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Ice Seal Movements and Foraging:

Village-Based Satellite Tracking and Collection of Traditional Ecological Knowledge Regarding Ringed and Bearded Seals – Final Report

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Cover photo: An adult male ringed seal (RS19-03-M) captured near Utqiaġvik, Alaska, on 23 June 2019 with a satellite-linked transmitter (SPLASH tag) epoxied to the hair on its back. Photo by Kevin Fisher.

Prepared under BOEM Contract M13PC00015

Pinniped Movements and Foraging:

Village-Based Satellite Tracking and Collection of Traditional Ecological Knowledge Regarding Ringed and Bearded Seals

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Project Organization Page

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Lori Quakenbush is a Wildlife Biologist IV and Program Leader for the Arctic Marine Mammal Program within the Alaska Department of Fish and Game. Her role in this project was that of Principal Investigator and Project Manager and her activities included coordination, communication, contracting, permitting, tagging, presentations, traditional knowledge interviews, report writing, and manuscript preparation.

Justin A. Crawford is a Wildlife Biologist II for the Arctic Marine Mammal Program within the Alaska Department of Fish and Game. His role in this project was that of Principal Investigator and his activities included coordination, tagging, tag and data management, archive, analysis, map production, and report and manuscript preparation.

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Justin R. Olnes is a Wildlife Biologist II for the Arctic Marine Mammal Program within the Alaska Department of Fish and Game. His role in this project was assistance with tagging, data management, analysis, and report, and manuscript preparation.

Key Project Personnel:
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Merlin Henry is an Alaskan subsistence hunter and resident of Koyuk. He is trained and experienced in handling seals and is a Co-Investigator on our NOAA seal research permit. He assisted with the capture and tagging of seals in northern Norton Sound.

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Table of Contents

List of Figures

List of Tables

List of Appendices

Appendix J. Huntington, H.P., M. Nelson, and L.T. Quakenbush. 2016. Traditional knowledge regarding ringed seals, bearded seals, and walrus near Kotzebue, Alaska. Final report to the Eskimo Walrus Commission, the Ice Seal Committee, and the Bureau of Ocean Energy Management for contract #M13PC00015. 11pp.

Appendix K. Crawford, J.A., M.A. Nelson, L. Quakenbush, A.L. Von Duyke, M. Henry, A. Niksik, A. Simon, J. Goodwin, A.Whiting, K. Frost, J. London, and P. Boveng. 2017. Update of hunter-assisted seal tagging and traditional knowledge studies of Pacific Arctic seals, 2016 and beyond. Alaska Marine Science Symposium 23–27 January, Anchorage, AK (abstract and poster).

Appendix L. Bowhead and seal maps to National Marine Fisheries Service for use in Quintillion Project biological opinion.

Appendix M. Huntington, H.P., M. Nelson, and L.T. Quakenbush. 2017. Traditional knowledge regarding marine mammals near Hooper Bay, Alaska. Final report to the Eskimo Walrus Commission, the Ice Seal Committee, and the Bureau of Ocean Energy Management for contract #M13PC00015. 10pp.

Appendix N. Huntington, H.P., M. Nelson, and L.T. Quakenbush. 2017. Traditional knowledge regarding marine mammals near Mekoryuk, Alaska. Final report to the Eskimo Walrus Commission, the Ice Seal Committee, and the Bureau of Ocean Energy Management for contract #M13PC00015. 10pp.

Appendix O. Huntington, H.P., M. Nelson, and L.T. Quakenbush. 2017. Traditional knowledge regarding marine mammals near Scammon Bay, Alaska. Final report to the Eskimo Walrus Commission, the Ice Seal Committee, and the Bureau of Ocean Energy Management for contract #M13PC00015. 10pp.

Appendix P. Crawford, J.A., M.A. Nelson, L. Quakenbush, J. Goodwin, K. Frost, A. Whiting, and M. Druckenmiller. 2017. Seasonal movements, habitat use, and dive behavior of pup and yearling bearded seals in the Pacific Arctic. Society of Marine Mammalogy, 22–27 October 2017, Halifax, Nova Scotia, Canada (abstract and poster).

Appendix Q. Nelson, M., H. Huntington, and L. Quakenbush. 2017. Evaluating impacts of climate change on indigenous marine mammal hunting in northern and western Alaska using traditional knowledge. Society of Marine Mammalogy, 22–27 October 2017, Halifax, Nova Scotia, Canada (abstract and poster).

Appendix R. Crawford, J.A., M.A. Nelson, L. Quakenbush, A. Bryan, A.L. Von Duyke, M. Henry, A. Niksik, J. Goodwin, A. Whiting, and M. Druckenmiller. 2018. Seasonal movements, habitat use, and dive behavior of pup and yearling bearded seals in the Pacific Arctic. Alaska Marine Science Symposium 22–26 January, Anchorage, AK (abstract and poster).

Appendix S. Huntington, H., L. Quakenbush, and M. Nelson. 2018. Climate change, marine mammals, and indigenous hunting in northern Alaska: insights from a decade of traditional knowledge interviews. Alaska Marine Science Symposium 22–25 January, Anchorage, AK (abstract).

Appendix T. Crawford, J.A., L.T. Quakenbush, A. Bryan, M.A. Nelson and A.L. Von Duyke. 2019. Seasonal movements and high-use areas of spotted seals (*Phoca largha*) in the Pacific Arctic. Alaska Marine Science Symposium. 28–31 January 2019. Anchorage, Alaska, USA. (abstract and poster).

Appendix U. Crawford, J. A., L. Quakenbush, M. Nelson, R. Adam, A. Bryan, J. J. Citta, A. L. Von Duyke, and S. R. Okkonen. 2019. Oceanographic characteristics associated with movements and high-use areas of spotted seals (*Phoca largha*) in the Chukchi and Bering seas. Society for Marine Mammalogy Conference, 9–12 December, Barcelona, Spain.

Executive Summary

Four species of seals in Alaska are referred to as "ice-associated seals" or "ice seals" because they use sea ice for some important life history events such as pupping, nursing, molting, and resting. Three of these seals, bearded (*Erignathus barbatus*), ringed (*Pusa or Phoca hispida*), and spotted seals (*Phoca largha*) are important subsistence species used by coastal Alaska Natives for food, oil, materials, clothing, and handicrafts. Ribbon seals (*Histriophoca fasciata*), the fourth species, are less common in Alaskan waters and used less often by subsistence-based communities. Ice seal summer habitat coincides with areas of interest for oil and gas development and seasonal movements overlap with shipping lanes, therefore information is needed to better understand ice seal migration routes and feeding areas to plan lease sales, permit exploration and development activities, design shipping lanes, and provide effective mitigation measures. We combined satellite-linked transmitter technology, traditional and local knowledge and skills of Native subsistence seal hunters to greatly increase our understanding of ringed, bearded, and spotted seal movements and behavior. Objectives for this project from September 2013 to September 2019 included: 1) estimating movements and behavior of ice seals (including movements between haulouts and feeding areas) within shipping lanes and the Beaufort and Chukchi seas planning areas; 2) evaluating the effect of changes in ice seal behavior relative to changes in sea ice; 3) estimating ice seal use of haulouts by age class and other potential factors; and 4) documenting traditional knowledge of ice seal movements, behavior, and use of habitats. All objectives were successfully met, except for determining use of haulouts by age class for ringed and bearded seals due to low sample size for some age classes. Use of haulouts and haul-out behavior was described for each species but could only be analyzed by age class for spotted seals.

During this project we deployed 67 transmitters on 26 bearded, 16 ringed, and 25 spotted seals at eight locations; four locations in the Bering Sea, two locations in the Chukchi Sea and two locations in the Beaufort Sea. Primary (glue-on) tags (SPLASH10 and CTD tags) provided location, dive data and temperature profiles, and haul-out durations; flipper-mounted tags (SPOT tags) provided location and haul-out durations, but only when seals were hauled out. Transmitters deployed on ringed, bearded, and spotted seals provided information on movements, dive behavior, and hauling out behavior during all seasons, which allowed us to identify important high-use areas including feeding areas, use of sea ice, and potential interactions with oil and gas areas, seismic activities, and ship traffic. Local and traditional knowledge was documented for 13 communities, to further our understanding of seal behavior and how it may be changing. We finalized 11 reports of traditional knowledge that included ice seals and published two peer-reviewed papers on traditional knowledge in science journals. All reports are available to the public.

Using data from this project we learned that young bearded seals tagged in the Bering and Chukchi seas made strong seasonal (north in summer and south in fall) movements, but those tagged in the Beaufort Sea did not travel south of ~70 °N. We would not have identified this difference in movement pattern had we not deployed tags over a large area of the species' range. Pup and yearling bearded seals were able to remain in open water without hauling out for several weeks at a time. Five young bearded seals were tracked in ice free waters for 26, 30, 36, 38, and

50 days between haul-out bouts. Foraging areas identified for bearded seals included Barrow Canyon, Kotzebue Sound, Bering Strait, Norton Sound, northeast and southeast of St. Lawrence Island, and along the 100 m isobath of the Bering Shelf.

All 16 tagged, mostly adult, ringed seals exhibited strong, seasonal, latitudinal patterns in movements throughout the year, using high-latitudes during the open-water season (July–November) and lower latitudes, near or south of the Bering Strait, when ice was present (December–June). Foraging areas identified for ringed seals included Barrow Canyon and the intercontinental shelf break in the northern Chukchi Sea.

All 17 spotted seals tagged in the Beaufort Sea made strong, seasonal movements between the Beaufort and Bering seas, but six of seven seals tagged in the Bering Sea stayed in the Bering Sea all year. By mid-January all spotted seals were in the Bering Sea. Foraging areas identified for spotted seals during the open water season included southern Barrow Canyon, Peard Bay, and between Icy Cape and Herald Shoals in the Chukchi Sea and between the Yukon-Kuskokwim Delta and St. Lawrence Island in the Bering Sea. Foraging during the ice-covered season included broad use of the Bering Sea shelf.

On average, bearded and ringed seals traveled less and were closer to land when ice was present than spotted seals. Bearded seals used ice and land to haul out during the open water season, however their haul-out durations were twice as long on ice. Ringed seals were more likely to haul out during the ice-covered season than the open water season, but we identified four times when ringed seals hauled out on land. Spotted seals regularly haul out on ice and land and regularly used land haulouts at Dease Inlet, Icy Cape, Kotzebue Sound, and Scammon Bay. In general, spotted seals spent 1–21 days foraging and 1–6 days hauled out. Spotted seals older than 1 year were more likely to haul out and to haul out longer than pups regardless of the season.

We documented several examples of within season and seasonal site fidelity. For example, some spotted seals returned to rest near areas they were tagged (Dease Inlet and Scammon Bay) one to two months later. Some seals returned to areas during the same season in consecutive years, including 5 of 6 bearded seals (67%), 3 of 5 ringed seals (60%), and 4 of 5 spotted seals (80%).

The three seal species differed in their use of ice. Bearded and ringed seals used ice when it was available, using higher concentrations during January–June (monthly average 50–75%) and open water during July–November. Spotted seals, however, used much lower ice concentrations (~40%) and remained much closer to the ice edge in winter when ringed and bearded seals were well into the ice. We identified changes in behavior of each species with decreasing sea ice. Ringed seals were found and captured in June in Kotzebue Sound in 2014 and 2017, but not after 2017. During years that sea ice did not advance into the central Bering Sea (2017 and 2018), bearded seals restricted their winter movements to the northern and eastern Bering Sea. Spotted seals continued to use the Bering Sea shelf in the east, staying near land, islands, and shorefast ice suitable for hauling out in winter until ice formed in the central Bering Sea, then they expanded their use to the western Bering Sea shelf break.

Almost half of all tagged seals (32 of 67, 48%) used the Chukchi Sea Lease Sale 193 area and were located within the area an average of 5 days (range = 1–37 days). The timing of entry differed by species; bearded seals generally entered earliest, using the area from 30 May to 19 September, ringed seals used the area later from 11 June to 19 October, and spotted seals entered latest using the area from 2 August to 31 December. While in the area, bearded and ringed seals ranged widely but were primarily located in the northeastern portion (in and near Hanna Shoal Walrus Use Area) while spotted seals primarily used the southern portion, south of 71.2°N.

Far fewer tagged seals (8 of 67, 12%) used the Beaufort Sea leased blocks in part because few seals traveled east of the Colville Delta, even though six seals were tagged there. Two bearded, four ringed, and two spotted seals spent some time in, or near, Beaufort Sea leased blocks. One bearded seal spent six months in the area, while two ringed seals spent 3–16 days each while migrating through the area, to the east in July and returning west in August or September. Two spotted seals passed through to the west leaving the Colville Delta where they were tagged.

One tagged ringed seal (RS14-02-F) may have been in the vicinity of an active seismic survey conducted between 1 June and 30 September 2014. The seismic survey was a 3D airgun array, however, the dates within the time period the survey was conducted, and the location of the seismic lines, are proprietary to the company that conducted the operation and are not available to the public. This ringed seal passed within 10 km of the seismic project location, near Prudhoe Bay, during late July while making a long-distance movement east towards Mackenzie Bay, Canada. Until details about seismic operations are available, we cannot acquire the information needed to overlay seal locations with seismic operations before, during, and after seismic surveys to analyze seal behavior.

Bearded seals were most likely to encounter ship traffic in Norton Sound throughout the year, and along Alaska's northwest coast in the summer. Ringed seals were more likely to encounter ship traffic in Norton Sound in the spring, in the northeastern Chukchi Sea in the summer, and in Norton Sound and the Bering Strait region in the fall. Spotted seals were more likely to encounter ship traffic in the northeastern Chukchi Sea and along Alaska's northwest coast in the summer and along the Russian coast and Bering Strait region in the fall. Given their tendency to return to and forage near the Alaskan coast, spotted seals may overlap least with shipping on Northern Sea Route along the Russian coast but may overlap with ships hauling ore from Red Dog Mine or other traffic along the Alaskan coast.

Results from this study contributed to understanding distribution, movements, and overlap of bearded, ringed, and spotted seals. Bearded, ringed, and spotted seals made extensive seasonal latitudinal movements. The extent of those movements, however, depended on where seals were tagged. Data collected by this project can be, used to compare seal behavior to previous and future seal tagging projects and be used for mitigation and management actions, including assisting aerial surveys of abundance.

Sea ice in the Beaufort, Chukchi, and Bering seas has been decreasing and the trend is expected to continue and appears to be accelerating. The effects of decreasing sea ice coupled with oil and gas development and increased shipping traffic on ice seals are not well understood, however results from this study have greatly increased what we know about ice seal movements, habitat use, haul-out behavior, interactions with oil and gas and shipping and has identified important objectives for future studies.

Due to the changes in seal movements over time documented by this study, we recommend seal tagging studies continue to monitor movements to asses further changes in seal behaviors associated with a warming climate. We recommend local and traditional ecological knowledge be collected to document current observations of seal hunters so they can be compared to previous conditions and to augment information from telemetry studies. Offshore industrial activity and shipping creates noise that may negatively affect seal behavior within areas ice seals use. As sea ice declines and areas have open water conditions for longer durations, more killer whales are likely to summer in the Bering, Chukchi, and Beaufort seas and stay longer, potentially influencing seal movements and use areas. The satellite-linked acoustic tag (Acousonde 3S) developed during a BOEM bowhead study (see OCS Study BOEM 2019-076) should be field tested and deployed on bearded seals to measure vocalizations of the seals instrumented with this tag and ambient noise levels that may include shipping and other industrial noise; all from the seals' perspective.

Introduction

Bearded (*Erignathus barbatus*), ringed (*Pusa* or *Phoca hispida*), spotted (*Phoca largha*), and ribbon (*Histriophoca fasciata*) seals are the four species of seals in Alaska called "ice-associated seals" or "ice seals" because they use sea ice for some important life history events such as pupping, nursing, molting, and resting. Ice seals are an important wildlife resource and an important source of food, clothing, and materials to the subsistence culture of coastal Alaska Natives. Ice seals are also important components of the Bering, Chukchi, and Beaufort seas ecosystems because they feed at several trophic levels (Shustov 1965, Frost and Lowry 1980, Lowry et al. 1980, Burns 1981, Lowry et al. 1981, Antonelis et al. 1994), may compete with some commercial fisheries (Lowry et al. 1978, Bukhtiyarov et al. 1984, Lowry 1984), and are eaten by polar bears (*Ursus maritimus;* Amstrup and DeMaster 1988). Reductions in sea ice (Wang et al. 2018), coupled with oil and gas activities, and increases in maritime shipping activity may affect these seals through multiple pathways (Kovacs et al. 2011). Ribbon seals are less common in Alaskan waters; therefore, they are rarely observed near shore and unlikely to be captured during shore-based tagging studies.

In 2012, bearded and ringed seals in Alaska were designated as threatened under the Endangered Species Act (ESA) because predicted changes in sea ice over the next century were expected to cause their populations to decline (U.S. Federal Register 2012a, b). At the time of listing there was no evidence that either population was declining, and subsistence harvests were considered sustainable and not a factor contributing to the listings.

Identifying important use areas, or habitats, and movements among habitats is necessary to ensure that oil and gas activities and other possible disturbances are minimized through mitigation and careful lease area planning. Satellite telemetry is a powerful tool to study the timing and location of migration routes, identify important habitats, determine interactions with industrial areas and shipping lanes and monitor seals' use of sea ice in a changing environment. Although a few satellite telemetry studies have been conducted in the past, sample sizes were small and more information is needed about ice seal movement, behavior, and habitat use in Alaska, especially how these change in response to rapid declines in sea ice.

Bearded Seals. Bearded seals are the largest of Alaska's ice seals and, although they can make breathing holes in heavy shore fast ice, they primarily use less consolidated pack ice. They are primarily benthic feeders and eat a variety of bottom-dwelling fish and invertebrates (Quakenbush et al. 2011b, Crawford et al. 2015). Bearded seals are also an important seal species for subsistence and are valued for their large size and good meat and oil. Their skins are used to cover boats (umiaks) used for bowhead whaling in some villages (e.g., Point Hope and Utqiaġvik) and 6,700–10,600 are harvested annually (Nelson et al. 2019). Due to their large size (up to 2.4 m (8 feet) long and > 230 kg (500 lbs.)) and their wariness, capturing adult bearded seals is challenging.

Only two adult bearded seals have been tagged in Alaska, both by NMFS personnel working with hunters from Kotzebue, (Boveng and Cameron 2013), therefore little is known about adult movements. Young bearded seals (pups and one-year-olds, locally called "ugrutchiaqs") are easier to catch; 35 were tagged in fall 2004–2006 and 2009 in Kotzebue Sound by a Native Village of Kotzebue project (funded by U.S. Fish and Wildlife Service Tribal Grants) and another was tagged near Point Barrow in September 2012 by NSB personnel. Tagged bearded seals moved south into the Bering Sea for the winter and north again in spring as the ice retreated (Kotzebue Marine Mammal News 2007, Breed et al. 2018, Cameron et al. 2018). Although bearded seals ranged widely, they occasionally made localized movements suggesting focused feeding and resting areas. Of seven bearded seals tagged in Kotzebue Sound with tags that transmitted for multiple years, three of them returned to the same area in the Bering Sea over two consecutive winters, showing remarkable winter site fidelity (Boveng and Cameron 2013). More movement data is needed to understand feeding and wintering areas, the importance of ice and how a changing ice environment will affect bearded seals.

Ringed Seals. Ringed seals are the smallest of the ice seals and their life history strategies are most closely associated with sea ice. They can live under 2 m or more of sea ice through which they maintain breathing holes by scratching ice with their claws. Ringed seals in Alaska waters eat fish (mostly Arctic cod, *Boreogadus saida*) and invertebrates (mostly crustaceans) (Quakenbush et al. 2011a, Crawford et al. 2015). Ringed seals are important for Alaska Native subsistence and 6,500–11,600 are harvested annually in Alaska (Nelson et al. 2019). The thick shore fast ice is used as breeding habitat by adults where both sexes build snow caves or "lairs" in snow drifts that form above their breathing holes (McLaren 1958, Smith 1973). At least in some regions, adults annually return to the same area for breeding where they appear to restrict their movements during spring (Kelly et al. 2010). Young ringed seals (mostly subadults) tagged near Paulatuk, in Northwest Territories, Canada, in September 2001 and 2002, made extensive movements westward past Point Barrow to the northern coast of Chukotka, Russia, and then south into the Chukchi and Bering seas (Harwood et al. 2012). During a cooperative project, the Native Village of Kotzebue, the University of Alaska, and the Alaska Department of Fish and Game (ADFG) tagged 37 ringed seals near Kotzebue, Alaska in 2007–2009 and identified differences in movements between age-classes, especially in winter. Adult seals tended to stay in the Chukchi Sea and northern Bering Sea during winter, while the subadults moved to the southern extent of the ice to winter along the ice edge (Crawford et al. 2012, Kotzebue Marine Mammal News 2012). Where subadults and adults occurred together, they dove to similar depths; although subadults were commonly located in deeper waters where they generally dove deeper than adults. Both age classes hauled out less and dove deeper, longer, and more frequently during midday than at other times of day (Crawford et al. 2019). The North Slope Borough (NSB) tagged 32 ringed seals near Utqiaġvik during July–October 2011. These seals moved north to the ice edge until late October when they began moving south and west. By mid-December, the seals were approaching or through Bering Strait (NSB, unpubl. data). ADFG tagged four ringed seals with a local subsistence hunter near Hooper Bay in June 2012. Although ringed seal distribution has been strongly correlated with the presence of sea ice in all months of the year, during the open-water season, ringed seals do occur in ice-free waters of the Beaufort, Chukchi, and Bering seas (Burns et al. 1981, Crawford et al. 2012).

Spotted seals. Spotted seals are less reliant on ice than ringed or bearded seals and they only maintain breathing holes in thin ice (Fay 1974). Thus, they use loose pack near the ice edge in winter and pups are born on top of the ice in spring. Spotted seals haul out on barrier islands and sandbars, in coastal areas, and in rivers during summer and their diet is more piscivorous than that of ringed and bearded seals (Quakenbush 1988, Quakenbush et al. 2009). Studies of spotted seal movements include 12 seals tagged at barrier island haulouts near Point Lay between 1991 and 1993 (Lowry et al. 1998). These seals moved between the coastal haulouts and offshore areas in August–November before migrating south to winter in the Bering Sea (Lowry et al. 1998). Spotted seals use nearshore areas and coastal haulouts in summer and fall, and when the ice forms in the winter they move offshore and haul out on ice (Lowry et al. 2000). Spotted seals tagged in Russian waters made similar movements (Lowry et al. 2000). In recent collaborations (2012–2015) with the NSB, spotted seals were tagged in the northern Chukchi Sea near Peard Bay (n = 3) and in the western Beaufort Sea in Dease Inlet (n = 20). Summer movements of spotted seals tagged in the 2000s varied from staying near the Alaskan coast to moving across the Chukchi Sea to Russia. Most of the tagged spotted seals moved west, into the Chukchi Sea, after leaving Dease Inlet and, although a few went east, they did not move east of the Colville River Delta; none entered Canadian waters in the eastern Beaufort Sea. Spotted seals also mix with harbor seals (*Phoca vitulina*) in the southern extent of their range in Bristol Bay, Alaska.

Satellite Telemetry. Satellite telemetry is a powerful tool for studying marine mammals that spend most of their time offshore in dark, remote, and icy locations during much of the year and often migrate long-distances (e.g., Quakenbush et al. 2010, Crawford et al. 2012 and 2019, Harwood et al. 2012, Citta et al., 2013, 2015, 2018). Once deployed, tags provide the seal's location and diving behavior in almost real time. Sample sizes in marine mammal telemetry studies tend to be low due to the short season for captures, often unsafe weather, and the cost of transmitters and data acquisition, however, the information received from each tag adds a remarkable amount of data that can be analyzed to address many questions. Sample sizes of tagged animals accumulate through time, which contributes to understanding behavior and variability of behavior seasonally, interannually, and eventually at the population level.

Feeding. ADFG has a subsistence harvest sampling program that analyzes stomach contents of ringed, bearded, and spotted seals. We use this extensive diet database to guide our interpretations of diving behavior collected by the tags (Quakenbush et al. 2009, Quakenbush et al. 2011a, Quakenbush et al. 2011b, Crawford et al. 2015 and 2019). Diet information from the stomachs of subsistence harvested seals is collected in the same years and in some of the same locations as the satellite tag deployments, as well as in some areas tagged seals move through.

Disturbance. The primary source of disturbance to seals is most likely man-made noise produced by ships, barges and tugs, small boats, air traffic, and seismic and drilling operations. It is not clear how important sound is to ice seals; ringed and spotted seals are not known to be very vocal. Male bearded seals, however, advertise their breeding territory by singing in the spring (Ray et al. 1969, Burns 1981, Van Parijs and Clark 2006) and one study determined that male bearded seals are vocal year-round (MacIntyre et al. 2013). An acoustic study found that individual males could be identified by their vocalizations and found the same six adult male bearded seals singing near Point Barrow over a 16 year period (Van Parijs and Clark 2006) indicating that, at least seasonally, vocal communications are important for bearded seals and adult males are territorial showing long-term seasonal site fidelity.

Seals are curious and often surface near a vessel to look at it, but it is not known if seals are attracted to man-made noise or vessels. It is also not known how seals react to drill ships or airgun arrays used during seismic testing. The movements and dive behavior of tagged seals could provide information regarding whether seals are attracted to or displaced from high-noise areas.

Understanding the extent and timing of ice seal movements will be important for planning lease sale areas, oil and gas activities, and shipping lanes so that they minimize impacts to the populations. Although some seals make long-distance movements during summer they may return to a commonly used area during other times of the year. Locating these high-use areas and determining how they are used may identify important areas in need of protection for each species.

Offshore leases have been sold by Minerals Management Service (MMS), now Bureau of Ocean Energy Management (BOEM), for oil and gas exploration and development in the Outer Continental Shelf (OCS) east of Point Barrow, in the Beaufort Sea, and west of Point Barrow in the Chukchi Sea. These leases have overlapped with areas used by ice seals. Although leases in the Chukchi Sea were quite active during four years (2013–2016) of this six-year (2013–2019) seal study, all were relinquished by 2017, however, some leases continue to be active in the Beaufort Sea. Thus, a more thorough and current understanding of ice seal movements and habitat use is important for providing information used in 1) environmental impact statements and environmental assessments under the National Environmental Policy Act, the Marine Mammal Protection Act, and the ESA; 2) planning future lease sales; 3) permitting exploration, development, production and their related activities; and 4) designing effective mitigation for activities.

Methods

Coordination

Meetings with the Ice Seal Committee (ISC), local hunters, tribal councils, communities, and the North Slope Borough (NSB) were fundamental to this tagging project. Communications with National Marine Fisheries Service, Marine Mammal Lab (MML), and NSB regarding research and tagging activities were important for coordination and for increasing sample sizes. Meetings with tag manufacturers were also important for solving technical issues with the tags.

Tagging

The timing and location of tag deployments were guided by interested hunters, community subsistence activities, timing of the seal molt, and access to seals. As with all our Arctic marine mammal studies, this work was conducted in a manner that did not interfere with subsistence activities.

We used a combination of tag types to collect short-term (months) location, dive, haul-out, and oceanographic data as well as long-term (years) location and haul-out data. SPLASH tags (also known as MK10 tags, Wildlife Computers, Redmond, WA, USA) provide location, dive data, and haul-out behavior, and were purchased for this BOEM project (Fig. 1). We also deployed CTD tags (Conductivity-Temperature-Depth, Sea Mammal Research Unit, St. Andrews, Scotland) with funding from the Office of Naval Research (ONR) for a concurrent study focused on seal movements relative to oceanographic parameters. CTD tags provided location, dive, haul-out, and ocean salinity and temperature data (conductivity and temperature at depth intervals). By combining movement and dive data from tags purchased by BOEM and ONR, we increased the number of seals caught, the number of locations we deployed tags, and the type of information we collected from tagged seals, which strengthened the inferences we were able to make for tagged seals to the benefit of both supporters. We include data from BOEM tags in our ONR reports, when appropriate, for the same reasons.

Either a SPLASH or CTD tag was glued (with epoxy) to the hair of the seal's back (and occasionally head); these tags fell off during the annual pelage molt in spring. Only seals captured after the molt will retain an epoxied tag. The third tag type, a SPOT tag (Wildlife Computers, Redmond, WA, USA) was attached to a hind flipper and provided location and haul-out data, but only when the seal was out of the water (Fig. 1). These tags were not affected by the molt and were programmed to conserve battery life and transmit data for up to two years. Most seals were tagged with a flipper-mounted SPOT tag but only seals that molted before capture were instrumented with a SPLASH tag or a CTD tag. SPOT tags were purchased by this BOEM project; MML provided an additional 16 SPOT tags and NSB provided 5 SPOT tags.

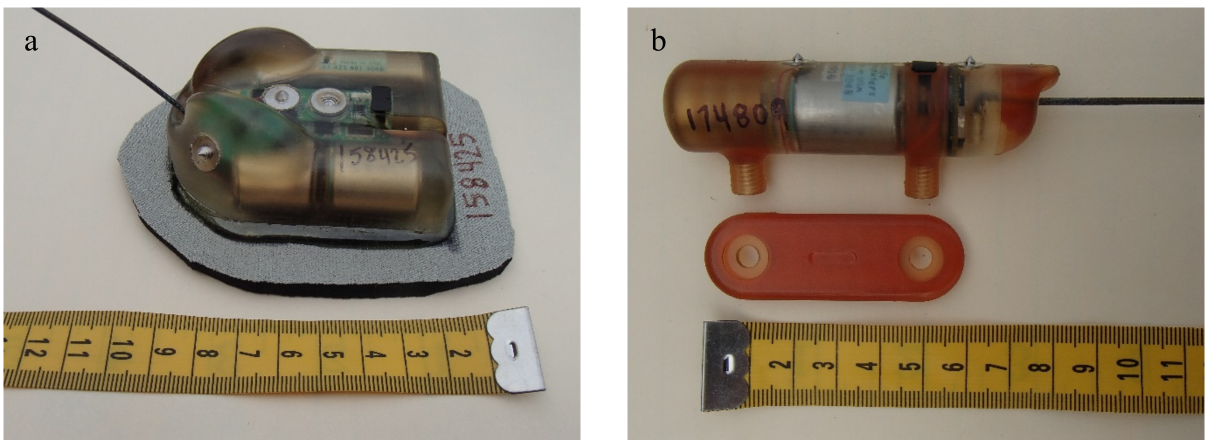


Figure 1. Satellite transmitters deployed on ice seals: a) SPLASH tags epoxied to the seal's back or head, and b) flipper-mounted SPOT6 tag. Both transmitters were manufactured by Wildlife Computers, Redmond, WA, USA. Ruler is in cm.

Typically, seals were captured in large mesh (~12–15-inch stretch) nylon or monofilament nets built with light lead lines that allowed captured seals to reach the surface to breathe. The nets were placed in areas known by subsistence hunters as traditional subsistence netting areas near shore, around pack ice, or in rivers, when seals were present.

Mapping

To keep all interested parties informed of the project and share the movements of tagged seals, we produced maps of seal tracks and sent them to an extensive mailing list that included many seal and other subsistence hunters as well as agency and oil company personnel at least every two weeks. ArcGIS version 10.3 (ESRI 2014) was used for mapping. The maps and information about the project were also posted at the Alaska Department of Fish and Game's (ADFG) webpage:
http://www.adfg.alaska.gov/index.cfm?adfg=marinemammalprogram.icesealmovements

Location Processing and Data Management

Locations and ancillary sensor data (i.e., dive, haul-out, temperature, and salinity) are transmitted to and processed by the Argos system of satellites (Harris et al. 1990). Raw transmitter locations are estimated based upon the Doppler Effect and the error associated with each location (quality) depends on the number of transmissions sent by tags, when the seal was at the surface, that were received by Argos satellites. Location quality was estimated by the Argos system and characterized by "location classes" (see the Argos User's Manual for a complete description; available online from argos-system.org/manual/).

We processed the raw location data depending upon how the data were to be used. We typically filtered raw location data prior to mapping and statistical modelling. The goal of a filter is to remove locations that are known to be unlikely or impossible. Filters calculate the distance between successive locations and use their timestamps to calculate velocity. If including the location results in a velocity that is physically impossible for the species, then that location is removed. Some filters also use an angular component to remove locations with a high degree of location error that fall far from the estimated line of travel, but still within the threshold velocity. These locations are essentially outliers and they create "spikes" or acute deviations in the line of travel (e.g., Freitas et al. 2008, Keating 1994). For location *i*, this deviation is measured as the angle between locations *i*-1, *i*, and *i*+1. We used a Speed-Distance-Angle (SDA) filter developed by Freitas et al. (2008) extensively. This filter has separate velocity and angular components and was fit with R software (available online from R-project.org). The filter removed seal locations that resulted in swim velocities of > 2.5 m/s, unless they were within 5 km of the previous location. The threshold velocity of 2.5 m/s was based on literature review indicating this velocity is the maximum observed speed of seals not fleeing vessels or assisted by currents (Williams and Kooyman 1985, Lowry et al. 1998). Otherwise, we used the default settings within the Freitas et al. (2008) filter; i.e., within 2.5 km of the track line, locations resulting in angles < 15° were removed and locations between 2.5 and 5 km of the track line were removed if they resulted in angles < 25° (see the manual for package 'argosfilter' for more detail, available online at cran.R-project.org). We used this filter for the regular maps we distributed and posted on our webpage and for analyses of seal locations in our published papers (Crawford et al. 2012, 2019).

To estimate daily locations, we modelled location data using the continuous-time Correlated Random Walk (CRW) model developed by Johnson et al. (2008). The model, which treats movement as a velocity process, is available in the R statistical package 'crawl'. We estimated two parameters, β, the autocorrelation in velocity and σ, the variation in velocity. Location error was assumed to be normally distributed with a mean of 0. Argos locations with quality scores 3, 2, and 1 have estimated standard deviations of 250 m, 500 m, and 1500 m, respectively, but standard deviations for poor quality location scores (0, A, and B) are not estimated (see the Argos user's manual: https://www.argos-system.org/manual/) (Fancy et al. 1988; Stewart et al. 1989; Harris et al. 1990). To incorporate location measurement error for poor quality locations into the seal movement model, we used the error distributions from Johnson et al. (2008), which are based upon the observations of Vincent et al. (2002).

More recently, we have explored an additional method for estimating daily locations that also infers one of two behavioral states for each location estimate: transiting or resident behavior. Joint-estimation state-space models (R package: 'bsam', Jonsen et al. 2005, Jonsen 2016) infer behavior based on movement parameters (velocity, turn angle and their autocorrelation), where transiting behavior is characterized by greater velocities and more correlated turning angles (moving in a straight line). Resident behavior is characterized by slower velocities and less correlated turning angles (milling or lingering). This method can be analyzed with dive data so we can better identify important habitats and how they associate with animal behavior.

A copy of the raw and decoded Argos data (with associated metadata) is archived at ADFG in Fairbanks and backed-up on State of Alaska servers in Juneau and Anchorage. The 'raw data' include location, dive, haul-out, and oceanographic data types. We worked with the Animal Telemetry Network (ATN) and the Alaska Ocean Observing System (AOOS) to better prepare them for archiving telemetry data with necessary metadata so that data could be used appropriately by third parties in the future.

Decoding, analyzing, and interpreting raw Argos data are not straightforward. Transmitters have complex settings, such as daily transmission limits or duty cycling, and dive data are often simplified for transmission into user-defined intervals. Even seemingly simple tasks, such as calculating correction factors for aerial surveys, require detailed knowledge of how tags were programmed to sample the environment, including how often they transmit (up-link) to satellites, sample water depth, determine if they are wet or dry, how they define the start and end of dives, and how they define a haul-out bout. Determining how to proceed with data management and analysis requires substantial time and expertise. Although we have the expertise to understand and manage the raw data we collected, we are concerned that future users may not, which could result in data that are unintentionally misused and misinterpreted. Because of this, we explored the level and complexity of metadata necessary for future users to adequately understand what can and should not be done with data we collect. We also suggested to ATN and AOOS that archiving data products that are processed for end-users may be useful, thereby removing the responsibility from naïve users to appropriately decode, analyze, and interpret raw data.

Movement, Dive, and Haul-out Analyses

Seal movement, dive, and haul-out data were examined in relation to bathymetry, distance from land, and sea ice cover. Most analyses were conducted with R statistical software using a model selection framework to compare habitat use and movements by species, age class, sex, time of day, and month. A typical analysis consisted of building linear or linear mixed-effects models using the 'lm', 'lmer' (package: 'lme4'), or 'lme' (package: 'nlme') functions in R and comparing various models via Akaike's Information Criterion (AIC) to select the best fitting model. Significant parameters (i.e. age class or month) within the final model were then used to identify and describe important patterns. When necessary, random effects (such as year or individual seal) were included.

For analyses of sea ice habitat, we defined ice conditions as 'water' (0% ice concentration), 'marginal ice zone' (15–80% ice concentration), and 'heavy ice' (> 80% ice concentration). We defined the ice edge as 15% ice concentration, delineating open water from pack ice (> 15% ice concentration). Sea ice data were daily Sea Ice Concentrations from Nimbus-7 SMMR and

DMSP SSM/I-SSMIS Passive Microwave Data at 25 km resolution, projected using NSIDC's polar stereographic projection. (Data obtained from: ftp://sidads.colorado.edu/pub/DATASETS/nsidc0051_gsfc_nasateam_seaice/final-gsfc/).

Methods used to determine high-use areas for seals was based on the movement behavior of each species. Bearded seals are primarily benthic foragers; therefore, we used a state-space model to infer foraging locations (lingering or resident behavioral state) from traveling locations (transiting behavioral state). For ringed and spotted seals, high-use areas were identified by assessing location densities by season. We identified high-use (core) areas based on the density of daily estimated locations (CRW model) within 50 x 50 km square cells across our study area. We considered the volume of locations in each cell the utilization distribution (UD) and high-use areas to be cells with UDs of < 50% volume. UDs are akin to density, a 95% UD contains 95% of all locations, essentially all areas an animal used. Lower percentages identify areas with higher densities (more animals in a smaller area or volume of locations). Designations of seasons were different for ringed and spotted seals because we based them on species-specific seasonal movements.

Analysis of Time Spent Within Areas of Petroleum Interest

We used all telemetry data collected between 2014 and 2019 to quantify when tagged seals were present within areas of petroleum interest. Transmitter locations were filtered as described above. When calculating the number of calendar days that seals were located within various oil and gas exploration/lease areas we pooled data from all study years (2014–2019). Although pooling across years provides a more general understanding of when seals might be located within a petroleum area, it removes the ability to detect annual variability. Tags were deployed from June through October and, on average, transmitted data for 4.5–7 months. As such, tags provided locations until mid-February through May of the year after they were deployed, a period that generally includes their migration north through the Chukchi Sea. Therefore, documenting the range of days that seals were present within an area will be a minimum estimate because some tags likely went off the air while seals were still in those areas.

We examined seal use of the Alaskan Chukchi and Beaufort Sea oil and gas program areas (Fig. 2):

1. Alaskan Chukchi Sea: All of Lease Sale 193 area.
2. General activity when near leased blocks in the Alaskan Beaufort Sea.

Analysis of Ship Traffic

We used Automatic Identification System (AIS) data collected from maritime ships to identify highly used shipping areas and those areas that overlapped with seal locations. AIS data were compiled by ExactEarth (Cambridge, Ontario, Canada) and made available to us by the Wildlife Conservation Society. AIS data included areas used by seals in the Bering and Chukchi seas during 2013–2015. AIS data extended to the northern Chukchi Sea (72°N), south of St. Lawrence Island (62.5°N), east to Point Barrow (156.5°W), and west to Anadyr Gulf and Chaunskaya Bay, Russia (172.5 °E). Monthly density rasters of maritime shipping traffic were made using a kernel utilization volume distribution of the AIS data and grid sizes < 2 km. The input AIS data for each month was cleaned by removing the points that had incomplete Maritime Mobile Service Identity numbers, fewer than 10 points for that vessel, or the reported speed was less than 2 knots or greater than 30 knots. Rasters were generated with R statistical software using the 'kernelUD' and 'getvolumeUD' functions from the package 'adehabitatHR'. Monthly rasters of densities were then averaged across month to match seasons with open-water that we report (Spring: April–June, Summer: July–September, and Fall: October–December). January–March had few ship locations within the study area after data cleaning so no rasters were generated. We then overlaid daily estimated locations (CRW model) of bearded, ringed, and spotted seals to determine areas of overlap with maritime shipping traffic. We further identified the seasonal proportion of each seal species locations that were generally within shipping areas, 95% density volume, and highly used shipping areas, 50% density volume.

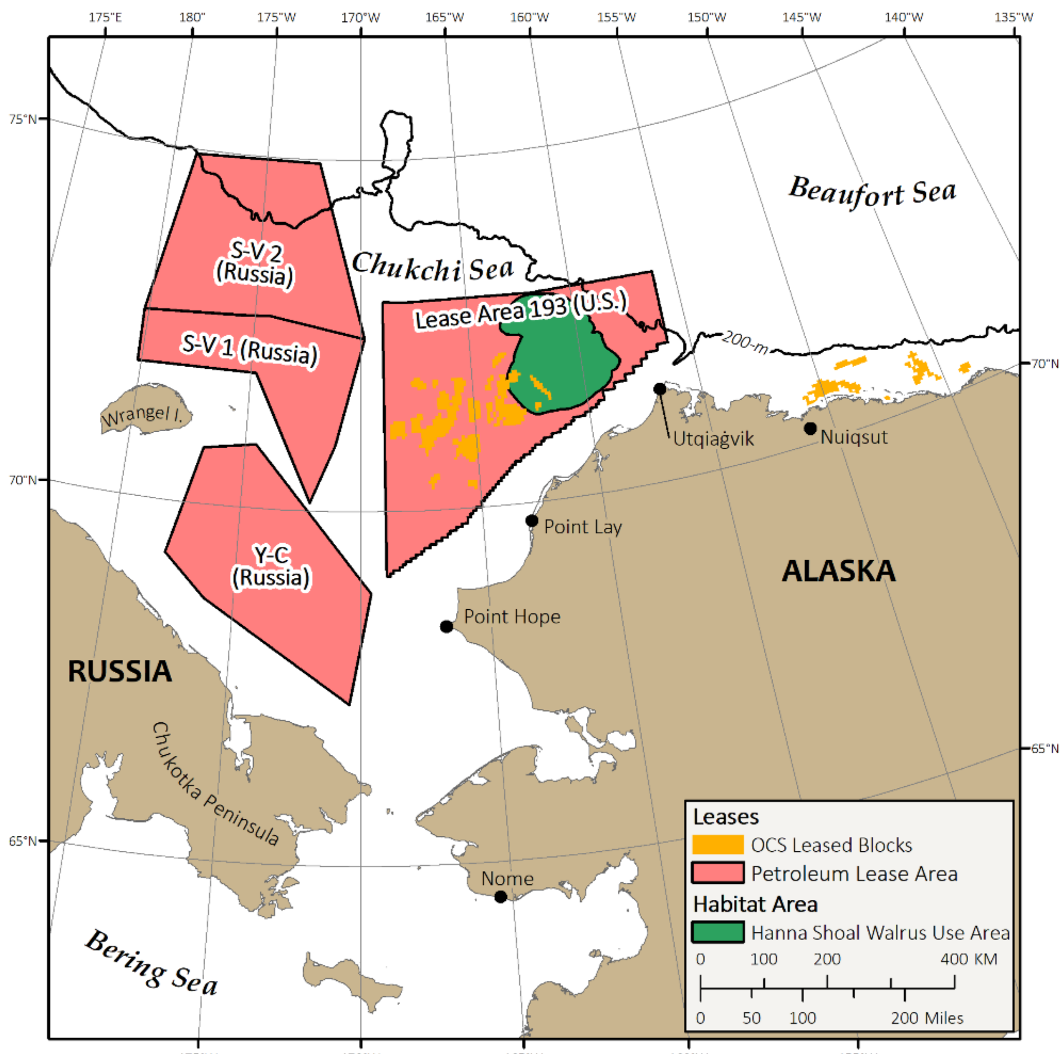


Figure 2. Map of the Chukchi and Beaufort seas with U.S. and proposed Russian petroleum exploration/development lease areas (red), and U.S. Outer Continental Shelf (OCS) historically leased blocks (orange). Proposed Russian petroleum areas include: Severo-Vrangelevskiy 1 (S-V 1), Severo-Vrangelevskiy 2 (S-V 2), and Yuzhno-Chukotsky (Y-C). The Hanna Shoal Walrus Use Area, recognized as an important foraging area for walruses was delineated by Jay et al. (2012) using utilization distributions of tagged walruses from June through September, is also shown (green). Note that OCS Leased Blocks associated with the Chukchi Sea Lease Sale 193 area were active during the study period, however, all were relinquished by 2017.

Safety

Safety plans were specific for each area and tagging effort. We purchased safety equipment and trained participants in its use. Safety equipment included Mustang floatation suits, waterproof handheld radios, satellite phones and other emergency communication devices, personal satellite-linked locator beacons and GPS units. Communication with a shore-base was coordinated prior to each trip.

Traditional Ecological Knowledge

A valuable component of this study was the collection of traditional ecological knowledge (TEK) regarding seal movements, timing of migration, and hauling out behavior provided by seal hunters. TEK was collected by organizing a formal interview or interviews with hunters and elders in a community. The interview process followed a semi-directive interview described by Huntington (1998) in which researchers initiated a discussion around various topics of interest, but allowed the person or group being interviewed to determine the order in which topics are discussed and to make connections among various topics the researchers might not have anticipated. The people interviewed were recommended by each community's Tribal Council and by other seal hunters.

We also collected TEK when we worked with hunters to catch seals for satellite tag deployments. To catch ringed, bearded, and spotted seals safely and effectively requires knowledge of local currents, tides, weather patterns, sea ice, seal behavior, and seal availability. TEK gained using both methods was then incorporated into a traditional knowledge report (e.g., Huntington and Quakenbush 2009, 2013; Huntington et al. 2012) and included in project annual and final reports.

Results

Coordination

We worked with the ISC, NSB, and local seal hunters. A chronology of the project history and accomplishments are included in Table 1. We also sent maps to an extensive list of interested entities (~185) including individual subsistence hunters, tribal council offices, ISC, NSB, BOEM, ONR, NOAA, University of Alaska, United States Coast Guard (USCG), and oil and gas industry personnel. We maintained a webpage on ADFG's website that explained the project, provided annual updates of seals tagged and the communities and hunter-taggers we worked with, and was updated bi-weekly with the maps of seal movements: http://www.adfg.alaska.gov/index.cfm?adfg=marinemammalprogram.icesealmovements.

Table 1. Project history from September 2013 through September 2019. Appendices are referenced here in chronological order.

Month	Year	Event
September	2013	Received contract from BOEM.
January	2014	Project update to ISC, discussed locations for tagging and TEK. Met with collaborators, a capture-net maker, and BOEM COR at the Alaska Marine Science Symposium (AMSS).
February		Teleconference with NMFS, MML regarding seal tagging in Kotzebue.
March		Trained hunters from Hooper Bay, Elim, Koyuk, Unalakleet, and St. Michael to safely capture and tag seals.
April		Coordinated with Native Village of Kotzebue (NVOK) for seal tagging.
June		Tagged one young bearded and four ringed seals near Kotzebue.
September		Tagged three young bearded seals near Koyuk.
January	2015	Poster "*Hunter-assisted study on ringed and bearded seal movements, habitat use and traditional knowledge*" at AMSS, Anchorage (Appendix A). Traveled to Barrow to collect TEK. Submitted annual report to BOEM.
February		Traveled to Elim, St. Michael, and Stebbins to collect TEK.
March		Presented project update at the ISC annual meeting. Conducted a hunter-tagger training workshop for hunters from the North Slope (Kaktovik, Barrow, and Wainwright), Maniilaq (Kotzebue), Kawerak (Nome, Elim, and St. Michael), Yukon-Kuskokwim Delta (Scammon Bay and Hooper Bay), and Bristol Bay (Togiak).
April–May		Coordinated with NVOK for seal tagging in June. Received updated Animal Care and Use protocol (ADFG ACUC #2015-25).
May		Tagged one ringed seal near Hooper Bay.
June		Attempted to catch adult bearded seals near Kotzebue; poor ice, none caught.
August		Tagged four young bearded and one ringed seal near St. Michael and four bearded seals near Koyuk.
December		Oral presentation at Polar Seal Tagging Workshop in San Francisco at Biennial Marine Mammal Conference. Poster "*Effects of changing sea ice on marine mammals and subsistence hunters in northern Alaska*" in San Francisco at the American Geophysical Union Conference (Appendix B). Worked with Shishmaref, Kivalina, and Kotzebue IRA's, hunters, and ISC to organize a TEK gathering trip in January 2016. Final Barrow, Elim, St. Michael, Stebbins TEK reports (Appendices C–E).
January	2016	Posters "*Hunter-assisted study on ringed and bearded seal movements, habitat use and traditional knowledge*" (Appendix F) and "*Effects of changing sea ice on marine mammals and subsistence hunters in northern Alaska*" (Appendix G) at AMMS, Anchorage. Traveled to Shishmaref, Kivalina, and Kotzebue to collect TEK. Submitted annual permit report to NMFS for research permit #15324. Submitted annual report to BOEM.
January–March		Sent draft TEK reports to interviewees for review, comment, and approval.
April		Received Animal Care and Use Committee Assurance of Animal Care protocol (ADFG ACUC #2016-23). Submitted application to NMFS for new seal research permit.

April–July		Final Shishmaref, Kivalina, and Kotzebue TEK reports (Appendices H–J). Drafted manuscript combining TEK data for submission to Biology Letters.
June		Update to ISC on seal tagging and TEK. Tagged one ringed seal near St. Michael.
July		Tagged four young bearded seals near St. Michael.
August		"*Effects of changing sea ice on marine mammals and subsistence hunters in northern Alaska from traditional knowledge interviews"* published Biology Letters (Huntington et al. 2016). Tagged one young bearded seal near Utqiaġvik (Barrow).
September		Tagged two bearded seals near Koyuk. Traveled to St. Michael to catch seals but weather conditions were poor. Applied for an extension of our current research permit (NMFS#15324) while our new permit is being processed.
January	2017	Poster "*Update of hunter-assisted seal tagging and traditional knowledge studies of Pacific Arctic seals, 2016 and beyond*" at AMSS, Anchorage (Appendix K). TEK interviews conducted in Hooper Bay, Scammon Bay, and Mekoryuk.
January–December		Prepared and contributed seal location data to the BOEM-funded synthesis of Arctic Research (SOAR II) analysis of marine mammal distributions.
January–March		Sent draft TEK reports to the interviewees for review and approval.
March		Submitted 2016 annual permit report to NMFS for research permit #15324.
April		Received Animal Care and Use Committee Assurance of Animal Care protocol (ADFG ACUC #0027-2017-27).
May		Provided maps to NMFS, Alaska Region, of bearded and ringed seals and bowhead whales by month (July–November) relative to Quintillion laying fiber optic cable for preparation of a biological opinion (Appendix L).
June		ISC update on seal tagging and TEK. Finalized TEK reports for Hooper Bay, Mekoryuk, and Scammon Bay (Appendices M–O). Tagged two ringed seals and one spotted seal near Buckland.
July		Tagged three spotted seals near Scammon Bay. Worked with the NSB to tag seals near Utqiaġvik (Barrow), but poor ice conditions and weather limited capture opportunities to two days.
August		Tagged one spotted seal near Utqiaġvik. Tagged one young bearded seal and three spotted seals near Nuiqsut. Traveled to St. Michael to catch seals but weather conditions were poor and limited capture opportunities to two days. Received and commented on new draft research permit from NMFS.
September		Tagged three young bearded seals near Koyuk. "*Evaluating the effects of climate change on indigenous marine mammal hunting in northern and western Alaska using traditional* knowledge" published in Frontiers in Marine Science (Huntington et al. 2017). Received final NMFS research permit #20466.
October		Oral presentation for Canada-U.S. Oil and Gas Research Forum, Anchorage. Posters "*Seasonal movements, habitat use, and dive behavior of pup and yearling bearded seals in the Pacific Arctic*" (Appendix P) and "*Evaluating impacts of climate change on indigenous marine mammal hunting in northern and western Alaska using traditional knowledge"* (Appendix Q) at Society for Marine Mammalogy Conf. in Halifax, Nova Scotia, Canada. Tagged one bearded seal near Nome.

November		Provided haul-out data for ringed seals to NOAA Fisheries, Marine Mammal Lab, for correction factor to aid aerial survey data for population estimate. Provided maps of seal use areas to USGS for Chukchi Sea polar bear studies.
December		Prepared annual report to BOEM. Presented project at the Animal Telemetry Network Workshop in Anchorage. Provided ringed seal movements between the Chukchi and Bering seas for a CAFF project on ringed seal ecotypes circumpolar-wide.
January	2018	Posters "*Seasonal movements, habitat use, and dive behavior of pup and yearling bearded seals in the Pacific Arctic*" and "*Climate change, marine mammals, and indigenous hunting in northern Alaska: insights from a decade of traditional knowledge interviews*" at AMSS (Appendix R and S).
January–December	2018	Provided daily estimated locations of tagged seals to BOEM (Warren Horowitz, Physical Oceanographer) for use in planning and permitting.
February		"*A multi-species synthesis of satellite telemetry data in the Pacific Arctic (1987–2015): Overlap of marine mammal distributions and core use areas*" was published in Deep-Sea Research Part II (Citta et al. 2018), includes seal location data from this project.
March		Submitted 2017 annual permit report to NMFS for research permit #20466.
April		Received Animal Care and Use Committee Assurance of Animal Care protocol (ADFG ACUC #0027-2018-29).
June		ISC update on seal tagging and TEK.
July		Tagged two spotted seals near Scammon Bay. Worked with the NSB near Utqiaġvik, but poor ice conditions and weather limited capture opportunities to one day; tagged one spotted seal. St. Michael taggers searched for seals on two occasions but did not find any.
August		St. Michael taggers searched for seals on four occasions but did not find any.
September		Tagged two spotted seals on the Colville River near Nuiqsut. Tagged one young bearded seal near Koyuk. Tagged three spotted seals in Dease Inlet near Utqiaġvik.
December		Prepared annual report to BOEM. Analyzed location and haul-out data for spotted seal poster at AMSS.
January	2019	Poster "*Seasonal movements and high-use areas of spotted seals (*Phoca largha*) in the Pacific Arctic*" at AMSS (Appendix T). Submitted annual report to BOEM.
February–May		Prepared bearded seal movement and dive behavior manuscript.
April		Submitted abstract "*Oceanographic characteristics associated with movements and high-use areas of spotted seals (*Phoca largha*) in the Chukchi and Bering seas*" (Appendix U) to be presented at the Society for Marine Mammalogy Conference in December 2019 in Barcelona, Spain.
May		Attended ISC meeting and presented an update on seal tagging.
June		Tagged five ringed seals near Utqiaġvik. Submitted manuscript "*Movement, diving, and haul-out behaviors of juvenile bearded seals in the Bering, Chukchi and Beaufort Seas, 2014–2018*" to Polar Biology.
September		Final report to BOEM.

Tagged Seals

During 2014–2019, we deployed 122 satellite-linked transmitters on 67 seals (26 bearded, 16 ringed, and 25 spotted seals) (Table 2). We deployed 59 primary tags attached with epoxy (24 SPLASH tags and 35 CTD tags), and most seals (63 of 67) also received a secondary flipper-mounted SPOT tag.

Table 2. Bearded, ringed, and spotted seals tagged with satellite-linked transmitters during 2014–2019. Primary tags (SPLASH or CTD) were attached with epoxy and fell off during the annual pelage molt in spring. Secondary tags (SPOT) were attached to inter-digital webbing of a hind flipper and could transmit for multiple years. Seal ages were determined by counting foreflipper claw annuli. Durations of tag transmissions (Dur., # days) do not include tags deployed on seals that were harvested while the tag was still active or those deployed in 2019 that were active as of the drafting of this report. Five SPOT and one CTD tags did not transmit data or locations. Seal ID: BS = bearded, RS = ringed, SS = spotted.

				Date				
Seal ID	Species	Sex	Age (Yrs)	Deployed	Most Recent Location	Capture Location	Primary Tag Type[a] (Dur.)	SPOT Flipper-Tag (Dur.)
BS14-01-M	Bearded	M	0	18 Jun 2014	22 May 2015	Kotzebue Sound	SPLASH (257)	Yes[b] (338)
RS14-01-M	Ringed	M	7	18 Jun 2014	12 May 2016	Kotzebue Sound	SPLASH (173)	Yes[b] (694)
RS14-02-F	Ringed	F	6	18 Jun 2014	11 Jun 2015	Kotzebue Sound	SPLASH (213)	Yes[b] (357)
RS14-03-M	Ringed	M	6	19 Jun 2014	15 Jun 2015	Kotzebue Sound	SPLASH (213)	Yes[b] (361)
RS14-04-F	Ringed	F	6	19 Jun 2014	06 Jul 2015	Kotzebue Sound	None	Yes[b] (382)
BS14-02-M	Bearded	M	0	26 Sep 2014	31 Dec 2015	Koyuk River	SPLASH (127)	Yes[b] (461)
BS14-03-M	Bearded	M	0	26 Sep 2014	17 Nov 2014	Koyuk River	SPLASH (52)	Yes[b] (0)
BS14-04-M	Bearded	M	0	30 Sep 2014	18 Jul 2015	Koyuk River	SPLASH (89)	Yes[b] (291)
RS15-01-M	Ringed	M	1	14 May 2015	05 Aug 2015	Hooper Bay	None	Yes[b] (83)
BS15-01-M	Bearded	M	0	18 Aug 2015	09 Oct 2015	Koyuk River	SPLASH (53)	Yes[b] (0)
BS15-02-M	Bearded	M	0	18 Aug 2015	20 Oct 2015	Koyuk River	SPLASH (64)	Yes[b] (0)
BS15-03-F	Bearded	F	0	19 Aug 2015	19 Jan 2016	Koyuk River	SPLASH (153)	Yes[b] (119)
BS15-04-F	Bearded	F	0	20 Aug 2015	04 Jan 2016	Koyuk River	SPLASH (135)	Yes[b] (138)

BS15-05-M[e]	Bearded	M	0	22 Aug 2015	31 Aug 2015	St. Michael Canal	SPLASH (9)	Yes[b] (10)
BS15-06-F	Bearded	F	1	22 Aug 2015	01 Sep 2015	St. Michael Canal	SPLASH (10)	Yes[b] (10)
BS15-07-M	Bearded	M	1	23 Aug 2015	10 Sep 2016	St. Michael Canal	SPLASH (193)	Yes[b] (384)
BS15-08-F	Bearded	F	1	23 Aug 2015	11 Dec 2015	St. Michael Canal	SPLASH (91)	Yes[b] (110)
RS15-02-F	Ringed	F	0	23 Aug 2015	15 Dec 2015	St. Michael Canal	None	Yes[b] (115)
RS16-01-M	Ringed	M	0	10 Jun 2016	16 Sep 2016	St. Michael Canal	None	Yes[b] (98)
RS16-02-M	Ringed	M	8	01 Jul 2016	18 Apr 2017	Utqiaġvik	CTD (291)	Yes[c] (193)
RS16-07-M	Ringed	M	7	01 Jul 2016	31 Jan 2017	Utqiaġvik	CTD (110)	Yes[c] (214)
BS16-01-M	Bearded	M	0	03 Jul 2016	16 Jun 2017	St. Michael Canal	SPLASH (33)	Yes[b] (348)
BS16-02-M	Bearded	M	0	04 Jul 2016	17 Jul 2016	St. Michael Canal	None	Yes[b] (13)
BS16-03-F	Bearded	F	0	17 Jul 2016	25 Mar 2017	St. Michael Canal	None	Yes[b] (251)
BS16-04-F[e]	Bearded	F	0	23 Jul 2016	06 Aug 2016	St. Michael Canal	CTD (14)	Yes[b] (14)
SS16-01-F	Spotted	F	3	27 Jul 2016	08 Jun 2017	Dease Inlet (Utqiaġvik)	CTD (229)	Yes[c] (316)
SS16-03-M	Spotted	M	4	03 Aug 2016	10 Feb 2017	Dease Inlet (Utqiaġvik)	CTD (191)	Yes[c] (0)
SS16-05-M	Spotted	M	1	14 Aug 2016	01 Feb 2017	Dease Inlet (Utqiaġvik)	CTD (171)	Yes[d] (126)
BS16-05-F	Bearded	F	1	15 Aug 2016	13 Aug 2017	Utqiaġvik	None	Yes[b] (363)
SS16-06-F	Spotted	F	5	17 Aug 2016	29 Jul 2017	Dease Inlet (Utqiaġvik)	CTD (169)	Yes[d] (346)
SS16-07-M	Spotted	M	6	17 Aug 2016	19 Jul 2017	Dease Inlet (Utqiaġvik)	CTD (153)	Yes[d] (336)
SS16-08-M	Spotted	M	1	25 Aug 2016	07 Apr 2017	Dease Inlet (Utqiaġvik)	CTD (225)	No
SS16-09-F	Spotted	F	5	25 Aug 2016	05 Apr 2017	Dease Inlet (Utqiaġvik)	CTD (223)	No
BS16-06-M	Bearded	M	0	20 Sep 2016	11 Jun 2017	Koyuk River	CTD (158)	Yes[b] (264)

BS16-07-F	Bearded	F	0	20 Sep 2016	25 Sep 2017	Koyuk River	SPLASH (224)	Yes[b] (370)
SS16-10-F	Spotted	F	1	18 Oct 2016	04 Mar 2017	Scammon Bay	CTD (137)	No
SS16-11-F	Spotted	F	1	18 Oct 2016	05 May 2017	Scammon Bay	CTD (199)	No
BS16-08-M	Bearded	M	1	10 Nov 2016	11 Mar 2017	Cape Nome	CTD (84)	Yes[b] (121)
RS17-01-M	Ringed	M	7	20 Jun 2017	15 May 2018	Kotzebue Sound	SPLASH (266)	Yes[b] (329)
RS17-02-M	Ringed	M	5	22 Jun 2017	23 Feb 2018	Kotzebue Sound	CTD (149)	Yes[b] (246)
SS17-01-M	Spotted	M	0	22 Jun 2017	23 Jun 2017	Kotzebue Sound	None	Yes[b] (1)
SS17-02-M	Spotted	M	5	10 Jul 2017	27 Apr 2019	Scammon Bay	CTD (289)	Yes[b] (657)
SS17-03-F	Spotted	F	0	11 Jul 2017	31 Jan 2018	Scammon Bay	SPLASH (147)	Yes[b] (204)
SS17-04-M	Spotted	M	0	11 Jul 2017	28 Feb 2018	Scammon Bay	SPLASH (184)	Yes[b] (232)
SS17-05-M	Spotted	M	3	25 Jul 2017	13 Jan 2018	Dease Inlet (Utqiaġvik)	CTD (172)	Yes[c] (0)
SS17-06-F	Spotted	F	0	09 Aug 2017	07 Jun 2018	Colville River (Nuiqsut)	CTD (140)	Yes[d] (302)
BS17-01-F	Bearded	F	0	10 Aug 2017	19 Apr 2019	Colville River (Nuiqsut)	CTD (221)	Yes[b] (591)
SS17-07-M	Spotted	M	2	16 Aug 2017	11 Jan 2018	Fish Creek (Nuiqsut)	CTD (148)	Yes[d] (96)
SS17-08-F	Spotted	F	1	16 Aug 2017	26 Feb 2018	Fish Creek (Nuiqsut)	CTD (194)	Yes[d] (100)
BS17-02-F	Bearded	F	0	20 Sep 2017	03 Jul 2019	Koyuk River	CTD (147)	Yes[b] (652)
BS17-03-M	Bearded	M	0	21 Sep 2017	06 Nov 2017	Koyuk River	CTD (45)	Yes[b] (45)
BS17-04-F	Bearded	F	0	22 Sep 2017	26 Jul 2018	Koyuk River	CTD (164)	Yes[b] (307)
BS17-05-F[e]	Bearded	F	0	20 Oct 2017	21 May 2018	Cape Nome	CTD (135)	Yes[b] (213)
SS18-01-M	Spotted	M	3	03 Jul 2018	04 Feb 2019	Scammon Bay	CTD (216)	Yes[b] (55)
SS18-02-M	Spotted	M	3	05 Jul 2018	Active	Scammon Bay	SPLASH (102)	Yes[b] (*A*)

SS18-03-F	Spotted	F	5	26 Jul 2018	19 Jun 2019	Dease Inlet (Utqiaġvik)	CTD (117)	Yes[b] (329)
SS18-04-F	Spotted	F	0	07 Sep 2018	03 Nov 2018	Fish Creek (Nuiqsut)	SPLASH (57)	Yes[d] (52)
SS18-05-F	Spotted	F	5	09 Sep 2018	09 Jan 2019	Fish Creek (Nuiqsut)	CTD (122)	Yes[d] (48)
SS18-06-M	Spotted	M	0	20 Sep 2018	30 May 2019	Dease Inlet (Utqiaġvik)	CTD (252)	Yes[b] (58)
SS18-07-F	Spotted	F	1	20 Sep 2018	22 May 2019	Dease Inlet (Utqiaġvik)	CTD (244)	Yes[b] (80)
BS18-01-F	Bearded	F	0	24 Sep 2018	16 Jul 2019	Koyuk River	CTD (152)	Yes[b] (296)
SS18-08-F	Spotted	F	1	27 Sep 2018	26 Apr 2019	Dease Inlet (Utqiaġvik)	CTD (0)	Yes[b] (212)
RS19-01-M	Ringed	M	6	22 Jun 2019	Active	Utqiaġvik	CTD (*A*)	Yes[b] (*A*)
RS19-02-M	Ringed	M	6	22 Jun 2019	Active	Utqiaġvik	CTD (*A*)	Yes[b] (*A*)
RS19-03-M	Ringed	M	10	23 Jun 2019	Active	Utqiaġvik	SPLASH (*A*)	Yes[b] (*A*)
RS19-04-M	Ringed	M	7	23 Jun 2019	Active	Utqiaġvik	CTD (*A*)	Yes[b] (*A*)
RS19-05-M	Ringed	M	6	24 Jun 2019	Active	Utqiaġvik	SPLASH (*A*)	Yes[d] (*A*)

[a] SPLASH tags were funded by BOEM (this project), CTD tags were funded by Office of Naval Research (concurrent project)
[b] SPOT tags funded by BOEM (this project); [c] SPOT tags provided by the North Slope Borough
[d] SPOT tags provided by NOAA Fisheries, Marine Mammal Lab; *A* = tag transmitting as of 30 September 2019
[e] Harvested or found dead

Bearded seals. We tagged 26 young bearded seals (ages 0 and 1 year old) in the Bering, Chukchi, and Beaufort seas near the communities of St. Michael, Koyuk, Nome, Buckland, Utqiaġvik, and Nuiqsut during 2014–2018 (Table 2 and Fig. 3). Captures occurred between June and November, with most in August (38%, 10 of 26; Fig. 4). During TEK interviews and public meetings held in seal hunting communities we learned that young bearded seals follow migrating fish into river systems to feed and then rest on the riverbanks (see Appendices C–E, H, M, O). Indeed, most bearded seals (85%, 22 of 26) were captured in, or near, river systems (St. Michael Canal, Koyuk River, and Colville River). Without this information and the experience of local hunters, very few bearded seals would have been tagged. The remaining four young bearded seals were captured in coastal areas, including two captured in subsistence nets used to harvest beluga whales near Nome.

Ringed seals. We tagged 16 ringed seals near the communities of Hooper Bay, St. Michael, Buckland, and Utqiaġvik during 2014–2017 and 2019 (Table 2, Fig. 3). Most (81%, 13 of 16) were adults (≥ 5 years old) captured between May and August, with most captured in June (75%, 12 of 16; Table 2, Fig. 4). Conditions reported by subsistence hunters that have shortened the hunting season (Huntington et al. 2016, 2017) have also shortened the tagging season. These conditions include earlier sea ice retreat in the spring and later formation in the fall and are associated with climate change. Areas where we found ringed seals in June in the early years of this study, had little to no ice, or ringed seals, in the later years. Because the molt occurs in May and early June, tagging earlier in the season, before molt, is not an option. In 2019, we tagged five adult ringed seals by working farther north, near Utqiaġvik, where sea ice was present in mid-June.

Spotted seals. We tagged 25 spotted seals near the communities of Scammon Bay, Buckland, Utqiaġvik (Dease Inlet), and Nuiqsut during 2016–2018 (Table 2, Fig. 3). Tagging of spotted seals was added to the objectives of this project in 2016 when we received a no cost extension. Almost half of the spotted seals tagged were subadults (1–3 years old; 48%, 12 of 25), seven were adults (≥ 4 years old; 28%) and six were pups (24%). We captured spotted seals between June and October, with most captured in August (36%, 9 of 25; Fig. 4). All spotted seals were captured by setting nets in the water at the edge of occupied haulouts on islands and river bars known to local hunters as haulout areas. Seals would get entangled in the net as they left the haulout.

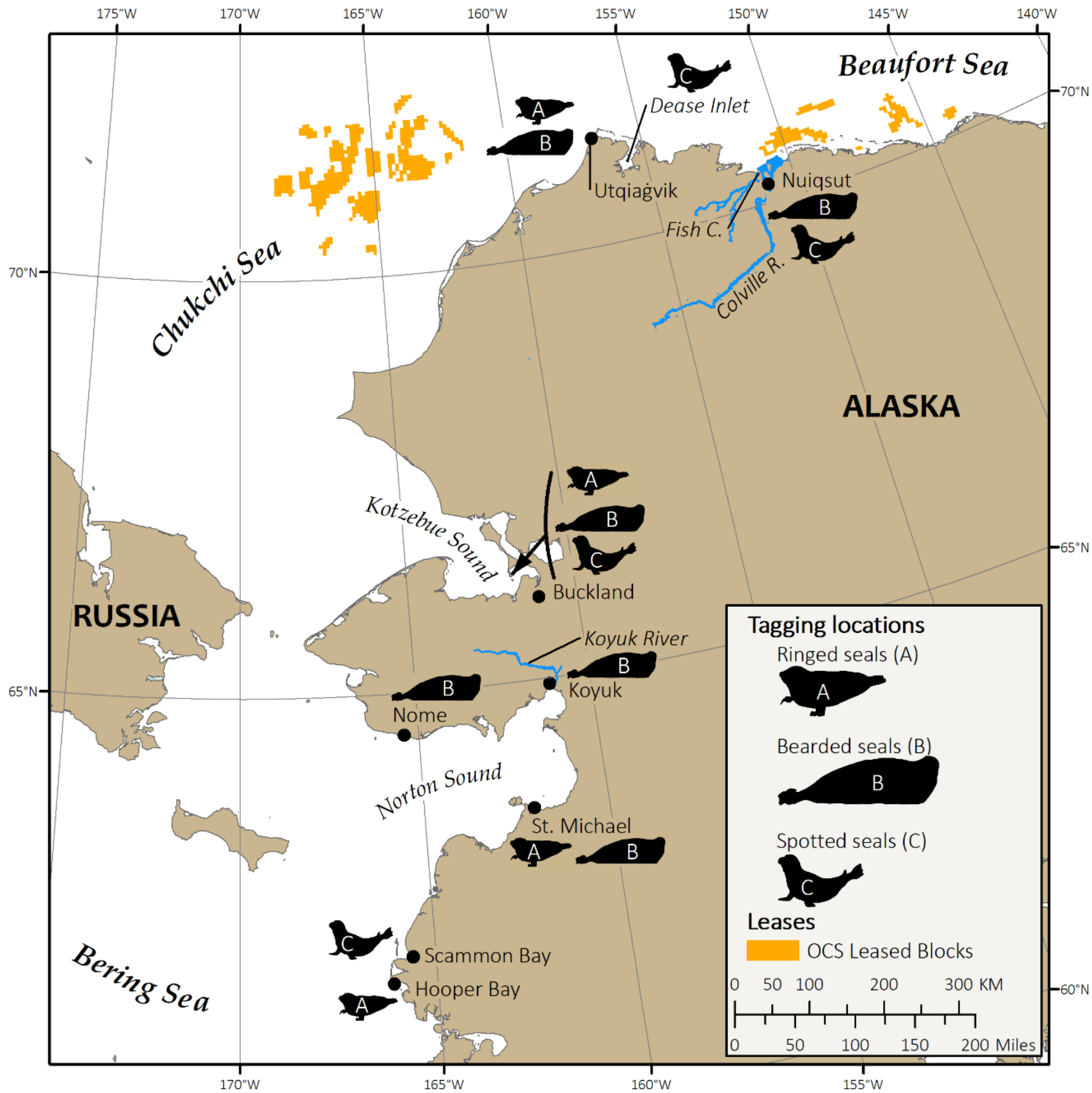


Figure 3. Locations where satellite-linked transmitters were deployed on bearded, ringed, and spotted seals during 2014–2018. OCS Leased Blocks associated with Chukchi Sea Lease Sale 193 area were active during 2013–2016; all were relinquished by 2017.

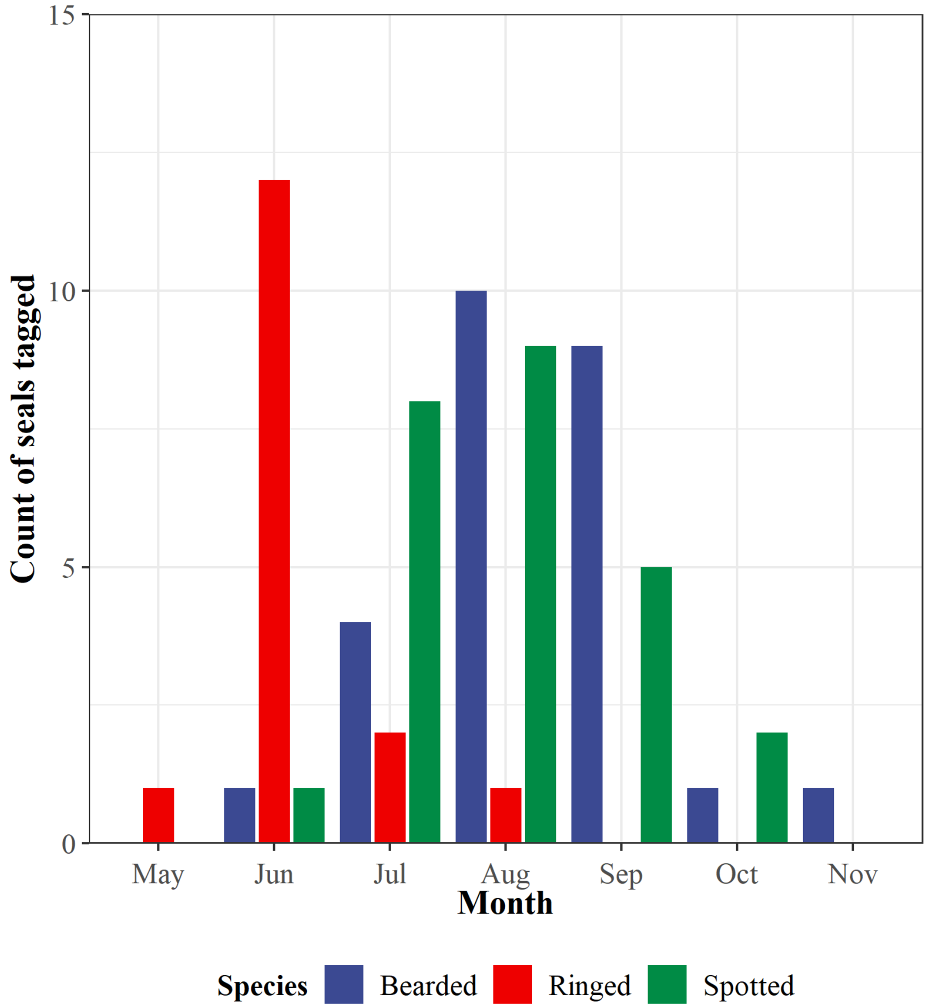


Figure 4. Count of bearded, ringed, and spotted seals tagged in the Bering, Chukchi, and Beaufort seas by month from 2014 to 2019.

Tag Performance

We primarily tagged seals between June and September (93%, 62 of 67; Fig. 4). The number of seals with active tags decline after deployment due to draining battery voltage, damage to the tag, and tag loss, including attachment wear and spring pelage molt. For bearded seals, more tags were active from September through January than February through August (Fig. 5a). For ringed seals, more tags were active in June and July than other months (Fig. 5b). For spotted seals, more tags were active in August through January than February through July (Fig. 5c).

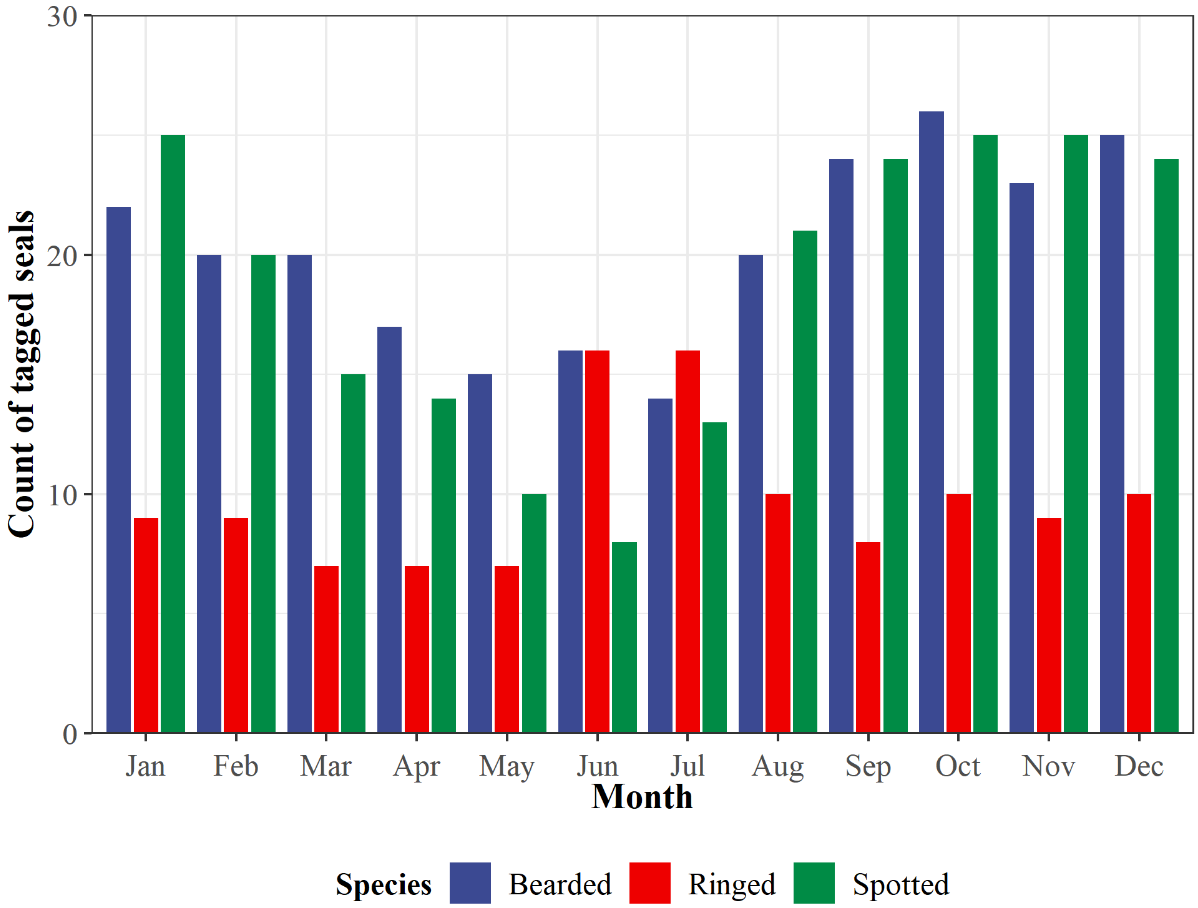


Figure 5. Number of bearded, ringed, and spotted seals with active tags by month, all years combined (2014–2019).

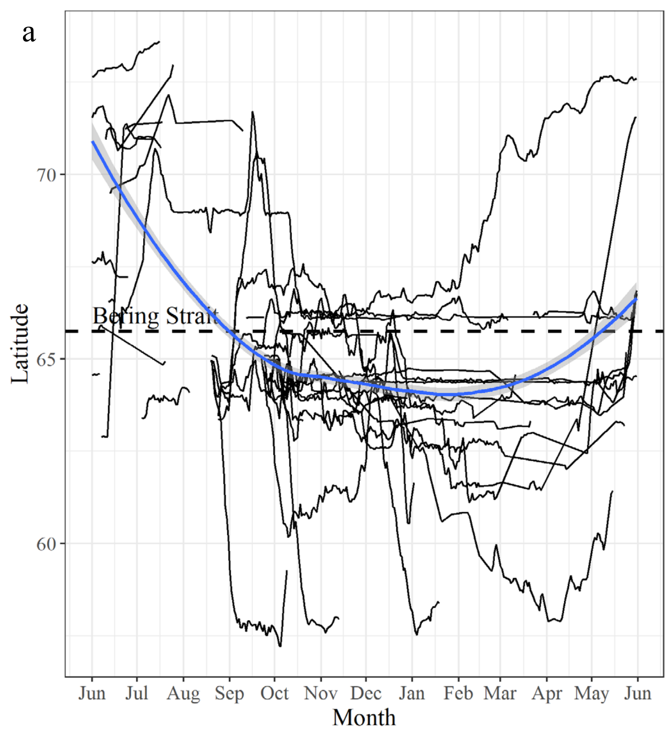
The number of days from deployment to last transmission (tag duration) did not differ among species, sex, age class, or deployment years ($P > 0.29$). Primary tags (SPLASH or CTD), epoxied to seals transmitted for similar durations (mean pooled duration 159 days, range 10–291 days, $P = 0.11$). Secondary tags (SPOT), attached to the hind flippers, transmitted an average of 72 days longer (mean duration 231 days, range 1–694 days) than primary tags ($P < 0.01$) (Table 2) and, for some seals, allowed us to assess seasonal site fidelity.

Seal Movements

We received locations from at least one of two tags deployed on all 67 seals instrumented during this project despite not receiving any locations from one CTD and five SPOT tags. Movements during the six years of this study were widespread from the eastern Beaufort Sea throughout the Chukchi Sea and the Bering Sea shelf. Seals moved north of the Chukchi Sea shelf break (200 m isobath), over the deep Arctic Basin and used shallow estuaries and river systems along the Chukotka Peninsula of Russia and the coast of Alaska. Between-year site fidelity (returning to the same area used in prior years during the same period) of foraging and resting sites was detected but varied considerably among individuals tracked for longer than one year. Although, individual movements were occasionally highly variable, we identified general trends in seasonal movements of each species of seal.

