was investigated based on a total of 134 trawl samples collected in the northern Bering Sea (NBS) and Chukchi Sea (CS) during 12 summers between 1990 and 2013. In recent years, the timing of sea ice retreat has become earlier in the NBS. The present study was performed to clarify the environmental factors that contribute to the structure of demersal fish assemblages. Walleye pollock *Gadus chalcogrammus* were numerically dominant, followed by Bering flounder *Hippoglossoides robustus* and Arctic cod *Boreogadus saida*. Stations were classified into four major faunal assemblages by cluster analysis based on species density: I) boreal assemblages occurring southeast of St. Lawrence Island; II) stations dominated by Arctic species in the CS; III) stations with mixed Arctic and boreal species southwest of St. Lawrence Island; and IV) a less abundant assemblage limited to the north of Point Hope, comprising Arctic species. A permutation test revealed that, of the four physical parameters considered (i.e., bottom temperature, bottom depth, timing of sea ice retreat (TSR) and timing of sampling), TSR was the most prominent variable; it constituted 19.4% of the overall variance in species density and 57.7% of the variance explained by environmental factors. Multiple regression was applied to further analyze the factors that affected interannual changes in the densities of three zoogeographic types in the NBS. While TSR was the major factor that affected the density of Arctic species, variables that included bottom temperature were important for boreal species. These results suggest that mechanisms associated with sea ice conditions (i.e., annual-scale factors), rather than summer bottom temperature (i.e., short-term factors), influence the distribution of demersal fish assemblages in the NBS and CS.

Nishizawa, B., N. Yamada, H. Hayashi, C. Wright, K. Kuletz, H. Ueno, T. Mukai, A. Yamaguchi, and Y. Watanuki. 2020. Timing of spring sea-ice retreat and summer seabird-prey associations in the northern Bering Sea. Deep Sea Research Part II: Topical Studies in Oceanography. 181-182:104898. https://doi.org/10.1016/j.dsr2.2020.104898

***Keywords*:** Arctic; sea ice; seabird distribution; acoustic; water mass; zooplankton; fish; northern Bering Sea

***Abstract*:** To understand the effect of an unusually early sea-ice retreat in the northern Bering Sea in the spring of 2018 on the marine ecosystem of the northern Bering Sea, we compared at-sea observations of seabird density and acoustic observations of prey (fish and zooplankton) biomass during shipboard surveys around St. Lawrence Island in the summers of 2017 and 2018. Densities of foraging seabirds in 2018 (piscivorous divers: 4.7 birds km−2, planktivorous divers: 5.1, shearwaters: 0.7, surface feeders: 6.6) were lower than those in 2017 (piscivorous divers: 14.7 birds km^{-2}, planktivorous divers: 10.3, shearwaters: 11.9, surface feeders:11.9). Acoustically-determined prey biomass in 2018 (fish: 6.4 m^2 nmi^{-2} zooplankton: 2.3) was also lower than in 2017 (fish: 18.4 m^2 nmi^{-2}, zooplankton: 5.5). Similarly, biomass of macrozooplankton (amphipods, euphausiids, *Neocalanus* spp. and *Calanus marshallae*) sampled using bongo nets was smaller in 2018. At scales of 5–30 km, correlations between the seabird density and prey biomass were weaker (−0.2–0.3 of Pearson's r) in 2018 than those in 2017 (0.4–0.9) for all seabirds except planktivorous divers. We suggest that the lack of sea ice, and the resulting lack of ice-edge phytoplankton blooms, may weaken trophic linkages by causing a low biomass of secondary consumers and hence a reduced density of seabirds.

NOAA NMFS Alaska Fisheries Science Center. 2012. Considerations for research planning in the northern Bering Sea research area. U.S. Dep. Commerce. NOAA Discussion Paper. Agenda D-1(d). 127 p. https://www.npfmc.org/wp-content/PDFdocuments/rural_outreach/NBSRA_DiscPap_912.pdf

***Keywords*:** climate change; ecosystem shifts; crab; fish; bottom trawl; Bering Sea

***Abstract*:** As a changing climate warms waters of the North Pacific and changes the timing of the ice cover in the northern Bering Sea, an ecosystem shift is expected that may extend the distribution of crab and fish populations northward into the subarctic Regions. In anticipation of commercially important stocks shifting northward, the North Pacific Fishery Management Council (Council) established the Northern Bering Sea Research Area (NBSRA) in 2008. This area is closed to nonpelagic (bottom) trawling pending understanding of its impacts on the near-pristine ecosystem. The National Marine Fisheries Service (NMFS) Alaska Fisheries Science Center (AFSC) was charged with developing a Research Plan to investigate the impacts of nonpelagic trawling in the NBSRA.

Noongwook, G., The Native Village of Savoonga, The Native Village of Gambell, H. P. Huntington, and J. C. George. 2007. Traditional knowledge of the bowhead whale (*Balaena mysticetus*) around St. Lawrence Island, Alaska. Arctic. 60(1):47-54. http://www.jstor.org/stable/40513157

***Keywords*:** bowhead whale; *Balaena mysticetus*; marine mammal; St. Lawrence Island; Bering Sea; traditional knowledge; Yupik; Alaska

***Abstract*:** Despite considerable research on the bowhead whale (*Balaena mysticetus*) in Alaskan waters, relatively little has been conducted in the northern Bering Sea. To help fill this gap, we documented traditional knowledge of bowhead whales held by Yupik whalers of St. Lawrence Island, Alaska. Results include descriptions of the seasonal movements, distribution, and abundance of bowheads near St. Lawrence Island. The bowhead population appears to be increasing, as is the number of young whales seen. Changing environmental conditions are influencing distribution, leading to a somewhat earlier spring migration and a greater presence of whales near the island in winter. Hunters describe two bowhead migration paths near the island. It is unknown whether these two paths are used by two genetically different groups of whales, or whether the animals are simply responding differently to oceanography conditions or geography. Our findings are consistent with studies of this bowhead population conducted elsewhere and suggest that additional research is needed to determine possible migratory (or genetic) differences between the two migrations of whales seen at St. Lawrence Island.

North Pacific Fishery Management Council. 2020. Fishery management plan for groundfish of the Bering Sea and Aleutian Islands management area. 1-175 p. 1007 West Third, Suite 400 Anchorage, Alaska 99501. https://www.npfmc.org/wp-content/PDFdocuments/fmp/GOA/GOAfmp.pdf

***Keywords*:** fisheries; management; EEZ; Bering Sea

***Abstract*:** This Fishery Management Plan (FMP) governs groundfish fisheries of the Bering Sea and Aleutian Islands Management Area (BSAI). The FMP management area is the United States (U.S.) Exclusive Economic Zone (EEZ) of the Bering Sea and that portion of the North Pacific Ocean adjacent to the Aleutian Islands which is between 170E W. longitude and the U.S.-Russian Convention Line of 1867. The FMP covers fisheries for all stocks of finfish and marine invertebrates except salmonids, shrimps, scallops, snails, king crab, Tanner crab, Dungeness crab, corals, surf clams, horsehair crab, lyre crab, Pacific halibut, and Pacific herring. The FMP was implemented on January 1, 1982. As of April 2004, it has been amended over seventy times, and its focus has changed from the regulation of mainly foreign fisheries to the management of fully domestic groundfish fisheries. This version of the FMP has been revised to remove or update obsolete references, as well as outdated catch data and other scientific information. The FMP has also been reorganized to provide readers with a clear understanding of the BSAI groundfish fishery and conservation and management measures promulgated by the FMP.

O'Leary, C. A., J. T. Thorson, J. N. Ianelli, and S. Kotwicki. 2020. Adapting to climate-driven distribution shifts using model-based indices and age composition from multiple surveys in the walleye pollock (*Gadus chalcogrammus*) stock assessment. Fisheries Oceanography. 29(6):541-557. https://doi.org/10.1111/fog.12494

***Keywords*:** Bering Sea; climate adaption; cold pool extent; index standardization; VAST; vector autoregressive spatio-temporal model; walleye pollock

***Abstract*:** The northern Bering Sea is transitioning from an Arctic to subarctic fish community as climate warms. Scientists and managers aim to understand how these changing conditions are influencing fish biomass and spatial distribution in this region, as both are used to inform stock assessments and fisheries management advice. Here, we use a spatio-temporal model for walleye pollock (*Gadus chalcogrammus*) to provide two inputs to its stock assessment model: (a) an alternative model-based biomass index and (b) alternative model-based age compositions. Both inputs were derived from multiple fishery-independent data that span different regions of space and time. We developed an assessment model that utilizes both the standard and model-based inputs from multiple surveys despite inconsistencies in spatial and temporal coverage, and we found that using these data provide an improved spatial and temporal scope of total pollock biomass. Age composition information indicated that pollock density is increasing and moving farther north, particularly for older pollock. We found that including an index of cold pool extent could be used to extrapolate pollock densities in the northern Bering Sea in unsampled years. Stock assessment parameter estimates were similar for standard and model-based input. This study demonstrates that spatio-temporal model-based estimates of a biomass index and age composition can facilitate rapid changes in stock assessment structure in response to climate driven shifts in spatial distribution. We conclude that assimilating data from regions neighboring standard survey areas, such as the Chukchi Sea and western Bering Sea, would improve understanding and management efforts as fish distributions change under a warming climate.

Olnes, J., J. Crawford, J. J. Citta, M. L. Druckenmiller, A. L. Von Duyke, and L. Quakenbush. 2020. Movement, diving, and haul-out behaviors of juvenile bearded seals in the Bering, Chukchi and Beaufort seas, 2014–2018. Polar Biology. 43(9):1307-1320. https://doi.org/10.1007/s00300-020-02710-6

***Keywords*:** marine mammal; seals; sea ice; ecosystems; climate

***Abstract*:** Bearded seals (*Erignathus barbatus*) are abundant in the Pacific Arctic and are an important subsistence resource for many Alaska Native communities. The Pacific Arctic is warming rapidly with substantial consequences predicted for ice-associated marine mammals, such as the bearded seal, which led to its 2012 listing as Threatened under the U.S. Endangered Species Act. We provide the most comprehensive description of juvenile bearded seal movement, diving, and haul-out behaviors for the Pacific Arctic, obtained from 24 seals tagged with satellite-linked data recorders along Alaska's coast from 2014 to 2018. Most seals (19 of 24) made north–south movements with the seasonal extent of sea ice, however, all three seals tagged north of Bering Strait made minimal north–south movements and two seals tagged in the Bering Sea moved north as sea ice advanced south. All seals primarily occupied shallow coastal waters and areas with intermediate-concentration pack ice or that were near the ice edge. Seals spent half their time near the sea floor. Hauling out occurred less in the winter and increased during spring and summer, coinciding with the annual molting period. When ice was at its minimum extent, seven seals

frequently hauled out on land. Juvenile bearded seals made use of much of the continental shelf in the Bering, Chukchi and Beaufort Seas, and their use of a broad range of ice concentrations and willingness to haul out on land suggests some resilience to changing sea ice conditions. However, whether the behaviors we documented in juveniles are similar for adult bearded seals remains unclear.

Olnes, J., G. A. Breed, M. L. Druckenmiller, J. J. Citta, J. A. Crawford, A. L. Von Duyke, and L. Quakenbush. 2021. Juvenile bearded seal response to a decade of sea ice change in the Bering, Chukchi, and Beaufort seas. Marine Ecology Progress Series. 661:229-242. https://doi.org/10.3354/meps13609

***Keywords*:** Pacific Arctic; *Erignathus barbatus*; satellite telemetry; habitat selection; state-space models; climate change

***Abstract*:** Significant reductions in sea ice in the Pacific Arctic have occurred over the last 2 decades. Comparing the results of similarly conducted studies, but from different time periods, can increase our understanding of how marine mammals are responding to this change. We modeled the habitat selection and movement behavior of juvenile bearded seals *Erignathus barbatus* tagged with satellite transmitters in the Bering, Chukchi, and Beaufort seas during 2014-2018, a period of rapid decline in sea ice cover. We compared our results to an earlier study of juvenile bearded seals tagged in the Chukchi Sea during 2004-2009, a period of relatively stable sea ice coverage, and found differences. Seals in the earlier period strongly selected habitat near the ice edge and intermediate ice concentrations (50-60%) in both winter and spring. Seals in the later period strongly selected habitat away from the ice edge, showed no selection for any ice concentration in winter, and weakly selected low ice concentrations in spring (<50%). The likely explanation for these differences is changes in sea ice habitat because the shift away from the ice edge corresponds with a shift in the distribution of intermediate ice concentrations that seals prefer. During the later period, seals still used intermediate ice, which occurred farther from the ice edge and was now the average ice concentration available to them, masking any preference for intermediate ice in the habitat selection model. This change in sea ice conditions, although significant, may not currently be detrimental for juvenile bearded seals.

Olsen, H. W., E. C. Clukey, and C. H. Nelson. 1982. Geotechnical characteristics of bottom sediments in the northeastern Bering Sea. Geologie en Mijnbouw. 61(1):91-103. http://pubs.er.usgs.gov/publication/70011784

***Keywords*:** geomorphology; bottom type; sediment; hydrodynamics; seismic; sand; silt; hydrocarbons; Yukon River; Norton Sound; Bering Sea

***Abstract*:** Sediment of Holocene age derived from the Yukon River, consisting dominantly of silty fine sand and sandy silt, covers the bottom of central and western Norton Sound, which is a high energy environment involving extensive ice loading, high waves, and strong

bottom currents. The sediment characteristics indicate that it is susceptible to liquefaction during major storms. Substantially finer grained, weak and highly compressible sediment of Holocene age covers eastern Norton Sound and the Port Clarence embayment, which are low energy environments. Pleistocene peaty deposits underlie the Holocene and late Pleistocene deposits in both Norton Sound and Chirikov Basin and are somewhat overconsolidated. The presence of gas indicates high in situ pore pressure and hence low material strength.

Oppel, S., and A. N. Powell. 2008. Assigning king eiders to wintering regions in the Bering Sea using stable isotopes of feathers and claws. Marine Ecology Progress Series. 373:149-156. https://doi.org/10.3354/meps07744

***Keywords*:** seabird; climate change; ecosystems; breeding; seasonality

***Abstract*:** Identification of wintering regions for birds sampled during the breeding season is crucial to understanding how events outside the breeding season may affect populations. We assigned king eiders captured on breeding grounds in northern Alaska to 3 broad geographic wintering regions in the Bering Sea using stable carbon and nitrogen isotopes obtained from head feathers. Using a discriminant function analysis of feathers obtained from birds tracked with satellite transmitters, we estimated that 88 % of feathers were assigned to the region in which they were grown. We then assigned 84 birds of unknown origin to wintering regions based on their head feather isotope ratios, and tested the utility of claws for geographic assignment. Based on the feather results, we estimated that similar proportions of birds in our study area use each of the 3 wintering regions in the Bering Sea. These results are in close agreement with estimates from satellite telemetry and show the usefulness of stable isotope signatures of feathers in assigning marine birds to geographic regions. The use of claws is currently limited by incomplete understanding of claw growth rates. Data presented here will allow managers of eiders, other marine birds, and marine mammals to assign animals to regions in the Bering Sea based on stable isotope signatures of body tissues.

Overland, J. E., P. J. Stabeno, and S. Salo. 1996. Direct evidence for northward flow on the northwestern Bering Sea shelf. Journal of Geophysical Research: Oceans. 101(C4):8971-8976. https://doi.org/10.1029/96JC00205

***Keywords*:** currents; Bering Strait

***Abstract*:** During the summer of 1994, a satellite-tracked drifter transited from the southeastern Bering Sea slope through Bering Strait by a route westward along the slope and then northward through Anadyr Canyon and Strait. The trajectory emphasizes the importance of a western location of northward flow on the Bering Sea shelf. The transit time was 2 months from Cape Navarin to Bering Strait with northward drift velocities of 5–40 cm/s.

Overland, J. E., M. Wang, K. R. Wood, D. B. Percival, and N. A. Bond. 2012. Recent Bering Sea warm and cold events in a 95-year context. Deep Sea Research Part II: Topical Studies in Oceanography. 65-70:6-13. https://doi.org/10.1016/j.dsr2.2012.02.013

Keywords**:** Bering Sea; climate change; atmospheric patterns; Pacific Decadal Oscillation

Abstract**:** The meteorology and oceanography of the southeastern Bering Sea shelf was recently dominated by a multi-year warm event (2000–2005) followed by a multi-year cold event (2007–2010). We put these recent events into the context of the 95-year air temperature record from St. Paul Island and with concurrent spatial meteorological fields. For March 2000–2005 the mean air temperature anomaly at St. Paul was 2.1 °C above the long-term mean, and for March 2007–2010 the mean temperature anomaly at St. Paul was 4.7 °C below the long-term mean. The only multi-year temperature deviations comparable to the first decade of the 2000s are a cold event from 1971 to 1976 followed by a warm event from 1978 to 1983. There was also a short warm event 1935–1937. The temperature transition between warm and cold events in the 1970s and 2000s took two years. While there are theoretical arguments for some physical memory processes in the North Pacific climate system, we cannot rule out that the recent warm and cold events are of a random nature: they are rare in the St. Paul temperature record, they are dominated by North Pacific-wide sea level pressure events rather than local Bering Sea processes, and they are consistent with a red noise model of climate variability. The 1970s transition appears to have an ENSO (El Niño–Southern Oscillation) influence, while the recent events are likely connected to Arctic-wide warming. Evidence provided by the 95-year St. Paul meteorological record reinforces the idea that a red-noise model of climate variability is appropriate for the North Pacific and southeastern Bering Sea. We stress the importance of relatively rare sub-decadal events and shifts, rather than multi-decadal variability associated with the Pacific Decadal Oscillation (PDO). Thus, in the future we can expect large positive and negative excursions in the region that can last for multiple years, but there is as yet little predictability for their timing and duration.

Overland, J. E., M. Wang, and T. J. Ballinger. 2018. Recent increased warming of the Alaskan marine Arctic due to midlatitude linkages. Advances in Atmospheric Sciences. 35(1):75-84. https://doi.org/10.1007/s00376-017-7026-1

Keywords**:** sea surface temperature; SST; model; Bering Strait

Abstract**:** Alaskan Arctic waters have participated in hemispheric-wide Arctic warming over the last two decades at over two times the rate of global warming. During 2008–13, this relative warming occurred only north of the Bering Strait and the atmospheric Arctic front that forms a north–south thermal barrier. This front separates the southeastern Bering Sea temperatures from Arctic air masses. Model projections show that future temperatures in the Chukchi and Beaufort seas continue to warm at a rate greater than the global rate, reaching a change of +4°C by 2040 relative to the 1981–2010 mean. Offshore at 74°N, climate models project the open water duration season to increase from a current average

of three months to five months by 2040. These rates are occasionally enhanced by midlatitude connections. Beginning in August 2014, additional Arctic warming was initiated due to increased SST anomalies in the North Pacific and associated shifts to southerly winds over Alaska, especially in winter 2015–16. While global warming and equatorial teleconnections are implicated in North Pacific SSTs, the ending of the 2014–16 North Pacific warm event demonstrates the importance of internal, chaotic atmospheric natural variability on weather conditions in any given year. Impacts from global warming on Alaskan Arctic temperature increases and sea-ice and snow loss, with occasional North Pacific support, are projected to continue to propagate through the marine ecosystem in the foreseeable future. The ecological and societal consequences of such changes show a radical departure from the current Arctic environment.