Bearded seals

The large-scale movements of bearded seals varied based on tagging location. Most bearded seals (*n* = 24) made broad latitudinal movements (Fig. 6a), however, those tagged in the Beaufort Sea (*n* = 2) did not travel south of ~70 °N (Fig. 6b).



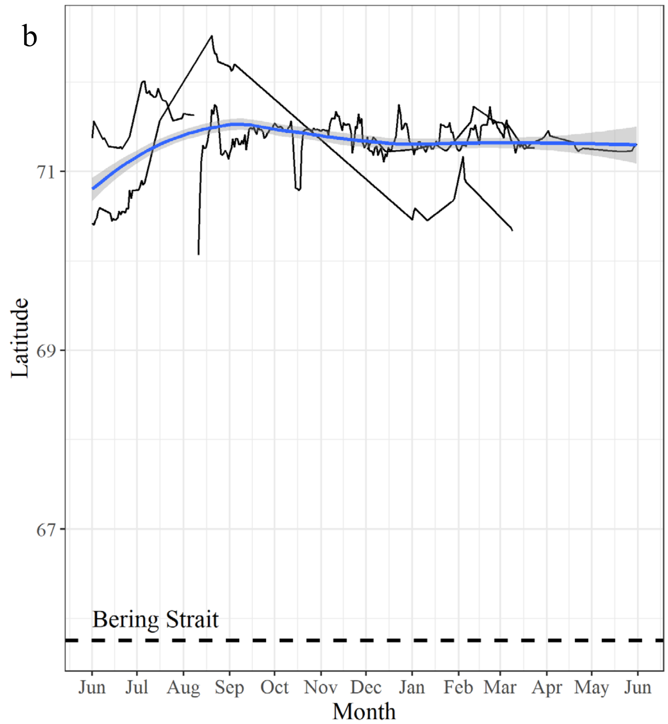


Figure 6. Latitudinal movements of bearded seals tagged in the a) Bering and Chukchi seas (n = 24) and b) Beaufort Sea (n = 2) by month during 2014–2019. Thin black lines are individual seals tracked by their primary tag. Dashed line delineates Bering Strait. June–October are generally ice-free months. November–May are generally characterized by ice formation, ice cover, and receding ice. Blue line and gray shaded region represent the smoothed conditional mean and standard error (SE) for latitudinal movements.

July–September. During this period of open water, bearded seals ($n = 22$) generally made localized movements near their tagging locations and stayed near shore, especially in Norton Sound (Fig. 7). A few bearded seals made long-distance movements soon after being tagged, including into the central Bering Sea and Mechigmenskaya Bay on the Chukotka Peninsula, Russia. Although most bearded seals were tagged in Norton Sound and stayed in that region during this period, beginning in September, some bearded seals moved north of the Bering Strait into the Chukchi Sea (Fig. 6a). During these northward movements, bearded seals generally stayed near shore, including entering Kotzebue Sound. Once in the northern Chukchi and Beaufort seas, bearded seals regularly moved along the 200-m isopleth, including near Barrow Canyon.

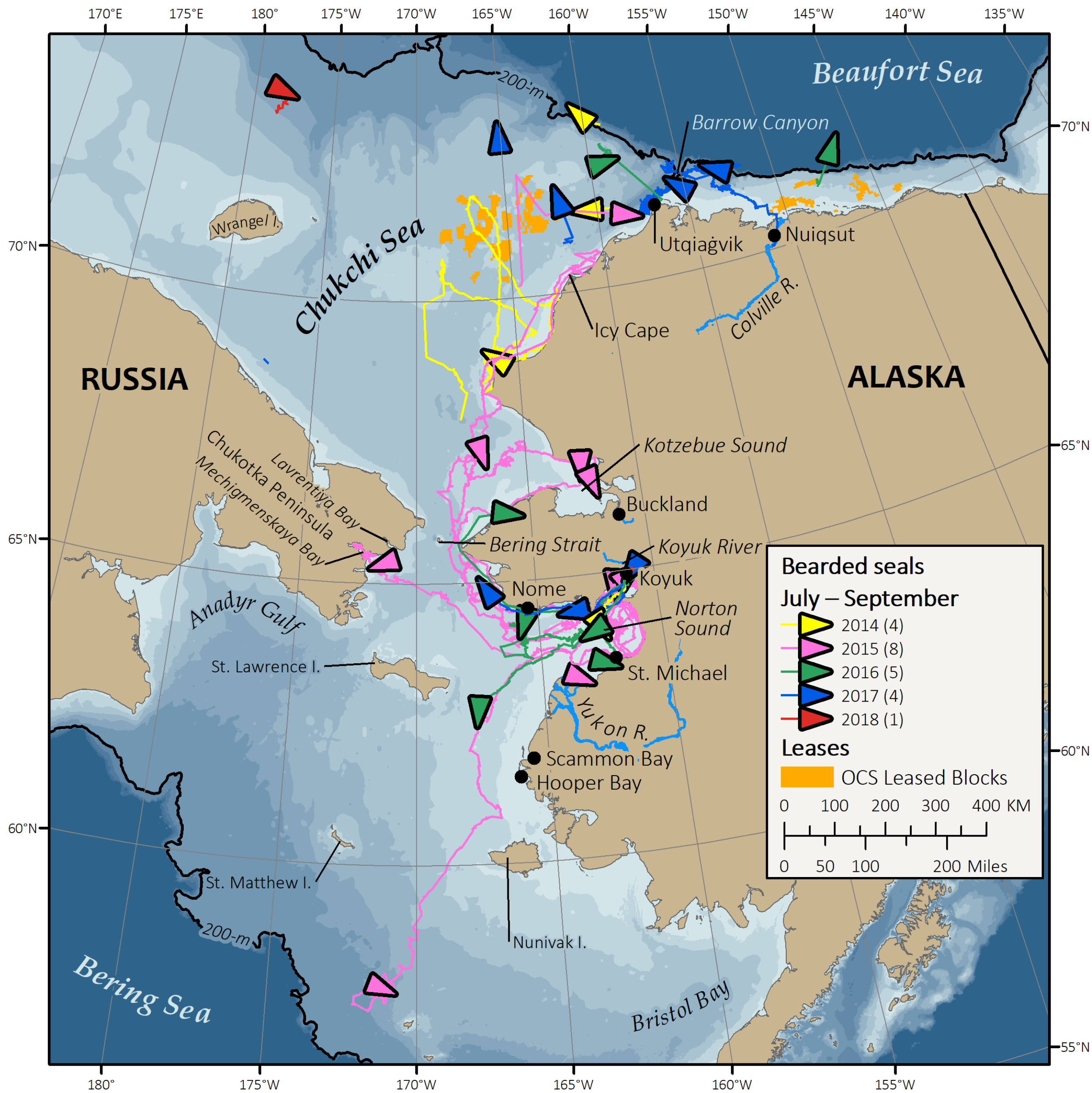


Figure 7. Movements of 22 bearded seals from July through September during 2014–2019. Movements are color-coded by the year seals were tagged. OCS Leased Blocks associated with Chukchi Sea Lease Sale 193 area were active during 2013–2016; all were relinquished by 2017.

October–December. During this period, most bearded seals (*n* = 23) stayed close to shore in Norton and Kotzebue sounds and when moving between them, but movements also varied by individual (Figs. 6 and 8). Four bearded seals spent time in the central Bering Sea, generally near the 100-m isopleth, well ahead of the advancing sea ice that could be used as a resting platform. Two bearded seals used coastal areas of the Chukotka Peninsula, entering Lavrentiya and Mechigmenskaya bays. One bearded seal (BS17-01-F) stayed in the northeast Chukchi Sea and made localized movements and foraging dives in and around Barrow Canyon.

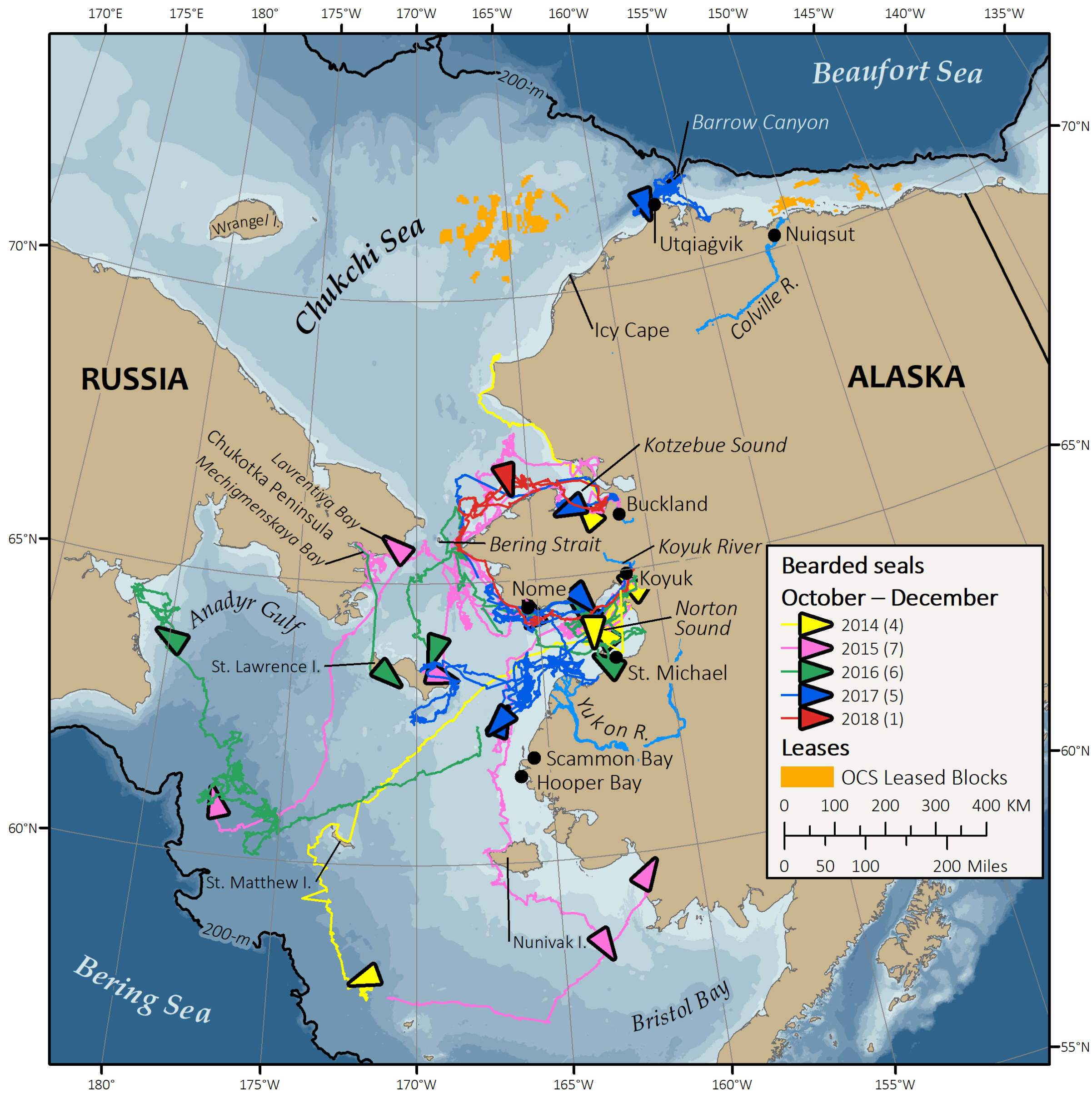


Figure 8. Movements of 23 bearded seals from October through December during 2014–2018. Movements are color-coded by the year seals were tagged. OCS Leased Blocks associated with Chukchi Sea Lease Sale 193 area were active during 2013–2016; all were relinquished by 2017.

January–March. During this period of ice cover, bearded seals (n = 18) exhibited two movement patterns; localized near shore and long-distance offshore (Fig. 9). Most bearded seals made localized movements that did not vary greatly by latitude (Fig. 6) and were near shore in highly consolidated ice, including near St. Lawrence Island, Bristol Bay, Norton Sound, Kotzebue Sound, Barrow Canyon, and the Beaufort Shelf. Three bearded seals made long-distance movements in less consolidated ice, two near the southern ice edge that were primarily offshore in the central and western Bering Sea (BS16-01-M and BS16-06-M) and one in the central Chukchi Sea (BS18-01-F).

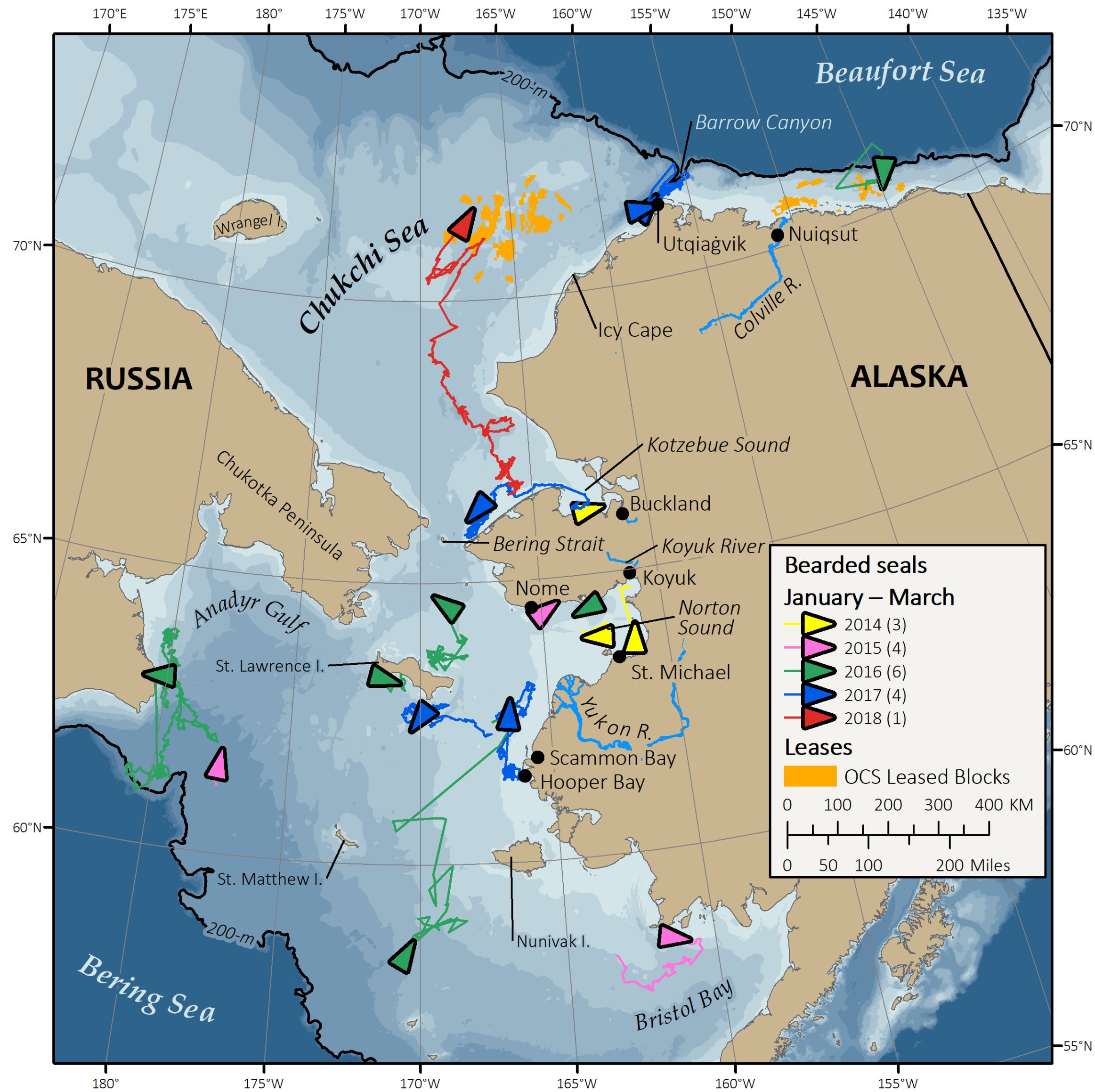


Figure 9. Movements of 18 bearded seals from January through March during 2015–2019. Movements are color-coded by the year seals were tagged. OCS Leased Blocks associated with Chukchi Sea Lease Sale 193 area were active during 2013–2016; all were relinquished by 2017.

April–June. We expected bearded seals to undergo their annual molt during this period; as such, we expected the primary tags epoxied to hair to fall off. We also expected the battery voltage of primary tags deployed the previous year to become too low to transmit locations. Therefore, most of the terminal locations plotted in Figure 10 represent the last locations from primary tags, which, unless we received locations from the flipper-mounted SPOT tags when the seal hauled out, likely were transmitted before the end of June. In other words, most seal tracks during this period represent less than three months of movements. In April, when sea ice had generally reached its southern-most extent, bearded seals (n = 16) were generally located near shore, from Anadyr Gulf and Norton Sound to the Beaufort Sea; however, most seals were either in Norton Sound, Kotzebue Sound, or areas between (Figs. 6 and 10). Two bearded seals, however, were located far from shore; BS16-01-M was in the central Bering Sea and BS18-01-F was in the northcentral Chukchi Sea. During this period, as ice began to retreat north, bearded seals generally moved north along the Alaskan coast, into the Chukchi Sea. Half of the seals (3 of 6) that started the period in the Bering Sea and migrated into the Chukchi Sea entered Kotzebue Sound. By the end of June, all but two bearded seals (BS16-06-M and BS17-03-M; 11 of 13) were in the Chukchi Sea (Fig. 6).

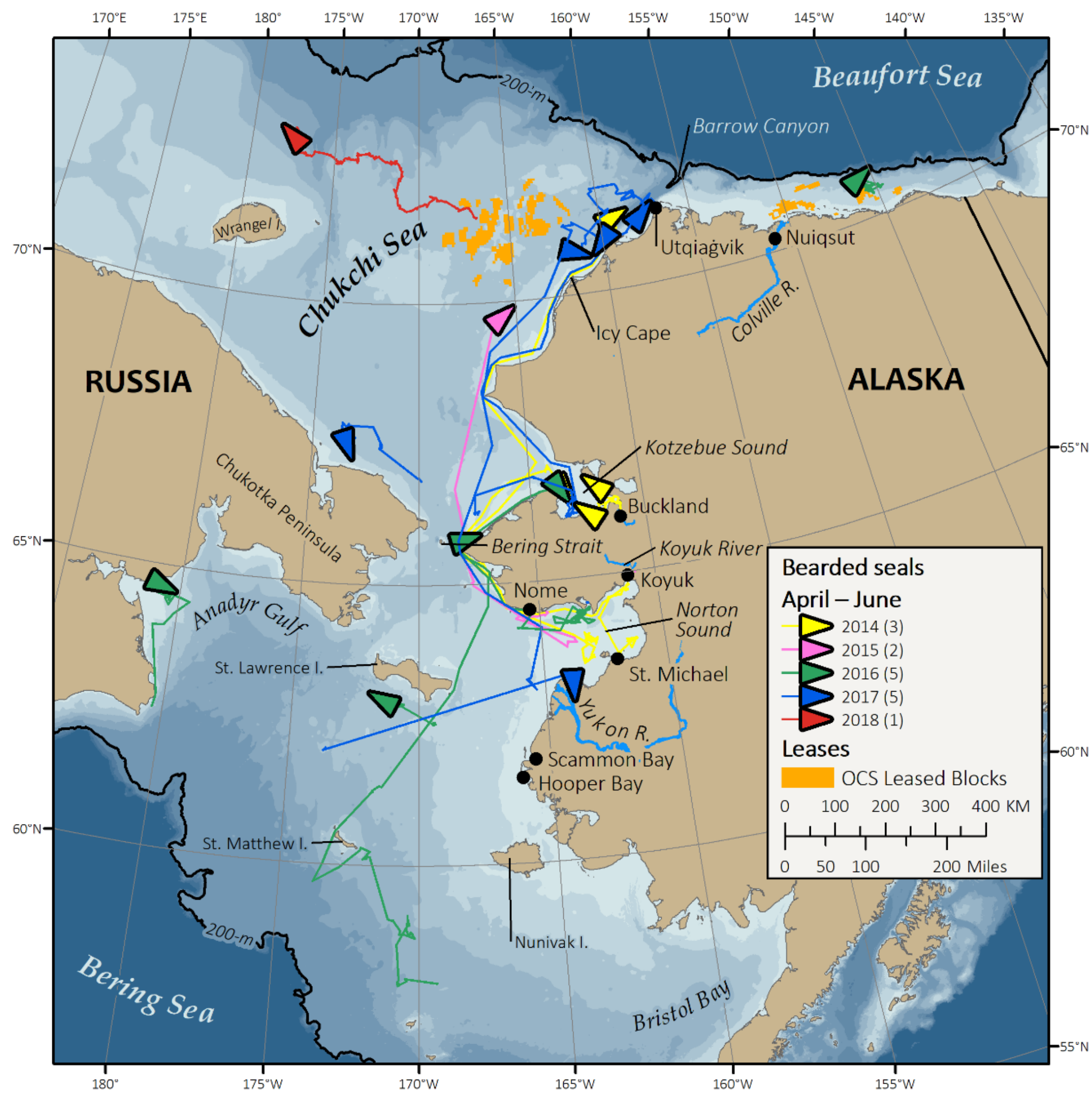


Figure 10. Movements of 16 bearded seals from April through June during 2014–2019. Movements are color-coded by the year seals were tagged. The terminal locations represent the last location received during this period, which were often before the end of June because primary tags fell off during molt. In some cases, however, the flipper-mounted SPOT tags provided additional locations during this period when the seal hauled out. OCS Leased Blocks associated with Chukchi Sea Lease Sale 193 area were active during 2013–2016; all were relinquished by 2017.

Site fidelity. Six bearded seals had tags that transmitted for 338 days or more (up to 651 days) (Table 2), and five of them exhibited fidelity to specific areas in consecutive years. Two seals tagged in September near Koyuk in northeastern Norton Sound (BS14-02-M, tracked for 461 days, and BS16-07-F, tracked for 370 days) returned to this area in the following year. BS14-02-M stayed in eastern Norton Sound from September 2014 to May 2015, then moved outside of Norton Sound, but returned in November and stayed until December 2015 when the tag stopped transmitting. BS16-07-F was tagged in the Inglutalik River, 16 km (10 miles) south of Koyuk, in September 2016 and returned to this river in July 2017.

BS17-01-F (tracked for 591 days) used the Barrow Canyon area during December to March for two consecutive years (Fig. 11). After being tagged in the Colville River in August 2017, this seal moved to and stayed near Barrow Canyon and nearshore areas southeast of Utqiaġvik from August 2017 to mid-July 2018, with the exception of a short trip to Smith Bay in October 2017, after which it returned to the Barrow Canyon area in December 2018 staying to March 2019.

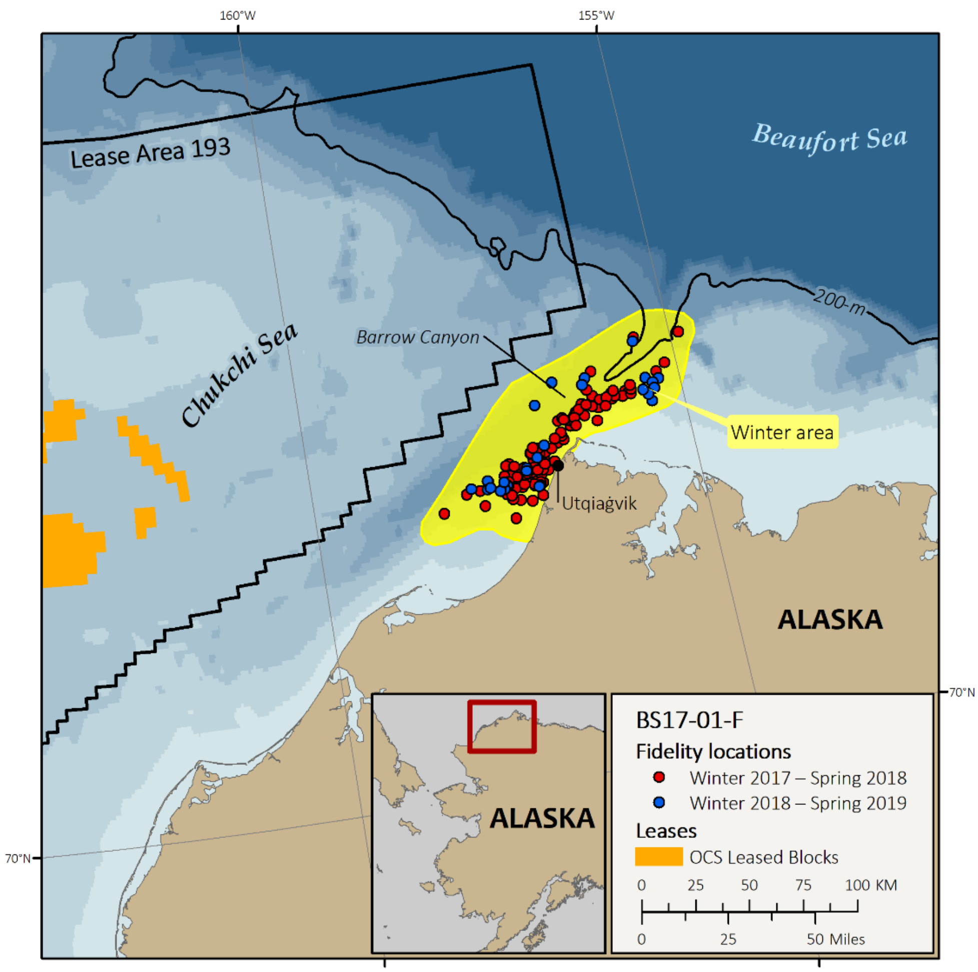


Figure 11. Locations of bearded seal BS17-01-F depicting site fidelity during winter (December–March) for two consecutive years. Red dots are locations during December 2017–March 2018; blue dots are locations during December 2018–March 2019. OCS Leased Blocks associated with Chukchi Sea Lease Sale 193 area *were active during 2013–2016; all were relinquished by 2017.*

One bearded seal (BS14-01-M, tracked for 338 days) used Kotzebue Sound during spring in two consecutive years. This seal was tagged in Kotzebue Sound in mid-June 2014 and left the Sound in late June but returned to southcentral Kotzebue Sound in mid-October where it remained until May 2015 when the tag stopped transmitting.

Bearded seal BS17-02-F, tracked for 651 days, used an area between the outlet of the Yukon River and Scammon Bay in the eastern Bering Sea in February of 2018 and 2019. Otherwise, despite being tracked for nearly two years, this seal did not exhibit fidelity to any other areas. Notably, during spring migration (May–July), this seal traveled along the Bering and Chukchi coast of Alaska in 2018, but along the northern coast of Chukotka, Russia, in 2019.

Bearded seal BS15-07-M, tracked for 384 days, did not exhibit fidelity to any specific areas. This seal was tagged in southern Norton Sound in late August 2015 and left the sound in mid-September, when it spent early October to mid-November in Kotzebue Sound and wintered in northern Norton Sound from late December 2015 to early May 2016. During July–September 2016, this seal was in the northeast Chukchi Sea.

Ringed seals
All ringed seals (n = 16) exhibited strong, seasonal, latitudinal patterns in movements throughout the year, using high-latitudes during the open-water season (July–November) and lower latitudes, near or south of the Bering Strait, when ice was present (December–June) (Fig. 12).

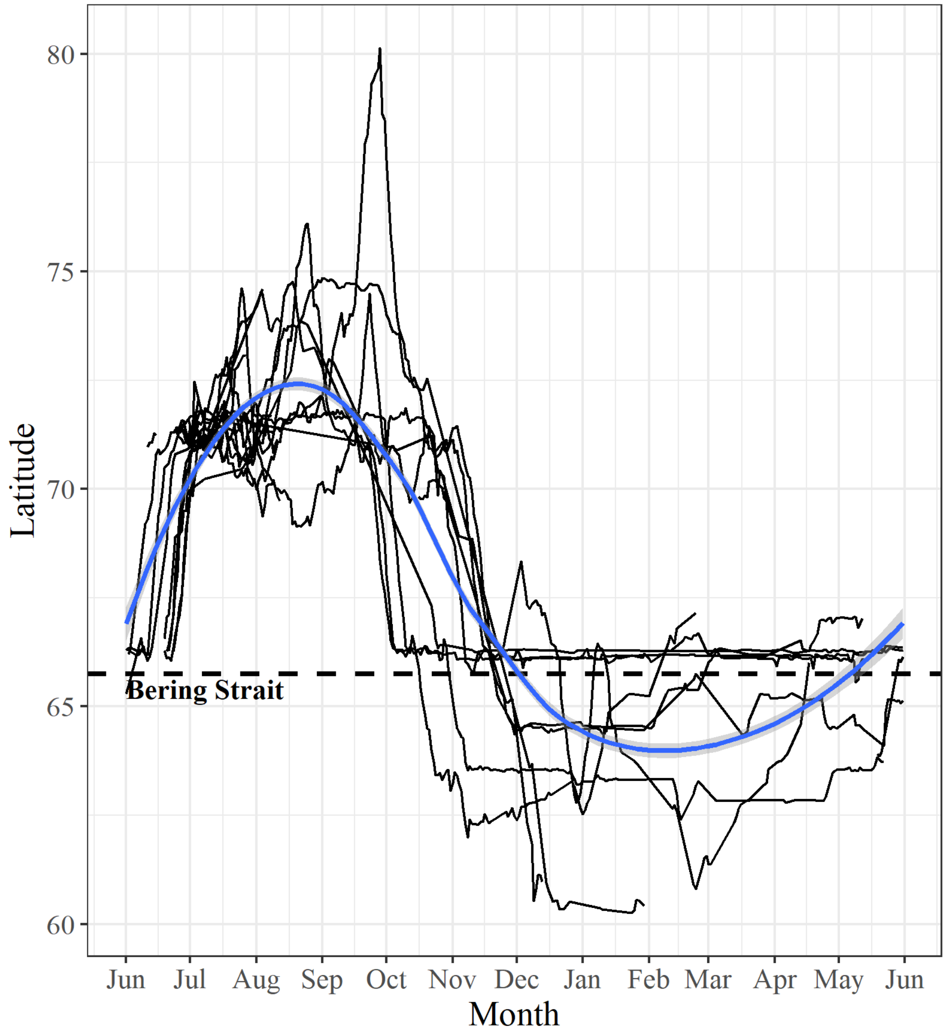


Figure 12. Latitudinal movements of ringed seals (n = 16) by month during 2014–2019. Thin black lines are individual seals tracked by their primary tag. Dashed line is Bering Strait. June–October are generally ice-free months. November–May are generally characterized by ice formation, ice cover, and receding ice. Blue line and gray shaded region represent the smoothed conditional mean and SE for latitudinal movements.

July–September. Ringed seals tracked during this period (n = 15) were primarily located in the northern Chukchi Sea, north of 70 °N (Figs. 12 and 13). Although movements of individuals varied, they primarily stayed on the intercontinental shelf in water < 200 m deep, between Utqiaġvik, Alaska, and Wrangel Island, Russia. Two ringed seals (RS14-02-F and RS16-02-M) moved along the Beaufort Shelf, east into the eastern Beaufort Sea, before returning along the shelf, into the eastern Chukchi Sea. Most seals spent some time near the 200-m isopleth during this period; however, two seals made distinct trips north into deeper water, one of which (RS17-01-M) made five trips north of the shelf break. By late September, only two ringed seals had moved south of 70 °N, ahead of the advancing sea ice (Fig. 12).

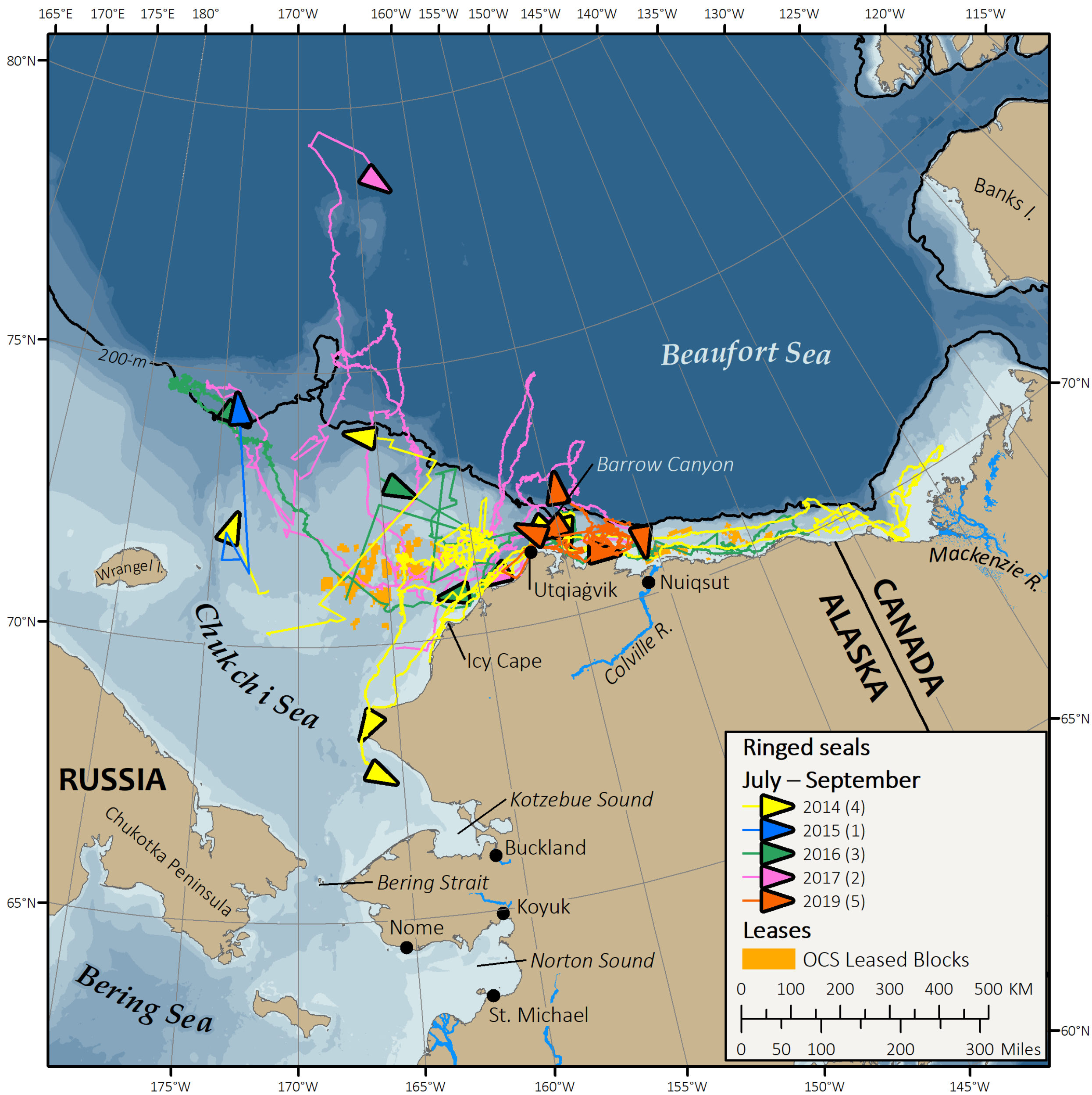


Figure 13. Movements of 15 ringed seals from July through September during 2014–2019. Movements are color-coded by the year seals were tagged. OCS Leased Blocks associated with Chukchi Sea Lease Sale 193 area were active during 2013–2016; all were relinquished by 2017.

October–December. In October, ringed seals (n = 9) were primarily in the northern Chukchi Sea, but moved south through December, ahead of the advancing sea ice (Figs. 12 and 14). During their migration, most ringed seals stayed near shore, using both the Alaskan and Russian coasts, and frequently entered coastal bays, inlets, and lagoons. For seals moving along the Alaskan coast, most entered Kotzebue Sound during their migration. Of note, before migrating south along the Alaskan coast, ringed seal RS17-01-M moved from the northcentral Chukchi Sea to the Beaufort coast of Alaska along the 200-m isopleth and made frequent foraging dives. By December, most ringed seals were south of Bering Strait (Fig. 12).

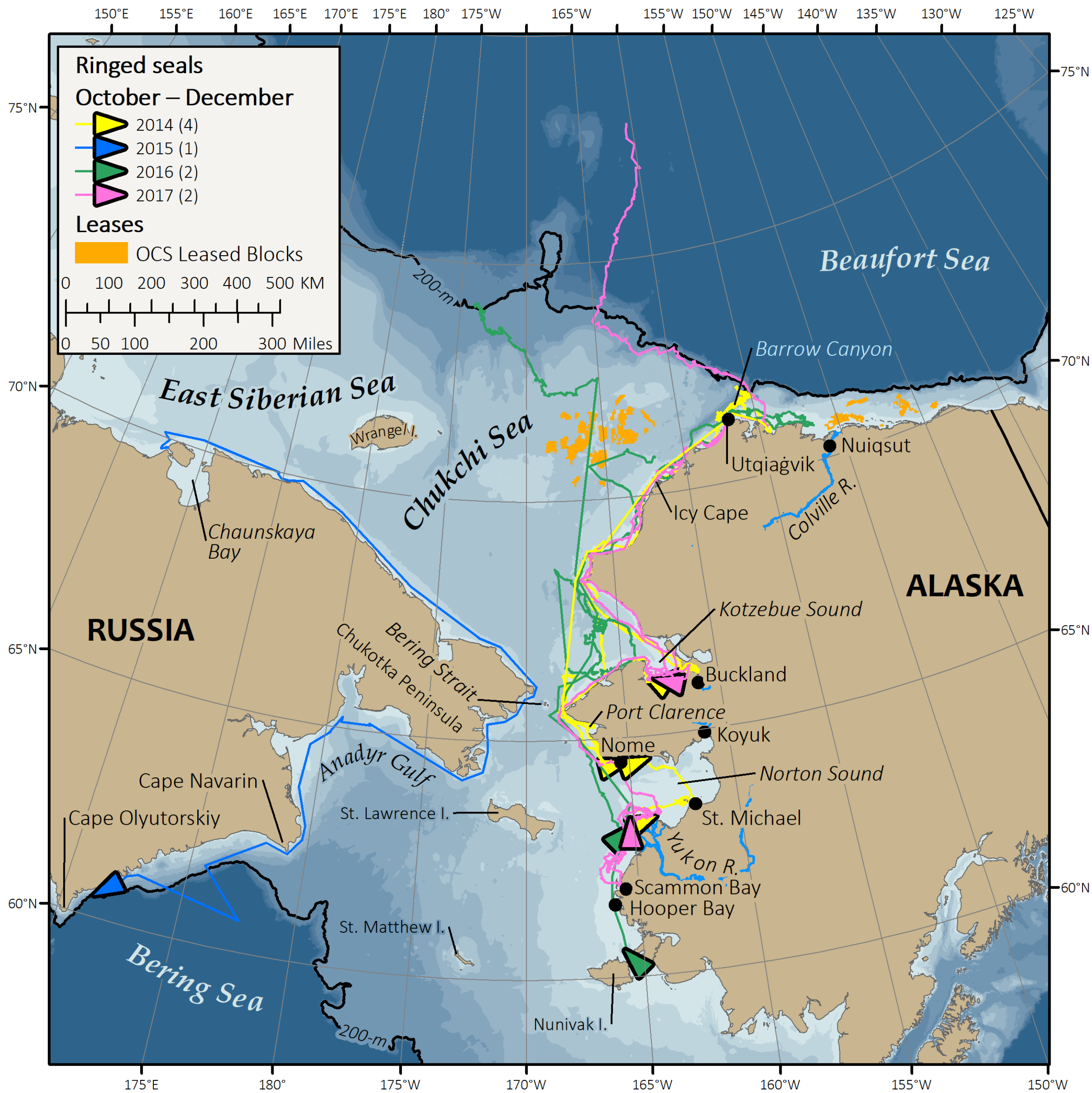


Figure 14. Movements of nine ringed seals from October through December during 2014–2018. Movements are color-coded by the year seals were tagged. OCS Leased Blocks associated with Chukchi Sea Lease Sale 193 area were active during 2013–2016; all were relinquished by 2017.

January–March. Ringed seals ($n = 8$) were primarily in Kotzebue Sound and the Bering Sea in early January (Figs. 12 and 15). During this period most ringed seals stayed near shore and in shorefast or dense pack ice. While most seals made localized movements in Kotzebue Sound or along the Bering Sea coast of Alaska, some seals made long-distance movements. Ringed seal RS14-01-M moved north along the coast from Nome into the southern Chukchi Sea; RS16-02-M moved between the Bering Strait, mouth of the Yukon River, Hooper Bay, and St. Lawrence Island; and RS17-02-M also moved north from the mouth of the Yukon River to Nome and into the southern Chukchi Sea along the north coast of the Chukotka Peninsula.

Figure 15. Movements of eight ringed seals from January through March during 2015–2018. Movements are color-coded by the year seals were tagged. OCS Leased Blocks associated with Chukchi Sea Lease Sale 193 area were active during 2013–2016; all were relinquished by 2017.

April–June. As stated above for bearded seals, most seal tracks during this period represent less than three months of movements because primary tags fell off or their battery drained before the end of June. The 13 ringed seals tracked during this time period were in the eastern Bering Sea, primarily in Norton Sound, or in the southern Chukchi Sea, primarily Kotzebue Sound, in early April (Figs. 12 and 16). During this period all ringed seals migrated north with the receding sea ice, most stayed near the ice edge as it moved into the central Chukchi Sea, but two seals tracked in April and May moved north along the northwestern Alaskan coast. Six seals tracked in April entered Kotzebue Sound (Fig. 16). By the end of June, most ringed seals were near, or north of, 70 °N, including the five ringed seals tagged near Utqiaġvik in mid-June 2019. (Figs. 12 and 16).

During this three-month period, four ringed seals were tracked during two consecutive years and one (RS14-01-M) for three consecutive years.

Figure 16. Movements of 13 ringed seals from April through June during 2014–2019. Movements are color-coded by the year seals were tagged. The terminal locations represent the last location received during this period, which were often before the end of June because primary tags fell off during molt. In some cases, however, the flipper-mounted SPOT tags provided additional locations during this period when the seal hauled out. OCS Leased Blocks associated with Chukchi Sea Lease Sale 193 area were active during 2013–2016; all were relinquished by 2017.

Site fidelity. Five ringed seals, all tagged in Kotzebue Sound in May or June, had tags that transmitted for 329 days or more (up to 694 days) (Table 2), and all five exhibited fidelity to areas or migration routes. In particular, ringed seal RS14-01-M (tracked for 694 days) used Barrow Canyon and Smith Bay (an area east of Dease Inlet in the Beaufort Sea) in the summer and fall of 2014 and 2015, then migrating south through the Chukchi Sea along the Alaskan Coast, entering Norton Sound in the Bering Sea in December of 2014 and 2015 (Fig. 17). RS14-01-M wintered in northern Norton Sound and along the western coast of Seward Peninsula in 2014 and 2015. This seal also used outer Kotzebue Sound during its northward migration in 2014, 2015, and 2016 and continued north of Kotzebue Sound, along the Alaskan coast to an area near Icy Cape in both 2014 and 2015.

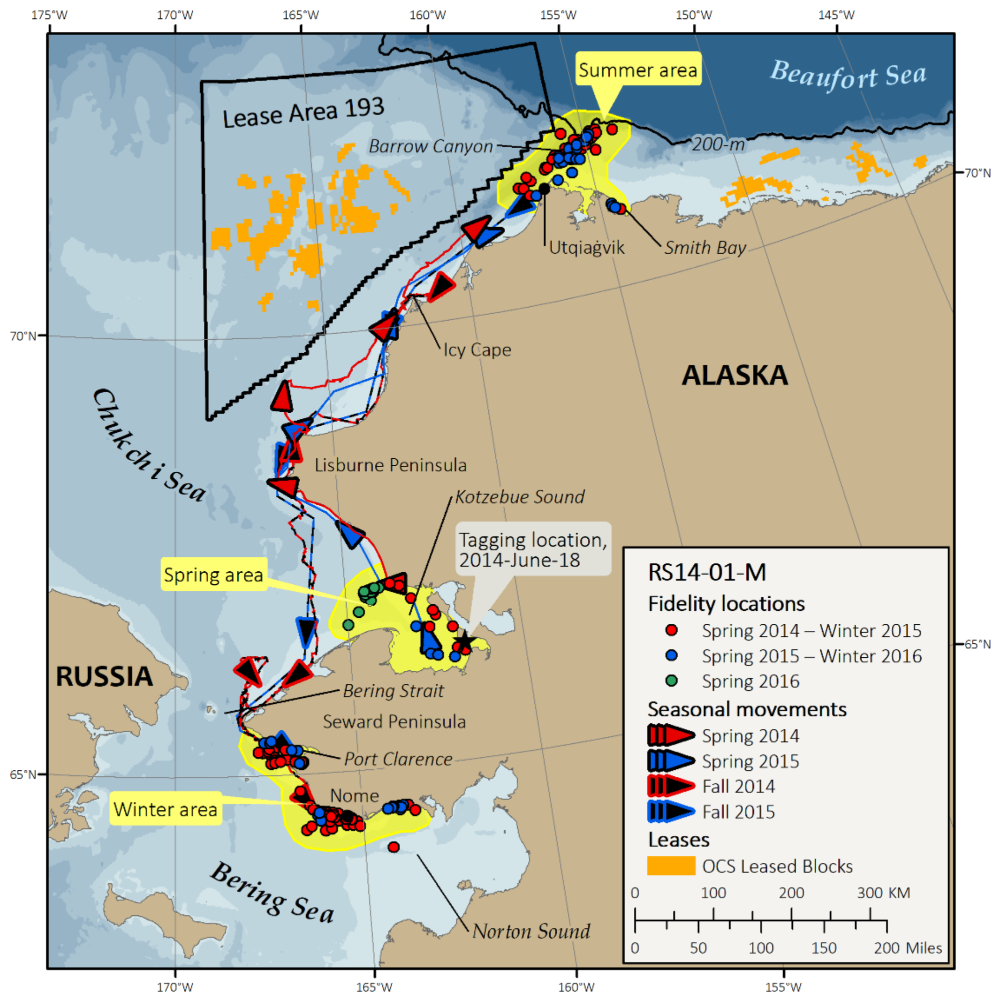


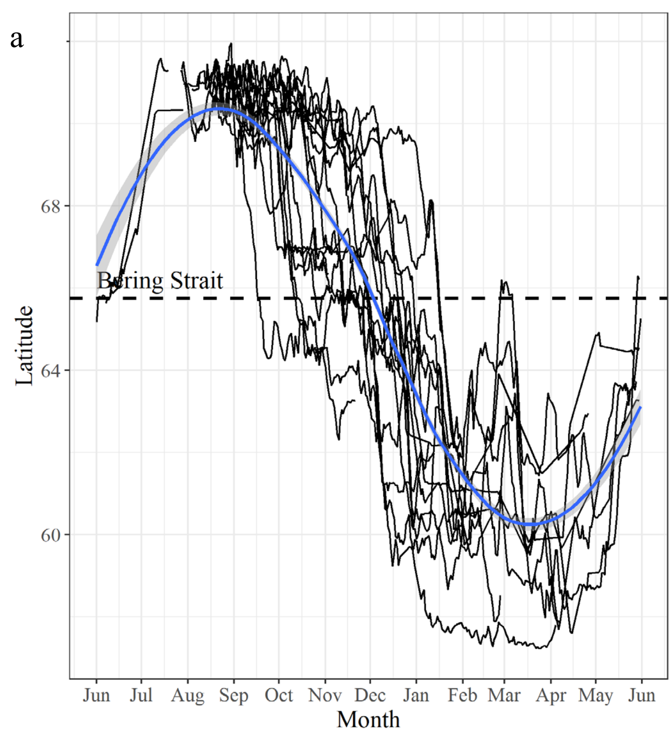
Figure 17. Locations and seasonal movements of ringed seal RS14-01-M (tagged in Kotzebue Sound) depicting site fidelity during summer (July–October) and winter (December–March) for two consecutive years and during spring (late-May–June) for three consecutive years. Red dots are locations during June 2014–March 2015; blue dots are locations during June 2015–March 2016; and yellow dots are locations during June 2016. Northward spring migrations are depicted by solid lines and colored arrows (2014 with red and 2015 with blue). Southward fall migrations are depicted by dashed lines and black arrows. OCS Leased Blocks associated with Chukchi Sea Lease Sale 193 area were active during 2013–2016; all were relinquished by 2017.

Ringed seal RS14-03-M (tracked for 361 days) used an area in the northeast Chukchi Sea, north and northwest of Icy Cape, in the late spring and early summer of 2014 and 2015. This seal left Kotzebue Sound in mid-June, soon after being tagged, and moved to this area in the northeast Chukchi Sea where it stayed from early July to mid-September 2014. It then wintered in Norton Sound and returned to this area in the northeast Chukchi Sea in mid-June 2015 when the tag stopped transmitting. RS14-04-F (tracked for 382 days) used southern Kotzebue Sound during the late spring of 2014 and 2015. This seal also left Kotzebue Sound in mid-June, soon after being tagged, and moved through the central and northern Chukchi Sea before returning to, and wintering in, Kotzebue Sound from late October 2014 to mid-June 2015.

Two other ringed seals (RS14-02-F, tracked for 357 days, and RS17-01-M, tracked for 329 days) also exhibited fidelity to Kotzebue Sound during their northward migration into the Chukchi Sea in two consecutive years in spring.

Spotted seals

Latitudinal movements of spotted seals varied by tagging location. Seals tagged in the Beaufort Sea (n = 17) made definitive, seasonal (south in fall and north in summer) movements between the Beaufort and Bering seas (Fig. 18a), but seals tagged in the Bering Sea (n = 7) tended to stay in the Bering Sea (Fig. 18b).



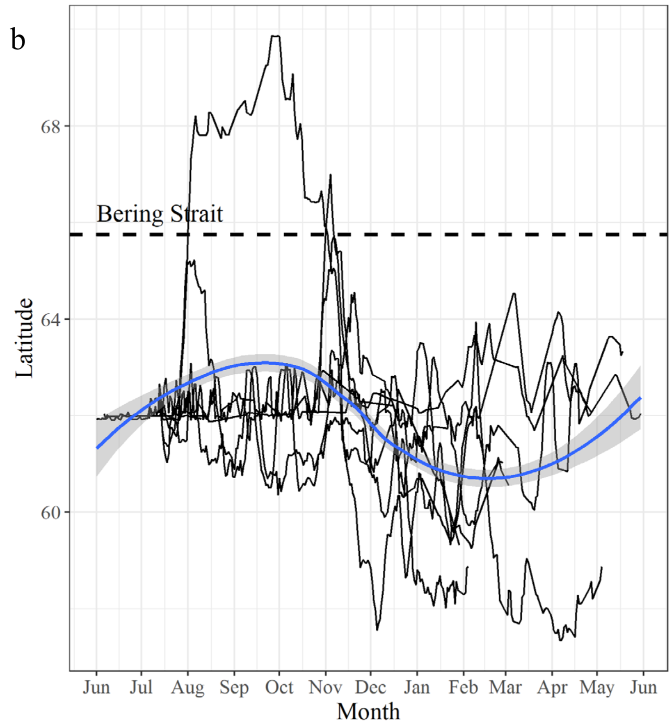


Figure 18. Latitudinal movements of spotted seals tagged in the a) Beaufort (n = 17) and b) Bering (n = 7) seas by month during 2016–2019. Thin black lines are individual seals tracked by their primary tag. Dashed line is Bering Strait. June–October are generally ice-free months. November–May are generally characterized by ice formation, ice cover, and receding ice. Blue line and gray shaded region represent the smoothed conditional mean and SE for latitudinal movements.

July–September. Spotted seals tagged in the Beaufort Sea (*n* = 15) made frequent west-east movements between foraging areas in the central Chukchi Sea and terrestrial resting areas on the Alaskan coast (Fig. 19). Between foraging trips, seals would generally make localized movements along the coastline of the northeast Chukchi Sea, including entering the Kugrua River, the Avak River, and Peard Bay, and rested on the barrier islands near Icy Cape. Seals also made long-distance movements back to the vicinity of their tagging locations in Dease Inlet, Fish Creek, and the Colville River. During these long-distance movements, seals would primarily stay near shore (Fig. 19). During this period, only one spotted seal tagged in the Beaufort Sea (SS16-08-M) moved south of 69 °N, ahead of the advancing sea ice. By the end of September, this seal left the Chukchi and entered the Bering Sea (Fig. 18a) along the east coast of the Chukotka Peninsula, including entering Lavrentiya Bay and Getlyanen Lagoon (Fig. 19).

Spotted seals tagged in the Bering Sea (*n* = 5) made similar frequent west-east movements between foraging areas in the eastern Bering Sea and coastal areas near the outlet of the Yukon River (Fig. 19). Between foraging trips these spotted seals would rest on barrier islands, including the islands where they were tagged in Scammon Bay, as well as islands south of Hooper Bay and on St. Lawrence Island. During this period, only one spotted seal tagged in the Bering Sea (SS18-01-M) moved north, through Bering Strait, into the Chukchi Sea (Fig. 18b). This seal moved west along the north coast of the Chukotka Peninsula where it entered the

Amguyema River twice; once on 5 August 2018 and again on 23 August 2018, each time staying in the river for 7–10 days where it likely foraged and was recorded hauling out a minimum of 72 straight hours both times (Fig. 19).

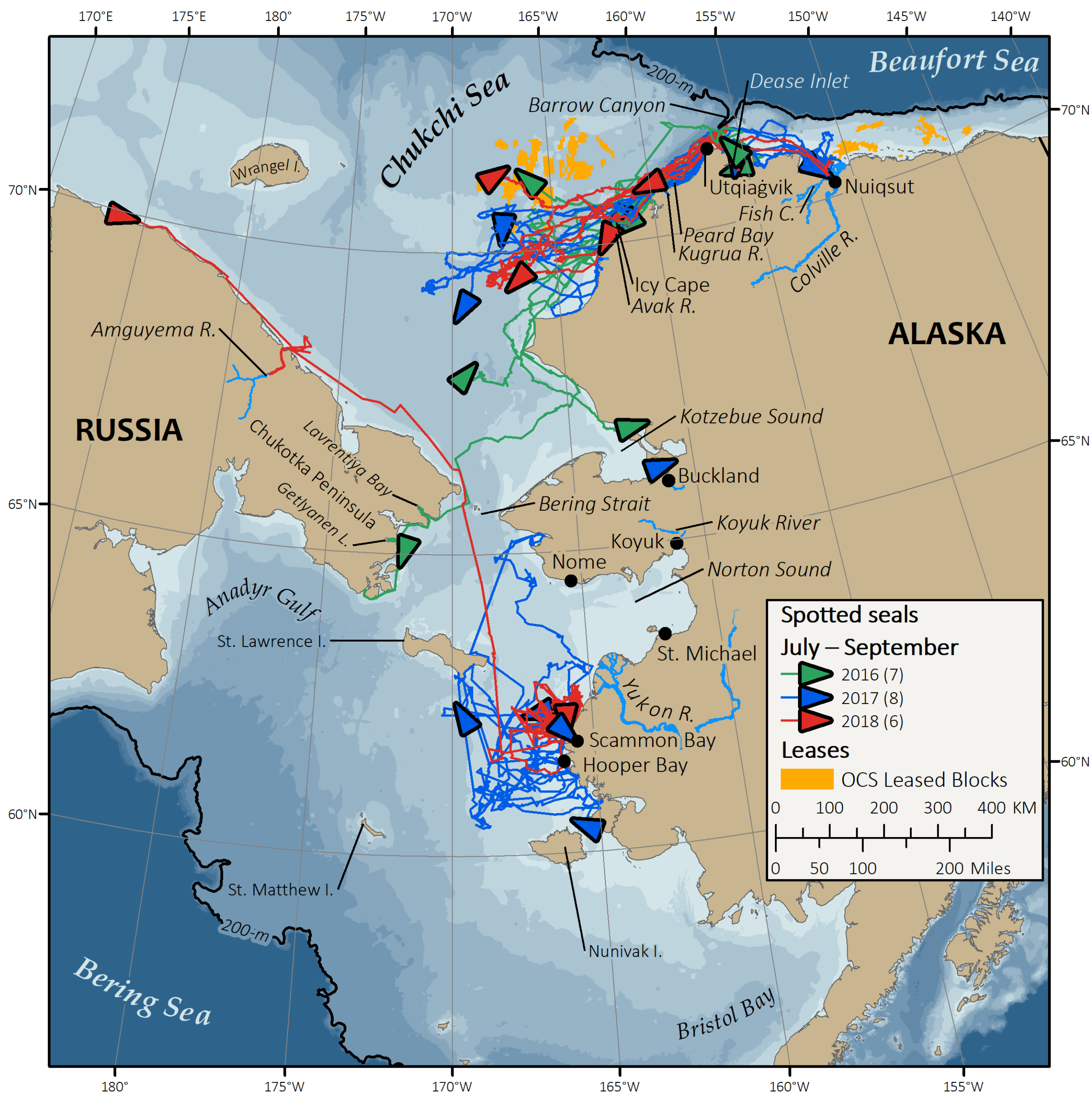


Figure 19. Movements of 21 spotted seals from July through September during 2016–2019. Movements are color-coded by the year seals were tagged. OCS Leased Blocks associated with Chukchi Sea Lease Sale 193 area were active during 2013–2016; all were relinquished by 2017.

October–December. Spotted seals tagged in the Beaufort Sea (*n* = 17) continued to make frequent west-east movements to forage in the central Chukchi Sea and haul out on land into mid-November (Fig. 20). As sea ice advanced south, seals migrated south, some near shore and others far from shore in open water. Seals that migrated along shore frequently entered coastal bays, inlets, and lagoons, including Kotzebue Sound, and used remote, coastal islands to haul out. Spotted seals tagged in the Bering Sea (n = 7) also continued to make frequent west-east movements to forage in the eastern Bering Sea and hauled out on barrier islands into mid-November (Fig. 20). By December, most spotted seals were south of Bering Strait (Fig. 18). When in the Bering Sea, movements of seals were similar, regardless of where they were tagged (Fig. 20).

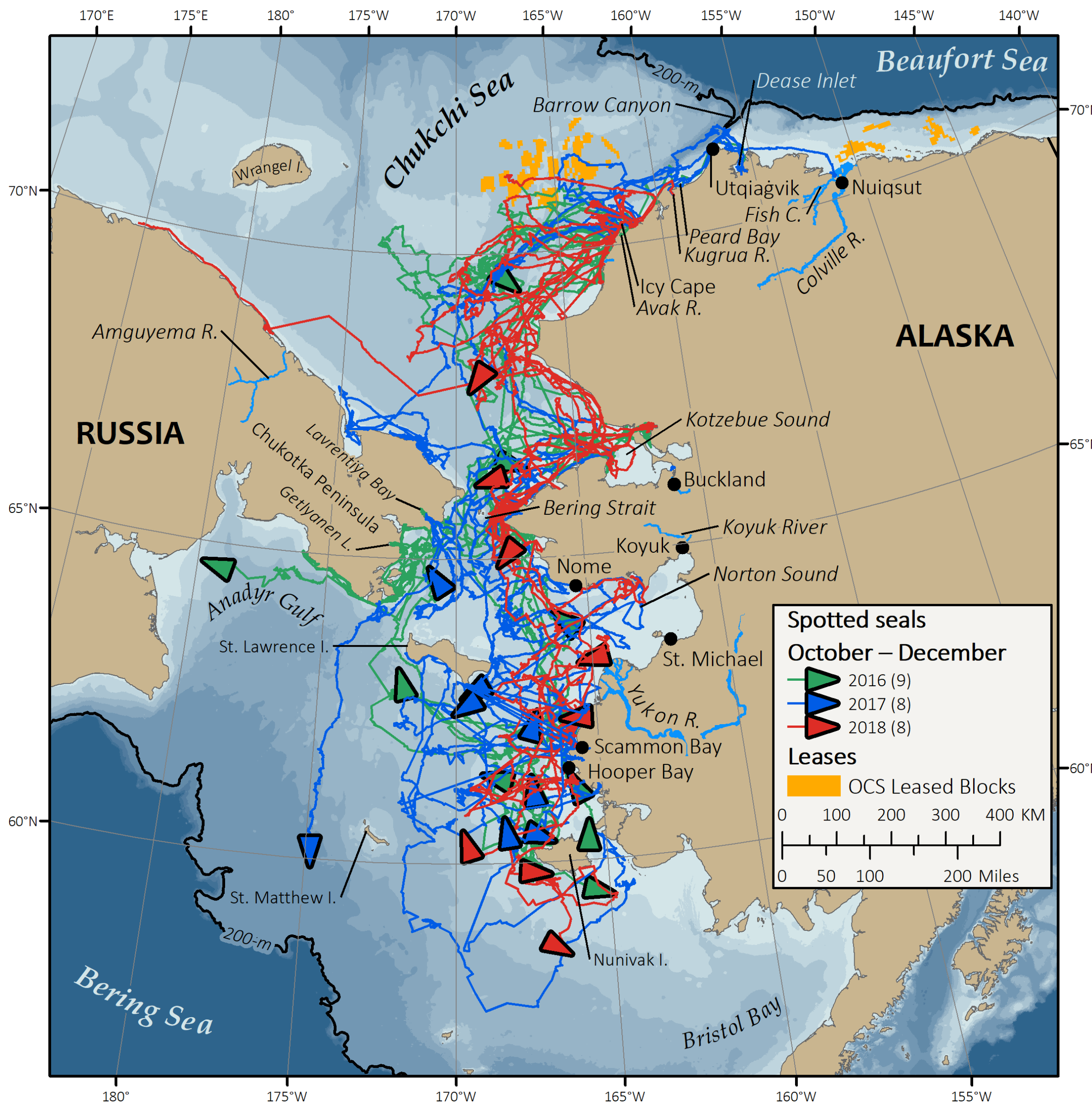


Figure 20. Movements of 25 spotted seals from October through December during 2016–2018. Movements are color-coded by the year seals were tagged. OCS Leased Blocks associated with Chukchi Sea Lease Sale 193 area were active during 2013–2016; all were relinquished by 2017.

January–March. By mid-January all spotted seals were in the Bering Sea (n = 23; Figs. 18 and 21). Throughout this period, all seals regardless of tagging location occupied pack ice and moved throughout the central Bering Sea. Spotted seals used the central Bering Sea regularly when ice was present. When ice was absent from the central Bering Sea and only located near shore, spotted seals generally restricted their movements closer to shore. By the end of March, all spotted seals were in the Central Bering Sea, generally near 61 °N, regardless of where they were tagged (Fig. 18).

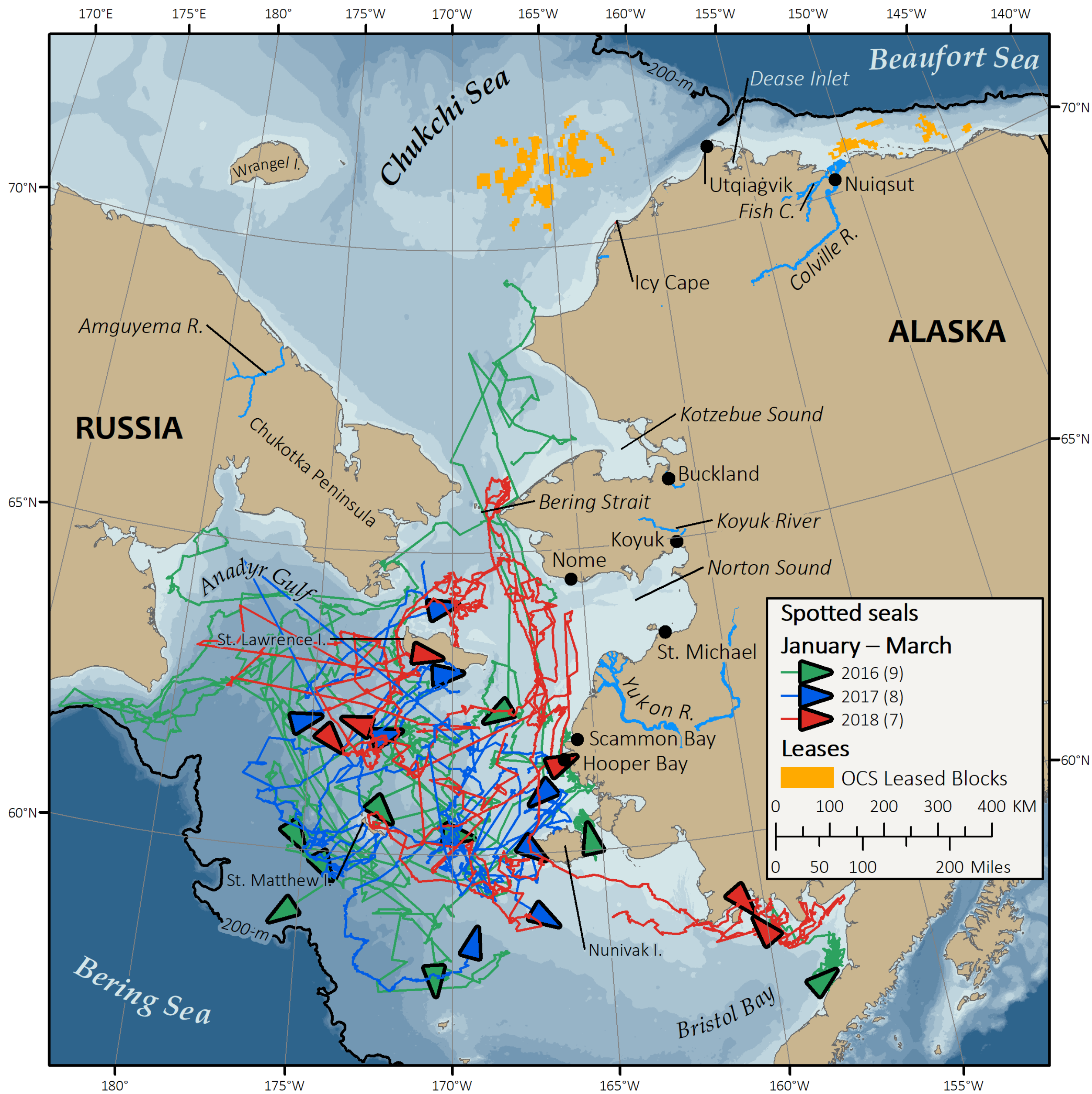


Figure 21. Movements of 24 spotted seals from January through March during 2017–2019. Movements are color-coded by the year seals were tagged. OCS Leased Blocks associated with Chukchi Sea Lease Sale 193 area were active during 2013–2016; all were relinquished by 2017.

April–June. Most seal tracks during this period represent less than three months of movements because primary tags fell off or their battery drained before the end of June. All spotted seals (*n* = 14) were in the Bering Sea in early April (Figs. 18 and 22). In April and May, all seals regardless of tagging location occupied pack ice and moved throughout the central and eastern Bering Sea. Spotted seals used the southern extent of the ice edge in the central Bering Sea regularly when ice was present. When ice was absent in the central Bering Sea and only located near the coast, spotted seals generally restricted their movements closer to the coast. One spotted seal (SS17-02-M) was located in two consecutive years during this three-month period; in 2018 this seal used areas near the mouth of the Yukon River, the barrier islands in Scammon Bay, and the central Bering Sea, south of St. Lawrence Island, but in 2019 it used areas in the central Bering Sea, west and southwest of St. Lawrence Island. By the end of June, two spotted seals, tagged in the Bering Sea, remained there (~62 °N) while three, tagged in the Chukchi Sea, moved north into the Chukchi Sea (~68 °N, Fig. 18).

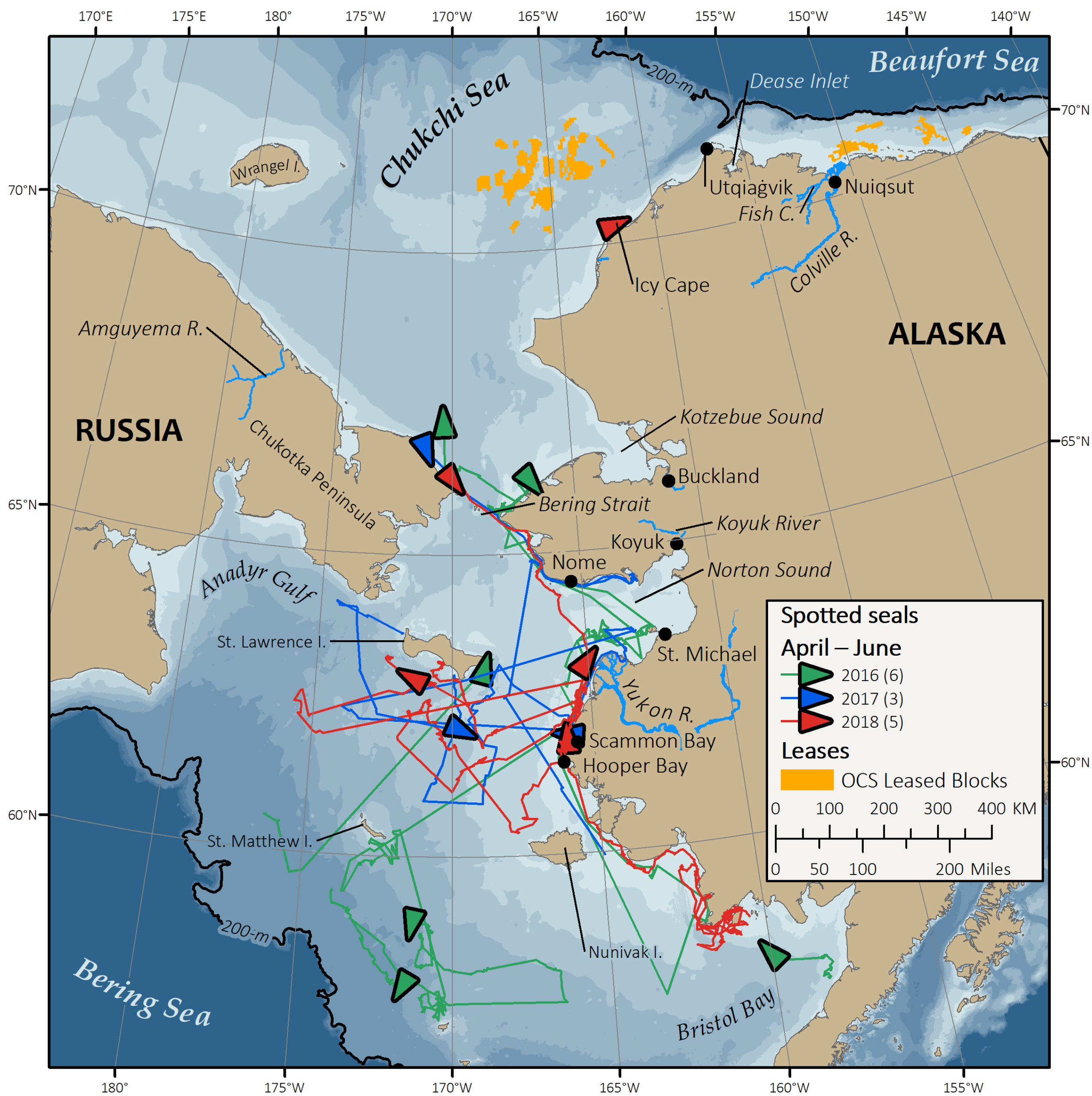


Figure 22. Movements of 14 spotted seals from April through June during 2016–2019. Movements are color-coded by the year seals were tagged. The terminal locations represent the last location received during this period, which were often before the end of June because primary tags fell off during molt. In some cases, however, the flipper-mounted SPOT tags provided additional locations during this period when the seal hauled out. OCS Leased Blocks associated with Chukchi Sea Lease Sale 193 area were active during 2013–2016; all were relinquished by 2017.

Site fidelity. Five spotted seals had tags that transmitted for more than 316 days (up to 647 days) and four of them exhibited fidelity to haulout sites or feeding areas in consecutive years. Two spotted seals, both tagged in August in the Beaufort Sea (Dease Inlet) exhibited fidelity to specific haulout sites in the summer of two consecutive years; SS16-06-F (tracked for 346 days) at Icy Cape and Peard Bay and SS16-07-M (tracked for 336 days) in Dease Inlet (Fig. 23).

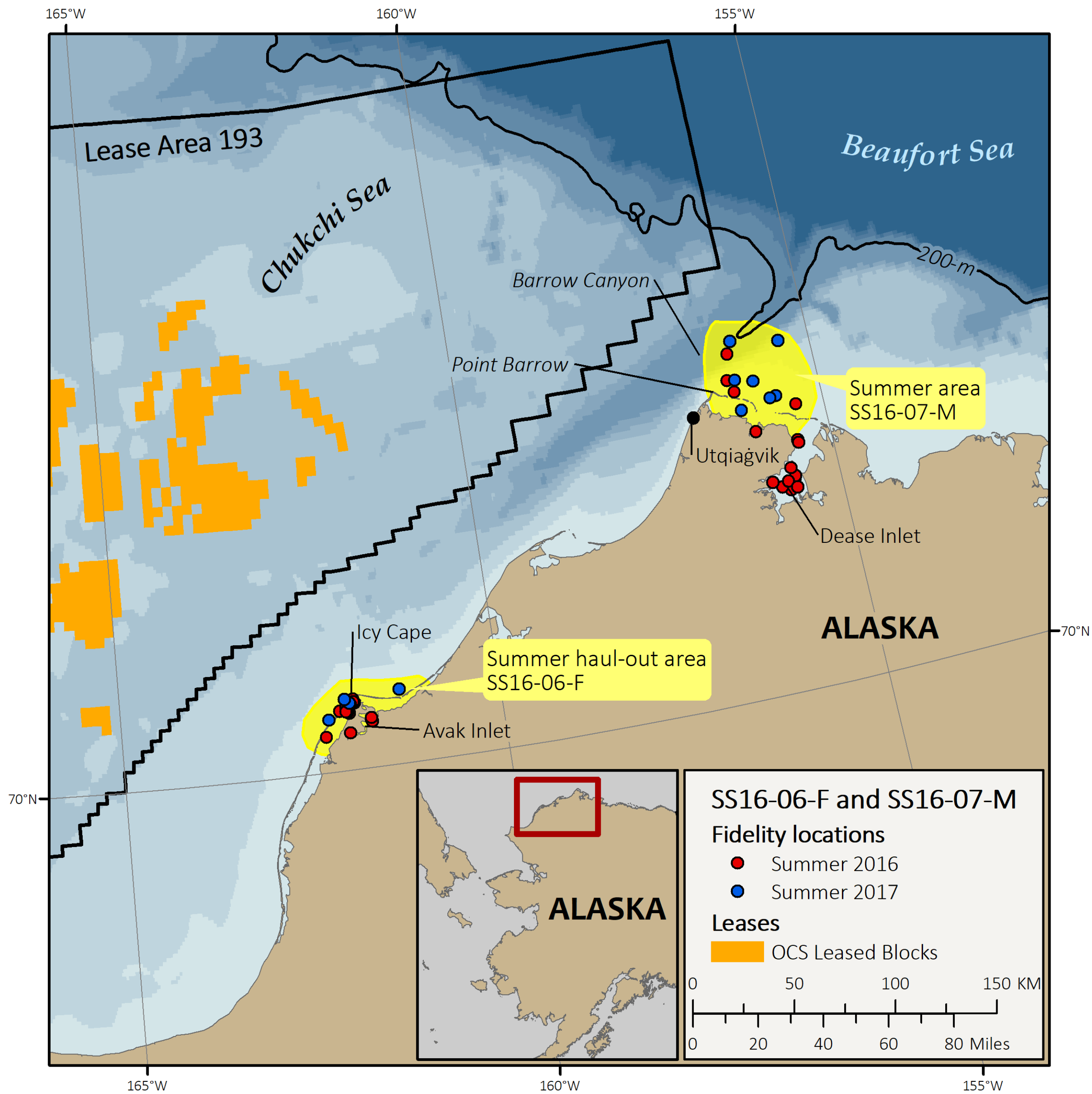


Figure 23. Locations of spotted seals SS16-06-F and SS16-07-M depicting site fidelity during summer (July–October) for two consecutive years. Red dots are locations during August–October 2016; blue dots are locations during July 2017. OCS Leased Blocks associated with Chukchi Sea Lease Sale 193 area were active during 2013–2016; all were relinquished by 2017.

Two spotted seals (SS17-02-M, tracked for 657 days and SS18-02-M, tracked for 452 days as of 30 September 2019), both tagged in the Bering Sea near Scammon Bay in July, also exhibited fidelity to specific haulout sites on barrier islands in Scammon Bay in the fall in two consecutive years. SS17-02-M also foraged between Scammon Bay and the mouth of the Yukon River in the fall and exhibited fidelity to the area between St. Lawrence and Nunivak islands in the Bering Sea in the winter of two consecutive years. One spotted seal, SS16-01-F (tracked for 316 days), was tagged in Dease Inlet in July, used the central and southern Chukchi Sea in the fall and wintered in the central Bering Sea but did not exhibit seasonal fidelity to haulout or feeding areas.

Distance Traveled

The average minimum total distance traveled for all seals combined was 8,347 km (Table 3). The overall shortest distance traveled was made by a bearded seal (1,282 km) and the longest distance traveled was made by a spotted seal (16,495 km). When the number of days tags provided locations for each seal was accounted for, spotted seals moved farther than bearded and ringed seals ($P < 0.01$) whose movements were not significantly different from each other ($P = 0.33$). Spotted seals tagged in the Beaufort Sea migrated south to winter in the Bering Sea, but spotted seals tagged in the Bering Sea rarely left there. Interestingly, despite moving farther from their tagging location, the total distances moved by spotted seals tagged in the Beaufort Sea did not differ from those tagged in the Bering Sea ($P = 0.22$).

Table 3. Distances traveled by tagged bearded, ringed, and spotted seals in the Bering, Chukchi, and Beaufort seas during 2014–2019.

	Bearded ($n = 22$)	**Ringed ($n = 11$)**	**Spotted ($n = 24$)**	**All seals ($n = 57$)**
Ave. min. distance (km)	6,166	8,076	10,470	8,347
Min. distance (km)	1,282	1,770	3,090	1,282
Max. distance (km)	15,480	16,374	16,495	16,495

Distance to Land

Seals of all three species used areas near land, including terrestrial haulouts and freshwater rivers, but also used areas 800 km from land. Distances to land, however, differed by seal species and months (all species, $P < 0.0001$), and were highly variable by individual. On average, the distances young bearded seals kept from land differed the least; they tended to remain closest to land (< 50 km) during November–January when ice was present, and farther from land (< 75 km) during April–September (Fig. 24). Ringed seals also were closer to land when ice was present (< 20 km) during November–May, and farther from land during the open-water season, June–October (> 45 km); they were farthest from land (~190 km) during September (Fig. 25). Spotted seals, however, tended to move farther from land when ice cover was maximal, January–April, and stayed closer to land during the open-water season, July–November (Fig. 26). On average, spotted seals were farthest from land during March (~140 km).

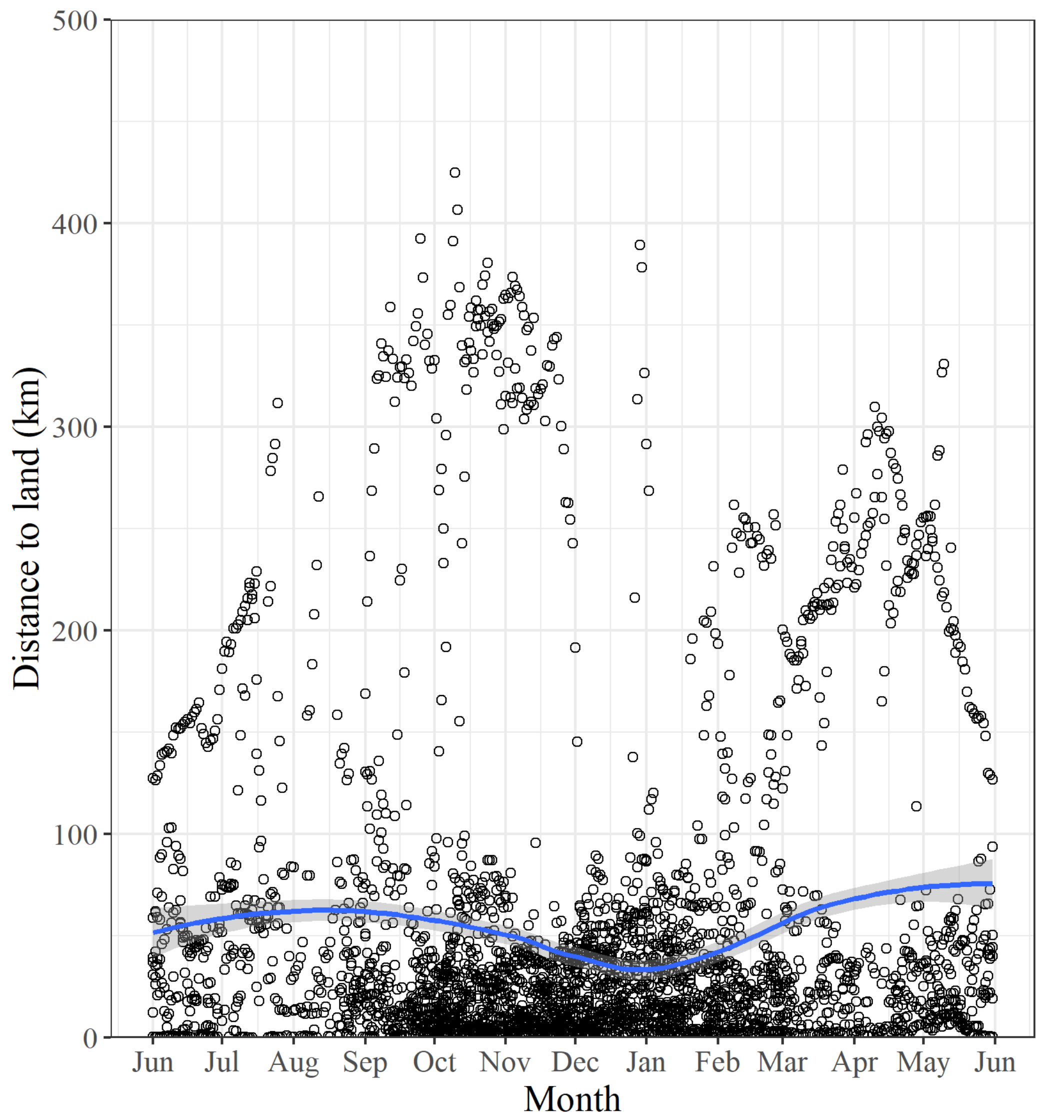


Figure 24. Distance to land (km) for daily estimated locations of 26 young bearded seals by month during 2014–2019. Blue line and gray shaded region represent the smoothed conditional mean and SE for distance to land.

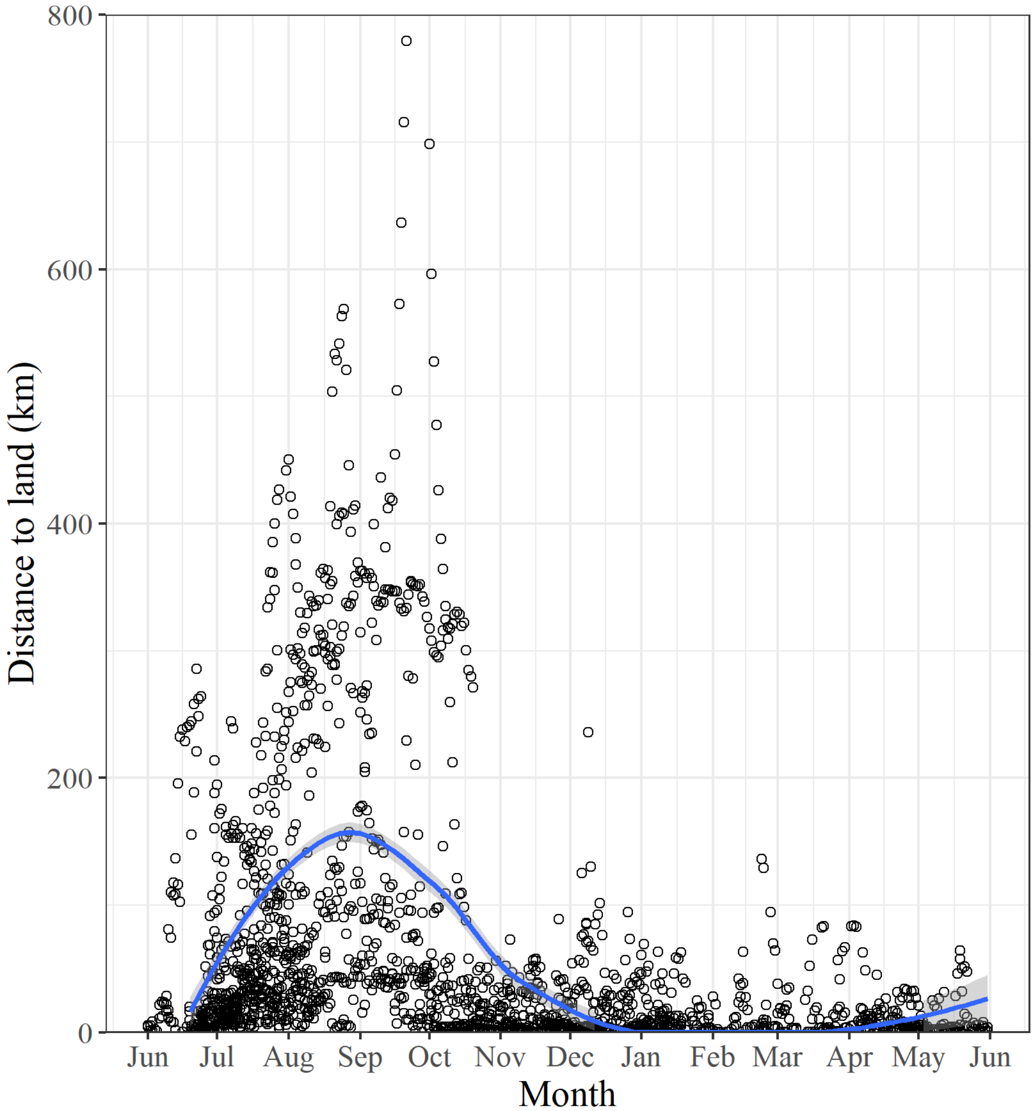


Figure 25. Distance to land (km) for daily estimated locations of 16 ringed seals (13 adults and 3 juveniles) by month during 2014–2019. Blue line and gray shaded region represent the smoothed conditional mean and SE for distance to land.

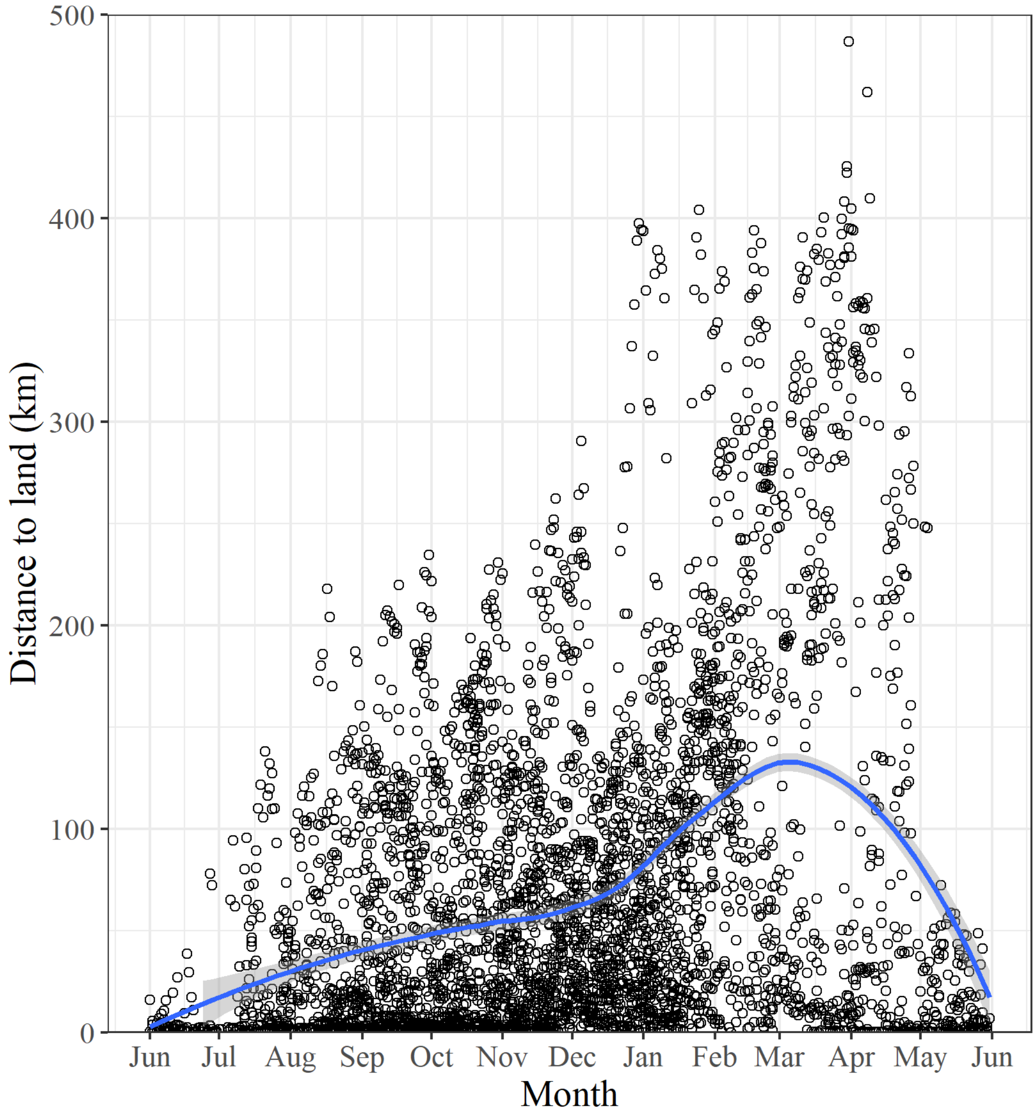


Figure 26. Distance to land (km) for daily estimated locations of 25 spotted seals by month during 2016–2019. Blue line and gray shaded region represent the smoothed conditional mean and SE for distance to land.

High-Use Areas Important for Foraging

Bearded seals. Bearded seals are primarily benthic foragers (85% of all dives are to the sea floor). To identify important foraging areas, we first explored how habitat covariates influence the time spent at the sea floor (i.e. feeding). We found they spent less time at the sea floor as sea ice concentration and water depth increased, and more time at the sea floor as distance from land increased, and these relationships varied seasonally (Fig. 27). Although these patterns were statistically significant, they only explained 10% of the variation in time spent at the sea floor. Rather, bearded seals appear to consistently dive to the sea floor throughout the year and in a variety of environmental conditions.

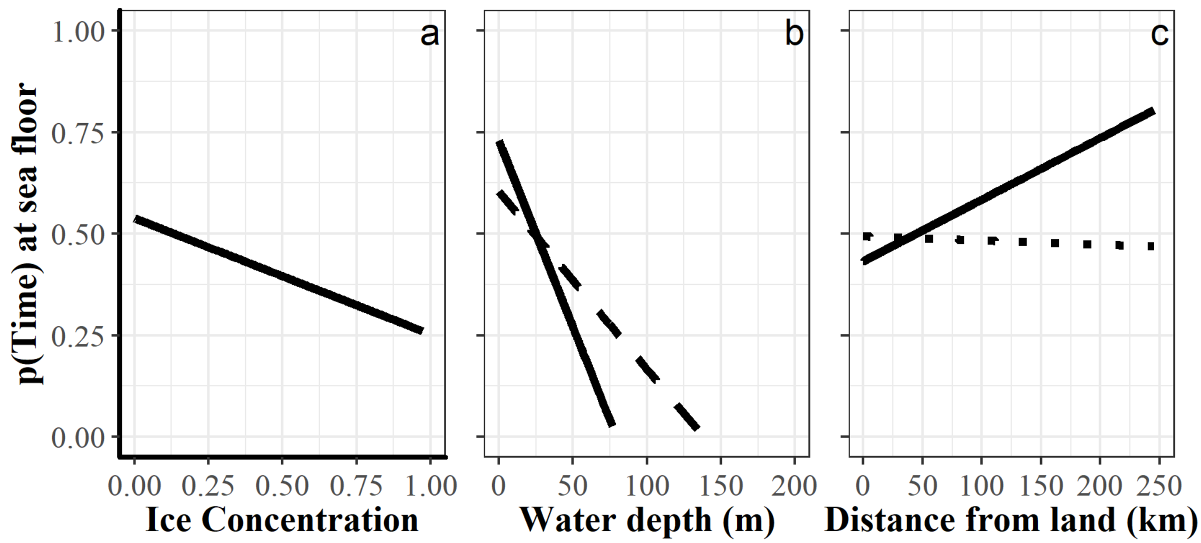


*Figure 27. The proportion of time bearded seals (n = 14) spent near the sea floor relative to the habitat variables (a) ice concentratoin, (b) water depth, and (c) distance from land. For ice concentration (a), solid line is the relationship during summer, fall and winter. For water depth (b), solid line depicts the proportion of time at the sea floor when seals are within the pack ice (> 15% ice concentration), and dashed line depicts this relationship when seals are in open water. For distance from land (c), the dotted line is the relationship during June–August and the solid line is the relationship during September–January. Figure reproduced from Olnes et al. (*In review*).*

Given their consistent dive pattern (it appears young bearded seals regularly dive to the sea floor looking for prey), we explored the use of a state-space model to infer foraging locations. If seals maintain a consistent dive pattern, then where they spend time in a resident behavioral state could indicate places where they have found prey. Our state-space model identified clear behavioral states for juvenile bearded seals (Figs. 28 and 29), however, where seals lingered in a resident state was highly individualistic, making the determination of high-use areas difficult to ascertain. Notable areas that are likely important for bearded seal foraging year-round are Barrow Canyon, southern Kotzebue Sound, Bering Strait, Norton Sound, and near St. Lawrence Island. During July–November, important areas also included Hope Basin, Mechigmenskaya Bay, Russia, and the ~100 m isopleth in the Bering Sea (Fig. 28); during December–June, important areas also included the mouth of the Yukon River and western Anadyr Gulf (Fig. 29). Much of the continental shelf, however, may also be important foraging habitat for bearded seals.

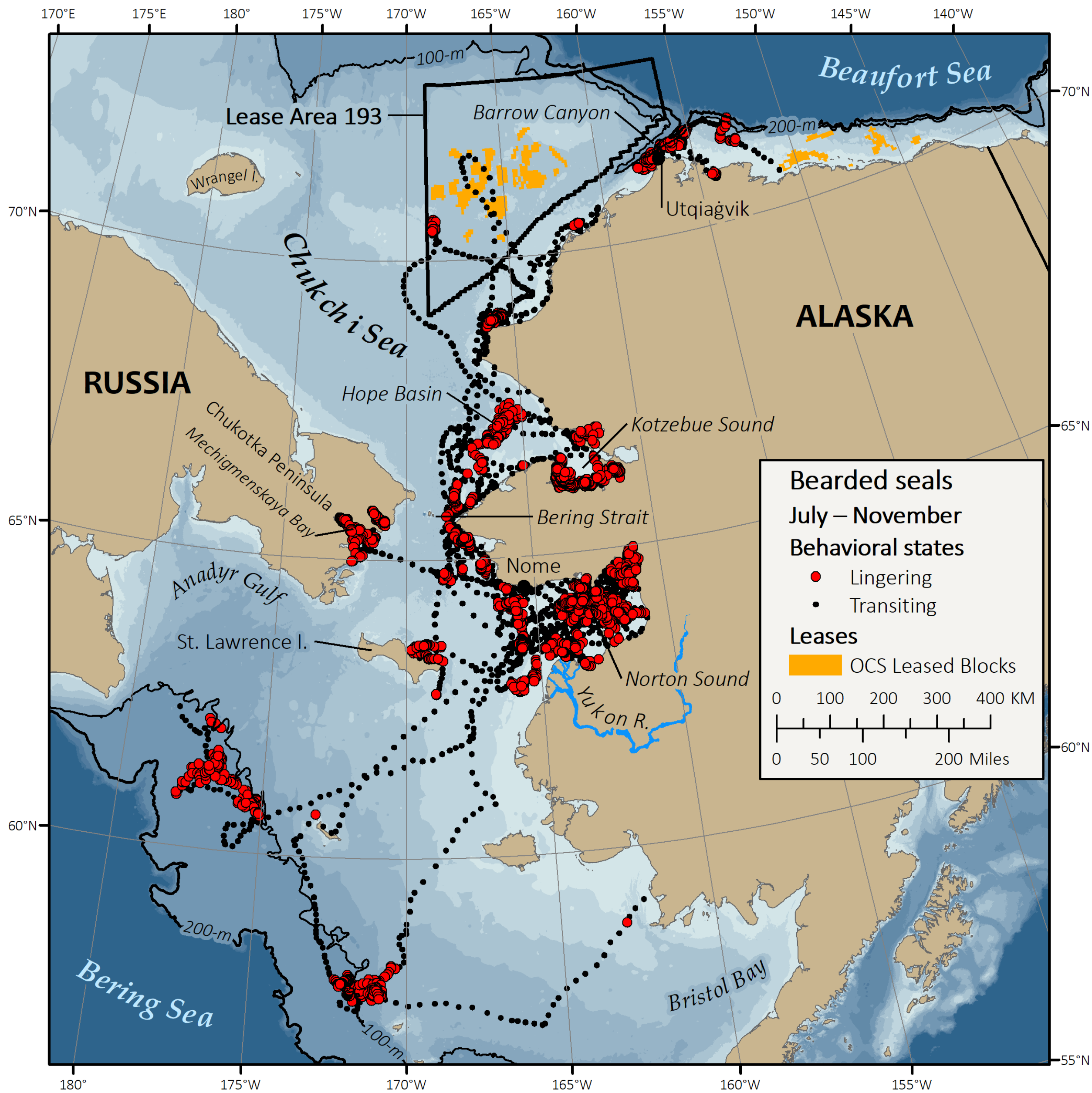


Figure 28. Juvenile bearded seal (n = 18) locations, as determined by a joint estimation state-space model, during July–November 2014–2017. Red dots are seal locations identified in lingering or resident behavioral state and small black dots are seal locations identified in transiting state.

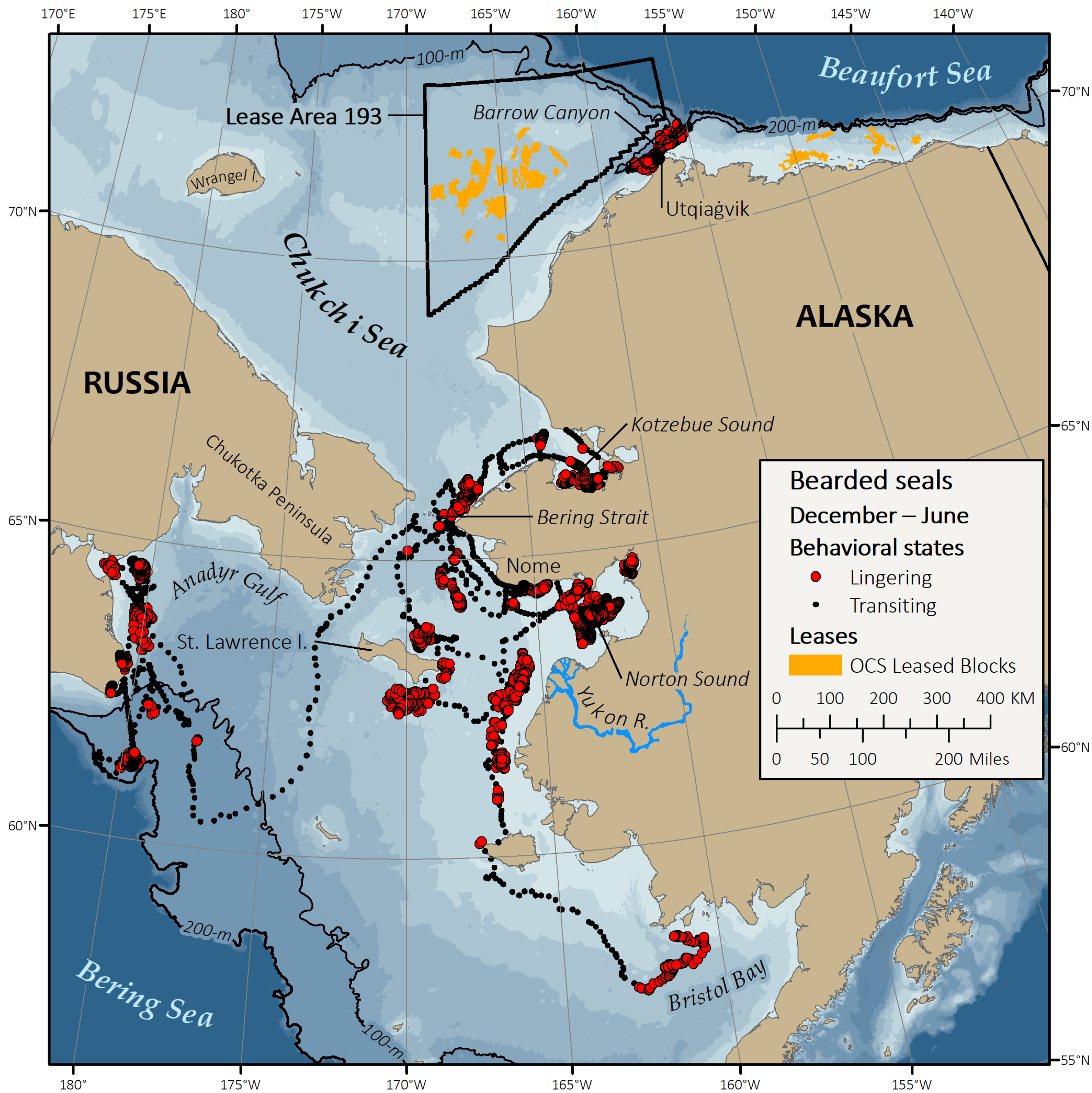


Figure 29. Juvenile bearded seal (n = 13) locations, as determined by a joint estimation state-space model, during December–June 2014–2018. Red dots are seal locations identified in lingering or resident behavioral state and small black dots are seal locations identified in transiting state.

Ringed seals. We identified core-use areas for ringed seals as utilization distributions of < 50% volume (i.e., areas with the highest density of locations) during the summer (July–September) and winter (December–May) seasons. We defined seasons of use based on the seasonal movements of ringed seals (Fig. 12). Ringed seals are generally at their northern extent during summer when the Chukchi Sea is primarily free of sea ice and at their southern extent during winter when sea ice has advanced into the Chukchi and Bering seas. Ringed seals generally made long-distance movements during the rest of the year, migrating south with the advancing sea ice during fall (October and November) and migrating north with the receding sea ice during spring (June).

During July–September, seals were generally located along the intercontinental shelf break of the Chukchi and Beaufort seas (200 m isobath), but the core-use area was north and east of Utqiaġvik, including Barrow Canyon and the western Beaufort Sea (Fig. 30). Sea ice often stays until late July in the core-use area and seals were located and foraged near sea ice while in these areas. During December–May, seals used areas as far south as Nunivak Island, the mouth of the Yukon River, Stuart Island, Port Clarence, and Nome, but the core-use area was in southern Kotzebue Sound (Fig. 31). Sea ice is highly concentrated (> 80%) there during this period, and most (10 of 13) seals used to identify high-use areas during this period were adults. This pattern of use likely indicates these seals were establishing winter territories.

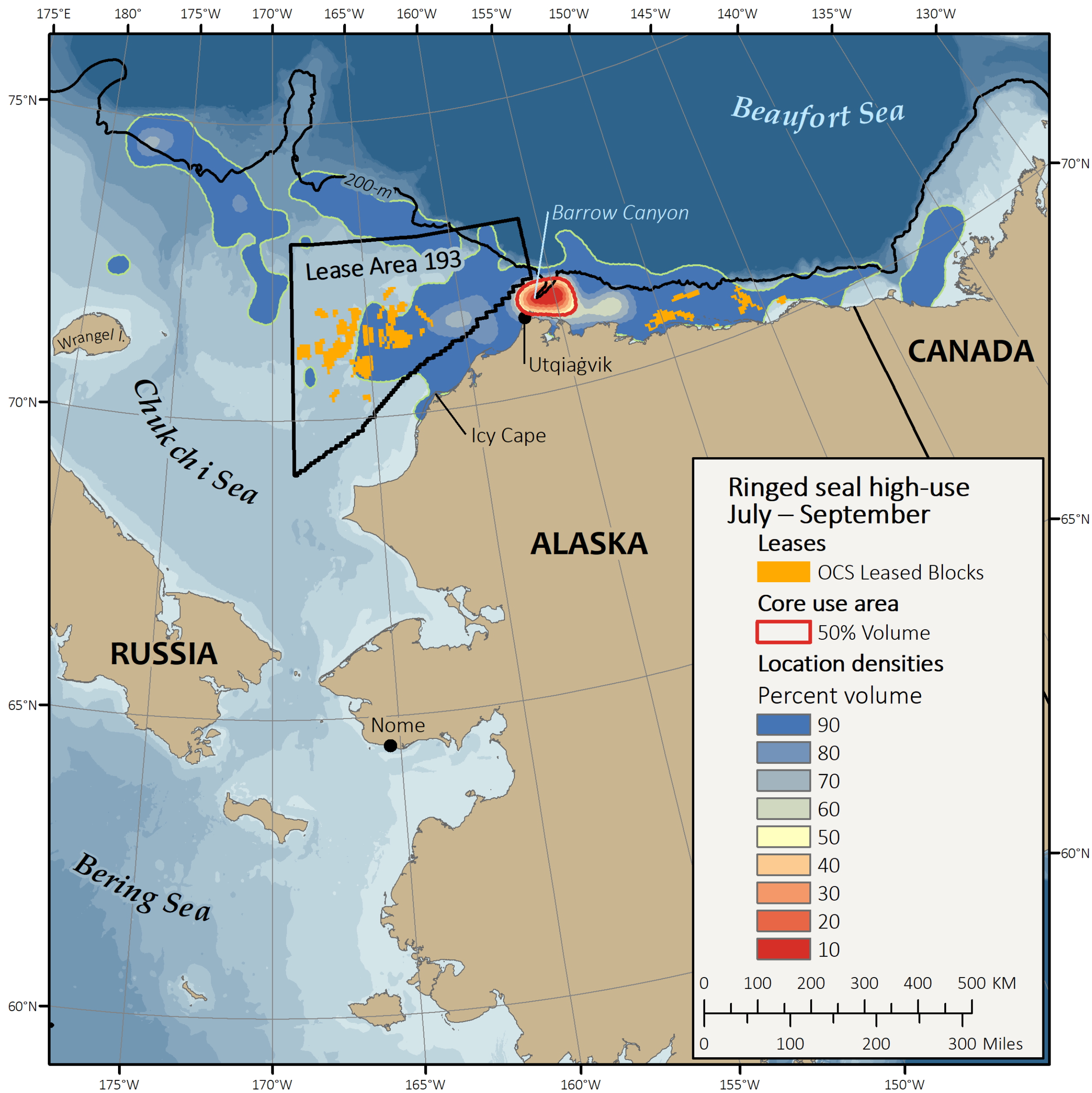


Figure 30. Distribution of ringed seals (n = 15) during July–September 2014–2019. Seals were tagged near Utqiaġvik (n = 7), Kotzebue Sound (n = 6), St. Michael (n = 1), and Hooper Bay (n = 1). Core-use areas (red circle) represent areas with utilization distributions < 50% volume (i.e., areas with the highest density of locations) within the season and delineate primary foraging areas. The lite-green line depicts the boundary of utilization distributions with < 90% volume and were used to differentiate location densities from areas with deep bathymetry.

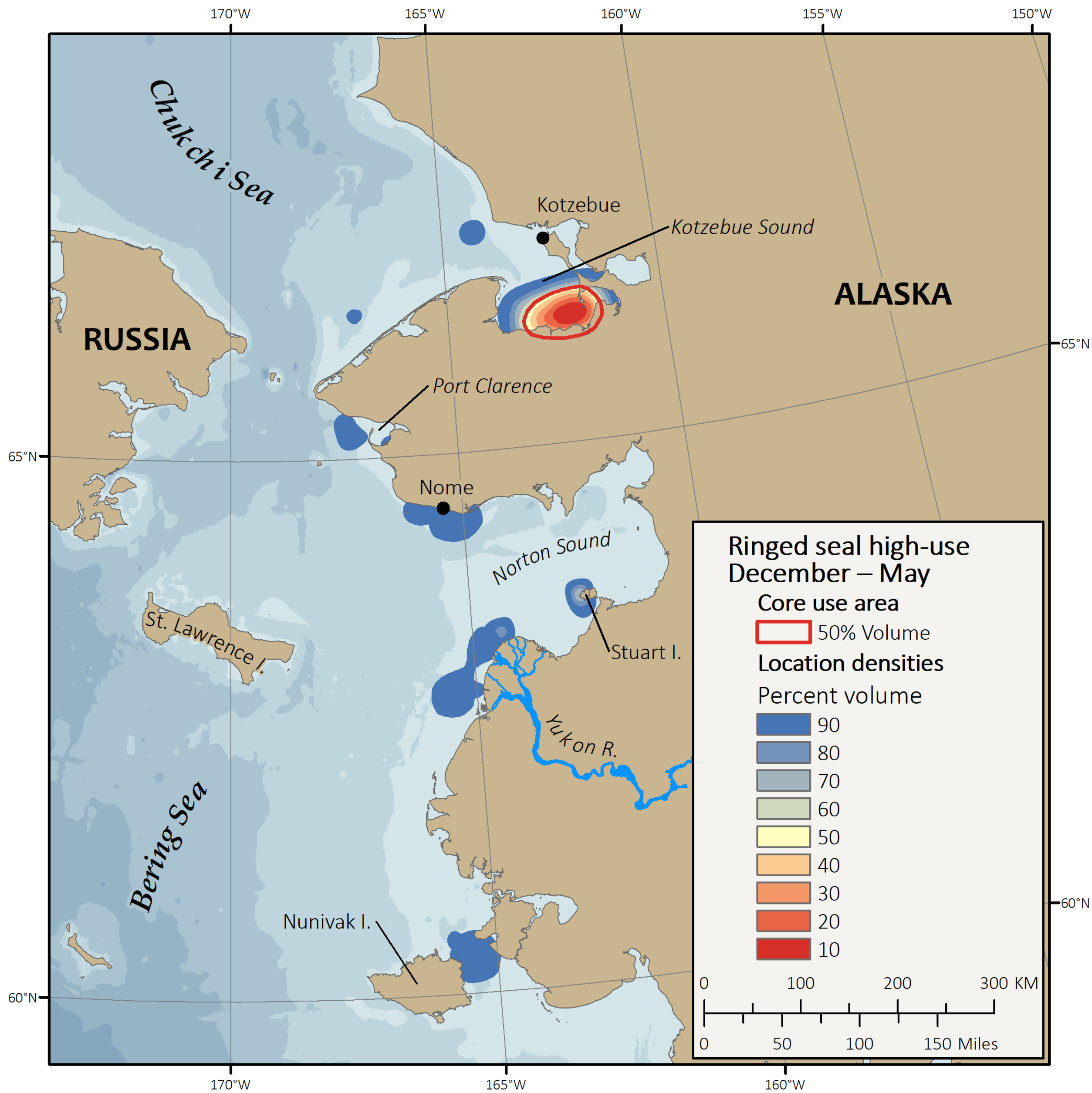


Figure 31. Distribution of ringed seals (n = 13) during December–May of 2014–2019. Seals were tagged near Utqiaġvik (n = 5), Kotzebue Sound (n = 6), St. Michael (n = 1), and Hooper Bay (n = 1). Core-use areas (red circle) represent areas with utilization distributions < 50% volume (i.e., areas with the highest density of locations) within the season and delineate primary foraging areas.

Spotted seals. We identified primary foraging and resting areas as core-use areas with utilization distributions < 50% volume (i.e., areas with the highest density of locations) within the open-water (May–November) and ice-covered (December–April) seasons. We used locations > 5 km from land to identify core-use areas important for foraging and locations < 5 km to identify core-use areas important for resting nearshore. While in resting areas spotted seals hauled out on land, often hauling out multiple times between foraging trips, but they also lingered in coastal waters and occasionally foraged there.

During the open-water season, spotted seals tagged in the Beaufort Sea moved between foraging areas in the Chukchi Sea and resting areas near the Alaskan coast (Fig. 32). The primary foraging area for spotted seals tagged in the Beaufort Sea was between Herald Shoal and the nearshore waters of the northeast Chukchi Sea (< 50 m deep; Fig. 33). On average, foraging trips in the Chukchi Sea lasted 9.7 days (range: 1–27 days) and seals traveled a total distance of 583 km (range: 83–1,610 km). Between foraging trips, resting areas primarily included islands near Icy Cape, Dease Inlet, and Kotzebue Sound (Fig. 34). Nearshore resting periods, associated with foraging trips in the Chukchi Sea, were on average 2.6 days (range: 0.5–8 days) and haul-outs (time out of the water) lasted 12.2 hrs (range: 0.5–106.0 hrs). For example, from 9 to 16 October 2016, SS16-06-F stayed within 5 km from shore of the barrier islands near Icy Cape, north of Point Lay, where it hauled out on land 10 times (mean duration = 9.3 hrs; range duration: 0.5–23.5 hrs; total duration = 92.6 hrs) and occasionally foraged. From 17–23 October 2016, this seal left Icy Cape to forage in the central Chukchi Sea, east of Herald Shoal, it then returned to Kasegaluk Lagoon and Icy Cape, from 23 to 28 October 2016, where it hauled out on land nine times (mean duration = 9.8 hrs; range duration: 1.0–37.7 hrs; total duration = 88.3 hrs) and occasionally foraged (Fig. 35).

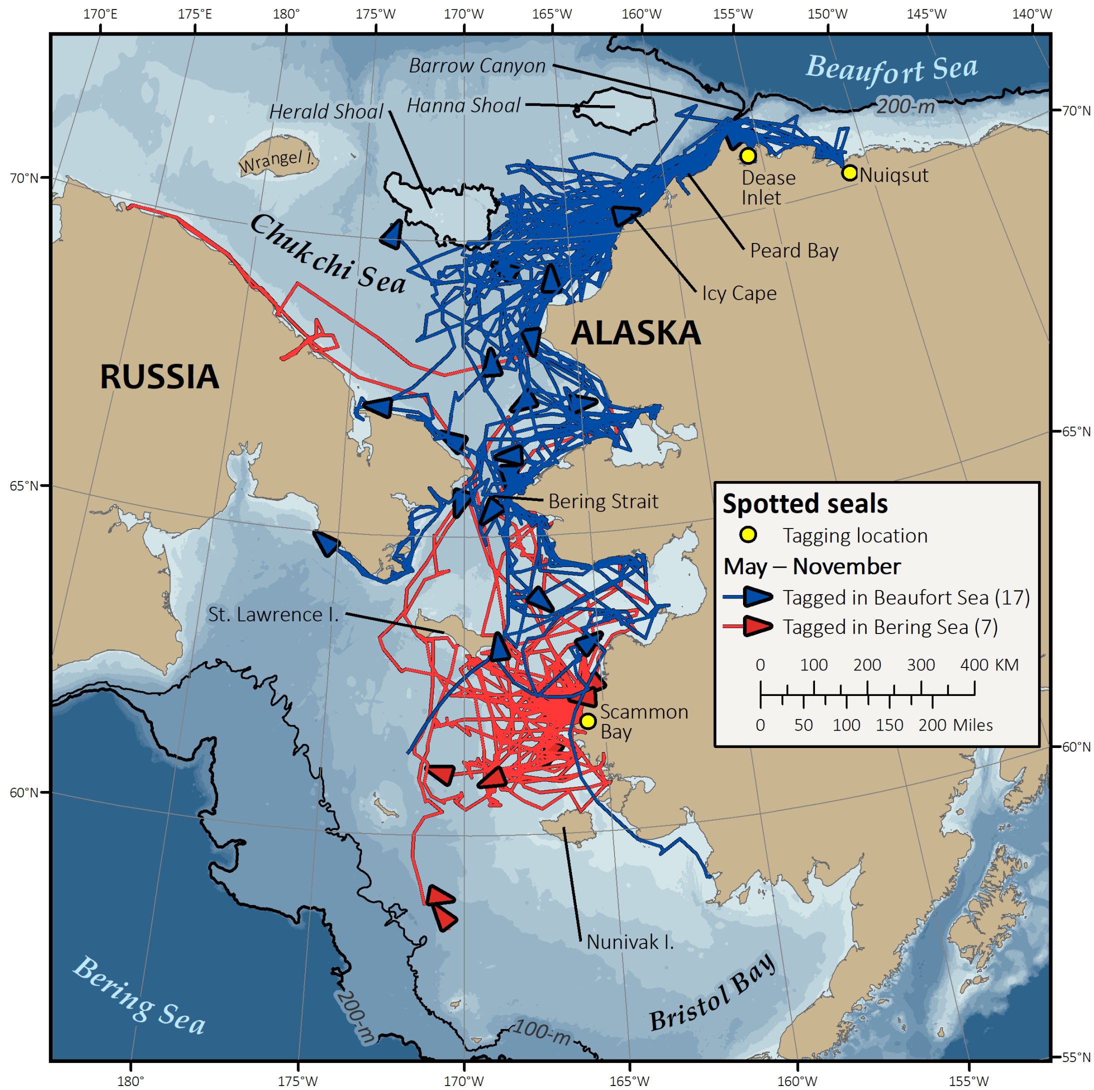


Figure 32. Movements of spotted seals in the Bering, Chukchi, and Beaufort seas during the open-water seasons (May–November) of 2016–2018. Spotted seals were tagged near Scammon Bay in the Bering Sea (n = 7; red lines) and Dease Inlet and the Colville River/Nuiqsut in the Beaufort Sea (n = 17; blue lines).

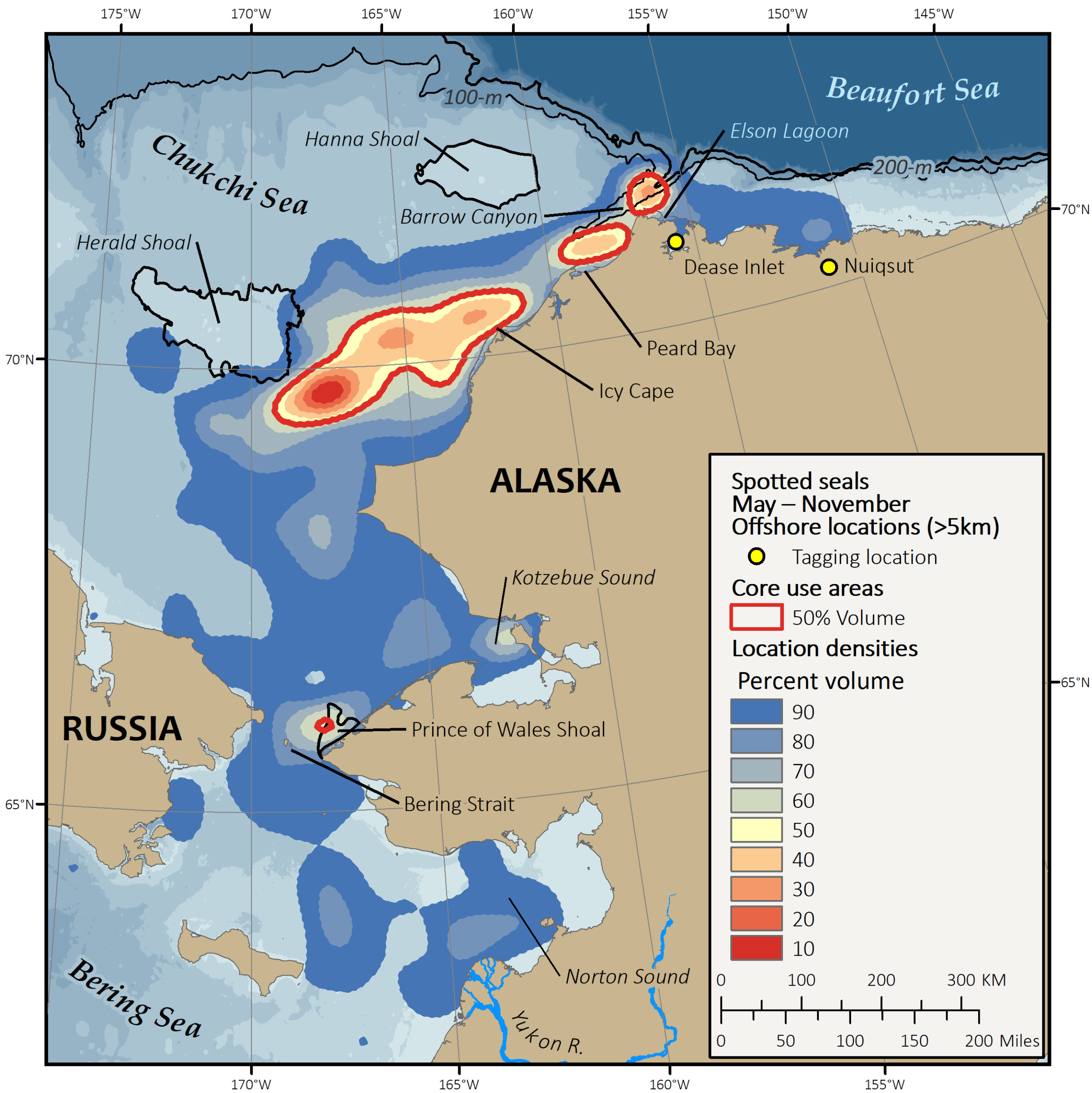


Figure 33. Offshore (>5 km) distribution of spotted seals during the open-water seasons (May–November) of 2016–2018. Seals were tagged in the Beaufort Sea (n = 17; Dease Inlet and Colville River/Nuiqsut). Core-use areas (red circles) represent areas with utilization distributions < 50% volume (i.e., areas with the highest density of locations) within the season and delineate primary foraging areas.

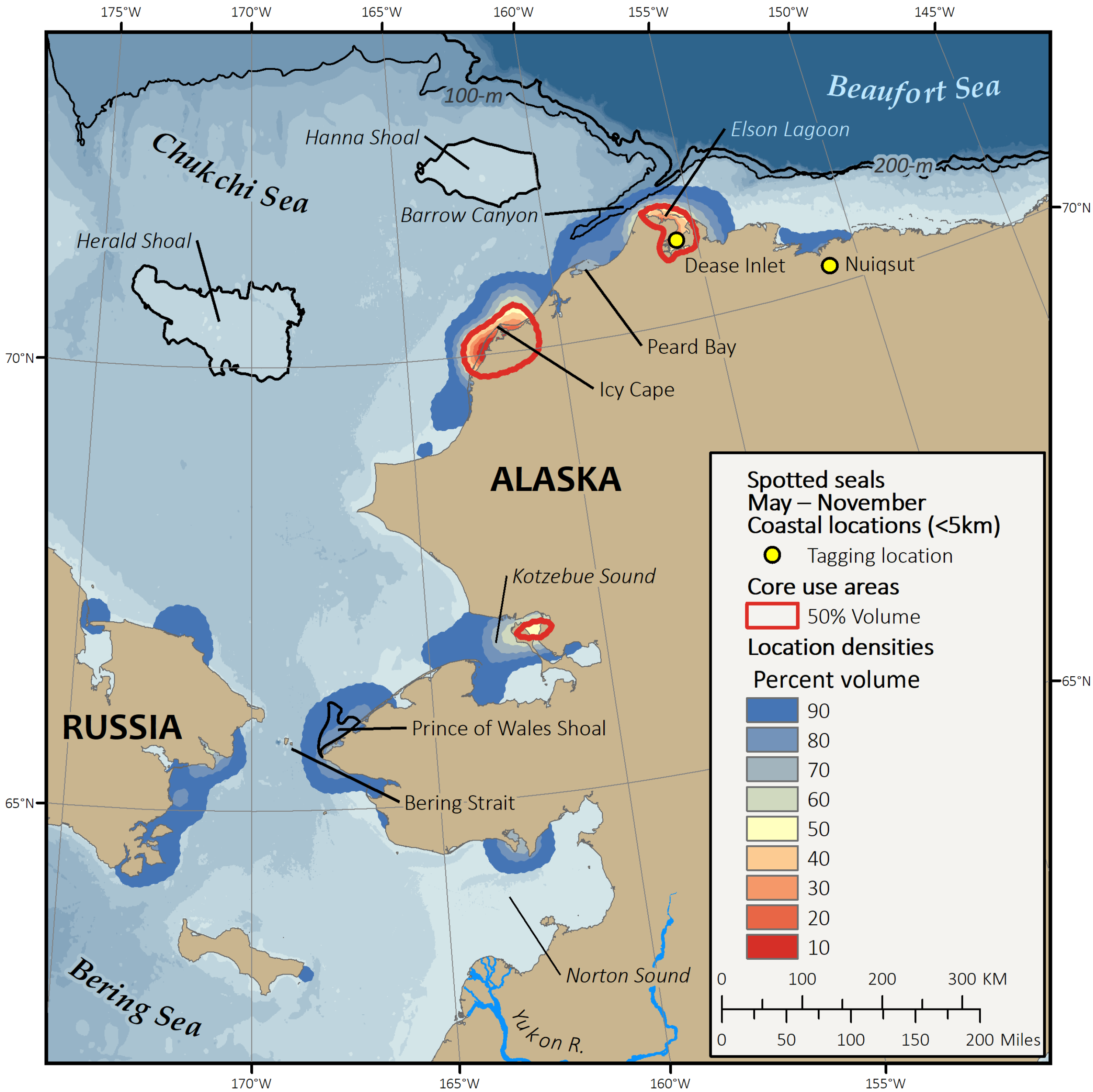


Figure 34. Nearshore (< 5 km) distribution (including terrestrial haulout locations) of spotted seals during the open-water seasons (May–November) of 2016–2018. Seals were tagged in the Beaufort Sea (n = 17; Dease Inlet and Colville River/Nuiqsut). Core-use areas (red circles) represent areas with utilization distributions < 50% volume (i.e., areas with the highest density of locations) within the season and delineate primary resting areas. Haul-out behavior data within these nearshore core-use areas further supported their identification as primary resting areas.

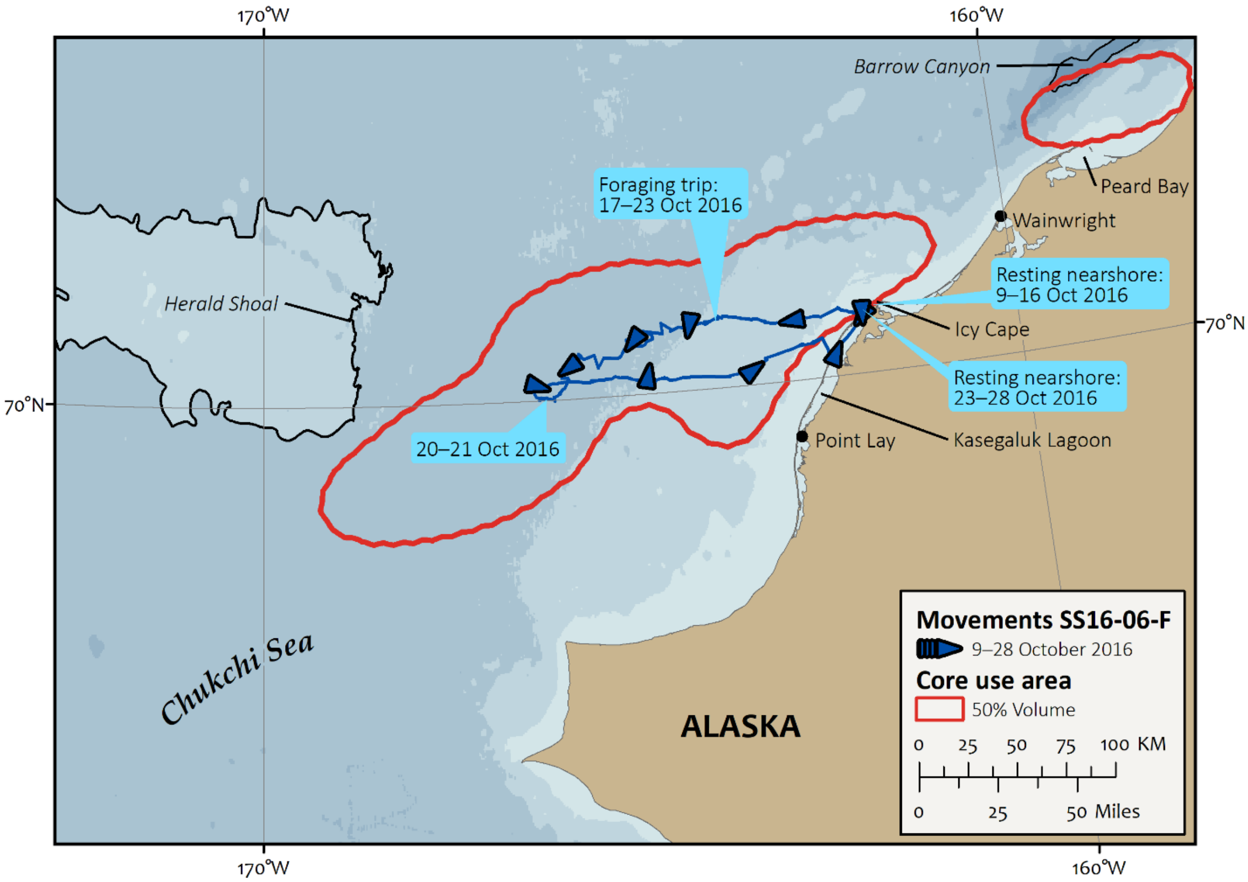


Figure 35. An example of movements and haulout behavior of one spotted seal (SS16-06-F) during October 2016. This seal was tagged in Dease Inlet on 17 August 2016. Core-use areas (red circles) represent areas with utilization distributions < 50% volume (i.e., areas with the highest density of locations) within the season and delineate primary foraging areas.

During the open-water season, spotted seals tagged in the Bering Sea moved between foraging areas in the central Bering Sea and the Alaskan coast (Fig. 32). On average, foraging trips in the Bering Sea lasted 5.9 days (range: 1–25 days) and seals traveled a total distance of 376 km (range: 86–1,293 km). Their primary foraging area was in the eastern Bering Sea, including Scammon Bay, where they were tagged (Fig. 36). Between foraging trips, resting areas primarily included islands near Scammon Bay (Fig. 37). Nearshore resting bouts, associated with foraging trips in the Bering Sea, were on average 2.8 days (range: 0.5–9 days) and individual haulouts lasted 9.6 hrs (range: 0.5–71.0 hrs).

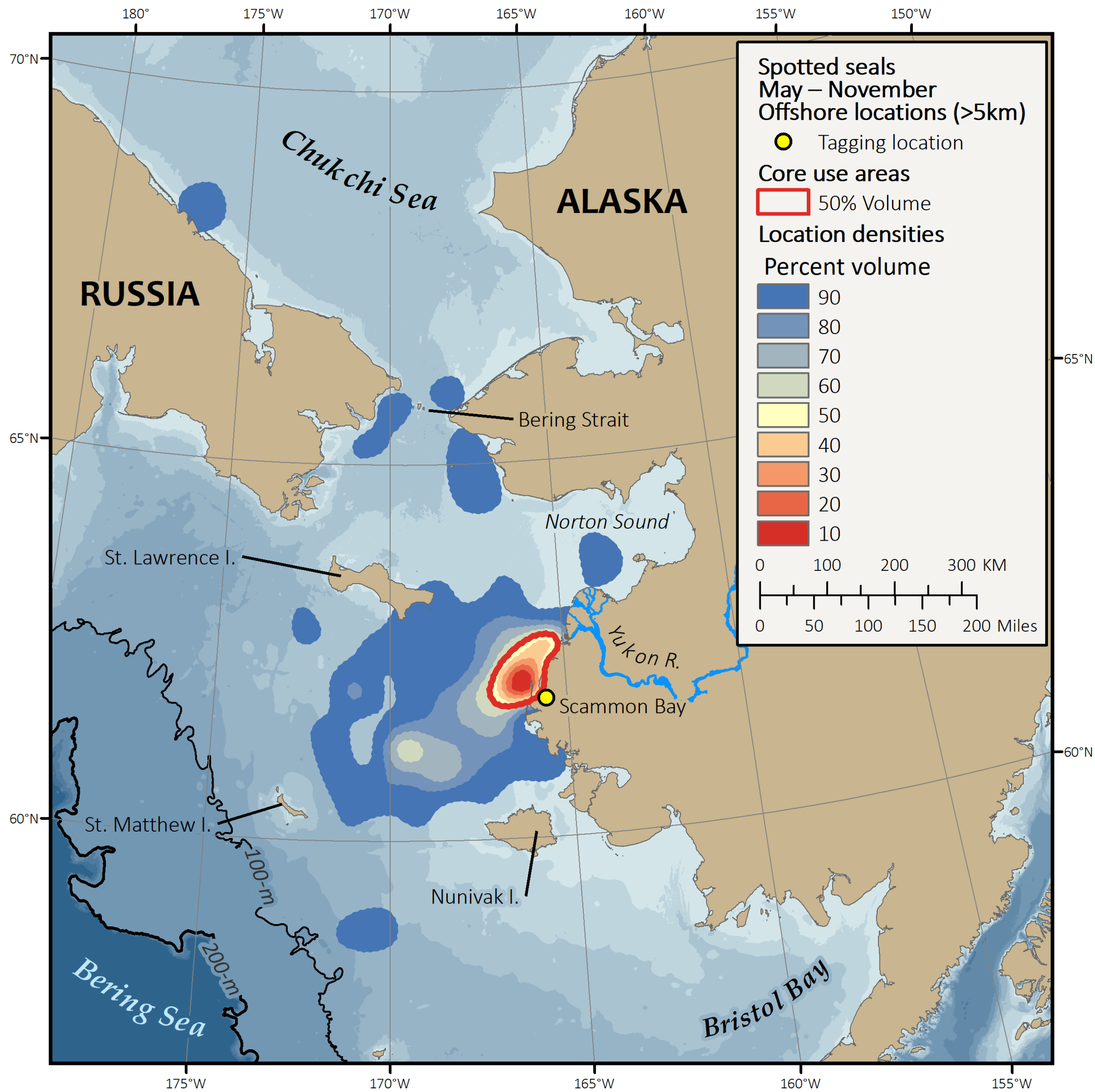


Figure 36. Offshore (> 5 km) distribution of spotted seals tagged in the Bering Sea (n = 7; Scammon Bay) during the open-water seasons (May–November) of 2016–2018. Core-use areas (red circle) represent areas with utilization distributions < 50% volume (i.e., areas with the highest density of locations) within the season and delineate primary foraging areas.

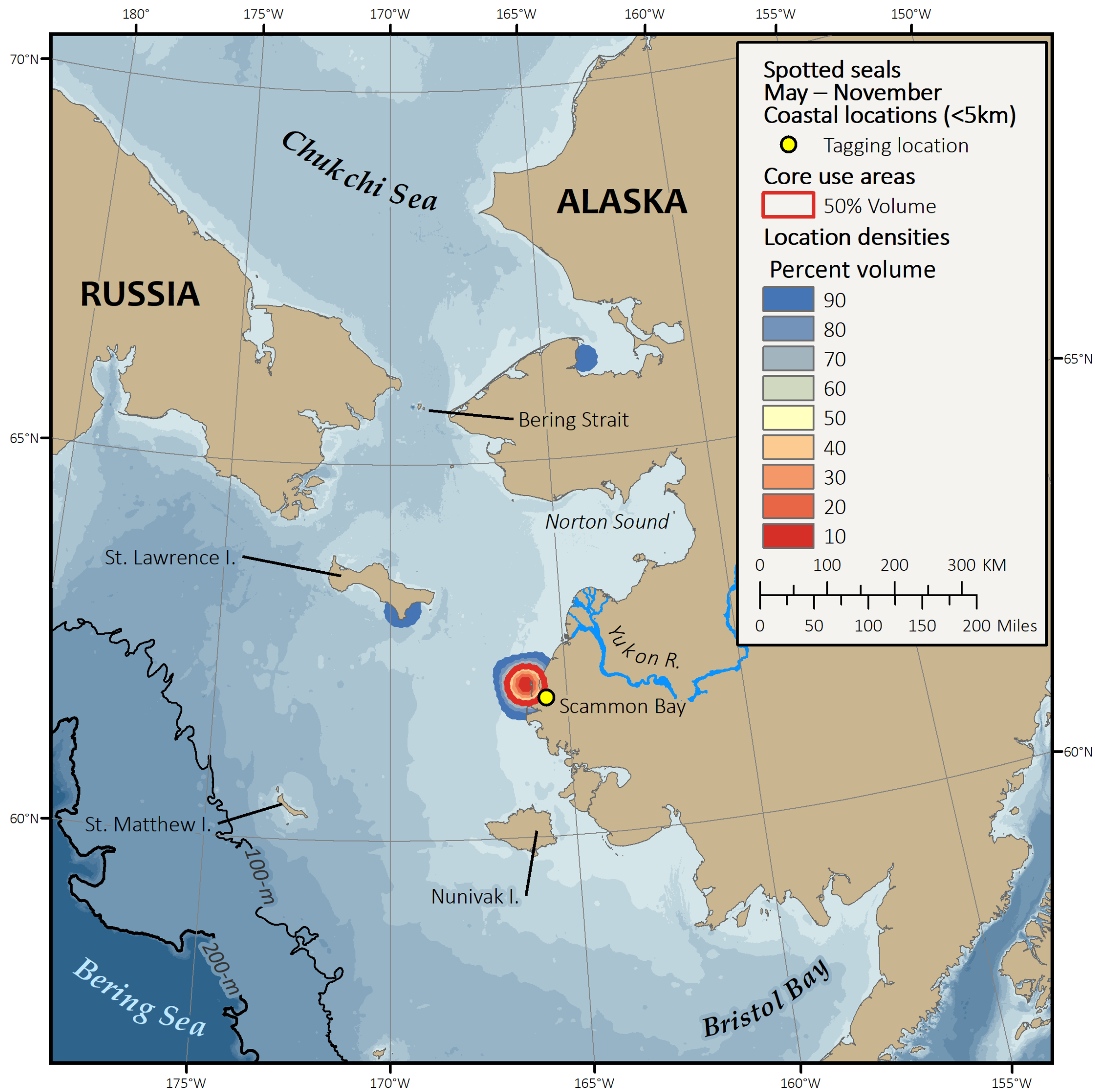


Figure 37. Nearshore (<5 km) distribution (including terrestrial haulout locations) of spotted seals tagged in the Bering Sea (n = 7; Scammon Bay) during the open-water seasons (May–November) of 2016–2018. Core-use areas (red circle) represent areas with utilization distributions < 50% volume (i.e., areas with the highest density of locations) within the season and delineate primary resting areas. Haul-out behavior data within these nearshore core-use areas further supported their identification as primary resting areas.

In December, spotted seals tagged in the Beaufort Sea moved south, ahead of the advancing pack ice (Fig. 38). By the end of December most spotted seals, regardless of tagging location, occupied pack ice, primarily in the marginal ice zone, and foraged in the central Bering Sea (Figs. 39, 40 and 41). Seals rested on sea ice between foraging bouts primarily near Nunivak Island and the Alaskan coast and Bristol Bay. Low sea ice in the Bering Sea in recent years may be limiting spotted seal use of the central Bering Sea, forcing spotted seals to restrict their movements to coastal areas where resting platforms, either shorefast ice or barrier islands, are available (Fig. 39).

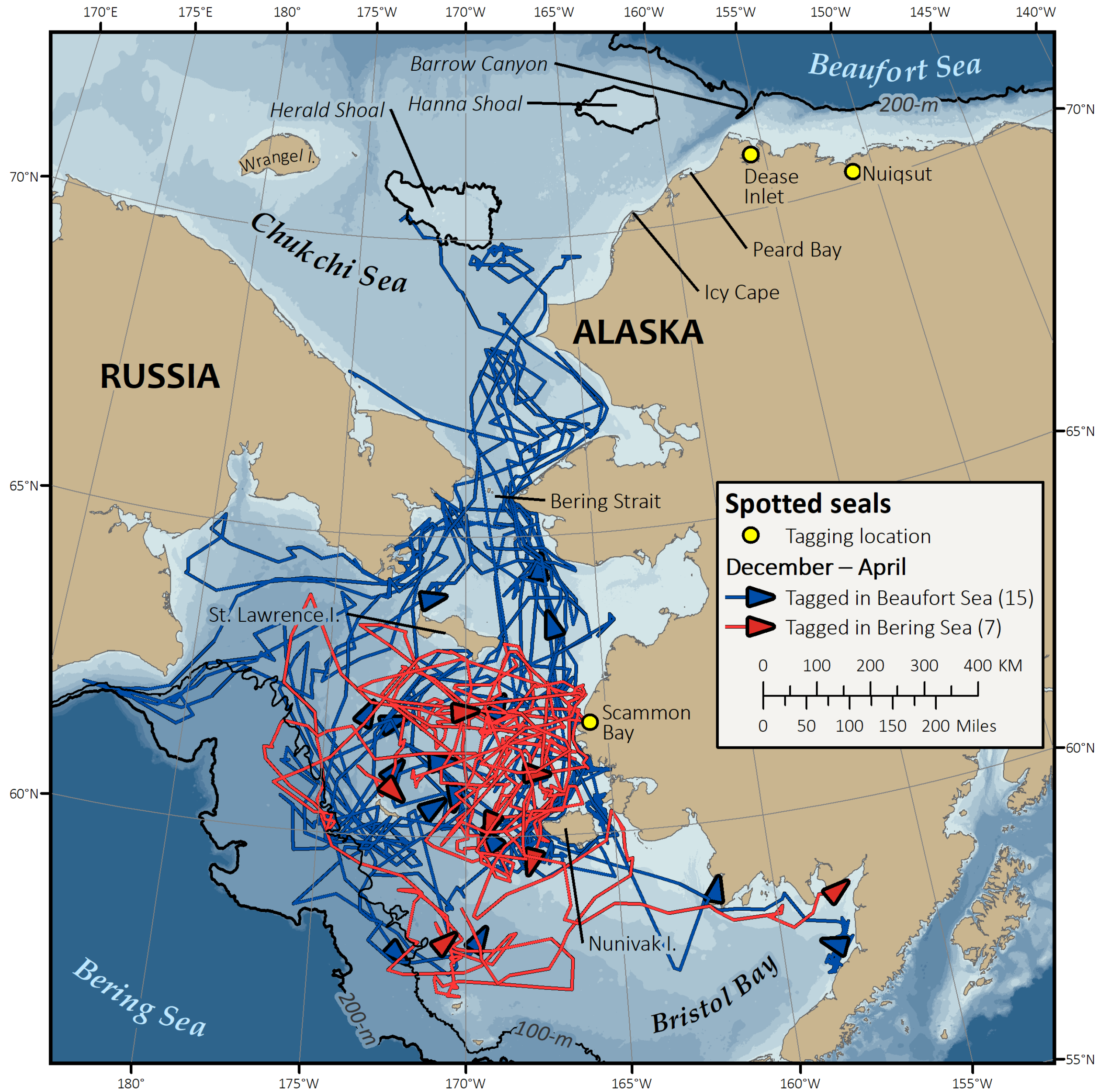


Figure 38. Movements of spotted seals in the Bering, Chukchi, and Beaufort seas during the ice-covered seasons (December–April), 2016–2018. Spotted seals were tagged near Dease Inlet and the Colville River/Nuiqsut in the Beaufort Sea (blue lines) and Scammon Bay in the Bering Sea (red lines).

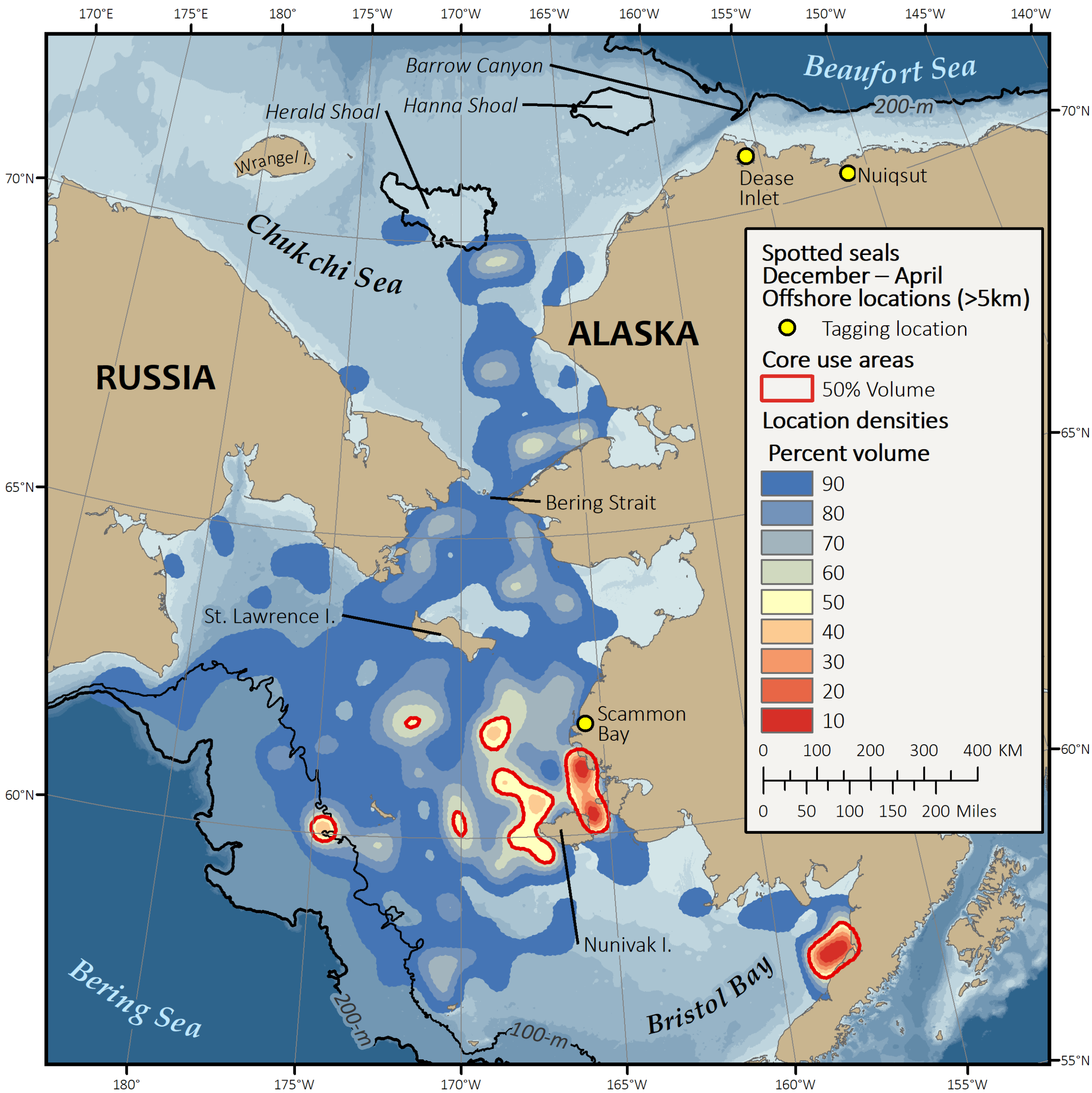


Figure 39. Offshore (> 5 km) distribution of all spotted seals during the ice-covered season (December–April) of 2016–2018. Seals were tagged in the Beaufort Sea (n = 17; Dease Inlet and Colville River/Nuiqsut) and Bering Sea (n = 7; Scammon Bay). Core-use areas (red circles) represent areas with utilization distributions < 50% volume (i.e., areas with the highest density of locations) within the season and delineate primary foraging and resting areas.

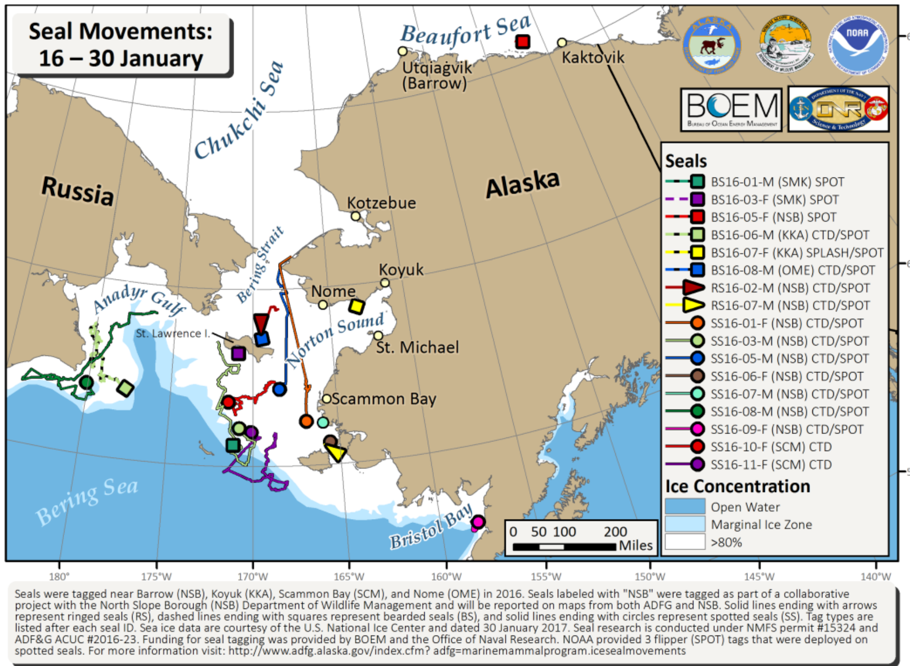


Figure 40. Movements of nine spotted seals, six bearded seals and two ringed seals in late January 2017 relative to sea ice. Seals were tagged with satellite transmitters during 2016. Sea ice data are courtesy of the U.S. National Ice Center and dated 30 January 2017.

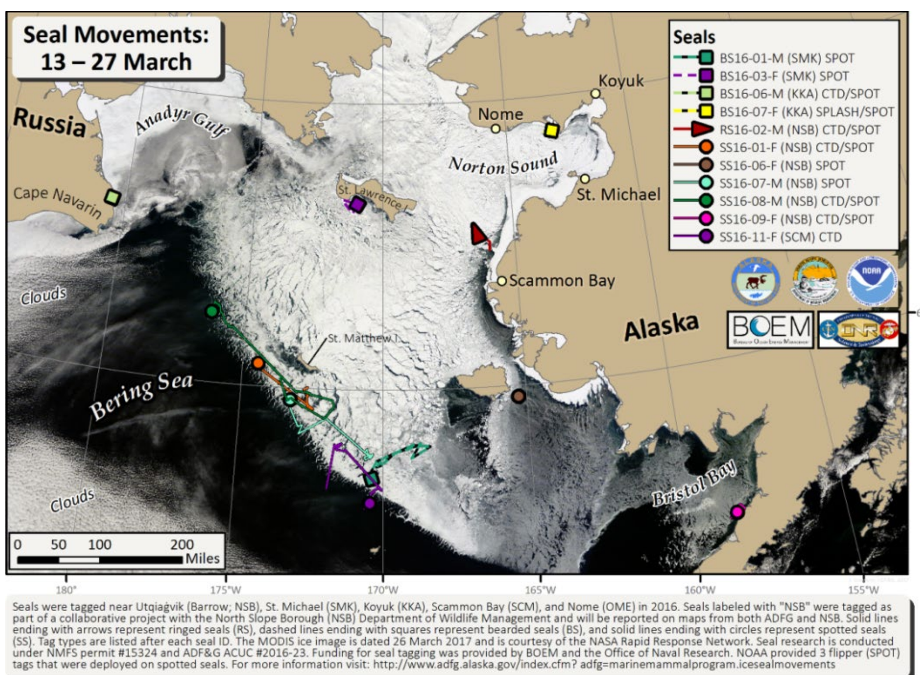


Figure 41. Movements of six spotted seals, four bearded seals, and one ringed seal in late March 2017 relative to sea ice. Seals were tagged with satellite transmitters during 2016. Sea ice data are from a 26 March 2017 MODIS ice image courtesy of the NASA Rapid Response Network.

The east-west movement patterns we observed of tagged spotted seals during the open-water period are likely associated with their use of land haulouts at fairly regular intervals between foraging trips. Indeed, during the winter months when ice is available for hauling out, spotted seals range far from shore along the ice edge into the central Bering Sea (Figs. 21, 22, and 38). In the winter, spotted seals used island haulouts at St. Lawrence, St. Matthew, and Nunivak islands in addition to a land haulout near Hooper Bay to access the central Bering Sea when little ice was present (Figs. 21 and 39).

Haul-out Behavior

Bearded Seals. During the open-water period (July–November), five young bearded seals spent 26–50 days in open water without hauling out (Fig. 42). One bearded seal spent 30 days in open-water without hauling out in the Beaufort and Chukchi seas in 2017, another spent 38 days in the Chukchi and Bering seas in 2015, and the other three stayed in the Bering Sea without hauling out for 26, 50, and 36 days, respectively in 2014, 2015, and 2016 (Fig. 42).

When bearded seals did haul out during the open-water period, they used both sea ice and land. We compared 34 haul-out bouts from six bearded seals on sea ice and 27 haul-out bouts from seven seals on land. The mean minimum haul-out duration for young bearded seals on ice (10.1 ± 1.4 hrs, mean ± standard error) was longer than when on land (5.0 ± 1.4 hrs; $P = 0.04$; Fig. 43). Bearded seals hauled out on land in Kotzebue Sound (Eschscholtz Bay and islands in the western Sound), and in Norton Sound (Norton Bay and near St. Michael). Seals hauled out on land may be disturbed more often, prematurely ending haul-out bouts.

Figure 42. Tracks of five young bearded seals that remained in open water and produced no haul-out record for durations of ~1 month or longer during 2014–2018.

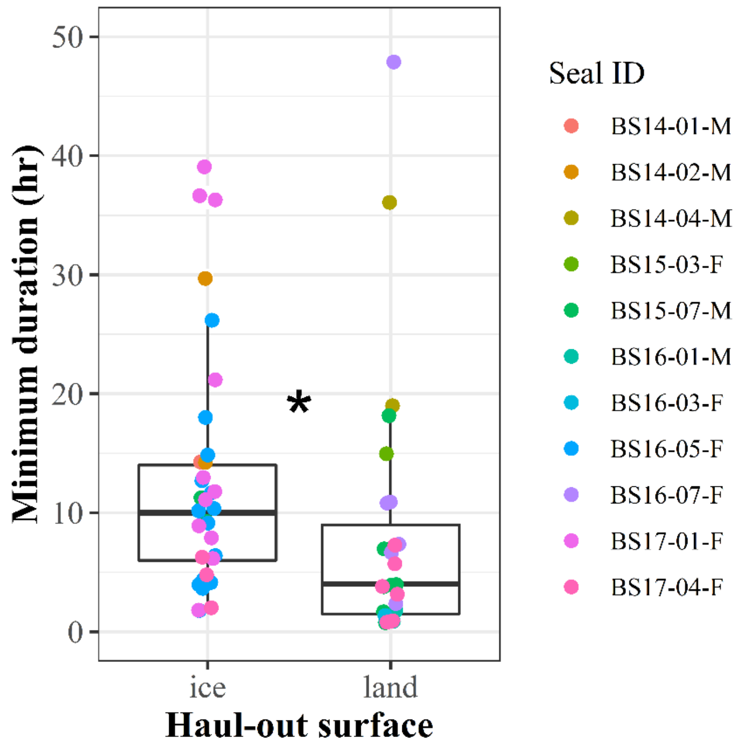


Figure 43. Boxplot of minimum haul-out durations (hrs) for juvenile bearded seals (n = 11) that hauled out on land versus on sea ice during the open-water period (July–October) during 2014–2018. Each point is the minimum duration of individual haul-out events, colored by individual seal. Asterisk denotes a significant difference between ice and land haulouts (P = 0.04).

Ringed Seal. Ringed seal haul-out behavior was seasonal and somewhat depended on the presence of ice. Eight of 11 tagged ringed seals were adults; therefore, we do not have the sample size to make comparisons between demographic classes regarding haul-out behavior. Ringed seals were more likely to haul out during the ice-covered season (daily haul-out probability = 57%) than the open-water season (48%; $P = 0.0162$) and haulout periods averaged 5 hrs. (Table 4). We identified four occasions when ringed seals hauled out on land, once near Icy Cape in July, once on the north shore of Russia in October, and twice on the north shore of the Seward Peninsula in November during their southward migration (Fig. 44). Two of these seals were males and two were females; the one that hauled out in Russia was a pup and the other three were adults at least 6 years old (Table 2).

Table 4. Haul-out duration and probability relative to seal species, season, and age class. The ice-covered season is December–April and the open-water season is May–November.

Species	Season	Age class (*n*)	Mean duration (hours)	Max duration (hours)	Daily haulout probability (%)
Bearded	Ice-covered	Young (19)	5.9	53	57.7
	Open-water	Young (24)	7.9	143	47.9
Ringed	Ice-covered	All ages (9)	4.8	23	56.9
	Open-water	All ages (11)	5.0	51	48.1
Spotted	Ice-covered	Non-pup (13)	9.2	54	41.3
	Ice-covered	Pup (9)	8.0	52	25.3
	Open-water	Non-pup (14)	8.3	146	43.9
	Open-water	Pup (10)	7.2	115	32.4

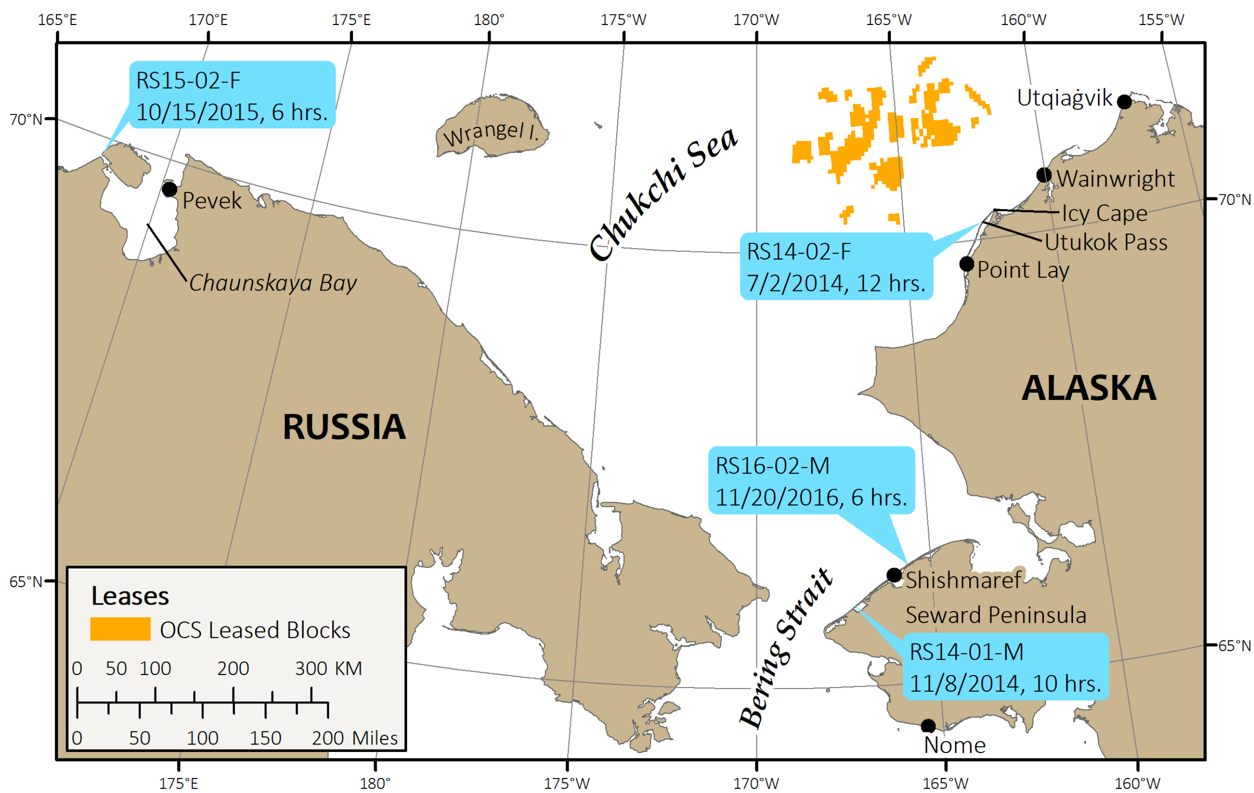


Figure 44. Locations where four ringed seals hauled out on land during 2014–2016. Seal ID and date and duration of haulout are listed in labels.

Spotted Seal. Spotted seals regularly hauled out on land and ice regardless of demographic class and our data identified four highly used land haulouts (Dease Inlet, Icy Cape, Kotzebue Sound, and Scammon Bay; Figs. 35 and 37) and at least 19 other sites. The seasonal pattern of haul-out durations among land sites was mostly similar between age classes; however, haul-out duration differed by age class. During the open-water season, spotted seals generally spent 1–21 days foraging before spending 1–6 days hauled out on land. Non-pup spotted seals were more likely to haul out (44%) than pups (32%) during the open-water season and during the ice-covered season (non-pups = 41%; pups = 25%; Table 4). Non-pups also hauled out longer than pups during the open-water (mean haul-out duration: non-pups =8.3 hrs, maximum = 146 hrs; pups = 7.2 hrs, maximum = 115 hrs) and during the ice-covered season (non-pups = 9.2 hrs, maximum = 54 hrs; pups = 8.0 hrs, maximum = 52 hrs). Although we have not formally analyzed the haul-out data for duration relative to other factors (e.g., weather, disturbance), it appears that spotted seals regularly travel to and from land haulouts between offshore feeding bouts, when ice is not available.

Use of Sea Ice

Bearded Seals. In general, the concentration of sea ice bearded seals used and their distance to the ice edge (15% ice concentration) differed by month ($P < 0.0001$), however their use of sea ice was highly variable. Despite variability in the timing and extent of sea ice during this study, the ice concentrations and distances to the ice edge used by bearded seals did not differ by year ($P > 0.19$). Bearded seals tended to use areas with the highest ice concentrations (> 50% mean ice concentration) from January through May (Fig. 45). Bearded seals tended to use pack ice (≥ 15% ice concentration) from December through the end of June and open water from July through November (Fig. 46).

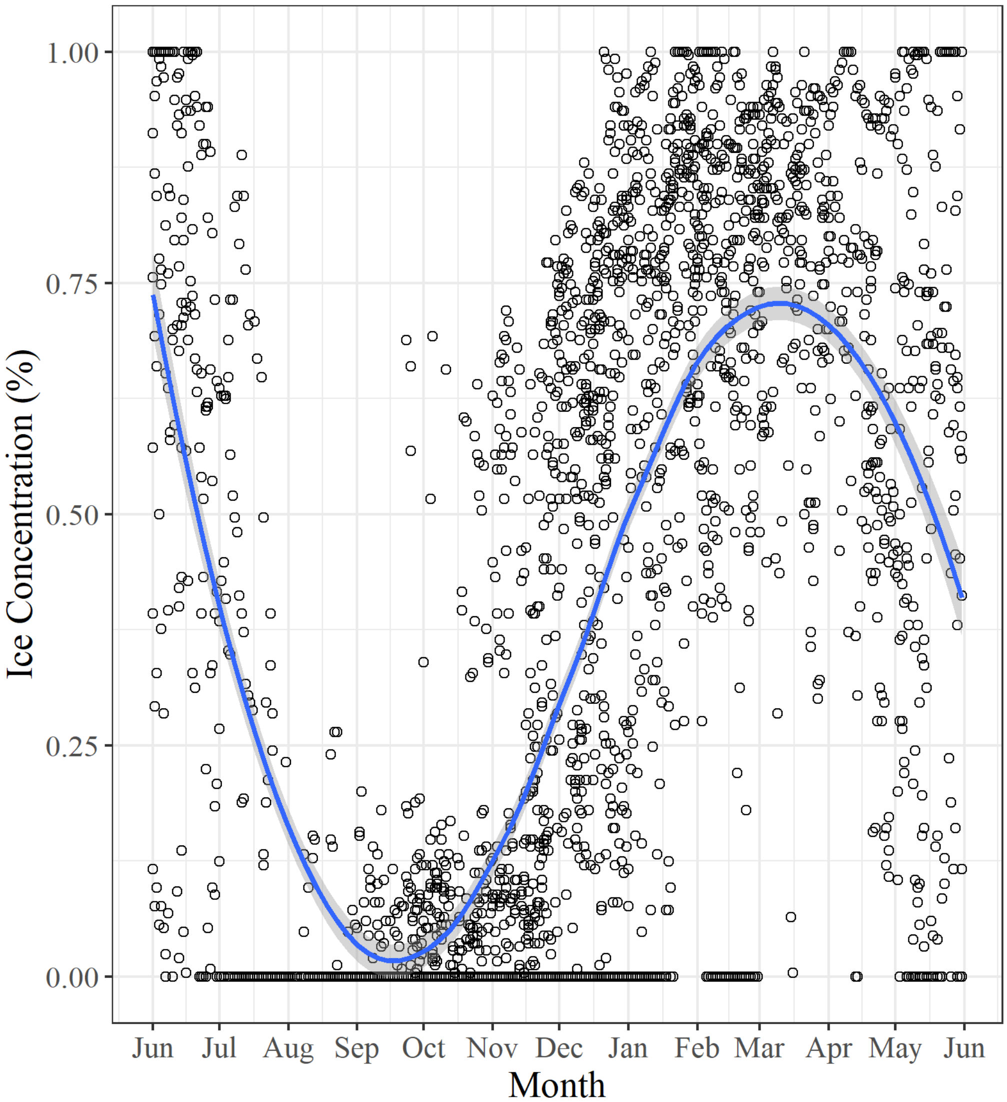


Figure 45. Sea ice concentration for daily estimated locations of 26 bearded seals by month during 2014–2019. Blue line and gray shaded region represent the smoothed conditional mean and SE of sea ice concentration for seal locations.