Pembroke, A., M. Balge, C. Gurshin, A. Hawkins, and A. N. Popper. 2013. Effects of noise on fish, fisheries, and invertebrates in the U.S. Atlantic and Arctic from energy industry sound-generating activities, workshop report. U.S. Dep. Interior, BOEM. OCS Study 2013-300. Obligation No.: M11PC00031. 361 p. https://espis.boem.gov/final%20reports/5361.pdf

***Keywords*:** sound; acoustic; marine mammals; vessel traffic; seismic

***Abstract*:** Sound from man-made sources has been increasing in the world's oceans via activities such as seismic exploration, pile driving, drilling, dredging, and vessel traffic. BOEM is responsible for evaluating the effects of these noise sources on biota. While advances have been made in understanding the effects on marine mammals, the sheer taxonomic and environmental diversity of fishes and invertebrates has made the task of understanding the effects on these species a much more onerous task. Much remains to be learned about the hearing or sound-producing capabilities of fishes and invertebrates, let alone how they respond to, and are potentially affected by, man-made sounds. This project encompasses three components: a literature synthesis, a workshop, and an analysis of information needed to improve BOEM's understanding of the issues and enhance BOEM's ability to make environmentally sound management decisions.

Petersen, M. R., W. W. Larned, and D. C. Douglas. 1999. At-sea distribution of spectacled eiders: A 120-year-old mystery resolved. The Auk. 116(4):1009-1020. https://doi.org/10.2307/4089681

***Keywords*:** seabird; climate change; ecosystems; breeding; seasonality

***Abstract*:** The at-sea distribution of the threatened spectacled eider (*Somateria fischeri*) has remained largely undocumented. We identified migration corridors, staging and molting areas, and wintering areas of adult Spectacled Eiders using implanted satellite-transmitters in birds from each of the three extant breeding grounds (North Slope and Yukon-Kuskokwim Delta in Alaska and arctic Russia). Based on transmitter locations, we conducted aerial surveys to provide visual confirmation of eider flocks and to estimate numbers of birds. We identified two principal molting and staging areas off coastal Alaska (Ledyard Bay and

eastern Norton Sound) and two off coastal Russia (Mechigmenskiy Bay on the eastern Chukotka Peninsula, and the area between the Indigirka and Kolyma deltas in the Republic of Sakha). We estimated that >10,000 birds molt and stage in monospecific flocks at Mechigmenskiy and Ledyard bays, and several thousand molt and stage in eastern Norton Sound. We further identified eastern Norton Sound as the principal molting and staging area for females nesting on the Yukon-Kuskokwim Delta, and Ledyard Bay and Mechigmenskiy Bay as the principal molting and staging areas for females nesting on the North Slope. Males marked at all three breeding grounds molt and stage in Mechigmenskiy Bay, Ledyard Bay, and the Indigirka-Kolyma delta region. Males from the Yukon-Kuskokwim Delta molt and stage mainly at Mechigmenskiy Bay. Equal numbers of males from the North Slope molt and stage at all three areas, and most males from arctic Russia molt and stage at the Indigirka-Kolyma delta region. Postbreeding migration corridors were offshore in the Bering, Chukchi, and Beaufort seas. In winter, eiders were in the Bering Sea south of St. Lawrence Island. Our estimates from surveys in late winter and early spring suggest that at least 333,000 birds winter in single-species flocks in the pack ice in the Bering Sea.

Phillips, E. M., H. M. Nevins, S. A. Hatch, A. M. Ramey, M. A. Miller, and J. T. Harvey. 2010. Seabird bycatch in Alaska demersal longline fishery trials: a demographic summary. Marine Ornithology: Journal of Seabird Research and Conservation. 38:111-117. http://pubs.er.usgs.gov/publication/70136182

Keywords**:** seabird; climate change; ecosystems; breeding; seasonality; fisheries; mortality events

Abstract**:** The seasonal and spatial demographics are summarized for seabirds killed incidentally during gear modification trials for a demersal longline fishery in the Bering Sea. We examined 417 carcasses, including Northern Fulmar *Fulmarus glacialis* (n = 205), Glaucous-winged Gull *Larus glaucescens* (n = 103), Short-tailed Shearwater *Puffinus tenuirostris* (n = 48), Glaucous Gull *Larus hyperboreus* (n = 23), Slaty-backed Gull *Larus schistisagus* (n = 4), Black-legged Kittiwake *Rissa tridactyla* (n = 1), Laysan Albatross *Diomedea immutabilis* (n = 1), and unidentified gull species *Larus* spp. (n = 32). There was a significant male bias in the sex ratio of fulmars but not of gulls or shearwaters. For the top three species killed, the age composition of resident species was dominated numerically by adults (Northern Fulmar 86%; Glaucous-winged Gull 63%), whereas migrant species were primarily immature birds (Short-tailed Shearwater 71%). The majority of migratory Short-tailed Shearwaters (88%) were caught in July and August, whereas 70% of resident fulmars and gulls were caught in October and November. Age-class frequencies did not differ by month of capture, indicating that adult mortality is substantial. Eighty percent of the fulmars caught during July and August were within 200 km of two colonies in the Bering Sea, whereas only 7% of fulmars were caught in the same area during September to November. This is one of the first demographic summaries of seabird bycatch in Alaska longline fisheries. Additional studies of the species, age and sex of seabirds subject to fisheries-related mortality will provide data necessary to evaluate population-level impacts.

Piatt, J. F., B. D. Roberts, and S. A. Hatch. 1990. Effects of human disturbance on breeding Least and Crested Auklets at St. Lawrence Island, Alaska. The Auk. 107(2):342-350. https://doi.org/10.2307/4087618

***Keywords*:** auklet; breeding; human disturbance; St Lawrence Island

***Abstract*:** We studied breeding success, chick growth, and diets of Least (*Aethia pusilla*) and Crested (*A. cristatella*) auklets on St. Lawrence Island, Alaska, in summer 1987. Least Auklets had higher breeding success on control plots (50-66%) than on disturbed plots (36%). Crested Auklets had a breeding success of 42% on disturbed plots. Predation by microtine rodents and weather accounted for most natural chick mortality. Least Auklet chicks grew at a maximum rate of 4.9 g/day, and Crested Auklet chicks at 12.8 g/day. Least Auklet chicks were fed mostly copepods (*Neocalanus plumchrus*), whereas Crested Auklet chicks were fed *Thysanoessa* euphausiids.

Piatt, J. F., B. D. Roberts, and S. A. Hatch. 1990. Colony attendance and population monitoring of least and crested auklets on St. Lawrence Island, Alaska. The Condor. 92(1):97-106. https://doi.org/10.2307/1368387

***Keywords*:** auklet; breeding; seasonality; St Lawrence Island

***Abstract*:** Diurnal and seasonal patterns of attendance of Least Auklets (*Aethia pusilla*) and Crested Auklets (*A. cristatella*) were studied in 1987 at breeding colonies on St. Lawrence Island, Alaska. Numbers of auklets attending eight 200-m^2 plots on talus slopes were counted throughout the day by observers on 11 occasions through the breeding season. Numbers attending smaller plots were recorded on time-lapse film on 71 different days. Another 16 200-m^2 plots were censused for auklets using surface counts. Within-day patterns of attendance were extremely variable over small and large temporal scales. Peaks of attendance occurred in late morning and late evening, with a 7- to 12-hr period of absence in the middle of the day. Attendance varied markedly between days, and numbers were negatively correlated with wind speed and the magnitude of tidal oscillations. Patterns of attendance also varied with stage of breeding, and counts were least variable during incubation and early chick rearing. Whereas Least Auklet numbers peaked during prelaying, Crested Auklet numbers peaked during incubation. Counts indicated that auklets at Kongkok Bay have increased about twofold since studies in the mid-1960s. Recommendations are made for future monitoring of auklet populations.

Pipko, I. I., I. P. Semiletov, P. Y. Tishchenko, S. P. Pugach, and J. P. Christensen. 2002. Carbonate chemistry dynamics in Bering Strait and the Chukchi Sea. Progress in Oceanography. 55(1):77-94. https://doi.org/10.1016/S0079-6611(02)00071-X

***Keywords*:** sea surface pCO_2; satellite remote sensing; semi-analytical algorithm; the Bering Sea; marine carbonate system

***Abstract*:** Fall dynamics of the carbonate system in the shallow Chukchi Sea is a result of the interaction between physical and biological processes such as mixing of different water masses, cooling, photosynthesis-respiration. The study area acts as a sink for atmospheric CO_2. The general trend in surface pCO_2 distribution is a decrease towards the ice edge, which is determined by the temperature decrease, whereas mesoscale variability of the carbonate parameters is controlled by the interaction between different waters. The calculated September 1996 flux of CO_2 from the air into the sea on eastern Chukchi Sea is about 1×10^{12} g C.

Pipko, I. I., S. P. Pugach, V. A. Luchin, O. P. Francis, N. I. Savelieva, A. N. Charkin, O. V. Dudarev, and I. P. Semiletov. 2021. Surface CO_2 system dynamics in the Gulf of Anadyr during the open water season. Continental Shelf Research. 217:104371. https://doi.org/10.1016/j.csr.2021.104371

***Keywords*:** Gulf of Anadyr; seawater CO system; air-sea CO fluxes; spatial variability

***Abstract*:** The Gulf of Anadyr (GA), one of the largest and most poorly investigated gulfs of the Bering Sea, is an important part of the Pacific Arctic. Drivers and mechanisms responsible for the spatial variations in surface seawater CO_2 system parameters and associated air–sea CO_2 fluxes were investigated during three oceanographic cruises conducted in the GA during the open water season of 1992, 2002, and 2011. It was shown that the surface waters of the GA were moderate to strong sinks for atmospheric CO_2 during this season: mean air-sea CO_2 fluxes for the investigated areas of the GA, for the three cruises, were −31, −15, and −30 mmol CO_2 m^{-2} d^{-1}, respectively. The summer air-sea CO_2 flux was attributed to intensive phytoplankton bloom, and fall CO_2 uptake coincided with a period of strong winds and seasonal enhanced primary production. The surface waters of the GA were supersaturated with respect to aragonite during the investigated period. Anadyr Strait, a region of high hydrodynamic activity, was the only area where CO_2 efflux was observed. Surface waters of the strait were supersaturated with respect to CO_2 and in quasi-equilibrium with respect to aragonite. We found that during the late summer/fall season, the Anadyr Current exported a well-mixed, relatively cold, salty, nutrient- and CO_2-rich water through the western Anadyr Strait into the Chirikov Basin. Our research highlights the need for mesoscale studies of the western Bering Sea to produce the most accurate assessment of the regional CO_2 budget.

Pulsifer, P., S. Gearheard, H. Huntington, M. Parsons, C. McNeave, and H. McCann. 2012. The role of data management in engaging communities in Arctic research: Overview of the exchange for local observations and knowledge of the Arctic (ELOKA). Polar Geography. 35:1-20. https://doi.org/10.1080/1088937X.2012.708364

***Keywords*:** traditional knowledge; community engagement; Arctic

***Abstract*:** Local and traditional knowledge (LTK) was a key component of many projects in the 2007–2009 International Polar Year (IPY) and much information was amassed through

maps, interviews with local experts, photographs, artwork, and other forms of documentation. Unlike conventional physical and life sciences, few options exist for those seeking data management for social, cultural, or traditional knowledge projects. This poses many problems for researchers and communities alike. The collaborative demands of the IPY data policy emphasized the need for effective and appropriate means of recording, preserving, and sharing the information collected in Arctic communities. This article describes the history and activities of the Exchange for Local Observations and Knowledge of the Arctic, a project launched during the IPY that continues to facilitate the collection, preservation, exchange, and use of local observations and knowledge. Using examples, we describe new approaches and special considerations for managing community data. We also show how data management can assist in linking LTK and various sciences and building connections between researchers and communities and across communities. Data management, if designed to serve local needs as well as broader interests, can help to facilitate new relationships between local communities and global researchers.

Quakenbush, L. T., R. J. Small, and J. J. Citta. 2013. Satellite tracking of bowhead whales. U.S. Dep. Interior, BOEM. OCS Study 2013-01110. Obligation No.: M10PC00085. 60 p. https://www.adfg.alaska.gov/static/research/programs/marinemammals/pdfs/bowhead_2013_boem_final_report.pdf

***Keywords*:** bowhead whale; relative abundance; distribution; Bering Sea; marine mammal; Chukchi Sea; Beaufort Sea

***Abstract*:** The western Arctic (or Bering-Chukchi-Beaufort) stock of bowhead whales (*Balaena mysticetus*) is of high importance due to the nutritional and cultural role of bowhead whales to coastal Alaska Natives of the Bering, Chukchi, and Beaufort seas, their role in the marine ecosystem, and because their summer range overlaps with areas identified for potential oil and gas development. Movement and feeding patterns of this stock of bowhead whales, however, are not well understood. Increasing our understanding of bowhead whale movements, habitat use, and behavior will aid in resource planning and conservation. We worked with Native whalers from Alaska and marine mammal hunters from Canada to attach 46 satellite transmitters to bowhead whales during a five year period. This final report covers the time period from August 2005 to July 2010 and includes movements and behavior of 37 bowhead whales tagged near Barrow, Alaska and nine tagged in Canada. We have documented the annual distribution of western Arctic bowhead whales, including summering and wintering areas, and the migratory routes that connect these areas. At the request of the Alaska Eskimo Whaling Commission, we conducted traditional knowledge interviews in as many whaling villages as possible and report our findings. We have described how bowhead whales move through Oil and Gas Lease Sale Area 193 in the spring and fall. We have described locations and times when shipping may affect bowhead migration or feeding and have documented an interaction between a bowhead whale and a seismic vessel.

Quakenbush, L., J. Citta, J. C. George, M. P. Heide-Jørgensen, H. Brower, L. Harwood, B. Adams, C. Pokiak, J. Pokiak, and E. Lea. 2018. Bering-Chukchi-Beaufort stock of bowhead whales: 2006–2017 satellite telemetry results with some observations on stock substructure. International Whaling Commission. SC/67B/AWMP/04. http://www.adfg.alaska.gov/static/home/library/pdfs/wildlife/research_pdfs/quakenbush_et_al_2018_bowhead_whales.pdf

***Keywords*:** bowhead whale; marine mammal; relative abundance; distribution; Bering Sea; Chukchi Sea; Beaufort Sea

***Abstract*:** Sixty-four satellite transmitters provided data on bowhead whales from the Bering-Chukchi-Beaufort (BCB) stock between 2006 and 2017 to study their movements and behavior. Sixty-one of which were tagged in the Beaufort Sea and three were tagged in the Bering Sea. In winter, bowhead whales used the western Bering Sea in areas of heavy ice with little use of open water areas. All but one tagged whale migrated past Point Barrow in spring and went to Amundsen Gulf. That whale migrated up the Chukotka coast and summered in the Chukchi Sea. While most whales summered within the Canadian Beaufort Sea, extensive summer movements included travel far to the north and northeast to overlap with bowhead whales from the Baffin Bay-Davis Strait stock. Other summer movements included trips between the Canadian Beaufort and Barrow and back again. One whale, tagged near Point Barrow, traveled to the northern coast of Chukotka, Russia, in the following summer, and did not return to Canada that summer. Fall movements coincided in space and time with oil and gas activities and potentially with shipping activities. Core-use areas that are likely important feeding areas included Amundsen Gulf in spring and summer; Tuktoyaktuk Shelf in summer; Point Barrow in summer and fall; the northern Chukotka coast in fall; and the western Bering Sea in winter. Recent changes in late summer movements (i.e., greater use of mid and western Beaufort Sea) and less use of previous core-use areas in the Bering Sea in winter that were largely ice-free in winter 2016/17 and 2017/18 have occurred and may become more common. None of the movements from tagged whales suggest a multi-stock condition exists within the BCB bowhead whale population.

Roach, A. T., K. Aagaard, C. H. Pease, S. A. Salo, T. Weingartner, V. Pavlov, and M. Kulakov. 1995. Direct measurements of transport and water properties through the Bering Strait. Journal of Geophysical Research. 100(C9):18443-18457. https://doi.org/10.1029/95jc01673

***Keywords*:** salinity; temperature; currents; Bering Strait

***Abstract*:** Four years of temperature, salinity, and velocity data enable a direct computation of volume transport and a temporal description of water properties exchanged through the Bering Strait. The mean volume transport over the 4-year period (September 1990 through September 1994) is 0.83 Sv northward with a weekly standard deviation of 0.66 Sv. The maximum error in this mean estimate is 30%. Interannual variability in transport is typically 0.1 Sv but can, at times, reach nearly 50% of the mean. The transport of 1.14 Sv during the

first 9 months of 1994 is the largest in the last 50 years. The rate of winter salinity increase is very similar from year to year, suggesting regional average ice formation of about 5 cm d-1. The amplitude of the annual salinity cycle is about 2 psu, with salinity reaching a maximum in early April. There can be large interannual variations in the salinity (about 1), particularly in winter. Background autumn salinities average 32.0 in the eastern and 32.6 in the western channel.

Robards, M., H. P. Huntington, M. Druckenmiller, J. Lefevre, S. K. Moses, Z. Stevenson, A. Watson, and M. Williams. 2018. Understanding and adapting to observed changes in the Alaskan Arctic: Actionable knowledge co-production with Alaska Native communities. Deep Sea Research Part II: Topical Studies in Oceanography. 152:203-213. https://doi.org/10.1016/j.dsr2.2018.02.008

***Keywords*:** climate change; sea ice; marine mammals; traditional knowledge; Arctic; management

***Abstract*:** Global changes in climate, connectivity, and commerce are having profound impacts on the Arctic environment and inhabitants. There is widespread recognition of the value of incorporating different worldviews and perspectives when seeking to understand the consequences of these impacts. In turn, attention to local needs, perspectives, and cultures is seen as essential for fostering effective adaptation planning, or more broadly, the resilience of local peoples. The emerging literature on "knowledge co-production" identifies factors that can help incorporate such local information. This field focuses on how different models of what has been termed the "science-policy interface" can incorporate multiple epistemologies. Such an approach goes beyond observing or assessing change from different scales and perspectives, to defining conditions that support the co-production of actionable knowledge. This approach requires the development of response tools that can accommodate the dynamic relationships among people, wildlife, and habitats that straddle cultures, timescapes, and sometimes, national boundaries. We use lessons from seven Alaskan cases studies to describe a typology of five elements important for the co-production of locally relevant actionable knowledge. Three elements are consistent with earlier work, including 1) evolving communities of practice, 2) iterative processes for defining problems and solutions, and 3) presence of boundary organizations, such as a government agency, university, or co-management council. Our results for the Alaskan Arctic also emphasize the critical need to incorporate 4) the consistent provision of sufficient funds and labor that may transcend any one specific project goal or funding cycle, and 5) long temporal scales (sometimes decades) for achieving the co-production of actionable knowledge. Our results have direct relevance to understanding the mechanisms that might foster greater success in more formalized co-management regimes.