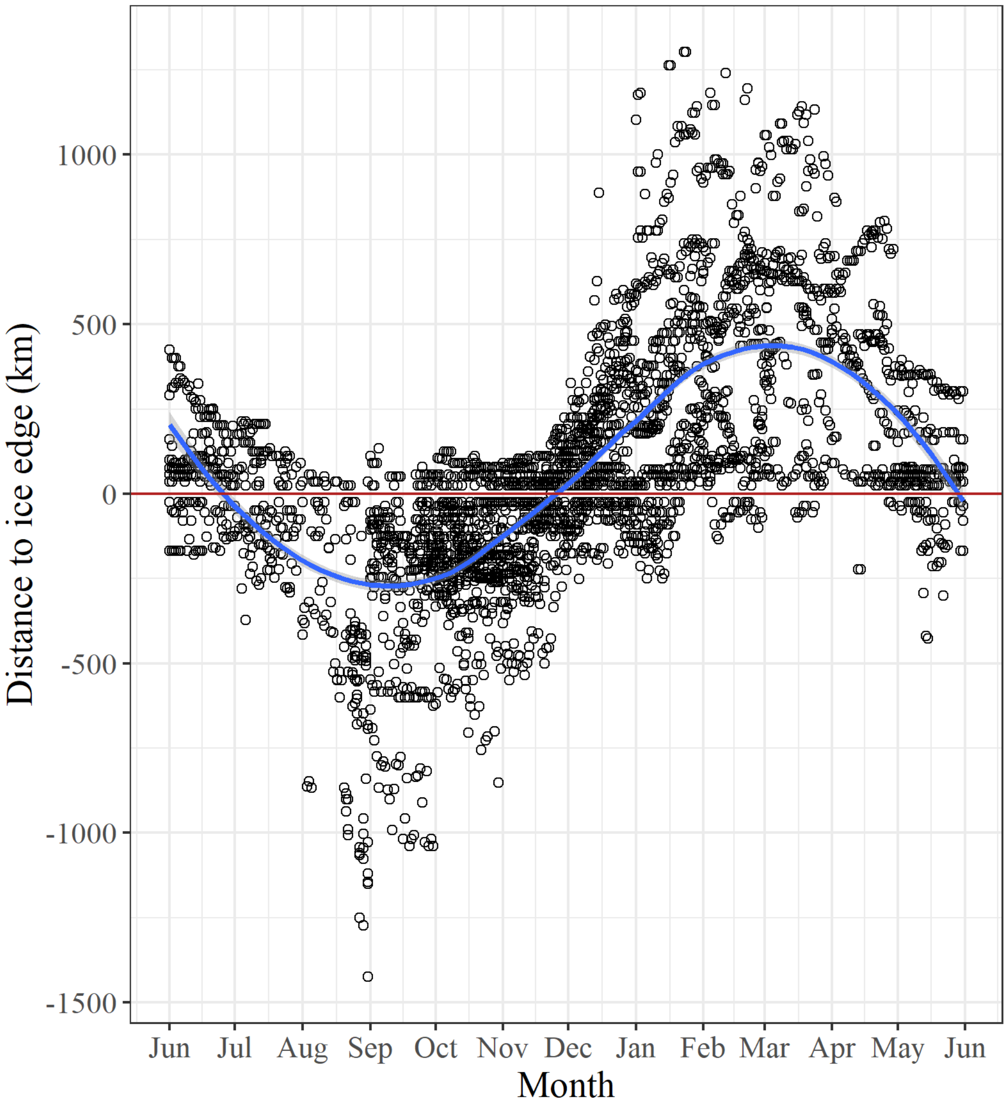


Figure 46. Mean distance (km) to the ice edge (15% ice concentration) from daily estimated locations of 26 bearded seals by month during 2014–2019. Red line represents the ice edge. Positive values represent a location that is within the ice edge (areas ≥ 15% ice concentration, i.e., pack ice). A negative value represents a location that is outside of the ice edge (areas < 15% ice concentration). Blue line and gray shaded region represent the smoothed conditional mean and SE of distance to the ice edge for seal locations.

We further examined sea ice habitat use by bearded seals during the open-water period, when sea ice is at its minimal extent, from July to October. A total of 3,119 6-hr location estimates were available for July to October 2014–2018 using the 'crawl' model in R. During this period, 72% (n = 2,255) of locations were in open water, 20% (642) were in 0 – 15% ice concentration, and 7% (222) were in pack ice. This pattern was consistent across all years, except for 2018 when less data were available from fewer tagged seals.

Ringed seals. In general, the concentration of sea ice ringed seals used and their distance to the ice edge (15% ice concentration) differed by month ($P < 0.0001$), however their use of sea ice was highly variable. Despite variability in the timing and extent of sea ice during this project period, ice concentrations and distances to the ice edge used by ringed seals did not differ by year ($P > 0.10$). Ringed seals tended to use areas with the highest concentrations (> 50% mean ice concentration) from January through June (Fig. 47). Similar to bearded seals, ringed seals tended to use pack ice (≥ 15% ice concentration) from December through the end of June and use areas of open water from July through November (Fig. 48).

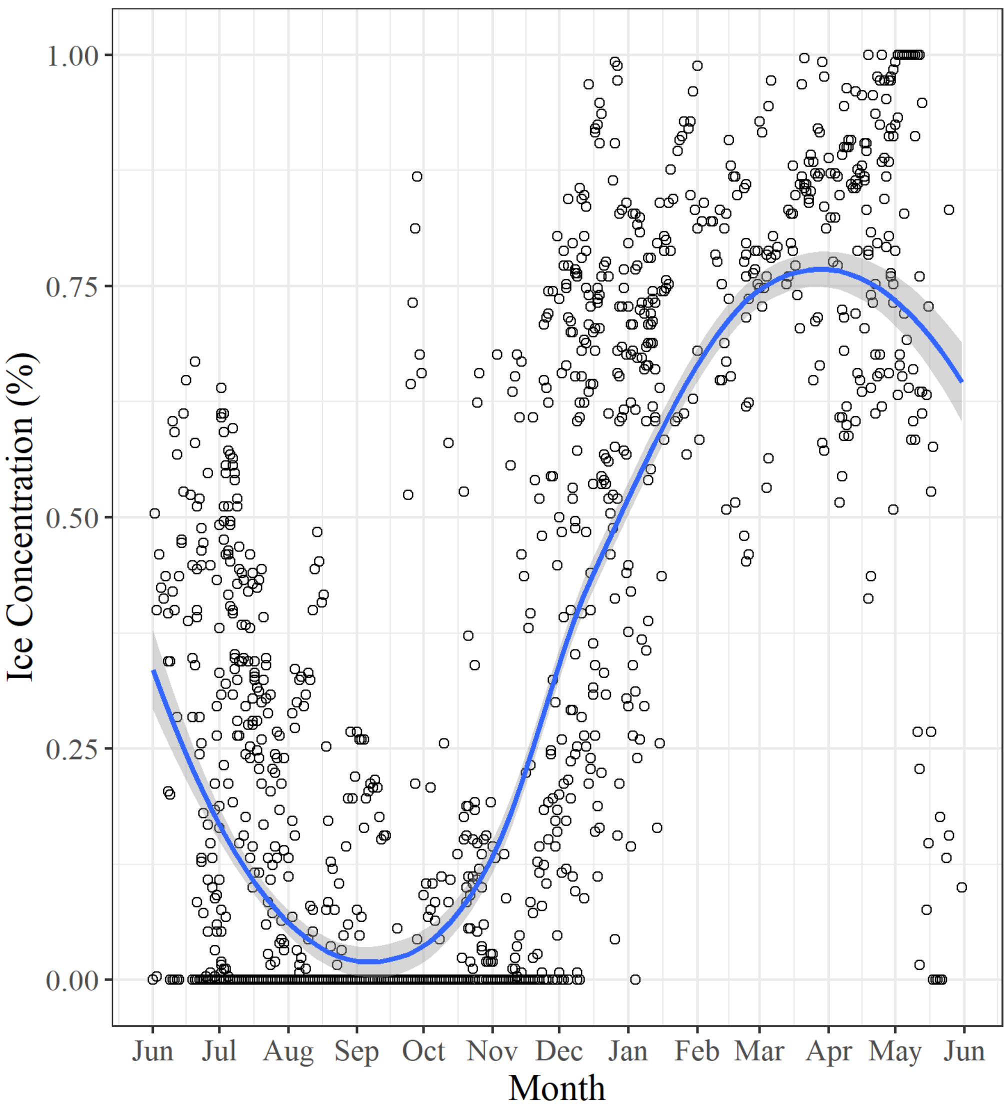


Figure 47. Sea ice concentration for daily estimated locations of 16 ringed seals by month during 2014–2019. Blue line and gray shaded region represent the smoothed conditional mean and SE of sea ice concentration for seal locations.

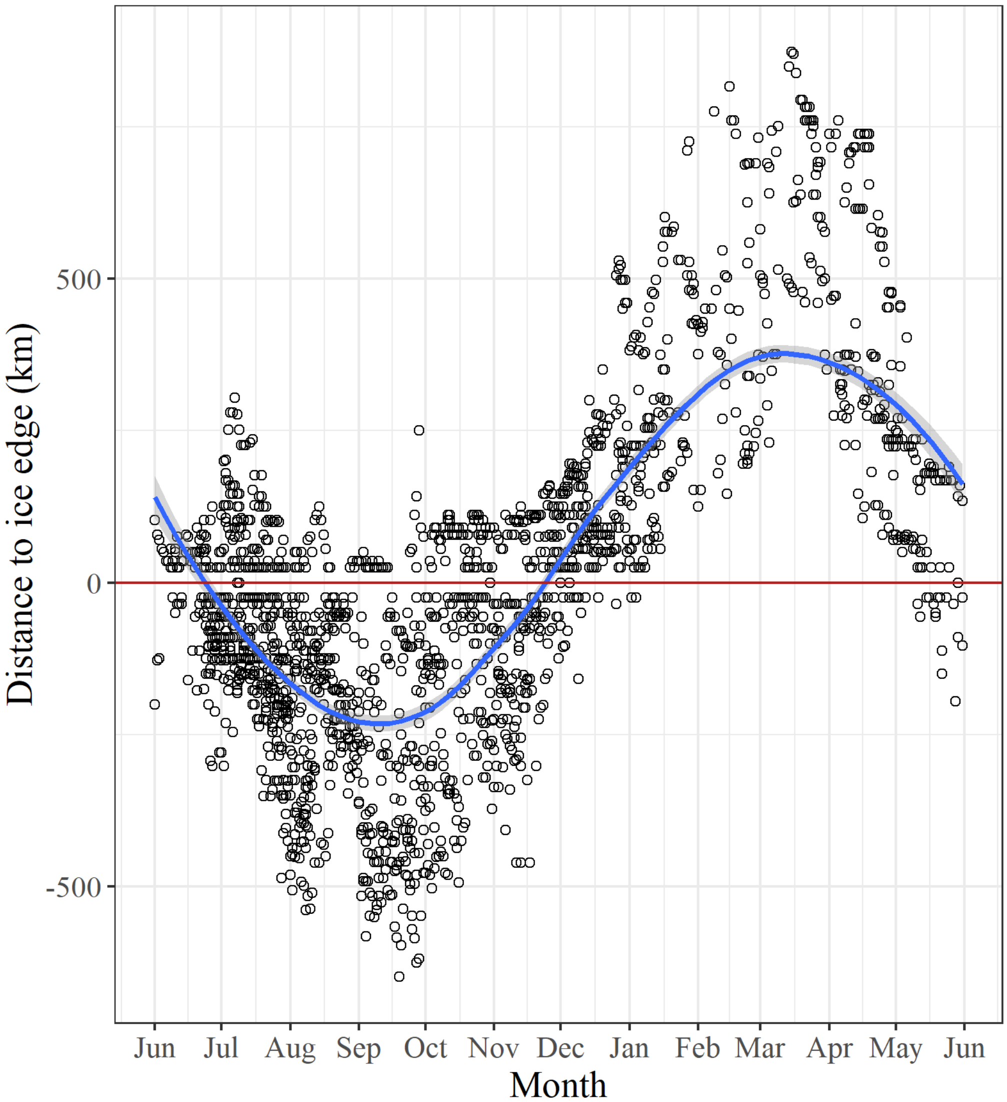


Figure 48. Mean distance (km) to the ice edge (15% ice concentration) from daily estimated locations of 16 ringed seals by month during 2014–2019. Red line represents the ice edge. Positive values represent a location that is within the ice edge (areas ≥ 15% ice concentration i.e., pack ice). A negative value represents a location that is outside of the ice edge (areas < 15% ice concentration). Blue line and gray shaded region represent the smoothed conditional mean and SE of distance to the ice edge for seal locations.

Spotted seals. In general, the concentration of sea ice spotted seals used and their distance to the ice edge (15% ice concentration) differed by month and year ($P < 0.0001$), however their use of sea ice was highly variable. All spotted seals tended to use areas with higher ice concentrations from January through March (Fig. 49). During the ice-covered seasons of 2016/17 (seals tagged in 2016) and 2018/19 (seals tagged in 2018), spotted seals used areas with higher ice concentrations then during the 2017/18 ice-covered season (seals tagged in 2017) (Fig. 49). During the ice-covered season of 2017/18, seals (tagged in 2017) rarely used pack ice (≥ 15% ice concentration; Fig. 49). However, unlike bearded and ringed seals, spotted seals tended to use pack ice for a shorter duration, from December through March, and used areas of open water the rest of the year (Fig. 50). Seals tagged in 2016 and 2018 used areas outside of the ice edge (i.e., in open water) from April through November, whereas seals tagged in 2017 used areas outside of the ice edge throughout the year.

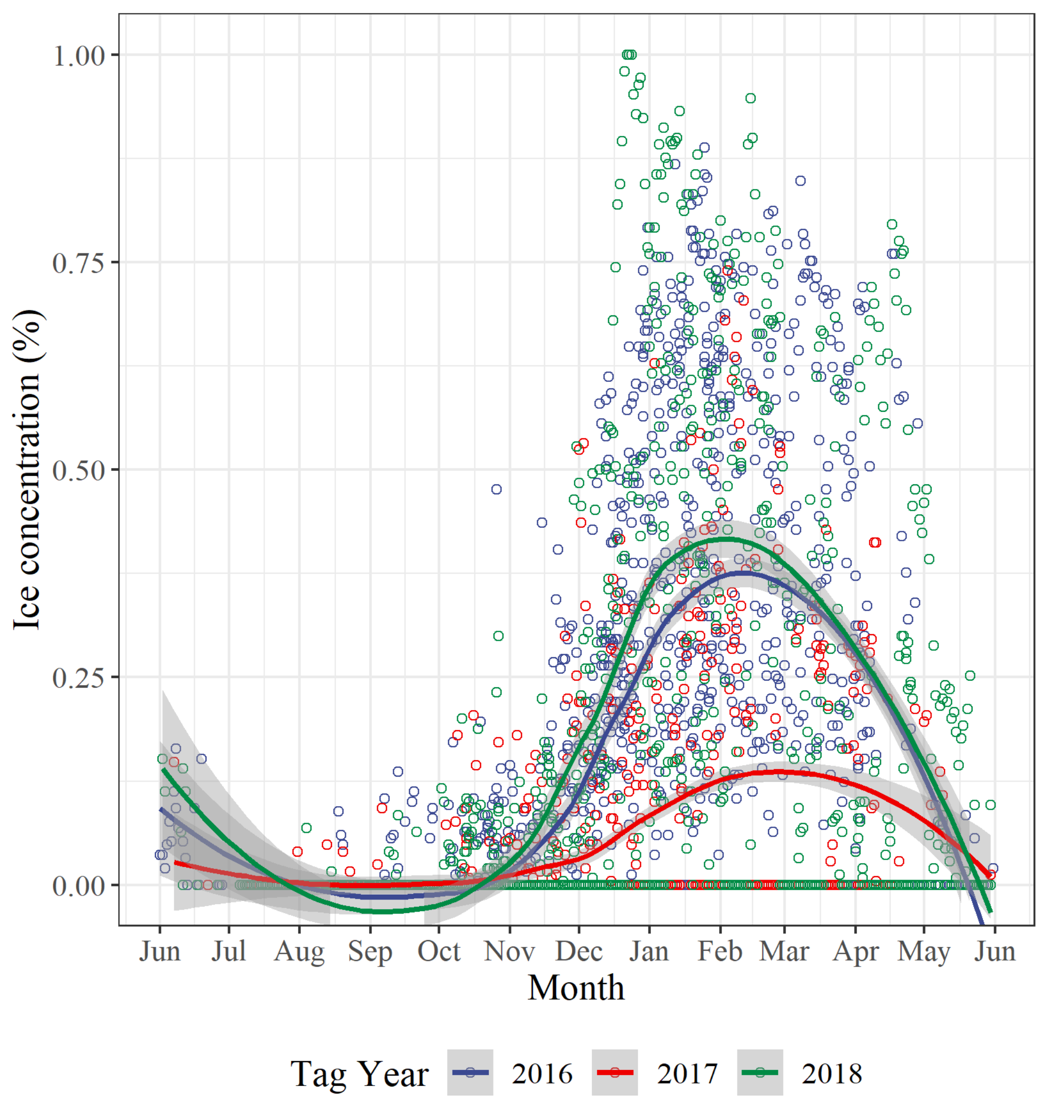


Figure 49. Sea ice concentration for daily estimated locations of 25 spotted seals by month during 2016–2019. Lines and gray shaded regions represent the smoothed conditional mean and SE of sea ice concentration for locations of seals tagged in 2016, 2017, and 2018.

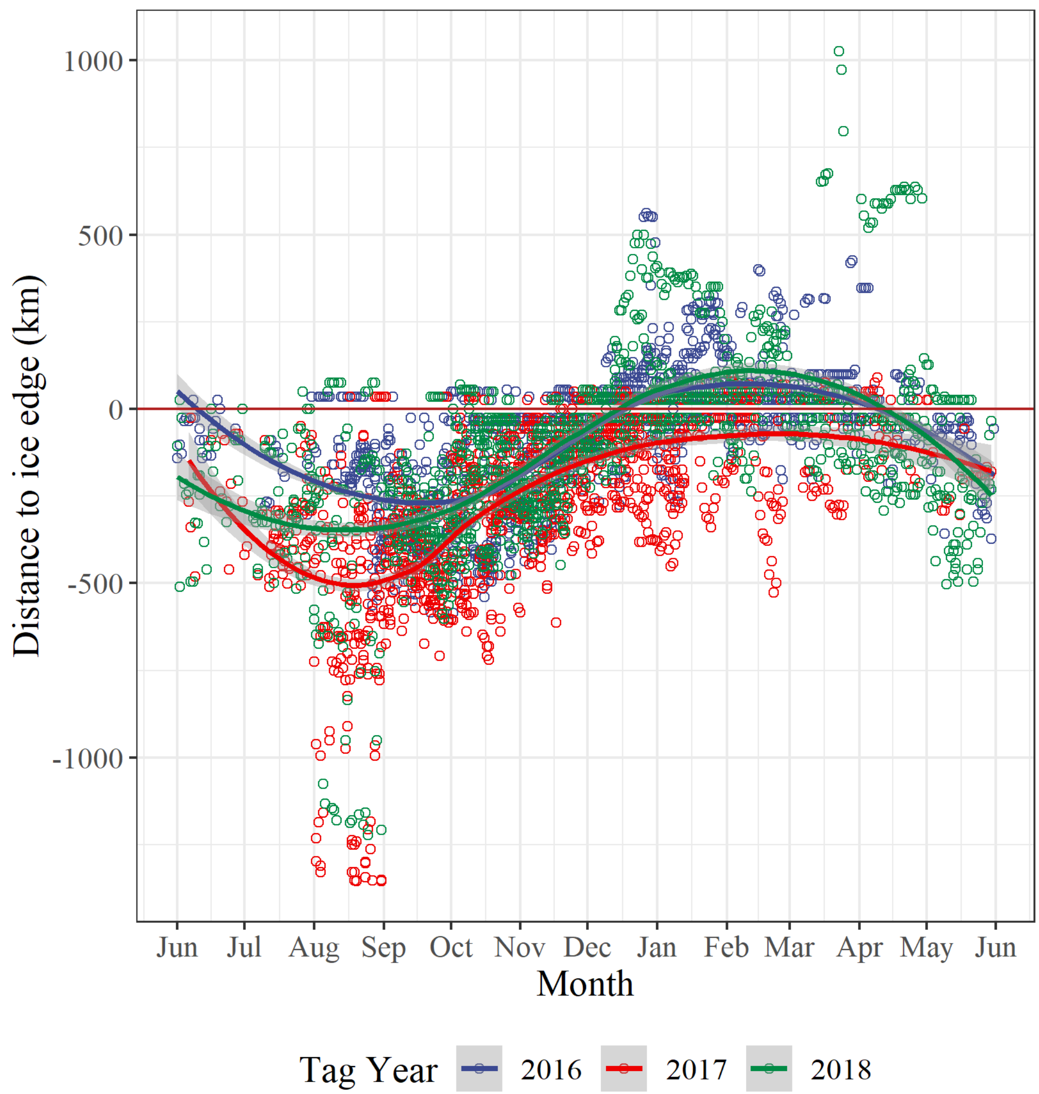


Figure 50. Mean distance (km) to the ice edge (15% ice concentration) from daily estimated locations of 25 spotted seals by month during 2016–2019. Red line represents the ice edge. Positive values represent a location that is within the ice edge (areas ≥ 15% ice concentration i.e., pack ice). A negative value represents a location that is outside of the ice edge (areas < 15% ice concentration). Lines and gray shaded regions represent the smoothed conditional mean and SE of distance to the ice edge for locations of seals tagged in 2016, 2017, and 2018.

Use of Oil and Gas Areas

Chukchi Sea. From 2015 to 2019, 32 of 67 (48%) tagged seals entered Chukchi Sea Lease Sale 193 area. On average, tagged seals were located within the 193 area for 5 days (range = 1–37 days; Table 5). One bearded seal, BS18-01-F wintered in the northern Chukchi Sea and used waters in the 193 area from 25 February to 12 April. Other bearded seals were located within the 193 area between 30 May and 31 December (Table 5; Fig. 51). The timing of entering the 193 area differed by species; bearded seals generally entered earliest, from 30 May to 19 September, and at most had two seals in the 193 area at the same time. Ringed seals used the 193 area later from 11 June to 19 October, and at most, five seals were in the 193 area at once in early July.

Spotted seals entered latest from 2 August to 31 December, and at most, nine seals were in the 193 area at one time in mid-September (Fig. 51). While in the 193 area, bearded and ringed seals ranged widely but were primarily located in the northeastern portion (in and near the Hanna Shoal Walrus Use Area) while spotted seals primarily used the southern portion, south of 71.2°N (Fig. 52).

Residence patterns within the leased blocks within the Lease Sale 193 area were similar to those within the larger 193 area (Fig. 51), except that the leased blocks represent a small area, thus fewer seals were located within the block boundaries and those that were in the leased blocks were there for a shorter period of time.

Beaufort Sea. Although relatively few tagged seals moved east of Dease Inlet, a few seals did enter, or move near, lease blocks in the Beaufort Sea. Two bearded seals entered lease blocks in the Beaufort Sea (Figs. 7, 9, and 10). Bearded seal BS16-05-F used areas near lease blocks in the Beaufort Sea from 1 January to 16 July and BS17-01-F, tagged on the Colville River, passed through the western most blocks on 11 August when it left the river after being tagged and moved into the western Beaufort Sea. Two ringed seals entered lease blocks in the Beaufort Sea (Fig. 13). Ringed seal RS14-02-F moved east across the Beaufort Sea Shelf and spent the late summer near the mouth of the Mackenzie River in the Canadian Beaufort Sea. This ringed seal entered the lease blocks in the Beaufort Sea during 24–30 July while traveling east and during 10–12 September while traveling west back to the western Beaufort Sea. During a similar movement pattern to the Alaska-Canada border, RS16-02-M entered the lease blocks of the Beaufort Sea from 15 to 30 July during its eastern migration and from 4 to 8 August during its western migration back to the western Beaufort Sea. Two other ringed seals (RS19-05-M and RS17-02-M) approached the western most edge of the blocks on 14 and 26 July, respectively, but did not enter the lease blocks. Spotted seals did not move east of the mouth of the Colville River, even though five seals were tagged near there (Fig. 19). Spotted seals SS17-06-F and SS17-08-F, both tagged in the Colville River Delta, briefly passed through the southwest portion of the western most lease block when they moved to the western Beaufort Sea.

Table 5. Summary of tagged bearded, ringed, and spotted seals entering the Chukchi Sea Lease Sale 193 area during 2014–2019.

	Bearded (*n* = 8)	**Ringed (*n* = 10)**	**Spotted (*n* = 14)**	**All seals (*n* = 32)**
Earliest date in Area	25 Feb	11 Jun	2 Aug	25 Feb
Average entry date in Area	9 Jul	10 Jul	9 Sep	2 Aug
Latest date in Area	19 Sep	19 Oct	31 Dec	31 Dec
Average last date in Area	15-Aug	20-Aug	23-Oct	12-Sep
Average duration in Area (days)	3.6	5.3	5.1	4.8
Minimum duration in Area (days)	1	1	1	1
Maximum duration in Area (days)	18	37	21	37
Total trips into Area	25	40	61	126
Max seals in Area during a week	2	5	9	13
Week of maximum seals in Area	multiple, primarily mid-July	5 Jul	17 Sep	17 Sep

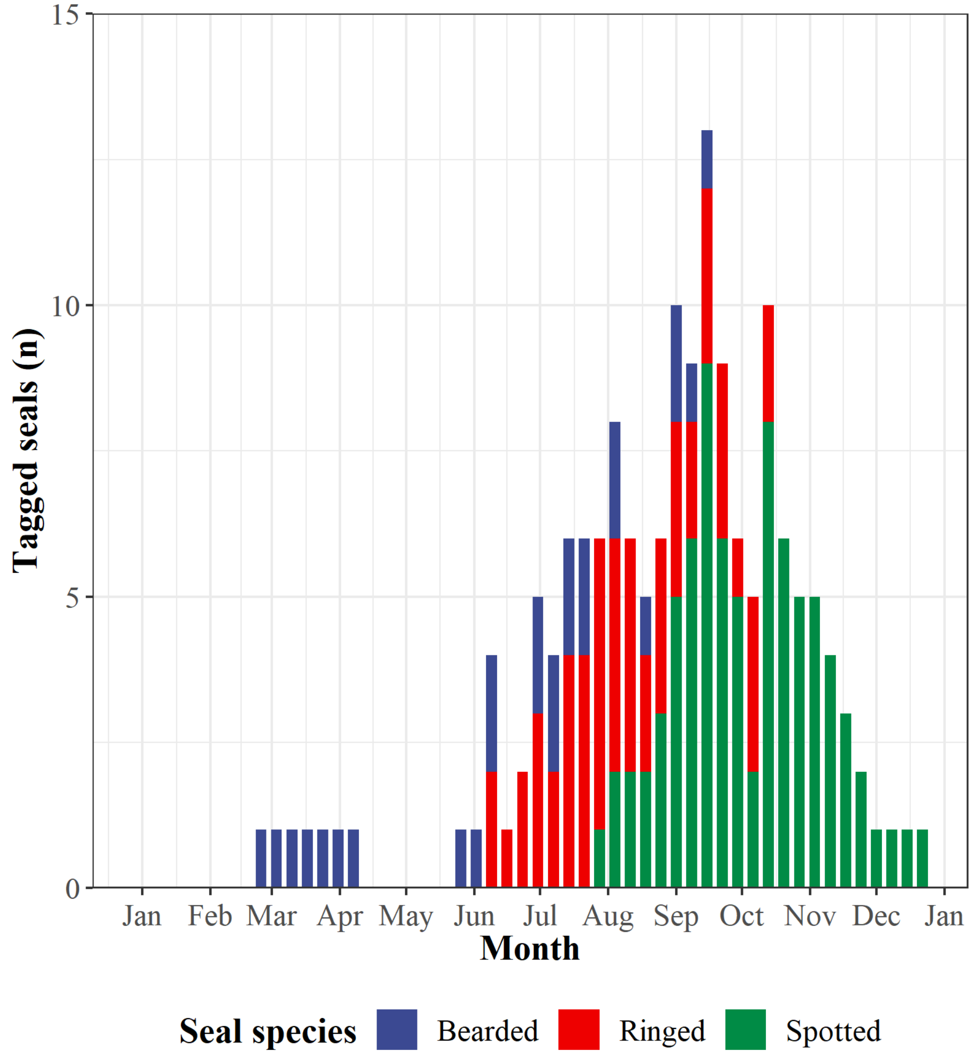


Figure 51. Number of tagged bearded, ringed, and spotted seals that were in the Lease Sale 193 area in Alaskan waters by week of the year, all years combined (2014–2019).

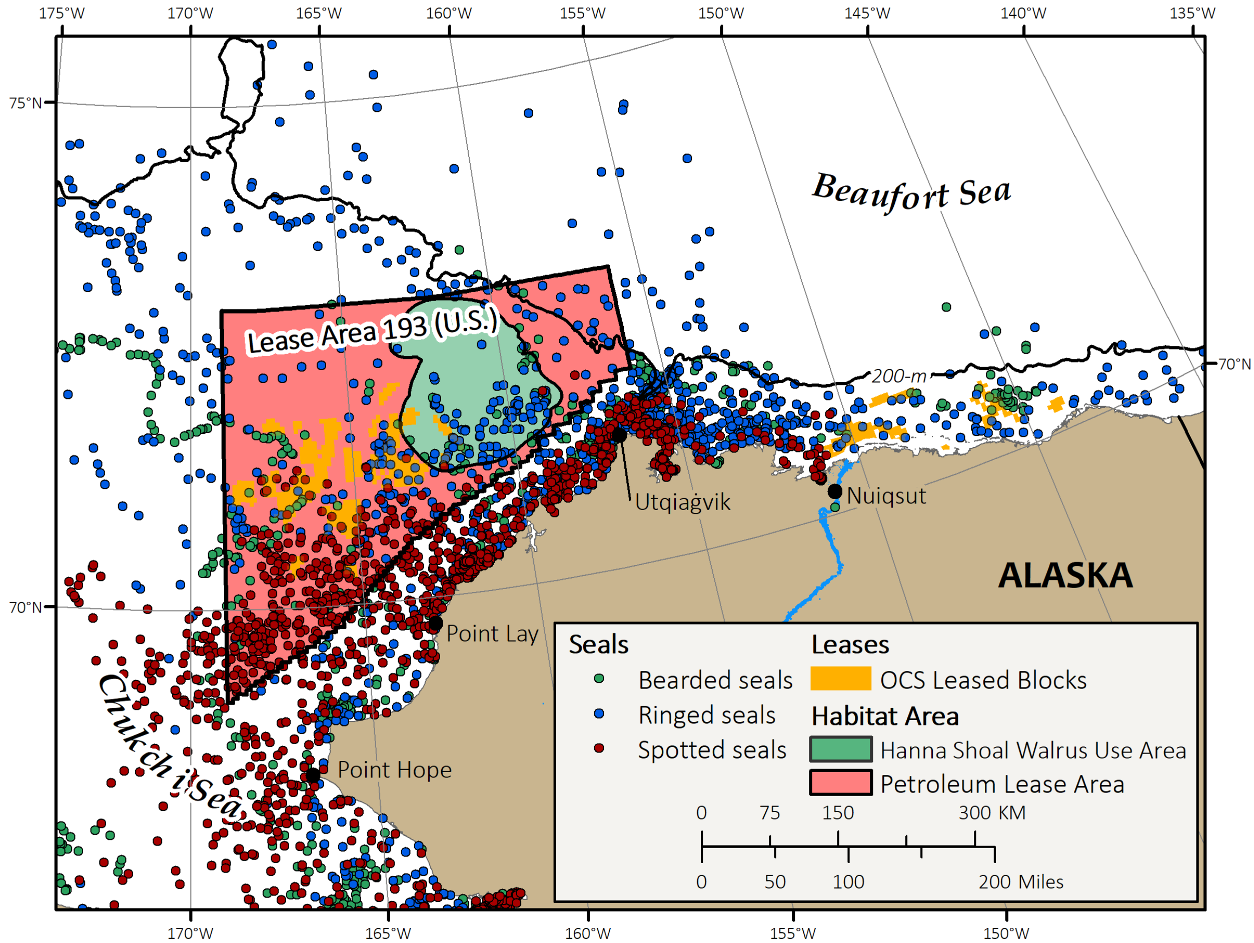


Figure 52. Locations of 57 tagged seals in all months 2014–2019 relative to OCS lease blocks in Chukchi Sea Lease Sale 193 area and in the Beaufort Sea. OCS lease blocks associated with Chukchi Sea Lease Sale 193 were active during the study period; all were relinquished by 2017.

Seismic Analyses

The activity associated with oil and gas exploration that has the greatest potential for harm in the Chukchi Sea is seismic testing due to the high noise levels associated with it. Many seismic arrays tow 36 airguns and noise levels can be as high as 210 dB depending on water depth, bottom substrate, and distance from the source. There is little information about how noise affects ice seal communication, navigation, and movements. Seals have good hearing and may be sensitive to noise. A study involving captive ringed and spotted seals showed limited sensitivity to seismic exposures, however, the authors stress that untrained, wild seals are likely to elicit a stronger response and emphasize that seismic surveys consist of continuous pulses over longer durations rather than a single pulse (Reichmuth et al. 2016).

One tagged ringed seal (RS14-02-F) may have been in the vicinity of an active seismic survey conducted between 1 June and 30 September 2014. The seismic survey was a 3D airgun array, however the dates within the time period the survey was conducted, and the location of the seismic lines are proprietary to the company that conducted it and are not available to the public. This ringed seal passed within 10 km of the seismic project location, near Prudhoe Bay, during late July while making a long-distance movement east towards Mackenzie Bay in Canadian water. Until details about seismic operations are available, we cannot acquire the information needed to overlay seal locations with the seismic operation before, during, and after the survey to analyze seal behavior.

Ship Traffic

During the shipping season, between April and December (all years combined), tagged seals were located within areas of ship traffic (< 95% traffic volume density) for 40% of days tracked, and they were in high traffic areas (< 50% traffic volume density) for 4% of those days. The proportion of seals located in traffic areas, however, differed somewhat by seal species and season.

During spring (April–June), bearded seals were in ship traffic areas more often (49% of days) than ringed and spotted seals (Fig. 53a), primarily in Norton Sound (Fig. 54), although all seals were in high traffic areas < 3% of days during spring (Fig. 53b).

During summer (July–September), all seals were in ship traffic areas more often than during spring (44% of days) and bearded seals were in these areas most often (69% of days) (Fig. 53a). Bearded seals again overlapped with traffic areas primarily in Norton Sound, while ringed and spotted seals overlapped primarily in the northeastern Chukchi Sea (Fig. 55). All seals were in high traffic areas 9% of days during summer (Fig. 53b), primarily in Norton Sound and the northeastern Chukchi Sea (Fig. 55).

During fall (October–December), all seals were in ship traffic areas for a similar percent of days (~39%; Fig. 53a) and were in traffic areas spread widely across the Bering and Chukchi seas (Fig. 56). All seals were in high traffic areas < 2% of days during fall (Fig. 53b).

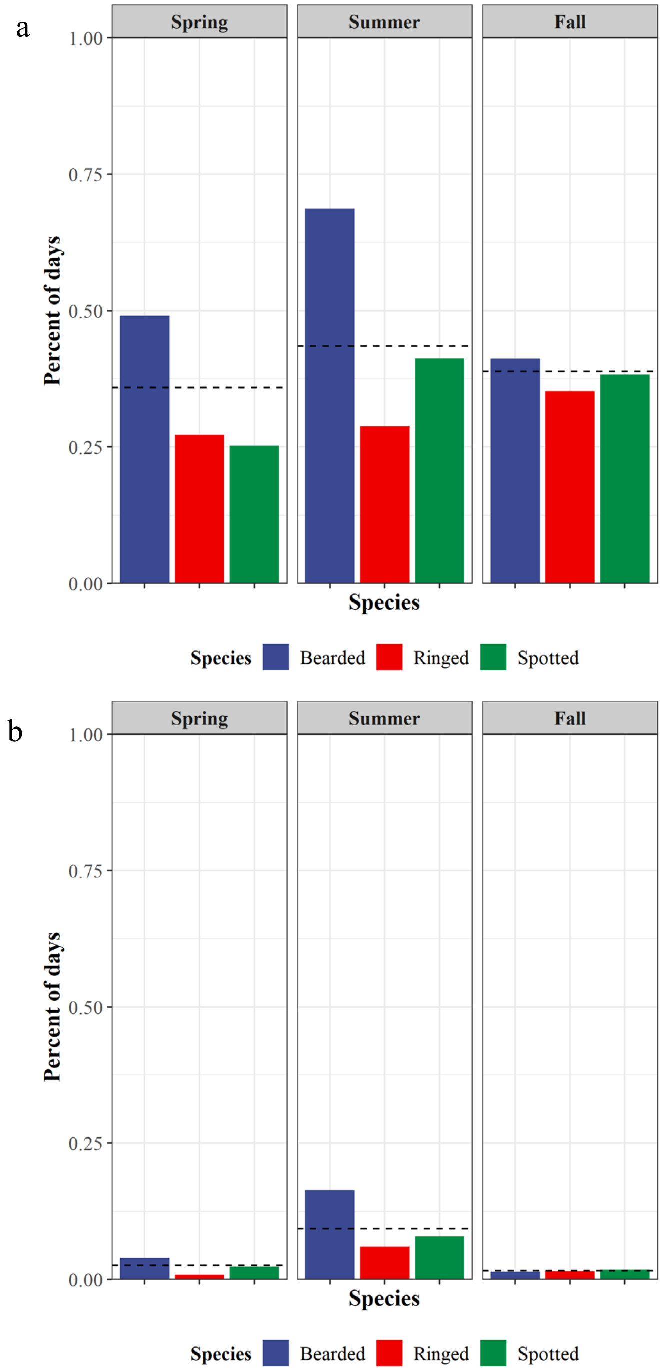


Figure 53. Percent of days tagged bearded, ringed, and spotted seals were within a) any, < 95% ship traffic volume densities and b) high, < 50% ship traffic volume densities in the Bering and Chukchi seas during the spring, summer and fall of 2014–2019. Dashed lines represent the mean percent of days all seals were within ship traffic areas during each season.

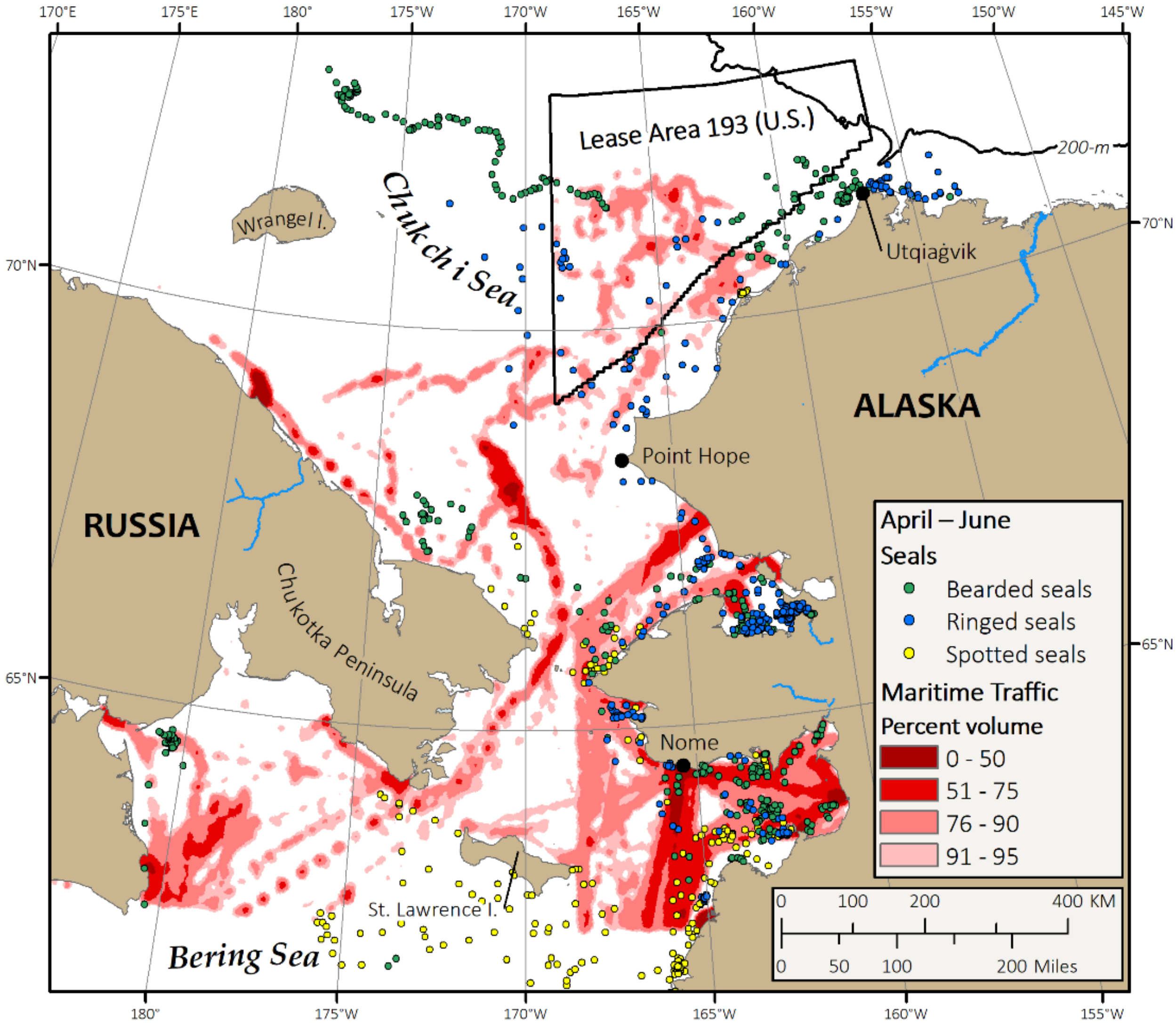


Figure 54. Locations of tagged bearded (n = 14), ringed (n = 13), and spotted seals (n = 13) and density estimates (red) for ship traffic derived from Automatic Identification System (AIS) data in the northern Bering and Chukchi seas from April to June during 2013–2015. Colored circles are daily seal locations estimated using the CRW model.

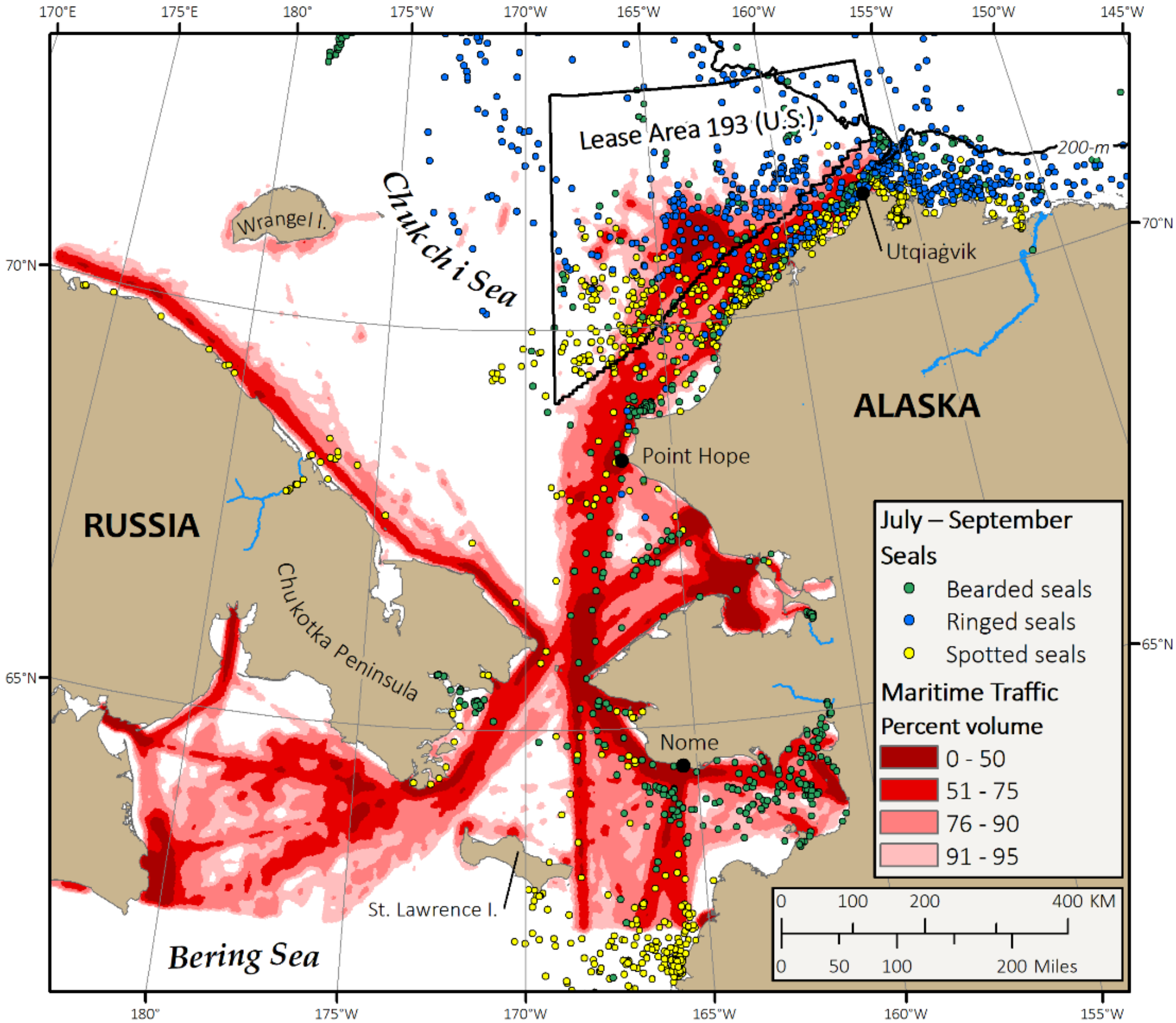


Figure 55. Locations of tagged bearded (n = 20), ringed (n = 15), and spotted seals (n = 20) and density estimates (red) for ship traffic derived from Automatic Identification System (AIS) data in the northern Bering and Chukchi seas from July to September during 2013–2015. Colored circles are daily seal locations estimated using the CRW model.

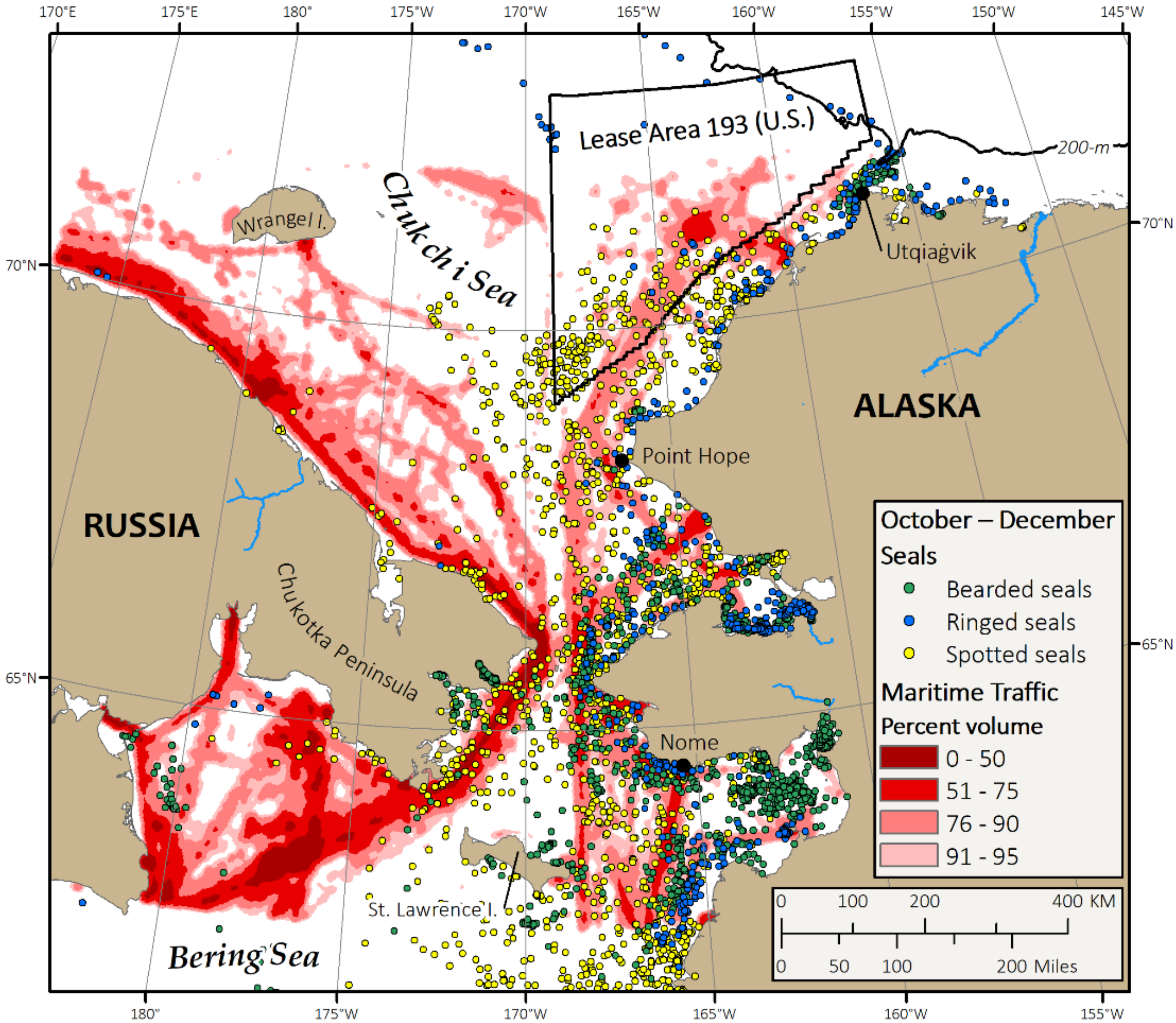


Figure 56. Locations of tagged bearded (n = 21), ringed (n = 9), and spotted seals (n = 24) and density estimates (red) for ship traffic derived from Automatic Identification System (AIS) data in the northern Bering and Chukchi seas from October to December during 2013–2015. Colored circles are daily seal locations estimated using the CRW model.

Local and Traditional Knowledge

In addition to greatly improving our ability to find, catch, and tag seals, Alaska Native seal hunters made many valuable contributions to this project regarding local and traditional knowledge of seal movements, timing of migration, and haul-out behavior. Information from interviews in Barrow (now Utqiaġvik), Shishmaref, Kivalina, Kotzebue, Elim, St. Michael, Stebbins, Scammon Bay, Hooper Bay, and Mekoryuk during this project (2015–2017) are contained in reports made for the communities, publications, and are incorporated into the results of this final report. Final reports are included here as Appendices C–E, H–J, M–O and are available at ADFG's webpage at http://www.adfg.alaska.gov/index.cfm?adfg=marinemammalprogram.traditionalknowledgereports.

Traditional knowledge interviews conducted during our BOEM walrus study (OCS Study BOEM 2016-053) in Wainwright, Point Lay and Point Hope included information on seals and are also are referenced here (Table 6) and available at our webpage. Full references for publications (Huntington *et al.* 2016 and Huntington *et al.* 2017) are included in our List of Publications and Products. Details of the communities, topics, and numbers interviewed are presented in Table 6. Hunter experience relative to when and where to find seals and how to set nets to capture them was extremely important to this study. We worked with Tribal Councils to identify seal hunters that had extensive knowledge and were interested in participating in traditional knowledge interviews.

Table 6. Summary of traditional ecological knowledge interviews, final reports, and publications that include ice seals.

Community	Year	Species discussed	No. interviewed	Reference
Point Lay and Wainwright	2012	Seals, walrus	5 13	Huntington *et al.* 2012
Point Hope	2013	Seals, walrus, bowhead whale, beluga whale	8	Huntington and Quakenbush 2013
Barrow	2015	Seals, walrus, polar bear, bowhead whale, beluga whale	10	Appendix C
Elim	2015	Seals, walrus, beluga whale	8	Appendix D
St. Michael and Stebbins	2015	Seals, walrus	8 2	Appendix E
Kivalina	2016	Seals, walrus, bowhead whale	5	Appendix I
Kotzebue	2016	Seals, walrus	6	Appendix J
Shishmaref	2016	Seals, walrus	5	Appendix H
Scammon Bay	2017	Marine mammals	5	Appendix O
Hooper Bay	2017	Marine mammals	11	Appendix M
Mekoryuk	2017	Marine mammals	7	Appendix N
13 communities	**5 years**	**7 species**	**93 interviews**	**11 reports**

Traditional knowledge interviews provided information that generally supported the movements and behaviors we documented for tagged seals, but also added information that could not be obtained from telemetry. For example, interviews from Utqiaġvik (Barrow) confirmed that bearded seals are often seen where the Chukchi and Beaufort waters meet (i.e., Barrow Canyon) and one of the tagged bearded seals stayed there year-round (Figs.7–10). We learned from many of the seal hunters at different locations (e.g., Utqiaġvik, Kotzebue, Kivalina, Elim, Stebbins, St. Michael, Shishmaref, and Mekoryuk) that bearded seals, especially young bearded seals, swim up rivers in summer and fall. Using this information 22 of 26 bearded seals we tagged were caught up rivers. Without this information we would not have known to look for bearded seals up rivers and would have only caught a few in bays. We also learned in the Utqiaġvik interviews that bearded seals can sleep at the surface in open water potentially explaining the long periods (26–50 days) we documented between haul-outs (Fig. 42).

Utqiaġvik and Elim hunters mentioned that ringed seals haul out on land. Although it is more common for young ringed seals, adults are also observed hauling out on land. Utqiaġvik hunters mentioned seeing ringed seals hauled out on land near Peard Bay. Our data identified four instances of ringed seals hauled out on land, three of these were adults, including one near Peard Bay (Fig. 44).

Hunters say that many ringed and bearded seals winter in Norton Sound. Our analysis of high-use areas showed that ringed seals used Kotzebue Sound more than Norton Sound, but that bearded seals used both during the winter. This may indicate a bias in our sample of ringed seals, likely due to where seals were tagged, or that low concentrations of sea ice in Norton Sound limited ringed seal use.

Traditional knowledge interviews provided information about movements and behavior of adult bearded seals that we could not match with telemetry data because we did not catch any adults. Shishmaref hunters reported that young bearded seals migrate north with adults but migrate south before the adults. Nunivak hunters reported that most of the bearded seals seen on the south side of the Island in winter are yearlings and that older seals stay farther north. Bearded seals in Kotzebue Sound in fall are mostly juveniles, but adults are hunted there in spring.

Accomplishment of Objectives and Tasks

This study was designed to provide specific data and analyses to address the objectives listed below and integrate them with concurrent research on marine mammals in the Beaufort and Chukchi seas Lease Sale Areas. Specific objectives are as follows:

Objective 1: Estimate patterns of movement and behavior of bearded, spotted, and ringed seals, each with their own specific behavior, migrating to and moving about within the BOEM Beaufort and Chukchi Seas Planning Areas. Particular emphasis will be placed on estimating movements within ship traffic lanes and between haulout sites and feeding areas near potential oil and gas development sites.

Bearded Seals. Bearded seals made highly individualistic movements that covered much of the continental shelf in the Bering, Chukchi and Beaufort seas (Figs. 7–10). Thus, where seals hauled out (both on land and sea ice) and where they were likely feeding (i.e. exhibiting resident behavior, Fig. 28), demonstrated a broad use of the area, rather than concentrated areas or hotspots. Over the course of their movements, seals passed through lease areas in the Chukchi and Beaufort seas (Fig. 52), however their tendency to remain near the coast meant they used the Lease Sale 193 area less than ringed or spotted seals (Table 5). Bearded seals were most likely to encounter ship traffic in Norton Sound throughout the year (Figs. 54–56), and along Alaska's northwest coast in the summer (Fig. 55). Five of 6 bearded seals exhibited seasonal fidelity to specific areas, including near Barrow Canyon and the outlet of the Yukon River during winter and areas of Norton Sound during fall.

Ringed Seals. Ringed seals moved north in summer and made north-south movements often over deep water (north of the 200-m isobath; Fig. 13). Many of these movements occurred when the ice edge had receded north of the Chukchi-Beaufort shelf break and appeared to be trips to the ice edge and smaller patches of sea ice. For example, RS17-01-M made a long trip to the ice edge and RS17-02-M made three trips to the ice edge, north of the shelf break (Fig. 13). During these north-south trips, ringed seals hauled out on ice over deep water to the north but did not haul out when they returned to the shallow water shelf. During these trips north, over deep water and during the open-water season, ringed seals would generally not overlap with ship traffic located closer to the coast. High-use foraging areas were primarily near Utqiaġvik, Barrow Canyon, and the western Beaufort Sea during the open-water period (Fig. 30); during the ice-covered season they were primarily located in Kotzebue Sound (Fig. 31). Ringed seals were more likely to encounter ship traffic in Norton Sound in the spring (Fig. 54), in the northeastern Chukchi Sea in the summer (Fig. 55), and in Norton Sound and the Bering Strait region in the fall (Fig. 56). From June to October, ringed seals ranged widely throughout the Lease Sale 193 area (Fig. 52) and occasionally moved through the lease blocks in the Beaufort Sea. Five of 5 ringed seals exhibited seasonal fidelity to specific areas and migration routes, including Kotzebue Sound during spring, Barrow Canyon during the open-water period, northern Norton Sound and along the western coast of Seward Peninsula during winter, and moving through the Chukchi Sea along the Alaskan Coast during the fall migration south and spring migration north.

Spotted Seals. During the open-water season (May–November), spotted seals tended to repeat east-west movements between offshore foraging areas and the Alaskan coast, including returning to their tagging locations (Figs. 19 and 32). High-use foraging areas were between Herald Shoal and the nearshore waters of the northeast Chukchi Sea (< 50 m deep; Fig. 33) and included the southern portion of Lease Sale 193 area (Fig. 52). Spotted seals were more likely to encounter ship traffic in the northeastern Chukchi Sea and along Alaska's northwest coast in the summer (Fig. 55) and along the Russian coast and Bering Strait region in the fall (Fig. 56). Given their tendency to return to and forage near the Alaskan coast, spotted seals may overlap least with shipping on Northern Sea Route along the Russian coast but may overlap with ships hauling ore from Red Dog Mine or other traffic along the Alaskan coast. Spotted seals have the potential to overlap with oil and gas activities near Alaskan shores in the Beaufort, Chukchi, and Bering seas and land haulouts may be important habitats sensitive to disturbance. Four of 5 spotted seals exhibited seasonal fidelity to specific areas, including east of Point Barrow, in the Beaufort Sea, during the open water period and haulout sites on barrier islands near Icy Cape during summer and in Scammon Bay during fall.

We have accomplished Objective 1 by describing patterns of movement during ice-covered and open-water seasons relative to ice conditions, distance to shore, lease areas, and ship traffic for bearded, spotted, and ringed seals. We also identified haulout and feeding areas and described patterns of their use. In addition, we have described the degree to which seals show fidelity to some areas seasonally, and to migration routes.

Objective 2: Estimate and evaluate the effect of any changes in bearded, spotted, and ringed seal behavior related to changes in ice coverage and ice quality in the Beaufort and Chukchi Seas.

Although the duration of our study (2014–2019) was likely not long enough to fully evaluate the effects of changes in bearded seal behavior relative to changes in sea ice, there is some evidence that bearded seals may be responding to changing ice conditions. Young bearded seals generally make seasonal north-south movements in response to seasonal ice extent and have exhibited a preference for the ice edge (10–15% ice concentration) (Cameron et al. 2018, Breed et al. 2018) and the transitional ice between small and large ice floes (70–90% ice concentration; Simpkins et al. 2003, Cameron et al. 2018). Our data, however, suggest this relationship may be changing as bearded seals were often found far north of the ice edge, in less-consolidated pack ice, during maximum ice extent (50–75% ice concentration during January–April; Figs. 45 and 46), with some individuals wintering in the Chukchi and Beaufort seas (Figs. 9 and 10) (Olnes et al. *In prep*.). As ice becomes less extensive and more variable, young bearded seals may use a broader area of less-consolidated pack ice than in the past when ice was more densely concentrated and thus restricted seal movements.

For ringed seals, our data indicate an earlier migration north and delayed migration south mirroring changes in ice retreat and formation. We tagged ringed seals in Kotzebue Sound in June of 2014 and 2017, however after 2017, sea ice had retreated from the Sound during May. Ringed seals could however be found near Point Barrow in June 2019. Compared to ringed seals tagged in Kotzebue Sound (2007–2009) (Crawford et al. 2012, 2018), seals in this study tended to move farther north of the Chukchi Sea shelf break, likely to follow ice that had receded farther north than during the previous study.

We tracked spotted seals in the central Bering Sea in winter, including when very little ice was present. As mentioned above, spotted seals moved through open water that would have been ice covered in previous years and made trips back to land haulouts at St. Lawrence, St. Matthew, and Nunivak islands, and at the spit north of Hooper Bay. They used these terrestrial haulouts until ice formed. They also did not use areas in the western Bering Sea that were identified as high-use areas during previous winters and in years with more ice coverage (see Citta et al. 2018, Fig. 4b). These results suggest that spotted seals can continue to access open water areas south of the ice edge, as they do during the open-water season, by returning to haul out on islands and fast-ice until pack ice forms giving them greater access to the western Bering Sea.

We accomplished Objective 2 by analyzing data collected during this study that demonstrates changes in behavior relative to sea ice by all three ice seal species and by comparing our results to those in the published literature.

Objective 3: Estimate bearded, spotted, and ringed seal use of haulouts by demographic class and estimate the duration of occupancy as related to weather, disturbance, and other potential factors.

Bearded seals tagged were mostly pups (26) and a few yearlings (5); therefore, we could not evaluate haul-out behavior by age. Young bearded seals, however, were more likely to haul-out during the ice-covered season (December–April, daily haul-out probability = 58%) with an average haul-out duration of 5.9 hrs and maximum duration 53 hrs (Table 4). Although young bearded seals hauled out less during the open-water season (May–November, 48%) they hauled out longer (mean haul-out duration = 7.9 hrs, maximum duration = 143 hrs) when ice was at its minimum extent (July – October). During both periods, seals hauled out on both sea ice and land. Haul-out durations on land were half as long as that on ice (Fig. 43), likely because the incidence of disturbance was greater. Of greater interest than haul-out duration (hrs) perhaps, was the duration between haul-outs (weeks) while young bearded seals were in open water far from land. Five young bearded seals remained in open water for 26–50 days without hauling out at all (Fig. 42).

Most ringed seals tagged to date were adults (13 of 16); therefore, we do not have the sample size to make statistical comparisons between demographic classes. Ringed seals were more likely to haul out during the ice-covered season (daily haul-out probability = 57%) than the open-water season (48%); however, haul-out durations were similar between seasons, 4.8 and 5.0 hrs, respectively (Table 4). We found four instances where ringed seals hauled out on land, primarily during their fall migration south. Haulout durations while on land were from 6 to 12 hours.

Spotted seals regularly hauled out on land and ice regardless of demographic class. During the open-water season, spotted seals generally spent 1–21 days foraging before spending 1–6 days hauled out on land. Spotted seals older than pups (i.e., non-pups) were more likely to haul out (44%) than pups (32%) during the open-water season and during the ice-covered season (non-pups = 41%; pups = 25%; Table 4). Non-pups also hauled out roughly one hour longer than pups during the open-water (mean haul-out duration: non-pups =8.3 hrs, pups = 7.2 hrs) and during the ice-covered season (non-pups = 9.2 hrs, pups = 8.0 hrs). It appears that spotted seals regularly travel to and from land haulouts between offshore feeding bouts, when ice is not available. When available, spotted seals prefer to haul out on ice.

We accomplished Objective 3 in that we collected haul-out behavior on three species of ice seals, however, we could only compare demographic classes for spotted seals.

Objective 4: Create a database of traditional knowledge of bearded, spotted, and ringed seal behaviors including, but not necessarily limited to, movements, social behavior, and use of habitat including both feeding and pupping areas.

We conducted traditional knowledge interviews in 10 communities where ice seals were focal species and in three additional communities where other marine mammals (e.g., bowheads and walruses) were the focus, but information about ice seals was included. We finalized nine reports of traditional knowledge that included ice seals and published two peer-reviewed papers on traditional knowledge in science journals (Huntington et al. 2016, 2017).

We have listed all reports and publications in Table 6 and in the Publications and Products section of this report and made all the reports available on our ADFG webpage: (http://www.adfg.alaska.gov/index.cfm?adfg=marinemammalprogram.traditionalknowledgereports) and we added these reports as Supplementary Material to Huntington et al. (2016). Electronic supplementary material is available at http://dx.doi.org/10.1098/rsbl.2016.0198 or via http://rsbl.royalsocietypublishing.org. In addition, we have archived the reports on the Exchange for Local Observations and Knowledge of the Arctic (ELOKA) website https://eloka-arctic.org/websites

We did not create a database of seal behavior from traditional knowledge documents because such a database would distill the information and disassociate the behavior from the context which is fundamental to Traditional Ecological Knowledge.

We accomplished Objective 4 by collecting traditional knowledge across a large geographic area, representing the range of ice seals and ice seal hunters in Alaska, and made it available through publication and websites. We found, however, that creating a database would be counter to the principles of traditional knowledge and therefore did not accomplish that component of the objective.

TASK 1. DATA REVIEW AND HYPOTHESIS DEVELOPMENT

We used ADFG's extensive library of old and recent published and unpublished literature from the U.S., Russia, Norway, and Canada regarding ice seals. We reviewed available data on ice seals, advances in satellite telemetry, and modelling techniques for movement analysis and resource selection. In addition to our own data we peer reviewed manuscripts and read literature on ice seal movements and behavior from all species and collaborated with the NSB and MML on tagging projects. We also worked with the hunters to develop working hypotheses related to the objectives of this study.

TASK 2. EXPERIMENTAL DESIGN AND FIELD WORK

ADFG has worked with local Alaska Native seal hunters throughout this project to catch and tag ringed, bearded, and spotted seals where possible at multiple sites each year. Tagging sites have included the Colville River, Dease Inlet, Utqiaġvik, Buckland, Nome, Koyuk, St. Michael, Scammon Bay, and Hooper Bay. Alaska Native subsistence hunters and other community members participate in all aspects of the project development and information from the project is shared directly with participants on a regular basis, through the regular movement maps distributed by email, through meetings with the ISC, and on the ADFG webpage. Project activities did not interfere with subsistence activities as defined by each community where the activity occurred.

Seals were tagged with satellite transmitters capable of providing either long-term location data (flipper-mounted tags that provided data for up to 2 years), or short-term location data and dive information (head or back-mounted tags that provided data up to 8 months). Duty cycles and other battery saving options were determined based on the objectives and changed as data were collected and evaluated. Settings used in previous studies by us (Quakenbush et al. 2010a, Crawford et al. 2011) and others (NMFS) for duty cycles, dive behavior, and other parameters served as the standard until new information suggested other settings would provide better or more data.

We have had success with satellite tags manufactured by Wildlife Computers in our studies of bowhead, gray, and beluga whales, and walruses and seals. Newer versions of the SPOT and SPLASH (now Splash10) tags were available for this project and they had improved capabilities for collecting water temperature at depth and for more detailed dive profiles. We used these tags throughout the project.

In addition to deploying tags we also measured, weighed, sexed, counted claw annuli, collected the skin plug made to attach the flipper tag, and collected blood from each captured seal when possible. Claw annuli provided a minimum age, skin samples were archived for genetics studies, and blood serum was screened for disease exposure and archived for future studies.

We built upon the traditional knowledge (TEK) efforts conducted during the BOEM Walrus project *Pinniped Movements and Foraging: Walrus Habitat Use in the Potential Drilling Area* (AK-09-01) (Huntington et al. 2012). Our interview framework, where interviews were loosely structured around a series of questions, but participants could divert to other topics they felt were important, resulted in productive gathering of TEK.

TASK 3. DATA ANALYSIS AND REPORTING

We provided regular maps of tagged seals when they were on the air to our e-mail list (185 member) and we archived the maps at our webpage. Data analysis is described in detail in the Methods section of this report. We explored and implemented the most current methods for analyzing complex data collected during this study, such as modelling predicted locations and behavioral states. Given the variable behaviors of each species of ice seal, and thus the variable nature of the data for each species, we implemented multiple analytical approaches to best address our objectives. For example, we found that state-space models were best for addressing foraging areas of bearded seals, but that utilization distributions were more appropriate for identifying spotted seal foraging areas.

We reported results to the ISC at their annual meetings and at all Alaska Marine Science Symposia (Appendices A, F, G, I, K, O, P. R, S, and T), at the Society for Marine Mammalogy Biennial Conferences (Appendices P, Q, and U), at the American Geophysical Union (Appendix B).

TASK 4. INTEGRATION OF FINDINGS WITH OTHER RELATED TASKS

We provided maps and data to BOEM and others for integration into other projects, one paper was published in 2018 using data from this project for SOAR (Phase II) titled "*Multi-species marine mammal use of the Bering, Chukchi, and Beaufort seas*" (Citta et al. 2018, See List of Publications and Products).

We provided our tagged seal movement data to augment other projects and efforts:

1) We made our maps and other products available through our webpage http://www.adfg.alaska.gov/index.cfm?adfg=marinemammalprogram.icesealmovementsarchive
2) Many consulting companies, agencies, researchers, and other entities downloaded these maps for their needs.
3) We provided monthly maps (July–November) of tagged bearded and ringed seal locations relative to Quintillion's fiber optic cable route to NMFS, Alaska Region for preparation of a biological opinion (Appendix L).
4) We provided movements data for use in developing shipping lanes through Bering Strait.
5) We provided time at surface data to MML for use in aerial survey correction factors to estimate abundance.
6) We provided location, dive, and haul-out data to international collaborators for a Pan-Arctic study to identify important areas for marine mammals across the Arctic.
7) We combined location, dive, and haul-out data from our ONR project with the BOEM project to increase sample size for all species.

TASK 5. DATA MANAGEMENT AND ARCHIVAL

We ensured that all data were properly recorded, validated, backed up, and archived to be available to other investigators after the objectives and obligations of this project were met. Location data from Argos were downloaded weekly and complete files were received monthly. These data were archived on ADFG's servers and on CDs as unprocessed data files. Processed data are also archived on ADFG's servers and CDs. Processed locations were imported into ArcGIS software and maps were plotted using ArcMap. Maps were produced and e-mailed to interested parties regularly and then placed on the ADFG webpage.

ADFG maintains an archive of all data collected during this study. We worked with ATN and the Alaska Ocean Observing System to improve metadata requirements and presentation of data online. We presented at their workshop in Anchorage in 2017 and continue to participate in discussions for developing the ATN into a useful tool for federal agencies and researchers. Our current data archive and access policy is consistent with standards adopted by BOEM, the National Oceanographic Data Center, NOAA, and other federal agencies.

TASK 6. LOCAL COORDINATION, OUTREACH, AND PERMITTING

ADFG worked with the ISC and local communities to identify coastal communities with hunters interested in tagging seals. We worked cooperatively with the seal hunters to deploy the tags. We attended local tribal or city meetings prior to tagging to explain the project and hear local questions and concerns to determine if any changes should be made to the study plan. We received community approval prior to tagging. We worked with the hunters and the communities to determine their interest in TEK interviews prior to conducting interviews and reported results using their preferred media. Research results were shared with the participating communities by presentations at meetings, posters, flyers, or reports depending on the community preference; often we used more than one method (Table 1 and List of Publications and Products below). Updates to the ISC were co-presented by hunters and researchers whenever possible.

We presented results at the Alaska Marine Science Symposium and at the Society for Marine Mammalogy Biennial Conference (See Table 1 and List of Publications and Products below) and published papers for the peer-reviewed scientific literature. These presentations and papers include hunters as co-authors or presenters as appropriate. The seal movement maps we produced were our primary method of outreach with the most recent tagged seal locations and a description of any additional pertinent information. We often received responses and discussion among recipients in real time when the map was sent. The e-mail list included many subsistence hunters as well as agency personnel. The maps then went to our ADFG webpage http://www.adfg.alaska.gov/index.cfm?adfg=marinemammalprogram.icesealmovementsarchive where they are available along with animations of seal movements relative to sea ice and other information about the seal tagging project.

Marine mammal research permits required under the Marine Mammal Protection Act take more than 12 months to acquire and renew. Seal research was conducted under NMFS Permits #15324 and 20466 issued to ADFG as required under the Marine Mammal Protection Act. ADFG also requires an annual review by the Institutional Animal Care and Use Committee (IACUC) of projects that handle live animals for compliance under the Animal Welfare Act (IACUC Nos. 2013-020, 2014-03, 2015-25, 2016-23, 0027-2017-27, 0027-2018-29). We kept all research permits up to date and fulfilled all permit-related reporting requirements. We purchased land use permits when required by local communities for non-tribal members to use the beaches and other areas.

TASK 7. LOGISTICS/SAFETY PLAN

Our logistics plan included using local hunter’s expertise to determine what capture method should be used, how nets should be set to catch seals for tagging, and where and when capture activities should occur to avoid any interference with subsistence hunting. In some cases, nets were set using local boats and in other cases set from shore. Appropriate floatation devices were worn, and some combination of hand-held marine VHF radios, Emergency Personal Locator Beacons, and satellite telephones were carried. A First Aid kit and GPS unit were also required equipment. An emergency plan was made for each location and included the local radio frequencies, an onshore contact, and procedures for an emergency.

Safety plans were developed specific to each tagging effort based on the local logistics, infrastructure, and measures already in place. Safety equipment was present and inspected to ensure it was in working order. Radio communication was established between boats and with a contact on shore. In addition to marine VHF radios, radio beacons, and satellite telephones were on board boats. In the Utqiaġvik area a “float plan” was filed with the NSB Search and Rescue office prior to departure.

Discussion

Coordination

The success of this project was largely due to our partnership with Alaska Native seal hunters and their interest in learning to capture and tag seals to support research that contributes to a better understanding of seals in general and how climate change may affect seal biology. The collaboration among hunter-taggers (in Nuiqsut, Kotzebue, Buckland, Nome, Koyuk, St. Michael, Scammon Bay, and Hooper Bay), NSB personnel, and ADFG biologists established an excellent framework for catching and tagging seals and for exchanging information. Seal hunters knew where to find seals and where to set nets to catch them. We worked with hunters, communities, and other researchers to learn about movements and habitat use of bearded, ringed, and spotted seals and how they are changing with decreasing sea ice and increasing human activities (e.g., oil and gas and shipping) in the Arctic. We made the results of this project available to communities where seals were tagged, to the ISC at their annual meeting, and to others interested in seal movements in the Arctic by e-mailing maps of recent movements, maintaining a webpage of project activities and movement updates, and presenting results in villages during tag trainings. We collaborated with MML by sharing seal tags and data. We presented results at the Alaska Marine Science Symposium annually (Appendices A, F, G, K, R, S, T). We also posted citations to publications, analyses, posters, and other products on our webpage. These products are used by many entities for environmental assessments, biological opinions, incidental harassment applications and authorizations in oil company reports and in species and habitat maps.

Tag Performance

Primary tags (SPLASH and CTD tags) provided locations and data for a mean duration of 159 days (5.3 months), range 10–291 days. Many factors affect tag performance, including low battery voltage, tag and antenna damage, and tag loss due to attachment wear and spring pelage molt. The expected battery life for these tags was 5–8 months depending on the number of daily transmissions attempted and the amount of data transmitted to satellites. The performance of these tags matched our expectations.

Flipper-mounted SPOT tags were programed to conserve battery life and to provide location data for 1–2 years, with the goal to assess seasonal fidelity over consecutive years. Identifying specific areas used over multiple years is valuable when assessing high-use areas and important seal habitat. SPOT tags provided locations and data for a mean duration of 231 days (7.7 months), range 1–694 days (maximum of almost 2 years). Flipper-mounted SPOT tags deployed on five bearded, two ringed, and two spotted seals provided data for longer than 1 year.

Seal Movements

During this project (2014–2019), we deployed transmitters on 67 seals (26 bearded, 16 ringed, and 25 spotted seals) at nine tagging locations in the Beaufort, Chukchi, and Bering seas (Table 2). This is the first study in Alaska to deploy satellite transmitters on three sympatric species at multiple locations within three seas (Beaufort, Chukchi, and Bering) in the same year to better understand ice seal movements, habitat use, ecology, and the effect of tagging location on observed movements. We identified similarities and differences in movements and areas used by species and by tagging location within species.

Overall distribution. Bearded and ringed seals moved farther north than spotted seals in spring when ice moved north of the continental shelf. Ringed seals used less of the central Bering Sea in fall and winter and more of coastal areas than either bearded or spotted seals. This apparent low use of the central Bering Sea in winter by ringed seals, however, may be because few subadult ringed seals were tagged during this study. In a previous study, subadult ringed seals wintered in the central Bering Sea near the southern ice extent, while adults wintered farther north and closer to shore (Crawford et al. 2012). Adult ringed seals establish breeding territories in winter and spring where they maintain breathing holes and build lairs for pupping on heavier, more stable ice (Smith and Stirling 1975), however, subadults may take advantage of the productive, less consolidated ice habitat in central Bering Sea, where they do not need to maintain breathing holes or avoid adult territories (Crawford et al. 2012).

All three species of ice seals made extensive use of the intercontinental shelf in the Bering, Chukchi, and western Beaufort seas. Documenting this broad use of the region is attributable to capturing and tagging seals in multiple locations throughout their range in Alaska. For example, if we relied solely on data from juvenile bearded seals tagged in Norton Sound, we would not have documented that some juveniles remain in the Beaufort Sea throughout winter, as this behavior was only exhibited by seals tagged in in the Beaufort Sea. Tagging seals at multiple locations within the same season is critical to understanding the true extent of each species' movements and use of the region.

Latitudinal. All species (although not all individuals) made latitudinal movements seasonally. For bearded and spotted seals, these movements differed by where they were tagged. Most bearded seals made large latitudinal movements seasonally, however two bearded seals tagged in the Beaufort Sea stayed north of 70 °N (Fig. 6). Spotted seals (14 of 15) tagged in the Beaufort Sea stayed north of 69 °N until they moved south with advancing sea ice. Spotted seals tagged in the Bering Sea (n = 7) tended to stay in the Bering Sea (Fig. 18). These results suggest that range-wide ice seal movements are more complicated than those found by telemetry studies that deployed tags from one location. Future telemetry studies should tag seals at multiple locations throughout their range.

It is likely that patterns of latitudinal movement will change with changes in sea ice. For example, less consolidated pack ice may reduce southward movements as seals are able to move in ice farther north, as appears to be the case with bearded seals. Conversely, as ice retreats farther north during the open-water season, seals may also move farther north as exhibited by two ringed seals in this study that traveled beyond the intercontinental shelf to reach ice.

Site fidelity. The minimum proportion of seals that exhibited seasonal fidelity to specific areas was similar among species (16–19%). However, only 16 tags (on 67 seals) provided data long enough to assess seasonal fidelity. Although the proportion is not overwhelming, some areas repeatedly used by individuals were remarkably specific (See Figs. 11, 17, and 23).

The ability to document site fidelity is dependent on the longevity of satellite tags, highlighting the value of deploying multiple tags on individuals. Although the SPLASH and CTD tags provided more detailed data, the SPOT flipper tags transmitted longer and were critical for documenting habitat use over multiple years.

Distance traveled. Overall, spotted seals traveled farther overall distances than bearded and ringed seals, likely due to their "central-place" foraging style (Orians and Pearson 1979, Sjøberg and Ball 2000). Spotted seals made many east-west movements during the open-water season, foraging in areas offshore and hauling out onshore during the open-water season. In contrast, bearded and ringed seals stayed in foraging areas longer or foraged near sea ice (especially ringed seals) where they hauled out near foraging areas.

All species moved extensively throughout the region, often crossing the Chukchi and Bering seas to use coastal areas in Russia. Our data show that all three seal species made use of the entire intercontinental shelf.

Distance to land. Bearded and ringed seals were closest to land during the ice-covered season and farther from land during the open-water season while spotted seals were farthest from land when ice was at its maximum. That ringed seals were closer to land when ice was present (Nov-May) could be explained by their choice of heavier (including landfast) ice as pupping habitat and most of the ringed seals in this study were adults (81%, 13 of 16). Bearded seals had the same tendency but presumably for a different reason because none of the tagged bearded seals in this study were of breeding age. Juvenile bearded seals may use nearshore areas in part because distance to land is correlated with water depth and, as benthic foragers, they may use areas with shallower water. We did not tag any adult bearded seals, therefore we cannot report on areas they used, although two adult bearded seals that were tagged in a prior study also primarily used areas near land (< 50 km; Boveng and Cameron 2013). Spotted seals winter along the southern ice edge, which generally reaches the central Bering Sea by March (See Fig. 41), and they pup there in April–May. The offshore areas spotted seals use when ice is present generally have less consolidated pack ice (< 50%; see Fig. 49); spotted seals use the central Bering Sea during years sea ice forms there, however in low ice years, when ice is restricted to the coastal areas of Alaska and Russia, spotted seal remain closer to land.

High-Use Areas

During the open-water season, bearded seals primarily used nearshore areas, but also used Hope Basin in the southern Chukchi Sea, Mechigmenskaya Bay, Russia, in the northern Bering Sea, and central and west central Bering Sea along the 100–200 m isobath (Fig. 28). Ringed seals used the northern continental shelf and were centered on Barrow Canyon and the northeastern Beaufort Sea (Fig. 30). High-use areas for spotted seals differed by where seals were tagged. Spotted seals tagged in the Beaufort Sea used Barrow Canyon, but in shallower waters and closer to shore than areas used by ringed seals (Fig. 33). These seals also used the area between Herald Shoal and nearshore areas of Peard Bay and Icy Cape. The southernmost area of use for spotted seals tagged in the Beaufort Sea was near Bering Strait (Fig. 33). Spotted seals tagged in the Bering Sea used areas near Scammon Bay, where they were tagged (Fig. 36).

During the ice-covered season, bearded seals used Barrow Canyon, southern Kotzebue Sound, Bering Strait, Norton Sound, and near St. Lawrence Island, the mouth of the Yukon River and southwestern Anadyr Gulf (Fig. 29). Ringed seals primarily used Kotzebue Sound but also other nearshore areas in the Chukchi and Bering seas (Fig. 31), while spotted seals used the central Bering Sea regardless of which sea they were tagged in (Fig. 39).

In addition to marine high-use areas, spotted seals also had coastal high-use areas (haulouts) in the Beaufort Sea (Dease Inlet), Chukchi Sea (Icy Cape, northern Kotzebue Sound) and Bering Sea (Scammon Bay) (Fig. 34 and 37). Although spotted seals were tagged at haulouts in the Colville River and nearby Fish Creek, they used these haulouts less often, possibly because those seals were tagged in late summer near the end of when spotted seals could haul out on land along the Beaufort Sea coast and most tags stopped transmitting before seals would return there the following year. In other words, spotted seals could use the Colville River more often, and possibly exhibit fidelity to the area, then our data were able to show.

High-use areas that overlapped among species included Barrow Canyon, Kotzebue Sound, Norton Sound, and the Bering Sea shelf break between the 100 and 200 m isobaths. Barrow Canyon was used by one bearded seal in all seasons and by ringed and spotted seals during the open-water period, although spotted seals used only the shallow zone close to shore. Kotzebue and Norton sounds were used by bearded seals in all seasons, ringed seals only during the ice-covered season, and spotted seals only in the open-water season. The Bering Sea shelf break was used by bearded seals in all seasons, but not by ringed seals during this study, although it was used by subadults during winter in a previous study (Crawford et al. 2012). Spotted seals used this area only during the ice-covered season.

Although we identified high-use areas for all three species, it is important to note that the identification of high-use areas is limited by the movements of the seals tagged, which likely only partially represent high-use areas used by the population as a whole. As more seals are tagged, our understanding of high-use areas may change. For example, we expect that data from more bearded seals will further emphasize the individualistic nature of their movements, but also reinforce the importance of high-use areas already identified, such as Barrow Canyon or Norton Sound. For spotted seals, it is likely that tagging more individuals will identify additional land-based haulouts.

Haulout Behavior

This study documented that young bearded seals spent 26–50 days between haul-out bouts during the open-water period demonstrating their ability to access habitats far from the mainland or islands (Fig. 42). It is likely that adults are at least as capable, if not more so. During the open-water period, ringed seals primarily used high-latitude areas near the shelf break in the Chukchi Sea, areas generally proximal to remnant sea ice, which they used to haul out. Therefore, ringed seals in our study did not spend long periods of time between haul-out bouts. During the open-water season, spotted seals in the Bering and Chukchi seas spent 1–25 days on foraging trips without hauling out. When sea ice was present, however, spotted seals behaved similarly to ringed seals and made shorter duration foraging trips near ice and hauled out more often.

These behaviors are noteworthy as they suggest bearded and spotted seals can remain at sea for extended durations without requiring a haul-out platform nearby. Durations at sea are less clear for ringed seals because they usually stay with the ice and have ready access to it for resting. We documented ringed seals moving far off the shelf to the north to access sea ice; however, we cannot assess whether the purpose was to haul out or to feed on their primary fish prey (Arctic cod), which are also associated with ice. Native Alaskan seal hunters have observed bearded seals sleeping in the water; this behavior may allow seals to stay in foraging areas longer because they do not need to leave these areas to find haul-out platforms to rest on when in open water.

We documented four instances of ringed seals hauled out on land (Fig. 44), which is considered rare in Alaskan waters (Kelly 1988), although common in other parts of their range, including the Sea of Okhotsk (Ognev 1935), White Sea (Lukin 2006), and has recently become common in Svalbard (Lydersen et al. 2017). Ringed seals that hauled out on land included two males and two females, of which one was a pup (female) and three were adults. The haul-out dates ranged from 2 July to 20 November and durations lasted 6–12 hours. We also documented bearded seals hauling out on land in Kotzebue and Norton sounds. We further documented the high-use of several common spotted seal haulouts on land, near Dease Inlet, Icy Cape, Kotzebue Sound, and Scammon Bay.

When bearded seals hauled out on land, the duration of their haul-outs were shorter than when on sea ice, presumably because they are more easily disturbed on land. Although hauling out on ice, when it is available, is likely preferred because predation risk is lower (i.e., land-based predators cannot access them on ice), all three species did haul out on land during this study.

Use of Sea Ice

Bearded and ringed seals used similar ice concentrations during the same months; low concentrations in September–October and an average of 75% concentration in February–April (Figs. 45 and 47). Spotted seals, on the other hand, used lower concentrations (average 0–40%) regardless of the time of year (Fig. 49).

During the open–water period all species were 250 km or more away from the ice edge (defined as < 15% ice concentration) (Figs. 46, 48, and 50). During the ice-covered season, bearded seals were farthest from the ice edge and into the ice (400 km; Fig. 45), followed by ringed seals (300 km; Fig. 48), and spotted seals (100 km; Fig. 50).

Use of Oil and Gas Areas

All three species used the Chukchi Sea Lease Sale 193 area during the open-water season when industrial activity would be highest. Although more spotted seals were located within the 193 area ($n = 9$) they used it over a shorter time by entering later in the season (2 August). Spotted seals use of land and their frequent offshore-nearshore movements suggest they could be affected by industry related traffic between the 193 area and shore facilities at Wainwright (between Peard Bay and Utqiaġvik). Spotted seal movements documented during this study began in 2016 and did not overlap with activity within the 193 area, which had ended. Thus, foraging trips from Icy Cape to Herald Shoal that appear to avoid some of the 193 area were not influenced by industrial activity but, instead represent normal movements to and time spent in areas spotted seals preferred to forage.

Ship Traffic
Bearded seals are most likely to be affected by ship traffic because their movements overlap with highly used shipping lanes more often than ringed and spotted seals, especially in Norton Sound in spring and summer and in the eastern Chukchi Sea in fall. Ringed and spotted seals overlap with ship traffic most in the Chukchi Sea in the fall. Inferences regarding overlap between seal movements and the ship traffic data presented here should be made with caution because ship data were collected during 2013–2015. Ship traffic in the northeastern Chukchi Sea likely diminished as the oil and gas activity in the 193 area ended in 2016. On the other hand, as the open-water period has lengthened, cargo traffic may have increased.

Traditional Knowledge
Traditional knowledge related to seals and other marine mammals was collected and reported for 13 communities (Table 6). We published two TEK papers in the peer-reviewed scientific literature based on these reports (Huntington et al. 2016, Huntington et al. 2017). All TEK reports are available at the ADFG webpage:
http://www.adfg.alaska.gov/index.cfm?adfg=marinemammalprogram.traditionalknowledgereports

These interviews contribute substantially to the body of information regarding seal movements and behavior and were extremely valuable to this study. In some cases, hunters provided information that supported telemetry results and in other cases provided information that suggests our telemetry data were biased. Furthermore, they provided additional information that could not be gained from telemetry. Hunters informed us about young bearded seals using the Koyuk River (Appendix D) and estuary near St. Michael (Appendix E). Without this information we would have tagged far fewer bearded seals. TEK regarding areas bearded seals use seasonally and their movements suggest that adult bearded seal behavior is likely different from that of young seals; at least for some areas and times of year.

Limitations of Data
We learned a great deal about three sympatric ice seal species during this study, however, we know some of our results are biased by sample size and by limitations of data collected by satellite-linked transmitters on marine mammals in the marine environment. For example, we know from a previous study that adult and subadult ringed seals behave differently in winter (Crawford et al 2012). Our sample of ringed seals included few subadults, therefore we did not document use of the Bering Sea shelf break in winter by ringed seals. It is likely that our sample of only young bearded seals (no adults) has similar repercussions.

Our data are also seasonally biased because we must wait until after seals molt to attach primary tags. Therefore, sample sizes of tagged seals are biased for the open-water period, during summer and fall, and slowly diminish during winter as battery power drains and tags drop off (Fig. 5). As such, haul-out data collected during the seals' annual molt that could be used to inform correction factors for aerial surveys is limited.

Conclusions

During this study we collected and analyzed extensive data regarding bearded, ringed, and spotted seals throughout their range in Alaskan, Russian, and Canadian waters. We worked with Alaska Native subsistence seal hunters to tag seals near Nuiqsut, Kotzebue, Buckland, Nome, Koyuk, St. Michael, Scammon Bay, and Hooper Bay, and with NSB personnel in Utqiaġvik and Nuiqsut to tag and to train interested hunters. We kept the ISC informed about this project at their annual meetings. We collaborated with MML and NSB by sharing seal tags and data. We made the results of this project available to the communities where seals were tagged and to others interested in seal movements in the Arctic by e-mailing maps, maintaining a webpage, and presenting results in villages during community meetings and tagger trainings. We worked with hunters, communities, and other researchers to learn about movements and habitat use of bearded, ringed, and spotted seals and how they are changing with decreasing sea ice and increasing human activities (e.g., oil and gas and shipping) in the Arctic. We published three papers in peer-reviewed journals containing data from this project: (1) *Effects of changing sea ice on marine mammals and subsistence hunters in northern Alaska from traditional knowledge interviews* (Huntington et al. 2016), (2) *Evaluating the effects of climate change on indigenous marine mammal hunting in northern and western Alaska using traditional knowledge* (Huntington et al. 2017), (3) *A multi-species synthesis of satellite telemetry data in the Pacific Arctic (1987–2015): overlap of marine mammal distributions and core use areas* (Citta et al. 2018). In addition, we have one paper in review, and another in preparation: (1) *Movement, diving, and haul-out behaviors of juvenile bearded seals in the Bering, Chukchi and Beaufort seas, 2014–2018* (Olnes et al. *In review*), (2) *Juvenile bearded seal responses to 10 years of sea ice change in the Bering, Chukchi and Beaufort Seas* (Olnes et al. *In prep.*). We made numerous oral and poster presentations at conferences, symposia, and meetings (See Appendices).

Results from this study contributed to understanding the distribution, movements, and overlap of bearded, ringed, and spotted seals. These include, but are not limited to:

Bearded, ringed, and spotted seals made extensive seasonal latitudinal movements. The extent of those movements, however, depended on where seals were tagged. Bearded seals tagged in the Beaufort Sea did not travel south of 70 °N, while bearded seals tagged in Norton Sound made more extensive movements. Spotted seals tagged in the Beaufort Sea stayed north of 69 °N until they accompanied the advancing sea ice south. Spotted seals tagged in the Bering Sea tended to stay in the Bering Sea. These results have large implications for the interpretation of movements in studies where all seals are tagged in the same location and indicate changes in the design of future telemetry studies are needed.

We summarized the movements of bearded, ringed, and spotted seals, walruses, bowhead whales, gray whales, and beluga whales in the Bering, Chukchi, and Beaufort seas through 2015 and then overlaid these data to identify multi-species core-use areas. In addition to overlapping with other seals, ringed seals overlapped with gray, bowhead, and Norton Sound beluga whales, and walruses in summer and with Eastern Beaufort and Norton Sound stock of beluga whales and walruses in winter. Bearded seals overlapped more with gray whales and Norton Sound belugas than other seals in summer and with Eastern Bering and Chukchi Sea belugas in winter than with other seals. Spotted seals overlapped more with bearded seals than ringed seals but also with walruses, gray, and beluga whales in summer and with all species in winter (Citta et al. 2018).

Recommendations

1. Additional satellite telemetry studies are needed to monitor seal movements and behavior as climate and ocean waters warm and the timing, extent, and availability of sea ice changes. As we demonstrated during this study, seal behavior has changed with changes in sea ice coverage and changes are likely to continue, though we cannot predict what those changes will be. To be effective, mitigation measures for oil and gas activities will likely require changes that can only be determined by continued monitoring of seal movements associated with sea ice through time.

2. There is a need to tag adult bearded seals because we expect their movements and high-use areas may be different from that of young bearded seals. We recommend further work on developing methods to catch adult bearded seals.

3. Seals have become more difficult to hunt, due to larger storms and less, more variable sea ice. We recommend that local and traditional ecological knowledge be updated as the climate continues to warm and sea ice continues to change to better understand how seal behavior changes.

4. A comprehensive analysis of seal interactions with seismic activities and other sources of industrial noise is needed. Seal tracks that spatially and temporally overlap with seismic operations need to be analyzed to learn about seal behavior near seismic activities. Oil and seismic companies need to be forthcoming with their program track lines (location and dates, number of guns used, and time on and off) for this analysis to occur. Removing the geo-reference to where the survey actually occurred could be done to maintain the proprietary nature of the seismic program and still allow the analysis to occur.

5. Offshore industrial activity creates noise that may negatively affect seal behavior. We recommend field testing the Acousonde 3S acoustic tag that combines satellite telemetry and acoustic technology to directly monitor noise levels that seals are exposed to. This tag could be deployed on bearded seals to document how bearded seal vocalizations (e.g., rate, loudness) change with noise level.

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List of Publications and Products

Publications are listed chronologically:

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. Biology Letters, doi:10.1098/rsbl.2016.0198.

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Report to the Eskimo Walrus Commission, the Ice Seal Committee, and the Bureau of Ocean Energy Management. 8pp. Appendix C.

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Abstracts:

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Other:
Seal and bowhead maps to National Marine Fisheries Service for use in Quintillion Project biological opinion

Ringed seal location and haul-out data were provided to MML to inform correction factors used with aerial surveys to make abundance estimates.

Seal location and haul-out data were provided to the CAFF (Conservation of Arctic Flora and Fauna) marine mammal network group to contribute to a circumpolar assessment of marine mammal hotspots.

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Appendix A.

Hunter-assisted study on ringed and bearded seal movements, habitat use, and traditional knowledge

Mark A. Nelson[1], Lori Quakenbush[1], John Goodwin[2], Merlin Henry[3], Alex Whiting[4], Kathy Frost[5], and Justin Crawford[1]

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Ringed (*Pusa hispida*), and bearded (*Erignathus barbatus*) seals are considered "ice associated seals" or "ice seals" because sea ice is important for pupping, nursing, molting, and resting. In Alaska, these seals are found in the Bering, Chukchi, and Beaufort seas. They are important subsistence species used by Alaska Natives for food, oil, clothing, and handicrafts. Changes in the timing and extent of sea ice have increased access to the Arctic, increasing the need to plan shipping lanes, oil and gas lease sales, and to develop mitigation measures to minimize effects on seals. Our understanding of important seal habitats and the timing and magnitude of movements by species, sex, and age, however, is limited. Cooperative hunter-biologist satellite-tagging studies in Kotzebue Sound, and more recently at Barrow and Hooper Bay, have begun to gather this information. The focus of this study is to deploy satellite transmitters on ringed and bearded seals through additional cooperative projects with coastal Alaska communities. In 2014, we trained hunter-taggers from the Norton Sound villages of Koyuk, St. Michael, Unalakleet, and Elim. Four ringed seals and one bearded seal were satellite-tagged near Kotzebue in June, as were three bearded seals near Koyuk in September. All five seals tagged near Kotzebue traveled north for the summer. The bearded seal stayed in the Chukchi Sea near Cape Lisburne. One ringed seal spent time offshore from Wainwright, one near Barrow canyon, one near Wrangel Island, and one traveled east through the Beaufort Sea to Mackenzie Bay and back to Kotzebue Sound. The Koyuk bearded seals spent time in the local rivers before moving out into Norton Sound. Tracking seals tagged at several widely-spaced locations will allow us to better understand the range and timing of movements, their use of sea ice including haul out behavior, important habitats, and seasonal site fidelity. Future plans include training more hunter-taggers, and documenting local and traditional knowledge to better understand how seals are responding to changing sea ice, increased shipping, and oil and gas activity.

337 words (350 max)

Hunter-assisted study on ringed and bearded seal movements, habitat use, and TEK

Appendix A.

Mark A. Nelson[1], Lori Quakenbush[1], John Goodwin[2], Merlin Henry[3], Alex Whiting[4], Kathy Frost[5], and Justin Crawford[1]

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Introduction

Ringed (*Pusa hispida*) and bearded (*Erignathus barbatus*) seals are called "ice seals" because they use sea ice for pupping, nursing, molting, and resting. In Alaska, these seals are found in the Bering, Chukchi, and Beaufort seas. They are important subsistence species used by Alaska Natives for food, oil, clothing, and handicrafts. Changes in the timing and extent of sea ice not only effect ice seal habitat, but also have increased access to the Arctic, increasing the need to plan shipping lanes, oil and gas lease sales, and to develop mitigation measures to minimize these effects on seals. Cooperative hunter-biologist satellite-tagging studies are increasing our understanding of important seal habitats, seasonal movements, use of sea ice including haul out behavior, and seasonal site fidelity. This project will build on past studies by tagging seals at several widely-spaced locations from Hooper Bay to Barrow (including Norton Sound and Kotzebue Sound) and by incorporating traditional knowledge.

Objectives

Work with seal hunters to:

- capture and tag ringed and bearded seals,
- document habitat use, movement patterns, and movement timing, and
- gather and document local and traditional knowledge of ringed and bearded seals.

2014 Activities

- Seal hunters were trained to tag seals with satellite-linked transmitters in Norton Sound and Hooper Bay.
- Hunter-taggers determined when and where to capture seals using local knowledge.
- Four ringed and one bearded seal were tagged near Kotzebue in June (Fig. 1).
- Three bearded seals were tagged near Koyuk in September (Fig. 1).

Future plans

- Continue to work with trained hunter-taggers and with new hunters and communities.
- Conduct workshops to document local and traditional knowledge to better understand seals movements in response to changing sea ice.

Acknowledgements

This project is funded by the Bureau of Ocean Energy Management. We appreciate the assistance of all the hunter-tagger crews; Albert Simon, Alexander Niksik Jr., Denali Whiting, Edward Ahyakak, Edwin Kotangan Jr., Frank Garfield, Gordon Eakon, Henry "Boyuk" Goodwin, and Pearl Goodwin. Research on ice seals was conducted under permit #15324 issued to the Alaska Department of Fish and Game by the National Marine Fisheries Service and under an approved ADF&G Animal Care and Use Committee Protocol #2014-03.

Movements of tagged seals during 2014

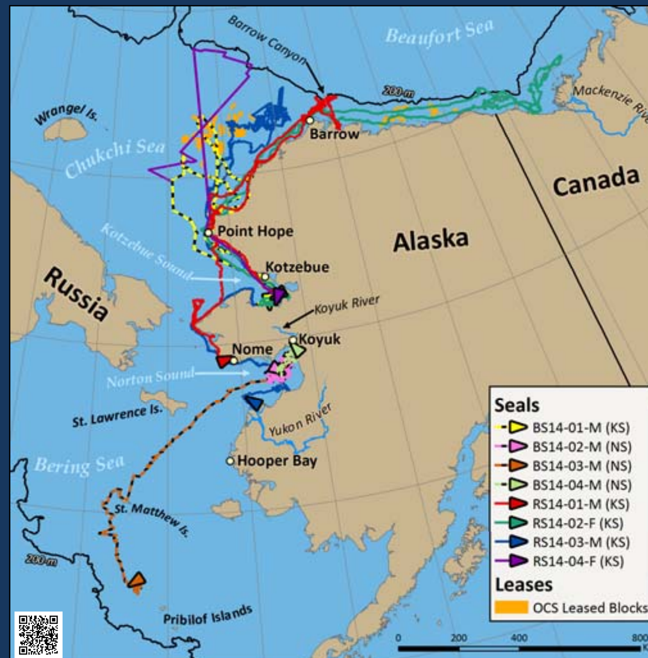


Figure 1. Movements of seals tagged in June and September during 2014. Seals tagged in Kotzebue Sound (KS) and Norton Sound (NS).

Norton Sound hunter-tagger training

Hunters from Elim, Koyuk, Unalakleet, and St. Michael learned how to tag seals with satellite transmitters in March.

Gordon Eakon practices attaching a transmitter to a seal flipper while Edwin Kotangan and Merlin Henry look on.

Alexander Niksik practices gluing a transmitter while Gordon Eakon and Merlin Henry look on.

Gordon Eakon shows a transmitter he attached to a subsistence harvested seal flipper.

Kotzebue Sound tagging - June

Four ringed and one bearded seal were tagged in Kotzebue Sound during June.

Pearl Goodwin keeps track of the data.

John and Pearl Goodwin searching for seals.

Frank Garfield, Edward Ahyakak, and Mark Nelson weighing a seal.

Edward Ahyakak applying epoxy to the back of a young bearded seal.

A young bearded seal is tagged and ready for release.

Frank Garfield, Boyuk Goodwin, Edward Ahyakak, and Kathy Frost tagging a ringed seal.

Norton Sound tagging - September

Three young bearded seals were tagged near Koyuk in September.

Merlin Henry prepares to tag a young bearded seal 15 miles up the Koyuk River.

Merlin Henry with a young bearded seal prior to release into the Koyuk River.

Effects of Changing Sea Ice on Marine Mammals and Subsistence Hunters in Northern Alaska

Appendix B.

Paper number:

GC23D-1172

Henry P. Huntington[1], Lori Quakenbush[2], and Mark Nelson[2]

[1] Huntington Consulting, Eagle River, Alaska, USA hph@alaska.net,
[2]Alaska Department of Fish and Game, Fairbanks, Alaska

Overview

Marine mammals are important sources of food for indigenous residents of northern Alaska. Changing sea ice extent and thickness affect the behavior of animals and thus the success of hunters. Documenting the traditional knowledge of Iñupiaq and Yup'ik hunters concerning marine mammals and sea ice makes a wide range of information and insight relevant to ecology, conservation, and human activity. We interviewed hunters in villages from the northern Bering Sea to the Beaufort Sea about bowhead whales, walruses, and ice seals, (ringed, bearded, spotted, and ribbon). Traditional knowledge is the product of careful, systematic observation of the environment, confirmed by repeated observation or comparison with the observations of others. This knowledge is shared among hunters through stories and conversation, and treated with care and attention, including attributing the observations and interpretations to the individuals who made them (Noongwook et al. 2007). We documented observations of the migratory and local movements of marine mammals, feeding and reproductive behavior, predation, habitat use, response to disturbance including human activity, and other aspects of the life history and ecology of these animals.

Methods

- We used the semi-directive interview method to collect traditional knowledge from subsistence hunters and community members (Huntington 1998).
- We interviewed people from 8 communities between 2007 and 2015 (Table 1).
- After the interviews, we prepared a draft report that was reviewed and approved by all the participants.
- The final report was prepared after all the comments had been addressed.

Table 1. Summary of interviews.

Community	*Year*	*Species Focus*	*No. of Participants*
Kaktovik	2007	Bowhead whales	6
Barrow	2007	Bowhead whales	6
Wainwright	2008	Bowhead whales	7
Point Lay	2011	Walrus	5
Wainwright	2011	Walrus	13
Point Hope	2013	Walrus	8
Barrow	2015	Walrus and ice seals	10
Elim	2015	Ice seals and walrus	8
St. Michael & Stebbins	2015	Ice seals and walrus	8
Total 8 communities	5 years	6 species	71 participants

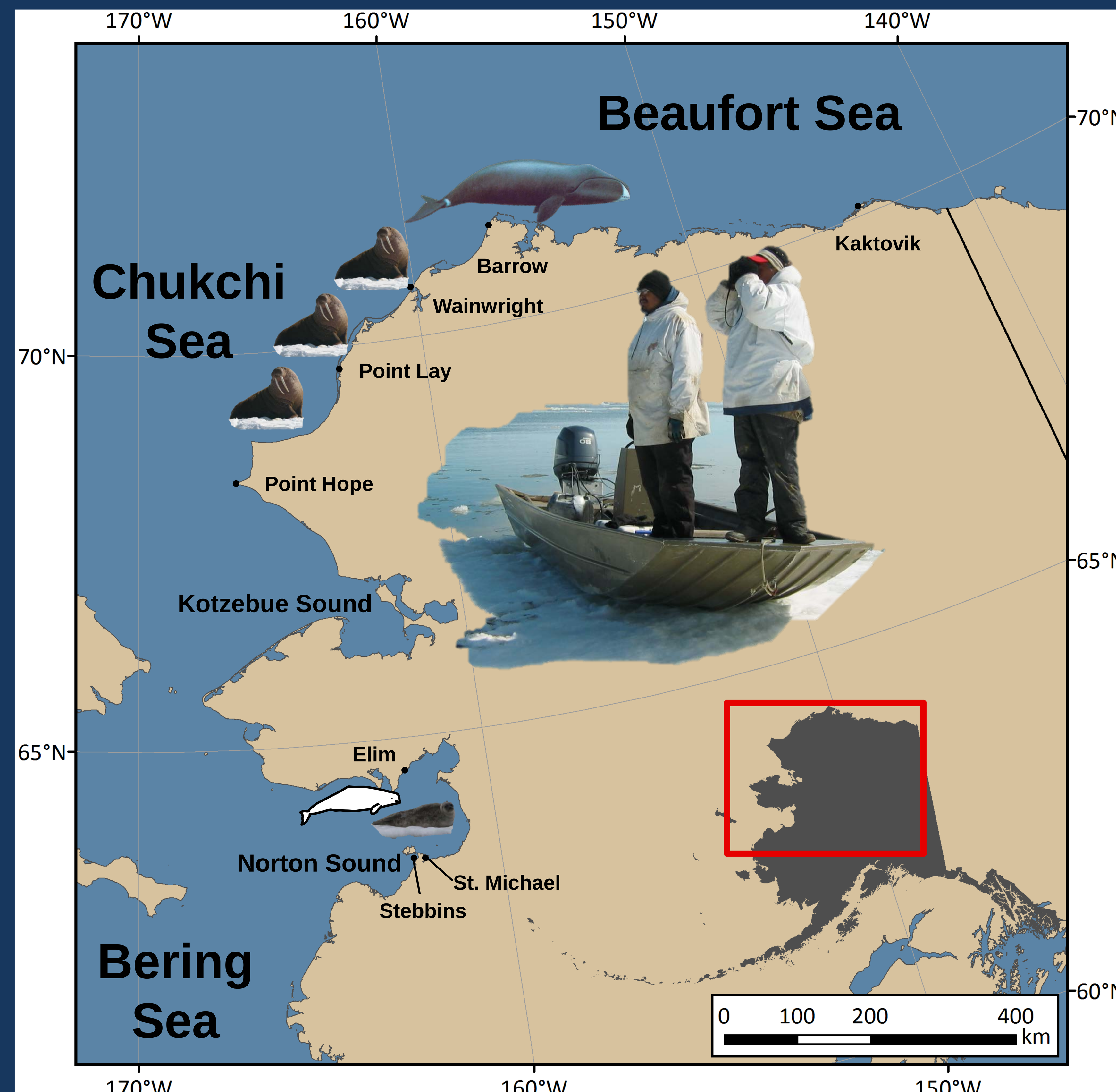
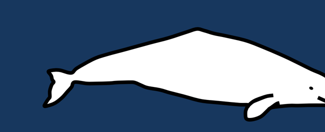


Figure 1. Map of study area and participating communities. Icons correspond to detailed observations about walruses, ice seals, and beluga and bowhead whales.

General Observations
(Recorded in many communities)

- Ice seals are available for a shorter period of time.
- In the past, pack ice came and went all summer, but now retreats from shore and does not return until freeze-up.
- Because of thinner sea ice, it is harder to find a place to haul a bowhead whale onto ice for butchering.
- Hunting and traveling is more dangerous because of thinner ice in winter and spring.
- More efficient boat motors enable hunters to travel farther to retreating ice.
- Less sea ice and bigger storms reduce the number of good hunting days.
- Increased oil and gas activity and greater shipping traffic are concerns; impacts to subsistence are still unknown but potentially large.
- Hunters have adjusted for changing sea ice by hunting earlier in the spring and later into the fall and winter to get what they need.

Specific Observations
(Recorded in one or two communities)



Beluga whales (*Delphinapterus leucas*) and killer whales (*Orcinus orca*) were seen near Elim in Norton Bay in January 2015, when ice was unusually late in forming (Figure 1).

Walrus are hauling out on land near Point Lay in the tens of thousands. Walrus hauled out on land many times in the past century but in smaller groups.

There is less snow on the sea ice in Norton Bay, reducing the habitat available for seal dens; however; there are still many breathing holes in the ice in spring.

Thinner shorefast ice off of Barrow has shifted spring feeding areas and the distribution of bowhead whales, so that few are now seen along the ice edge to the southwest of the community, which used to be a good hunting area.

Snowmachine noise near Barrow may be changing migration patterns away from shorefast ice.

Conclusions

Our findings are consistent with other recent studies of traditional knowledge and marine mammals in the region (e.g., Noongwook et al. 2007, Galginaitis 2013, Huntington et al. 2013, Kawerak 2013, Voorhees et al. 2014), which note both the responses of marine mammals to changing conditions and the innovations of hunters to shifts in timing, distribution, and behavior of the animals they seek. In these studies and in ours, hunters emphasized that the impacts to animals and people are a result of the interactions among many factors rather than to changing sea ice acting alone.

Acknowledgements

We appreciate the skill, expertise, and generosity of the 71 hunters who participated in the interviews, and the communities and Tribal Councils of Kaktovik, Barrow, Wainwright, Point Lay, Point Hope, Elim, Stebbins, and St. Michael that facilitated this work. We also thank the Alaska Eskimo Whaling Commission, the Eskimo Walrus Commission, and the Ice Seal Committee for their support and guidance. We are grateful to the Bureau of Ocean Energy Management, the Minerals Management Service, ConocoPhillips, and the Coastal Marine Institute for funding.

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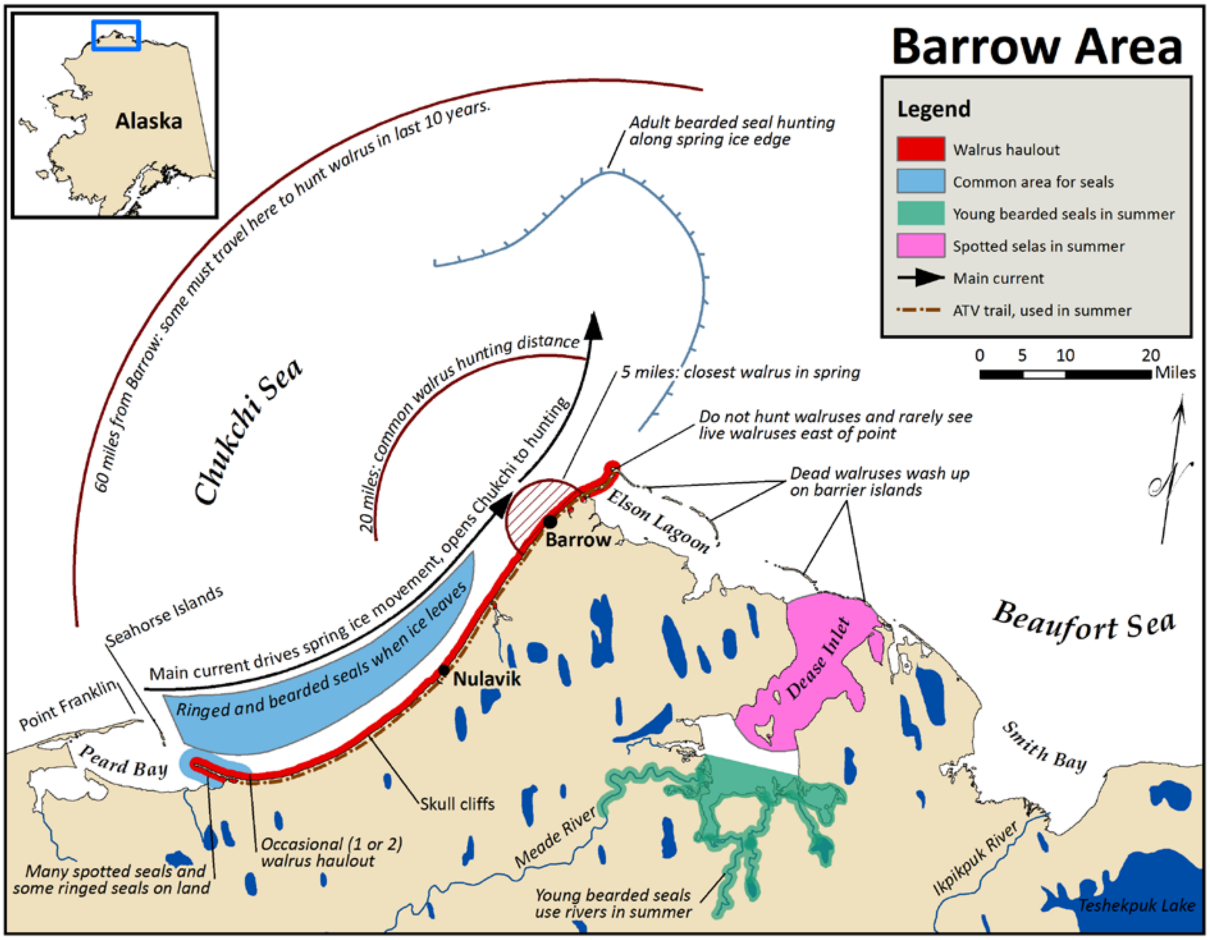
Appendix C.

Traditional Knowledge Regarding Walrus, Ringed Seals, and Bearded Seals near Barrow, Alaska



Traditional Knowledge Regarding Walrus, Ringed Seals, and Bearded Seals near Barrow, Alaska

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Final Report

Approved December 2015

Final report should be cited as:
Huntington, H.P., M. Nelson, and L.T. Quakenbush. 2015. Traditional knowledge regarding walrus, ringed seals, and bearded seals near Barrow, Alaska. Final report to the Eskimo Walrus Commission, the Ice Seal Committee, and the Bureau of Ocean Energy Management for contract #M13PC00015. 8pp.

Introduction

Walrus, ringed seals, and bearded seals are important species for subsistence harvests by Iñupiat hunters in northern Alaska. They are also iconic Arctic marine mammals, and at risk from climate change. Increasing industrial activity in the Chukchi Sea is an additional potential stressor to walrus and seal populations. A satellite telemetry study of the distribution, behavior, and movements of walrus and seals is an important contribution to monitoring the effects of a changing environment and the potential effects from industrial activity. While placing satellite transmitters on walrus and seals provides detailed information about the movements and some behaviors of individual animals, documenting traditional knowledge about walrus and seals, through interviews with residents of coastal communities, provides valuable complementary contemporaneous and historical information about the general patterns of each species.

This report summarizes information gathered from interviews with hunters and other knowledgeable residents in Barrow, Alaska, in January 2015. This traditional knowledge project used the same approach that the Native Village of Savoonga used when documenting traditional knowledge about bowhead whales on St. Lawrence Island (Noongwook et al. 2007).

Methods

We used the semi-directive interview method, in which the interviewers raise a number of topics with the person being interviewed, but do not rely solely on a formal list of questions (Huntington 1998). Instead, the interview is closer to a discussion or conversation, proceeding in directions determined by the person being interviewed, reflecting his/her knowledge, the associations made between walrus and other parts of the environment, and so on. The interviewers use their list of topics to raise additional points for discussion, but do not curtail discussion of additional topics introduced by persons being interviewed.

In Barrow, we interviewed ten people: one group of four, two groups of two each, and two individually. Those interviewed were Ernest Nageak, Van Edwardsen, Ronald Uyeno, Jonah Leavitt, Willie Koonaloak, John Heffle, and four people who wished to remain anonymous. The interviews were conducted on January 29, at the Iñupiat Heritage Center.

The topics identified by the research team in advance of the interviewers were:

Haul-out patterns on land
Observations of orphaned calves
Timing and location of walrus and seal sightings
Behavior of walrus and seals
Parts of walrus and seals eaten by humans
Changes over time for all topics

The results are presented under different headings, reflecting the actual information collected and the fact that some of the subjects blend together, especially changes seen over time in regard to all of the topics. The interviewers were Henry Huntington and Mark Nelson. Lori Quakenbush is the project leader.

Ringed and Bearded Seals

Ringed seals are generally found on the Chukchi Sea side of Point Barrow, including in front of the town of Barrow. They are usually found closer to shore and so are the first seals seen when boating out to hunt seals or walrus. When hunting from boats, Barrow hunters prefer to hunt bearded seals, passing ringed seals by, unless they are teaching a young hunter how to hunt for seals. When the ice is far out, seals may be found near river and creek mouths, where feeding is often good.

In spring, many ringed seals haul out on the ice. Ringed seals may haul out on land to rest. This can be seen south of Barrow towards Peard Bay. It is less common near Barrow, where there is often a lot of four-wheeler traffic. Ringed seals with bald spots and sores, which were most common in the summer of 2011, hauled out more frequently on the beach than ringed seals usually do. Seals with these signs of disease have been seen in subsequent years, too, but less often. The diseased seals are thin and do not flee an approaching person. Instead, it is possible to walk right up to them. Hunters avoid animals with signs of disease, so these animals were not hunted. Hunters also avoid ringed seals with black faces, as these seals taste like kerosene (Note: these are known to be adult males in rut, which develop a strong taste and smell).

Bearded seals are generally found farther from shore. They used to be found closer to Barrow. In summer, they may be 20–30 miles north of Point Barrow, along the ice or where the Chukchi and Beaufort waters meet. They are often plentiful that far out, but not seen as often closer to shore. While bearded seals are often associated with ice, they will remain in ice-free waters, too. They can be seen in front of Barrow, and juveniles are often seen off Elson Lagoon. In summer when there is no ice, bearded seals can be found in the current about 7 miles from shore. Hunters are taught to go out to the current and drift along until they see seals. Sometimes fewer seals are seen later in the summer. In these conditions, many boats may compete while chasing the same seal, which is not the way it used to be. The best hunting time for bearded seals is in July when the ice is beginning to go out.

Bearded seals can also sleep in open water. Hunters have come across bearded seals lying on the surface. When the seals are awakened by the boat, they react quickly, diving with a splash.

Bearded seals swim up the rivers that flow into Admiralty Bay. Bearded seals of all ages have been seen to do this. The seals are probably eating whitefish in the rivers. This is not a common occurrence however, most young bearded seals are found around the barrier islands and outside Dease Inlet during the summer.

In recent years, bearded seals have had thinner blubber. Hunters need to get to a seal quickly before it sinks. The seal oil they produce is also different from the way seal oil used to be.

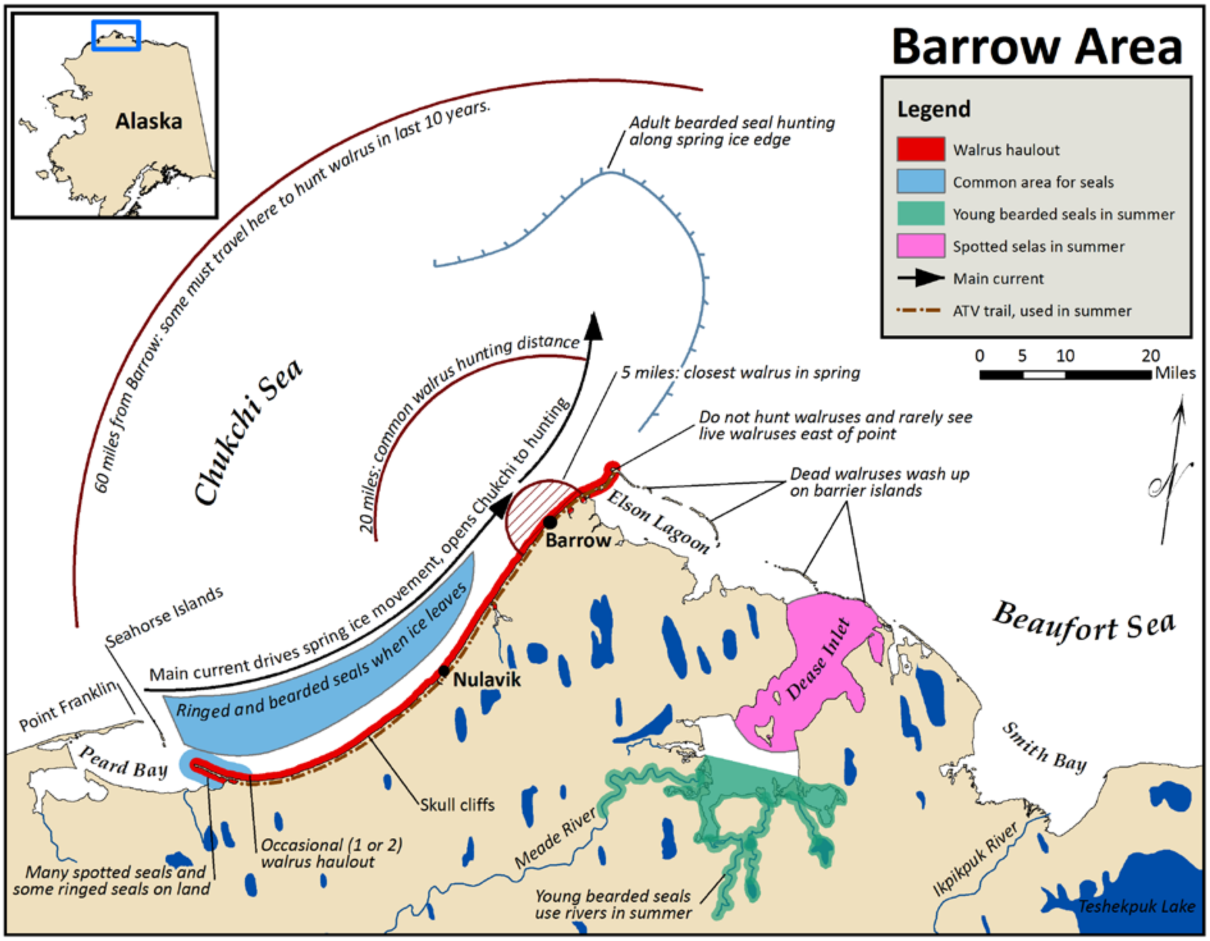

Figure 1. Movements and behavior of ringed seal, bearded seal, spotted seal, and walrus near Barrow as described during traditional knowledge interviews, January 2015.

Walrus

Walrus are harvested in Barrow when they are accessible. Walrus hunting occurs in the Chukchi Sea, but not the Beaufort Sea. Hunters typically head west, or first go south to Peard Bay and then offshore. Access depends primarily on ice conditions and can vary greatly from year to year near Barrow. Some hunters have gone as far as 60 miles offshore, which is possible now due to the fuel efficiency of four-stroke engines. Traveling this far, however carries risks if the weather changes for the worse. Recent changes in sea ice distribution and thickness have been the dominant factor responsible for changes in walrus distribution and behavior in recent years.

Walrus migrate north in spring, drifting with sea ice carried in the northbound currents of the Chukchi Sea. When shorefast ice breaks up, which is happening earlier and earlier, Barrow hunters are able to begin hunting by boat. East winds carry sea ice away from shore, making access difficult. West winds bring sea ice closer to the Barrow coast, bringing walrus and bearded seals with the ice. Walrus are typically carried north past the City of Barrow and onwards past Point Barrow. Only occasionally are walrus seen in the Beaufort Sea, to the east of Point Barrow. The eddies that form to the northeast of Point Barrow do attract beluga whales and bearded seals, and may be responsible for walrus carcasses washing up on the barrier islands that border Elson Lagoon. Formerly, the ice would come and go during the summer as the winds shift, bringing ice and animals back several times, providing several hunting opportunities. In recent years, the ice usually does not return after it leaves the Barrow area and may leave faster when it goes out. The hunting season is thus shorter now, though still variable depending on the conditions of each year.

Ice thickness plays a role, too. Formerly, walrus were found on large ice floes in herds of up to 3,000 animals. Today, ice floes are smaller and thinner, so walrus are typically found in small groups (10–15 animals) or mid-size groups (50–100). Hunters could smell the large herds a long way away, but the smaller groups do not have as strong an odor. When walrus leave the ice floes, the floes rebound and rise higher out of the water. Thinner ice is noticeable at other times, too. During spring whaling, it is harder to find flat areas of ice that are thick enough to support a large bowhead whale for butchering. Formerly, any flat area was thick enough, but this is no longer the case.

Walrus are occasionally seen swimming in open water, presumably traveling from haulouts to feeding areas. This has been observed 4–5 miles offshore, with the walrus heading south, and no ice in sight. Individual walrus have been seen swimming along the shore in late August, with no ice in sight. Walrus can be hunted in open water, but it is much harder than hunting them when hauled out on ice floes, and they must be towed to ice or land for butchering. Walrus are also very dangerous when in the water. They can be aggressive and attack boats, and have been known to team up when doing so. This can occur when a walrus has been killed and the other walrus do not want to leave it. Dropping empty rifle shells into the water can scare walrus away, perhaps from the appearance or the sound.

Occasionally a single walrus, and more rarely two walrus together, will haul out on shore in the Barrow area. This is more common to the south of Barrow, towards Nulavik and Skull Cliffs, but can also be seen towards Point Barrow. Hunters have not seen three or more walrus hauling out together in the Barrow area. Walrus that haul out near Barrow are usually hunted; they will be seen by people who travel up and down the coast by four-wheeler, a common summer activity. Once, a sick walrus went inland from Elson Lagoon behind the Naval Arctic Research Lab (NARL) hangars. Sick walrus and sick polar bears will take themselves off to die. There does not appear to be a change in hauling out behavior in the Barrow area, although it may be more common in the past decade or so.

One hunter/carver recently saw a walrus skull that had many cavities in its teeth. He had not seen that before.

Orphaned calves are found occasionally in the Barrow area, but this is not common. It typically occurs after there has been a hunt. The last instance was three or more years prior to the interviews. When calves can be nursed to health, they are given to a zoo or other facility. There does not appear to be any trend in the frequency of orphaned calf sightings.

Walrus have excellent hearing. They do not react to people speaking in normal voices. Instead, they become suspicious if people are whispering or otherwise trying to be quiet. Walrus are generally noisy animals, so the additional noise does not bother them. The same is sometimes true of other animals—they react more to people who are trying to sneak up to them or sneak past, than to those who show that they have seen the animals and are aware that the animals have seen or heard them.

Offshore oil and gas activity could have impacts to walrus and walrus prey. This could have a bigger impact on walrus-dependent communities, especially Gambell and Savoonga.

Barrow residents eat the skin, blubber, meat, kidneys, and heart of walrus. They do not typically eat liver or intestines. All parts are equally likely to be eaten by anyone eating walrus; there are no parts that are given specially to people of different ages or gender. Some people like to eat clams from walrus stomachs, but recently the stomachs have been mostly empty.

Polar Bears

Polar bears occasionally swim ashore in summer, having come a long way from the ice. They are typically exhausted. Polar bear monitors let them rest, rather than scaring them back into the water right away. Elders also say to leave animals alone when they come to shore, to let them rest. One bear collapsed on reaching shore and slept for a day or two, before getting up and walking to the Barrow bone pile.

Other Observations

Many things are changing. Skin boats left in the open in summer will now discolor and turn dark. They need to be covered with a tarp, whereas before they could be left out and would bleach in the sun.

Multi-year ice rarely shows up now, whereas it used to arrive reliably in October as the ocean began to freeze.

Traditional and Modern Knowledge and Ideas for Research

Younger hunters distinguished traditional knowledge from modern knowledge. The former is what can be learned from elders and others with long experience. Younger hunters have modern knowledge, having only hunted from motorboat and snowmachine, not with dog teams and other older equipment. They thus have different knowledge than their fathers and grandfathers, though they still have the skills to hunt effectively and to know how to interact with animals. The younger hunters are also well aware of how rapidly conditions are changing, and are able to provide knowledge about recent changes in a way that elders who have not hunted for many years may not.

The U.S. Fish and Wildlife Service has been paying more attention to traditional knowledge, which is a good thing and can be very helpful in many situations. At the same time, however, there are concerns about asking the same people the same kinds of questions over and over, or going to the same people to ask about different species but still taking up their time repeatedly. Better coordination in meetings and in research can help reduce the burden on the community, as it can on the ecosystem for field studies. Doing things once rather than several times would be better.

The U.S. Fish and Wildlife Service is also good at circulating information about their polar bear surveys, including photos of the aircraft involved, and flight plans and dates. This lets people know what to expect and how to recognize the aircraft and personnel who are involved, instead of wondering who is doing what and what impact they are having on hunters and on animals.

When walrus are being hunted from Barrow, there may be as many as 30–40 boats on the water. Finding ways to record the observations of these hunters could be a big contribution to walrus monitoring and research, and for other species, too. Hunters pay attention to oddities, such as unusual body condition or markings, and could take photos and bring this to the attention of biologists. Facebook might be a great way to organize hunters and report observations.

Acknowledgements
We appreciate the support of the Eskimo Walrus Commission and the Ice Seal Committee for this project and are grateful to Joe Sage and Thomas Olemaun for identifying participants and helping to set up interviews. The Bureau of Ocean Energy Management (BOEM) funded the work as part of Contract Nos. M09PC00027 and M13PC00015 and we appreciate the support of Charles Monnett, Catherine Coon, and Dan Holiday. Justin Crawford prepared the maps used during the interviews and the figures in this report.

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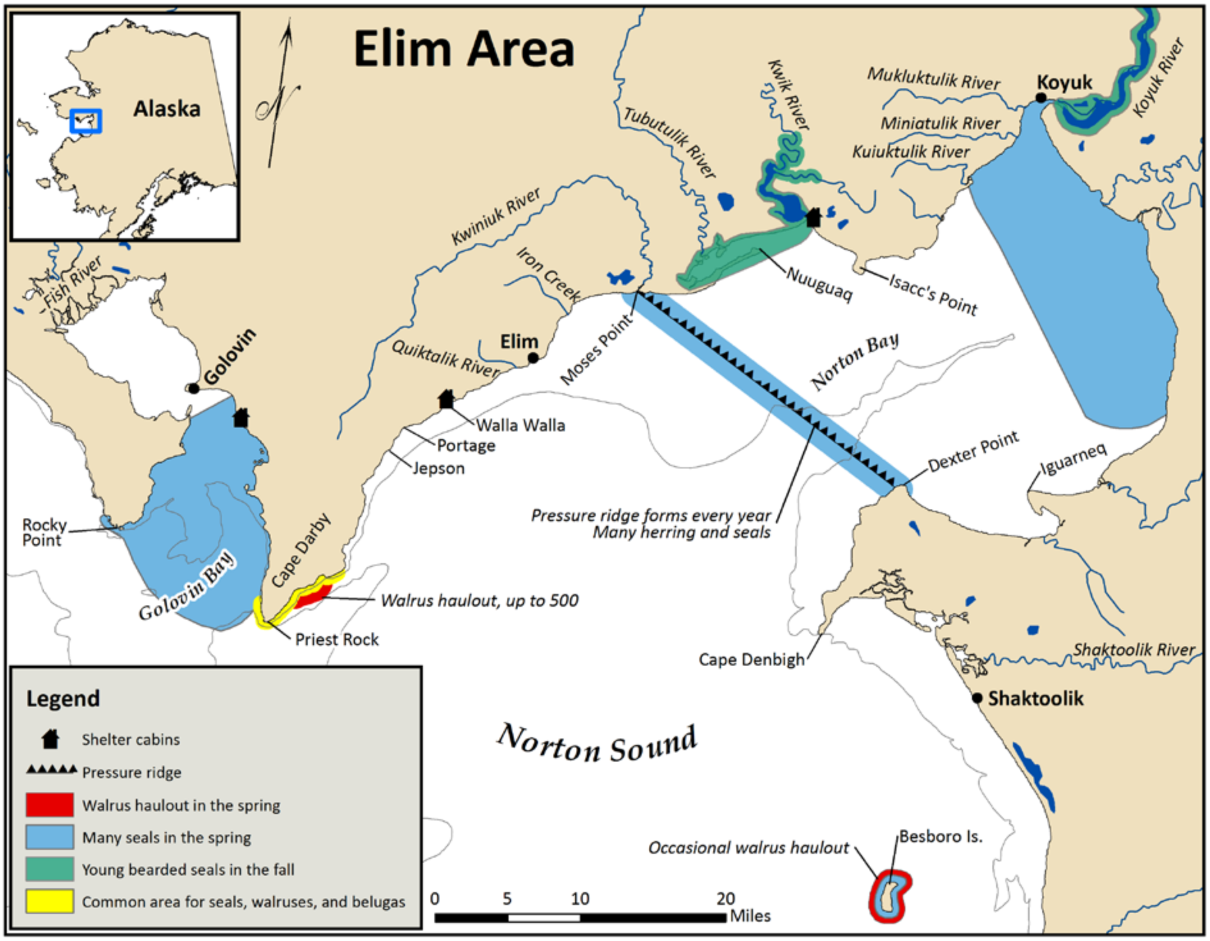
Appendix D.

Traditional Knowledge Regarding Ringed Seals, Bearded Seals, and Walrus near Elim, Alaska



Traditional Knowledge Regarding Ringed Seals, Bearded Seals, and Walrus near Elim, Alaska

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Introduction

Ringed seals and bearded seals are important species for subsistence harvests by Iñupiat and Yup'ik hunters from Elim, in northern Norton Sound, in western Alaska. Walrus are found and hunted in this area, too. These marine mammals are iconic Arctic animals, and at risk from climate change. Increasing industrial activity in the Chukchi Sea, coastal development in the Norton Sound region, and shipping through the Bering Strait are additional potential stressors to seal and walrus populations. A satellite telemetry study of the distribution, behavior, and movements of seals and walrus is an important contribution to monitoring the effects of a changing environment and the potential effects from industrial activity. While placing satellite transmitters on seals and walrus provides detailed information about the movements and some behaviors of individual animals, documenting traditional knowledge about seals and walrus, through interviews with residents of coastal communities, provides valuable complementary contemporaneous and historical information about the general patterns of each species.

This report summarizes information gathered from interviews with hunters and other knowledgeable residents in Elim, Alaska, in February 2015. This traditional knowledge project used the same approach that the Native Village of Savoonga used when documenting traditional knowledge about bowhead whales on St. Lawrence Island (Noongwook et al. 2007).

Previous projects on traditional knowledge of seals have been conducted, one under the Elim-Shaktoolik-Koyuk Marine Mammal Commission in 1999 (Huntington 2000) and another on walrus and ice seals conducted by Kawerak Inc., in 2010–2013 in communities throughout the Bering Strait region, including Elim (Kawerak, Inc., 2013). Except as noted below, the information presented here comes from our February 2015 interviews and not from either prior project. A compilation of results from all three projects may be carried out later, to document changes over time and other aspects of seals and walrus.

Methods

We used the semi-directive interview method, in which the interviewers raise a number of topics with the person being interviewed, but do not rely solely on a formal list of questions (Huntington 1998). Instead, the interview is closer to a discussion or conversation, proceeding in directions determined by the person being interviewed, reflecting his/her knowledge, the associations made between walrus and other parts of the environment, and so on. The interviewers use their list of topics to raise additional points for discussion, but do not curtail discussion of additional topics introduced by the person being interviewed.

In Elim, we interviewed eight people in one group. Those interviewed were Darlene Katchatag, Martin Murray, Charles Saccheus, and five others who wished to remain anonymous. The interview was conducted on February 3, at the Elim IRA Council office.

The topics identified by the research team in advance of the interviewers were:

Haulouts on land
Overwintering areas and behavior
Use of lagoons and rivers
Feeding patterns and prey

Differences between ringed and bearded seals
Impacts from climate change
Parts of seals that people eat

The results are presented under different headings, reflecting the actual information collected and the fact that some of the subjects blend together, especially changes seen over time in regard to all of the topics. The interviewers were Henry Huntington and Mark Nelson. Lori Quakenbush is the project leader.

Ringed Seals
In early spring, ringed seals will lie on the sea ice by the hundreds throughout Norton Bay and stay in the area until the ice starts to break up more in the later spring. A few areas hold higher numbers of seals throughout the year and especially during the spring; Besboro Island, Golovin Bay, upper Norton Bay, Rocky Point and around Cape Darby. There is a persistent pressure ridge that forms from Moses Point to Dexter Point during the winter and spring that also holds many ringed and bearded seals. The snow is not as deep now as it used to be and there are fewer seal dens on the ice because of it, but there are still lots of seal breathing holes noticed mostly by fishermen who go out on the ice to deploy their crab pots in spring between Elim and Cape Darby. Pressure ridges like the one from Moses Point to Dexter Point are important for breathing holes and denning habitat. Ringed and bearded seals have always wintered in Norton Bay, especially near the mouths of creeks where fish are plentiful.

Ringed seals are occasionally seen hauled out on the beach. Usually this is young seals in the spring. Ringed seals do not haul out in large groups like walrus and are much more solitary. Historically in the spring and summer seals were taken with nets for subsistence, but this is less common now with most hunters choosing to use a rifle and harpoon instead. When a ringed seal is caught alive they are generally easy to control as they do not bite people. They will use their powerful claws to scratch at a person though.

Ringed seals feed on mostly fish such as herring, capelin, tomcod, skipjack (smelt, cisco?), and sometimes shrimp. Herring are found in large numbers along the pressure ridges especially between Moses Point and Dexter Point where they are sometimes pushed out onto the ice and preyed on by seagulls.

Elim residents eat the blubber (oil), meat, heart, kidneys, liver, and intestines of ringed seals. Seal oil is very healthy, especially for brain development in children. Coastal residents trade seal oil with interior Indians. A seal taken in November yielded clear seal oil with little flavor, so salt had to be added to give it more flavor.

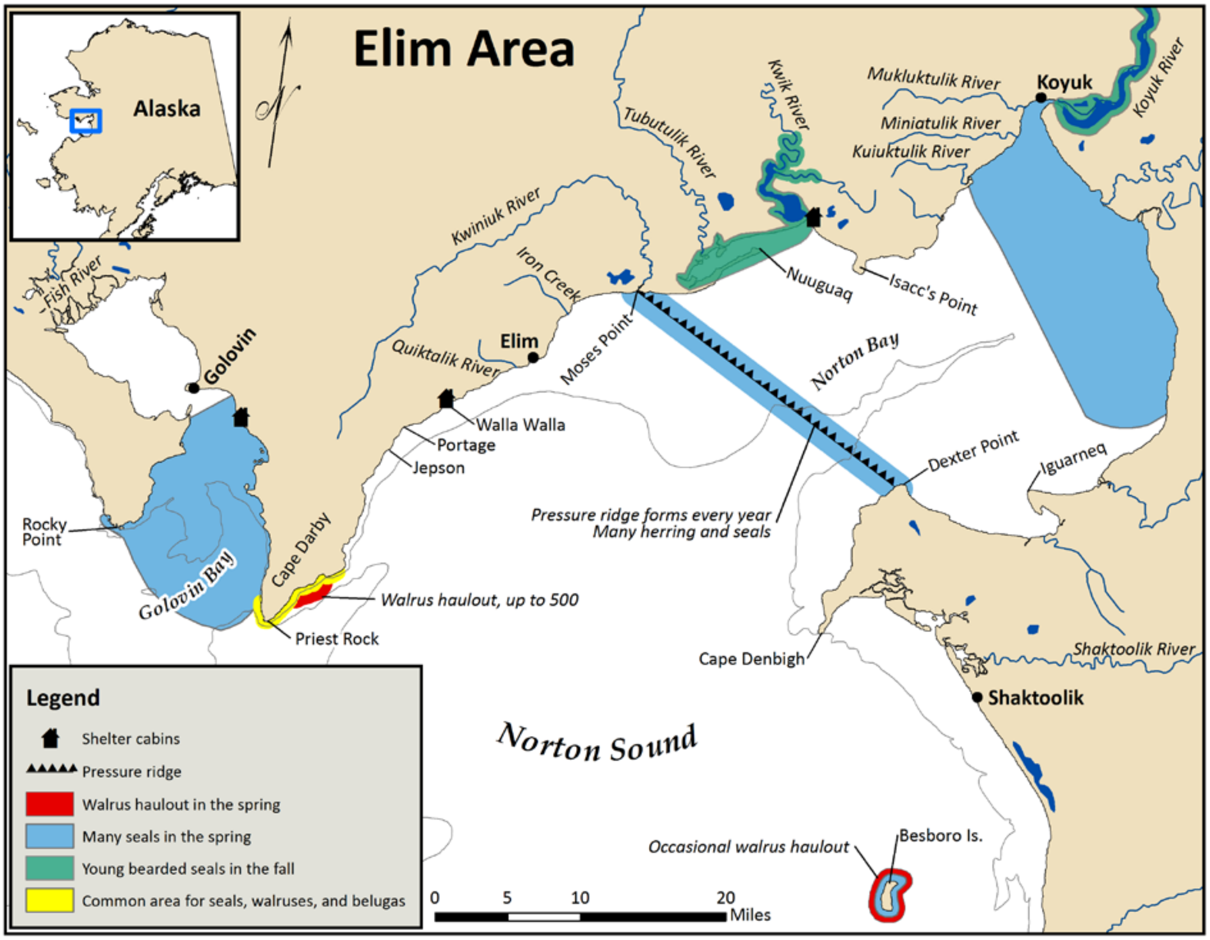

Figure 1. Movements and behavior of ringed seal, bearded seal, spotted seal, walrus, and beluga whales near Elim as described during traditional knowledge interviews, February 2015.

Bearded Seals

Bearded seals will haul out on the sea ice in spring, younger animals closer to shore on shorefast ice and older animals further out on the pack ice usually more than 15 miles from Elim. Young-of-the-year bearded seals will go up the Koyuk and Kwik Rivers in August and September. They eat clams, which can be found far upriver, and isopods. They are not found up the Tubutulik River, but can be seen in the lagoon at the mouth of the river. Adult bearded seals have been seen occasionally up the Kwik River, but not very often.

Bearded seals are more sensitive to noise than ringed or ribbon seals for example; if a ribbon seal on an ice floe is approached by hunters in a boat, it will flee away from the hunters across the floe, even if there is open water right next to it in the direction of the boat but bearded seals will dive into the open water instead. Hunters say that this behavior shows that bearded seals are much smarter and more wary than ribbon seals. Young bearded seals will fight back when caught in a net. They have long claws and will try to scratch a person, but they do not bite.

Bearded seals have clams, shrimp, and isopods in their stomachs. They do not have fish in their stomachs except for young bearded seals in rivers, they feed on whitefish. Old bearded seals have teeth that are worn down to the gums. Their blubber is yellow and yields yellow seal oil.

Elim residents eat the blubber (oil), meat, heart, kidneys, liver, and outer covering of the intestines of bearded seals.

Walrus

Walrus haul out occasionally on the east side of Cape Darby. This happens when there is no ice in Norton Sound. The walrus do not haul out on the west side of the Cape. There may be 500 or more walrus hauled out at a time. When there is no more room for walrus to haul out, other walrus will inflate their necks and float as they sleep, drifting in the current. After they drift a mile or two, they swim back to the haulout and repeat this behavior. There are sometimes some baby walrus in the haulout, in June. Walrus also haul out, though less frequently, on Besboro Island, in similar numbers to those seen at Cape Darby.

Walrus usually have clams in their stomachs. If the walrus has been on top of the ice for a while, the clams are partly digested. If the walrus has just hauled out on the ice after diving or still swimming, the clams will be fresh. These clams are ready to be cooked. Many people enjoy eating them.

Other Information

Qairaliq seals are no longer seen. These were described in the 1999 project (Huntington 2000) as small seals seen in April, May, and June, with thin skin that was useful for many purposes. The 1999 study reported that *qairaliq* seals came to the area in great numbers in the 1980s, but fewer were seen by 1999.

Elim hunters had no further information about *iigliq* seals, also reported in the 1999 study.

A bearded seal was once taken that had metal in the muscle near its ribs.

Green algae grows on the bottom of the sea ice, attracting fish. This has always happened.

In the summer of 2014 there were so many jellyfish they clogged fishing nets. The jellyfish were also larger than usual. Starfish taken in crab pots appeared to be eating jellyfish.

Small, pink krill are common throughout Norton Bay. They can be found under rocks and come to the surface with crab pots that are hauled up.

A few years ago, orange foam was found on the beaches throughout the area. The cause of this was not known and it only happened the one time.

Sea ice formed very late in the winter of 2014–15. There was a lot of open water near Unalakleet and even by Koyuk into December 2014. Beluga whales were seen swimming past Elim in January, being pursued by killer whales. It is very rare for belugas to be seen near Elim in January.

Belugas prefer to eat tomcod and shrimp, even if there are herring in the area. They also like salmon, which they eat all summer. Silver salmon in September are a favorite food of belugas. Belugas chase salmon and, when they are right behind the fish, give a blast of sound that stuns the fish, so the fish turns belly up. Then the beluga swallows the salmon whole.

Belugas can drown in a net in 10 minutes or less. They struggle, which uses up their air quickly. The belugas are used for subsistence and the lungs used to be fed to dogs. They feel spongy and were not eaten by people.

Spotted seals haul out in groups in many locations, including Rocky Point and have teeth like dogs. Spotted seals will bite people.

Animals carry their history, like human beings, including their own lives and the lives of their parents and grandparents. Animals have brains and spirits. It is essential to keep the ocean free and clean so that the animals can flourish and live healthy lives.

Concerns

Elim residents asked whether there have been any studies in the Nome area to determine if there are impacts from dredging and port construction. They expect more activity along the coastline of the region, and think it is important to learn what we can from the development that is occurring already. They pointed out that the dredging results in muddy water, which they expect affects marine mammals and other sea animals.

There is a lot more commercial crabbing in summer in the Norton Bay area now.

More hunters from other villages seem to be coming to the Norton Bay area to hunt.

Acknowledgements

We appreciate the support of the Eskimo Walrus Commission and the Ice Seal Committee for this project and are grateful to Charles Saccheus and Carol Nagaruk for helping to set up the group interview. The Bureau of Ocean Energy Management (BOEM) funded the work as part of Contract Nos. M09PC00027 and M13PC00015 and we appreciate the support of Charles Monnett, Catherine Coon, and Dan Holiday. Justin Crawford prepared the maps used during the interviews and the figures in this report.

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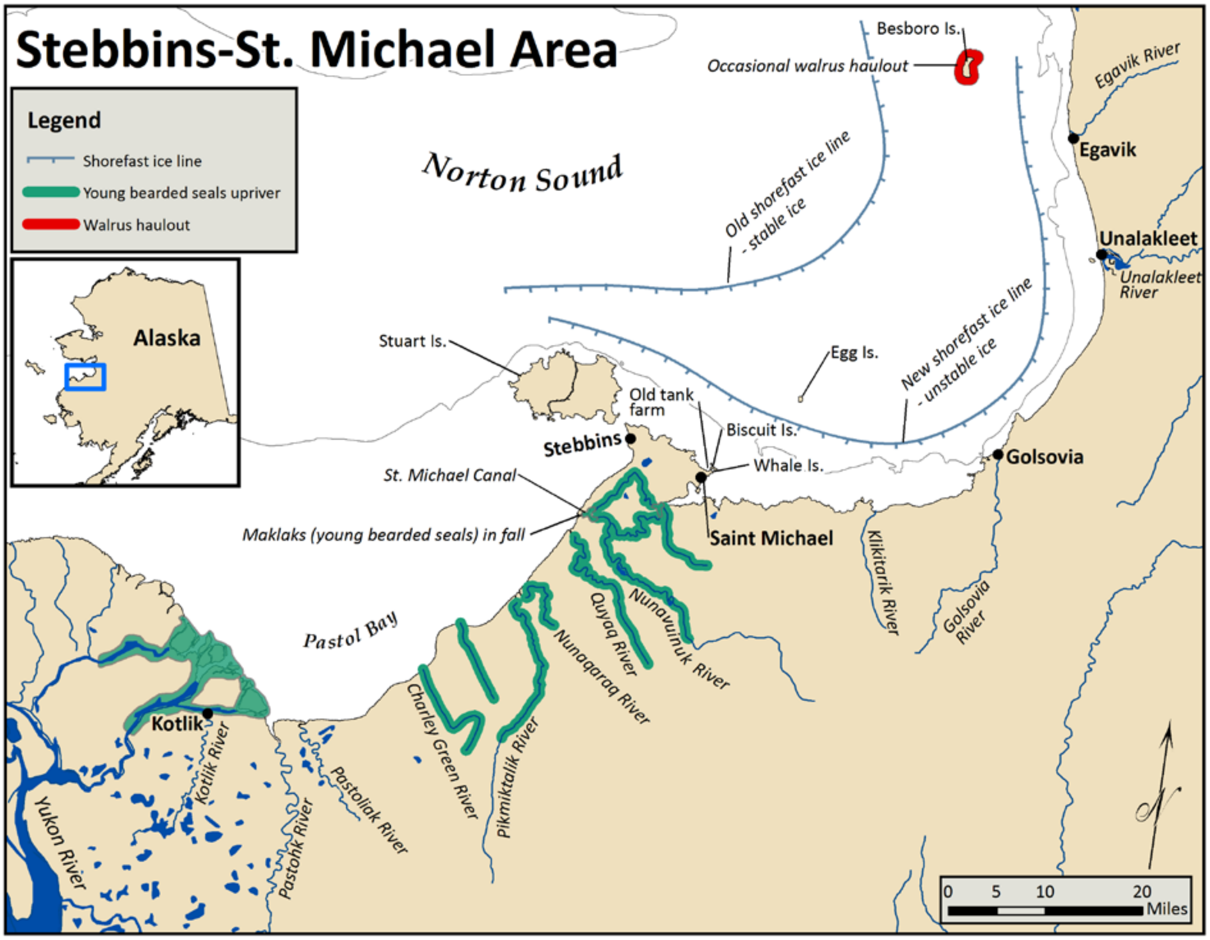
Traditional Knowledge Regarding Ringed Seals, Bearded Seals, and Walrus near St. Michael and Stebbins, Alaska



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Introduction

Ringed seals and bearded seals are important species for subsistence harvests by Iñupiaq and Yup'ik hunters from St. Michael and Stebbins in southern Norton Sound, Alaska. Walrus are found and hunted in this area, too. These marine mammals are iconic Arctic animals, and at risk from climate change. Increasing industrial activity in the Chukchi Sea, coastal development in the Norton Sound region, and shipping through the Bering Strait are additional potential stressors to seal and walrus populations. A satellite telemetry study of the distribution, behavior, and movements of seal and walrus is an important contribution to monitoring the effects of a changing environment and the potential effects from industrial activity. While placing satellite transmitters on seals and walrus provides detailed information about the movements and some behaviors of individual animals, documenting traditional knowledge about seals and walrus, through interviews with residents of coastal communities, provides valuable complementary contemporaneous and historical information about the general patterns of each species.

This report summarizes information gathered from interviews held in St. Michael with hunters and other knowledgeable residents from St. Michael and Stebbins in February 2015. This traditional knowledge project used the same approach that the Native Village of Savoonga used when documenting traditional knowledge about bowhead whales on St. Lawrence Island (Noongwook et al. 2007).

A previous project on traditional knowledge of walrus and ice seals was conducted by Kawerak Inc., in 2010–2013 in communities throughout the Bering Strait region, including St. Michael and Stebbins (Kawerak, Inc., 2013). Except as noted below, the information presented here comes from our February 2015 interviews and not from the Kawerak project. A compilation of results from the two projects may be carried out later, to document changes over time and other aspects of seals and walrus.

Methods

We used the semi-directive interview method, in which the interviewers raise a number of topics with the person being interviewed, but do not rely solely on a formal list of questions (Huntington 1998). Instead, the interview is closer to a discussion or conversation, proceeding in directions determined by the person being interviewed, reflecting his/her knowledge, the associations made between walrus and other parts of the environment, and so on. The interviewers use their list of topics to raise additional points for discussion, but do not curtail discussion of additional topics introduced by the person being interviewed.

In St. Michael, we interviewed eight people in one group. Those interviewed from St. Michael were Charlie Fitka, Harold T. Kobuk, Nick Lupsin, Alexander Niksik Jr., and two others that wished to remain anonymous. Two people from Stebbins were interviewed who wished to remain anonymous. The interview was conducted on February 4, at the St. Michael IRA Council office.

The topics identified by the research team in advance of the interviewers were:

- Haulouts on land
- Overwintering areas and behavior
- Use of lagoons and rivers
- Feeding patterns and prey
- Differences between ringed and bearded seals
- Impacts from climate change
- Parts of seals that people eat

The results are presented under different headings, reflecting the actual information collected and the fact that some of the subjects blend together, especially changes seen over time in regard to all of the topics. The interviewers were Henry Huntington and Mark Nelson. Lori Quakenbush is the project leader.

Ringed Seals

During the winter and spring there are many ringed seals near Stebbins and St. Michael. They maintain breathing holes in the shorefast ice and in the drifting pack ice. When it is sunny there will by many ringed seals hauled out on the ice, occasionally they make enough noise that they can be heard from town. Ringed seals start to leave when the ice diminishes in Norton Sound, but there are still a lot around during the herring runs in June. Ringed, bearded, and spotted seals all eat herring when they are spawning and their face and whiskers are sometimes covered with herring eggs when they surface to breath. Seals gain weight quickly during the herring run. Ringed seals also eat tomcod (i.e., saffron cod, *Eleginus gracilis*) and other fish, but also eat small shrimp, which are especially plentiful in the Golsovia area.

Ringed seals start sunning with the increasing light in February and by April have started pupping in their snow dens. The rutting males during this time have black faces, smell like gasoline, and are not hunted or eaten. These rutting males are called *tiigaq*.

Residents of St. Michael and Stebbins eat seal meat, blubber (oil), heart, liver, kidneys, intestines, and the spinal cord of ringed and bearded seals. Some people like to eat aged seal flipper, but this is not common anymore.

Some sick seals were seen in 2011, but not large numbers of them. One sick young ringed seal was seen on the beach in the summer of 2014. It did not flee when approached on a four-wheeler. A sick spotted seal was seen in the fall of 2014.

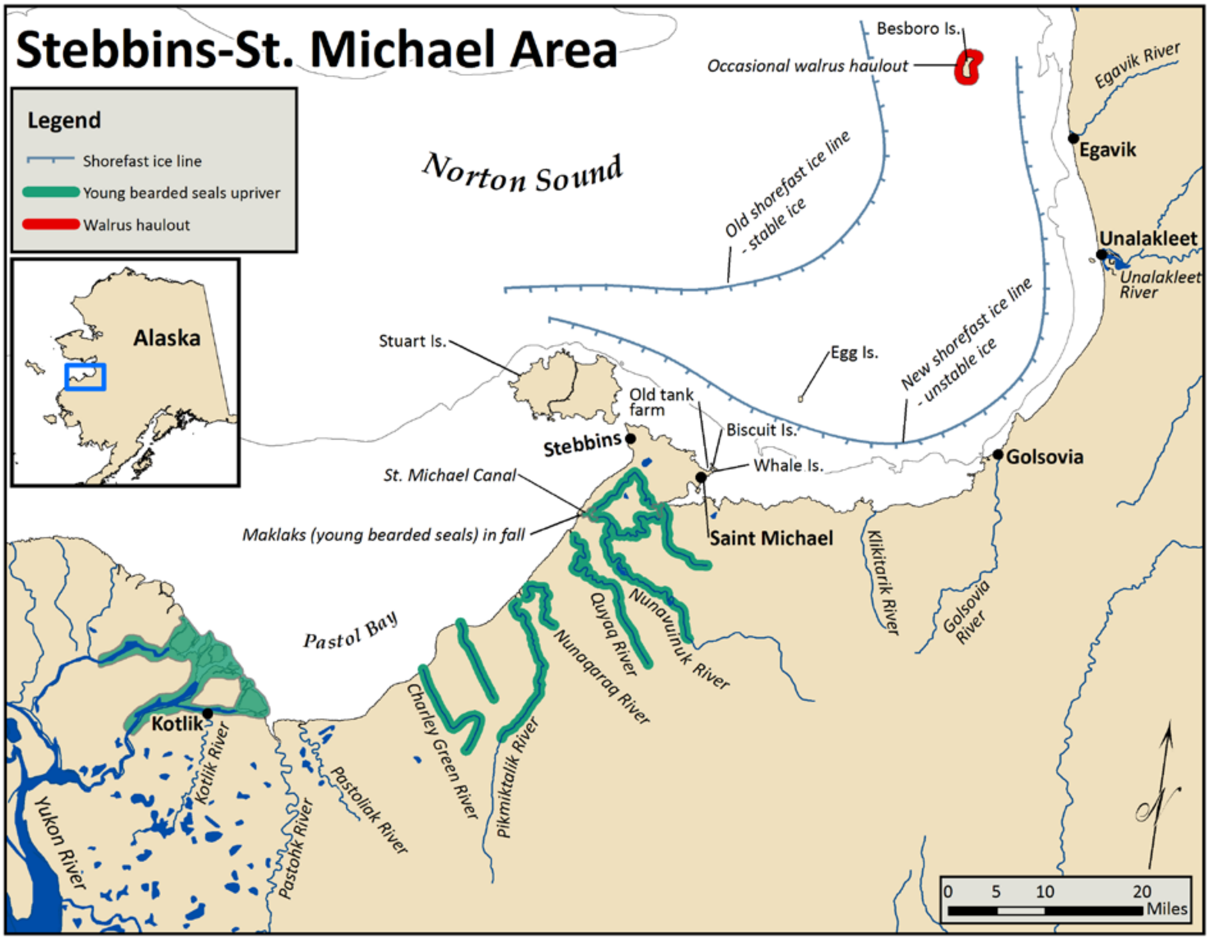

Figure 1. Movements and behavior of ringed seal, bearded seal, spotted seal and walrus near St. Michael and Stebbins as described during traditional knowledge interviews, February 2015.

Bearded Seals

Adult bearded seals are found farther away from the shore in winter and spring, than ringed seals. They are rarely seen near shore hauled out on shorefast ice, but are hunted around Whale Island. Young bearded seals are sometimes found up rivers, including the Yukon as well as smaller rivers around St. Michael and Stebbins. Older bearded seals and ringed seals are not seen in the rivers. Young bearded seals may haul out on riverbanks or mudflats but adult bearded seals are never seen on land.

Ugruq is the term for adult bearded seals; this is an Iñupiaq word. Hunters here also use the Yup'ik word *Omnigaq* for adult bearded seals. The Yup'ik word *maklak* is used for young bearded seals.

The size of adult bearded seals has decreased in recent years. In the past, hunters would see very large bearded seals off of Stuart Island that are believed to have come from farther north. More recently, it is more common to find bearded seals that are a little smaller than these very large ones.

Bearded seals eat whatever they can find farther out in the ocean: shrimp, crab, clams, and fish such as flounder. Some of the shrimp found in bearded seal stomachs are large, the size of a person's hand. When young bearded seals are in rivers they will eat whitefish and tomcod.

One hunter reported harvesting an *ugruq* with a white tissue around its liver. They described it to be white as paper and did not eat the liver, but did eat the meat and blubber.

Walrus

Walrus arrive in spring, hauled out on ice that is carried by currents. They are usually farther from shore, for example near Egg Island. The walrus include bulls, cows, and calves. Walrus are not often seen on land around Stebbins or St. Michael, but occasionally one or two will haul out on Egg Island and Whale Island; one of the small islands just north of St. Michael. One walrus swam up the Yukon River as far as Pilot Station (~120 miles) and stayed in the Pitka's Point (~100 river miles from coast) area for a while. Other walrus have been seen near the mouth of the Yukon and also in St. Michael and Little St. Michael Canal in fall. Even though living walrus are not seen very often, dead walrus wash up on shore regularly in the spring when the currents are just right.

Walrus cows will search for their calves when they become separated. The cows can find the calves when this happens.

St. Michael and Stebbins residents eat the meat, blubber, heart, and liver of walrus. They do not eat the kidney or intestines and only occasionally eat the clams from walrus stomachs.

Sea Ice

The ice has changed greatly and rapidly in the past two decades. In the 1970s and 1980s, the shorefast ice extended out to Egg Island. Hunters could travel over the ice to Egg Island or to Golsovia. Today the shorefast ice extends only a few miles from shore and it is not possible to travel that far on the ice. The ice is also thinner and breaks off more easily, making conditions more dangerous. The ice used to form large pans, but now it is more crumbled up.

In the winter of 2014–15, the ice did not freeze near Stebbins until December. The ice was only a few inches thick when it went out again. There was rain in January, and the ice remains thin and unstable.

Other Information

There are fewer spotted seals in this area since the ice started changing in the 1990s and 2000s. Spotted seals may be seen on the ice near shore during the fall and spring. Steller sea lions, gray whales, and humpback whales are rare occurrences in the area and may scare away other animals when they are around. There used to be puffins in the St. Michael/Stebbins area, but they are no longer seen here.

There used to be commercial beach seiners operating in this area during herring season. They would sometimes snag buoys and anchors belonging to St. Michael and Stebbins residents, which was not popular. This fishery is no longer being conducted.

The water level is higher in summer now than it used to be. There is more algae, and the fish are changing, too. Some St. Michael residents caught what they thought were chum salmon, but which turned out to be another kind of fish. Another fisherman caught two chum salmon a couple years ago, but they smelled like gas when his wife cut their heads off.

The old St. Michael village fuel tank farm may have affected seals. There are fewer seals around there now than there used to be. The tank farm has been moved to the west end of the village now.

Acknowledgements
We appreciate the support of the Eskimo Walrus Commission and the Ice Seal Committee for this project and are grateful to Alexander Niksik Jr. for helping to set up the group interview. The Bureau of Ocean Energy Management (BOEM) funded the work as part of Contract Nos. M09PC00027 and M13PC00015 with the support of Charles Monnett, Catherine Coon, and Dan Holiday. Justin Crawford prepared the maps used during the interviews and the figure in this report.

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Appendix F.