Robertson, D. E., and K. H. Abel. 1979. Natural distribution and environmental background of trace heavy metals in Alaskan shelf and estuarine areas. U.S. Dep of Interior, USGS. US Dept. of Commerce, National Oceanic and Atmospheric Administration; US Dept. of the Interior, Minerals Management Service, Alaska OCS Region. Report No.: MMS 90-0074 RU-506. 227-

419 p. Pacific Northwest Laboratories Richland, Washington 99352. https://espis.boem.gov/final%20reports/772.pdf

***Keywords*:** heavy metals; environmental background; sediment; Alaska

***Abstract*:** Data are presented which help describe the natural distribution and environmental background of trace metals in Alaskan shelf and estuarine areas selected for future offshore oil exploration and recovery. This baseline information will provide a basis for assessing any future environmental perturbations of the trace metal distribution in the Alaskan shelf environment by the oil production operations. The suite of trace metals which have been emphasized in our phase of the overall Outer Continental Shelf Environmental Assessment Program (OCSEAP) are those most amenable to measurement by neutron activation analysis and include V, As, Sb, Zn, Co, Ba, Mn, Fe and Cr. These analyses complement the measurements of other investigators using atomic absorption spectrometry and techniques. In addition to the above elements we have major and trace elements automatically detected by the activation methods which we employ. This multielement X-ray fluorescence also measured other instrumental neutron approach is extremely valuable because much additional information is available to more completely characterize the biogeochemistry and history of the many samples which have been analyzed.

Romano, M. D., H. M. Renner, K. J. Kuletz, J. K. Parrish, T. Jones, H. K. Burgess, D. A. Cushing, and D. Causey. 2020. Die-offs, reproductive failure, and changing at-sea abundance of murres in the Bering and Chukchi Seas in 2018. Deep Sea Research Part II: Topical Studies in Oceanography. 181-182:104877. https://doi.org/10.1016/j.dsr2.2020.104877

***Keywords*:** at-sea survey; Bering Sea; Chukchi Sea; common murre; die-off; productivity; reproductive success; seabird; thick-billed murre

***Abstract*:** Common and thick-billed murres are among the most numerous and widespread seabirds in the northern hemisphere though they appear to be especially susceptible to mass die-off events. During the spring and summer of 2018, the Bering Sea experienced warmer than average sea temperatures following a winter of unprecedented, near complete lack of sea ice. To determine if breeding murres were negatively affected by these warm sea temperatures, surveys at most of the major murre breeding colonies in the eastern Bering and eastern Chukchi seas were conducted during the 2018 breeding season. Nearly all colonies surveyed experienced near-complete reproductive failure. Concurrently, above average levels of murre mortality were observed, primarily at St. Lawrence Island and in the Bering Strait region. The timing of this mortality is somewhat unusual and concerning as it occurred during the breeding season. Based on surveys at sea, overall murre abundance offshore was generally lower in 2018 compared to recent years (2012–2017), particularly in the northern Bering Sea, yet mean density for thick-billed murres increased in the Chukchi Sea. Reproductive failure is rare at monitored murre colonies within the study area and the widespread reproductive failures observed in 2018 were unprecedented over

four decades of monitoring, but consistent with the reproductive failure of murres documented in the Gulf of Alaska and southeastern Bering Sea following a large murre die-off in 2015–2016. The combination of large-scale reproductive failure, evidence of elevated levels of mortality, and low abundance of birds offshore suggest that murres experienced severe distress in the Bering and Chukchi sea region during the summer of 2018.

Rooper, C. N., I. Ortiz, A. J. Hermann, N. Laman, W. Cheng, K. Kearney, K. Aydin, and V. Bartolino. 2021. Predicted shifts of groundfish distribution in the Eastern Bering Sea under climate change, with implications for fish populations and fisheries management. ICES Journal of Marine Science. 78(1):220-234. https://doi.org/10.1093/icesjms/fsaa215

***Keywords*:** Alaska; climate change; demersal fish; fish habitat; generalized additive modelling; regional ocean model systems; species distribution modelling; trawl surveys

***Abstract*:** Climate-related distribution shifts for marine species are, in general, amplified in northern latitudes. The objective of this study was to predict future distributions of commercially important species in the eastern Bering Sea under six climate scenarios, by incorporating predictions of future oceanographic conditions. We used species distribution modelling to determine potential distribution changes in four time periods (2013–2017, 2030–2039, 2060–2069, and 2090–2099) relative to 1982–2012 for 16 marine fish and invertebrates. Most species were predicted to have significant shifts in the centre of gravity of the predicted abundance, the area occupied, and the proportion of the predicted abundance found in the standard bottom trawl survey area. On average the shifts were modest, averaging 35.2 km (ranging from 1 to 202 km). There were significant differences in the predicted trend for distribution metrics among climate scenarios, with the most extensive changes in distribution resulting from Representative Concentration Pathway 8.5 climate scenarios. The variability in distributional shifts among years and climate scenarios was high, although the magnitudes were low. This study provides a basis for understanding where fish populations might expand or contract in future years. This will provide managers' information that can help guide appropriate actions under warming conditions.

Roscigno, P. F., S. Kohl, and H. J. O'Connor. 1990. Results of the second joint U.S.-U.S.S.R. Bering Sea expedition summer 1984. U.S. Fish and Wildlife Service Biological Report 90(13). P. F. Roscigno (editor). U.S. Deptartment of the Interior, Fish and Wildlife Service, and U.S.S.R. State Committee on Hydrometeorology and Natural Environmental Control. Washington, D.C. 317 p. https://doi.org/10.5962/bhl.title.45482

***Keywords*:** Bering Sea; Joint U.S.-U.S.S.R. Bering Sea Expedition; marine pollution; scientific expeditions; testing

***Abstract*:** No abstract available.

Ruggerone, G. T., B. A. Agler, and J. L. Nielsen. 2011. Evidence for competition at sea between Norton Sound chum salmon and Asian hatchery chum salmon. Environmental Biology of Fishes. 94(1):149-163. https://doi.org/10.1007/s10641-011-9856-5

***Keywords*:** Arctic-Yukon-Kuskokwim; Alaska; chum salmon; hatchery versus wild salmon; competition; density-dependence; tragedy of the commons

***Abstract*:** Increasing production of hatchery salmon over the past four decades has led to concerns about possible density-dependent effects on wild Pacific salmon populations in the North Pacific Ocean. The concern arises because salmon from distant regions overlap in the ocean, and wild salmon populations having low productivity may compete for food with abundant hatchery populations. We tested the hypothesis that adult length-at-age, age-at-maturation, productivity, and abundance of a Norton Sound, Alaska, chum salmon population were influenced by Asian hatchery chum salmon, which have become exceptionally abundant and surpassed the abundance of wild chum salmon in the North Pacific beginning in the early 1980s. We found that smaller adult length-at-age, delayed age-at-maturation, and reduced productivity and abundance of the Norton Sound salmon population were associated with greater production of Asian hatchery chum salmon since 1965. Modeling of the density-dependent relationship, while controlling for other influential variables, indicated that an increase in adult hatchery chum salmon abundance from 10 million to 80 million adult fish led to a 72% reduction in the abundance of the wild chum salmon population. These findings indicate that competition with hatchery chum salmon contributed to the low productivity and abundance of Norton Sound chum salmon, which includes several stocks that are classified as Stocks of Concern by the State of Alaska. This study provides new evidence indicating that large-scale hatchery production may influence body size, age-at-maturation, productivity and abundance of a distant wild salmon population.

Saitoh, S.-i., T. Iida, and K. Sasaoka. 2002. A description of temporal and spatial variability in the Bering Sea spring phytoplankton blooms (1997–1999) using satelite multi-sensor remote sensing. Progress in Oceanography. 55(1-2):131-146. https://doi.org/10.1016/s0079-6611(02)00074-5

***Keywords*:** sea surface temperature; sea ice; wind; phytoplankton; Bering Sea

***Abstract*:** The Bering Sea is well known as a highly productive marginal sea. The objectives of this study were to clarify the interannual variability of spring bloom dynamics of the Bering Sea and to describe the spatial variability of this highly productive area using satellite multi-sensor remote sensing. We used multi-sensor remote sensing data sets of ocean color (OCTS and SeaWiFS), sea surface temperature (AVHRR), sea ice (SSM/I) and sea wind (SSM/I) to understand the complexity of the Bering Sea ecosystem. Phytoplankton biomass depends on the timing of sea ice melting and tends to increase when the melting is delayed. Wind stress is one of the important factors controlling the timing of the spring bloom. In 1997 and 1998, the east–west distribution of phytoplankton biomass exhibited a seesaw

pattern, either high in west and low in east or low in west and high in east. We hypothesize that this seesaw pattern results from changes in the position and intensity of the Aleutian Low during spring and its relation to the El Niño–La Niña phenomena. During the El Niño period of 1998, the Aleutian Low shifted to the east of its normal position, and weak wind stresses facilitated the development of stratification and enhancement of spring bloom in the west. Conversely, when the Aleutian Low moved over into the western region in spring 1997, the same situation occurred in the east. Thus, the movements of the Aleutian Low promote a west-east seesaw pattern of sea surface wind stress, and consequently a corresponding seesaw pattern in phytoplankton biomass resulting from the subsequent variations in the depth of the mixed layer.

Sambrotto, R. N., J. J. Goering, and C. P. McRoy. 1984. Large yearly production of phytoplankton in the western Bering Strait. Science. 225(4667):1147-50. https://doi.org/10.1126/science.225.4667.1147

***Keywords*:** carbon; sea ice; phytoplankton; Bering Strait

***Abstract*:** Production in the western Bering Strait is estimated at 324 grams of carbon per square meter per year over 2.12x 10^4 square kilometers. An ice-reduced growing season makes this large amount of primary production unexpected, but it is consistent with the area's large upper trophic level stocks. The productivity is fueled by a cross-shelf flow of nutrient-rich water from the Bering Sea continental slope. This phytoplankton production system from June through September is analogous to a laboratory continuous culture.

Sample, T. M., and J. Robert J. Wolotira. 1985. Demersal fish and shellfish resources of Norton Sound and adjacent waters during 1979. U.S. Dep. Commerce. NOAA Tech. Memo. NMFS F/NWC-89. 231 p. 7600 Sand Point Way N.E., Seattle, WA 98115. https://repository.library.noaa.gov/view/noaa/23326

***Keywords*:** fish; crab; bottom trawl; surveys; Norton Sound

***Abstract*:** In July-August, 1979 the National Marine Fisheries Service of the Northwest and Alaska Fisheries Center conducted a bottom trawl survey in the marine waters of Norton Sound. This report describes survey and analytical methods used and summarizes results in a series of tables and figures and in data appendices. Summarized in the Results Section are a list of species taken during the survey, abundance estimates of major taxonomic groups of fish and invertebrates, and rankings of individual species of groundfish in terms of relative abundance. For principal species of groundfish, geographic distributions and size and age conposition are illustrated and abundance estimates given. The Discussion Section compares results of the 1979 survey with information collected during a previous survey conducted in 1976. The appendices contain the detailed station and catch data and computer listings of abundance estimates and biological characteristics of the sampled populations of principal species of groundfish.

Sancetta, C., and S. W. Robinson. 1983. Diatom evidence on Wisconsin and Holocene events in the Bering Sea. Quaternary Research. 20(2):232-245. https://doi.org/10.1016/0033-5894(83)90079-0

***Keywords*:** sediment; sediment cores; phytoplankton; paleoenvironment; Alaska

***Abstract*:** Previous work on surface (modern) sediments has defined diatom species which appear to be good indicators of various oceanographic/ecologic conditions in the North Pacific Ocean and marginal seas. Three long cores from the eastern and northern sides of the Aleutian Basin show changes in species assemblage which can be interpreted in terms of changes in the ocean environment during the last glaciation (Wisconsin) and the Holocene. The early and late Wisconsin maxima were times of prolonged annual sea-ice cover and a short cool period of phytoplankton productivity during the ice-free season. The middle Wisconsin interstade, at least in the southern Bering Sea, had greater seasonal contrast than today, with some winter sea-ice cover, an intensified temperature minimum, and high spring productivity. Variations in clastic and reworked fossil material imply varying degrees of transport to the basin by Alaskan rivers. The results of Jouse from the central Bering Sea generally correspond with those presented here, although there are problems with direct comparison.

Sasaki, H., H. Hattori, O. Matsuda, A. Tanimura, and M. Fukuchi. 1993. Variability in the flux of rapidly sinking particles at the Chirikov Basin of the northern Bering Sea in summer 1988. La mer. 31:19-29. http://www.sfjo-lamer.org/la_mer/31-1/%95%B6%8F%91%96%BC%20_31-1-3.pdf

***Keywords*:** carbon; chlorophyll; phytoplankton; sediment; sediment transport

***Abstract*:** A time-series sediment trap was deployed at 13 m above the bottom at the Chirikov depocenter (about 50 m depth) of the northern Bering Sea from 20 June, 1988 to 24 September, 1988. Twelve consecutive samples were collected with a time interval of 8 days. According to the physical conditions (temperature, current speed and direction) around the trap site, the deployement period can be separated into three distinct short periods, phase I (from 20 June to 7 August), phase II (from 7 August to 31 August) and phase III (from 31 August to 24 September). Averaged daily carbon flux was higher in phase I (490 mgC m^{-2}) than those in phase II (425 mgC m^{-2}) and in phase III (429 mgC m^{-2}). In phase I, northward flowing and cold Bering Shelf Anadyr Water (BSAW) induced to produce autochthonous large sinking particles (LG) around the trap site and also carried allochthonous small particles (SM) from the south. In phase II, when the cold BSAW and warm Alaskan Coastal Water (ACW) occurred alternatively, LG fraction decreased possibly due to the less influence of BSAW. In phase III, BSAW replaced ACW, and LG fraction increased again, though the fecal pellet composition of LG were quite different from that in Phase I. The LG increase in phase III was primarily attributed to a fall phytoplankton bloom and intensified herbivorous grazing activities.

Schell, D. M., B. A. Barnett, and K. A. Vinette. 1998. Carbon and nitrogen isotope ratios in zooplankton of the Bering, Chukchi and Beaufort Seas. Marine Ecology Progress Series. 162:11-23. http://www.int-res.com/articles/meps/162/m162p011.pdf

***Keywords*:** stable isotopes; Bering Sea; Chukchi Sea; Beaufort Sea; 6I3C; 6I5N; euphausiids; copepods; chaetognaths

***Abstract*:** Zooplankton from the Bering, Chukchi, and Beaufort seas and a transect across the Arctic Ocean were collected from 369 stations on 18 cruises in the years 1985-1990 and 1993-1995. Carbon and nitrogen isotope ratio analyses were performed on the major taxonomic groups present-calanoid copepods, euphausiids and chaetognaths. The sampled waters around Alaska were divlded into 11 subregions based on water mass characteristics and the zooplankton statistically tested for significant differences in the isotope ratios. Within all regions, copepods were significantly more depleted in I3C than euphausiids (average 6I3C difference for copepods = -1.1 Ym than euphausiids), but showed no significant differences from euphausiids in 615N except in the eastern Alaskan Beaufort Sea where copepods were relatively enriched in "N. The greatest variability in isotope ratios was among geographic regions. All taxa tested were I3C-depleted In the eastern Beaufort Sea, the Arctic Ocean and in deep waters of the southwestern Bering Sea relative to the continental shelf waters of the Bering and Chukchi seas. The maximum enrichments were found in the southwestern Chukchi Sea and central Bering Sea shelf waters. The advection of water northward through the Bering Strait was evident as a plume of enriched zooplankton extending to the shelf break in the Arctic Ocean. In contrast, the 6I5N within taxa generally increased moving northward from the deep Bering Sea to the Chukchi Sea and eastward into the Beaufort Sea. The 6I5N values for chaetognaths were 2.5 to 3%~ more enriched than copepods or euphausiids in all locations, consistent with their carnivorous diet. Comparisons of zooplankton isotope ratios among years and cruises within the same region revealed no significant differences. Low 6I5N and 6I3C values in zooplankton of the pelagic Bering Sea are presumed to result from the isotopic discrimination arising in the presence of high nutrient abundances and slow phytoplankton growth rates whereas depleted values in coastal waters of the Canadian Beaufort Sea presumably derive from Mackenzie River inputs of terrestrially derived carbon and nitrogenous nutrients with low I5N and I3C abundances. The geographic heterogeneity in isotope ratios over short distances indicates a need for caution in the interpretation of isotope ratios in marine mammals and birds with regard to trophic status and habitat usage.

Seitz, A., M. Courtney, and B. Scanlon. 2014. Dispersal patterns and summer ocean distribution of adult Dolly Varden from the Wulik River, Alaska, evaluated using satellite telemetry. University of Alaska Coastal Marine Institute and U.S. Dep of Interior, BOEM. OCS Study 2014-663. 39 p. https://espis.boem.gov/final%20reports/5404.pdf

***Keywords*:** climate change; ecosystems; fisheries; fish; Dolly Varden

***Abstract*:** In northwest Alaska near the Chukchi Sea, Dolly Varden charr *Salvelinus malma* is highly valued as a subsistence fish and local residents harvest thousands of these fish each year. While it is known that Dolly Varden may be widely distributed throughout the Pacific Ocean, it is not known whether this species occupies the offshore area of the Chukchi Sea. This area is an ecologically important feeding area for many marine mammals, fish, and seabirds, and may also be explored for oil and gas development. If Dolly Varden from northwestern Alaska occupies the offshore area of the Chukchi Sea, individual fish may potentially interact with oil and gas exploration and development activities. The objectives of this study were (1) to describe baseline ecological information about Dolly Varden tagged in the Wulik River, Alaska, and (2) describe temporal and spatial distribution in outer continental shelf areas to better understand potential interactions among Dolly Varden and exploration and development activities in the Chukchi, Bering and/or Beaufort Seas.