Hunter-assisted study on ringed and bearded seal movements, habitat use, and traditional knowledge

Mark A. Nelson[1], Lori Quakenbush[1], Merlin Henry[2], Alexander Niksik[3], Albert Simon[4], John Goodwin[5], Alex Whiting[5], Kathy Frost[6], and Justin Crawford[1]

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Alaska Marine Science Symposium, 25–29 January 2016, Anchorage AK

Ringed (*Pusa hispida*) and bearded (*Erignathus barbatus*) seals depend on sea ice for pupping, nursing, molting, and resting. In Alaska, these seals are found in the Bering, Chukchi, and Beaufort seas and are important subsistence species used by Alaska Natives for food, oil, clothing, and handicrafts. Changes in the timing and extent of sea ice have increased access to the Arctic, increasing the need to plan shipping lanes, oil and gas lease sales, and develop mitigation measures to minimize effects on seals. Our understanding of important seal habitats and the timing and magnitude of movements by species, sex, and age, however, is limited. Expanding upon a cooperative satellite-tagging study with hunter-taggers and biologists in Kotzebue Sound that tagged more than 70 ringed and bearded seals, this study works with hunter-taggers from other regions in widely spaced villages to better understand range and timing of movements, relationship with sea ice, important habitats, and degree of seasonal site fidelity and minimize the effects of one tagging location. In 2014 and 2015, hunter-taggers from Kotzebue, Koyuk, St. Michael, and Hooper Bay captured, tagged, and released 12 bearded seals and six ringed seals. In 2014, four ringed seals and one bearded seal tagged in Kotzebue Sound spent the winter in Kotzebue Sound (2 ringed and 1 bearded) and Norton Sound (2 ringed). Two of three bearded seals tagged in Norton Sound in 2014 spent the winter there while one wintered in the Bering Sea. In 2015, three of eight bearded seals tagged in August in Norton Sound moved north into the Chukchi Sea, a fourth spent time due west in Mechigmenan Inlet (Russia), a fifth moved south to near St. Paul Island, and the remaining three stayed in Norton Sound. Local and traditional knowledge is also important to understand how seals respond to changing sea ice conditions. We met with hunter-taggers and other subsistence users in Barrow, Elim, St. Michael, and Stebbins to document historic seal behavior and recent changes. Future plans include training more hunter-taggers, and documenting more local and traditional knowledge to better understand how seals are responding to their changing environment.

Appendix F.

Hunter-assisted study on ringed and bearded seal movements, habitat use, and TEK

Mark A. Nelson[1], Lori Quakenbush[1], Merlin Henry[2], Alexander Niksik[3], Albert Simon[4], John Goodwin[5], Alex Whiting[6], Kathy Frost[7], and Justin Crawford[1]

[1] Alaska Department of Fish and Game, Fairbanks, Alaska, Mark.Nelson@alaska.gov, [2] Seal hunter and resident of Koyuk, Alaska; [3] Seal hunter and resident of St. Michael, Alaska; [4] Seal hunter and resident of Hooper Bay, Alaska, [5] Seal hunter and resident of Kotzebue, Alaska, [6] Native Village of Kotzebue, Alaska, [7] School of Fish and Ocean Science, Fairbanks, Alaska

Introduction

Ringed (*Pusa hispida*) and bearded (*Erignathus barbatus*) seals are called "ice seals" because they use sea ice for pupping, nursing, molting, and resting. In Alaska, these seals are found in the Bering, Chukchi, and Beaufort seas. They are important subsistence species used by Alaska Natives for food, oil, clothing, and handicrafts. The timing and extent of sea ice have increased access to the Arctic, increasing the need to plan shipping lanes, oil and gas lease sales, and to develop mitigation measures to minimize these effects on seals, but understanding how these changes will affect ice seals and their habitat is less clear. Cooperative hunter-biologist satellite-tagging studies are increasing our understanding of important seal habitats, seasonal movements, use of sea ice including haul out behavior, and seasonal site fidelity. This project builds on past studies by tagging seals at several widely-spaced locations and by incorporating traditional knowledge.

Objectives

Work with seal hunters to:

- capture and tag ringed and bearded seals;
- document ice seal habitat use and movement; and
- gather and document local and traditional knowledge.

Activities

2014

- Seal hunters were trained to tag seals with satellite-linked transmitters in Norton Sound, Hooper Bay, and Kotzebue.
- Hunter-taggers determined when and where to capture seals using local knowledge.
- Four ringed and one bearded seal were tagged near Kotzebue in June (Fig. 1).
- Three bearded seals were tagged near Koyuk in September (Fig. 1).

2015

- Traditional knowledge was collected in Barrow, Elim, St. Michael, and Stebbins in January and February. See results in Poster 103 (Row 10).
- The Ice Seal Committee (ISC) brought hunters from the North Slope, Northwest Arctic, Bering Strait, Yukon-Kuskokwim Delta, and Bristol Bay together in March to learn how to deploy satellite tags on seals.
- One ringed seal was tagged near Hooper Bay in May (Fig. 1).
- Four bearded seals were tagged near Koyuk in August (Fig. 1).
- One ringed and four bearded seals were tagged near St. Michael in August (Fig. 1).

Norton Sound

Alex Niksik prepares to release a bearded seal near St. Michael.

Palsson Fitka and Alex Niksik releasing a bearded seal.

Merlin Henry prepares to release a tagged bearded seal near Koyuk.

Young bearded seals look toward the water upon release.

Hooper Bay

Albert Simon II prepares to tag a ringed seal near Hooper Bay.


Albert Simon and Evan Napoleon looking for seals near Hooper Bay.

Kotzebue Sound

John Goodwin and crew search for bearded seals in Kotzebue Sound.

Hunter-tagger Training

The training was funded by the ISC, with assistance from ADF&G, NSB, and NMML.

Movements of tagged seals

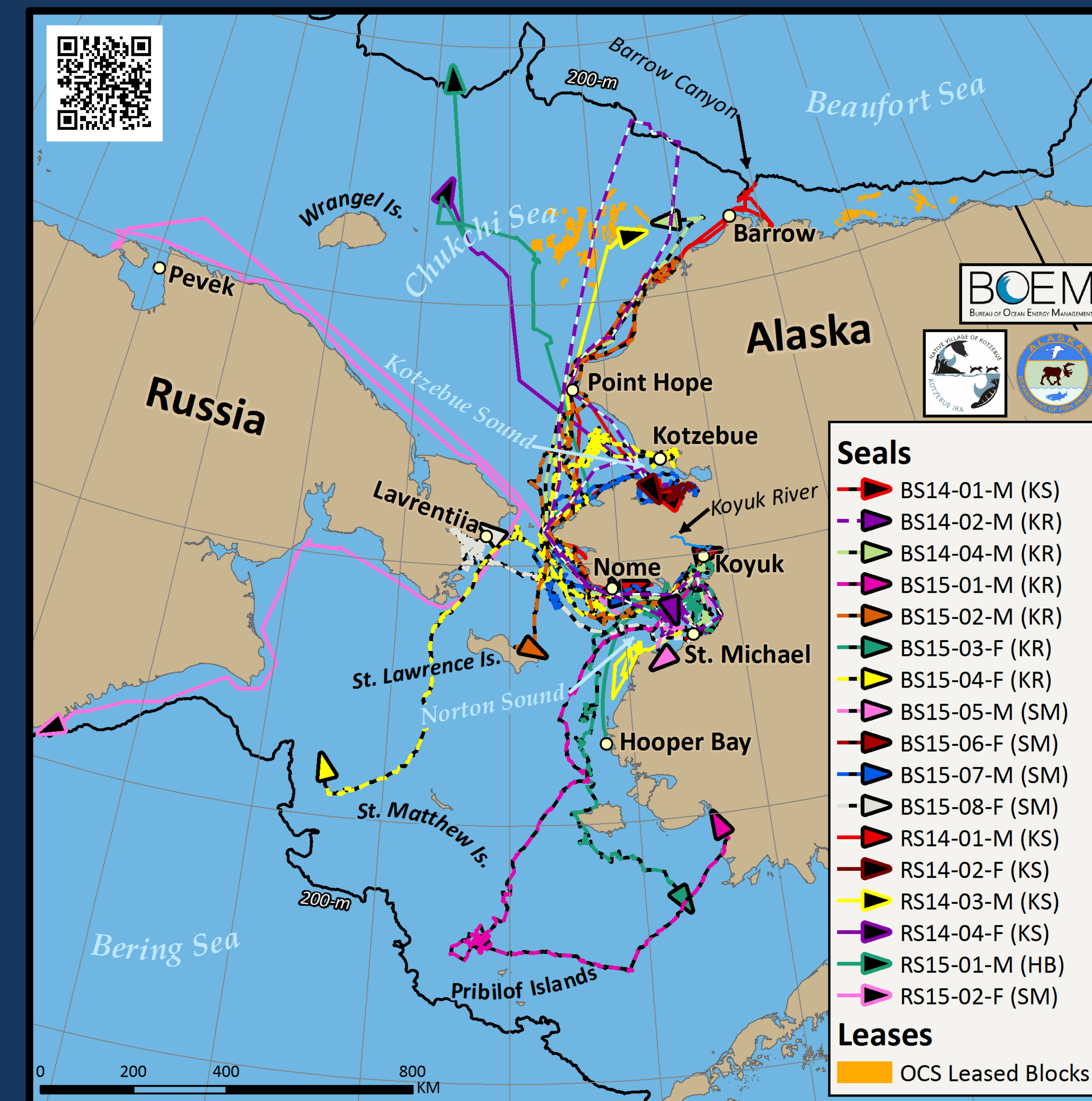

Figure 1. Movements of seals tagged during 2014 and 2015 near Kotzebue Sound (KS), Koyuk River (KR), St. Michael (SM), and Hooper Bay (HB).

Future plans

- Continue to work with trained hunter-taggers and with new hunters and communities.
- Conduct workshops to document local and traditional knowledge to better understand seal movements in response to changing sea ice.

Acknowledgements

This project is funded by the Bureau of Ocean Energy Management. We appreciate the assistance of all the hunter-tagger crews; Albert Simon II, Palsson Fitka, Denali Whiting, Edward Ahyakak, Edwin Kotangan Jr., Frank Garfield, Gordon Eakon, Henry "Boyuk" Goodwin, Allen Stone, and Pearl Goodwin. Research on ice seals was conducted under permit #15324 issued to the Alaska Department of Fish and Game by the National Marine Fisheries Service and under an approved ADF&G Animal Care and Use Committee Protocol #2014-03 and 2015-25.

Appendix G.

Changing Sea Ice, Marine Mammals, and Subsistence Hunters in Northern Alaska

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Marine mammals are important sources of food for indigenous residents of northern Alaska. Changing sea ice patterns affect the behavior of animals and thus the success of hunters. Documenting the traditional knowledge of Iñupiaq and Yup'ik hunters concerning marine mammals and sea ice makes a wide range of information and insight relevant to ecology, conservation, and human activity accessible. We interviewed hunters in villages from the northern Bering, Chukchi, and Beaufort seas about the movements and behaviors of bowhead whales, walruses, and ice seals (ringed, bearded, spotted, and ribbon seals). Information gathered through the interview process is combined with movements of animals from tracking data (i.e., satellite telemetry), from three different projects funded by the Bureau of Ocean Energy Management, to provide a more complete picture than either method would alone. Hunters reported extensive changes in sea ice, with resulting effects on the timing of migrations, the distribution and behavior of the animals, and the efficacy of certain hunting practices. For example, it has become increasingly difficult to find ice thick enough to support a bowhead whale for butchering and seal hunters must hunt earlier in the spring for seals due to a the rapid break-up and retreat of sea ice. While many changes are limiting, some expand opportunities; St. Lawrence Island can now hunt bowhead whales in winter as well as spring. Hunters acknowledged the positive changes of technological advances, such as more powerful and efficient outboard engines, that have increased their hunting range. Effects of changes, such as increased shipping traffic and oil and gas development are still largely unknown but have the potential to be negative. Continued environmental changes, increased disturbance from human activity, and how marine mammals respond to these changes will likely further challenge the ability of hunters to secure food for their communities. Iñupiaq and Yup'ik hunters, however, are well known for their innovation and flexibility, which may be tested while adjusting to the rapid changes.

Appendix G.

The Effects of Changing Sea Ice on Marine Mammals and their Hunters in Northern Alaska

Henry P. Huntington[1], Lori Quakenbush[2], and Mark Nelson[2]

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Overview

Marine mammals are important sources of food for indigenous residents of northern Alaska. Changing sea ice extent and thickness may affect the behavior of animals and thus the success of hunters. Documenting the traditional knowledge of Iñupiaq and Yup'ik hunters concerning marine mammals and sea ice makes a wide range of information and insight relevant to ecology, conservation, and human activity. We interviewed hunters in villages from the northern Bering Sea to the Beaufort Sea about bowhead whales, walruses, and ice seals, (ringed, bearded, spotted, and ribbon). Traditional knowledge is the product of careful, systematic observation of the environment, confirmed by repeated observation or comparison with the observations of others. This knowledge is shared among hunters through stories and conversation, and treated with care and attention, including attributing the observations and interpretations to the individuals who made them (Noongwook et al. 2007). We documented observations of the migratory and local movements of marine mammals, feeding and reproductive behavior, predation, habitat use, response to disturbance including human activity, and other aspects of the life history and ecology of these animals.

Methods

- We used the semi-directive interview method to collect traditional knowledge from subsistence hunters and community members (Huntington 1998).
- We interviewed people from 11 communities between 2007 and 2016 (Table 1).
- After the interviews, we prepared a draft report that was reviewed and approved by all the participants.
- The final report was prepared after all the comments had been addressed.

Table 1. Summary of interviews
* data pending participant approval and not presented here

Community	Year	Species Focus	No. of Participants
Kaktovik	2007	Bowhead whales	6
Barrow	2007	Bowhead whales	6
Wainwright	2008	Bowhead whales	7
Point Lay	2011	Walrus	5
Wainwright	2011	Walrus	13
Point Hope	2013	Walrus	8
Barrow	2015	Walrus and ice seals	10
Elim	2015	Ice seals and walrus	8
St. Michael & Stebbins	2015	Ice seals and walrus	8
*Shishmaref	2016	Ice seals	5
*Kotzebue	2016	Ice seals	6
*Kivalina	2016	Ice seals	5
Total 11 communities	6 years	7 species	87 participants

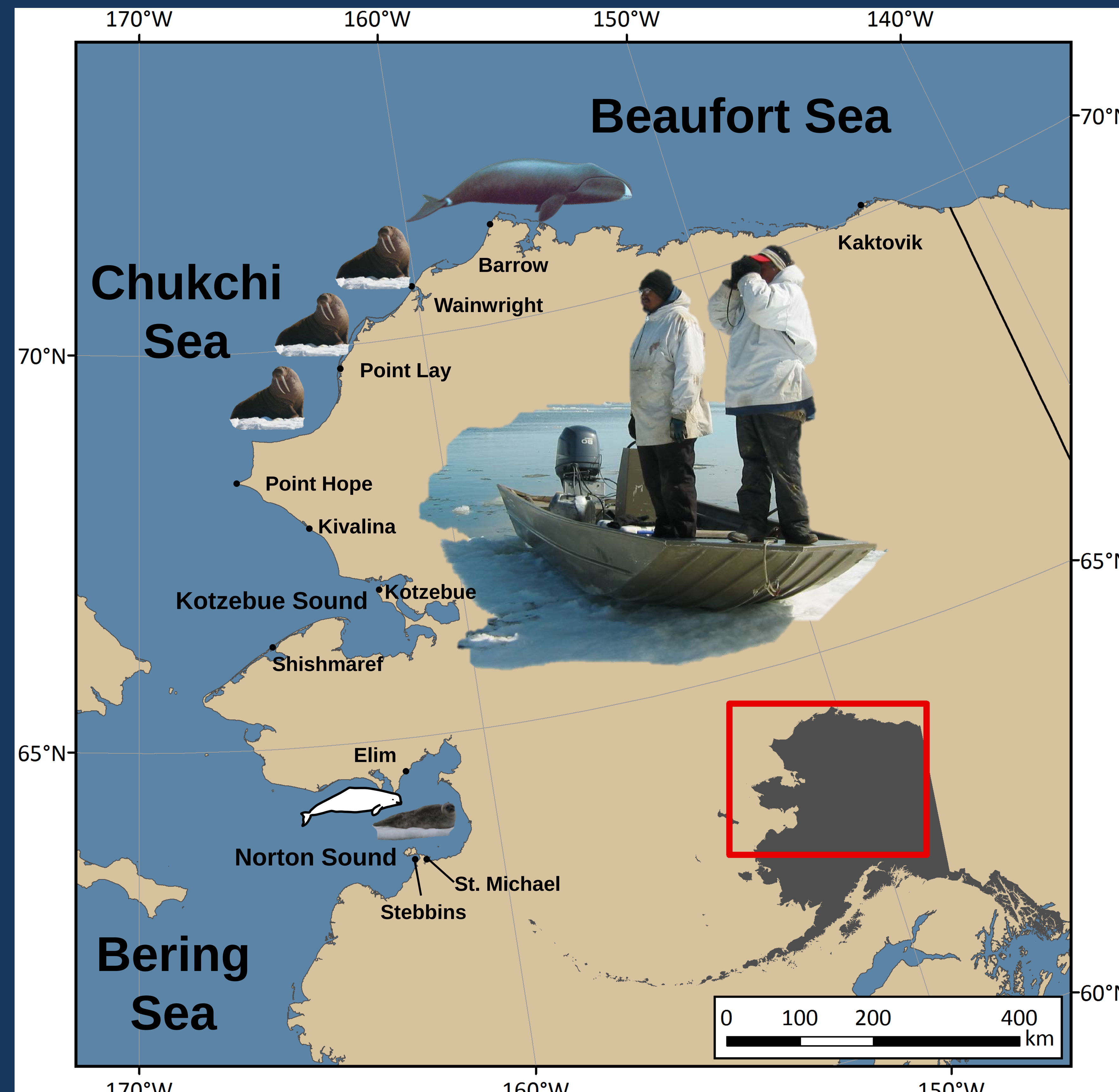

Figure 1. Map of study area and participating communities. Icons correspond to detailed observations about walruses, ice seals, and beluga and bowhead whales.

General Observations
(Recorded in many communities)

- Ice seals are available for a shorter period of time.
- In the past, pack ice came and went all summer, but now retreats from shore and does not return until freeze-up.
- Because of thinner sea ice, it is harder to find a place to haul a bowhead whale onto ice for butchering.
- Hunting and traveling is more dangerous because of thinner ice in winter and spring.
- More efficient boat motors enable hunters to travel farther to retreating ice.
- Less sea ice and bigger storms reduce the number of good hunting days.
- Increased oil and gas activity and greater shipping traffic are concerns; impacts to subsistence are still unknown but potentially large.
- Hunters have adjusted to changing sea ice by hunting earlier in the spring and later into the fall and winter to get what they need.

Specific Observations
(Recorded in one or two communities)

Beluga whales (*Delphinapterus leucas*) and killer whales (*Orcinus orca*) were seen near Elim in Norton Bay in January 2015, when ice was unusually late in forming (Figure 1).

Walrus are hauling out on land near Point Lay by the tens of thousands. Walrus hauled out on land many times in the past century but in smaller groups.

There is less snow on the sea ice in Norton Sound, reducing the habitat available for seal dens; however, there are still many breathing holes in the ice in spring.

Thinner shorefast ice off of Barrow has shifted spring feeding areas and the distribution of bowhead whales, so that few are now seen along the ice edge to the southwest of the community, which used to be a good hunting area.

Snowmachine noise near Barrow may be changing migration patterns away from shorefast ice.

Conclusions

Our findings are consistent with other recent studies of traditional knowledge and marine mammals in the region (e.g., Noongwook et al. 2007, Galginaitis 2013, Huntington et al. 2013, Kawerak 2013, Voorhees et al. 2014), which note both the responses of marine mammals to changing conditions and the innovations of hunters to shifts in timing, distribution, and behavior of the animals they seek. In these studies, and in ours, hunters emphasized that the impacts to animals and people are a result of the interactions among many factors rather than to changing sea ice acting alone.

Acknowledgements

We appreciate the skill, expertise, and generosity of the 87 hunters who participated in the interviews, and the communities and Tribal Councils of Kaktovik, Barrow, Wainwright, Point Lay, Point Hope, Elim, Stebbins, St. Michael, Shishmaref, Kotzebue, and Kivalina that facilitated this work. We also thank the Alaska Eskimo Whaling Commission, the Eskimo Walrus Commission, and the Ice Seal Committee for their support and guidance. We are grateful to the Bureau of Ocean Energy Management, the Minerals Management Service, ConocoPhillips, and the Coastal Marine Institute for funding.

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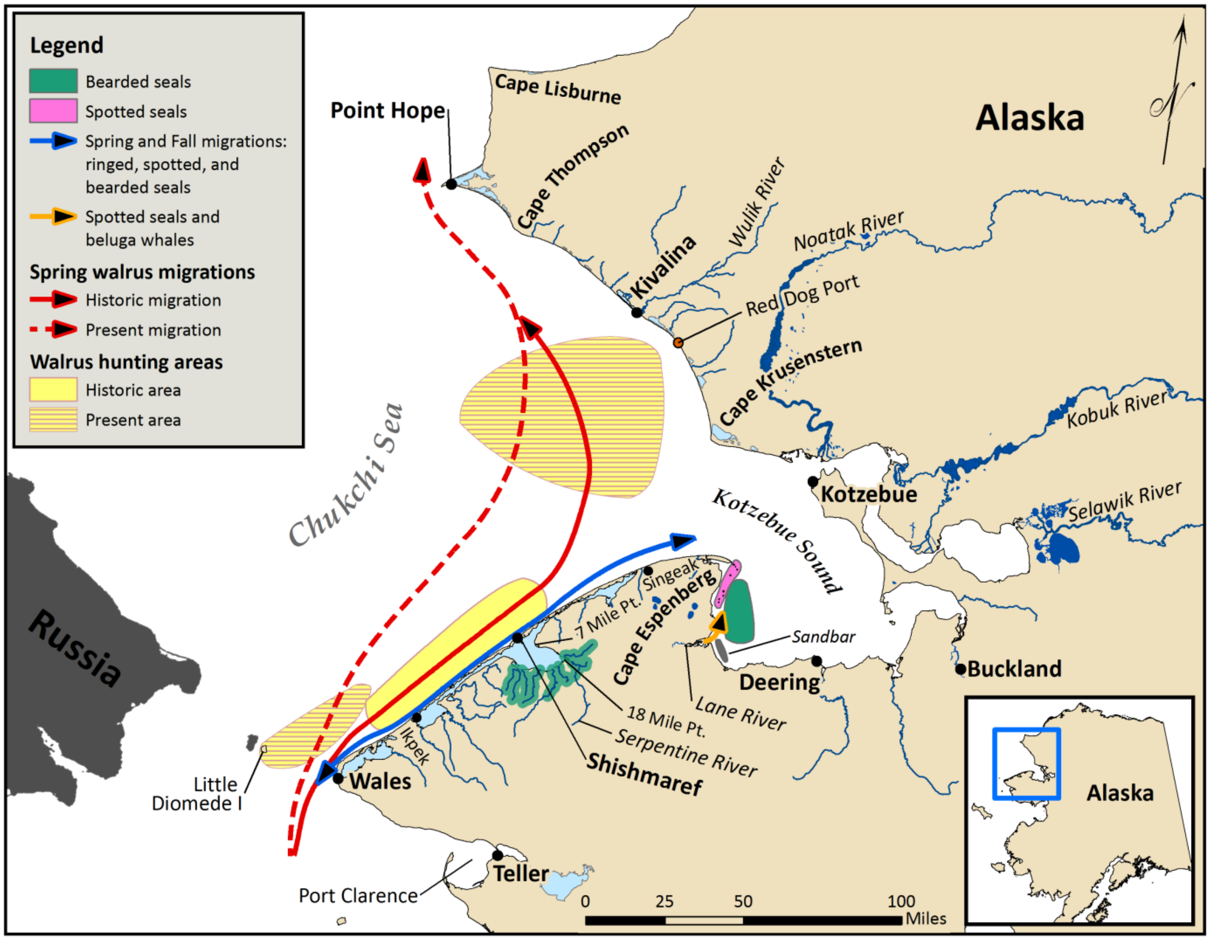
Traditional Knowledge Regarding Ringed Seals, Bearded Seals, and Walrus near Shishmaref, Alaska



Traditional Knowledge Regarding Ringed Seals, Bearded Seals, and Walrus near Shishmaref, Alaska

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Final Report
Approved July 2016

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Introduction

Bearded seals, spotted seals, and ringed seals are important species for subsistence harvests by Iñupiat hunters from Shishmaref (population 579), on the northern coast of the Seward Peninsula, in the Chukchi Sea coast, just north of Bering Strait in Alaska. Walrus are found and hunted in this area, too. These Arctic marine mammal populations are at potential risk from climate change, increasing industrial activity, coastal development, and shipping through Bering. Scientific studies of distribution, behavior, movements, and habitat use of seals and walrus have made important contributions to understanding the effects of a changing environment and the potential effects from industrial activity. For example, placing satellite transmitters on seals and walrus provides detailed information about the movements and some behaviors of individual animals. Documenting traditional knowledge about seals and walrus, through interviews with residents of coastal communities, however, provides valuable complementary current and historical information about the general patterns of each species.

This report summarizes information gathered from interviews with hunters and other knowledgeable residents in Shishmaref, Alaska, in January 2016. This traditional knowledge project used the same approach that the Native Village of Savoonga used when documenting traditional knowledge about bowhead whales on St. Lawrence Island (Noongwook et al. 2007).

Methods

We used the semi-directive interview method, in which the interviewers raise a number of topics with the person being interviewed, but do not rely solely on a formal list of questions (Huntington 1998). Instead, the interview is closer to a discussion or conversation, proceeding in directions determined by the person being interviewed, reflecting his/her knowledge, the associations made between walrus and other parts of the environment, and so on. The interviewers use their list of topics to raise additional points for discussion, but do not curtail discussion of additional topics introduced by the person being interviewed.

In Shishmaref, we interviewed five people, three in one group and two individually. Those interviewed were Glenn Nayokpuk, William Olanna, Bert Iyatunguk, Fred Weyiouanna, and Morris Kiyutelluk. The interviews were conducted on January 4 and 5, in the homes of the interviewees and at the Shishmaref IRA Council office.

The topics identified by the research team in advance of the interviewers were:

Haulouts on land
Overwintering areas and behavior
Use of lagoons and rivers
Feeding patterns and prey
Differences between ringed and bearded seals
Impacts from climate change
Parts of seals that people eat

The results are presented under different headings, reflecting the actual information collected and the fact that some of the subjects blend together, especially changes seen over time in regard to all of the topics. The interviewers were Henry Huntington and Mark Nelson. Lori Quakenbush is the project leader.

General Observations

In spring, bearded seals come first, followed by walrus, and then spotted seals. When the spotted seals are plentiful near Shishmaref, hunters know the bearded seal season is over, unless they go most of the way to Kotzebue to catch up to them. Today, the changing climate is shortening the time separating the migrations and they are blending together such that bearded seals and walrus may arrive at the same time.

Animals are arriving earlier in spring than they used to, and the spring season is over sooner. It used to be that duck hunting came before bearded seal hunting, but now bearded seal hunting takes place at the same time as duck hunting. Eggs and berries also come earlier than they used to.

Seals are not common around Shishmaref in summer, from about July to September. They are at Cape Espenberg and in Kotzebue Sound.

In fall, there are more seals in the Shishmaref area than there used to be.

Sea ice breaks up earlier than it used to and freezes much later. This winter (2015-16), there was open water on the ocean until Christmas, when it usually freezes by November. The ice is thin and dangerous much of the time, not solid and reliable as it once was in winter. There are no large pressure ridges to hold the ice in place, so in spring the ice will break up quickly and be dangerous to travel on.

Seals feed on herring and salmon, which are plentiful in the Shishmaref area.

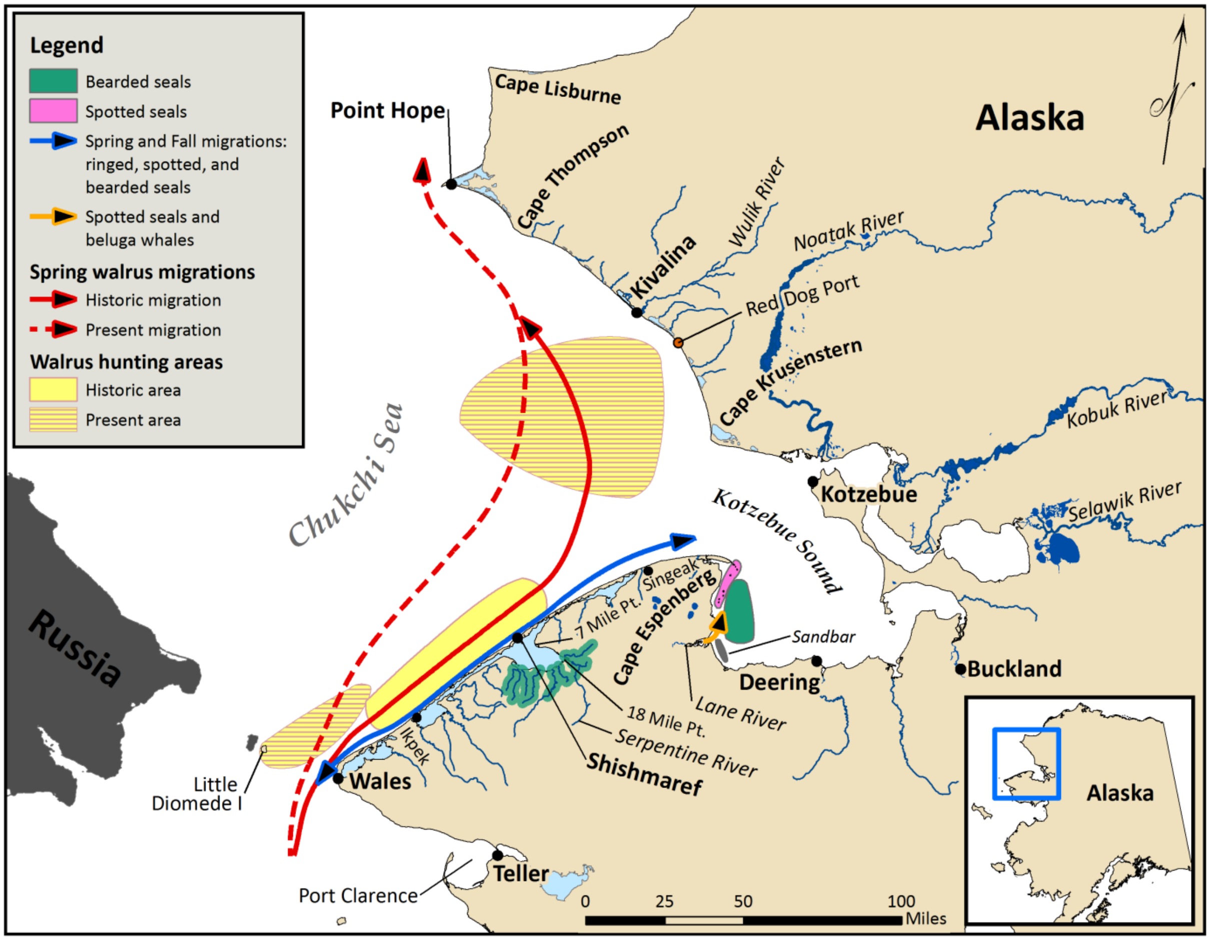

Figure 1. Movements and behavior of bearded seals, spotted seals, ringed seals, walrus, and beluga whales as described during traditional knowledge interviews, January 2016.

Bearded Seals

Bearded seals are the main source of food for Shishmaref residents. Bearded seal oil and meat are a typical winter meal. Bearded seals are hunted mainly in spring, from the shorefast ice or in the pack ice when boating is possible.

In spring, bearded seals migrate closer to the shore and the village than they used to. Hunters do not have to travel as far, unless they are held on shore because the sea ice is piled up against the land. In those years, hunters may have to travel very far, sometimes to northern Kotzebue Sound, in pursuit of bearded seals.

Young bearded seals (unmiaq) migrate north with the adults, but migrate back south slightly ahead of the adults. Unmiaq's are also found up rivers in summer, especially the Serpentine River and occasionally in smaller rivers and tributaries. They are likely feeding on salmon.

Bearded seals return to the Shishmaref area in late fall, when slush ice starts to form on the ocean. In spring, the bearded seals surface often as they migrate past the village. In fall, they travel differently, surfacing infrequently and moving fast.

One fall during the slush ice period, one hunter saw one pan of sea ice full of spotted seals and another pan nearby that was full of bearded seals.

In recent years, since the Fukushima nuclear reactor breach in 2011, hunters have seen many diseased animals, with sores around their flippers and back end, with white livers, and with bald spots or even with no hair at all. The hair can feel like sandpaper instead of being smooth, and in fall it may come out easily when it should be firmly attached to the skin. In 2015, there were more sick seals than in 2014.

Hunters once found a worm in a bearded seal's liver, most likely a liver fluke. The animal appeared healthy otherwise, though its blubber was yellow-orange.

In spring 2015, after the sea ice broke up, hunters caught a young bearded seals (*unmiaq*) but found that it was covered with white spots. This was something different from the hair loss hunters were familiar with. Hunters do not like to eat diseased animals. One hunter's grandmother told him not to eat seals that have no hair where they are supposed to have hair. Many hunters do not even want to touch animals that appear severely ill.

Bearded seals in fall also showed signs of disease. Diseased seals of all species are typically thin, with little blubber, and do not dive right away or stay down for long. One seal did not dive until three shots were fired at it. Healthy seals dive right away and can stay down for a long time.

People in Shishmaref eat the oil, meat, liver, intestines, kidneys, heart, and lungs of bearded seals. The blubber is rendered into oil. Meat is dried and stored in oil. Liver is cooked and then stored in oil. Intestines are dried, cooked, and stored in oil. Lungs are half-dried and then eaten. They can become hard as wood if left too long. Flippers are hung up with the drying meat until they become tasty. In the old days, seal oil and meat would be stored in sealskin pokes, in shallow holes in the ground, covered with wood. In fall, the ground would freeze and water in the hole would freeze, helping protect the pokes from bears and foxes. The quality of seal meat, seal oil, and seal hides does not appear to have changed.

Some bearded seals have claw marks, probably from polar bears as the seals are hunted in spring.

Albino bearded seals are seen, though rarely.

Spotted Seals

Spotted seals are typically hunted in fall when they return to the Shishmaref area from Cape Espenberg and Kotzebue Sound. They are the first seals seen in early fall before the ice starts to form.

Spotted seals haul out in large numbers on small islands south of Cape Espenberg on the Kotzebue Sound side. They are also seen in large numbers in the mouth of the Lane River, farther south of Cape Espenberg on the same side, particularly in the deep water channel on the north side of the Lane estuary.

In fall 2015, hundreds of spotted seals were seen on top of ice in Shishmaref Lagoon near the mouth of the Serpentine River. During open water, spotted seals are abundant near the entrances to Shishmaref Lagoon likely eating fish because the fishing is poor. The fish arrive in higher numbers once the ice forms and the seals leave.

Spotted seals in recent years have been larger than they used to be. The spotted seals found near Cape Espenberg, at Singeak, and at Ikpek (southwest of Shishmaref) are all big. The spotted seals in Shishmaref Lagoon are only 4-5 feet long, not the big ones.

Spotted seals also suffer from the disease that afflicts bearded seals, the one that causes hair loss.

Ringed Seals

Ringed seals, referred to as common seals, are typically hunted in fall, but can be hunted year round if they are available.

Ringed seals return to the Shishmaref area in late fall, like bearded seals, when slush ice starts to form on the ocean.

The harvest of ringed seals has declined due to the disease that has been seen on so many bearded, spotted, and ringed seals in the past five or so years. People do not want to hunt animals that may be sick. Some ringed seals and ringed seal pups are seen on the beach in summer, but people do not want to harvest them or touch them or even feed them to dogs because of the risk of disease.

Walrus

Walrus are hunted in spring as they migrate northwards with the retreating ice. Walrus migrate farther off shore now because the pack ice is less dense and more broken than in the past.

Walrus are occasionally seen in fall, as lone animals swimming past. One was seen in Shishmaref Lagoon. Some individuals are seen hauled out on the beach, by themselves.

Walrus can be seen sometimes on very small ice floes, instead of in larger groups on larger ice pans the way they used to haul out. Sometimes only the small floes are available.

In the 1970s and early 1980s, some hunters went over 50 miles offshore on the ice by snowmachine to hunt walrus. In those days, the weather was cold and the sea ice was solid.

Today, walrus are sometimes hunted from the ice edge in May. They used to be hunted along the shore north and south of Shishmaref. In some years, hunters have to go as far as Kotzebue Sound and even close to Kivalina to pursue walrus as they migrate northwards. When they do so, hunters may go to Cape Espenberg and wait for good weather for traveling across Kotzebue Sound. Hunters have also gone as far south as Wales and Diomede to pursue animals.

Walrus appear healthy, with no sign of the disease afflicting seals. Some walrus are skinny, perhaps due to retreating sea ice and having to swim farther from their resting places atop the ice to their feeding areas.

Other Information

Ribbon seals are very skittish, diving off ice floes at the slightest sound or smell of people.

It is harder to find polar bears than it was 20 years ago. They are typically seen in spring when they go out with the sea ice. Nowadays, some get stranded on land. Some are seen swimming straight out to sea, presumably in search of sea ice. Hunters in Shishmaref do not believe the polar bears survive this attempt. Polar bears are seen more often inland than they used to be, usually in early spring before the ice goes out.

Steller sea lions are occasionally seen in the Shishmaref area. This is a relatively new phenomenon, but is still rare.

The Lane River area is a good place to hunt belugas in late summer and fall.

In spring 2015, killer whales kept a gray whale cow and calf close to shore near Shishmaref. The killer whales may have taken the calf.

Hunters can push whales in the direction they want them to go by slapping the water with their paddles. This imitates the behavior of killer whales, which slap their tails and dorsal fin on the water to scare the whales and push them in the direction the killer whales want them to go. Whales have occasionally come into Shishmaref Lagoon, but this has not happened in recent years. The bones of a whale can be found a short distance upstream from the mouth of the Serpentine River, where hunters pursued it many years ago. It is not known what species of whale it was.

Shishmaref hunters took a bowhead whale once, when it came closer to the shorefast ice than usual.

Many more gray whale carcasses are seen along the coast near Shishmaref than there used to be. Bowhead whale carcasses remain rare.

Fish arrive in spring after the ice goes out.

There are more seabirds in the Shishmaref area now than there used to be. There are also different birds

There are different crabs in the Shishmaref area in recent years.

Some hunters will print satellite images of sea ice before going out on the shorefast ice in spring.

The channels into Shishmaref Lagoon formed relatively recently. The one to the north of the village, for example, opened within the past two generations. The grandmother of one Shishmaref resident described jumping over the narrow channel when she was young, as it was forming.

Caribou are found closer to the village recently than they have been for many years. The warmer weather may be an influence. The elders said the caribou would return to this area. They can be seen on the mainland not far from Shishmaref. It used to be that only a few caribou might be seen, but now there are hundreds if not thousands. Predators are closer, too, including wolves, wolverine, and brown bears.

It used to be possible to predict good weather for a couple of days, so that hunters could cross Kotzebue Sound for example. Now, the winds and bad weather can come up very quickly.

Acknowledgements
We are grateful for the skill, expertise, and generosity of the five hunters who participated in the interviews. We appreciate the support of the Eskimo Walrus Commission and the Ice Seal Committee for this project and are grateful to Jane Kakoona, Karen Olanna, and Renee Kuzuguk from the Shishmaref IRA Council office for helping to set up the interviews. The Bureau of Ocean Energy Management (BOEM) funded the work as part of Contract Nos. M09PC00027 and M13PC00015 and we appreciate the support of Charles Monnett, Catherine Coon, Dan Holiday, and Carol Fairfield. Justin Crawford prepared the maps used during the interviews and the figure in this report.

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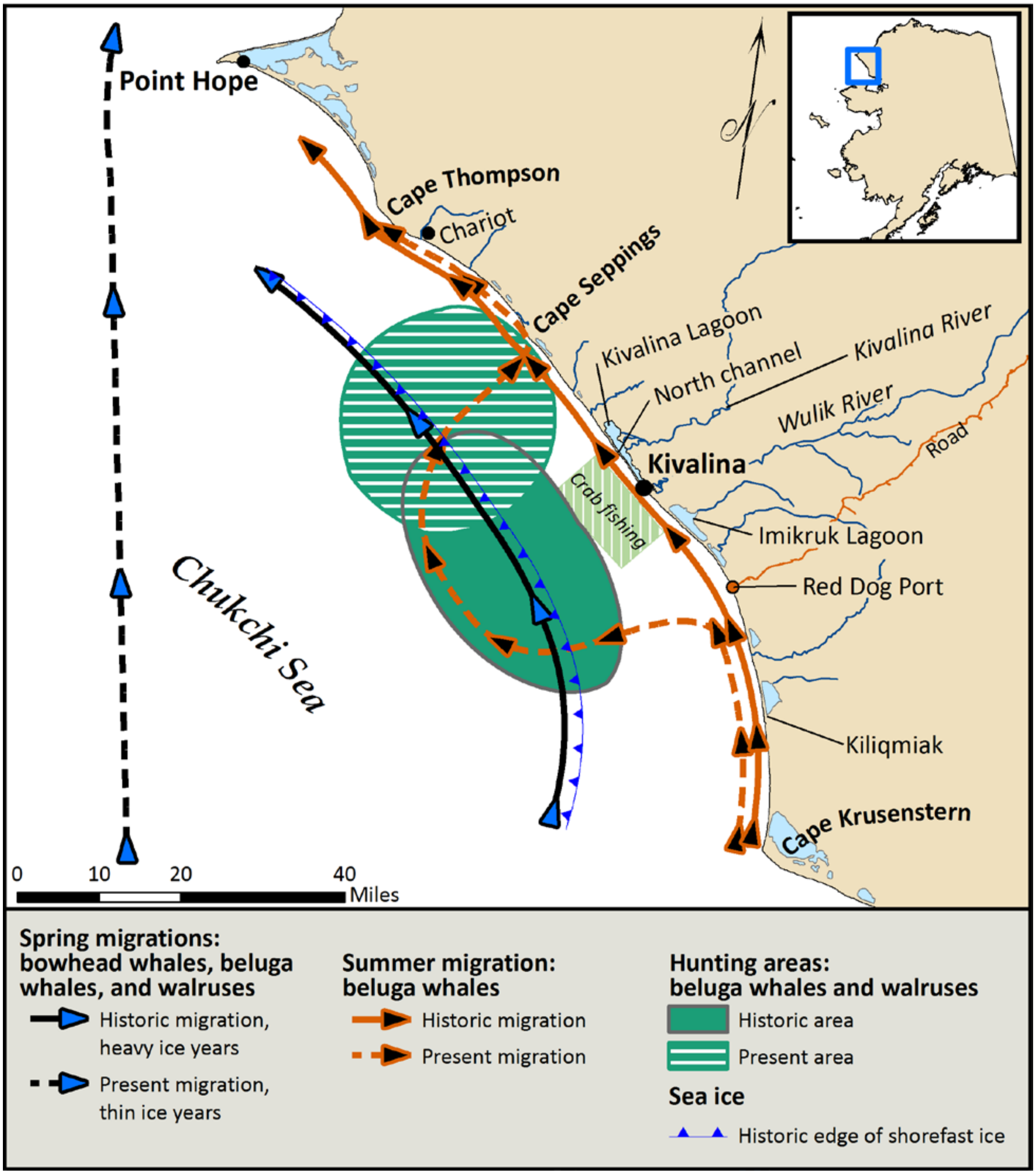
Appendix I.

Traditional Knowledge Regarding Ringed Seals, Bearded Seals, Walrus, and Bowhead Whales near Kivalina, Alaska



Traditional Knowledge Regarding Ringed Seals, Bearded Seals, Walrus, and Bowhead Whales near Kivalina, Alaska

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Introduction

Ringed and bearded seals are important species for subsistence harvests by Iñupiat hunters from Kivalina (population 384), on the Chukchi Sea coast of northwestern Alaska. Walrus are found and hunted in this area, too. These Arctic marine mammal populations are at potential risk from climate change, increasing industrial activity, coastal development, and shipping through Bering Strait. Scientific studies of distribution, behavior, movements, and habitat use of seals and walrus have made important contributions to understanding the effects of a changing environment and the potential effects from industrial activity. For example, placing satellite transmitters on seals and walrus provides detailed information about the movements and some behaviors of individual animals. Documenting traditional knowledge about seals and walrus, through interviews with residents of coastal communities, however, provides valuable complementary current and historical information about the general patterns of each species.

This report summarizes information gathered from interviews with hunters and other knowledgeable residents in Kivalina, Alaska, in January 2016. This traditional knowledge project used the same approach that the Native Village of Savoonga used when documenting traditional knowledge about bowhead whales on St. Lawrence Island (Noongwook et al. 2007).

Methods

We used the semi-directive interview method, in which the interviewers raise a number of topics with the person being interviewed, but do not rely solely on a formal list of questions (Huntington 1998). Instead, the interview is closer to a discussion or conversation, proceeding in directions determined by the person being interviewed, reflecting his/her knowledge, the associations made between walrus and other parts of the environment, and so on. The interviewers use their list of topics to raise additional points for discussion, but do not curtail discussion of additional topics introduced by the person being interviewed.

In Kivalina, we interviewed five people. Those interviewed were Leonard Knox, Allen Knox, Replogle Swan, Dolly Swan, and Enoch Adams Jr. The interviews were conducted on January7, 2016, at the Kivalina Tribal (IRA) Council office and in the homes of interviewees.

The topics identified by the research team in advance of the interviewers were:

Haulouts on land
Overwintering areas and behavior
Use of lagoons and rivers
Feeding patterns and prey
Differences between ringed and bearded seals
Impacts from climate change
Parts of seals that people eat

The results are presented under different headings, reflecting the actual information collected and the fact that some of the subjects blend together, especially changes seen over time in regard to all of the topics. The interviewers were Henry Huntington and Mark Nelson. Lori Quakenbush is the project leader.

General Information

Marine mammals continue to be abundant in the Kivalina area. The migratory patterns remain largely the same, with variation in timing from year to year. The big change for hunters is that the ice is no longer a reliable platform for hunting, but is instead a dangerous place that prevents hunters from reaching marine mammals or limits the length of the hunting period.

The number of marine mammals coming past Kivalina has decreased considerably since construction of the Red Dog Mine Port Site in the late 1980s. The noise from that facility deflects marine mammals migrating up the coast, pushing them offshore and out of reach of Kivalina hunters. For example, beluga whales used to be seen every summer, but after the construction of the Port Site, they do not come to Kivalina from the south any more. As a consequence, hunters from Kivalina now often travel northwest of the community towards Cape Thompson to go hunting. It is expensive to travel far to go hunting. Many hunters also go to the area of the north channel into the lagoon, where it is quieter.

A great deal has changed in recent years, but hunters are adjusting to these changes. What used to take place is not what happens now. The availability of high-powered outboards and high-powered rifles has helped hunters adjust in ways that would not have been possible 50 or 100 years ago. A boat trip to Point Hope now takes two hours, instead of all day. Hunters can make day trips from the village instead of having to camp out on the land or ice. People need to be thinking in new ways a lot now.

Kivalina hunters do not pursue marine mammals in fall. They are hunting caribou at that time of year. Not many seals are seen in fall.

Bearded seals, caribou, and fish are the primary subsistence resources that sustain Kivalina. Other species, such as bowhead whales, beluga whales, and walrus are appreciated when they are available, but not essential to the community's well-being.

People eat the blubber (oil) and meat of bearded and ringed seals. They also eat many of the organs of both seals. Elders enjoy small seals of either species. Seals are fat in spring, and their blubber is good for seal oil. Fall seals are not as good for oil. In late spring, male ringed seals are darker and have a different taste "like kerosene" in the words of one hunter. Spotted seal meat is not eaten because it does not taste good, but spotted seal blubber may be used for oil if necessary. There has been no real change in the quality of seal meat or oil.

Sharing of seals and other animals is very important for Kivalina hunters. Hunters will take animals for their families, their relatives, elders, and others in the community. The first animal of the season is typically shared, so many people are excited when a hunter gets his or her first animal, knowing it will be distributed to others. People say that if you give first, more will come, so they do not like to keep their first catch. This practice applies to caribou and to marine mammals.

Shorefast ice does not stay as long as it used to. In some years, it starts to melt as early as March. The ice used to be thicker than it is now, and seems to be getting thinner. This year, in early January, there is open water to the beach. Last winter, 2015, the ice did not stay for good until March. This winter may be similar. Shorefast ice used to form in early fall and stay until June, but this is no longer the case.

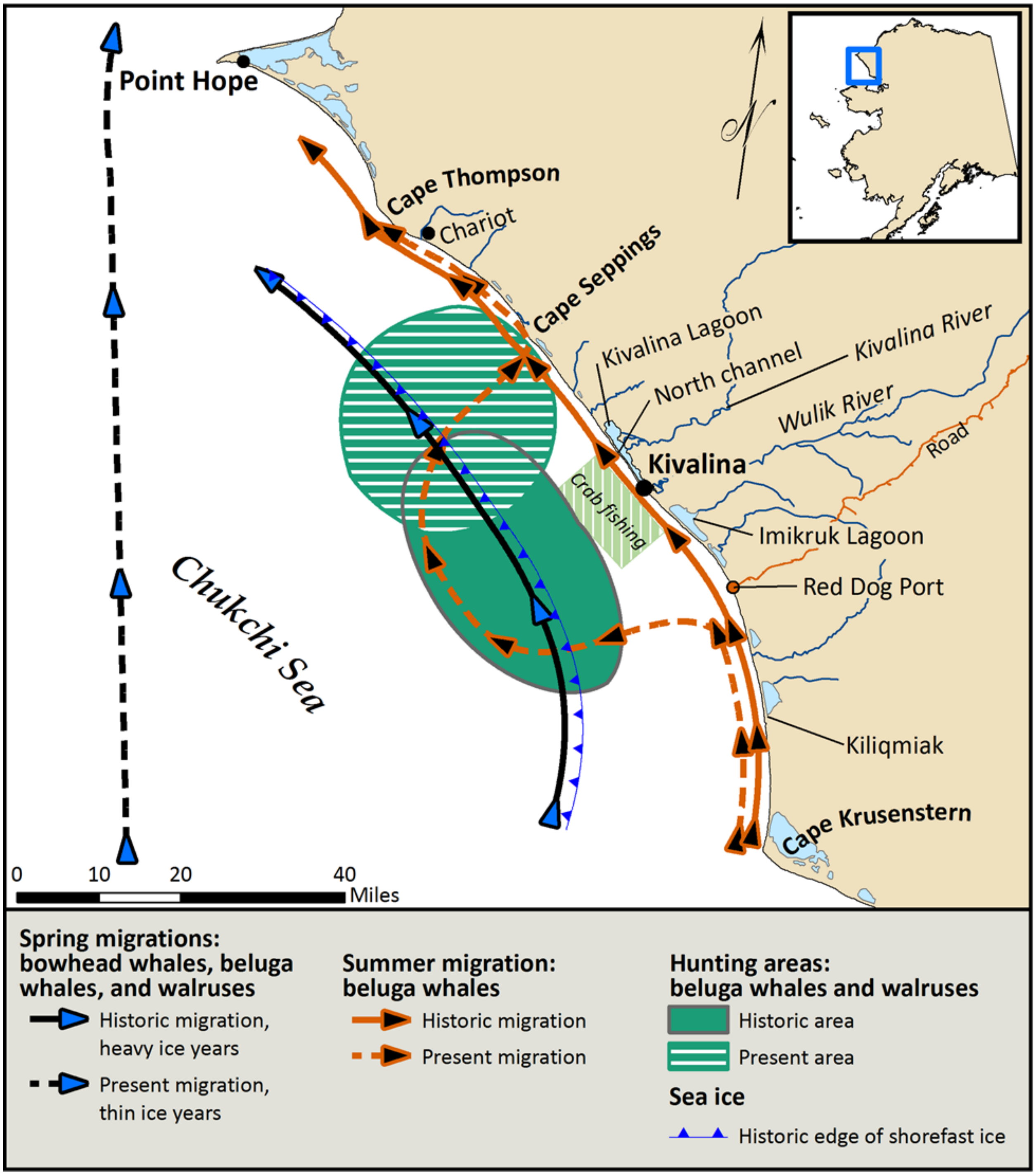

Figure 1. Movements and behavior of bearded seals, spotted seals, ringed seals, walrus, beluga whales, and bowhead whales as described during traditional knowledge interviews, January 2016.

Bearded Seals

Bearded seals start to haul out on the ice in spring when the days get longer. Many seals are seen at this time of year.

They are usually not hunted until the bowhead and beluga hunt is over, so as not to scare off the whales. Bearded seal hunting takes place before it is too warm, so that the meat will not spoil or be affected by insects as it is drying on racks.

In recent years, the thin ice has made it dangerous to go hunting for bearded seals on top of the ice. In 2015, the ice disappeared very quickly after break-up, so the opportunity for hunting bearded seals by boat was very short. In the late 1990s, hunters were caught by surprise one year when the hunting period was only a week long instead of several weeks. After that, they made sure to take advantage of the opportunity as soon as it came. That worked, until last year. In 2015, however, the season was much shorter, again catching hunters by surprise. Offshore winds carried the ice out, but the ice did not come back in after the winds died, as it used to do. This happened once before, in the 1980s. Now hunters fear it will be the new pattern.

A few bearded seals remain in the area after the ice goes out. Bearded seals come through the channel into the lagoon in summer, following fish. Young bearded seals go up rivers in fall. Bearded seals start returning to the area in fall.

A few sick bearded seals have been seen in recent years, with large hairless areas. One young bearded seal taken last October in open water had about half its hair missing. It did not have sores on its skin, but it was skinny. Most seals are healthy, but it used to be very rare to encounter a sick seal.

Ringed Seals

Some ringed seals stay all winter in the Kivalina area. In mid-winter, ringed seals are fat and in their prime. Hunters cannot get them now because the ice is thin or there is open water. Whereas hunting used to start in December or January, it is often not possible to hunt ringed seals until February or March.

It is important to take ringed seal in winter to make bleached sealskin leather, which requires cold weather to cure properly. Bleached ringed sealskin is becoming a rare commodity in Kivalina.

Small, sickly ringed seals have been seen on the beach in the past few years. They do not move off when people approach. They are not common, only a few each year, but this is a new phenomenon. One hunter said the previous time he saw a sick seal was at least 30 years ago, in contrast to seeing at least one each year now.

Spotted Seals

Spotted seals arrive after the ice leaves. Some pups can be seen on the beach all summer, going out to feed and coming back to rest and avoid danger. Spotted seals are seen all summer. Few people hunt spotted seals. Their skins are beautiful and warm, if tanned properly, but the meat is not wanted and the blubber is usually thin. People could get more spotted seals than ringed or bearded seals these days. Spotted seals do not seem to be affected as much by changes in ice, as they come for the fish rather than the ice.

Walrus
Walrus come northwards past Kivalina in spring when the ice starts to break up, at the end of the bearded seal season. Walrus used to follow a path that brought them past Kivalina, but now seem to go straight from Shishmaref to Point Hope or Cape Thompson, which takes them 50 miles away from Kivalina, too far to go in a boat in broken ice.

Occasionally a walrus will be seen hauled out on the beach. They prefer ice, but will haul out on land if there is no ice.

Walrus are seen going south in fall. A few stray walrus are seen in summer, heading south.

One hunter took a female walrus each of the past two summers, in July, but the blubber was thin and the meat was very dark and red and stinky. They were excited about getting a walrus, because that has become rare for Kivalina hunters, but they could not eat it.

Women are not allowed to go walrus hunting because of stories from long ago of walrus chasing boats and even turning boats over.

Bowhead and Beluga Whales
Bowhead and beluga whales are normally hunted in spring as they migrate north through the leads in the ice. The whales continue to follow this pattern, but with more open water they can take a more direct route from Wales to Point Hope, bypassing Kivalina. When the ice is thick offshore, then bowheads and belugas are more likely to follow the leads along the shore in the Kivalina area. The whales that do come past Kivalina are typically 20 miles offshore. When there was stable shorefast ice in spring, hunters could go 20 miles out and camp at the ice edge to hunt whales. Now, it is too dangerous, so hunters do not have access to the whales. With the thin ice, Kivalina hunters would not be able to pull a large bowhead whale out of the water. There is still an opportunity, but it is shorter than it used to be.

A few belugas will be seen in summer, usually coming from the north. They may be deflected offshore near the Red Dog Port Site, then return to the coast near Cape Seppings. Some come south to feed in the river mouths along the coast, which is why they stay close to shore at this time. Last summer (2015), killer whales kept the belugas in the shallow water close to shore, where hunters could get them. Hunters did not see the killer whales, but heard reports of killer whales from people in Point Hope. The belugas stayed in shallow water, avoiding killer whales even though it made them vulnerable to human hunters. This happens from time to time, but not consistently. Killer whales are doing what they have always done.

Other Information
Gray whales come into the area at the end of summer.

Humpback whales were seen in front of Kivalina in July 2015, a time when there were lots of herring in the area. Humpbacks are seen every few years, usually in July when there are many chum salmon coming up the coast.

There are porpoises (harbor porpoises, *Phocoena phocoena*) in the Kivalina area in summer, but hunters do not pursue them.

Polar bears still come to the Kivalina area, but would usually be encountered by hunters at the ice edge during whaling season. Now that hunters cannot go as far out on the shorefast ice, they see fewer polar bears. Two polar bears have made dens in the hills behind Kivalina this winter.

One hunter found an eight-foot shark on the beach at the end of July one year.

Crabbing is good at Kivalina, especially in fall. The crabs are plentiful in deeper water about five miles from shore.

Some shrimp wash up on the beach after fall storms, along with small fish known as *akaluaq*. Squid and unusual fishes have been washing up on the beach in recent years, which is odd. The squid, which are black and a few inches long, have not been seen before. Some people have also seen swimming worms in the ocean, up to a foot long, the thickness of a pencil. Smaller worms were seen last summer, in a school towards Cape Thompson, at a time when there were also three gray whales nearby. Someone saw a swimming octopus in one recent year.

Acknowledgements

We are grateful for the skill, expertise, and generosity of the five people who participated in the interviews. We appreciate the support of the Eskimo Walrus Commission and the Ice Seal Committee for this project and are grateful to Enoch Adams Jr. for helping to set up the interviews and to Stanley Hawley and the Kivalina IRA Council for use of their office space. The Bureau of Ocean Energy Management (BOEM) funded the work as part of Contract Nos. M09PC00027 and M13PC00015 and we appreciate the support of Charles Monnett, Catherine Coon, Dan Holiday, and Carol Fairfield. Justin Crawford prepared the maps used during the interviews and the figures in this report.

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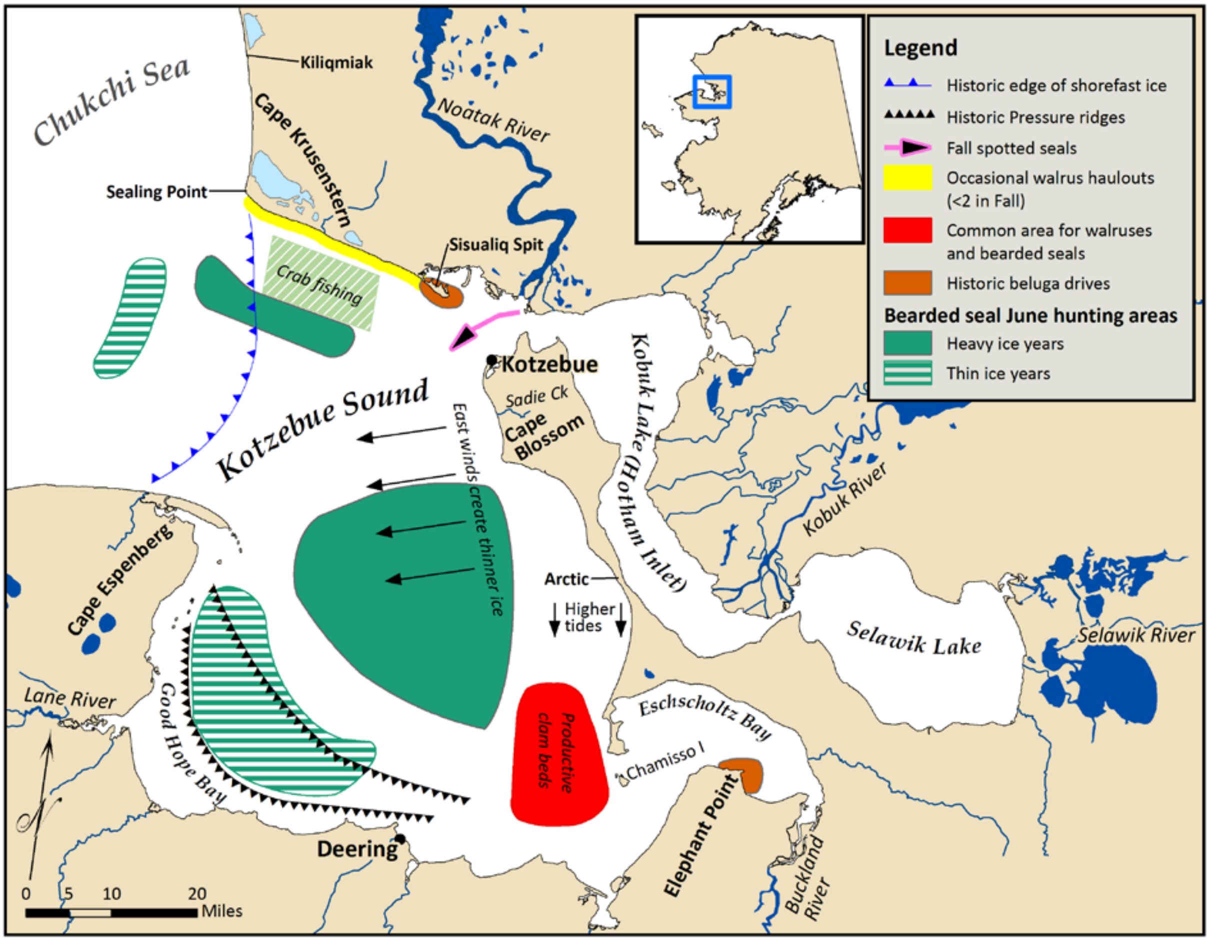
Appendix J.

Traditional Knowledge Regarding Ringed Seals, Bearded Seals, and Walrus near Kotzebue, Alaska



Traditional Knowledge Regarding Ringed Seals, Bearded Seals, and Walrus near Kotzebue, Alaska

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Introduction

Ringed seals and bearded seals are important species for subsistence harvests by Iñupiat hunters from Kotzebue (population 3,284), in northwestern Alaska. Walrus are found and hunted in this area, too. These Arctic marine mammal populations are at potential risk from climate change, increasing industrial activity, coastal development, and shipping through Bering Strait. Scientific studies of distribution, behavior, movements, and habitat use of seals and walrus have made important contributions to understanding the effects of a changing environment and the potential effects from industrial activity. For example, placing satellite transmitters on seals and walrus provides detailed information about the movements and some behaviors of individual animals. Documenting traditional knowledge about seals and walrus, through interviews with residents of coastal communities, however, provides valuable complementary current and historical information about the general patterns of each species.

This report summarizes information gathered from interviews with hunters and other knowledgeable residents in Kotzebue, Alaska, in January 2016. This traditional knowledge project used the same approach that the Native Village of Savoonga used when documenting traditional knowledge about bowhead whales on St. Lawrence Island (Noongwook et al. 2007).

Methods

We used the semi-directive interview method, in which the interviewers raise a number of topics with the person being interviewed, but do not rely solely on a formal list of questions (Huntington 1998). Instead, the interview is closer to a discussion or conversation, proceeding in directions determined by the person being interviewed, reflecting his/her knowledge, the associations made between walrus and other parts of the environment, and so on. The interviewers use their list of topics to raise additional points for discussion, but do not curtail discussion of additional topics introduced by the person being interviewed.

In Kotzebue, we interviewed six people individually. Those interviewed were John Goodwin, Cyrus Harris, Willie Goodwin, Enoch (Atamuk) Sheidt, Henry (Boyuk) Goodwin, and Lance Kramer. The interviews were conducted on January 6 and 7, 2016, in the home of one interviewee, at the Kotzebue IRA Council office, at the Nullagvik Hotel, and, in one case, beginning at the Bering Air terminal, en route to Kivalina, at the Kivalina community center, and concluding at the Kivalina IRA Council office.

The topics identified by the research team in advance of the interviewers were:

- Haulouts on land
- Overwintering areas and behavior
- Use of lagoons and rivers
- Feeding patterns and prey
- Differences between ringed and bearded seals
- Impacts from climate change
- Parts of seals that people eat

The results are presented under different headings, reflecting the actual information collected and the fact that some of the subjects blend together, especially changes seen over time in regard to all of the topics. The interviewers were Henry Huntington and Mark Nelson. Lori Quakenbush is the project leader.

General Observations about Seals

Hunters on the coast would take seals for their own families and also for families that could not hunt for themselves, such as elders and widows. They would also take seals to trade with people from upriver, getting dried fish and furs in return.

People eat seal oil, meat, heart, kidneys, intestine, and liver of seals. Bearded seals are preferred, though all seals can be eaten. From spotted seals, hunters usually take the hide and blubber, as the meat is not regarded as tasty. Bearded seal flippers would be aged underground and eaten after a few weeks. In the old days, people would store seal and other foods in sealskin pokes in ice cellars. Today, they typically use electric freezers and modern containers.

Elders like young bearded seals, which produce nice, clear oil. Older male bearded seals yield oil that is yellow and less preferred.

By May, seals are making holes in the ice and coming out to lie on top of the ice. Historically, hunters would start hunting when the seals started hauling out atop the ice. Most of the seals seen at this time are adult seals, but hunters would also take young seals when they came out of their lairs. The skins were very desirable at that stage, soft and good for liners. The best hunting for pups was in years with little snow in early spring, which did not happen every year.

Soon after break-up, only bearded and ringed seals are around. Later on, while the ice is still there, spotted seals arrive and the bearded seals and most ringed seals leave. Spotted seals are aggressive and scare off the other seals. Once spotted seals are there, hunters either stop looking for bearded seals or look elsewhere for bearded seals. This is usually in June or July.

There are seals year round in Kotzebue Sound and along the coast. From satellite tagging, hunters now know that the juveniles travel far, even into the Bering Sea, whereas older seals tend to stay closer to Kotzebue Sound.

Hunters can get bearded, ringed, and spotted seals in fall, though the bearded seals are almost all juveniles.

The quality of seal and walrus meat, blubber, other foods, oil and hides has not changed. Seal behavior has not changed, either, despite changes to the ice.

This past year, seals were fat and healthy, and there were many pups, despite the poor ice conditions for hunters. Hundreds if not thousands of seals were seen in Eschscholtz Bay in 2015. Lots of seals were seen between Kotzebue and the Chamisso Islands, including seals sleeping on the water surface. The only big change is the loss of hunting opportunity due to poor ice and rapid disappearance of ice after break-up starts.

When the snow melts early, there is no protection for seal pups from predators such as jaegers and ravens and foxes. The roof of the den collapses and the pup is exposed. Under the snow, seals move around and make escape routes from their dens.

The smallest pups do not go into the water.

There are as many or more seals now as there were in the past. There has never been a shortage of seals compared with people's needs. There is not as much hunting, largely because there are fewer dogs to feed. Hunters also used to get seals to make sealskin pokes for storing oil and meat, but today there are other containers so no need to hunt seals for this purpose.

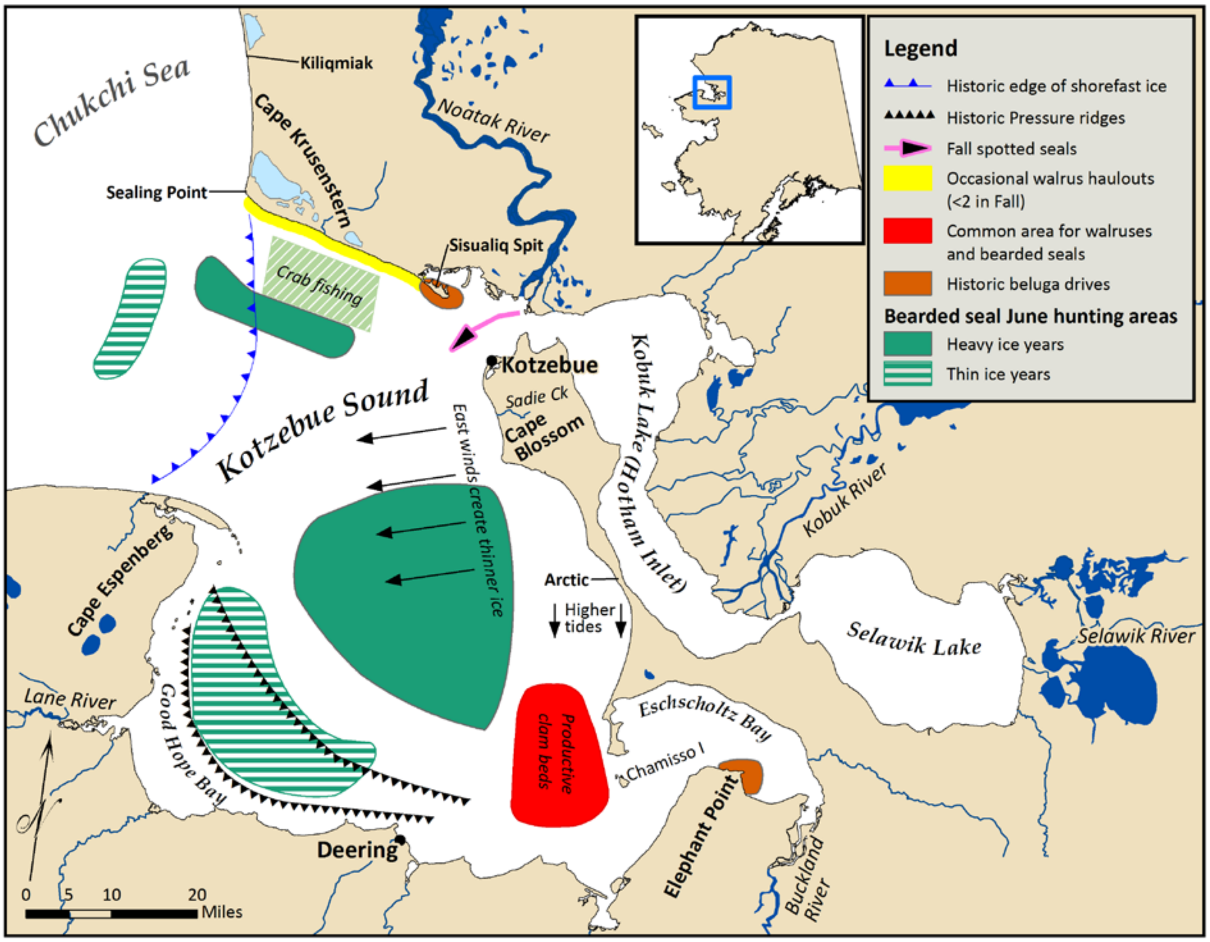

Figure 1. Movements and behavior of bearded seals, spotted seals, ringed seals, walrus, and beluga whales as described during traditional knowledge interviews, January 2016.

Seals and Disease

It seems there may even be an overpopulation of seals, which could cause starvation if there is not enough food for all the seals. When animals starve, they can develop many different kinds of disease, which may help explain the skin sores and other problems hunters saw a few years ago.

Hair loss is normal in seals, and can be seen on bearded, ringed, and spotted seals. When seals were taken, hunters' wives would pull on the hair to see if the hair was firmly attached or if the seal was in the middle of the molt. Seals that are molting or have lost hair are good for making leather, for ropes and mukluk soles and other purposes. Hairless seals would be fed to dogs, or if they seemed fat and healthy otherwise would be eaten by people. One hunter took a hairless ringed seal in winter, and his grandmother said he should burn it, so he did. People would say the seals did not spend enough time on top of the ice to molt fully. The hair loss may also have come from rubbing against the seabed. The loss of ice in recent years may mean the seals cannot spend as much time hauled out as they used to, which could affect the molt. Seals may have to learn to adapt, for example by hauling out on land instead of ice.

The recent hair loss, accompanied by skin sores and other signs of ill health, is a new phenomenon. Hunters do not want to handle, much less eat, seals that show signs of poor health. In addition to the sores, the seals appear lethargic. Ringed seals hauled out on the beach do not flee, so would be easy to catch, but hunters do not want to approach them once they see they are sick. This illness occurred first in 2011, but seems mostly to have disappeared. Some hunters see it as nature's way of dealing with overpopulation of seals.

Bearded Seals

In spring, bearded seals are the focus for hunting, getting food for spring and for the following winter. When the ice started to break up, hunters would go to Sealing Point (near Cape Krusenstern) to hunt bearded seals. In the days before outboard motors, hunters would use kayaks to go between floes and in the cracks in the ice to pursue bearded seals.

The ice edge off Cape Krusenstern is a good place to hunt bearded seals, though the seals move around. Many may be seen one day, and none the next day, in the same spot. The waters about 10 miles west of Cape Blossom are also rich with seals, but this is farther from shore and more dangerous to travel to. The waters north of Cape Krusenstern are also good for hunting, at Kiliqmiak, just south of Rabbit Creek. There are many creeks and other places on either side of Cape Krusenstern where hunters can find refuge in case of bad weather. There are fewer places to find refuge in southern Kotzebue Sound.

It used to be that there were two or three weeks of good hunting conditions for bearded seals, as the ice broke up but before it was gone entirely. In spring 2015, there was only a week or less, because the ice disappeared very quickly after break-up. This is due in part to more east wind, blowing the ice out, and in part to thinner ice during the winter, making it easier to melt and move. The lack of ice also meant that waves could build up more in Kotzebue Sound, increasing the risk for hunters. Some ice remained towards Goodhope Bay, but it was dangerous to go that far in open water. Still, if hunters can find an ice floe, there are often bearded seals nearby, so the hunting can be good. With so little ice, the bearded seals have few options left, so are concentrated near the floes that remain. The risk of exposure to wind and waves is still higher for hunters with so little ice.

Bearded seals come in earlier than they used to, but often stay on thin ice where hunters cannot reach them. Thinner ice also makes it harder to hunt for bearded seals, as travel on top of the ice is more dangerous for hunters. Bearded seals can be hunted while they are swimming in open water, but hunters prefer to get them on the ice since hauling them in and out of the boat is difficult. The adult bearded seals come in earlier because the ice breaks up earlier, but they do not stay as long because the ice goes away quickly, leaving only swimming seals.

Bearded seals need white ice (thicker ice), but there is more and more black ice (thinner, younger ice) in Kotzebue Sound these days, which produces fewer pressure ridges and thus less denning habitat. The ice is no longer suitable for camping during the spring hunt. The ice that is left moves very quickly in the currents and can break up quickly, making it dangerous for camping. Adult bearded seals in spring have thinner blubber than they did in the past, only an inch or an inch-and-a-half thick as opposed to three to four inches.

Yearling bearded seals (*ugruchiaq*) return in September, before the ice starts to form. Many of these seals spend time up rivers, including the Ugrugvik Lakes, just north of the mouth of the Kobuk River. A bearded seal was seen close to Ambler on the Kobuk River in September 2015. There are often bearded and ringed seals up the Kobuk, and seemed to be even more this past fall (2015), well over a dozen. Some bearded and ringed seals also go up the Noatak River. There were more yearling bearded seals last fall (2015) than ever before. They appeared very healthy.

One hunter has checked the stomachs of three bearded seals in his lifetime. All were full of shrimp. The seals will feed throughout Kotzebue Sound, but a prime feeding area is off the Chamisso Islands.

Ringed Seals

Some ringed seals will stay in Kotzebue Sound during summer, but most move away because they do not like to be around spotted seals. Ringed seals return in late summer. The juveniles come first, and the adults later in fall after the spotted seals have started to leave. Adult ringed seals will stay in Kotzebue Sound all winter. They make their dens in the pressure ridges. Large ridges used to form in the middle of Kotzebue Sound, but the ice today is thinner. Merging currents at Cape Blossom also created pressure ridges close to shore, but today this area is often open water even into winter, reducing denning habitat for ringed seals. In mid-winter, ringed seals are fat and healthy, at their most prime condition. They float very well at this time of year.

Spotted Seals

After the ice is gone in summer, spotted seals are the ones seen in the area until fall. They come to feed on the fish in Kotzebue Sound and in the rivers. Spotted seals are molting when they arrive. That is the time of year when everything is molting. Many spotted seals go up the Noatak River, to just below the hatchery, though they are generally in the lower part of the river. They also go into Hotham Inlet, Kobuk Lake, and Selawik Lake. They feed on fish in the freshwater areas.

After the ice floes start to form in fall, spotted seals will haul out in the hundreds and ride the ice to the southwest when the wind blows from the northeast. In fall 2015, thousands of spotted seals were seen in front of Kotzebue. Buckland hunters took many spotted seals in Eschscholtz Bay, including by the mouth of the Buckland River.

Spotted seals may be arriving a little later than they used to, and are staying a lot longer in fall.

Walrus
Walrus come into Kotzebue Sound in spring, and feed in the waters off the Chamisso Islands in southern Kotzebue Sound. They may have young there, too. They stay while there is still ice in the area.

In fall, one or two walrus may haul out on the beach to the east of Cape Krusenstern. There are never many that do this.

When there are walrus around, seals will not be seen. The seals stay away from walrus.

A walrus taken last summer had shrimp in its stomach.

Beluga Whales
Beluga whales will come into Kotzebue Sound when the ice starts to break up, coming in the cracks that form from Cape Espenberg and Cape Krusenstern.

There has been a huge change in beluga whales in Kotzebue Sound. It is not even clear that there is a Kotzebue Sound population any more. People used to get them every year. Sisualiq is named for beluga whales (*sisuaq*), and there used to be drive hunts there every summer. The drive hunt used to be well organized and coordinated, but now people tend to go for themselves rather than as a group. Belugas do not go into Eschscholtz Bay the way they used to, either. The few sightings in recent years have been around the mouth of the Noatak River, with a few in Eschscholtz Bay, and one juvenile beluga as far upriver as Selawik Lake. One beluga was seen in the shallows between Kotzebue and Sisualiq, in only a few feet of water, during the tomcod run in October, which is very late for a beluga to be seen near Kotzebue.

There is a lot of boat traffic these days, especially hunters from Kotzebue going after bearded seals towards Cape Krusenstern or putting in crab pots north of Kotzebue. The noise may deter belugas from coming into the Sound. Elders said the belugas came in because it was quiet. When air traffic increased at Kotzebue, the belugas started to decline. The noise of jet planes can be heard even at Sisualiq. The conflict between Buckland and Kotzebue hunters over hunting in Eschscholtz Bay (Elephant Point), which was the last place belugas were plentiful in Kotzebue Sound, may also have contributed to the decline. The custom is to let the first animals pass, but these days there are no animals to follow the first ones. Today, though, hunters may pursue the first animals. Hunters no longer coordinate the hunt the way they used to. Most beluga hunting today is with nets.

The ice entrapment of belugas in Russia in the mid-1980s seems the most likely explanation for their disappearance. There was a lot of harvest prior to that, but it seems hard to believe that overharvest is the explanation for the nearly complete disappearance of belugas from Kotzebue Sound.

The belugas that came into Kotzebue Sound in large numbers in one year in the 1990s were thinner than the belugas Kotzebue hunters are used to taking.

A group of belugas came to the Sadie Creek area a few years ago. Hunters think killer whales chased them in, because the belugas nearly beached themselves in the shallows.

One year, hunters found a king salmon in the stomach of a beluga whale. Two other belugas taken at the same time had only tomcod in their stomachs. A beluga taken in summer 2015 had a stomach full of crabs. Crabs are sometimes seen in beluga stomachs, but usually the stomachs are mostly full of fish.

Killer whales

There are more killer whales than there used to be in the Kotzebue Sound area. This is known from observations and also from the results of acoustic monitoring done by the Kotzebue IRA Council. When they follow belugas, the belugas will stay very close to shore and even go into very shallow water. Killer whales stay where the water is deep. One hunter saw a killer whale kill a large male beluga by holding it under water until it died. After that, the killer whales tore the beluga apart.

Other Information

Fewer ribbon seals are seen now than in the past. Hunters used to encounter them now and then, but hardly seem them now. People never ate them, but took the hides and fed the meat and blubber to dogs. One hunter saw many ribbon seals a few years ago, between Point Hope and Cape Lisburne.

A fur seal was once seen in Kotzebue Sound, many years ago.

The waters between Cape Espenberg and Cape Krusenstern are very dynamic, with open water and moving ice in winter and spring, and an abundance of marine mammals.

The southern end of Kotzebue Sound, including Eschscholtz Bay, has tides of about four feet. Boats hauled up at Cape Espenberg can be left high and dry at low tide if hunters are not paying attention. The northern end, including Kotzebue, does not.

The water level in northern Kotzebue Sound, Hotham Inlet, Kobuk Lake, and Selawik Lake is controlled by wind. North and east winds cause the water level to drop; west and south winds cause it to rise, with the highest water coming from south winds. Fish movements are determined by the currents caused by the wind. There used to be little south wind in summer, but September would bring south winds, causing the water to rise. The prevailing wind in winter is from the east, lowering the water and preventing flooding. Today, there is more flooding due to changing wind patterns.

An east wind opens the ice to the west of a line between Cape Espenberg and Cape Krusenstern. In the old days, hunters would travel to the ice edge by dog team when there was an east wind so they could hunt seals there. They would wait for the wind to calm down, so that the risk of being blown out to sea was less, and then have a day or two of seal hunting before the open water froze over again. Today, east winds may open the ice may well within Kotzebue Sound. While new ice may form on the open water, the ice still remains thin and does not have time to become thick. It seems that the east winds are stronger than they used to be.

In those days, the ice in Kotzebue Sound was five to six feet thick, and there was no moving ice inside of the Espenberg-Krusenstern line. There were more pressure ridges in Kotzebue Sound, including very large ones in the middle of the sound. Seals make their lairs in the pressure ridges, where the ice and snow provide good habitat. Today, the ice is thinner and flatter, though there are still some smaller pressure ridges, closer to shore, so there is still denning habitat for seals. The thinner ice is more dangerous for traveling, as it can open up or form cracks well into Kotzebue Sound. No longer can hunters travel straight from Kotzebue to Cape Espenberg—the ice is too unreliable. There is much less shorefast ice, since there are not large pressure ridges to hold the ice in place. There are fewer strong west winds to push the ice into Kotzebue Sound and build up those pressure ridges, and the ice is thinner. Hunters used to be able to camp on the ice past Cape Krusenstern, but today the ice is not reliable.

While ice and weather conditions have always varied from year to year, the changes have really taken effect over the past fifteen years or so. In the 1980s, there was still ice for hunting bearded seals into July, but now the ice is gone in June.

When the ice goes out in spring, Kotzebue Sound opens up a week or two after Kobuk and Selawik Lakes. The elders have always said it is dangerous to go out while there is still ice in Kobuk Lake and Hotham Inlet. In some years, the ice goes out quickly, and in other years it goes back and forth in Kotzebue Sound for some weeks.

A strong current carries spring pack ice from Cape Espenberg northwards towards Cape Krusenstern. A current along the coast from Shishmaref merges with a current coming from Goodhope Bay and southern Kotzebue Sound to produce a stronger current going north. This current does not go into northern Kotzebue Sound, but goes north past Cape Krusenstern.