Sexson, M. G., D. M. Mulcahy, M. Spriggs, and G. E. Myers. 2014. Factors influencing immediate post-release survival of spectacled eiders following surgical implantation of transmitters with percutaneous antennae. The Journal of Wildlife Management. 78(3):550-560. https://doi.org/10.1002/jwmg.690

***Keywords*:** seabird; climate change; ecosystems; breeding; seasonality; Spectacled Eider

***Abstract*:** Surgically implanted transmitters are a common method for tracking animal movements. Immediately following surgical implantation, animals pass through a critical recovery phase when behaviors may deviate from normal and the likelihood of individual survival may be reduced. Therefore, data collected during this period may be censored to minimize bias introduced by surgery-related behaviors or mortality. However, immediate post-release mortalities negate a sampling effort and reduce the amount of data potentially collected after the censoring period. Wildlife biologists should employ methods to support an animal's survival through this period, but factors contributing to immediate post-release survival have not been formally assessed. We evaluated factors that potentially influenced the immediate post-release survival of 56 spectacled eiders (*Somateria fischeri*) marked with coelomically implanted satellite transmitters with percutaneous antennae in northern Alaska in 2010 and 2011. We modeled survival through the first 14 days following release and assessed the relative importance and effect of 15 covariates hypothesized to influence survival during this immediate post-release period. Estimated daily survival rate increased over the duration of the immediate post-release period; the probability of mortality was greatest within the first 5 days following release. Our top-ranking model included the effect of 2 blood analytes, pH and hematocrit, measured prior to surgical implantation of a transmitter. We found a positive response to pH; eiders exhibiting acidemia (low pH) prior to surgery were less likely to survive the immediate post-release period. We found a curvilinear response to hematocrit; eiders exhibiting extremely low or high pre-surgery hematocrit were also less likely to survive the immediate post-release period. In the interest of maximizing the survival of marked birds following release, hematological data obtained prior to surgical implantation of telemetry equipment may be useful when screening for optimal surgical candidates or informing appropriate response to mitigate potentially

deleterious disorders such as acidemia. Published 2014. This article is a U.S. Government work and is in the public domain in the USA.

Sexson, M. G., M. R. Petersen, G. A. Breed, and A. N. Powell. 2016. Shifts in the distribution of molting Spectacled Eiders (*Somateria fischeri*) indicate ecosystem change in the Arctic. The Condor. 118(3):463-476. https://doi.org/10.1650/CONDOR-15-139.1

***Keywords*:** seabird; climate change; ecosystems; seasonality; Spectacled Eider

***Abstract*:** Shifts in the distribution of benthivorous predators provide an indication of underlying environmental changes in benthic-mediated ecosystems. Spectacled Eiders (*Somateria fischeri*) are benthivorous sea ducks that spend the nonbreeding portion of their annual cycle in the Bering, Chukchi, Beaufort, and East Siberian seas. Sea ducks generally molt in biologically productive areas with abundant prey. If the distribution of eiders at molting areas matches prey abundance, spatial shifts may indicate changes in environmental conditions in the Arctic. We used a randomization procedure to test for shifts in the distribution of satellite telemetry locations received from Spectacled Eiders in the 1990s and 2008–2011 within 4 late-summer, ice-free molting areas: Indigirka–Kolyma, northern Russia; Ledyard Bay, eastern Chukchi Sea; Norton Sound, northeastern Bering Sea; and Mechigmenskiy Gulf, northwestern Bering Sea. We also tested for interannual and interdecadal changes in dive depth required to reach prey, which might affect the energetic costs of foraging during the molting period. Transmitter-marked birds used each molting area in each year, although the distribution of Spectacled Eiders shifted within each area. Interdecadal shifts in Ledyard Bay and Norton Sound decreased dive depth in recent years, although minor differences in depth were biologically negligible in relation to the energetic expense of feather growth. Shifts in Mechigmenskiy Gulf and Indigirka–Kolyma did not occur consistently within or among decades, which suggests greater interannual variability among environmental factors that influence distribution in these areas. Shifts in each molting area suggest dynamic ecosystem processes, with implications for Spectacled Eiders if changes result in novel competition or predation, or in shifting prey regimes.

Sherwood, K. W., J. Larson, C. D. Comer, J. D. Craig, and C. Reitmeier. 2006. Norton basin planning area (Alaska) – Province summary. U.S. Dep of Interior, BOEM Minerals Management Service Alaska OCS Region. Norton Basin Province Summary 2006. 17 p. https://www.boem.gov/sites/default/files/about-boem/BOEM-Regions/Alaska-Region/Resource-Evaluation/Released-Geological-and-Geophysical-Data/Norton-Basin-Province-Summary.pdf

***Keywords*:** geology; petroleum; hydrocarbons; BOEM; Norton Basin

***Abstract*:** No abstract available.

Siddon, E. C., S. G. Zador, and G. L. Hunt. 2020. Ecological responses to climate perturbations and minimal sea ice in the northern Bering Sea. Deep Sea Research Part II: Topical Studies in Oceanography. 181-182:104914. https://doi.org/10.1016/j.dsr2.2020.104914

***Keywords*:** sub-arctic; climate warming; ecosystem response; species distributions; diatoms; zooplankton; commercially important fish; snow crab; seabird; ecology; marine mammal; die-offs; ice seals

***Abstract*:** The winter of 2017/2018 saw a composite of weather events that delayed sea ice formation in the northern Bering Sea (NBS) into early 2018. Residual warmth in the water column and strong southerly (i.e., warm) winds in February resulted in the lowest ice extent on record. Salinity has historically driven vertical stratification of the water column in the NBS, but with little sea ice formation and rejection of salty brine, there was a greatly diminished contribution of salinity to the stratification of the water column. The reduction of sea ice extent and duration likely resulted in a reduction in the amount of ice algae, which is an important subsidy for both the pelagic and benthic food webs. In 2018, the NBS had low abundances of large, lipid-rich copepods, while there were above average numbers of small, lipid-poor copepods. Shifts in the distribution of crab and fish populations over the eastern Bering Sea shelf occurred in response to the unusually warm sea temperatures in winter and spring 2018. More than 50% of Pacific cod biomass in the eastern Bering Sea was found over the northern shelf in 2018 concurrent with unexpectedly high abundance of snow crab in the NBS. A seabird die-off event in summer 2018 was unprecedented in terms of spatial and temporal scale and widespread reproductive failures also occurred. High numbers of dead marine mammals were found along the shorelines of the NBS and an Unusual Mortality Event, an official designation for marine mammals, was declared for bearded, ringed, and spotted seals in September 2019. The 2018 events indicate that when climate warming results in extended periods of reduced sea ice cover in the NBS, there may be long-term changes in energy flow and ecosystem structure. Following the low sea ice conditions of 2018, winter 2018/2019 brought a second year of low sea ice. Although it is clear that the climate perturbations experienced in 2018 and 2019 had acute impacts on many components of the NBS marine ecosystem, it is less clear what the long term impacts of this event will be if there is a return to “normal” sea ice cover in future years.

Sigler, M. F., H. R. Harvey, J. Ashjian, M. W. Lomas, J. M. Napp, P. J. Stabeno, and T. I. Van Pelt. 2010. How does climate change affect the Bering Sea ecosystem? Eos, Transactions American Geophysical Union. 91(48):457-458. https://doi.org/10.1029/2010EO480001

***Keywords*:** climate change; marine ecosystem; fisheries; cultural issues; Bering Sea; sea ice

***Abstract*:** The Bering Sea is one of the most productive marine ecosystems in the world, sustaining nearly half of U.S. annual commercial fish catches and providing food and cultural value to thousands of coastal and island residents. Fish and crab are abundant in the Bering Sea; whales, seals, and seabirds migrate there every year. In winter, the topography, latitude, atmosphere, and ocean circulation combine to produce a sea ice advance in the

Bering Sea unmatched elsewhere in the Northern Hemisphere, and in spring the retreating ice; longer daylight hours; and nutrient-rich, deep-ocean waters forced up onto the broad continental shelf result in intense marine productivity (Figure 1). This seasonal ice cover is a major driver of Bering Sea ecology, making this ecosystem particularly sensitive to changes in climate. Predicted changes in ice cover in the coming decades have intensified concern about the future of this economically and culturally important region. In response, the North Pacific Research Board (NPRB) and the U.S. National Science Foundation (NSF) entered into a partnership in 2007 to support the Bering Sea Project, a comprehensive $52 million investigation to understand how climate change is affecting the Bering Sea ecosystem, ranging from lower trophic levels (e.g., plankton) to fish, seabirds, marine mammals, and, ultimately, humans. The project integrates two research programs, the NSF Bering Ecosystem Study (BEST) and the NPRB Bering Sea Integrated Ecosystem Research Program (BSIERP), with substantial in-kind contributions from the U.S. National Oceanic and Atmospheric Administration (NOAA) and the U.S. Fish and Wildlife Service.

Sigler, M. F., M. Renner, S. L. Danielson, L. B. Eisner, R. R. Lauth, K. J. Kuletz, E. A. Logerwell, and G. L. Hunt. 2011. Fluxes, fins, and feathers: Relationships among the Bering, Chukchi, and Beaufort Seas in a time of climate change. Oceanography. 24(3):250-265. http://www.jstor.org/stable/24861320

Keywords**:** climate change; marine ecosystem; fisheries; cultural issues; sea ice; ecosystem shifts; Bering Sea; Chukchi Sea; Beaufort Sea; St Lawrence Island

Abstract**:** Ocean currents, water masses, and seasonal sea ice formation determine linkages among and barriers between the biotas of the Bering, Chukchi, and Beaufort Seas. The Bering Sea communicates with the Chukchi and Beaufort Seas via northward advection of water, nutrients, and plankton through Bering Strait. However, continuity of the ocean's physical properties is modulated by regional differences in heat, salt, and sea ice budgets, in particular, along the meridional gradient. Using summer density data from zooplankton, fish (bottom and surface trawl), and seabird surveys, we define three biogeographic provinces: the Eastern Bering Shelf Province (the eastern Bering Sea shelf south of Saint Lawrence Island), the Chirikov-Chukchi Province (the eastern Bering Sea shelf north of Saint Lawrence Island [Chirikov Basin] and Chukchi Sea), and the Beaufort Sea Province. Regional differences in summer distributions of biota largely reflect the underlying oceanography. Climate warming will reduce the duration and possibly the extent of seasonal ice cover in the Eastern Bering Shelf Province, but this warming may not lead to increased abundance of some subarctic species because seasonal ice cover and cold (< 2°C) bottom waters on the Bering shelf form a barrier to the northward migration of subarctic bottom fish species typical of the southeastern Bering Sea. While Arctic species that are dependent upon the summer extent of sea ice face an uncertain future, other Arctic species' resilience to a changing climate will be derived from waters that continue to freeze each winter.

Sigler, M. F., F. J. Mueter, B. A. Bluhm, M. S. Busby, E. D. Cokelet, S. L. Danielson, A. D. Robertis, L. B. Eisner, E. V. Farley, K. Iken, K. J. Kuletz, R. R. Lauth, E. A. Logerwell, and A. I. Pinchuk. 2017. Late summer zoogeography of the northern Bering and Chukchi seas. Deep Sea Research Part II: Topical Studies in Oceanography. 135:168-189. https://doi.org/10.1016/j.dsr2.2016.03.005

Keywords**:** Bering Sea; Chukchi Sea; zoogeography; zooplankton; fishes; invertebrates; seabirds

Abstract**:** Ocean currents, water masses, and seasonal sea ice formation contribute to determining relationships among the biota of the Bering and Chukchi seas. The Bering Sea communicates with the Chukchi Sea via northward advection of water, nutrients, organic matter, and plankton through Bering Strait. We used data from concurrent surveys of zooplankton, pelagic fishes and jellyfish, epibenthic fishes and invertebrates, and seabirds to identify faunal distribution patterns and environmental factors that are related to these faunal distributions within the US portions of the Chukchi Sea shelf and Bering Sea shelf north of Nunivak Island. Regional differences in late summer (August–September) distributions of biota largely reflected the underlying hydrography. Depth, temperature, salinity, stratification, and chlorophyll a, but less so sediment-related or nutrient-related factors, were related to the distributions of the assemblages (zooplankton: depth, salinity, stratification; pelagic fishes and jellyfish: depth, stratification, chlorophyll a; epibenthic fishes and invertebrates: depth, temperature, salinity; seabirds: temperature, salinity, stratification). These six environmental factors that most influenced distributions of zooplankton, pelagic fishes/jellyfish, epibenthic fishes and invertebrate, and seabird assemblages likely can be simplified to three factors reflecting bottom depth, water mass, and their stratification and productivity (which are tightly linked in the study region). The assemblages were principally structured from nearshore to offshore and from south to north. The nearshore to offshore contrast usually was stronger in the south, where the enormous discharge of the Yukon River is more apparent and extends farther offshore, influencing zooplankton, pelagic fish/jellyfish, and seabird assemblages. Some assemblages overlapped spatially (e.g., seabird and zooplankton), indicating shared influential environmental factors or trophic linkages among assemblages. The gradients in assemblage composition were gradual for epibenthic taxa, abrupt for zooplankton taxa, and intermediate for pelagic fish/jellyfish and seabird taxa, implying that zooplankton assemblage structure is most strongly tied to water mass, epibenthic least, with the other two taxa intermediates. Three communities (i.e., cross-assemblage groupings) emerged based on maps of ordination axes and core use areas by taxa; one associated with Alaska Coastal Water (warmer, fresher, nutrient depauperate), second associated with Chirikov Basin and the southern Chukchi Sea (colder, saltier, nutrient rich), and third associated with the northern Chukchi shelf (colder and saltier but not as nutrient rich). Gradients in species composition occurred both within and between these communities. The Chirikov Basin/southern Chukchi Sea community was characterized by distinct zooplankton and seabird taxa, but was not strongly associated with distinct pelagic or epibenthic fish and invertebrate taxa. Although comprehensive data were only available for a single year and

annual variation may affect the generality of our results, our comprehensive ecosystem survey approach yielded new insights into the ecological relationships (specifically, gradients in assemblage composition and identification of communities) of this Arctic region.

Simpkins, M. A., L. M. Hiruki-Raring, G. Sheffield, J. M. Grebmeier, and J. L. Bengtson. 2003. Habitat selection by ice-associated pinnipeds near St. Lawrence Island, Alaska in March 2001. Polar Biology. 26(9):577-586. https://doi.org/10.1007/s00300-003-0527-7

***Keywords*:** seals; walrus; sea ice; marine mammals; St Lawrence Island

***Abstract*:** Aerial surveys of ice-associated pinnipeds were conducted south of St. Lawrence Island in March 2001. The observed distributions of bearded seals (*Erignathus barbatus*), ribbon seals (*Phoca fasciata*), ringed seals (*P. hispida*), spotted seals (*P. largha*), and walruses (*Odobenus rosmarus*) were compared to the distributions of ice habitat types and benthic communities. Randomization tests were used to investigate habitat selection for each species. Both ringed seals and walruses preferred large ice floes (>48 m in diameter) that were common in the interior ice pack. Spotted seals favored smaller ice floes (<20 m in diameter) common near the ice edge, and bearded seals avoided large floes and preferred transitional habitat between small and large floes. Ringed seals also seemed to prefer areas with greater than 90% sea ice coverage, and bearded seals preferred 70–90% sea ice coverage while avoiding areas with greater than 90% coverage. All species, except spotted seals, were seen most frequently in a region of high benthic biomass, and randomization tests suggested that bearded seals actively selected that region.

Skolnik, J., C. D. Holleyman, J. Schwochert, and Jack Faucett Associates. 2002. Sub-Arctic economic impact model for petroleum activities in Alaska (Sub-Arctic IMPAK). U.S. Dep. Interior, Minerals Management Service. OCS Study 2002-060. Obligation No.: 01-00-PO-17115 & 01-02-PO-85307. Technical Report No. 165. 107 p. https://espis.boem.gov/final%20reports/3395.pdf

***Keywords*:** IMPLAN; OCS Sub-Arctic Subregion; oil Industry; economic impacts; employment; earnings; input-output; manpower

***Abstract*:** Production of oil and gas in the offshore Alaskan Arctic relies upon a set of technologies unlike those used anywhere else in the world. Remote locations temperatures of 60 degrees below zero and shifting ice flows that rule out traditional platforms waterborne craft and sea-floor pipelines are just a few of the challenges that must be overcome. The solutions include roads and islands built of ice man-made gravel islands pipelines buried below the ocean floor and cold weather retrofitted vehicles and equipment that are run for years without ever being turned-off. Economic impact modeling of these activities also requires a set of methods that are unique. Readily available regional economic impact models contain production functions that are based on national averages. These national-level input coefficients cannot accurately reflect the unique arctic

production function. These models are also unable to accurately trace the regional distribution of purchases made by the industry or the workers who commute to the site. Finally, these readily available models do not have enough detail to accurately model the differing impact of specific projects. This report describes the development of a first step model that can be combined with a readily available regional model to produce more accurate estimates of economic impacts. The first step model utilizes vectors of purchases disaggregated by both geographic area and activity to allow a more accurate accounting of the inputs required for a specific project. The vectors are constructed by coding detailed engineering estimates of inputs to the individual activities. These direct inputs can then be used to stimulate the standard regional impact models.

Song, X., Y. Bai, W.-J. Cai, C.-T. A. Chen, D. Pan, X. He, and Q. Zhu. 2016. Remote sensing of sea surface pCO_2 in the Bering Sea in summer based on a mechanistic semi-analytical algorithm (MeSAA). Remote Sensing. 8(7):558. https://www.mdpi.com/2072-4292/8/7/558

***Keywords*:** satellite imagery; carbon; phytoplankton; chlorophyll; ecosystems; Bering Sea

***Abstract*:** The Bering Sea, one of the largest and most productive marginal seas, is a crucial carbon sink for the marine carbonate system. However, restricted by the tough observation conditions, few underway datasets of sea surface partial pressure of carbon dioxide (pCO_2) have been obtained, with most of them in the eastern areas. Satellite remote sensing data can provide valuable information covered by a large area synchronously with high temporal resolution for assessments of pCO_2 that subsequently allow quantification of air-sea carbon dioxide 2 flux. However, pCO_2 in the Bering Sea is controlled by multiple factors and thus it is hard to develop a remote sensing algorithm with empirical regression methods. In this paper pCO_2 in the Bering Sea from July to September was derived based on a mechanistic semi-analytical algorithm (MeSAA). It was assumed that the observed pCO_2 can be analytically expressed as the sum of individual components controlled by major factors. First, a reference water mass that was minimally influenced by biology and mixing was identified in the central basin, and then thermodynamic and biological effects were parameterized for the entire area. Finally, we estimated pCO_2 with satellite temperature and chlorophyll data. Satellite results agreed well with the underway observations. Our study suggested that throughout the Bering Sea the biological effect on pCO_2 was more than twice as important as temperature, and contributions of other effects were relatively small. Furthermore, satellite observations demonstrate that the spring phytoplankton bloom had a delayed effect on summer pCO_2 but that the influence of this biological event varied regionally; it was more significant on the continental slope, with a later bloom, than that on the shelf with an early bloom. Overall, the MeSAA algorithm was not only able to estimate pCO_2 in the Bering Sea for the first time, but also provided a quantitative analysis of the contribution of various processes that influence pCO_2.

Speckman, S. G., V. I. Chernook, D. M. Burn, M. S. Udevitz, A. A. Kochnev, A. Vasilev, C. V. Jay, A. Lisovsky, A. S. Fischbach, and R. B. Benter. 2011. Results and evaluation of a survey to estimate Pacific walrus population size, 20061. Marine Mammal Science. 27(3):514-553. https://doi.org/10.1111/j.1748-7692.2010.00419.x

***Keywords*:** walrus; marine mammals; Bering Sea

***Abstract*:** In spring 2006, we conducted a collaborative U.S.–Russia survey to estimate abundance of the Pacific walrus (*Odobenus rosmarus divergens*). The Bering Sea was partitioned into survey blocks, and a systematic random sample of transects within a subset of the blocks was surveyed with airborne thermal scanners using standard strip-transect methodology. Counts of walruses in photographed groups were used to model the relation between thermal signatures and the number of walruses in groups, which was used to estimate the number of walruses in groups that were detected by the scanner but not photographed. We also modeled the probability of thermally detecting various-sized walrus groups to estimate the number of walruses in groups undetected by the scanner. We used data from radio-tagged walruses to adjust on-ice estimates to account for walruses in the water during the survey. The estimated area of available habitat averaged 668,000 km^2 and the area of surveyed blocks was 318,204 $km^{2.}$ The number of Pacific walruses within the surveyed area was estimated at 129,000 with 95% confidence limits of 55,000–507,000 individuals. Poor weather conditions precluded surveying in other areas; therefore, this value represents the number of Pacific walruses within about half of potential walrus habitat.

Springer, A., D. Roseneau, B. Cooper, P. Martin, A. D. McGuire, E. Murphy, and G. van Vliet. 1985. Population and trophics studies of seabirds in the northern Bering and eastern Chukchi Seas, 1983. U.S. Dep. of Interior, MMS and U.S. Dep. of Commerce, NOAA. OCS Environmental Assessment Program. RU-460. 243-305 p. Fairbanks, Alaska. https://www.researchgate.net/publication/275831568_Population_and_trophics_studies_of_seabirds_in_the_northern_Bering_and_eastern_Chukchi_Seas_1983

***Keywords*:** St Matthew Hall; Norton Basin; Hope Basin; Chukchi Sea; Alaska; biology; seabirds; Bering Strait; behavior; distribution; breeding; nesting; feeding; St Lawrence Island; Norton Sound; survey; aerial observations; diversity; abundance; shorebirds; birds; murre; kittiwake; auklet; puffin; cormorant; Alaska region

***Abstract*:** The objectives of this study were to monitor population numbers, reproductive success and food habits of key seabird species in the Bering and Chukchi seas. The work was undertaken in order to understand the relationships of seabird populations to the physical and biological processes controlling regional marine communities.

Springer, A. M., E. C. Murphy, D. G. Roseneau, C. P. McRoy, and B. A. Cooper. 1987. The paradox of pelagic food webs in the northern Bering Sea—I. Seabird food habits. Continental Shelf Research. 7(8):895-911. https://doi.org/10.1016/0278-4343(87)90005-7

***Keywords*:** Seabirds; fish; zooplankton; plankton; ecosystem; Bering Sea; Chukchi Sea; Yukon River; Bering Strait

***Abstract*:** Two distinct environmental settings in the Bering Strait region of the northern Bering Sea lead to characteristic pathways of energy flow through primarily pelagic food webs to avian consumers. In Norton Sound, a large, shallow embayment on the northeastern coast, the physical environment is dominated by the discharge of the Yukon River and by a large seasonal temperature signal. Seabirds breeding at Bluff, the largest colony in Norton Sound, number in the order of 5×10^4 and require 1.2×10^6 g C d^{-1}. Two piscivorous species constitute the bulk of all seabirds there and are supported by a pelagic food web typical of the coastal zone of the Bering and Chukchi seas. This food web also is present around St. Lawrence Island, on the northwestern shelf, and is important to at least one species of seabird there. In addition, and generally more important, St. Lawrence Island is in a biologically rich environment resulting from the northward flow of water that originates along the continental shelf break of the Bering Sea. This flow apparently accounts for the unexpected presence of oceanic zooplankton and a diversity of forage fishes on the shallow northern shelf that support an abundant and taxonomically rich avifauna. In comparison to Norton Sound, breeding seabirds on St. Lawrence Island number in the order of 2×10^6, with planktivores consuming about 8×10^6 g C d^{-1} and piscivores consuming about 16×10^6 g C d^{-1}.

Springer, A. M., C. P. McRoy, and K. R. Turco. 1989. The paradox of pelagic food webs in the northern Bering Sea—II. Zooplankton communities. Continental Shelf Research. 9(4):359-386. https://doi.org/10.1016/0278-4343(89)90039-3

***Keywords*:** nutrients; zooplankton; plankton; ecosystem; Bering Sea; Chukchi Sea

***Abstract*:** Anadyr Water, a "river" of oceanic water originating over the continental slope of the Bering Sea, transports oceanic zooplankton onto the shallow northern shelf and into the Chukchi Sea through western Bering Strait. The oceanic copepods *Neocalanus cristatus*, *N. plumchrus*, *Eucalanus bungii* and *Metridia pacifica* dominated the biomass of herbivorous zooplankton in Anadyr Water on the Bering-Chukchi shelf, averaging about 5 g m^{-2} (dry weight) in midsummer and 2 g m^{-2} in later summer of 1985 and 1986. The biomass of copepods was at times augmented considerably by that of a larvacean, *Oikopleura* spp. Oceanic water was replaced to the east, and often overlain by, lighter water formed on the continental shelf. The oceanic species were not present in waters of shelf origin, where *Calanus marshallae* was the major herbivore, averaging about 1 g m^{-2} in summer 1985, but only 0.2–0.5 g m^{-2} in 1986. In the low salinity, nearshore water, *C. marshallae* was uncommon and *Pseudocalanus* spp. and *Acartia longiremis* predominated. A preliminary estimate indicated that in the order of 1.8×10^{12} g C of boreal zooplankton were carried into the Chukchi Sea during summer 1985. On average, the grazers were unable to control prodigious diatom growth that resulted from concentrated nutrients also carried by Anadyr Water into the area. In contrast, the smaller biomass of grazers in the shelf community, away from the region of high diatom biomass, might have had a much greater influence

over the standing stock of phytoplankton following the spring bloom, and, at times, could have consumed the daily primary production. The highly productive pelagic food web of oceanic origin in the north does not have close coupling between primary producers and zooplankton, or between zooplankton and their predators, and contrasts with the oceanic community in the southeastern Bering Sea, where the same species of herbivores apparently have a much greater effect on phytoplankton biomass, and provide an efficient transfer of the available fixed energy to upper trophic levels in pelagic food webs.

Springer, A. M., and C. P. McRoy. 1993. The paradox of pelagic food webs in the northern Bering Sea—III. Patterns of primary production. Continental Shelf Research. 13(5-6):575-599. https://doi.org/10.1016/0278-4343(93)90095-f

Keywords**:** nutrients; phytoplankton; plankton; ecosystem; Bering Sea; Chukchi Sea

Abstract**:** The advective supply of nutrients to the Bering-Chukchi continental shelf via a north-flowing "river" of oceanic water originating along the continental slope in the Bering Sea maintains a large portion of these shelf waters in eutrophic bloom summer-long. Known as the Anadyr Stream, this nutrient injection sustains conditions of high phytoplankton productivity and biomass in a region of the western Arctic that would otherwise be unproductive, as are adjacent shelf areas unaffected by the current. A production plume dominated by large chain-forming diatoms extends from the Gulf of Anadyr in the south to the southern Chukchi Sea in the north, has daily carbon uptake rates as high as 16 g C m^{-2} day^{-1}, and has an estimated annual production of about 470 g C m^{-2} $year^{-1}$. Maximum production occurs in three pools of especially prolific growth (Gulf of Anadyr, Chirikov Basin and southern Chukchi Sea) where rates could be as great as 720–840 g C m^{-2} $year^{-1}$. Outside of the plume, nutrients remain low following the spring bloom and a typical successional flora is dominated by flagellates and small diatoms throughout summer. Post-bloom productivity in this region is generally about 0.5 g C m^{-2} day^{-1}, and annual production is approximately 80 g C m^{-2} $year^{-1}$. The contrasting primary production regimes lead to major differences in food webs and in the energy transferred to higher trophic levels within the western Arctic.

Stabeno, P. J., E. V. Farley Jr, N. B. Kachel, S. Moore, C. W. Mordy, J. M. Napp, J. E. Overland, A. I. Pinchuk, and M. F. Sigler. 2012. A comparison of the physics of the northern and southern shelves of the eastern Bering Sea and some implications for the ecosystem. Deep Sea Research Part II: Topical Studies in Oceanography. 65-70:14-30. https://doi.org/10.1016/j.dsr2.2012.02.019

Keywords**:** Bering Sea; ecosystem; climate; hydrography; sea ice; zooplankton; whales; fish

Abstract**:** Sufficient oceanographic measurements have been made in recent years to describe the latitudinal variation in the physics of the eastern Bering Sea shelf and the potential impact of climate change on the species assemblages in the two ecosystems (north and south). Many of the predicted ecosystem changes will result from alterations in

the timing and extent of sea ice. It is predicted that the sea ice in the northern Bering Sea will be less common in May, but will continue to be extensive through April. In contrast, the southern shelf will have, on average, much less sea ice than currently observed, but with large interannual and multiyear variability until at least 2050. Thus, even under current climate warming scenarios, bottom temperatures on the northern shelf will remain cold. Based on biophysical measurements, the southern and northern ecosystems were divided by a North-South Transition at ~60°N. The northern middle shelf was characterized by a freshwater lens at the surface, cold bottom temperatures, and a thicker pycnocline than found on the southern shelf. Subsurface phytoplankton blooms were common. In contrast, the southern shelf stratification was largely determined by temperature alone; the pycnocline was thin (often <3 m) and subsurface blooms were uncommon. Biological responses to climate warming could include greater north-south differences in zooplankton community structure, the transport of large Outer Shelf Domain crustacean zooplankton to the middle shelf, and the disappearance of two principal prey taxa (*Calanus* spp. and *Thysanoessa* spp.) of planktivorous fish, seabirds and whales. The response of commercially and ecologically important fish species is predicted to vary. Some species of fish (e.g., juvenile sockeye salmon, *Oncorhynchus nerka*) may expand their summer range into the northern Bering Sea; some (e.g., pink salmon, *O. gorbuscha*) may increase in abundance while still other species (e.g., walleye pollock and arrowtooth flounder; *Theragra chalcogramma* and *Atheresthes stomias*, respectively) are unlikely to become common in the north. The projected warming of the southern shelf will limit the distribution of arctic species (e.g., snow crab, *Chionoecetes opilio*) to the northern shelf and will likely permit expansion of subarctic species into the southern Bering Sea. The distribution and abundance of baleen whales will respond to shifts in prey availability; for instance, if prey are advected northward from the southeastern Bering Sea, an extension of range and an increase in seasonally migratory baleen whale numbers is anticipated. Thus, alteration of this ecosystem in response to climate change is expected to result in something other than a simple northward shift in the distribution of all species.

Stabeno, P. J., N. B. Kachel, S. E. Moore, J. M. Napp, M. Sigler, A. Yamaguchi, and A. N. Zerbini. 2012. Comparison of warm and cold years on the southeastern Bering Sea shelf and some implications for the ecosystem. Deep Sea Research Part II: Topical Studies in Oceanography. 65-70:31-45. https://doi.org/10.1016/j.dsr2.2012.02.020

Keywords**:** Bering Sea; interannual variability; ocean currents; ecosystem; climate; zooplankton

Abstract**:** The southeastern, middle shelf of the Bering Sea has exhibited extreme variability in sea ice extent, temperature, and the distribution and abundance of species at multiple trophic levels over the past four decades. From 1972–2000, there was high interannual variability of areal extent of sea ice during spring (March–April). In 2000, this shifted to a 5-year (2001–2005) period of low ice extent during spring, which transitioned to a 4-year (2007–2010) period of extensive sea ice. High (low) areal extent of sea ice in spring was associated with cold (warm) water column temperatures for the following 6–7 months. The

ocean currents also differed between warm and cold years. During cold years, the monthly-mean currents over the shelf were largely westward, while in warm years the direction of currents was more variable, with northward flow during December–February and relatively weak flow during the remainder of the year. The types and abundance of zooplankton differed sharply between warm and cold years. This was especially true during the prolonged warm period (2001–2005) and cold period (2007–2010), and was less evident during the years of high interannual variability. During the warm period, there was a lack of large copepods and euphausiids over the shelf; however, their populations rebounded during cold period. Small crustacean zooplankton taxa did not appear to vary between and warm and cold years. For both walleye pollock and Pacific cod, year-class strength (recruitment) was low during the prolonged warm period, but improved during the following cold period. Year-class strength did not appear to vary as a function of warm and cold years during the period of high year-to-year variability. Also, recruitment of arrowtooth flounder (a predator of pollock and cod) did not appear influenced by the warm or cold years. Finally, the distribution and relative abundance of fin whales appeared to differ in warm and cold years, with fewer whales on the southeastern, middle shelf during warm years.

Stabeno, P. J., and S. W. Bell. 2019. Extreme Conditions in the Bering Sea (2017–2018): Record-Breaking Low Sea-Ice Extent. Geophysical Research Letters. 46(15):8952-8959. https://doi.org/10.1029/2019GL083816

Keywords**:** Bering Sea; ecosystem; climate; hydrography; sea ice

Abstract**:** The lowest winter-maximum areal sea-ice coverage on record (1980–2019) in the Bering Sea occurred in the winter of 2017/2018. Sea ice arrived late due to warm southerly winds in November. More typical northerly winds (albeit warm) in December and January advanced the ice, but strong, warm southerlies in February and March forced the ice to retreat. The cold pool (shelf region with bottom water < 2°C) was the smallest on record, because of two related mechanisms: (1) lack of direct cooling in winter by melting sea ice and (2) weaker vertical stratification (no ice melt reduced the vertical salinity gradient) allowing surface heating to penetrate into the near bottom water during summer. February 2019 exhibited another outbreak of warm southerly winds forcing ice to retreat. The number of >31-day outbreaks of southerly winds in winter has increased since 2016.

Stabeno, P. J., S. W. Bell, N. A. Bond, D. G. Kimmel, C. W. Mordy, and M. E. Sullivan. 2019. Distributed biological observatory region 1: Physics, chemistry and plankton in the northern Bering Sea. Deep Sea Research Part II: Topical Studies in Oceanography. 162:8-21. https://doi.org/10.1016/j.dsr2.2018.11.006

Keywords**:** Bering Sea; Chukchi Sea; ecosystem; climate; hydrography; salinity

Abstract**:** Historically, the northern Bering Sea has been largely ice covered for 5–6 months each year. From 1980 to 2014, there was considerable variability in the timing of ice arrival

and retreat, but there was no significant trend in these variables. During three of the last four years (2014–2015, 2016–2017, 2017–2018) ice has arrived later and retreated earlier, resulting in a shorter ice season. These changes may be related to the delayed arrival of sea ice in the Chukchi Sea, under the paradigm that the Chukchi Sea freezes before the northern Bering Sea. Under such a sequence of events, the continued delay in arrival of sea ice in the Chukchi Sea will in turn delay the arrival of ice in the northern (and hence southern) Bering Sea; thus, past predictions that the northern Bering Sea will remain cold for the foreseeable future may be in question. In the northern Bering Sea, periods of 10–15 years with extensive ice in December and January are interrupted by shorter periods (2–5 years) of less extensive ice cover. The periods of low ice cover in December and January in the northern Bering Sea tend to coincide with periods of low ice cover in March and April in the southern Bering Sea. Sea ice impacts the marine ecosystem in multiple ways: early retreat of sea ice is correlated with warmer sea surface temperatures in the summer; delayed arrival of sea ice results in warmer bottom temperatures in fall and winter; multiple, consecutive years of extensive ice appear to be related to decreasing salinity and nutrients (nitrate and phosphate); and the timing of ice retreat influences the life cycle of *Calanus* spp. as warmer waters increase their development rate.

Stafford, K. M., M. Castellote, M. Guerra, and C. L. Berchok. 2018. Seasonal acoustic environments of beluga and bowhead whale core-use regions in the Pacific Arctic. Deep Sea Research Part II: Topical Studies in Oceanography. 152:108-120. https://doi.org/10.1016/j.dsr2.2017.08.003

Keywords**:** Arctic zone; ambient noise; bowhead whale; beluga whale; marine mammal

Abstract**:** The acoustic environment of two focal Arctic species, bowhead (*Balaena mysticetus*) and beluga (*Delphinapterus leucas*) whales, varied among the three core-use regions of the Pacific Arctic examined during the months in which both species occur: (1) January-March in the St. Lawrence Island/Anadyr Strait region, (2) November-January in the Bering Strait region, and (3) August-October in the Barrow Canyon region. Biological noise (consisting of the signals of bowhead whales, walrus and bearded seals) dominated the acoustic environment for the focal species in the St. Lawrence Island/Anadyr Strait region, which was covered with ice throughout the months studied. In the Bering Strait region whales were exposed primarily to environmental noise (in the form of wind noise) during November, before the region was ice-covered in December, and biological noise (from bowhead and walrus) again was prevalent. Anthropogenic noise dominated the Barrow Canyon region for the focal species in late summer and fall (August through October); this was also the only region in which the two species did not overlap with sea ice. Under open water conditions both near Barrow Canyon and in Bering Strait, noise levels were tightly correlated with wind. However, with climate-change driven increases in open water leading to rising noise levels across multiple fronts (atmospheric, biological, anthropogenic), the relatively pristine acoustic environment of Arctic cetaceans is changing rapidly. Characterizing the acoustic habitat of these regions before they are further altered should be considered a management and conservation priority in the Arctic.

Stevenson, D. E., and R. R. Lauth. 2018. Bottom trawl surveys in the northern Bering Sea indicate recent shifts in the distribution of marine species. Polar Biology. 42(2):407-421. https://doi.org/10.1007/s00300-018-2431-1

Keywords**:** cold pool; climate shift; Arctic; biogeography

Abstract**:** The climate regime in the eastern Bering Sea has recently been dominated by a pattern of multi-year stanzas, in which several successive years of minimal sea-ice formation and warm summer temperatures (e.g., 2002–2005, 2014–2017) alternate with several years of relatively extensive sea-ice formation and cold summer temperatures (e.g., 2006–2013). This emerging climate pattern may be forcing long-term changes in the spatial distributions of the Bering Sea's marine fauna. The National Marine Fisheries Service's Alaska Fisheries Science Center recently conducted two bottom trawl surveys covering the entire Bering Sea shelf from the Alaska Peninsula to the Bering Strait. The first, in the summer of 2010, was conducted during a cold year when the majority of the continental shelf was covered by a pool of cold (< 2°C) water. The second, in the summer of 2017, was during a warmer year with water temperatures above the long-term survey mean. These two surveys recorded significantly different spatial distributions for populations of several commercially important fish species, including walleye pollock (Gadus chalcogrammus), Pacific cod (*Gadus macrocephalus*), and several flatfish species, as well as jellyfishes. Population shifts included latitudinal displacement as well as variable recruitment success. The large-scale distributional shifts reported here for high-biomass species raise questions about long-term ecosystem impacts, and highlight the need for continued monitoring. They also raise questions about our management strategies for these and other species in Alaska's large marine ecosystems.