There used to be more snow, on the ice and in town.

The weather used to be easier to predict. Now it is hard to read. Clouds forming on the tops of mountains are a good indicator that winds are coming, as are the ways high clouds form or disappear in the sky.

Hunters use satellite imagery of sea ice to plan boat travel in Kotzebue Sound, to help improve safety and efficiency as they will know where to find ice for hunting bearded seals.

Concerns

Continued climate change, and subsequent changes, like more commercial shipping, remain a concern. If the ship traffic starts to occur when marine mammals are migrating, it could be a major conflict or impact. The Arctic Waterways Safety Committee is a good forum for discussing shipping. Having a shipping lane from Bering Strait to Canada would be a good way to reduce impacts and risks to hunters.

The reports of dying murres and poor salmon returns from around the state raise concern about how much the ocean is changing and what that is likely to mean for people in Kotzebue, even if seals in Kotzebue Sound appear to be doing well so far.

Acknowledgements
We are grateful for the skill, expertise, and generosity of the six hunters who participated in the interviews. We appreciate the support of the Eskimo Walrus Commission and the Ice Seal Committee for this project and are grateful to John Goodwin and Alex Whiting for helping to set up the interviews and to the Kotzebue IRA Council for providing space for interviews. The Bureau of Ocean Energy Management (BOEM) funded the work as part of Contract Nos. M09PC00027 and M13PC00015 and we appreciate the support of Charles Monnett, Catherine Coon, Dan Holiday, and Carol Fairfield. Justin Crawford prepared the maps used during the interviews and the figure in this report.

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Update of hunter-assisted seal tagging and traditional knowledge studies of Pacific Arctic seals, 2016 and beyond.

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[4] Seal hunter and resident of St. Michael, AK;
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Ringed (*Pusa hispida*), bearded (*Erignathus barbatus*), and spotted (*Phoca largha*) seals use sea ice for pupping, nursing, molting, and resting. Decreases in the extent of sea ice and lengthening of the open water season have eased access to the Arctic, expediting the need to plan development activities to minimize effects on seals. Our understanding of seal habitats, behavior, and timing of movements by all species, age, and sex classes, however, is limited. We expanded upon a cooperative satellite telemetry study of Pacific Arctic seals with hunter-taggers and biologists in Kotzebue Sound, first through a National Marine Fisheries Service (NMFS) funded project, and currently through the merger of two studies, funded separately by the Bureau of Ocean Energy Management and Office of Naval Research, further fostering collaborations among the Alaska Department of Fish and Game, North Slope Borough, NMFS, Ice Seal Committee, and subsistence seal hunters. We worked with hunter-taggers from five villages along the Bering, Chukchi, and Beaufort seas to deploy transmitters on seals to study habitat use, timing of movements, seasonal site fidelity, and association and use of sea ice and oceanographic features. By tagging seals in multiple locations and seasons, we minimize the biases from deploying all of the tags at the same location during the same season. In 2016, four bearded and one ringed seal tagged in 2014 and 2015 wintered in the Bering Sea and Norton Sound. Seven bearded, three ringed, and seven spotted seals were tagged near Barrow, Koyuk, and St. Michael. Seals tracked during 2016 ranged in all three Arctic seas from Bristol Bay in the Bering Sea, to the north and west (near Wrangel Island, Russia) in the Chukchi Sea, and east to Kaktovik, Alaska in the Beaufort Sea. Local and traditional knowledge enhances our understanding of how seals and hunters may respond to changing sea ice conditions. Reports generated from interviews of subsistence users in Barrow, Elim, St. Michael, Stebbins, Kivalina, Kotzebue, Shishmaref, Pt. Lay, and Wainwright were summarized in a publication in 2016. Future plans include training more hunter-taggers and tagging additional seals from coastal villages.

Update of hunter-assisted seal tagging and traditional knowledge studies of Pacific Arctic seals, 2016 and beyond

Appendix K.

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[2]North Slope Borough, Department of Wildlife Management, Utqiaġvik, AK, [3]Seal hunter and resident of Koyuk, AK,

[4]Seal hunter and resident of St. Michael, AK, [5]Seal hunter and resident of Hooper Bay, AK,

[6]Seal hunter and resident of Kotzebue, AK and Ice Seal Committee Chairman, [7]Native Village of Kotzebue, AK

[8]School of Fish and Ocean Science, UAF, Fairbanks, AK, [9]Polar Ecosystems Program, Alaska Fisheries Science Center, MML-NOAA, Seattle, WA

Introduction

Ringed (*Pusa hispida*), bearded (*Erignathus barbatus*), and spotted (*Phoca largha*) seals are called "ice seals" because they use sea ice for pupping, nursing, molting, and resting. In Alaska, these seals are located in the Bering, Chukchi, and Beaufort seas. They are important subsistence species used by Alaska Natives for food, oil, clothing, and handicrafts. Decreases in the extent of sea ice and lengthening of the open water season have eased industrial access to the Arctic, expediting the need to develop mitigation measures to minimize anthropogenic effects on seals, but our understanding of how changes in sea ice will affect ice seals and their habitat is not clear.

Cooperative satellite telemetry studies among hunters and biologists are increasing our understanding of important habitats, seasonal movements, use of sea ice including haul-out behavior, and seasonal site fidelity. This project expands on past studies by tagging seals at several widely-spaced locations through two studies, funded separately by the Bureau of Ocean Energy Management (BOEM) and Office of Naval Research (ONR), and further fostering collaborations among the Alaska Department of Fish and Game (ADFG), North Slope Borough Department of Wildlife Management (NSB), Marine Mammal Laboratory-NOAA (MML), Ice Seal Committee, and subsistence seal hunters. Traditional knowledge is incorporated into our findings to further explain seal movements in response to changing sea ice.

Objectives

Work with seal hunters to:

- Capture and tag ringed, bearded, and spotted seals.
- Document seal habitat use and movements:
  - **BOEM Study:** document seal movements and foraging using:
    - **SPLASH tags**: collect location and dive data (Wildlife Computers, USA).
    - **SPOT tags**: collect location and haul-out data (Wildlife Computers, USA).
  - **ONR Study:** document seal movements and ocean conditions using:
    - **CTD tags**: collect location, dive, and water conductivity, temperature, and depth data (Sea Mammal Research Unit, Scotland).
  - When possible, we tagged each seal with either a SPLASH or CTD tag epoxied to their back or head and a SPOT tag attached to their flipper.
- Gather and document local and traditional knowledge.

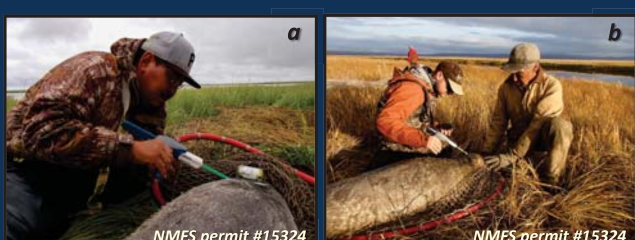

Figure 1. Attaching satellite-linked transmitters to captured bearded seals: a) Palsson Fitka, resident of St. Michael, on the St. Michael Canal, July 2016 and, b) Merlin Henry, resident of Koyuk, and Mark Nelson (ADFG), on the Inglutalik River, September 2016.

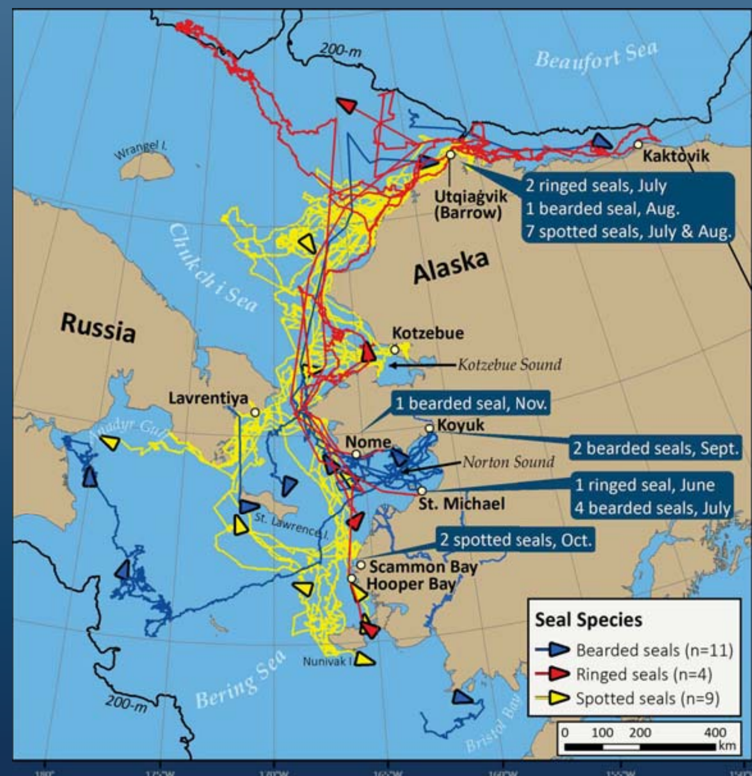

Figure 2. Movements of 4 ringed, 11 bearded, and 9 spotted seals during 2016. Seals were tagged with satellite-linked transmitters during 2014, 2015, and 2016 in Kotzebue Sound and near Hooper Bay, Scammon Bay, St. Michael, Koyuk, Nome, and Utqiaġvik (Barrow). Balloons contain number of seals tagged by species and month in 2016.

Table 1. Number of ringed, bearded, and spotted seals tagged with SPLASH, CTD, and SPOT tags in 2016. As part of a collaborative effort to deploy tags, multiple agencies provided seal tags. The agency that provided the tag or the funding for the tag is listed in parenthesis and includes: BOEM, ONR, NSB, and MML.

Seal species	SPLASH (BOEM)	CTD (ONR)	SPOT (BOEM)	SPOT (NSB)	SPOT (MML)	No. tagged individuals
Ringed		2	1	2		**3**
Bearded	2	3	8			**8**
Spotted		9		2	3	**9**
Total	**2**	**14**	**9**	**4**	**3**	**20**

Activities in 2016

- We deployed satellite-linked transmitters on **20 seals (3 ringed, 8 bearded, and 9 spotted seals)** (Table 1).
- We **tracked the movements of 24 seals**, including 3 bearded seals tagged in 2015 and 1 ringed seal tagged in 2014 (Fig. 2).
  - Maps of seal movements were distributed weekly and displayed on the following webpages:

ADFG **NSB** **Animal Telemetry Network**

- **Traditional knowledge interviews were conducted** in Shishmaref, Kivalina, and Kotzebue in January and finalized in separate reports in June.
- Traditional knowledge collected under several BOEM projects (bowhead, walrus, and seal) was published in August (Huntington *et al.* 2016).

Future Work

- Continue to work with trained hunter-taggers and with new hunters and communities to tag seals.
- Conduct interviews to document local and traditional knowledge to better understand seal movements in response to changing sea ice.
- Continue to combine location data with traditional knowledge to better understand seal movements and habitat use in a changing environment.

Acknowledgements

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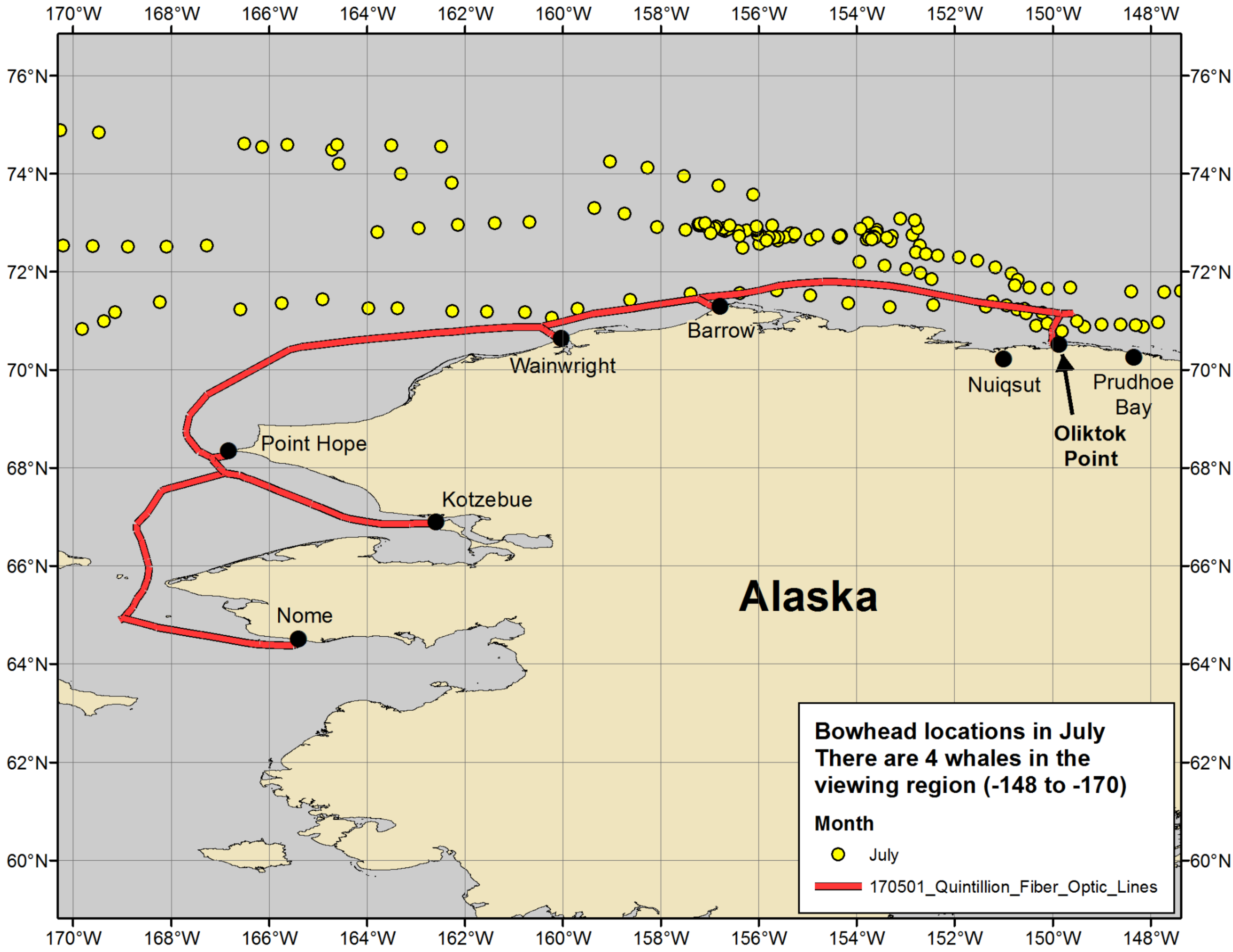
Appendix L.



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Barrow
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Nuiqsut
Prudhoe Bay
Oliktok Point
Point Hope
Kotzebue
Nome
Alaska
Bowhead locations in July
There are 4 whales in the viewing region (-148 to -170)
Month
July
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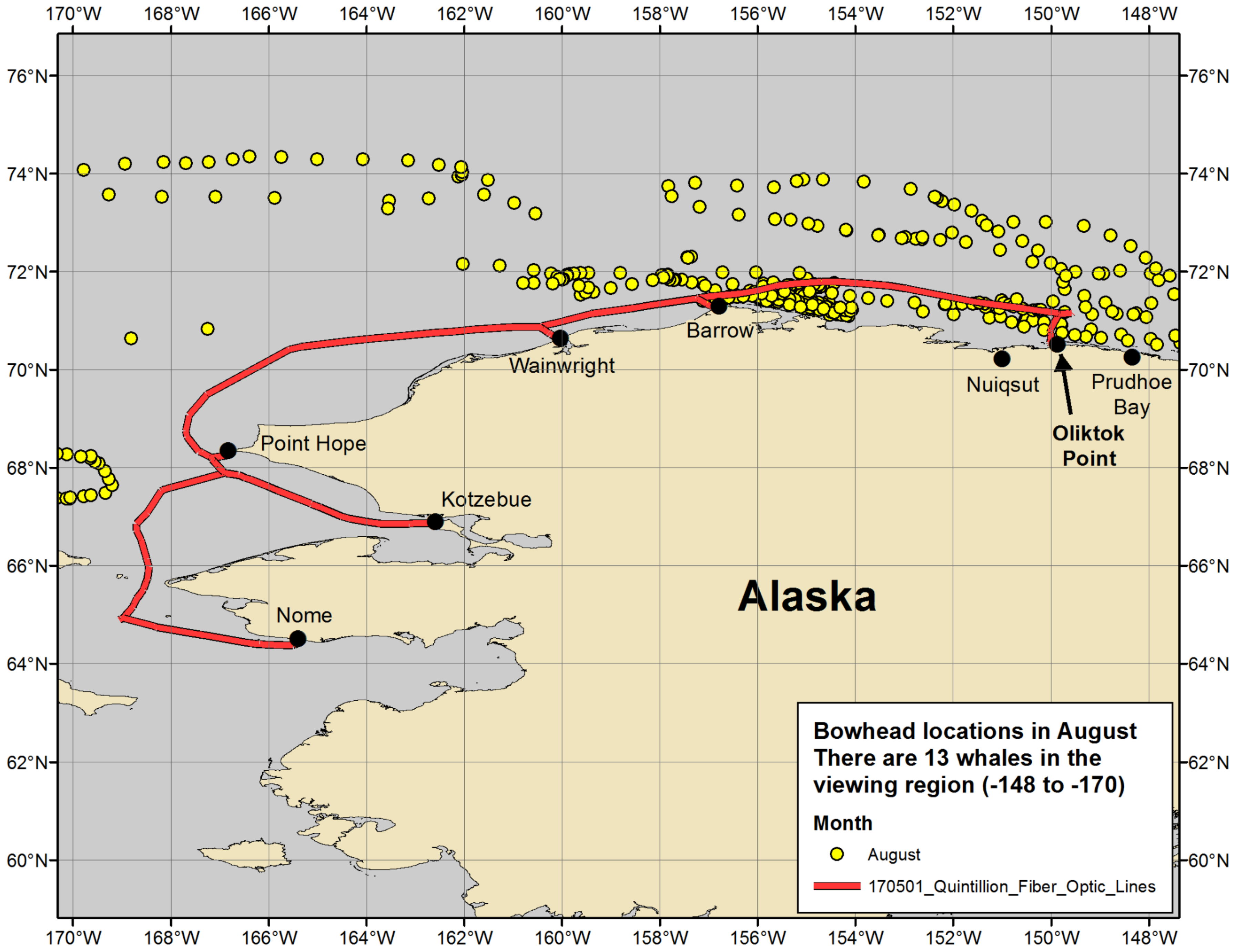
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Barrow
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Bowhead locations in August
There are 13 whales in the viewing region (-148 to -170)
Month
August
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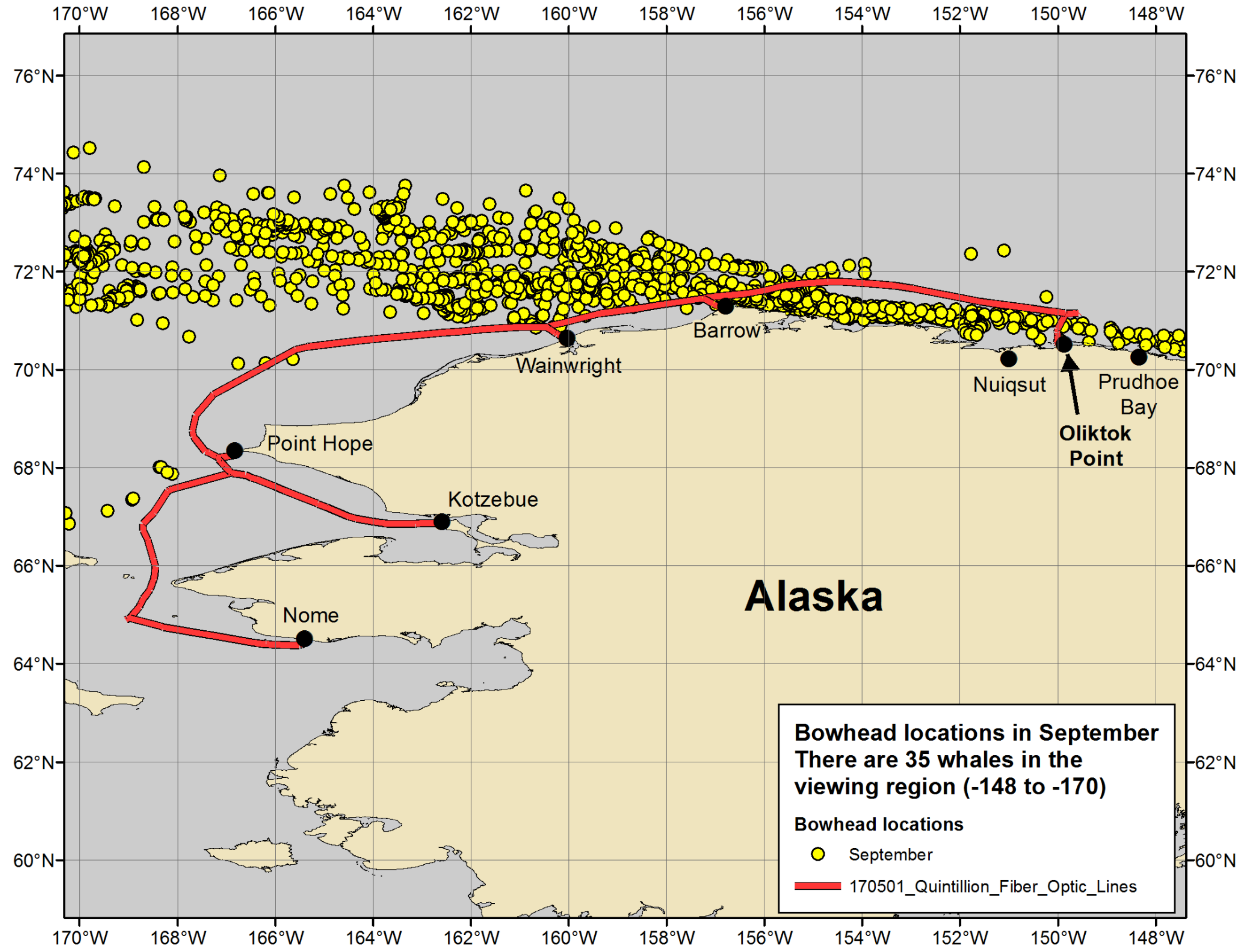

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Barrow
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Prudhoe Bay
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Point Hope
Kotzebue
Nome
Alaska
Bowhead locations in September
There are 35 whales in the viewing region (-148 to -170)
Bowhead locations
September
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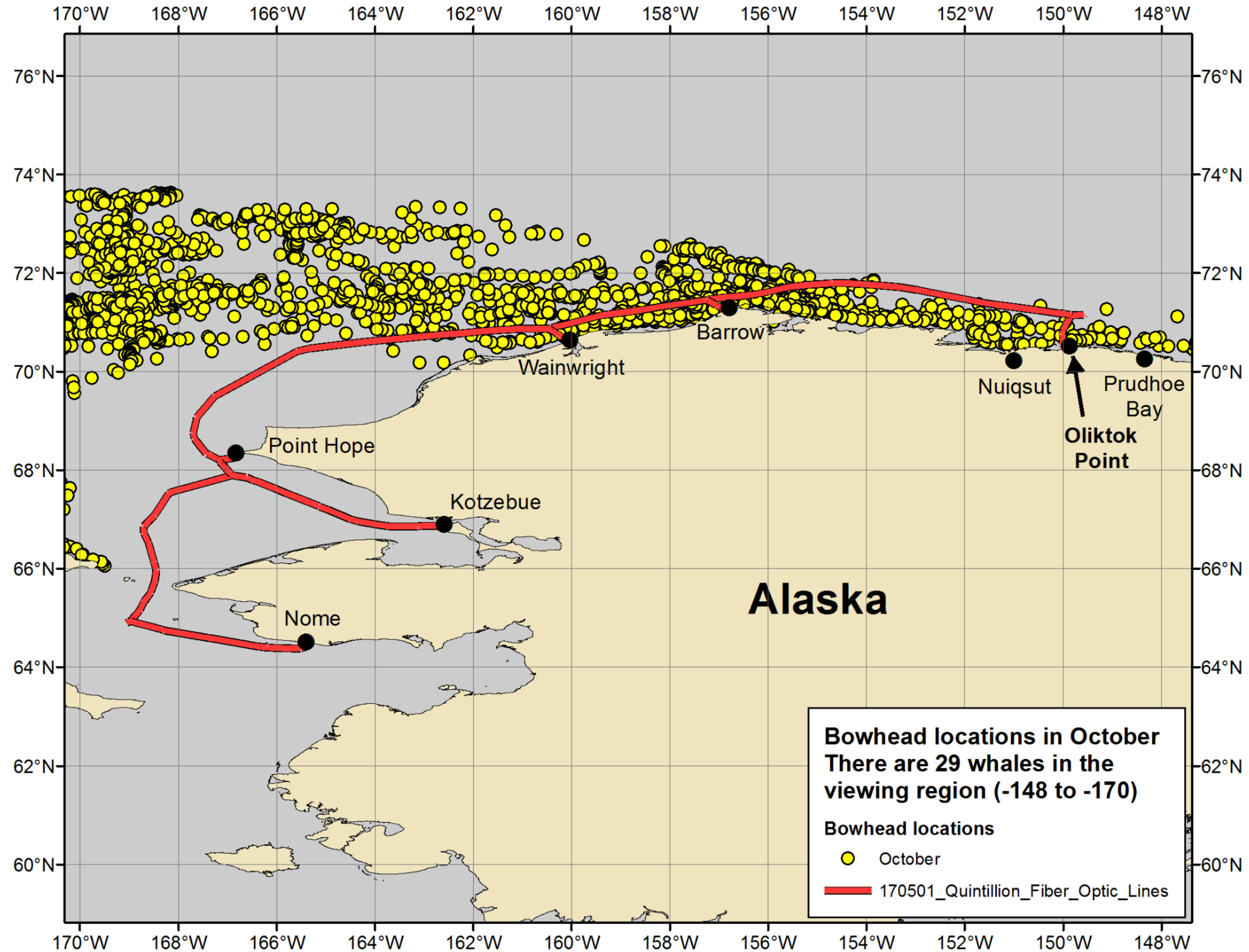

Bowhead locations in October
There are 29 whales in the viewing region (-148 to -170)
Bowhead locations
October
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Barrow
Nuiqsut
Prudhoe Bay
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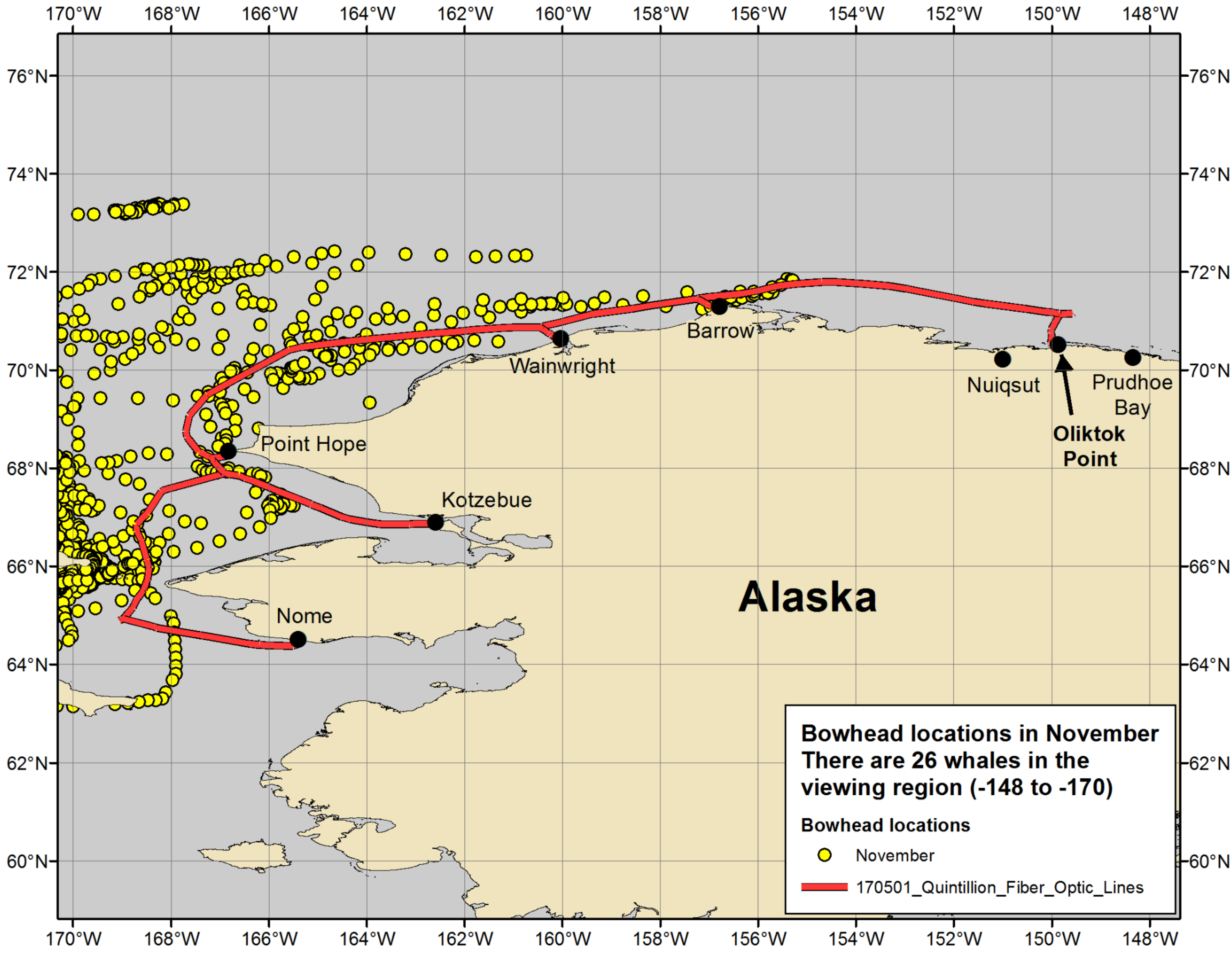

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Prudhoe Bay
Oliktok Point
Point Hope
Kotzebue
Nome
Alaska
Bowhead locations in November
There are 26 whales in the viewing region (-148 to -170)
Bowhead locations
November
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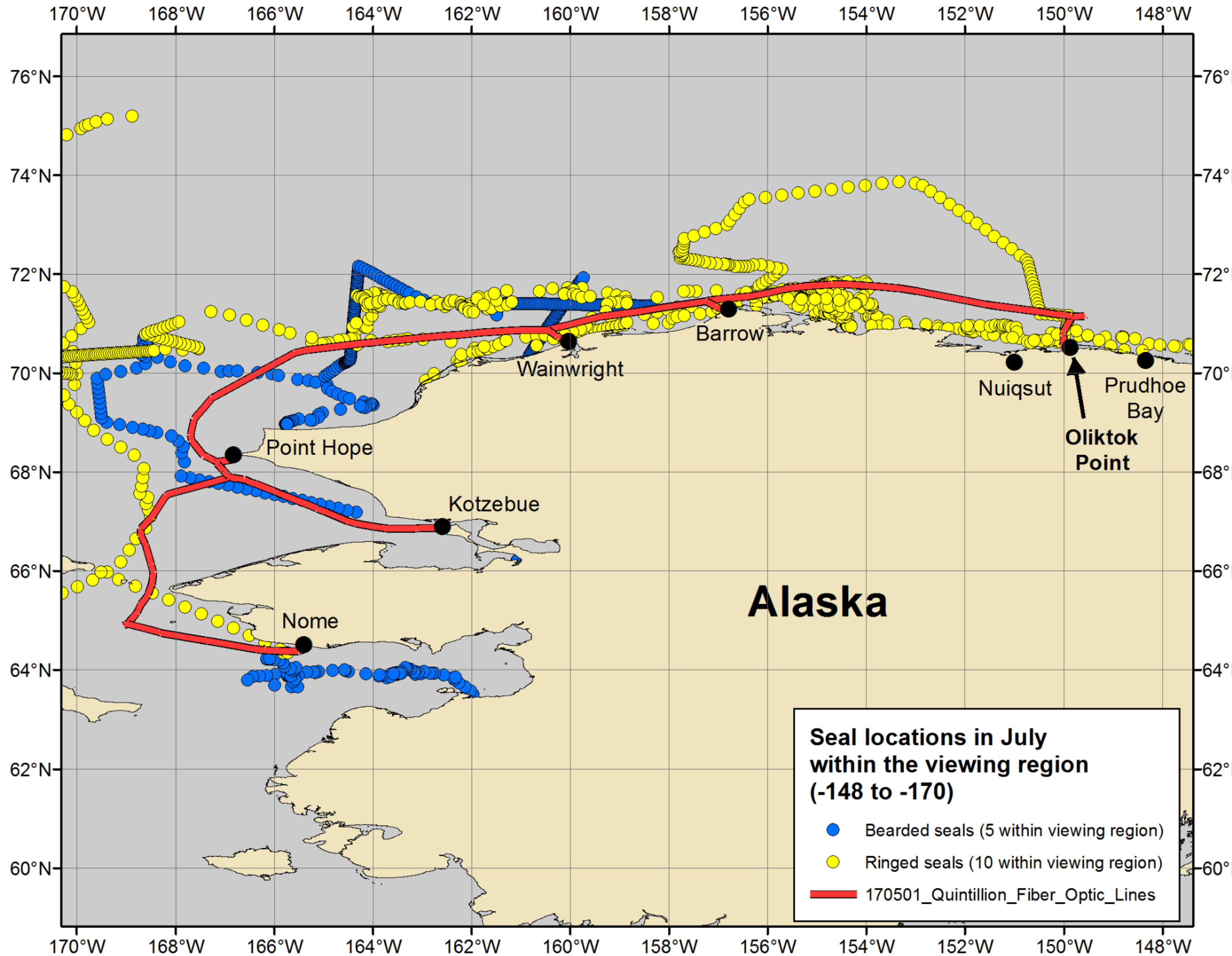

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Prudhoe Bay
Oliktok Point
Point Hope
Kotzebue
Nome
Alaska
Seal locations in July within the viewing region (-148 to -170)
Bearded seals (5 within viewing region)
Ringed seals (10 within viewing region)
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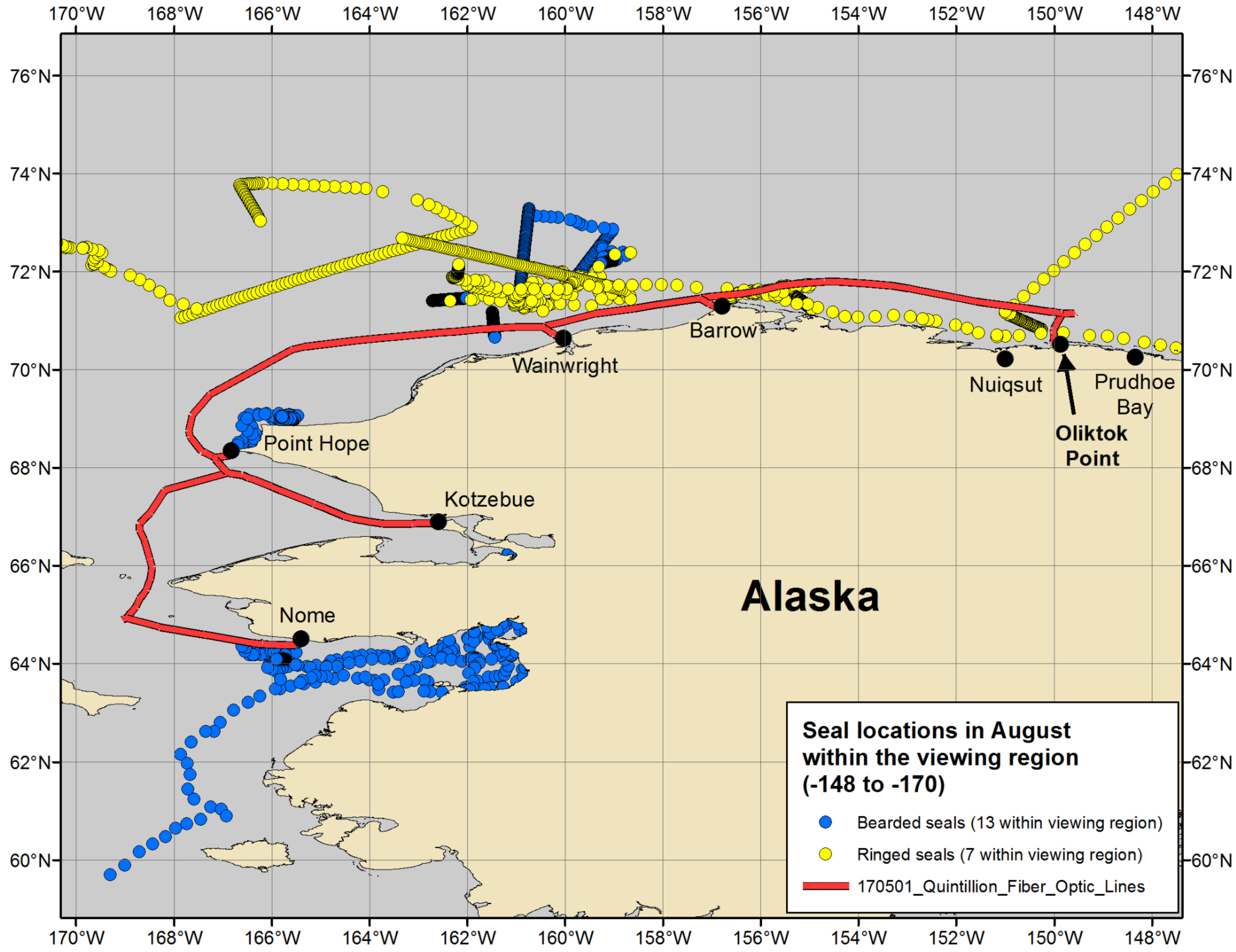
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Wainwright
Nuiqsut
Prudhoe Bay
Oliktok Point
Point Hope
Kotzebue
Nome
Alaska
Seal locations in August within the viewing region (-148 to -170)
Bearded seals (13 within viewing region)
Ringed seals (7 within viewing region)
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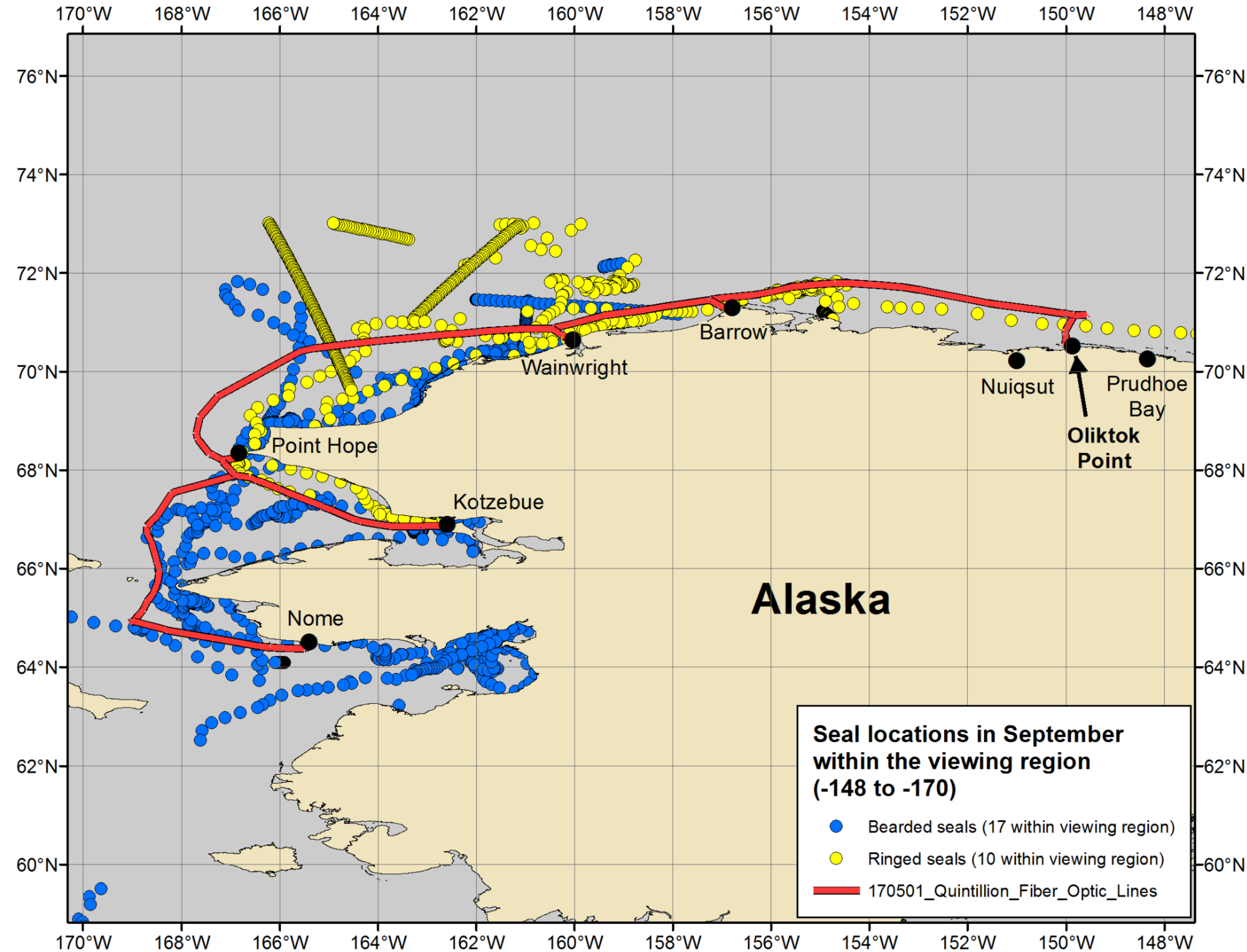

Seal locations in September within the viewing region (-148 to -170)
Bearded seals (17 within viewing region)
Ringed seals (10 within viewing region)
170501_Quintillion_Fiber_Optic_Lines
Alaska
Point Hope
Kotzebue
Nome
Wainwright
Barrow
Nuiqsut
Prudhoe Bay
Oliktok Point
170°W
168°W
166°W
164°W
162°W
160°W
158°W
156°W
154°W
152°W
150°W
148°W
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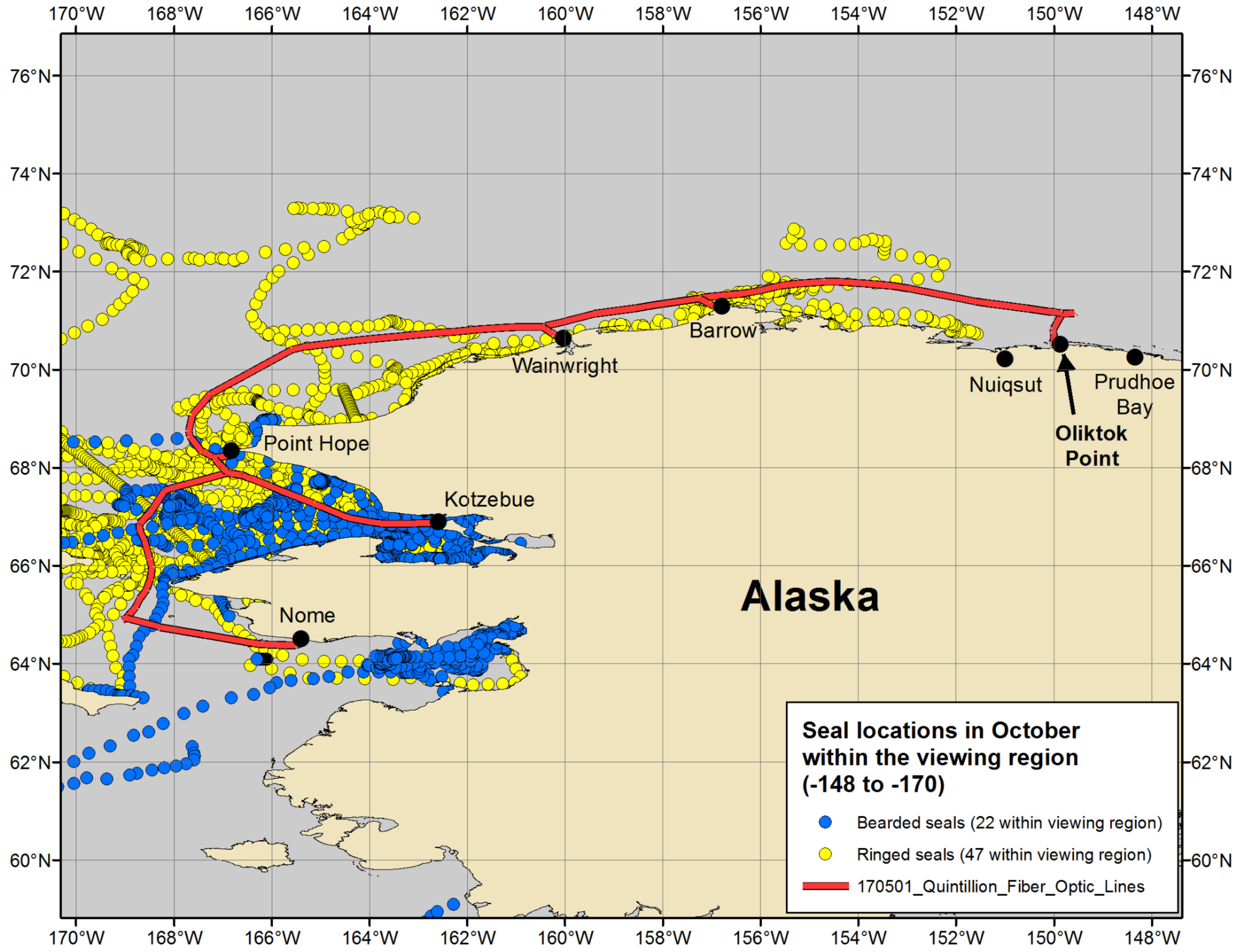
74°N
72°N
70°N
68°N
66°N
64°N
62°N
60°N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162°W
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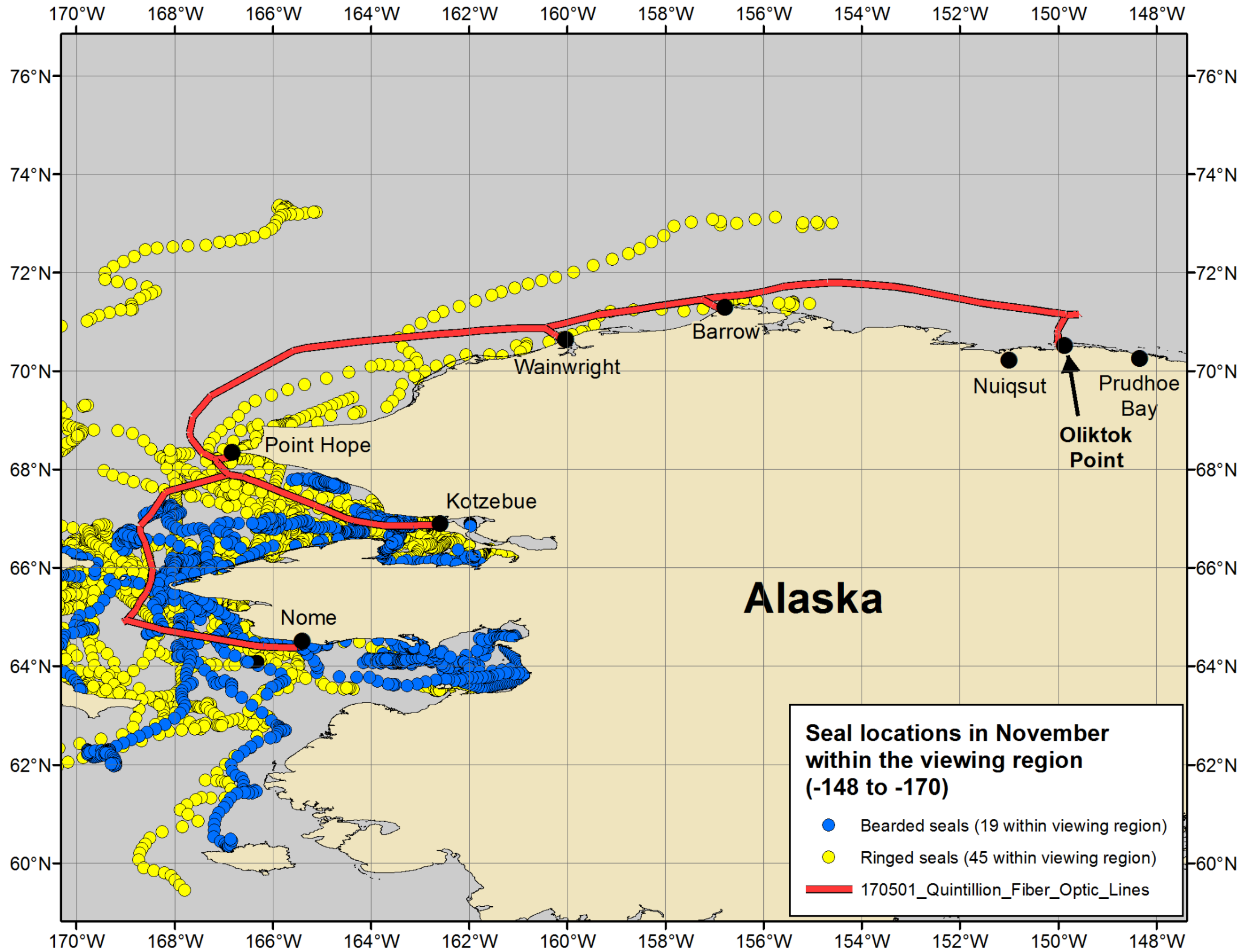
152°W
150°W
148°W
76°N
74°N
72°N
70°N
68°N
66°N
64°N
62°N
60°N
Point Hope
Wainwright
Barrow
Nuiqsut
Prudhoe Bay
Oliktok Point
Kotzebue
Nome
Alaska
Seal locations in October within the viewing region (-148 to -170)
Bearded seals (22 within viewing region)
Ringed seals (47 within viewing region)
170501_Quintillion_Fiber_Optic_Lines



170°W
168°W
166°W
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158°W
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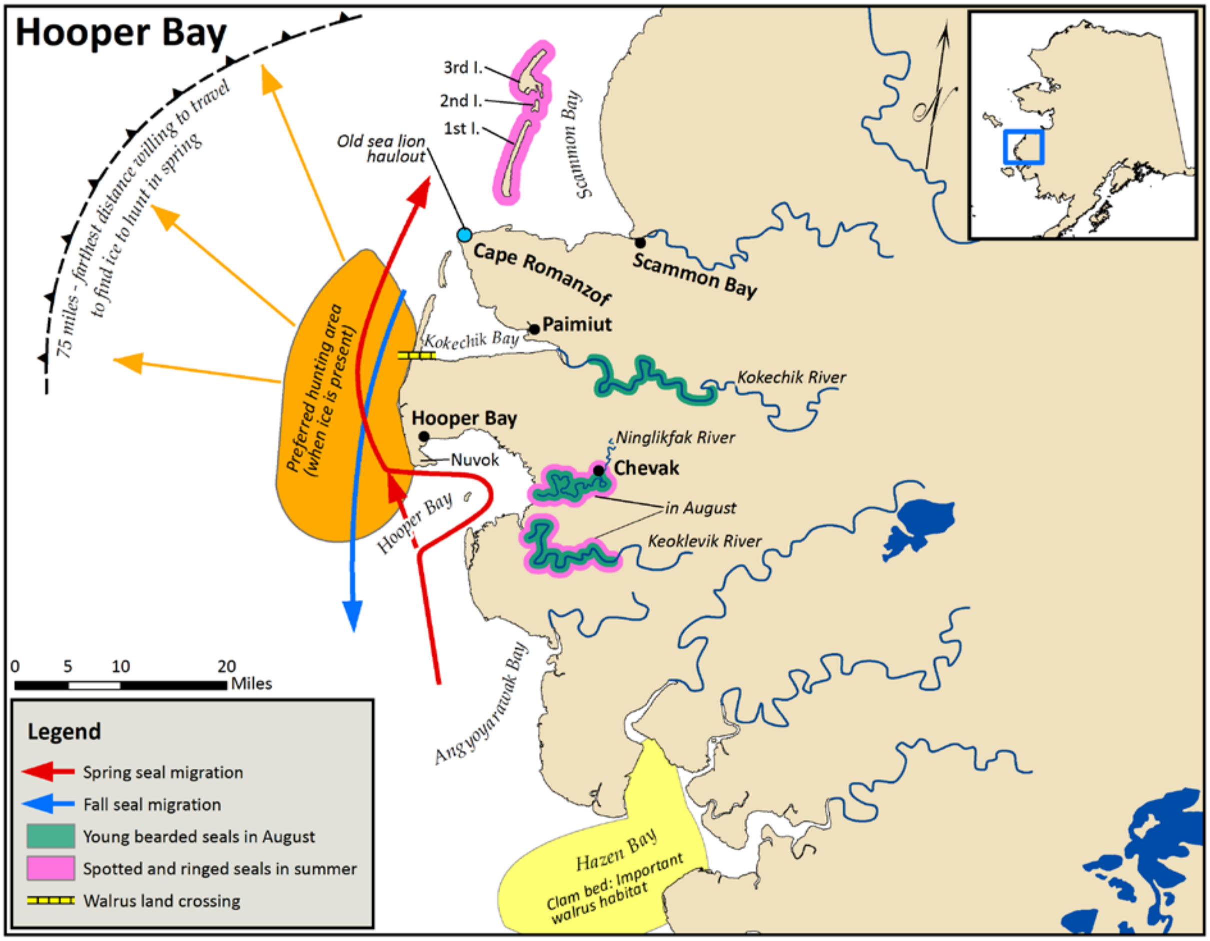
152°W
150°W
148°W
76°N
74°N
72°N
70°N
68°N
66°N
64°N
62°N
60°N
Point Hope
Kotzebue
Wainwright
Barrow
Nuiqsut
Prudhoe Bay
Oliktok Point
Nome
Alaska
Seal locations in November within the viewing region (-148 to -170)
Bearded seals (19 within viewing region)
Ringed seals (45 within viewing region)
170501_Quintillion_Fiber_Optic_Lines

Appendix M.

Traditional Knowledge Regarding Marine Mammals near Hooper Bay, Alaska



Traditional Knowledge Regarding Marine Mammals near Hooper Bay, Alaska

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Approved June 2017

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Huntington, H.P., M. Nelson, L.T. Quakenbush. 2017. Traditional knowledge regarding marine mammals near Hooper Bay, Alaska. Final report to the Eskimo Walrus Commission, the Ice Seal Committee, and the Bureau of Ocean Energy Management for contract #M13PC00015. 10pp.

Introduction

Seals, walrus, and beluga whales are important for subsistence harvests by Yup'ik hunters from Hooper Bay, Alaska. These animals are also iconic Arctic marine mammals at risk from climate change. Industrial activity in the Bering and Chukchi seas, coastal development in the Norton Sound region, and shipping through Bering Strait are additional potential stressors to these marine mammals. The study of the distribution, behavior, and movements of marine mammals is an important contribution to monitoring the effects of a changing environment and the potential effects of industrial activity. Placing satellite transmitters on seals, walrus, beluga whales, and other species provides detailed information about the movements, habitat use, and behavior of some individual animals. Satellite telemetry studies, however are limited in the number of individuals per species that can be instrumented, therefore it is difficult to know how well tagged animal movements and behavior represent the population as a whole. Documenting traditional knowledge about timing of migration, behavior, and the age classes of marine mammals at specific locations through interviews with residents of coastal communities provides important context in which to interpret the satellite telemetry studies as well as providing contemporaneous and historical information about general patterns in marine mammal distribution, movement, and behavior that complement the science greatly. The integration of these two different but equally important types of information provides a broader more comprehensive overview of how Arctic marine mammals and hunters operate in their environment and how changes in the environment are influential.

This report summarizes information gathered from interviews held in Hooper Bay with hunters and other knowledgeable residents in January 2017. This traditional knowledge project used the same approach that the Native Village of Savoonga used when documenting traditional knowledge about bowhead whales on St. Lawrence Island (Noongwook et al. 2007).

Methods

We used the semi-directive interview method, in which the interviewers raise a number of topics with the person being interviewed, but do not rely solely on a formal list of questions (Huntington 1998). Instead, the interview is closer to a discussion or conversation, proceeding in directions determined by the person being interviewed, reflecting that person's knowledge, associations made between animals and the environment, and so on. The interviewers use a list of topics of interest to raise additional points for discussion, but do not curtail discussion of additional topics introduced by the person being interviewed.

In Hooper Bay, we interviewed 11 persons, five individually and six in one group. The interviewees were Albert Simon, Albert Simon II, John Lake, and eight others who wished to remain anonymous. The interviews were conducted on January 9, 2017 in the homes of interviewees and at the Sea Lion corporation apartments.

The topics of interest identified by the research team in advance of the interviewers were:

Seasonal patterns of distribution of ice seals, walruses, and beluga whales
Haulouts on land
Use of rivers
Feeding patterns and prey
Impacts from climate change and hunter responses to those changes
Parts of marine mammals that people eat
Information about other marine mammals
Information about other aspects of the environment and people

Table 1. List of Yup'ik, English, and scientific names of marine mammals mentioned in this report.

	Yup'ik name	English name	Scientific name
	Maklak	bearded seal	*Erignathus barbatus*
	Maklagaq	young bearded seal	*Erignathus barbatus*
	Issuriq	spotted seal	*Phoca largha*
	Nayiq	ringed seal	*Phoca* or *Pusa hispida*
	Qaygulek	ribbon seal	*Histriophoca fasciata*
	Kaugpak	Pacific walrus	*Odobenus rosmarus*
	Uinaq	Steller sea lion	*Eumetopias jubatus*
	Cituaq	beluga whale	*Delphinapterus leucas*

The results are presented under different headings, reflecting the actual information collected and the fact that some of the subjects blend together, especially changes seen over time in regard to all of the topics. The interviewers were Henry Huntington and Mark Nelson. Lori Quakenbush is the project leader.

Ringed Seals

Ringed seals are found in the Hooper Bay area from fall to spring when sea ice is present. They are abundant in the area during this period. Today there seems to be fewer ringed seals in the Hooper Bay area, perhaps because of the changes in ice conditions, drawing the seals to the ice edge farther away. A few individuals may be found in the area in summer, sometimes these are young ringed seals in rivers, but the majority head north with the ice. Occasionally a ringed seal pup will be seen on the beach in summer. Ringed seals return when there is ice, the timing of which depends on the weather but may be in December or January. Even with changes in sea ice, seals of all kinds remain abundant. The coast is their highway.

One hunter once found a seal lying on an ice floe on its back, with its stomach open, perhaps killed by a polar bear.

Ringed seals eat herring in May. Their faces may be covered with herring eggs. Ringed and spotted seals seem to have similar diets.

Mostly it is hard to tell what ringed seals are doing just by watching them on the surface. They just pop up out of nowhere, with little indication of where they have been or what they have been doing.

Ringed seal skins can be blown up like a balloon and dried. They are used for the upper parts of mukluks (boots). There are several styles of mukluks, including ones for casual wear around the village, knee-high ones for going on the tundra, and thigh-high ones for cold weather. Ringed seal skins can also be used to make pokes, for storing fish and other foods. To store fish, the fish are put into the poke, and then seal oil is added to preserve the fish. After the fish are eaten and the oil is drained out, the skin can then be used to make watertight hip boots. Ringed seal skin is also used as rope, for lashing bearded seal skin boat covers to the boat frame, or making sleds or harpoons.

Seal meat can be dried on a rack outside and eaten like jerky. It is good when dipped in seal oil. Seal oil is also good to eat with vegetables gathered from the tundra in spring. The head, flippers, and tail of seals can be aged and eaten.

Male seals during the rut smell like gasoline. Their blubber can be used, but not the meat.

Sick seals have been seen occasionally, but most seals are healthy. Sick seals have boils on their skin and black fur. This is a relatively new phenomenon, seen in the past dozen or so years among ringed and spotted seals. One diseased seal, with pustules along its lungs and heart, was cut open and left on the beach, but even ravens and gulls would not eat it. Sometimes seals are seen with hair rubbed off, but this is thought to be caused by them hauling out and resting on ice.

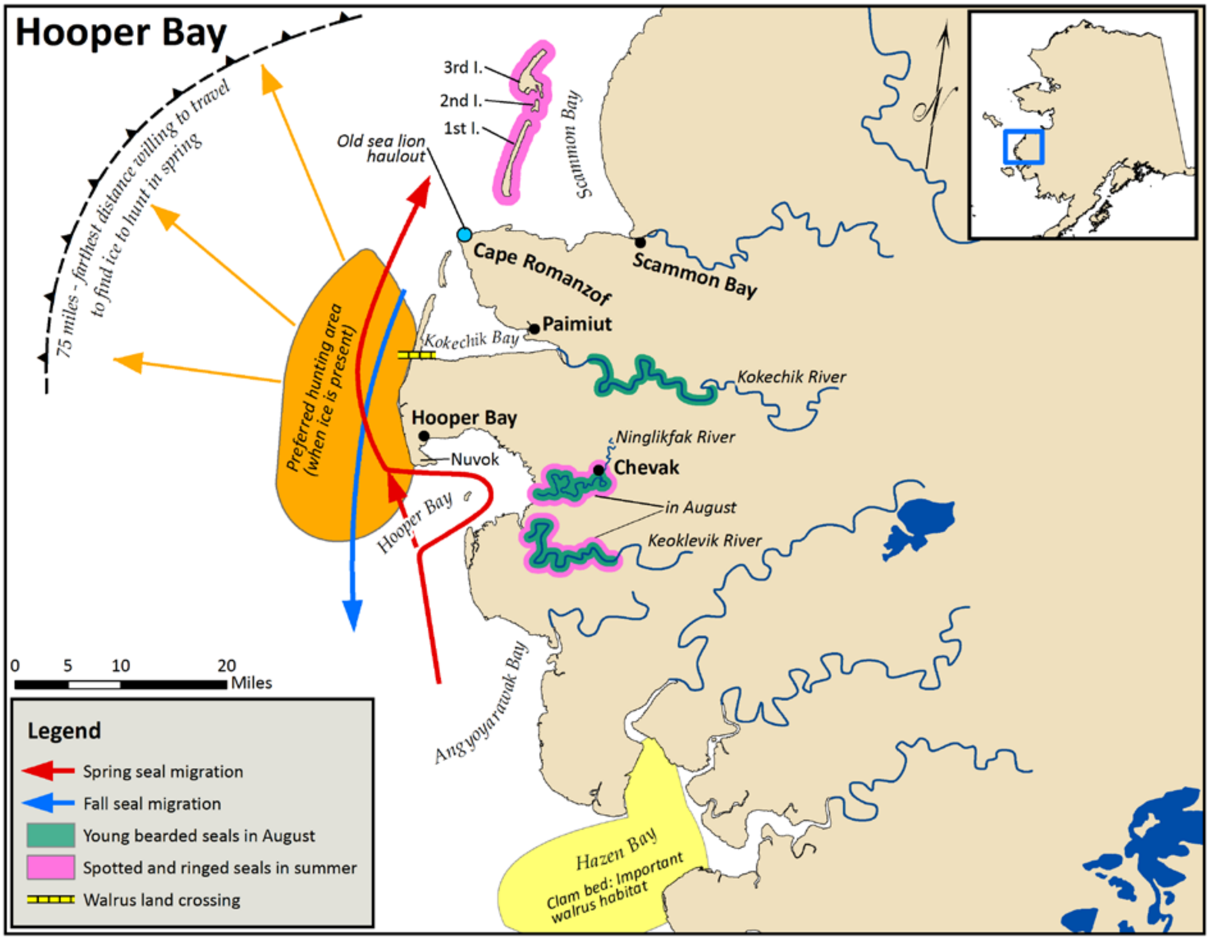

Figure 1. Movements and behavior of seals, walrus, and whales as described during traditional knowledge interviews, January 2017.

Spotted Seals

Spotted seals used to arrive in abundance in April following the beach, going after fish, probably tomcod (i.e., saffron cod) on their way north, but now they are found all winter long, whenever there is open water. . Most spotted seals head north by early to mid-May, with the sea ice, but some stay into June, often in rivers. There are many spotted seals on the three islands off Scammon Bay in summer, so many that they can be smelled from a distance. In fall, most spotted seals in the Hooper Bay area are subadults.

Spotted seals eat tomcod and smelt in late winter and early spring. There are lots of seals when there are lots of fish. In May, they eat herring and their faces can be covered with herring eggs. Spotted seal stomachs can also have clams in them. Feeding seals stay in one area, whereas migrating seals are heading in the direction of migration. The surfacing behavior is the same, however. Winter spotted seals are tasty, but spring spotted seals have a strong smell and flavor. Spotted seal skins are used for making hats and gloves.

Bearded Seals

Bearded seals typically arrive in large numbers in late March, remaining abundant through April and into May, as long as there is ice. In recent years, they have been arriving earlier, sometimes in February. Mothers with pups are slower when migrating. Some bearded seals may be found in the area all winter. Pregnant bearded seals have been taken in January. After the ice leaves, some juvenile bearded seals will stay in the area, going up rivers after fish such as whitefish, at times far up the rivers in late summer and are seen when people travel to pick berries (Figure 1). A few bearded seals stay in the area in summer, and are occasionally caught in salmon nets. In fall, most bearded seals in the Hooper Bay area are subadults or young of the year. One hunter took a pregnant bearded seal once in November.

Bearded seal stomachs have clams and shrimp and some small fish. In spring, bearded seal males will dive and call to the females. The calls can be heard by people on the surface of the water. Younger bearded seals are better than adults at hiding from hunters in broken ice, with only their nose out of water. Older seals are not afraid of hunters, don't hide as well, and are easier to find and hunt.

Bearded seal skins are used for the soles of mukluks (boots). These skins can also be used for kayak covers and skin boat covers. The skins are sewn together with sinew from beluga whales. Yellow moss is soaked in seal oil and used as caulk on the seams. A hole in a skin boat can be easily repaired at sea by using seal oil to join the skins back together. Bearded seal flippers, tail, and head can be aged in summer and eaten. Bearded seal intestines are rinsed, cooked, and eaten. The stomach can be dried out and inflated and used for storage, for seal oil or for berries and other things. The intestinal lining of bearded seals can be used to make raincoats or to make windows for old-style houses. People eat the kidneys, liver, heart, lungs, and other organs of bearded seals. These can be eaten raw or cooked. A bearded seal swimming in the sea is ready to eat as soon as it is harvested.

Walrus

Walrus are typically seen in spring, often in Hazen Bay where clams are abundant (Figure 1). The clams can be seen by river mouths when the tide is out. Walrus can also be seen on thick sea ice when it is present in spring, but this is less common now than it used to be. When west or northwest winds would bring thick sea ice to Hooper Bay, up to 50 walrus might be seen on a single floe, depressing the ice low enough to make it appear the walrus were lying on the water. A walrus was once seen on the beach in May, but this was unusual. Adults are not seen on land, only on ice and in the water. Young walrus have been taken in fall and in December near Hooper Bay, but this was very unusual. These days, walrus can sometimes be seen even in mid-winter, which never used to happen.

The elders say walrus used to take a shortcut overland at the base of the spit going to Kokechik Bay (Figure 1). The sandbars across the mouth of the bay used to be larger and formed a more complete barrier.

Beluga Whales

Beluga whales arrive in April and May, migrating north. They may pass by or come into the bay in the fall on their southern migration. They do not come into the bay as frequently as in the past, but when fish are available they will come into Hooper Bay feeding. In the fall of 2016, belugas were seen approaching the bay but then turning away, likely due to the presence of barges and the commotion associated with construction on the runway, which is near the shore. Belugas are regarded as sensitive to noise and disturbance. Belugas were seen in the area in January 2016, a time of year when they never used to be seen here.

Belugas commonly had their young in Hooper Bay, but have switched to having young in Kokechik Bay to avoid the barge and other boat traffic. Lately, belugas seem to come by during times of high wind and waves, making it difficult to hunt them. Beluga meat, skin, and organs can be stored and prepared in various ways: dried, aged, fresh.

Other Marine Mammal Species

Ribbon seals are sometimes seen in fall and winter near Hooper Bay. They make good seal oil, but the meat is strong and bloody tasting.

Sea lions were common in the area until the 1970s and early 1980s. Hooper Bay's village corporation is named the Sea Lion Corporation. From the 1980s until recent years, however, sea lions were seen infrequently, usually by Cape Romanzof, where six or eight sea lions may haul out at a time, high on the rocks (Figure 1). In the past few years, sea lions seem to be returning in greater numbers, though they remain uncommon. They are typically seen in spring and summer, not so often in the fall. People would occasionally hunt sea lions in the 1970s—the meat is excellent—but they have not been hunted since the sea lion population declined.

Killer whales are seen in the Hooper Bay area. They have been seen hunting beluga whales, which swim close to shore to try to avoid the killer whales. Killer whales were once seen hunting a gray whale, which swam close to a hunter's boat in an apparent attempt to avoid the killer whales. Hunters know not to try to harm killer whales, because the killer whales will remember the individual who harmed them and seek them out, even years later.

Gray whales and occasionally bowhead whales are seen off Hooper Bay in spring, typically 15 or more miles offshore, migrating to the north. Minke whales have been seen in May near Hooper Bay. A humpback whale was seen in the area for the first time in the summer of 2016. Pilot whales were seen in the area for the first time a few years ago. Hooper Bay is along a whale migration path so many species are observed throughout the year.

Other Information

Sea ice is thinner and breaks up more quickly than it used to. There used to be solid ice for the middle months of winter, but now there is thin ice and there is more open water. It is hard to travel on the thin ice, whereas people used to go out by dog team or snowmachine to reach the ice edge. There is not much pack ice in the area any more. There is now little or no shorefast ice in winter, whereas there used to be extensive shorefast ice that hunters could use for traveling to the ice edge. Without the shorefast ice, launching boats directly from shore can be hazardous because of waves breaking in the nearshore shallows. In the deeper water at the edge of shorefast ice, the waves do not break in this way, so the hazard is much lower. There are fewer northwest winds, which used to bring the big, thick ice floes in along with the marine mammals. It is easier to hunt when there is ice, and thick ice provides a place to cut up larger seals. There are still plenty of seals, but hunters have to travel farther and look harder to find them.

There used to be more snow in Hooper Bay, creating deep drifts. Winters used to be colder. There used to be no flooding in winter, but a lack ice and strong winds have created high winter floods in recent years.

The weather has changed, making hunting harder and more dangerous. River mouths may be open during winter, and on the beach an ice ledge can form, making it difficult or impossible to get down to the beach in places. Even when there are plenty of seals on the ice, hunters may not be able to get to them.

Storms now are more persistent than they used to be, and there are more windy days and fewer calm days. More southeast winds bring more periods of high water and flooding. There is more east wind than there used to be, and less south wind.

There has been less driftwood in recent years, perhaps because the Yukon River does not flood as often in the Interior. Those floods carry many trees away down the river, bringing them to the coast.

The lakes where Hooper Bay residents get freshwater are drying out. Perhaps this is because of changing permafrost.

Moose are more common in the area than before, coming every summer. Black bears can be found in the mountains, in spring and especially in fall. One hunter said an elder had told him that strange animals would come to the area, and after that, there would be nothing, which is a scary prospect. There are sometimes swans in the area in November. Bees and ladybugs are now common in summer, and new insects such as hornets are arriving.

Salmon are coming in earlier. Fewer came in last summer than usual, but overall the salmon remain abundant. Even king salmon are plentiful, despite problems on the Kuskokwim and Yukon Rivers. In May, the north wind brings in the king salmon. There are more halibut, and also salmon sharks, which were not seen before. Someone found a small stingray (probably a skate) on the beach. Overall, the fish supply is abundant. Fishermen sometimes see fish that have been wounded by seals. Some smelt have been seen with boils, scars, and black spots, which appears to be new in the past 15 or so years.

The rapid retreat of sea ice in spring means hunters have a shorter period for hunting ice-associated marine mammals such as seals and walrus. It is important to take advantage of the opportunities to hunt when they happen, since they are so brief these days. Larger boats and more powerful motors mean they can go farther offshore to find ice and animals, as much as 60 miles from land, but this entails considerable risk and expense, as well as much disappointment if no marine mammals can be found. The problem is not a shortage of animals—there are still plenty of seals and other marine mammals and the animals are healthy. The problem is getting to them, either because they are far away or because ice conditions are not favorable for hunting or traveling.

The lessons of the elders are important ones, reflecting the skills and values that allowed people to survive and thrive in this region for countless generations. Hunting comes from necessity not recreation. Successful hunters should share with those in need, especially elders who can no longer hunt for themselves. While the connection to the land is weakening as people rely more and more on the store and other outside sources of the things they need, it is still essential to pass on to one's children the essential values of respect and sharing. Hunters used to prepare extensively before going out, to be ready for any situation. Ammunition was scarce and expensive, so hunters had to be sure of their shot and be sure they could retrieve an animal they shot. They were prepared to be patient, to wait all day for a seal. They were not greedy and did not get excited, but stayed calm and relaxed. They placed safety first. Today, many hunters go out without emergency gear and without making these kinds of physical and mental preparations.

Acknowledgements

We are grateful for the skill, expertise, and generosity of the eleven hunters who participated in the interviews. We appreciate the support of the Eskimo Walrus Commission and the Ice Seal Committee for this project and are grateful to Albert Simon for helping to set up the interviews. The Bureau of Ocean Energy Management (BOEM) funded the work as part of Contract No. M13PC00015 and we appreciate the support of Carol Fairfield and Catherine Coon. Justin Crawford prepared the maps used during the interviews and the figure in this report.

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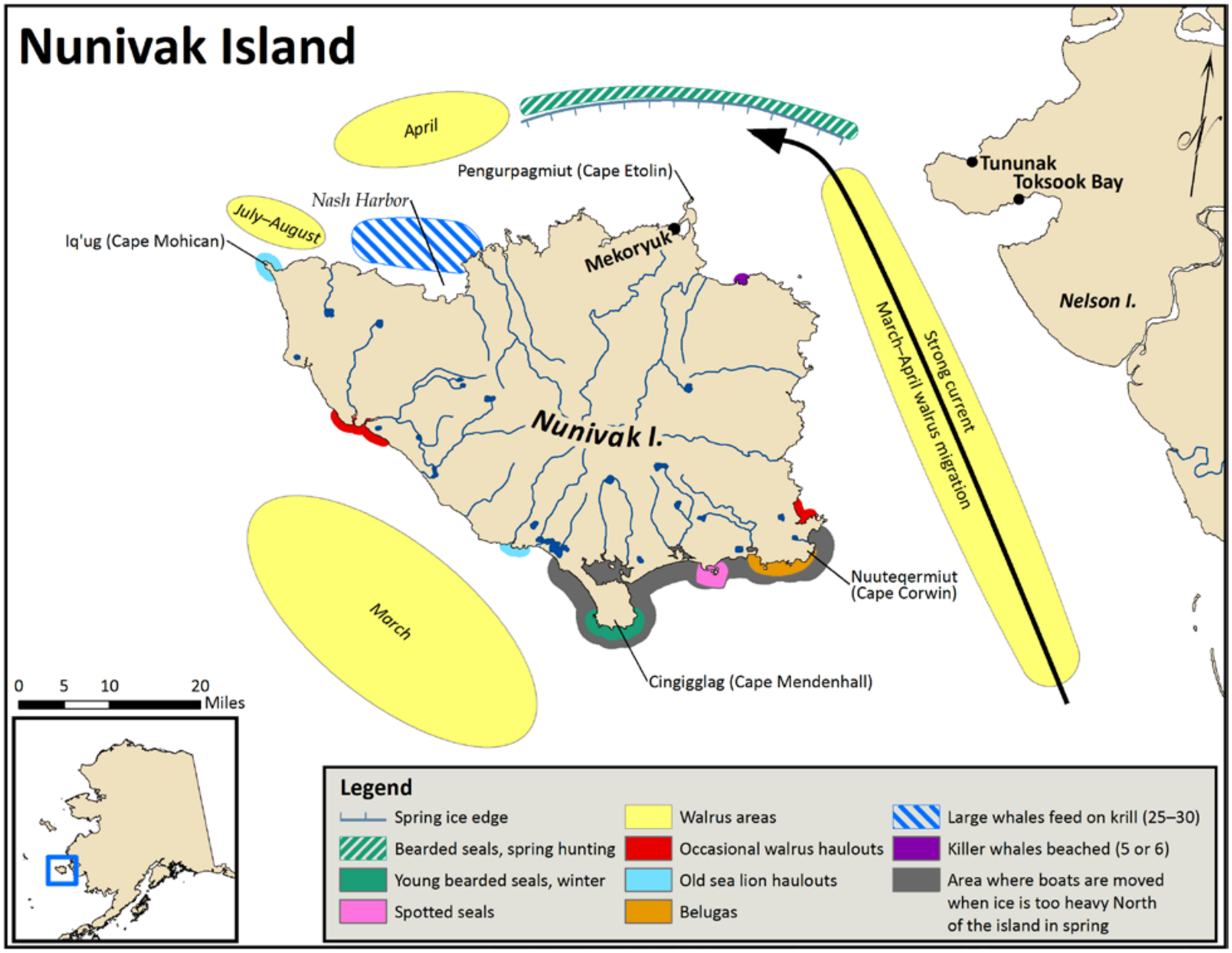
Noongwook, G., the Native Village of Gambell, the Native Village of Savoonga, H.P. Huntington, and J.C. George. 2007. Traditional knowledge of the bowhead whale (*Balaena mysticetus*) around St. Lawrence Island, Alaska. Arctic 60(1):47–54.

Appendix N.

Traditional Knowledge Regarding Marine Mammals near Mekoryuk, Alaska



Traditional Knowledge Regarding Marine Mammals near Mekoryuk, Alaska

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Introduction

Seals, walrus, and beluga whales are important for subsistence harvests by Cup'ig hunters from Mekoryuk, Alaska. These animals are also iconic Arctic marine mammals at risk from climate change. Industrial activity in the Bering and Chukchi seas, coastal development in the Norton Sound region, and shipping through Bering Strait are additional potential stressors to these marine mammals. The study of the distribution, behavior, and movements of marine mammals is an important contribution to monitoring the effects of a changing environment and the potential effects of industrial activity. Placing satellite transmitters on seals, walrus, beluga whales, and other species provides detailed information about the movements, habitat use, and behavior of some individual animals. Satellite telemetry studies, however are limited in the number of individuals per species that can be instrumented, therefore it is difficult to know how well tagged animal movements and behavior represent the population as a whole. Documenting traditional knowledge about timing of migration, behavior, and the age classes of marine mammals at specific locations through interviews with residents of coastal communities provides important context in which to interpret the satellite telemetry studies as well as providing contemporaneous and historical information about general patterns in marine mammal distribution, movement, and behavior that complement the science greatly. The integration of these two different but equally important types of information provides a broader more comprehensive overview of how Arctic marine mammals and hunters operate in their environment and how changes in the environment are influential.

This report summarizes information gathered from interviews held in Mekoryuk with hunters and other knowledgeable residents in January 2017. This traditional knowledge project used the same approach that the Native Village of Savoonga used when documenting traditional knowledge about bowhead whales on St. Lawrence Island (Noongwook et al. 2007).

Methods

We used the semi-directive interview method, in which the interviewers raise a number of topics with the person being interviewed, but do not rely solely on a formal list of questions (Huntington 1998). Instead, the interview is closer to a discussion or conversation, proceeding in directions determined by the person being interviewed, reflecting that person's knowledge, associations made between animals and the environment, and so on. The interviewers use a list of topics of interest to raise additional points for discussion, but do not curtail discussion of additional topics introduced by the person being interviewed.

In Mekoryuk, we interviewed seven persons as a group. The interviewees were Albert Williams, Howard Amos, and five others who wished to remain anonymous. The interviews were conducted on January 13, 2017 at the Native Village of Mekoryuk office.

The topics identified by the research team in advance of the interviewers were:

Seasonal patterns of distribution of ice seals, walruses, and beluga whales
Haulouts on land
Use of rivers
Feeding patterns and prey
Impacts from climate change and hunter responses to those changes
Parts of marine mammals that people eat
Information about other marine mammals
Information about other aspects of the environment and people

Table 1. List of Cup’ig, English, and scientific names of marine mammals mentioned in this report.

	Cup'ig name	English name	Scientific name
	Maklag	bearded seal	*Erignathus barbatus*
	Amirkar (sometimes maklassugar)	young bearded seal	*Erignathus barbatus*
	Issuri (sometimes Issurir)	spotted seal	*Phoca largha*
	Nayir	ringed seal	*Phoca* or *Pusa hispida*
	Qasrul'eg or Qasrulek	ribbon seal	*Histriophoca fasciata*
	Kaugpag	Pacific walrus	*Odobenus rosmarus*
	Apakcuq or Apakcug	Steller sea lion	*Eumetopias jubatus*
	Cetuar	beluga whale	*Delphinapterus leucas*
	Aatagat	Northern fur seal	*Callorhinus ursinus*
	Mangaqcuar	harbor porpoise	*Phocoena phocoena*
	Mangaqcuar	Dall's porpoise	*Phocoenoides dalli*

The results are presented under different headings, reflecting the actual information collected and the fact that some of the subjects blend together, especially changes seen over time in regard to all of the topics. The interviewers were Henry Huntington and Mark Nelson. Lori Quakenbush is the project leader.

Ringed Seals

Ringed seals are hunted in spring when the water starts to open up. Hunting is often right from the beach with a kayak. Ringed seals are around most of the year, but are more common when ice is close. Ringed seals used to be caught in nets in late fall, but nets are rarely used for catching seals now. They are hunted when bearded seals are not available and are preferred over spotted seals.

Spotted Seals

Spotted seals are present year-round, in abundance and even over-abundance according to some hunters. They are especially abundant during the herring run in May. Spotted seals haul out on rocks on the southeast side of the island and also on rocks on the beach in all the bays on the island (Figure 1). Because they are not usually hunted, the spotted seals just stay where they are and go where they want to. Spotted seal pups are sometimes seen alone on a beach.

Spotted seal oil has a strong taste. Other seals are preferred. Spotted seals are considered "emergency food," if a hunter does not get a bearded or ringed seal.