Stone, R. P., and S. D. Cairns. 2017. Deep-sea coral taxa in the Alaska region: Depth and geographical distribution. Online resource. https://repository.si.edu/handle/10088/34994

Keywords**:** coral; Alaska

Abstract**:** In summary, we have confirmed the presence of 137 unique coral taxa in Alaskan waters. Octocorals were the most speciose (89 taxa total), followed by hydrocorals (24 taxa), antipatharians (12 taxa) and scleractinians (12 taxa). The Aleutian Islands region has the most taxa (n=96), followed by the Gulf of Alaska Seamount Province (n=42), the eastern Gulf of Alaska (n=39), the western Gulf of Alaska (n=24), and the Bering Sea (n=18 taxa). Only a single coral species is known from the Arctic Region. Black corals (Order Antipatharia) were found over a depth range of 401-4685 m throughout the Alaska Region, scleractinians (Order Scleractinia) were found over a depth range of 17-6328 m, octocorals (Orders Alcyonacea and Pennatulacea) were found over a depth range of 3-4784 m, and hydrocorals (Order Anthoathecata) had the narrowest depth range of 10-2124 m in the region.

Takahashi, A., J.-B. Thiebot, A. Will, S. Tsukamoto, B. Merkel, and A. Kitaysky. 2021. Breeding together, wintering an ocean apart: Foraging ecology of the northern Bering Sea thick-billed and common murres in years of contrasting sea-ice conditions. Polar Science. 27:100552. https://doi.org/10.1016/j.polar.2020.100552

***Keywords*:** corticosterone; diving; migration; seabird; stable isotopes

***Abstract*:** Assessing impacts of environmental change on Arctic-breeding seabirds requires a better understanding of their year-round movement and foraging ecology. Here we examined the post-breeding movements and diving behavior of thick-billed (*Uria lomvia*) and common murres (*U. aalge*) breeding on St. Lawrence Island, northern Bering Sea, by using geolocators deployed in 2016 (n = 3, per species). During 2016–2019, we examined foraging niches and exposure to nutritional stress by using stable isotope signatures and corticosterone titers of blood and feather tissues (n = 60–96, per species). We found that thick-billed murres migrated to the Chukchi Sea in the fall and wintered in the western North Pacific, whereas common murres stayed in the eastern Bering Sea in the fall and wintered in the eastern North Pacific. Nutritional stress levels of breeding common murres were higher in 2017–2019, the period of historic low winter sea-ice extent, than in 2016. Higher nutritional stress levels of post-breeding thick-billed murres were associated with lower fall sea-ice extent in the Chukchi Sea. These results indicate that the loss of sea-ice might negatively affect murres breeding in the Pacific Arctic. Divergent migratory connectivity between the two murre species might also lead to different conservation threats both inside and outside the Arctic.

Temnykh, O. S., A. V. Zavolokin, and M. V. Koval. 2010. Russian salmon research under the NPAFC science plan 2006-2010: A review and future issues. North Pacific Anadromous Fish Commission. Pacific Research Fisheries Center (TINRO-Center). NPAFC Doc. 1238. 23 p. Vladivostok, Russia. https://www.researchgate.net/publication/273124000

***Keywords*:** fisheries; salmon; stock assessment; BASIS

***Abstract*:** Russian Salmon studies in 2006-2010 were conducted in accordance with the Far Eastern research program of Pacific salmon (Shuntov, 2008). These investigations have been integral part of the five-year science plan "Status and Trends in Production of Anadromous Stocks in Ocean Ecosystems" the main themes of which were three major research components: (1) Juvenile Anadromous Stocks in Ocean Ecosystems; (2) Anadromous Stocks in the Bering Sea Ecosystem (BASIS); and (3) Anadromous Stocks in the Western Subarctic Gyre and Gulf of Alaska Ecosystems. The purposes of this paper are to review the results of Russian salmon research related with the present Science Plan, and to propose future research for the appropriate conservation and utilization of Pacific salmon.

Thorsteinson, L. K., P. R. Becker, and D. A. Hale. 1989. The Yukon Delta, a synthesis of information. U.S. Dep. of Interior, MMS and U.S. Dep. of Commerce, NOAA. OCS Study 89-0081. Obligation No.: RU-696. 93 p. https://espis.boem.gov/final%20reports/2869.pdf

***Keywords*:** Yukon River; birds; fish; marine mammals; ecosystem; geology; nutrients; currents; river system; delta

***Abstract*:** This report provides a synthesis of environmental information on the Yukon Delta, primarily using results from studies conducted since 1983. The synthesis characterizes the major physical properties and resources of the Yukon Delta and identifies regional trends in biological use of major habitats. The Yukon Delta provides important seasonal habitat for numerous species of migratory birds, fish, and some marine mammals. The delta is characterized as a "pass-through" system or exporting-type estuary, where physical processes (river flooding, ice transport, coastal currents, and tidal mixing) and biological processes (metabolism and migration) annually remove wetland energy reserves (plants, invertebrates, and fish). The majority of river-borne particulate matter and dissolved nutrients are transported offshore with the Yukon River plume into the inner shelf waters of the northern Bering Sea. Juvenile salmon residence in the nearshore habitats is brief. Most salmon smelts appear to be carried 20 to 30 km offshore to the delta front by strong river currents during periods of outmigration. The delta front and inner shelf waters of Norton Sound might function as an "offshore estuary" for salmon by providing an area for the juveniles to physiologically adapt to the marine environment. Coastal mudflat and slough habitats are intermediate transition zones between terrestrial and estuarine/marine systems and might provide important areas for nutrient cycling and processing within the Yukon Delta. Calculation of waterbird energy requirements indicates an increase in the importance of coastal mud flats in the fall to swans, dabbling ducks, and shorebirds through providing an easily accessible source of food in the form of plants and invertebrates. Aquatic insects and meiofauna appear to be key components of deltaic food webs. They provide an abundant source of food for shorebirds and outmigrating fish at the appropriate times of the year when these higher organisms are present.

Udevitz, M. S., D. M. Burn, and M. A. Webber. 2008. Estimation of walrus populations on sea ice with infrared imagery and aerial photography. Marine Mammal Science. 24(1):57-70. https://doi.org/10.1111/j.1748-7692.2007.00169.x

***Keywords*:** marine mammal; walrus; aerial observations; St Lawrence Island

***Abstract*:** Population sizes of ice-associated pinnipeds have often been estimated with visual or photographic aerial surveys, but these methods require relatively slow speeds and low altitudes, limiting the area they can cover. Recent developments in infrared imagery and its integration with digital photography could allow substantially larger areas to be surveyed and more accurate enumeration of individuals, thereby solving major problems with previous survey methods. We conducted a trial survey in April 2003 to estimate the number of Pacific walruses (*Odobenus rosmarus divergens*) hauled out on sea ice around St. Lawrence Island, Alaska. The survey used high altitude infrared imagery to detect groups of walruses on strip transects. Low altitude digital photography was used to determine the number of walruses in a sample of detected groups and calibrate the infrared imagery for estimating the total number of walruses. We propose a survey design incorporating this

approach with satellite radio telemetry to estimate the proportion of the population in the water and additional low-level flights to estimate the proportion of the hauled-out population in groups too small to be detected in the infrared imagery. We believe that this approach offers the potential for obtaining reliable population estimates for walruses and other ice-associated pinnipeds.

Ueno, H., M. Komatsu, Z. Ji, R. Dobashi, M. Muramatsu, H. Abe, K. Imai, A. Ooki, and T. Hirawake. 2020. Stratification in the northern Bering Sea in early summer of 2017 and 2018. Deep Sea Research Part II: Topical Studies in Oceanography. 181-182:104820. https://doi.org/10.1016/j.dsr2.2020.104820

Keywords**:** northern Bering Sea; stratification; interannual variation; in situ data

Abstract**:** We investigated spatial and interannual variation in the physical environment in the northern Bering Sea focusing on stratification, which is one factor affecting biological production in Arctic/subarctic regions. In particular, we analyzed in situ data obtained onboard the training ship Oshoro Maru in early summer in 2017 and 2018. We found that stratification in the areas just north of St. Lawrence Island (around 64.5°N and west of 168.5°W) and south/southwest of St. Lawrence Island was significantly weaker in 2018 than in 2017. These results are consistent with the extremely low sea-ice extent present in the winter of 2017/2018, which would have resulted in less freshwater being supplied to the surface layers and a warmer and less saline bottom water. Conversely, stratification was as strong in 2018 as in 2017 in the area close to the Alaska mainland, including the Bering Strait area, suggesting that the Alaskan Coastal Water dominates stratification in this area in early summer. Moreover, we found that the weakly stratified water column in the Bering Strait area stratified quickly shortly after the occurrence of strong northerly winds, likely because of the Ekman transport of warm and low-salinity Alaskan Coastal Water from the east.

Van Hemert, C. R., R. J. Dusek, M. M. Smith, R. Kaler, G. Sheffield, L. M. Divine, K. J. Kuletz, S. Knowles, J. S. Lankton, D. R. Hardison, R. W. Litaker, T. Jones, H. K. Burgess, and J. K. Parrish. 2021. Investigation of algal toxins in a multispecies seabird die-off in the Bering and Chukchi seas. Journal of Wildlife Diseases. 57(2):399-407. 10.7589/JWD-D-20-00057

Keywords**:** seabirds; neurotoxins; mortality events; climate change; Bering Sea; Chukchi Sea

Abstract**:** Between 2014 and 2017, widespread seabird mortality events were documented annually in the Bering and Chukchi seas, concurrent with dramatic reductions of sea ice, warmer than average ocean temperatures, and rapid shifts in marine ecosystems. Among other changes in the marine environment, harmful algal blooms (HABs) that produce the neurotoxins saxitoxin (STX) and domoic acid (DA) have been identified as a growing concern in this region. Although STX and DA have been documented in Alaska (US) for decades, current projections suggest that the incidence of HABs is likely to increase with climate warming and may pose a threat to marine birds and other wildlife. In 2017, a multispecies

die-off consisting of primarily Northern Fulmars (*Fulmarus glacialis*) and Short-tailed Shearwaters (*Ardenna tenuirostris*) occurred in the Bering and Chukchi seas. To evaluate whether algal toxins may have contributed to bird mortality, we tested carcasses collected from multiple locations in western and northern Alaska for STX and DA. We did not detect DA in any samples, but STX was present in 60% of all individuals tested and in 88% of Northern Fulmars. Toxin concentrations in Northern Fulmars were within the range of those reported from other STX-induced bird die-offs, suggesting that STX may have contributed to mortalities. However, direct neurotoxic action by STX could not be confirmed and starvation appeared to be the proximate cause of death among birds examined in this study.

Von Duyke, A. L., D. C. Douglas, J. K. Herreman, and J. A. Crawford. 2020. Ringed seal (*Pusa hispida*) seasonal movements, diving, and haul-out behavior in the Beaufort, Chukchi, and Bering Seas (2011–2017). Ecology and Evolution. 10(12):5595-5616. https://doi.org/10.1002/ece3.6302

Keywords**:** marine mammal; seals; sea ice; ecosystems; climate

Abstract**:** Continued Arctic warming and sea-ice loss will have important implications for the conservation of ringed seals, a highly ice-dependent species. A better understanding of their spatial ecology will help characterize emerging ecological trends and inform management decisions. We deployed satellite transmitters on ringed seals in the summers of 2011, 2014, and 2016 near Utqiaġvik (formerly Barrow), Alaska, to monitor their movements, diving, and haul-out behavior. We present analyses of tracking and dive data provided by 17 seals that were tracked until at least January of the following year. Seals mostly ranged north of Utqiaġvik in the Beaufort and Chukchi Seas during summer before moving into the southern Chukchi and Bering Seas during winter. In all seasons, ringed seals occupied a diversity of habitats and spatial distributions, from near shore and localized, to far offshore and wide-ranging in drifting sea ice. Continental shelf waters were occupied for >96% of tracking days, during which repetitive diving (suggestive of foraging) primarily to the seafloor was the most frequent activity. From mid-summer to early fall, 12 seals made ~1-week forays off-shelf to the deep Arctic Basin, most reaching the retreating pack-ice, where they spent most of their time hauled out. Diel activity patterns suggested greater allocation of foraging efforts to midday hours. Haul-out patterns were complementary, occurring mostly at night until April-May when midday hours were preferred. Ringed seals captured in 2011—concurrent with an unusual mortality event that affected all ice-seal species—differed morphologically and behaviorally from seals captured in other years. Speculations about the physiology of molting and its role in energetics, habitat use, and behavior are discussed; along with possible evidence of purported ringed seal ecotypes.

Waga, H., T. Hirawake, and J. M. Grebmeier. 2020. Recent change in benthic macrofaunal community composition in relation to physical forcing in the Pacific Arctic. Polar Biology. 43(4):285-294. https://doi.org/10.1007/s00300-020-02632-3

Keywords**:** benthos; macrofauna composition; Pacific arctic; diversity; volume transports

***Abstract*:** There is growing evidence that increased Pacific water transport into the Arctic affects the marine ecosystem. One of the theoretical predictions for a future Arctic characterized by such environmental change is that subarctic taxa will expand northward and invade the native Arctic ecosystem. This study focuses on variation in macrofaunal community composition and the influence of changing physical drivers at known benthic hotspots in the Pacific Arctic. The average number of macrofaunal family-level taxa has increased significantly south of St. Lawrence Island and in the Chirikov Basin, whereas the number of macrofaunal taxa in the southeastern Chukchi Sea showed no significant trend over the 2000–2013 time period. However, the Shannon–Weaver diversity index, based on abundance, did not mirror these regional changes in the number of macrofaunal taxa, indicating that the abundance of newly present taxa was negligible compared to the entire abundance already present. We also investigated temporal variations in meridional sea level gradient and local winds, which contribute 2/3 and 1/3 of the variation in northward volume transport at Bering Strait, respectively. There were significant increasing trends in the meridional sea level gradient and local winds, suggesting the increased northward seawater volume transports over the benthic hotspots could contribute to the expansion of subarctic taxa into these northern Arctic regions. Our data suggest an increase in macrofaunal taxa type with increasing current transport northward into the Pacific Arctic region that could have a strong influence in restructuring the benthic ecosystem in this region in the future.

Wang, M., J. E. Overland, and P. Stabeno. 2012. Future climate of the Bering and Chukchi Seas projected by global climate models. Deep Sea Research Part II: Topical Studies in Oceanography. 65-70:46-57. https://doi.org/10.1016/j.dsr2.2012.02.022

***Keywords*:** climate models; regional climate; projections; Bering Sea; Chukchi Sea

***Abstract*:** Atmosphere–Ocean General Circulation Models (AOGCMs) are a major tool used by scientists to study the complex interaction of processes that control climate and climate change. Projections from these models for the 21st century are the basis for the Fourth Assessment Report (AR4) produced by the Intergovernmental Panel on Climate Change (IPCC). Here, we use simulations from this set of climate models developed for the IPCC AR4 to provide a regional assessment of sea ice extent, sea surface temperature (SST), and surface air temperature (SAT) critical to future marine ecosystems in the Bering Sea and the Chukchi Sea. To reduce uncertainties associated with the model projections, a two-step model culling technique is applied based on comparison to 20th century observations. For the Chukchi Sea, data and model projections show major September sea ice extent reduction compared to the 20th century beginning now, with nearly sea ice free conditions before mid-century. Earlier sea ice loss continues throughout fall with major loss in December before the end of the 21st century. By 2050, for the eastern Bering Sea, spring sea ice extent (average of March to May) would be 58% of its recent values (1980–1999 mean). December will become increasingly sea ice free over the next 40 years. The Bering Sea will continue to show major interannual variability in sea ice extent and SST. The majority of models had no systematic bias in their 20th century simulated regional SAT, an

indication that the models may provide considerable credibility for the Bering and the Chukchi Sea ecosystem projections. Largest air temperature increases are in fall (November to December) for both the Chukchi and the Bering Sea, with increases by 2050 of 3°C for the Bering Sea and increases in excess of 5°C for the Chukchi Sea.

Wang, J., H. Hu, J. Goes, J. Miksis-Olds, C. Mouw, E. D'Sa, H. Gomes, D. R. Wang, K. Mizobata, S.-i. Saitoh, and L. Luo. 2013. A modeling study of seasonal variations of sea ice and plankton in the Bering and Chukchi Seas during 2007–2008. Journal of Geophysical Research: Oceans. 118(3):1520-1533. https://doi.org/10.1029/2012JC008322

Keywords**:** nutrients; phytoplankton; plankton; zooplankton; ecosystem; Bering Sea; Chukchi Sea

Abstract**:** A nutrient (N), phytoplankton (P), zooplankton (Z), and detritus (D) ecosystem model coupled to an ice-ocean model was applied to the Bering and Chukchi Seas for 2007–2008. The model reasonably reproduces the seasonal cycles of sea ice, phytoplankton, and zooplankton in the Bering–Chukchi Seas. The spatial variation of the phytoplankton bloom was predominantly controlled by the retreat of sea ice and the increased gradient of the water temperature from the south to the north. The model captures the basic structure of the measured nutrients and chl-a along the Bering shelf during 4–23 July 2008, and along the Chukchi shelf during 5–12 August 2007. In summer 2008, the Green Belt bloom was not observed by either the satellite measurements or the model. The model-data comparison and analysis reveal the complexity of the lower trophic dynamics in the Bering and Chukchi Seas. The complexity is due to the nature that the physical and biological components interact at different manners in time and space, even in response to a same climate forcing, over the physically distinct geographic settings such as in the Bering and North Aleutian Slopes, deep Bering basins, Bering shelf, and Chukchi Sea. Sensitivity studies were conducted to reveal the underlying mechanisms (i.e., the bottom-up effects) of the Bering–Chukchi ecosystem in response to changes in light intensity, nutrient input from open boundaries, and air temperature. It was found that (1) a 10% increase in solar radiation or light intensity for the entire year has a small impact on the intensity and timing of the bloom in the physical–biological system since the light is not a limiting factor in the study region; (2) a 20% increase in nutrients from all the open boundaries results in an overall 7% increase in phytoplankton, with the Slope region being the largest, and the Bering shelf and Chukchi being the smallest; and (3) an increase in air temperature by 2°C over the entire calculation period can result in an overall increase in phytoplankton by 11%.