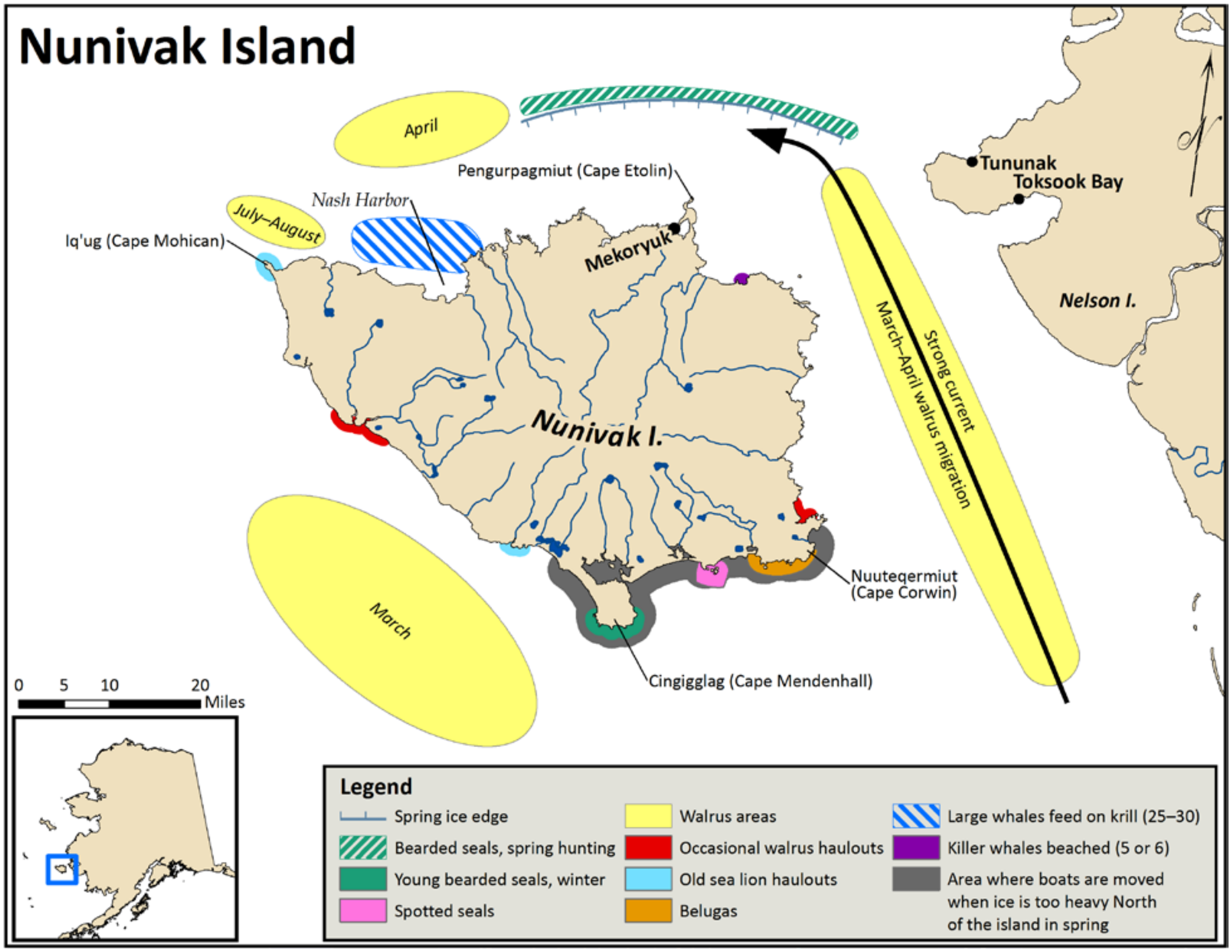

Figure 1. Movements and behavior of seals, walrus, and whales as described during traditional knowledge interviews, January 2017.

Bearded Seals

Bearded seals are seen on the southern coast of Nunivak Island in winter, especially off Cape Mendenhall on the south side of the island (Figure 1). Most of the bearded seals seen in winter are yearlings. Older, larger bearded seals stay farther north.

Young bearded seals are occasionally seen in river mouths or up rivers on the island. Yearlings are also seen in the bay by the village, rarely but it does happen from time to time.

Mekoryuk hunters see fewer bearded seals now. They used to see them more often off the north coast, about 15 miles offshore (Figure 1), but this is not so common anymore.

Bearded seals eat shrimp, small shell and hair crabs, and some small fish such as flounder and rockfish. Hunters have not seen clams in bearded seal stomachs.

Blubber thickness has been decreasing. Seal oil is very important in the diet of Mekoryuk residents. People eat all parts of the seal, including kidneys and intestines. The meat can be dried or frozen.

Mekoryuk residents primarily hunt for bearded seal. After that, they will look for walrus or ringed seals. Bearded seals are large enough to feed a family for a year, and will be shared with relatives, elders, and those in need.

Walrus

Walrus come in spring in herds that have males, females, and pups. In later spring, the herds may have more bulls. Lone walrus have been seen on the west side of the island in summer, hauled out on land. Long ago, in the wooden boat times, a herd of walrus was once seen hauled out on rocks on the east side of the island in June, after the ice had gone. A walrus was once taken off the south side of the island in June, after the ice had gone. In 2005 or 2006, a large group of male walrus came ashore on the beach near the village during halibut season in summer, early July (Figure 1). Walrus are occasionally seen in fall. In the fall of 2016, a herd of walrus came into the bay by the village.

A walrus was once seen well inland on the north side of the island, south of the village. Apparently the ice had come in and blocked access to the water. Perhaps the walrus was trying to reach open water on the other side of the island. Walrus have been known to get stranded in this way, when access back to the water is blocked by ice. Some walrus come on land in that situation.

Walrus eat clams. When hunters take a walrus east of Mekoryuk in April, the clams in its stomach are ready to eat. The clams are typically 2-4 inch butterclams. Hunters have not seen other prey in walrus stomachs.

People eat walrus heart and kidneys as well as meat and blubber. Some people age the flipper of the walrus.

Beluga Whales

A group of beluga whales was seen in March off the shore near the airport. Beluga whales were seen nearshore at the southeast end of the island about four or five years ago in late April or early May, after the ice had gone. Belugas are not too common around Nunivak Island, though there are stories about beluga whales coming ashore and turning into wolves. Historically, Mekoryuk residents were not whale hunters, though they would take the flippers from whales that washed up on the beach. Beluga whales are encountered regularly in the Nuuteqermiut (Cape Corwin) area (Figure 1).

Other Marine Mammal Species

Ribbon seals are seen and sometimes hunted in the area in fall, when the ice has begun coming in but boating is still possible. This is often in November. Ribbon seals are not seen in spring.

There are sea lions in the Mekoryuk area, but not as many as there used to be. Many sea lions used to haul out at Cape Mohican, but no longer (Figure 1). Once in a while, hunters will see a lone sea lion on the east side of the island. Sea lions have been seen on ice floes in a bay east of the village, on the northeast side of the island.

Killer whales are seen in late spring, when the ice goes out. They are not common. A few decades ago, a group of five or six killer whales beached themselves east of the village. No one knows why. Killer whales were once seen hunting a walrus that was on an ice floe.

There are many porpoise (most likely harbor porpoise, but could be Dall's porpoise) in the area. A group of 25-30 large whales of unknown species was once seen in the Nash Harbor area on the west end of the north side of the island, feeding in the bay (Figure 1). Many whales were seen one spring during egging season, off the southeast side of the island.

Other Information

Fishermen catch lots of skates now, while longlining for halibut. They never used to get skates and consider them a nuisance. Longlining for halibut was not done in the old days.

In winter, the north side of the island is typically blocked in by ice, so hunters have to go to the south side if they want to hunt. This means taking boats and other gear across the island, about a journey of about 45 miles.

The current is strong on the east side of the island, going north through Etolin Strait and then west along the north side of Nunivak Island. This current makes the north side dangerous, adding to the reasons for hunting off the south side in winter.

The ice has changed greatly in the past decade or two. Due to changes in ice conditions, the period of good hunting in spring is much shorter than it used to be. There used to be a few weeks of good hunting once the ice started breaking up. Now, hunters are lucky to have a week before the ice is gone, and the good hunting with it. If they miss the opportunity, they may be without seal oil.

Hunters also said the Cup'ig names of the months reflect what is happening in nature. The name for October means "when ponds freeze;" for November, "when sea ice covers the ocean." The timing of these events no longer follows the Cup'ig calendar. Freeze-up is coming later and later. Break-up comes earlier and is much faster than it used to be.

In early 2017, south winds created open water north of the island and the village, which used to be very unusual. Ice conditions are unpredictable now. The ice never used to move from the north side of the island in December, January, or February. It was rare to see open water at that time. Now, the ice can go away even in mid-winter. Even the bay in front of the village has had open water in wintertime in recent years. In the weeks prior to the interviews, people had been able to gather mussels from the beach, which was never possible in winter before.

Mekoryuk has seen rain in mid-winter, which never used to happen. In January 2017, there was little or no snow in the area, just hoarfrost covering the ground. This has made it hard to ride across the tundra to herd reindeer. In 2016, the snow was gone within a couple weeks of starting to melt.

In the old days, calm weather used to persist for a week or more. Nowadays, the winds will pick up again after a day or so. In old photos from Mekoryuk, people paddled kayaks across the bay in completely flat water.

Acknowledgements
We are grateful for the skill, expertise, and generosity of the seven hunters who participated in the interviews. We appreciate the support of the Eskimo Walrus Commission and the Ice Seal Committee for this project and are grateful to Dale Smith, Jr. for helping to set up the interviews. The Bureau of Ocean Energy Management (BOEM) funded the work as part of Contract No. M13PC00015 and we appreciate the support of Carol Fairfield and Catherine Coon. Justin Crawford prepared the maps used during the interviews and the figure in this report.

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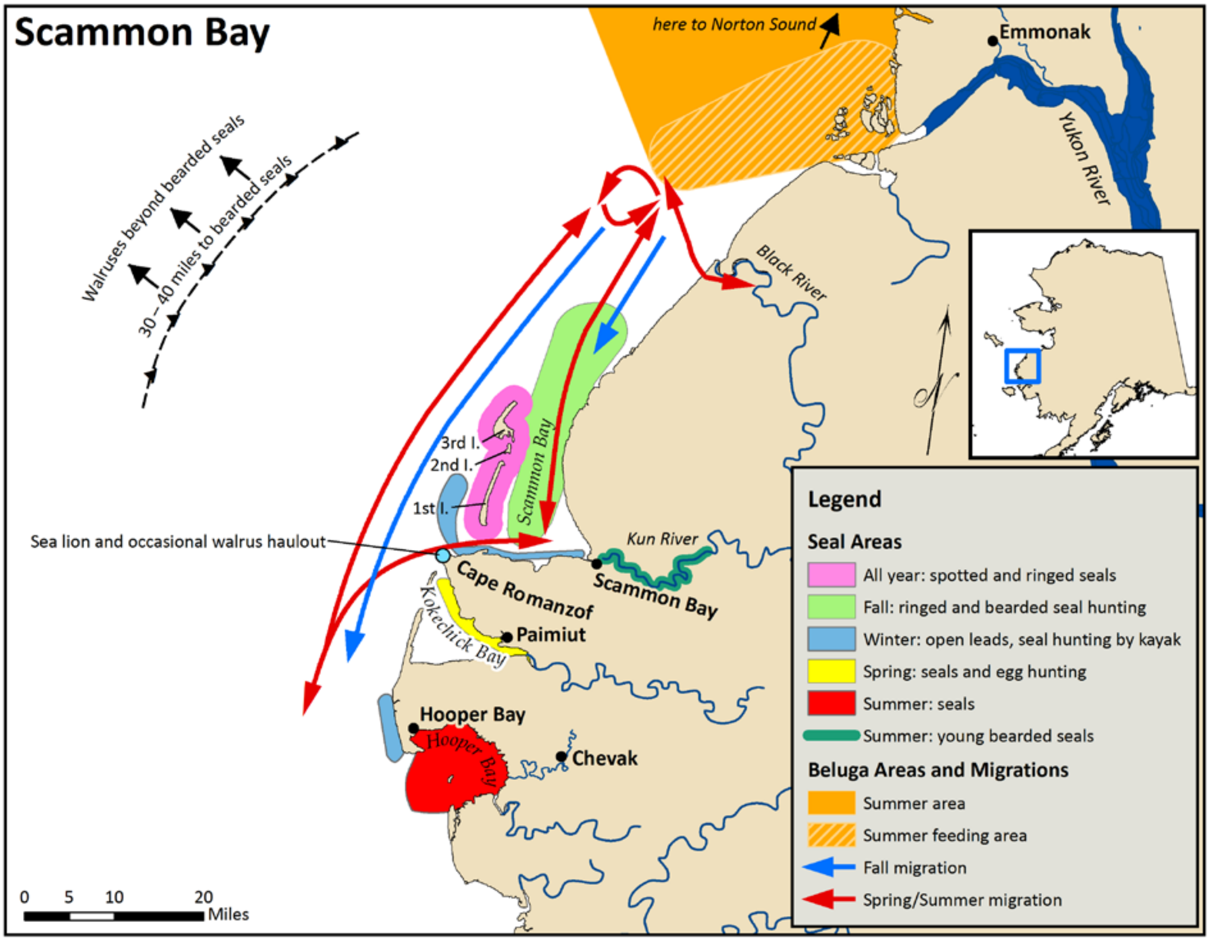
Huntington, H.P. 1998. Observations on the utility of the semi-directive interview for documenting traditional ecological knowledge. Arctic 51(3):237–242.

Noongwook, G., the Native Village of Gambell, the Native Village of Savoonga, 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.

Appendix O.

Traditional Knowledge Regarding Marine Mammals near Scammon Bay, Alaska



Traditional Knowledge Regarding Marine Mammals near Scammon Bay, Alaska

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Introduction

Seals, walrus, and beluga whales are important for subsistence harvests by Yup'ik hunters from Scammon Bay, Alaska. These animals are also iconic Arctic marine mammals at risk from climate change. Industrial activity in the Bering Sea, coastal development in the Norton Sound region, and shipping through Bering Strait are additional potential stressors to these marine mammals. The study of the distribution, behavior, and movements of marine mammals is an important contribution to monitoring the effects of a changing environment and the potential effects of industrial activity. Placing satellite transmitters on seals, walrus, beluga whales, and other species provides detailed information about the movements, habitat use, and behavior of some individual animals. Satellite telemetry studies, however are limited in the number of individuals per species that can be instrumented, therefore it is difficult to know how well tagged animal movements and behavior represent the population as a whole. Documenting traditional knowledge about timing of migration, behavior and the age classes of marine mammals at specific locations through interviews with residents of coastal communities, provides important context in which to interpret the satellite telemetry studies as well as providing contemporaneous and historical information about general patterns in marine mammal distribution, movement, and behavior that complement the science greatly. The integration of these two different but equally important types of information provides a broader more comprehensive overview of how Arctic marine mammals and hunters operate in their environment and how changes in the environment are influential.

This report summarizes information gathered from interviews held in Scammon Bay with hunters and other knowledgeable residents in January 2017. This traditional knowledge project used the same approach that the Native Village of Savoonga used when documenting traditional knowledge about bowhead whales on St. Lawrence Island (Noongwook et al. 2007).

Methods

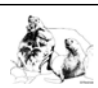
We used the semi-directive interview method, in which the interviewers raise a number of topics with the person being interviewed, but do not rely solely on a formal list of questions (Huntington 1998). Instead, the interview is closer to a discussion or conversation, proceeding in directions determined by the person being interviewed, reflecting that person's knowledge, associations made between animals and the environment, and so on. The interviewers use a list of topics of interest to raise additional points for discussion, but do not curtail discussion of additional topics introduced by the person being interviewed.

In Scammon Bay, we interviewed five persons individually. The interviewees were Morgan Simon, Jim Kaganak, Wybon Rivers, John Bell, and one other who wished to remain anonymous. The interviews were conducted on January 10 and 11, 2017 in the homes of three interviewees, at the office of one, and in the school library.

The topics of interest identified by the research team in advance of the interviewers were:

- Seasonal patterns of distribution of ice seals, walruses, and beluga whales
- Haulouts on land
- Use of rivers
- Feeding patterns and prey
- Impacts from climate change and hunter responses to those changes
- Parts of marine mammals that people eat
- Information about other marine mammals
- Information about other aspects of the environment and people

Table 1. List of Yup'ik, English, and scientific names of marine mammals mentioned in this report.

	Yup'ik name	**English name**	**Scientific name**
	Maklak	bearded seal	*Erignathus barbatus*
	Maklagaq	young bearded seal	*Erignathus barbatus*
	Issuriq	spotted seal	*Phoca largha*
	Nayiq	ringed seal	*Phoca* or *Pusa hispida*
	Qaygulek	ribbon seal	*Histriophoca fasciata*
	Kaugpak	Pacific walrus	*Odobenus rosmarus*
	Uinaq	Steller sea lion	*Eumetopias jubatus*
	Cituaq	beluga whale	*Delphinapterus leucas*

The results are presented under different headings, reflecting the actual information collected and the fact that some of the subjects blend together, especially changes seen over time in regard to all of the topics. The interviewers were Henry Huntington and Mark Nelson. Lori Quakenbush is the project leader.

<u>Ringed Seals</u>

A few ringed seals can be found in the Scammon Bay area year-round, but most arrive back in November or so, around the time the sea ice returns, when they can haul out on shorefast ice or on pack ice. They stay through the winter and spring, becoming more plentiful or at least more visible in March as the ice opens and hunters begin to go out by kayak. Some ringed seals stay in the area as late as May or so and don't leave until after the herring run. Ringed seals usually have small fish in their stomachs, and sometimes some shrimp.

Ringed seals used to be hunted mainly in spring, but now can be hunted in December through February, due to thinner sea ice and more open water. In spring, they are hunted mainly for the meat and oil. The oil is used to preserve dried fish and other things. Hunters avoid larger ringed seals in March and April, because they may be in rut and not suitable for eating. Ringed seal skins are used for hats, gloves, and boot uppers.

Two or so years ago, ringed seals with boils on their neck and bellies were seen, acting fearless unlike how seals usually behave. Some hunters went for spotted seals instead, as these appeared to be healthy. Another hunter reported ringed seals with red skin and open sores, on their backs. He said some spotted seals had similar sores. Seals with bald patches have been seen from time to time for as long as some hunters can remember (>30 years), but they are not common. Some seals in the past were skinny too, perhaps ill.

In 2011, after the Japanese earthquake and tsunami, some seals were seen behaving sluggishly, not fleeing when hunters approached. Hunters avoided those seals and went instead for the ones that were energetic as usual. This behavior lasted only a year or two.

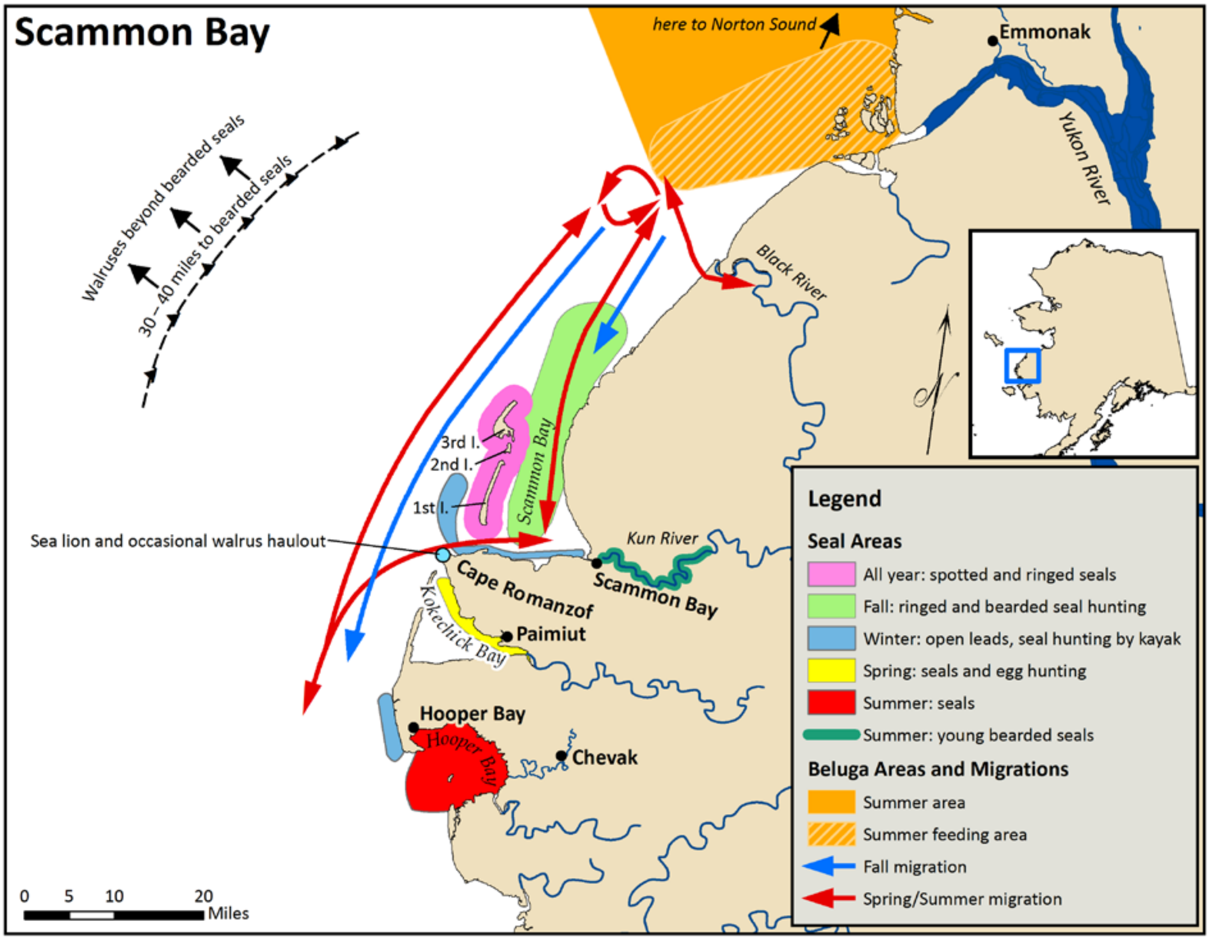


Figure 1. Movements and behavior of seals, walrus, and beluga whales as described during traditional knowledge interviews, January 2017.

Spotted Seals

Spotted seals are abundant. They are found in the area year-round. In spring, spotted seals become more common in April, after ringed and bearded seals start heading north. Hundreds of spotted seals can be seen in the weeks before break-up, sometimes in large gatherings. Spotted seals remain plentiful in May. In summer, 400–500 spotted seals haul out on the second and third islands off Scammon Bay (Figure 1), but not elsewhere in the area. Some ringed seals may haul out there, too, but after the herring run nearly all the seals in the area are spotted seals. Spotted seals are occasionally seen in the channel by the first island in summer. Spotted seals are hunted for their skin and oil.

This winter, spotted seals are more abundant than usual in the area, due to the open water and thin ice so close to shore. In late December, hunters saw mainly spotted seals and only a few ringed seals. In colder winters, ringed seals are more common than spotted seals and are the usual seal to see in January and February.

Spotted seals eat tomcod (i.e., saffron cod) when they are abundant in the area, and herring during the herring run. Some can be seen with herring eggs on their faces at that time of year. A spotted seal taken in late December 2016 had tomcod and smelt in its stomach. Hunters can tell if seals are feeding based on where the seals are and when, and on indicators like herring eggs on their faces. The surfacing behavior does not seem to change very much.

Bearded Seals

Some bearded seals are present throughout the winter, but they are generally secretive and few are seen. Most bearded seals come in spring, when the ice opens up a bit and they have their young. They used to arrive in mid-March, but now some will come as early as February, showing up a few miles offshore. Most leave for the north in April or May, after the herring run, but some juveniles stay all summer, often going up rivers where they appear to be following tomcod and whitefish runs throughout the summer. At Black River, two or three bearded seals can be seen coming in with the fish on each tide (Figure 1). In fall, bearded seals return with the sea ice, but most of these are sub-adults.

Bearded seals are pregnant in spring. Mother bearded seals are very protective of their young; they can be approached easily as they will not flee and abandon their pups.

Bearded seals have many, often large, shrimp in their stomachs in spring and also sea cucumbers or spoon worms. In September and October, they will also have small, sardine-like fish.

Bearded seals are hunted in spring. The meat is often dried and can be frozen, too. The innards are used to make soup. Nearly all of the animal is used, with the exception of some parts such as the bile ducts near the liver. Bearded seal is used to make oil. Bearded seal skins are tough.

Bearded seal hunting in spring is getting harder, due to poor hunting conditions and fewer seals. Hunting in fall is also challenging due to fewer seals.

One hunter has found bearded seals with discolored livers on two occasions, including white patches on the liver. He discarded the livers but kept the rest of the seals. Another bearded seal had warts or a similar looking problem on the skin of its belly.

Walrus

Walrus migrate past Scammon Bay 15–20 miles offshore from Cape Romanzof in April and May (Figure 1), with the large ice floes, though the timing is shifting earlier in the spring so now a few are seen in March and even February. The walrus may come closer if the ice brings them in. Walrus are in the area for a few weeks, but by May when the bay ice breaks up, hunters cannot travel offshore so may not see walrus after that. Walrus are rarely seen in the fall in this area.

In the spring of 2016, the ice left early and some small groups of bull walrus were seen swimming north in the open water, about 20 miles offshore by people who were halibut fishing. The hunter who saw this is unsure where they rested without ice to haul out on. Without big, thick ice floes, it can be hard to find walrus and other marine mammals.

One or two walrus may be found hauled out at Cape Romanzof at any time during summer (Figure 1). Walrus eat clams, no other diet items were identified.

Beluga Whales

Belugas come from the south in May and June, following the herring and the salmon. Scammon Bay itself may still be frozen over, but the water is opening beyond the barrier islands. In summer, belugas stay near the mouths of the Black and Yukon rivers, going in and out with the tide as they feed on fish (Figure 1). They can also be seen along the coast between Scammon Bay and Black River. In fall, belugas head south around the time of freeze-up, though not as many are seen in fall as in spring. They may be following whitefish and tomcod in fall. The latest one hunter caught a beluga whale was late November. No belugas were seen in the fall of 2016. In other years, belugas have gotten tangled in fish nets in fall. Belugas are not seen in winter, but hunters are also rarely out on the ocean in winter. One hunter once caught a young beluga whale up a river, where he had gone to pick berries with his wife.

When killer whales are nearby, belugas will move to the nearshore shallows or into a river. Once belugas were seen by the hundreds in the river in front of the village.

Other Marine Mammal Species

Ribbon seals are seen in the area in fall when the sea ice returns and the seals can haul out. The farther offshore, the more ribbon seals can be seen.

Sea lions are seen in spring, when the herring run occurs. They stay as long as the fish are in the area, about six weeks or so, and then they leave. A few will haul out at a time high on the rocks at Cape Romanzof (Figure 1). Sea lions are occasionally seen in rivers, chasing salmon. People leave sea lions alone, though they were occasionally hunted several decades ago.

Killer whales are seen more frequently in the area over the past 10 years or so. Last summer, a killer whale carcass was found for the first time in the area, on a beach. Halibut fishermen see killer whales offshore and they are seen during salmon season, too. People tend to stay away from killer whales. Killer whales have been seen chasing beluga whales in spring. Killer whales are seen occasionally in fall.

Large whales are sometimes seen in the area in summer, by halibut fishermen. These were not seen 10 years or more ago.

Porpoises (i.e., harbor porpoises) are increasingly common now, seen every time fishermen go out. The porpoises are small and their Yupik name means animals that herd fish, which benefits killer whales.

Sea otters are seen once in a great while here. This is not a new phenomenon, and typically happens in spring when it happens.

Unknown animals are seen from time to time and are known from stories. One seal-like animal washed up on shore but no one knew what it was.

Other Information

Hunters need to be ready to take advantage of opportunities when they arise, especially in times of change as is the case at present. Waiting for the usual hunting times may not work well.

Instead, hunters have to be ready to go at times that are not customary, but when seals and other animals may nonetheless be available and accessible. In spring, the good hunting period used to last two to three weeks, when it was possible to go boating in the ice but the ice was still close to Scammon Bay. Now, the ice goes away quickly and hunters may have less than a week of good conditions before the ice is a long way out. Hunters have to be ready to go when the conditions are good, which tends to be earlier in spring than it used to be. Some hunters have begun avoiding spring hunting, being wary of dangerous conditions, seeking instead to get seals in fall. That strategy appears to be working so far for the hunters who are using it.

It is important to take what you can, when you can, so long as it is done respectfully and without waste. Sharing with elders and others who cannot hunt is important. In the old days, if Scammon Bay hunters had a successful season, they would load kayaks with meat and other foods and take them to Hooper Bay and other communities to share.

Chum and pink salmon runs have been strong in recent years. In 2016, fish of both species were large. The pink salmon that fall were as large as the chum salmon had been two years previously. King salmon returns are down and there are strict regulations restricting fishing. Fishermen have made chum salmon strips instead of king salmon strips. They are not as tasty, but they are still smoked salmon. Salmon can also be salted and frozen. People use the heads and fins, too.

Halibut fishing in July is a relatively new activity, and a good way of getting additional food. Halibut seem to be declining, though, while pollock and cod (Pacific cod) have been caught for the first time in recent years. One year, fishermen caught many skates. Salmon sharks are also seen while halibut fishing, which is a newly found species to the area.

Herring come in spring when the ice goes out from the bay. This used to happen in late May and early June, but recently has been happening in mid-May. The herring nonetheless arrive as the ice goes out.

Puffins, cormorants, and other birds nest at Cape Romanzof. Some new birds are being seen in the area, which hunters do not recognize. One looks like a small version of an arctic tern, with a wingspan of 6-8 inches. In one year, a storm blew little black birds into the village.

Sea ice has changed a lot. There is less shorefast ice and the ice is often thin, breaking easily and floating away. The ice is not strong, and breaks up and melts quickly in spring. There are few big icebergs any more. The ice does not extend as far out into Scammon Bay. There used to be thick ice all the way to Cape Romanzof, over which people would travel while gathering driftwood. This is no longer possible. Hunting is best in March and April. By late April, it is now too warm and the ice goes away.

Snow and ice melt earlier in the spring than they used to, which can make traveling harder over land and when trying to cross rivers during May when people hunt black brant. Some people now use boats to go brant hunting.

There has been little snow in recent winters, which is unusual. March is usually the snowy month, but has not seen much snowfall in recent years. The lack of snow also means fewer drifts on the ice that seals can use to make lairs for giving birth.

The weather has been more violent in recent years. Fall storms come early, even in summer, causing flooding and driving fish away until the waters settle again. Winds are stronger now and the weather is warmer. Flooding has been getting worse in the Scammon Bay area due to a lack of ice and strong winds during the winter.

Lack of snow in the Interior means less flooding on the Yukon River, so fewer trees are washed down the river and driftwood is scarce in the Scammon Bay area. This has been the case the past three years or so. People who gather driftwood have to go farther and have had to use cottonwood instead of the preferred spruce.

Acknowledgements

We are grateful for the skill, expertise, and generosity of the five hunters who participated in the interviews. We appreciate the support of the Eskimo Walrus Commission and the Ice Seal Committee for this project and are grateful to Morgan Simon for helping to set up the interviews. The Bureau of Ocean Energy Management (BOEM) funded the work as part of Contract No. M13PC00015 and we appreciate the support of Carol Fairfield and Catherine Coon. Justin Crawford prepared the maps used during the interviews and the figure in this report.

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Appendix P.

Seasonal movements, habitat use, and dive behavior of pup and yearling bearded seals in the Pacific Arctic.

Justin A. Crawford[1]*, Mark A. Nelson[1], Lori Quakenbush[1], John Goodwin[2], Kathy Frost[3], Alex Whiting[4], and Matthew Druckenmiller[5]

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Society of Marine Mammalogy, 22–27 October 2017, Halifax, Nova Scotia, Canada

Bearded seals (*Erignathus barbatus*) are benthic foragers that use sea ice for pupping, nursing, molting, and resting. Changes in sea ice and water temperature associated with climate change may affect fish and invertebrate prey of bearded seals, and therefore their habitat use. Our understanding of foraging habitats, behavior, and timing of movements, however, is limited. We worked with Alaska Native hunter-taggers along the Bering and Chukchi coasts to deploy satellite-linked dive recorders on 20 young (< 2 years old) bearded seals from June through November 2014–2017. Seals were tracked 10–457 days. During the open-water period seals were located in the Chukchi and Bering seas. As sea ice advanced in December seals moved toward the Alaskan or Russian coast or the southern ice edge. By mid-December, 11 of 13 seals were in the Bering Sea, however one remained in the Beaufort Sea and another in the Chukchi Sea. We analyzed habitat use and dive behavior August–February. Seals were generally located 20 km closer to the coast during August, October, and December–February than during September and November ($P<0.01$) and in waters averaging 25–30 m deep August–January before moving to deeper waters in February (45 m; $P<0.01$). All seals made fewer benthic and more mid-water and surface dives during December than other months ($P<0.01$). Further, a higher proportion of benthic dives occurred during morning and afternoon (0700–1400; 90–93%) than at night (1900–0000; 72–78%; $P<0.01$). The durations of benthic dives were similar from August to November (5:30 min) but increased from December (6:45 min) through February (9:50 min; $P<0.01$). The presence and concentration of sea ice may influence habitat use and dive behavior and will be analyzed.

Appendix P.

Seasonal movements, habitat use, and dive behavior of pup and yearling bearded seals in the Pacific Arctic

Justin A. Crawford[1], Mark A. Nelson[1], Lori Quakenbush[1], John Goodwin[2], Kathy Frost[3], Alex Whiting[4], and Matthew Druckenmiller[5]

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[5]National Snow and Ice Data Center, University of Colorado, Boulder, Colorado, USA

Background

Bearded seals (*Erignathus barbatus*) are benthic foragers that use sea ice for pupping, nursing, molting, and resting. Observed and predicted decreases in the extent of sea ice and lengthening of the open water season associated with climate change may affect fish and invertebrate prey of bearded seals, and therefore affect seal foraging behavior. Our understanding of important habitats, foraging behavior, and timing of movements, is limited; however, cooperative satellite telemetry studies among hunters and biologists are increasing our understanding of seal behavior and how these behaviors may change with future decreases in sea ice.

This project expands on past studies by tagging seals at several widely-spaced locations along the Alaskan coast. We worked with Alaska Native hunter-taggers along the Beaufort, Bering and Chukchi sea coasts to deploy satellite-linked transmitters on young (< 2 years old) bearded seals from June through November 2014–2017. We used satellite telemetry to describe bearded seal movements and diving behavior in relation to sea ice and other environmental variables.

Methods

- We worked with seal hunters to capture bearded seals in entanglement nets. Satellite-linked transmitters were glued to the hair on their mid-dorsum and included:
  - **SPLASH and SPOT tags** (Wildlife Computers, Redmond, WA, USA) and
  - **CTD tags** (Sea Mammal Research Unit, St. Andrews, Scotland).
- **Movements and habitat associations**:
  - We estimated daily locations using a continuous-time Correlated Random Walk (CRW) model (package *crawl* in R).
  - We **evaluated habitat associations** from August–February, including: bathymetry, distance to coast, and ice zone.
- **Dive behavior**:
  - For 13 seals instrumented with SPLASH tags, we used the CRW model to predict dive locations to match dive dates and times.
  - Dives were classified as benthic if they were <5 m from the ocean floor.
  - We used a repeated-measures mixed model to test for differences in:
    - **Proportion of benthic dives**
    - **Dive duration of benthic dives**
  - Variables of interest included:
    - **Seal variable**: Sex
    - **Time variables**: Month and time of day
    - **Habitat variables**: Ice zone, bathymetry, and distance to coast
  - Models were fit using SAS software (PROCs GLIMMIX and MIXED) and the best model was selected using AICc.

Acknowledgements

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Results

- We deployed satellite-linked transmitters on **24 young bearded seals** from 2014–2017.
- Seals were **tracked 10–457 days**.

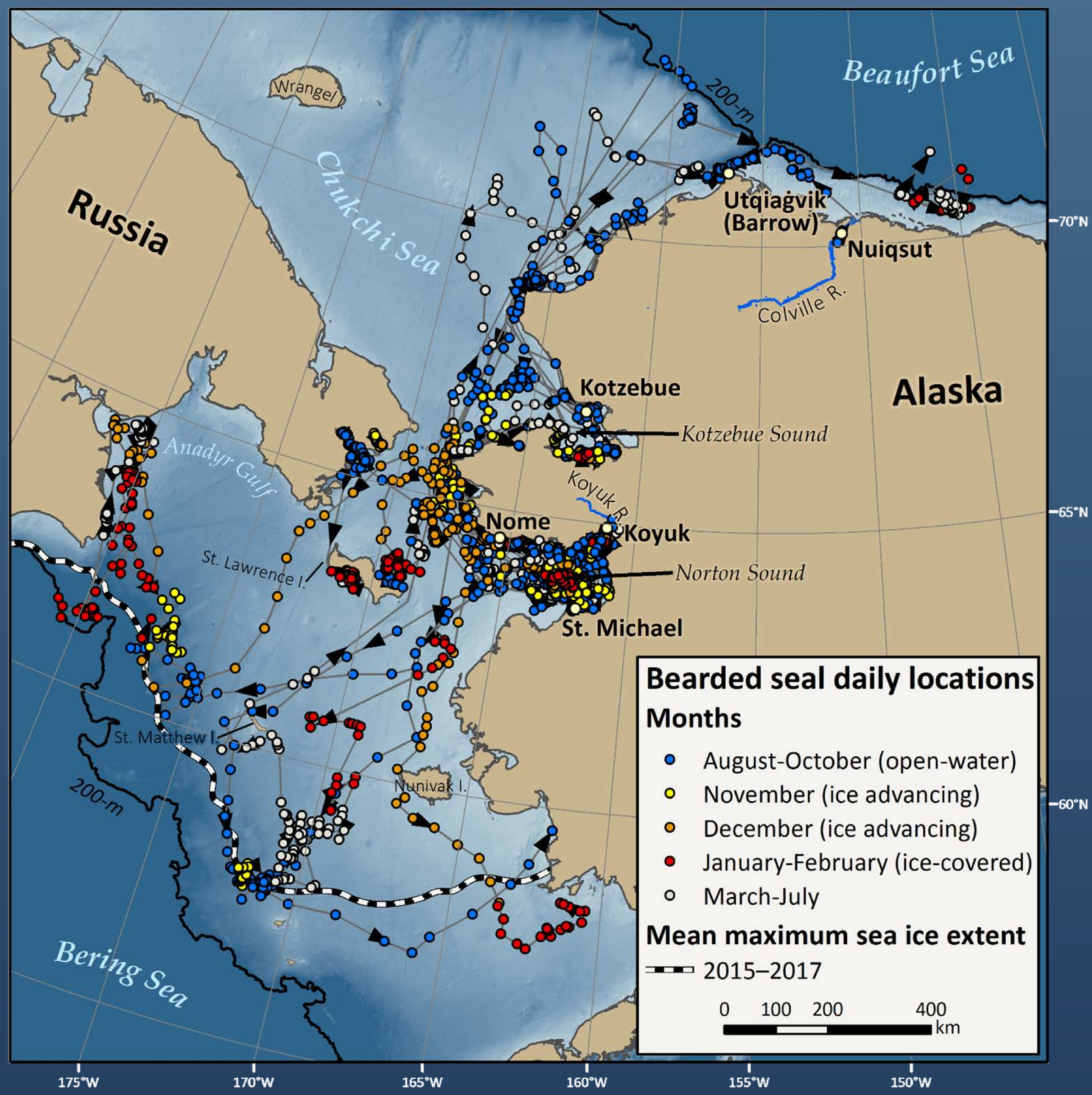

Figure 2. Movements of 24 bearded seals from 2014 to 2107. Seals were tagged with satellite-linked transmitters near St. Michael, Koyuk, Nome, Kotzebue, and Utqiaġvik (Barrow), Alaska. Daily locations were estimated using a CRW model.

Figure 1. Attaching satellite-linked transmitters to captured bearded seals: a) Palsson Fitka, July 2016 and, b) Merlin Henry, and Mark Nelson (ADFG), September 2016.

Learn more about ADF&G's ice seal tagging studies here

Movements and Habitat Associations

- As sea ice advanced south (September–February),
  - Seals moved toward coastal waters or the southern ice edge (Fig. 2).
  - Seals were **located in progressively heavier ice** (by concentration) with each successive month (*P*<0.01).
- During August–February, seals were located in waters ~25–45 m deep.

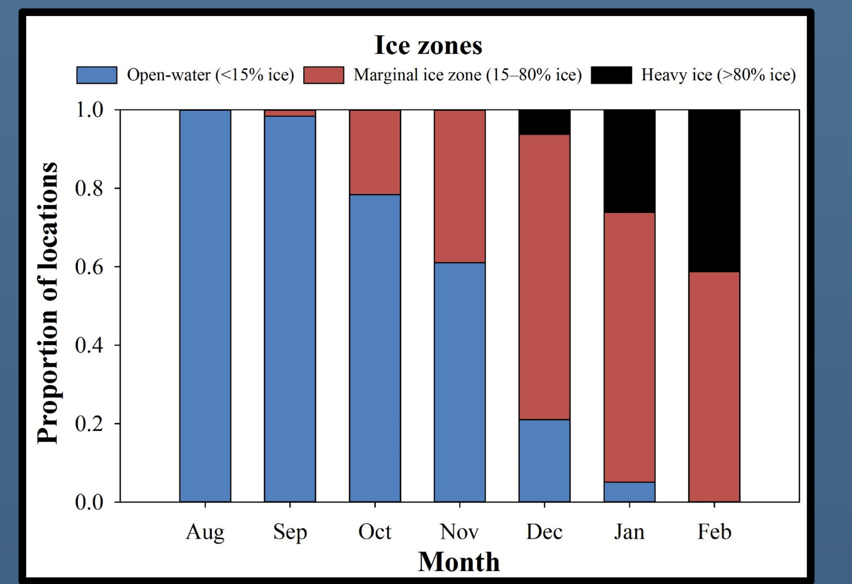

Figure 3. Proportion of estimated daily locations located in each ice zone by month.

Dive Behavior

Proportion of Benthic Dives

- Best model: **Ice zone X Hour + Bathymetry**
- Seal made proportionally **fewer benthic dives** from 0000–0400 when **in heavy ice** vs. marginal ice or open water (P<0.01).
- Overall, seals made proportionally fewer benthic dives from 1900–0000 than from 0700–1400 (P<0.01).
- Seals made proportionally fewer benthic dives in deep (50–70m; 60%) vs. shallow (0–40m; 87%) water (P<0.01).

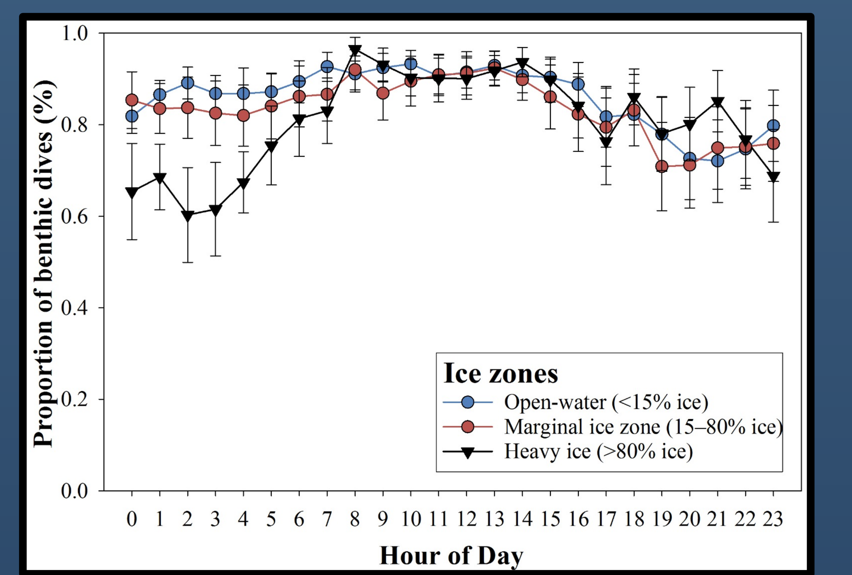

Figure 4. Proportion of benthic dives made in each ice zone by hour of day.

Duration of Benthic Dives

- Best model: **Ice zone X Hour**
- Seals made **shorter benthic dives when in heavy and marginal ice** vs. open water (*P*<0.01).
- Dives were longer from 2100–0200 than from 0900–1800 (*P*<0.01).

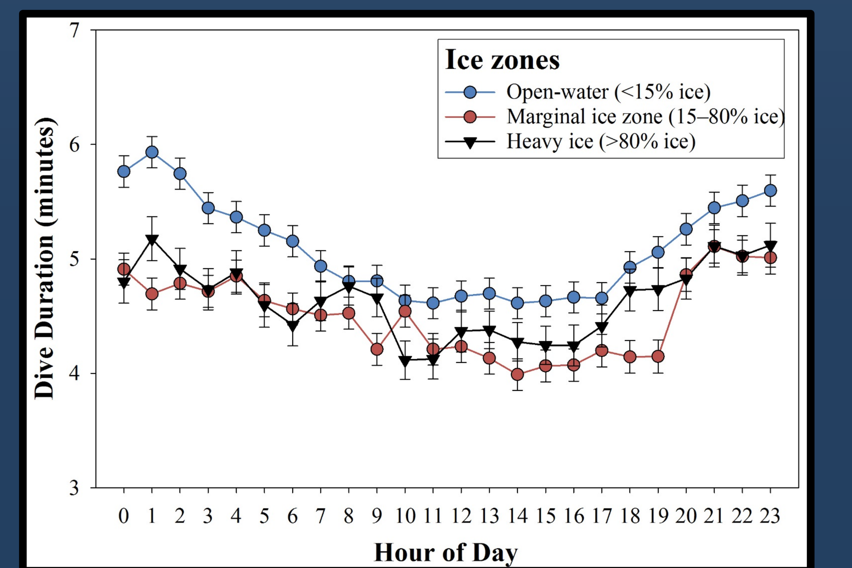

Figure 5. Dive duration of benthic dives made in each ice zone by hour of day.

Summary

- In heavy ice, seals made proportionally fewer benthic dives and durations were shorter in heavy and marginal ice than in open water.
- Seals made proportionally fewer benthic dives at night, possibly in response to the vertical migration of their prey; however, durations were longer at night than the rest of the day.
- The presence and concentration of sea ice appears associated with reduced benthic foraging.
- Continued studies of bearded seal foraging behavior are necessary to monitor for changes in behavior with continued changes in sea ice.

Appendix Q.

Evaluating impacts of climate change on indigenous marine mammal hunting in northern and western Alaska using traditional knowledge

Mark Nelson[1*], Henry Huntington[2], Lori Quakenbush[1]

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Society of Marine Mammalogy, 22-27 October 2017, Halifax, Nova Scotia, Canada

Indigenous residents of western and northern Alaska rely on marine mammals for food. Climate-related changes in sea ice conditions and weather are expected to affect behavior of animals and hunter access to them. Documenting traditional knowledge of Iñupiaq, Yup'ik, and Cup'ik hunters concerning marine mammals, the environment, and hunter success provides information relevant to ecology, conservation, and subsistence communities. We interviewed 110 hunters in 14 communities on the Bering, Chukchi, and Beaufort Sea coasts about these topics. A few changes were reported in marine mammal abundance, distribution, body condition, prey, and disease, however, most changes were environmental including sea ice conditions, weather, and timing of hunting seasons. Sea ice conditions are a major driver for hunting Arctic marine mammals, as most are associated with the ice and therefore more abundant or accessible when ice is present. The spring hunt, typically the most productive, has shortened from several weeks to one week or less depending on when the pack ice retreats and if it returns during summer. Hunters have had to adjust to harvest enough for food, which requires that they compare what they know against new observations. Traditional knowledge is a system in which existing information is interpreted and shared and new knowledge is acquired through observation and assimilated with what is already known. It is "traditional" because the system has long been used, not because the knowledge is only from the past. While traditional ways of preparing for the hunt, cooperation, patience, and sharing the harvest remain relatively constant, the acquisition and sharing of new information for hunting under new conditions is an important adaptive strategy. Alaska Native marine mammal hunters have demonstrated their ability to overcome changes in the past, are doing so in the present, and will likely continue to do so in the future.

Appendix Q.

Evaluating the Effects of Climate Change on Indigenous Marine Mammal Hunting in Northern and Western Alaska Using Traditional Knowledge

Mark Nelson[1], Henry P. Huntington[2], and Lori Quakenbush[1]

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[2]Huntington Consulting, Eagle River, Alaska, USA

BOEM Bureau of Ocean Energy Management

Overview

Indigenous residents of western and northern Alaska rely on marine mammals for subsistence including for food, materials, and culture. Documenting traditional knowledge of Iñupiaq, Yup'ik, and Cup'ik hunters concerning marine mammals, the environment, and hunter success provides information relevant to ecology, conservation, and subsistence communities. This compilation of traditional and local knowledge depicts changes in marine mammals including hunting seasons (dictated by weather and sea ice), distribution, health and body condition, and concerns of human activities.

Methods

- We used the semi-directive interview method to collect traditional knowledge from subsistence hunters and community members (Huntington 1998).
- We interviewed 110 people from 14 communities between 2007 and 2017 (Table 1, Figure 1).
- After the interviews, we prepared a draft report that was reviewed and approved by all the participants.
- A final report was prepared for each community that included a map detailing specific observations (e.g., maps on left side of Figure 1).
- Community specific observations were compared with other communities and similar observations were grouped together in Figure 1 (represented by colored and numbered boxes).

Table 1. Summary of interviews. Table is modified from Huntington et al. (2017).

Community	Year	Species focus	No. of Participants
Kaktovik	2007	Bowhead whales	6
Barrow	2007	Bowhead whales	6
Wainwright	2008	Bowhead whales	7
Point Lay	2011	Walrus	5
Wainwright	2011	Walrus	13
Point Hope	2013	Walrus	8
Barrow	2015	Walrus and ice seals	10
Elim	2015	Ice seals and walrus	8
St. Michael & Stebbins	2015	Ice seals and walrus	8
Kivalina	2016	Ice seals, walrus, bowhead whales	5
Kotzebue	2016	Ice seals	6
Shishmaref	2016	Ice seals and walrus	5
Hooper Bay	2017	Ice seals, walrus, beluga whales	11
Scammon Bay	2017	Ice seals, walrus, beluga whales	5
Mekoryuk	2017	Ice seals, walrus	7
Total 14 communities, 15 research visits	7 years over 11 year period	Focus on 7 species	110 participants

Discussion

- All communities reported extensive changes in the physical environment including sea ice, snow, and weather.
- All communities reported changes in marine mammal distribution, migration timing, health, and behavior.
- The largest changes to hunting are reportedly the result of changes to the physical environment (i.e., marine mammal populations appear to remain healthy and stable, but more difficult to access and hunt).
- Hunters acknowledge that traditional knowledge of active hunters must be updated more rapidly now to adapt to a rapidly changing physical environment.

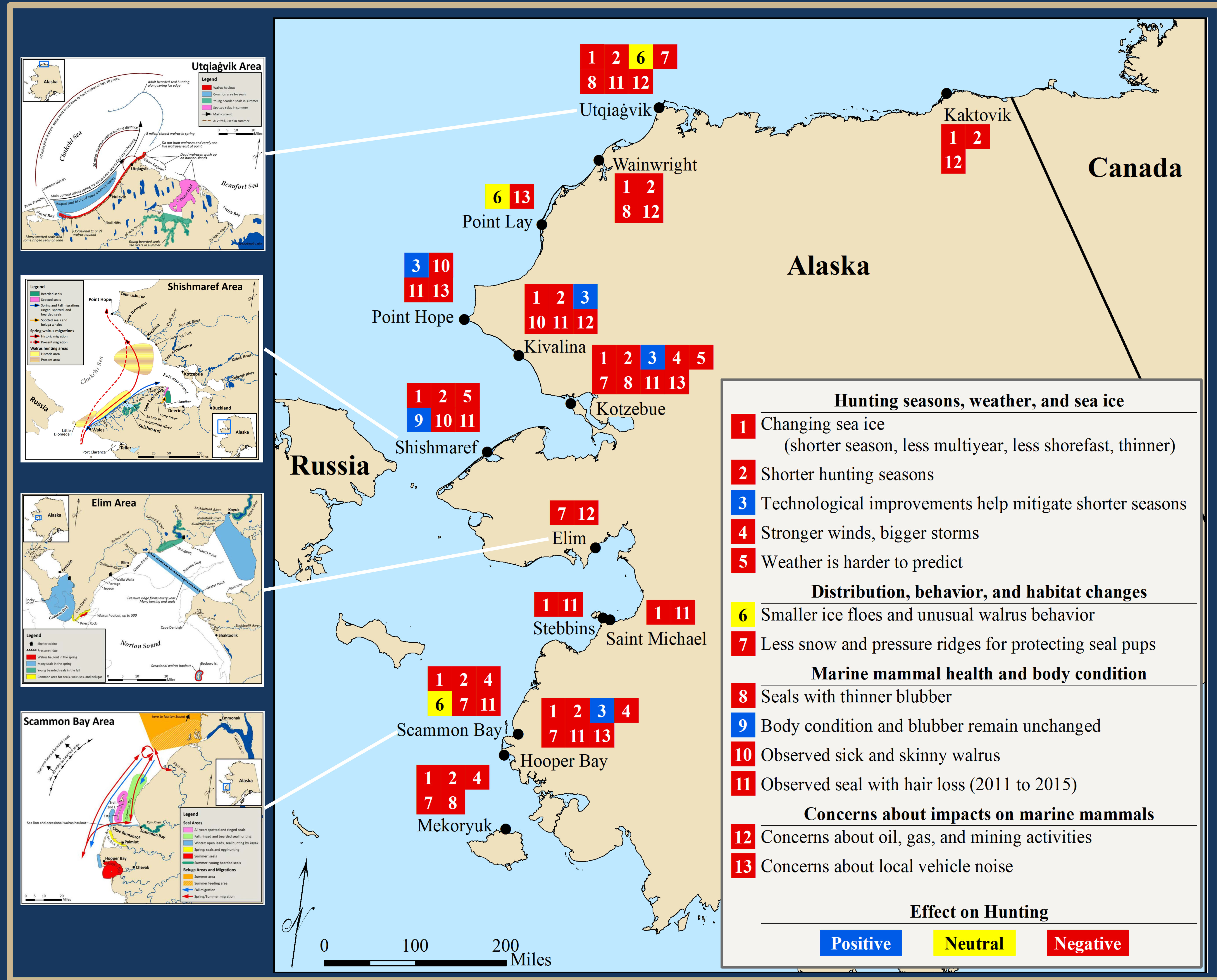

Figure 1. Map of study area and participating communities. Numbered boxes correspond to detailed observations about walruses, ice seals, and beluga and bowhead whales. Community maps at left represent the types of detailed information collected through traditional knowledge interviews. Figure is modified from Huntington et al. (2017).

Acknowledgements

We appreciate the skill, expertise, and generosity of the 110 hunters who participated in the interviews, and the communities and Tribal Councils of Kaktovik, Barrow, Wainwright, Point Lay, Point Hope, Elim, Stebbins, St. Michael, Shishmaref, Kotzebue, Kivalina, Scammon Bay, Hooper Bay, and Mekoryuk that facilitated this work. We also thank the Alaska Eskimo Whaling Commission, the Eskimo Walrus Commission, and the Ice Seal Committee for their support and guidance. We are grateful to Justin Crawford for producing Figure 1 and to the Bureau of Ocean Energy Management, the Minerals Management Service, ConocoPhillips, and the Coastal Marine Institute for funding.

References:

Huntington, H.P. 1998. Observations on the utility of the semi-directive interview for documenting traditional ecological knowledge. Arctic 51(3):237-242.

Huntington, H.P., Quakenbush, L.T., Nelson, M. 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

Appendix R.

Movements and dive behavior of young bearded seals as related to sea ice in the Pacific Arctic

Justin A. Crawford[1]*, Mark A. Nelson[1], Lori Quakenbush[1], Anna Bryan[1], Andrew L. Von Duyke[2], Merlin Henry[3], Alexander Niksik[4], John Goodwin[5], Alex Whiting[6], and Matthew Druckenmiller[7]

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[4] Alaska Native seal hunter and resident of St. Michael, Alaska, 99659;
[5] Alaska Native seal hunter and resident of Kotzebue, Alaska, 99752;
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Alaska Marine Science Symposium, 22–26 January 2018, Anchorage, Alaska, USA

Bearded seals (*Erignathus barbatus*) are benthic foragers that use sea ice for pupping, nursing, molting, and resting. Decreasing sea ice associated with climate change may affect fish and invertebrate prey of bearded seals, and therefore affect seal foraging behavior. Our understanding of foraging habitats, dive behavior, and timing of movements, however, is limited. We worked with Alaska Native hunter-taggers along the Beaufort, Bering and Chukchi sea coasts to deploy satellite-linked dive recorders on 24 young (< 2 years old) bearded seals from June through November 2014–2017. Seals were tracked 10–457 days. During the open-water period seals were located in the Beaufort, Chukchi and Bering seas. As sea ice advanced in December seals moved shoreward (toward the Alaskan or Russian coast) or toward the southern ice edge in the Bering Sea. By mid-December, 11 of 13 seals were in the Bering Sea; one remained in the Beaufort Sea and one in the Chukchi Sea. During August–February seals were generally located in waters averaging 25–45 m deep. We analyzed dive behavior for 13 of the 24 seals during August–February. As sea ice advanced south (September–February), seals were located in progressively heavier ice (by concentration) with each successive month, as expected for a pagophilic seal species. When located in heavy ice (>80% concentration), all seals made proportionally fewer benthic dives (80% benthic dives) than when in marginal ice (15–80% concentration; 85%) or open water (87%; P<0.01), and benthic dive durations were shorter in heavy (4:35 min) and marginal (4:30 min) ice than in open water (5:00 min; P<0.01). Dive behavior also differed by time of day with proportionally fewer benthic dives at night (1900–0000; 72–78%) than during morning and afternoon (0700–1400; 90–93%; P<0.01), however, benthic dive durations were longer at night (2100–0200; 5:30 min) than morning and afternoon (0900–1800; 4:30 min; P<0.01). The presence and concentration of sea ice appears associated with reduced benthic foraging. Continued studies of bearded seal foraging behavior are necessary to monitor for changes in behavior with continued changes in sea ice.

Appendix R.

Seasonal movements, habitat use, and dive behavior of pup and yearling bearded seals in the Pacific Arctic

Justin A. Crawford[1], Mark A. Nelson[1], Lori Quakenbush[1], John Goodwin[2], Kathy Frost[3], Alex Whiting[4], and Matthew Druckenmiller[5]

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[2]Seal hunter and resident of Kotzebue, Alaska, USA; [3]73-4388 Pa'iaha Street, Kailua Kona, Hawaii, USA; [4]Native Village of Kotzebue, Alaska, USA;
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Background

Bearded seals (*Erignathus barbatus*) are benthic foragers that use sea ice for pupping, nursing, molting, and resting. Observed and predicted decreases in the extent of sea ice and lengthening of the open water season associated with climate change may affect fish and invertebrate prey of bearded seals, and therefore affect seal foraging behavior. Our understanding of important habitats, foraging behavior, and timing of movements, is limited; however, cooperative satellite telemetry studies among hunters and biologists are increasing our understanding of seal behavior and how these behaviors may change with future decreases in sea ice.

This project expands on past studies by tagging seals at several widely-spaced locations along the Alaskan coast. We worked with Alaska Native hunter-taggers along the Beaufort, Bering and Chukchi sea coasts to deploy satellite-linked transmitters on young (< 2 years old) bearded seals from June through November 2014–2017. We used satellite telemetry to describe bearded seal movements and diving behavior in relation to sea ice and other environmental variables.

Methods

- We worked with seal hunters to capture bearded seals in entanglement nets. Satellite-linked transmitters were glued to the hair on their mid-dorsum and included:
  - **SPLASH and SPOT tags** (Wildlife Computers, Redmond, WA, USA) and
  - **CTD tags** (Sea Mammal Research Unit, St. Andrews, Scotland).
- **Movements and habitat associations**:
  - We estimated daily locations using a continuous-time Correlated Random Walk (CRW) model (package *crawl* in R).
  - We **evaluated habitat associations** from August–February, including: bathymetry, distance to coast, and ice zone.
- **Dive behavior**:
  - For 13 seals instrumented with SPLASH tags, we used the CRW model to predict dive locations to match dive dates and times.
  - Dives were classified as benthic if they were <5 m from the ocean floor.
  - We used a repeated-measures mixed model to test for differences in:
    - **Proportion of benthic dives**
    - **Dive duration of benthic dives**
  - Variables of interest included:
    - **Seal variable**: Sex
    - **Time variables**: Month and time of day
    - **Habitat variables**: Ice zone, bathymetry, and distance to coast
  - Models were fit using SAS software (PROCs GLIMMIX and MIXED) and the best model was selected using AICc.

Acknowledgements

Seal tagging projects were funded by the Bureau of Ocean Energy Management, USA and Office of Naval Research, USA. We appreciate the support of the Ice Seal Committee and assistance from the hunter-tagger crews; Morgan Henry, Alex Niksik Jr., Palsson Fitka, Stephan Horn Jr., Tom Gray, Denali Whiting, Edward Ahyakak, Frank Garfield, Henry "Boyuk" Goodwin, and Pearl Goodwin. We also thank Anna Bryan, Ryan Adam, Aaron Morris, Joe Skin, Isaac Leavitt, and Andrew von Duyke for tagging assistance. Research on ice seals was conducted under permit #15324 issued to ADFG by the National Marine Fisheries Service and under an approved ADFG Animal Care and Use Committee Protocol #2014-03, 2015-25, and 2016-23.

Results

- We deployed satellite-linked transmitters on **24 young bearded seals** from 2014–2017.
- Seals were **tracked 10–457 days**.

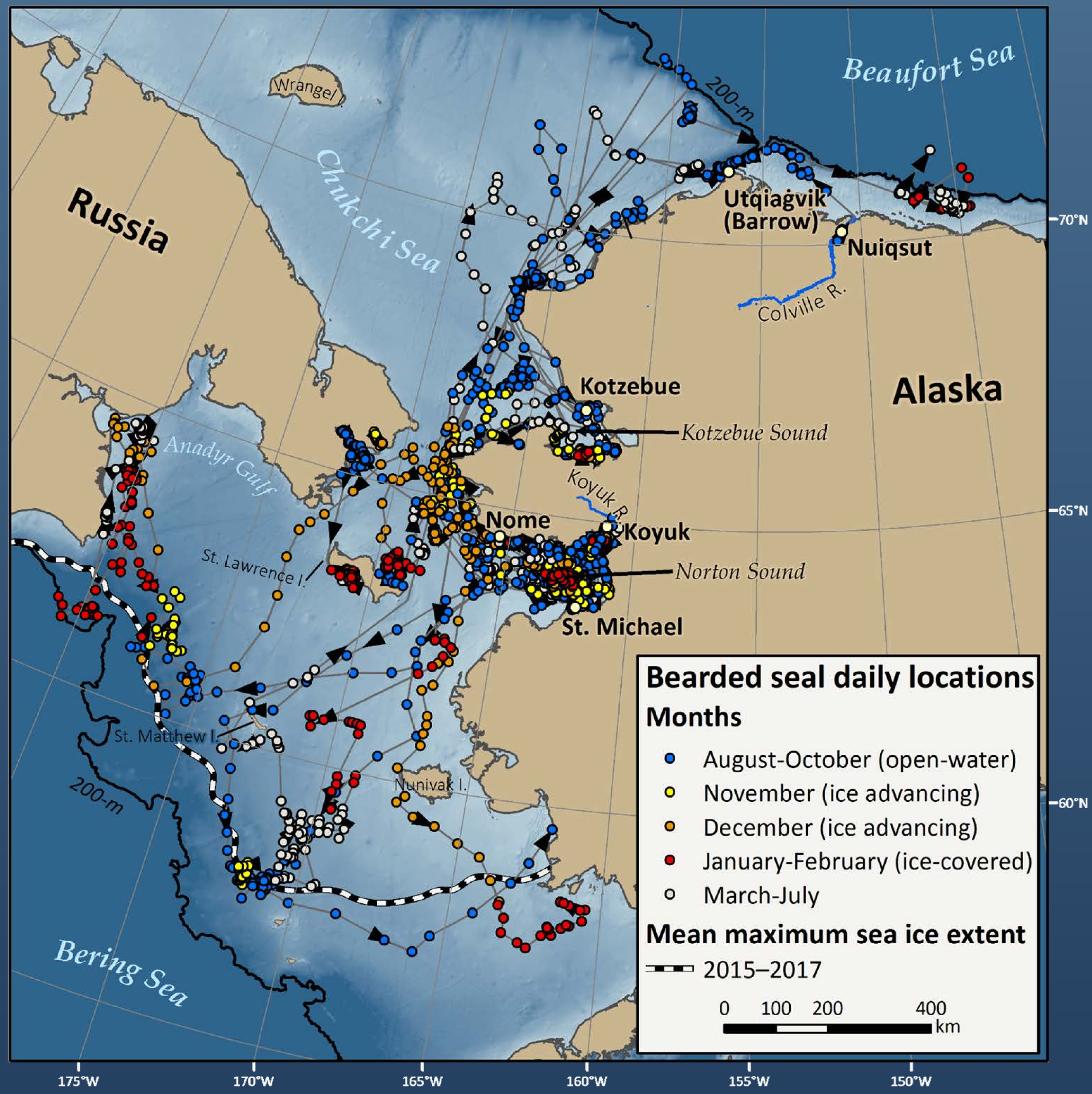

Figure 2. Movements of 24 bearded seals from 2014 to 2107. Seals were tagged with satellite-linked transmitters near St. Michael, Koyuk, Nome, Kotzebue, and Utqiaġvik (Barrow), Alaska. Daily locations were estimated using a CRW model.

Figure 1. Attaching satellite-linked transmitters to captured bearded seals: a) Palsson Fitka, July 2016 and, b) Merlin Henry, and Mark Nelson (ADFG), September 2016.

Learn more about ADF&G's ice seal tagging studies here

Movements and Habitat Associations

- As sea ice advanced south (September–February),
  - Seals moved toward coastal waters or the southern ice edge (Fig. 2).
  - Seals were **located in progressively heavier ice** (by concentration) with each successive month (P<0.01).
- During August–February, seals were located in waters ~25–45 m deep.

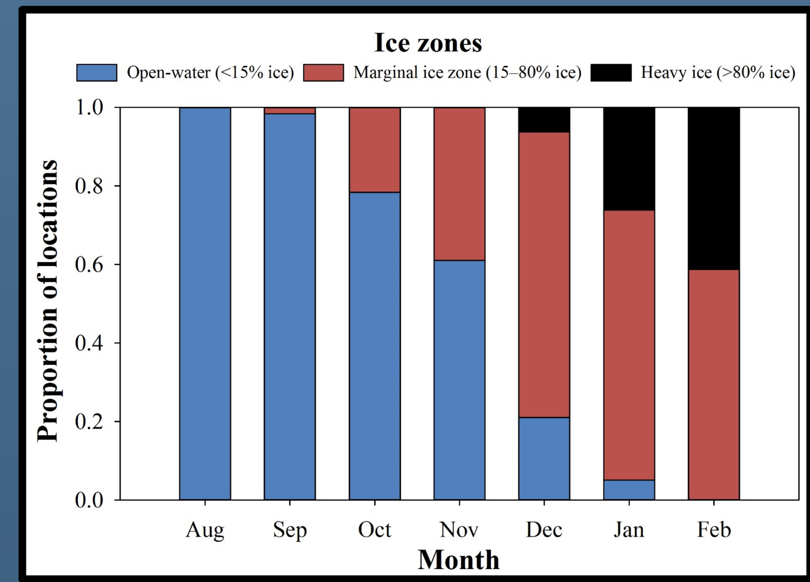

Figure 3. Proportion of estimated daily locations located in each ice zone by month.

Dive Behavior

Proportion of Benthic Dives

- Best model: **Ice zone X Hour + Bathymetry**
- Seal made proportionally **fewer benthic dives** from 0000–0400 when **in heavy ice** vs. marginal ice or open water (P<0.01).
- Overall, seals made proportionally fewer benthic dives from 1900–0000 than from 0700–1400 (P<0.01).
- Seals made proportionally fewer benthic dives in deep (50–70m; 60%) vs. shallow (0–40m; 87%) water (P<0.01).

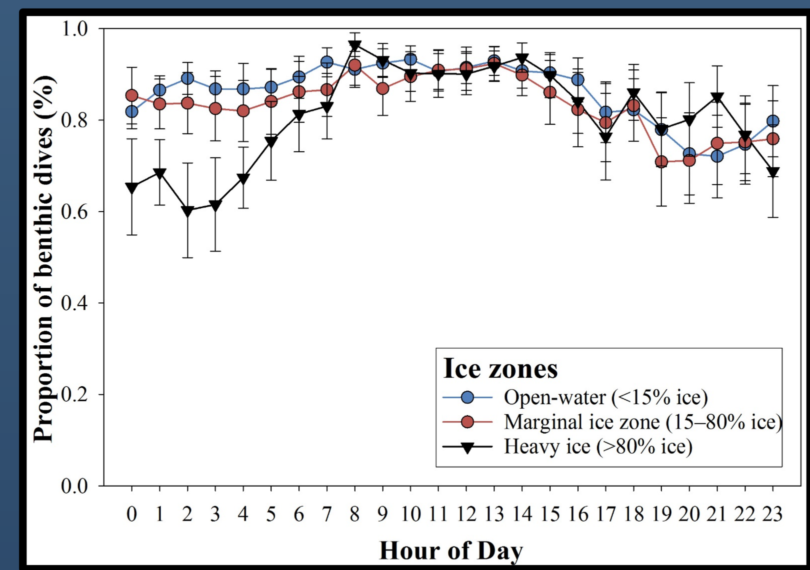

Figure 4. Proportion of benthic dives made in each ice zone by hour of day.

Duration of Benthic Dives

- Best model: **Ice zone X Hour**
- Seals made **shorter benthic dives when in heavy and marginal ice** vs. open water (P<0.01).
- Dives were longer from 2100–0200 than from 0900–1800 (P<0.01).

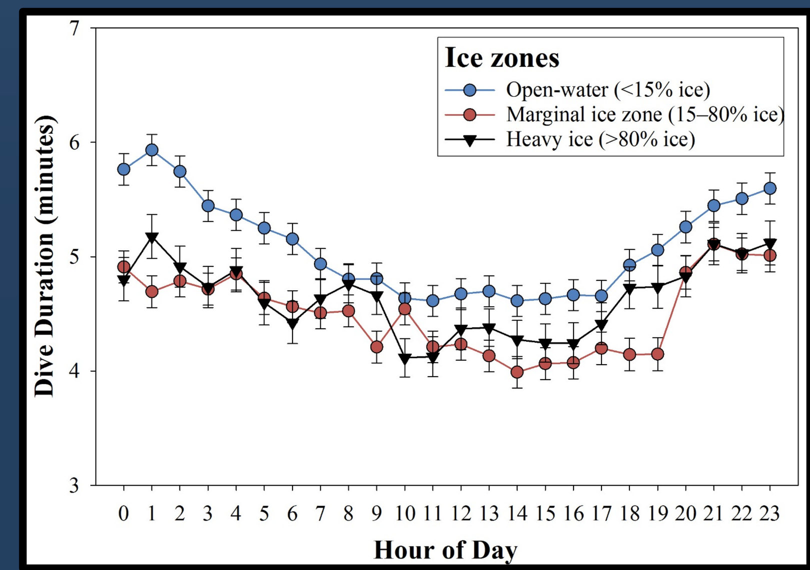

Figure 5. Dive duration of benthic dives made in each ice zone by hour of day.

Summary

- In heavy ice, seals made proportionally fewer benthic dives and durations were shorter in heavy and marginal ice than in open water.
- Seals made proportionally fewer benthic dives at night, possibly in response to the vertical migration of their prey; however, durations were longer at night than the rest of the day.
- The presence and concentration of sea ice appears associated with reduced benthic foraging.
- Continued studies of bearded seal foraging behavior are necessary to monitor for changes in behavior with continued changes in sea ice.

Appendix S.

Climate Change, Marine Mammals, and Indigenous Hunting in Northern Alaska: Insights from a Decade of Traditional Knowledge Interviews

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Alaska Marine Science Symposium, 22–25 January 2018, Anchorage AK

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.

Appendix T.

Seasonal movements and high-use areas of spotted seals (*Phoca largha*) in the Pacific Arctic.

Justin A. Crawford[1]*, Lori Quakenbush[1], Anna Bryan[1], Mark A. Nelson[1], Andrew L. Von Duyke[2]

[1] Alaska Department of Fish and Game, Fairbanks, AK;
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Alaska Marine Science Symposium, 28 January–1 February 2019, Anchorage AK

Spotted seals (*Phoca largha*) are pelagic foragers that use Bering Sea pack ice for pupping, nursing, and resting when ice is present (December–June) and nearshore habitats for resting during the open-water season (July–November). Warming of Pacific Arctic waters associated with climate change may affect fish and invertebrate prey of spotted seals, and therefore affect their foraging behavior. Decreases in the extent of sea ice and lengthening of the open-water season have eased access to the Arctic for development and shipping, prioritizing the need to identify areas important to seals. Our understanding of movements and foraging habitats of spotted seals, however, is limited. We worked with Alaska Native hunter-taggers along the Beaufort and Bering sea coasts to deploy satellite-linked tags on 24 spotted seals from July through September 2016–2018 to study movements and habitat use. Individual seals were tracked 137–443 days. During the open-water season, the movements and behavior of seals tagged in the Beaufort (Dease Inlet and Colville River) and Bering (Scammon Bay) seas differed. Seals tagged in the Beaufort Sea made frequent east-west movements between foraging areas in the Chukchi Sea and the Alaskan coast, including their tagging locations, often resting on islands near Icy Cape, Peard Bay, and Dease Inlet. The primary foraging area was between Herald Shoal and nearshore waters of the northeast Chukchi Sea (<50 m deep). Seals tagged in the Bering Sea also made frequent east-west movements, here between foraging areas in the central Bering Sea and the Alaskan coast, often resting on islands near Scammon Bay. The primary foraging area was between St. Lawrence Island and St. Matthew Island (<60 m deep). In December, seals tagged in the Beaufort Sea moved south, ahead of the advancing pack ice. By mid-January, all seals regardless of tagging location occupied pack ice and foraged in the central Bering Sea. These results show the importance of regionally spaced tagging locations to understanding movements and habitat use throughout the Pacific Arctic. Continued studies of seal movements will be necessary to monitor for changes in behavior with continued changes in climate and development activities.

Appendix T.

Seasonal movements and high-use areas of spotted seals (*Phoca largha*) in the Pacific Arctic

Justin A. Crawford[1], Lori Quakenbush[1], Anna Bryan[1], Mark A. Nelson[1], Andrew L. Von Duyke[2]

[1]Alaska Department of Fish and Game, Arctic Marine Mammals Program, Fairbanks, Alaska, Justin.Crawford@alaska.gov;

[2]North Slope Borough, Department of Wildlife Management, Utqiaġvik, Alaska

BOEM Bureau of Ocean Energy Management

Background

Spotted seals (*Phoca largha*) are pelagic foragers that use Bering Sea pack ice for pupping, nursing, and resting when ice is present and rest on shore during the open-water season. Warming of Pacific Arctic waters associated with climate change may affect fish and invertebrate prey of spotted seals, and therefore affect their foraging behavior. Decreases in the extent of sea ice and lengthening of the open-water season have eased access to the Arctic for development and shipping, prioritizing the need to identify areas important to seals. Our understanding of movements, high-use areas, and foraging habitats of spotted seals is limited. Therefore, we worked with Alaska Native hunter-taggers along the Beaufort and Bering sea coasts to deploy satellite-linked transmitters on spotted seals from July through October 2016–2018 to describe movements and identify high-use areas.

Methods

- We worked with seal hunters to capture spotted seals in entanglement nets and instrument them with satellite-linked transmitters.
  - **SPLASH** (Wildlife Computers, USA) or **CTD tags** (Sea Mammal Research Unit, Scotland) were glued to the hair on their mid-dorsum.
  - **SPOT tags** (Wildlife Computers, USA) were attached to a rear flipper.
- **Movements**:
  - We used location data collected by all SPLASH, CTD, and SPOT tags.
  - We estimated daily locations for all tagged seals using a continuous-time Correlated Random Walk (CRW) model (package *crawl* in R).
  - We **evaluated movements** of seals based on:
    - **Season**: Open-water (May–November) and Ice (December–April).
    - **Tagging area**: Beaufort and Bering seas.
- **High-Use Areas**:
  - We identified high-use (core) areas based on the density of daily estimated locations within 50×50 km square cells across our study area. The volume rasters calculated are utilization distributions (UD).
  - **UDs were calculated** for:
    - **Season**,
    - **Tagging area**, and
    - **Distance from shore**:
      - Offshore (>5 km): associated with foraging
      - Nearshore (<5 km): associated with resting and foraging
        - Haul-out data collected by tags informed identification of resting areas.
  - We considered **core areas** to be cells with UDs of <50% volume.

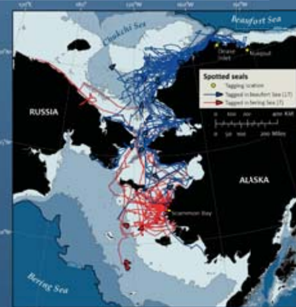
Spotted seal instrumented with a CTD tag, 2016.

Results

- We deployed satellite-linked transmitters on **24 spotted seals** from 2016–2018 (4 SPLASH, 20 CTD, and 24 SPOT tags).
- Seals were **tracked 137–443 days**.

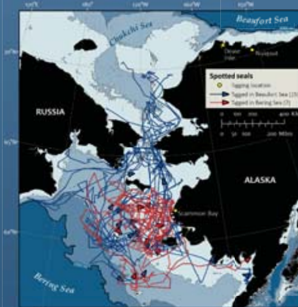
Learn more about ADF&G's ice seal tagging studies here

Open-Water Season Movements



- All seals made **frequent east-west movements** between foraging areas and the Alaskan coast, including returning to tagging locations.
- Seals **tagged in the Beaufort Sea** moved between foraging areas in the Chukchi Sea and the Alaskan coast.
- Seals **tagged in the Bering Sea** moved between foraging areas in the central Bering Sea and the Alaskan coast.
- **Seals rarely moved between the Bering and Chukchi seas.**

Ice Season Movements

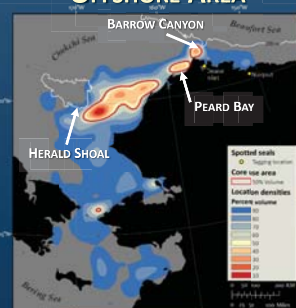


- In December, seals **tagged in the Beaufort Sea** moved south, ahead of the advancing pack ice.
- By mid-January, **all seals** regardless of tagging location occupied pack ice and foraged in the central Bering Sea.

High-Use Areas

Tagged in Beaufort

Offshore Area



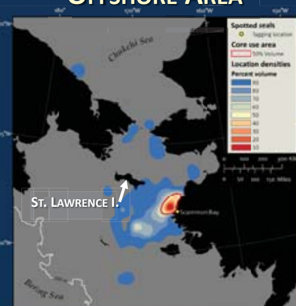
The primary foraging area was between Herald Shoal and nearshore waters of the northeast Chukchi Sea (<50 m deep).

Nearshore Area

Resting areas primarily included islands near Icy Cape, Dease Inlet and Kotzebue Sound.

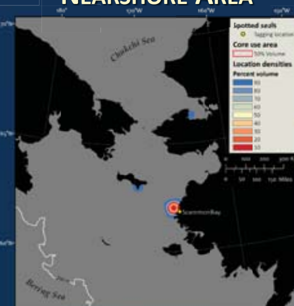
Tagged in Bering

Offshore Area



The primary foraging area was between the central Bering Sea and Alaska coast, including tagging location.

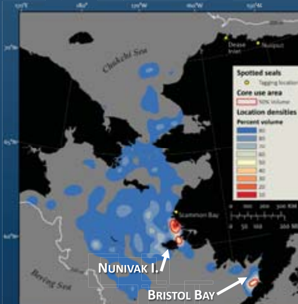
Nearshore Area



Resting areas primarily included islands near Scammon Bay, where they were tagged.

High-Use Areas

Tag location and Coastal proximity Pooled



- When sea ice was present, seal high-use areas overlapped regardless of tag location and distance from shore.
- Seals foraged and rested primarily near Nunivak Island and the Alaska coast.
- Low sea ice in the Bering Sea in recent years may be limiting spotted seals from using the central Bering Sea.

Summary

- Spotted seals in the Chukchi and Bering seas made frequent east-west foraging movements, rested on shore, and rarely moved between seas during the open-water season.
- Movement patterns we identified highlight the importance of tagging seals in multiple regions annually to understand movements and habitat use throughout their range.
- Continued studies of seal movements will be necessary to monitor for changes in behavior with changes in climate and development activities.

Future Work

- Examine how seal high-use areas are influenced by oceanographic characteristics and sea ice.

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Appendix U.

Oceanographic characteristics associated with movements and high-use areas of spotted seals (*Phoca largha*) in the Chukchi and Bering seas.

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Spotted seals (*Phoca largha*) are pelagic foragers that use seasonal pack ice for pupping, nursing, and resting when ice is present (December–June) and coastal haulout sites for resting during the open-water season (July–November). Decreases in the extent and duration of ice cover associated with climate change have eased access to the Arctic for development and shipping, prioritizing the identification of areas important to seals. We worked with Alaska Native hunters to deploy satellite-linked tags on 24 spotted seals (including 20 CTD tags) in nearshore areas of the Beaufort and Bering seas during 2016–2018 to study movements and identify high-use areas. Individual seals were tracked for 137–638 days. Seals tagged in the Beaufort Sea moved into the Chukchi Sea and made recurrent east-west movements, spending 1–27 days foraging near Herald Shoal, primarily in warm Alaskan Coastal Water, and 0.1–5.7 days resting on coastal islands. Seals tagged in the Bering Sea also made recurrent east-west movements, spending 1–25 days foraging in the central Bering Sea, primarily between St. Lawrence Island and St. Matthew Island in Alaskan Coastal Water and Bering Shelf Water, and 0.03–6.2 days resting on coastal islands. In December, seals in the Chukchi Sea moved south, ahead of the advancing pack ice, into the Bering Sea. By mid-January, all seals regardless of their tagging location foraged along the pack ice edge in the central Bering Sea. CTD data will be used to identify oceanographic characteristics of the high-use foraging areas. Tagging seals in both the Beaufort and Bering seas allowed us to identify spotted seal movements and high-use areas throughout the continental shelf. Further studies that include additional tagging locations will likely identify other important foraging and resting areas.

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The mission of the Environmental Studies Program is to provide the information needed to predict, assess, and manage impacts from offshore energy and