Wang, M., and J. E. Overland. 2015. Projected future duration of the sea-ice-free season in the Alaskan Arctic. Progress in Oceanography. 136:50-59. https://doi.org/10.1016/j.pocean.2015.01.001

Keywords**:** sea ice; summer sea ice; ecosystems; climate; marine mammals; shipping; Arctic; Chukchi Sea; Beaufort Sea

***Abstract*:** Global warming and continued reduction in sea ice cover will result in longer open water duration in the Arctic, which is important for the shipping industry, marine mammals, and other components of the regional ecosystem. In this study we assess the length of open water duration in the Alaskan Arctic over the next few decades using the set of latest coupled climate models (CMIP5). The Alaskan Arctic, including the Chukchi and the Beaufort Sea, has been a major region of summer sea ice retreat since 2007. Thirty five climate models from CMIP5 are evaluated and twelve are selected for composite projections based on their historical simulation performance. In the regions north of the Bering Strait (north of 70° N), future open-water duration shifts from a current 3–4months to a projected near 5months by 2040 based on the mean of the twelve selected climate models. There is considerable north–south gradient in projected durations. Open water duration is about 1month shorter along the same latitudes in the Beaufort Sea compared with that in the Chukchi Sea. Uncertainty is generally ±1 month estimated from the range of model results. Open-water duration in the Alaskan Arctic expands quickly in these models over the next decades which will impact regional economic access and potentially alter ecosystems. Yet

the northern Alaskan Arctic from January through May will remain sea ice covered into the second half of the century due to normal lack of sunlight.

Wang, S. W., A. M. Springer, S. M. Budge, L. Horstmann, L. T. Quakenbush, and M. J. Wooller. 2016. Carbon sources and trophic relationships of ice seals during recent environmental shifts in the Bering Sea. Ecological Applications*.* 26(3):830-845. https://doi.org/10.1890/14-2421

***Keywords*:** marine mammal; seals; sea ice; ecosystems; climate

***Abstract*:** Dramatic multiyear fluctuations in water temperature and seasonal sea ice extent and duration across the Bering–Chukchi continental shelf have occurred in this century, raising a pressing ecological question: Do such environmental changes alter marine production processes linking primary producers to upper trophic-level predators? We examined this question by comparing the blubber fatty acid (FA) composition and stable carbon isotope ratios of individual FA (δ13CFA) of adult ringed seals (*Pusa hispida*), bearded seals (*Erignathus barbatus*), spotted seals (*Phoca largha*), and ribbon seals (*Histriophoca fasciata*), collectively known as "ice seals," sampled during an anomalously warm, low sea ice period in 2002–2005 in the Bering Sea and a subsequent cold, high sea ice period in 2007–2010. δ13CFA values, used to estimate the contribution to seals of carbon derived from sea ice algae (sympagic production) relative to that derived from water column phytoplankton (pelagic production), indicated that during the cold period, sympagic production accounted for 62–80% of the FA in the blubber of bearded seals, 51–62% in spotted seals, and 21–60% in ringed seals. Moreover, the δ13CFA values of bearded seals indicated a greater incorporation of sympagic FAs during the cold period than the warm period. This result provides the first empirical evidence of an ecosystem-scale effect of a putative change in sympagic production in the Western Arctic. The FA composition of ice seals showed clear evidence of resource partitioning among ringed, bearded, and spotted seals, and little niche separation between spotted and ribbon seals, which is consistent with

previous studies. Despite interannual variability, the FA composition of ringed and bearded seals showed little evidence of differences in diet between the warm and cold periods. The findings that sympagic production contributes significantly to food webs supporting ice seals, and that the contribution apparently is less in warm years with low sea ice, raise an important concern: Will the projected warming and continuing loss of seasonal sea ice in the Arctic, and the associated decline of organic matter input from sympagic production, be compensated for by pelagic production to satisfy both pelagic and benthic carbon and energy needs?

Wang, M., Q. Yang, J. E. Overland, and P. Stabeno. 2018. Sea-ice cover timing in the Pacific Arctic: The present and projections to mid-century by selected CMIP5 models. Deep Sea Research Part II: Topical Studies in Oceanography. 152:22-34. https://doi.org/10.1016/j.dsr2.2017.11.017

Keywords**:** Climate models; Chukchi Sea; sea-ice projections; sea-ice break-up and freeze-up dates; annual sea-ice duration

Abstract**:** With the sea-ice cover in the Arctic fast declining, changes to the timing of sea-ice break-up and freeze-up is an urgent economic, social, and scientific concern. Based on daily sea-ice concentration data we assess three variables: the dates of sea-ice break-up and freeze-up, and the annual sea-ice duration in the Pacific Arctic. The simulation results from the coupled Atmosphere-Ocean General Circulation Models from phase 5 of the Coupled Model Intercomparison Project (CMIP5) are the source for this study. Compared with observations, CMIP5 models simulate all three variables well. The length of sea-ice duration is shrinking, with the strongest trend occurring for the period 1990–2014; this downward trend is projected to continue at least through mid-century by the CMIP5 models. Comparisons made at eight Chukchi Sea mooring sites and eight Distributed Biological Observatory (DBO) regions show consistent results. The 30-year averaged trend for annual sea-ice duration in the southern Chukchi Sea is projected to be −0.68 (−0.74) days/year to −1.20 (−1.17) days/year for 2015–2044 under RCP8.5 (RCP4.5) emissions scenarios. This is equivalent to a reduction of 20–36 days in the annual sea-ice duration. A similar negative trend is also found at all eight DBO regions. The reduction in annual sea-ice duration will include both earlier break-up dates and later freeze-up dates. However, models project that a later freeze-up contributes more than earlier break-up to the overall shortening of annual sea-ice duration. Around the Bering Strait area, future changes are the smallest, with less than 20 days change in duration during the next 30 years. In contrast, up to a 60-day reduction of the sea-ice duration in the East Siberian, Chukchi and Beaufort Seas is projected near the middle of the 21st century, when averaged over the period of 2030–2044.

Whitledge, T. E., R. R. Bidigare, S. I. Zeeman, R. N. Sambrotto, P. F. Roscigno, P. R. Jensen, J. M. Brooks, C. Trees, and D. M. Veidt. 1988. Biological measurements and related chemical-features in Soviet and United-States regions of the Bering Sea. Continental Shelf Research. 8(12):1299-1319. https://doi.org/10.1016/0278-4343(88)90042-8

***Keywords*:** nutrients; chlorophyll; zooplankton; plankton; diatoms; ecosystem; hydrocarbons; Bering Sea

***Abstract*:** The U.S. results of a joint U.S.-U.S.S.R. expedition to the Bering Sea in 1984 investigated the chemical and biological interactions in the south, east, north and west regions. The nutrients, phytoplankton biomass and primary productivity were enhanced near the ends of a north-south transect of stations. The southern end of the transect had characteristics of the North Pacific Ocean with high nutrient and low phytoplankton concentrations and an elevated concentration of peridinin indicative of dinoflagellates. The middle station of the transect, near the shelf break, had low nutrients and phytoplankton in the upper euphotic zone, but a submerged chlorophyll b maximum indicated green algae was located on the upper boundary of high ammonium concentration and pycnocline. The north end of the transect over the shelf at mid-depth on the boundary of high nitrate and ammonium concentrations produced the highest primary production. Pigment analysis (chlorophyll a, diadinoxanthin and fucoxanthin) indicated the dominance of diatoms and was coincidental to oxygen saturation values as large as 150%. The highest phaeophorbide a concentrations were also observed in this area, suggesting relatively high grazing stress. Measurements of low molecular weight hydrocarbons also suggest high microbiological degradation rates of organic matter in the sediments in the north region. Overall, this research strongly relates nutrient, oxygen and pigment concentrations to the production, decomposition and recycling processes in the open ocean and shelf areas of the Bering Sea.

Will, A., A. Takahashi, J.-B. Thiebot, A. Martinez, E. Kitaiskaia, L. Britt, D. Nichol, J. Murphy, A. Dimond, S. Tsukamoto, B. Nishizawa, Y. Niizuma, and A. Kitaysky. 2020. The breeding seabird community reveals that recent sea ice loss in the Pacific Arctic does not benefit piscivores and is detrimental to planktivores. Deep Sea Research Part II: Topical Studies in Oceanography. 181-182:104902. https://doi.org/10.1016/j.dsr2.2020.104902

***Keywords*:** Climate change; northern Bering Sea; nutritional stress; corticosterone; stable isotope analysis; trophic niche; resource partitioning; fish abundance; trawl survey; ecosystem transformation; biologging

***Abstract*:** Recent dramatic reductions of winter sea ice in the northern Bering Sea have raised the possibility that a rapid ecological transformation is underway. It has been hypothesized that with sufficient sea ice loss the cold pool thermal barrier separating the northern and southern Bering Sea would be breached, potentially benefiting piscivorous seabirds with an influx of abundant forage fish, but maybe causing food limitations for planktivorous seabirds that rely on cold-water associated species of zooplankton. During 2016–2019, we examined responses of the seabird community breeding on St. Lawrence Island to variable winter sea ice extent (low in 2018–2019). The seabird community includes piscivorous black-legged kittiwakes, thick-billed and common murres, and planktivorous crested and least auklets. We used a combination of stable isotope analysis and nutritional stress status analyses to examine if the region's ecosystem has shifted to a pelagic prey

base, and whether either foraging guild benefitted from such a shift. To interpret bird responses, we used stable isotope analyses of prey and trawl survey-derived abundance of forage size fish. Stable isotope values in blood tissues revealed no change in the prey base as reflected in the isotopic space used by the seabird community across the four study years. Sea-ice loss was, however, associated with increased nutritional stress in all seabird species and diverging foraging niches within guilds. Benthic forage-sized fish remained a key food source, with their abundance stable since 2010, and benthic-foraging thick-billed murres experienced relatively low nutritional stress across the study period. A significant increase in common murre nutritional stress levels between 2016 and 2017, and a shift in their isotopic niche indicative of higher reliance on benthic prey coincided with a decline in the abundance of pelagic forage fish in the region. Surface-foraging black-legged kittiwakes experienced steady increases in nutritional stress as the abundance of pelagic forage fish declined. The spring sea-ice loss was detrimental to planktivorous least and crested auklets that rely on zooplankton advected from the Bering Sea basin. During the study period both auklets have experienced severe nutritional stress (2018) and colony-wide reproductive failures (2018 and 2019). In conclusion, we found that increasingly warm conditions during 2016–2019 have challenged the adaptive ability of seabirds relying on pelagic fish and zooplankton advected into the region each summer, but have not yet resulted in a reorganization of the northern Bering Sea's benthic-dominated ecosystem.

Will, A., J.-B. Thiebot, H. S. Ip, P. Shoogukwruk, M. Annogiyuk, A. Takahashi, V. Shearn-Bochsler, M. L. Killian, M. Torchetti, and A. Kitaysky. 2020. Investigation of the 2018 thick-billed murre (*Uria lomvia*) die-off on St. Lawrence Island rules out food shortage as the cause. Deep Sea Research Part II: Topical Studies in Oceanography. 181-182:104879. https://doi.org/10.1016/j.dsr2.2020.104879

Keywords**:** feather corticosterone; avian influenza; food shortage; mortality; winter; seabirds; Arctic; marine environment; nutritional stress; subsistence harvest

Abstract**:** Die-offs of seabirds in Alaska have occurred with increased frequency since 2015. In 2018, on St. Lawrence Island, seabirds were reported washing up dead on beaches starting in late May, peaking in June, and continuing until early August. The cause of death was documented to be starvation, leading to the conclusion that a severe food shortage was to blame. We use physiology and colony-based observations to examine whether food shortage is a sufficient explanation for the die-off, or if evidence indicates an alternative cause of starvation such as disease. Specifically, we address what species were most affected, the timing of possible food shortages, and food shortage severity in a historical context. We found that thick-billed murres (*Uria lomvia*) were most affected by the die-off, making up 61% of all bird carcasses encountered during beach surveys. Thick-billed murre carcasses were proportionately more numerous (26:1) than would be expected based on ratios of thick-billed murres to co-occurring common murres (*U. aalge*) observed on breeding study plots (7:1). Concentrations of the stress hormone corticosterone, a reliable physiological indicator of nutritional stress, in thick-billed murre feathers grown in the fall indicate that foraging conditions in the northern Bering Sea were poor in the fall of 2017

and comparable in severity to those experienced by murres during the 1976–1977 Bering Sea regime shift. Concentrations of corticosterone in feathers grown during the pre-breeding molt indicate that foraging conditions in late winter 2018 were similar to previous years. The 2018 murre egg harvest in the village of Savoonga (on St. Lawrence Is.) was one-fifth the 1993–2012 average, and residents observed that fewer birds laid eggs in 2018. Exposure of thick-billed murres to nutritional stress in August, however, was no different in 2018 compared to 2016, 2017, and 2019, and was comparable to levels observed on St. George Island in 2003–2017. Prey abundance, measured by the National Oceanic and Atmospheric Administration in bottom-trawl surveys, was also similar in 2018 to 2017 and 2019, supporting the evidence that food was not scarce in the summer of 2018 in the vicinity of St. Lawrence Island. Of two moribund thick-billed murres collected at the end of the mortality event, one tested positive for a novel re-assortment H10 strain of avian influenza with Eurasian components, likely contracted during the non-breeding season. It is not currently known how widely spread infection of murres with the novel virus was, thus insufficient evidence exists to attribute the die-off to an outbreak of avian influenza. We conclude that food shortage alone is not an adequate explanation for the mortality of thick-billed murres in 2018, and highlight the importance of rapid response to mortality events in order to document alternative or confounding causes of mortality.

Wilson, R. E., S. A. Sonsthagen, N. Smé, A. J. Gharrett, A. R. Majewski, K. Wedemeyer, R. J. Nelson, and S. L. Talbot. 2020. Mitochondrial genome diversity and population mitogenomics of polar cod (*Boreogadus saida*) and Arctic dwelling gadoids. Polar Biology. 43(8):979-994. https://doi.org/10.1007/s00300-020-02703-5

Keywords**:** fisheries; cod; climate; ecosystem shifts; environmental change; genome

Abstract**:** High-latitude fish typically exhibit a narrow thermal tolerance window, which may pose challenges when coping with temperatures that shift outside of a species' range of tolerance. Due to its role in aerobic metabolism and energy balance, the mitochondrial genome is likely critical for the acclimation and adaptation to differing temperature regimes in marine ectotherms. As oceans continue to warm, there is growing need to understand the ability of organisms to respond to changing environmental conditions given evidence that some species, in particular cold-water species, may already be experiencing difficulties. To assess how Arctic gadids in Alaska have responded to differential thermal preferences in the past and how regions are interconnected, we sequenced complete mitochondrial genomes for four Arctic gadids to determine the distribution of mitochondrial diversity and population-level structure as well as to detect signatures of selection acting on the mitochondrial genome. We found little population-level structure within all four species with the clear exception of Gulf of Alaska saffron cod (*Eleginus gracilis*). Northern localities exhibited higher levels of genetic diversity and primarily northern lineages were observed within polar cod (*Boreogadus saida*) and saffron cod, likely reflecting asymmetrical dispersal and potentially admixture of distinct lineages via ocean currents. The main evolutionary force shaping the evolution of the mitogenome appears to be purifying selection, but we also identified potential positive selection of candidate amino acid replacements primarily

in complex I (ND genes) in polar cod. The high levels of mitochondrial diversity observed in our study and large population size may provide this species with the ability to respond evolutionarily (i.e. long-term) to a changing environment.

Wolotira, R. J., T. M. Sample, and M. Morin. 1977. Demersal fish and shellfish resources of Norton Sound, the southeastern Chukchi Sea, and adjacent waters in the baseline year 1976. U.S. Dep. Commerce, NOAA, NMFS, Alaska Fisheries Science Center. AFSC Processed Report. 326 p. 7600 Sand Point Way N.E., Seattle, WA 98115. https://repository.library.noaa.gov/view/noaa/5391

***Keywords*:** fish; shellfish; Norton Sound; Chukchi Sea; ecosystems; regional survey

***Abstract*:** This report contains findings from an intensive six-week survey (September-October, 1976) of fish and shellfish fauna in Norton Sound, the southeastern Chukchi Sea, and adjacent waters and a brief review of other pertinent information on the survey region from other data sources. Results of the survey defined the distributions and centers of abundance of several fish, crab, and snail species within the survey region and period. In addition, standing stock estimates and species composition of demersal fauna by geographic subdivisions of the survey region were determined. Analyses of species associations showed recurrent groupings of certain species and their regional distributions. Estimates of biological characteristics, including size and age composition, length-weight relationships, and growth characteristics, were provided for dominant fish species and for several species of crabs and snails. The 1976 baseline survey provided considerable information on the distribution and abundance of fish and shellfish in the study area. Overall, the relative abundance was very low for nearly all organisms intensively studied. A total biomass for all demersal fauna in the survey region was estimated at only 338,000 mt and those groups studied in detail (shellfish of potential economic importance and fish) comprised only 25% of this amount. In contrast, recent biomass estimates for similar faunal groups in the highly productive eastern Bering Sea are 60 times greater than that determined in our survey area.

Woodgate, R. A., and K. Aagaard. 2005. Revising the Bering Strait freshwater flux into the Arctic Ocean. Geophysical Research Letters. 32(2):L02602. https://doi.org/10.1029/2004GL021747

***Keywords*:** Bering Strait; Chukchi Sea; currents; climate; temperature; salinity; transport; seasonality; Alaskan Coastal Current

***Abstract*:** The freshwater flux through the Bering Strait into the Arctic Ocean is important regionally and globally, e.g. for Chukchi Sea hydrography, Arctic Ocean stratification, the global freshwater cycle, and the stability of the Atlantic overturning circulation. Aagaard and Carmack [1989] estimated the Bering Strait freshwater flux as 1670 km^3/yr (relative to 34.8 psu), assuming an annual mean transport (0.8 Sv) and salinity (32.5 psu). This is ~1/3rd of the total freshwater input to the Arctic. Using long-term moored measurements and ship-based observations, we show that this is a substantial underestimate of the freshwater

flux. Specifically, the warm, fresh Alaskan Coastal Current in the eastern Bering Strait may add ~400 km^3/yr. Seasonal stratification and ice transport may add another ~400 km^3/yr. Combined, these corrections are larger than the interannual variability observed by near-bottom measurements and near-surface measurements will be necessary to quantify this flux and its interannual variability.

Woodgate, R. A., K. Aagaard, and T. J. Weingartner. 2005. Monthly temperature, salinity, and transport variability of the Bering Strait through flow. Geophysical Research Letters. 32(4):L04601. https://doi.org/10.1029/2004gl021880

***Keywords*:** Bering Strait; Chukchi Sea; currents; climate; temperature; salinity; transport; seasonality

***Abstract*:** The Bering Strait through flow is important for the Chukchi Sea and the Arctic and Atlantic oceans. A realistic assessment of through flow properties is also necessary for validation and boundary conditions of high-resolution ocean models. From 14 years of moored measurements, we construct a monthly climatology of temperature, salinity and transport. The strong seasonality in all properties (~31.9 to 33 psu, ~−1.8 to 2.3°C and ~0.4 to 1.2 Sv) dominates the Chukchi Sea hydrography and implies significant seasonal variability in the equilibrium depth and ventilation properties of Pacific waters in the Arctic Ocean. Interannual variability is large in temperature and salinity. Although missing some significant events, an empirical linear fit to a local (model) wind yields a reasonable reconstruction of the water velocity, and we use the coefficients of this fit to estimate the magnitude of the Pacific-Arctic pressure-head forcing of the Bering Strait through flow.

Woodgate, R. A., K. Aagaard, and T. J. Weingartner. 2006. Interannual changes in the Bering Strait fluxes of volume, heat and freshwater between 1991 and 2004. Geophysical Research Letters. 33(15):L15609. https://doi.org/10.1029/2006gl026931

***Keywords*:** Alaskan Coastal Current; Bering Strait; currents; water mass; water mixing; salinity; meltwater

***Abstract*:** Year-round moorings (1990 to 2004) illustrate interannual variability of Bering Strait volume, freshwater and heat fluxes, which affect Arctic systems including sea-ice. Fluxes are lowest in 2001 and increase to 2004. Whilst 2004 freshwater and volume fluxes match previous maxima (1998), the 2004 heat flux is the highest recorded, partly due to ~0.5°C warmer temperatures since 2002. The Alaskan Coastal Current, contributing about 1/3rd of the heat and equation image of the freshwater fluxes, also shows strong warming and freshening between 2002 and 2004. The increased Bering Strait heat input between 2001 and 2004 (>2×10^{20} J) could melt 640,000 km^2 of 1 m thick ice; the 3-year freshwater increase (~800 km^3) is about equation image of annual Arctic river run-off. Weaker southward winds likely explain the increased volume flux (~0.7 to ~1 Sv), causing ~80% of the freshwater and ~50% of the heat flux increases.

Worne, S., Z. Stroynowski, S. Kender, and G. E. A. Swann. 2021. Sea-ice response to climate change in the Bering Sea during the mid-Pleistocene transition. Quaternary Science Reviews. 259:106918. https://doi.org/10.1016/j.quascirev.2021.106918

Keywords**:** sea-ice; Bering Sea; mid-Pleistocene; transition diatoms

Abstract**:** Sea-ice is believed to be an important control on climatic changes through the Mid-Pleistocene Transition (MPT; 0.6-1.2 Ma). However, the low resolution/short timescale of existing reconstructions prevents a full evaluation of these dynamics. Here, diatom assemblages from the Bering Sea are used to investigate sea-ice evolution on millennial timescales. We find that sea-ice was primarily controlled by ice-sheet/sea level fluctuations that modulated warm water flow into the Bering Sea. Facilitated by an amplified Walker circulation, sea-ice expansion began at ~1.05 Ma with a step-increase during the 900 kyr event. Maximal pack ice was simultaneous with glacial maxima, suggesting sea-ice was responding to, rather than modulating ice-sheet dynamics, as proposed by the sea-ice switch hypothesis. Significant pack ice, coupled with Bering Strait closure at 0.9 Ma, indicates that brine rejection played an integral role in the glacial expansion/deglacial collapse of intermediate waters during the MPT, regulating subarctic ocean-atmospheric exchanges of CO_2.

Wyllie-Echeverria, T., and W. S. Wooster. 1998. Year-to-year variations in Bering Sea ice cover and some consequences for fish distributions. Fisheries Oceanography. 7(2):159-170. https://doi.org/10.1046/j.1365-2419.1998.00058.x

Keywords**:** Aleutian Low Pressure System; Arctic cod; cold pool; decadal variability; sea ice; walleye pollock

Abstract**:** The southernmost extension of winter ice cover varies interannually and on longer time scales, reflecting large-scale changes in driving forces, especially in the position and intensity of the winter Aleutian Low Pressure System. A conspicuous pattern is alternating warm and cool periods of several years' duration. These variations in sea ice cover are reflected in the character of a subsurface cold pool, formed as stratification isolates the deeper cold waters from surface exchanges. The cold pool is better developed and more extensive in summers that follow deep southward penetration of winter sea ice. Interannual and decadal-scale variations in the distributions of some fish stocks reflect those of ice and thermal conditions. In particular, the distribution of walleye pollock, Theragra chalcogramma, varies significantly with multiannual cool and warm years while Arctic cod, Boreogadus saida, is only present within the cold pool. The relation among climate variations, sea ice cover, subsurface thermal conditions, and fish distribution provides information on how climate affects marine ecosystems and may also have practical application in predicting fish distributions.

Yamaguchi, A., F. Kimura, Y. Fukai, Y. Abe, K. Matsuno, A. Ooki, and T. Hirawake. 2021. Between-year comparison of interactions between environmental parameters and various plankton stocks in the northern Bering Sea during the summers of 2017 and 2018. Polar Science. 27:100555. https://doi.org/10.1016/j.polar.2020.100555

***Keywords*:** northern Bering Sea; plankton stock; yearly change; structural equation modelling (SEM) analysis

***Abstract*:** In the northern Bering Sea, ice coverage and retreat timing were low and early, respectively, in the 2017–2018 winter. To evaluate the effect of these anomalous ice conditions, we quantified various environmental parameters (temperature, salinity, mixed-layer depth, nutrients) and the standing stocks of various planktonic taxa (phytoplankton counts, meso- and macrozooplankton mass, jellyfish abundance) during July of 2017 and 2018. For each year, the interaction between each parameter was evaluated by structural equation modelling (SEM) analysis. Large yearly differences were detected for the interactions between environmental parameters and planktonic stocks. Thus, for 2017, a total of fifteen interactions were present between environmental parameters and various planktonic stocks. In 2018, however, only eight interactions were present. Among the interactions, four were common to the two years. It is notable that the path coefficients of these four interactions were all lower in 2018 than in 2017. These findings suggest that the small magnitude and short pulse of the phytoplankton bloom in 2018 may have failed to transfer production and energy to a higher trophic level even within the planktonic food web. Indeed, in 2018, mass mortality was reported for seabirds (two murre species) feeding on planktivorous fishes.

Yasumiishi, E. M., K. Cieciel, A. G. Andrews, J. Murphy, and J. A. Dimond. 2020. Climate-related changes in the biomass and distribution of small pelagic fishes in the eastern Bering Sea during late summer, 2002–2018. Deep Sea Research Part II: Topical Studies in Oceanography. 181-182:104907. https://doi.org/10.1016/j.dsr2.2020.104907

***Keywords*:** temperature; fish; marine ecosystem; pollock; salmon; capelin; herring

***Abstract*:** Climate change is altering the distribution and biomass of marine species in Arctic and sub-Arctic waters. In this study, we investigate the influence of sea temperature on the annual distribution and biomass of pelagic fishes in the eastern Bering Sea during late summer, 2002–2018. The distribution (easting, northing, and area occupied) and biomass of capelin, Pacific herring, juvenile chum salmon, juvenile pink salmon, juvenile sockeye salmon, and age-0 walleye pollock collected by surface trawl were estimated using a standardized geostatistical delta-generalized linear mixed modeling approach. Species showed varied responses to warming on a temporal scale. Warming corresponded with more northerly distributions for capelin and juvenile sockeye salmon, a more westerly distribution of juvenile sockeye salmon, and range expansions for juvenile chum and sockeye salmon. Warming corresponded to a decrease in the annual biomass of capelin and an increase in the biomass of herring, age-0 pollock, and juvenile sockeye salmon. The

spatio-temporal covariation in sea temperature and the distribution was nonlinear for juvenile pink salmon and age-0 pollock, positive for juvenile chum salmon and juvenile pink salmon, and negative for capelin indicating different responses of the distribution of pelagic fishes to warming in the eastern Bering Sea during late summer. In warmer areas, we found that the catch rates were higher for juvenile pink salmon, lower for capelin, and not significantly different for juvenile chum salmon, herring, age-0 pollock, and juvenile sockeye salmon. Juvenile sockeye salmon, a southerly distributed species in the survey area, appeared most responsive to warming. In this study, sockeye salmon and pollock are the most commercially important species while chum salmon are important for subsistence fishing. These temperature related changes during early life history stages for survival may have impacts on the numbers of these fishes recruiting to the fisheries.

Yeung, C., and M.-S. Yang. 2014. Habitat and infauna prey availability for flatfishes in the northern Bering Sea. Polar Biology. 37(12):1769-1784. https://doi.org/10.1007/s00300-014-1560-4

***Keywords*:** benthic communities; bottom trawl survey; climate; diets; infauna; spatial distribution

***Abstract*:** Yellowfin sole (*Limanda aspera*), northern rock sole (*Lepidopsetta polyxystra*), and Alaska plaice (*Pleuronectes quadrituberculatus*) are valuable flatfishes in the southeastern Bering Sea (EBS) bottom trawl fishery. The northern Bering Sea (NBS) is near their northern distribution limit. We conducted the first assessment of NBS habitat suitability for these benthivorous flatfishes from the perspective of prey availability in 2010. Benthic samples were collected at 12 trawl stations along a meridional transect extending from 60.5°N to 64.5°N east of St. Lawrence Island to characterize the prey environment. Stomach contents from the flatfishes were concomitantly collected to relate diets to prey fields. The diet compositions did not correspond spatially with the infauna communities. The flatfishes elected a prey group regardless of its relative availability. The spatial mismatch between diet and infauna compositions suggests that prey availability was high in the NBS. The flatfishes generally have versatile diets, but they were more selective of their prey here than in the EBS. The biomass and the abundance of the infauna along the transect were comparable with the EBS. Although niche overlap was high in the NBS, competition for food was likely lower than in the EBS because of the lower density of flatfish. The bottom temperatures in the NBS were in the same range as the EBS during the summer of 2010. The NBS appears to be suitable flatfish habitat at least during the summer ice-free period. The effects of climate warming on the prey environment and on the production and distribution of flatfish are complex and difficult to predict, but if the NBS were to shift over time toward milder winter conditions that more resemble the EBS, its suitability as flatfish habitat would presumably increase based on the present prey availability.

Yeung, C., L. A. Copeman, M. E. Matta, and M.-S. Yang. 2021. Latitudinal variation in the growth and condition of Juvenile flatfishes in the Bering Sea. Estuarine, Coastal and Shelf Science. 258:107416. https://doi.org/10.1016/j.ecss.2021.107416

Keywords**:** habitat; climate change; ecosystem; juvenile growth; subarctic; temperature; USA; Alaska; Bering Sea

Abstract**:** The Bering Sea spans a wide latitudinal range, connecting with the temperate North Pacific Ocean to the south and the arctic Chukchi Sea to the north. Climate change has rapidly and significantly altered Bering Sea ecosystem dynamics. The biomass of predominantly boreal marine species have increased in the subarctic northern Bering Sea following recent record-high water temperatures across the shelf. Among those species are two commercially-important flatfishes: yellowfin sole (*Limanda aspera*; YFS) and northern rock sole (*Lepidopsetta polyxystra*; NRS). In this study, the Bering Sea was divided latitudinally into three areas – north, central, and south – to assess the implications of a northward shift or expansion of juvenile flatfish habitat on production potential. The growth, diet, and condition of juveniles were compared among areas from 2016 to 2018. Summer bottom temperatures in the Bering Sea in 2016 and 2018 were anomalously warm, but 2017 temperatures were closer to the 2010–2018 average. Prey availability does not appear to be a limiting habitat factor across the Bering Sea. Juveniles of both species grow faster in length and to greater length-at age in the south. The morphometric-based condition of juvenile YFS appears to be better in the northern Bering Sea, while that of juvenile NRS also improves towards the north. Condition increased from 2016 to 2017, but then decreased slightly from 2017 to 2018. Although the results suggest larger size and faster growth of juveniles are associated with warmer bottom temperatures, there is also indication that growth and condition of juvenile flatfish may not continue to increase if current high temperatures persist in their habitat. Exploratory habitat models show that the condition of juvenile YFS may be negatively influenced by temperature. Negative effects on growth and energy storage may set in as the upper thermal physiological tolerance of each species is approached. The critical temperature maxima for each species is unknown, but it may be lower for the cold-adapted YFS than for NRS, implying that YFS may be less buffered against effects of climate warming.

Zacher, L. S., J. I. Richar, and R. J. Foy. 2020. The 2019 eastern and northern Bering Sea continental shelf trawl surveys: results for commercial crab species. U.S. Dep. Commerce. NOAA Tech. Memo. NMFS-AFSC-400. 234 p. Kodiak, AK. https://doi.org/10.25923/8jdb-5p39

Keywords**:** Alaskan king crab; biomass; crab populations; dredging (fisheries); estimates; fish stock assessment; snow crab; southern tanner crab; surveys

Abstract**:** The eastern Bering Sea bottom trawl survey has been annually conducted since 1975 by the Resource Assessment and Conservation Engineering Division of the Alaska Fisheries Science Center, National Marine Fisheries Service. The purpose of this survey is to collect data on the distribution and abundance of crab, groundfish, and other benthic resources in the eastern Bering Sea. These data are used to estimate population abundance and biomass for the management of commercially important species. This document includes the time series of results from 1975 to the present. In 2019, 375 total stations were sampled on the eastern Bering Sea shelf from 3 June to 28 July. In 2019 the overall

estimated biomass and abundance of Bristol Bay red king crab (*Paralithodes camtschaticus*) remained approximately the same, although there was a decline in legal male crab. Mature and legal red king crab males in the Pribilof Islands increased, while females and immature males declined or remained steady. Both red king crab populations saw an increase in pre-recruit abundance. There was an overall increase in estimated blue king crab biomass and abundance, except for Pribilof Islands immature females, of which none were caught in the survey. Estimated biomass and abundance of Tanner crab (*Chionoecetes bairdi*) declined for legal and mature males. Females and immature males remained approximately the same, except for the biomass of immature males east of 166o W, which increased. There was an overall increase in legal, mature, and pre-recruit male snow crab (*Chionoecetes opilio*), while immature males and all females declined. In addition to the standard eastern Bering Sea survey, in 2019, following the conclusion of the standard survey, 144 stations were sampled in the northern Bering Sea region, encompassing the region south of Bering Strait, and including Norton Sound. These stations were sampled between 28 July and 20 August. We report the results of this survey separately from the eastern Bering Sea survey, within the northern Bering Sea section of this report. Blue king crab occurred largely in the region north of St. Lawrence Island. Estimated biomass and abundance declined in 2019 and densities were lower than for the St. Matthew Island stock. Red king crab occurred primarily in Norton Sound, with an overall decline in the biomass and abundance of mature males and an increase in immature crab. Density and abundance estimates for immature red king crab in Norton Sound were higher than observed in the Bristol Bay District, but the reverse pattern was seen for mature red king crab. Snow crab dominated the northern Bering Sea catch, with increases in both biomass and abundance estimates for mature and legal crab, especially along the border between the eastern Bering Sea and northern Bering Sea survey areas. Immature snow crab were distributed throughout most of the northern Bering Sea, but declined in overall biomass and abundance.

Zhang, J., R. Woodgate, and S. Mangiameli. 2012. Towards seasonal prediction of the distribution and extent of cold bottom waters on the Bering Sea shelf. Deep Sea Research Part II: Topical Studies in Oceanography. 65-70:58-71. https://doi.org/10.1016/j.dsr2.2012.02.023

***Keywords*:** Bering Sea; cold pool; seasonal forecast

***Abstract*:** A coupled sea ice–ocean model, combined with observational and reanalysis data, is used to explore the seasonal predictability of the distribution and extent of cold bottom waters on the Bering Sea shelf through numerical simulations or statistical analyses. The model captures the spatiotemporal variability of trawl survey observations of bottom water temperature over the period 1970–2009. Of the various winter air–ice–ocean parameters considered, the interannual variability of the winter on-shelf heat transport across the Bering Sea shelf break, dominated by changes in ocean flow, is most highly correlated with the interannual variability of the bottom layer properties (bottom temperature, and the distribution and extent of cold bottom waters) in spring–summer. This suggests that the winter heat transport may be the best seasonal predictor of the bottom layer properties. To varying degrees, the winter mean simulated sea surface temperature (SST), National

Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis surface air temperature (SAT), simulated and observed sea ice extent, the Bering Strait outflow, and the Pacific Decadal Oscillation are also significantly correlated with the spring–summer bottom layer properties. This suggests that, with varying skill, they may also be useful for statistical seasonal predictions. Good agreement between observations and results of the coupled ice–ocean model suggests also the possibility of numerical seasonal predictions of the bottom layer properties. The simulated field of bottom layer temperature on the Bering Sea shelf on 31 May is a good predictor of the distribution and extent of cold bottom waters throughout late spring and summer. These variables, both in the model and in reality, do not change significantly from June to October, primarily owing to increased upper ocean stratification in late spring due to ice melt and surface warming, which tends to isolate and preserve the cold bottom waters on the shelf. However, the ocean stratification, and hence the isolation effect, is stronger in cold years than in warm years because more ice is available for melting in spring–summer.

Zimmerman, C. E., H. K. Swanson, E. C. Volk, and A. J. R. Kent. 2013. Species and life history affect the utility of otolith chemical composition for determining natal stream of origin for Pacific salmon. Transactions of the American Fisheries Society. 142(5):1370-1380. https://doi.org/10.1080/00028487.2013.811102

Keywords**:** salmon; otoliths; natal stream origins; water chemistry

Abstract**:** To test the utility of otolith chemical composition as a tool for determining the natal stream of origin for salmon, we examined water chemistry and otoliths of juvenile and adult chum salmon *Oncorhynchus keta* and coho salmon *O. kisutch* from three watersheds (five rivers) in the Norton Sound region of Alaska. The two species are characterized by different life histories: coho salmon rear in freshwater for up to 3 years, whereas chum salmon emigrate from freshwater shortly after emergence. We used laser ablation (LA) inductively coupled plasma (ICP) mass spectrometry (MS) to quantify element: Ca ratios for Mg, Mn, Zn, Sr, and Ba, and we used multicollector LA-ICP-MS to determine 87Sr:86Sr ratios in otolith regions corresponding to the period of freshwater residence. Significant differences existed in both water and otolith elemental composition, suggesting that otolith composition could be used to discriminate the natal origin of coho salmon and chum salmon but only when 87Sr:86Sr ratios were included in the discriminant function analyses. The best discriminant model included 87Sr:86Sr ratios, and without 87Sr:86Sr ratios it was difficult to discriminate among watersheds and rivers. Classification accuracy was 80% for coho salmon and 68% for chum salmon, indicating that this method does not provide sufficient sensitivity to estimate straying rates of Pacific salmon at the scale we studied.

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March 2022

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