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Pinniped Movements and Foraging

Village-Based Walrus Habitat Use Studies in the Chukchi Sea – Final Report

U.S. Department of the Interior
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Pinniped Movements and Foraging:

Village-Based Walrus Habitat Use Studies in the Chukchi Sea

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Project Organization Page

Authors:
Lori T. Quakenbush (M.S.) 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 (M.S.) 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, data management, archive, analysis, map production, and report and manuscript preparation.

John J. Citta (PhD.) is a Biometrician II with the Arctic Marine Mammal Program within the Alaska Department of Fish and Game. His role in this project was assistance with data management, analysis, and report, and manuscript preparation.

Mark A. Nelson (M.S. candidate) is a Fish and Wildlife Technician V for the Arctic Marine Mammal Program within the Alaska Department of Fish and Game. His role in this project was assistance with tagging and documentation of traditional knowledge.

Key Project Personnel:
Mikkel Jensen is an Industrial Designer within his Denmark-based company called Mikkel's Vaerkstad. He is an expert in walrus and bowhead whale tag anchor and deployment systems and his role in this project was to manufacture and attach tag anchors and provide tag deployment equipment.

Henry P. Huntington is a social scientist within his Alaska-based company called Huntington Consulting. He is an expert in traditional knowledge and arranged and conducted traditional knowledge interviews, and assisted in report and manuscript preparation.

Clarence Irrigoo, Perry Pungowiyi, and Edwin Noongwook are Alaskan subsistence walrus hunters who were key participants as walrus taggers. They also educated research crews regarding walrus behavior and sea ice conditions.

Willard Neokok, Warren Harding Lampe, and Leo Ferrero III are subsistence hunters and residents of Pt. Lay who were key participants as stewards of the terrestrial haulout. They accompanied researchers and assisted with erecting remote camera towers to minimize disturbance to walruses. They also conducted beach surveys for haulout sites and carcass surveys.

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Appendix F-12. Crawford, J. A., L. T. Quakenbush, J. J. Citta, C. Irrigoo Jr. and P. R. Lemons. 2016. Using movement, diving and haul out behavior to identify the relative importance of foraging areas for walruses in the Alaskan Chukchi Sea. Alaska Marine Science Symposium, 25–29 January, Anchorage, AK. (Abstract and poster).

Appendix G. Traditional Knowledge reports listed chronologically.

Appendix G-1. Huntington, H. P., M. Nelson, and L. T. Quakenbush. 2012. Traditional knowledge regarding walrus near Point Lay and Wainwright, Alaska. Report to the Eskimo Walrus Commission and the Bureau of Ocean Energy Management for contract #M09PC00027. 11 pp.

Appendix G-2. Huntington, H. P., and L. T. Quakenbush. 2013. Traditional knowledge regarding walrus near Point Hope, Alaska. Report to the Native Village of Point Hope, Alaska and Bureau of Ocean Energy Management for contract #M09PC00027. 9 pp.

Appendix G-3. Huntington, H. P., M. Nelson, and L. T. Quakenbush. 2015a. 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. 8 pp.

Appendix G-4. Huntington, H. P., M. Nelson, and L. T. Quakenbush. 2015b. Traditional knowledge regarding ringed seals, bearded seals and walrus near Elim, Alaska. Final report to the Eskimo Walrus Commission, the Ice Seal Committee, and the Bureau of Ocean Energy Management for contract #M13PC00015. 7 pp.

Appendix G-5. Huntington, H. P., M. Nelson, and L. T. Quakenbush. 2015c. Traditional knowledge regarding ringed seals, bearded seals, and walrus near St. Michael and Stebbins, Alaska. Final report to the Eskimo Walrus Commission, the Ice Seal Committee, and the Bureau of Ocean Energy Management for contract #M13PC00015. 7 pp.

Appendix G-6. Huntington, H. P., M. Nelson, and L. T. Quakenbush. 2016a. Traditional knowledge regarding ringed seals, bearded seals, and walrus near Kivalina, Alaska. Final report to the Eskimo Walrus Commission, the Ice Seal Committee, and the Bureau of Ocean Energy Management for contract #M13PC00015. 8 pp.

Appendix G-7. Huntington, H. P., M. Nelson, and L. T. Quakenbush. 2016b. 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. 11 pp.

Appendix G-8. Huntington, H. P., M. Nelson, and L. T. Quakenbush. 2016c. Traditional knowledge regarding ringed seals, bearded seals, and walrus near Shishmaref, Alaska. Final report to the Eskimo Walrus Commission, the Ice Seal Committee, and the Bureau of Ocean Energy Management for contract #M13PC00015. 8 pp.

Executive Summary

Working cooperatively with the Eskimo Walrus Commission and walrus hunters from Alaskan coastal communities, we designed a study to deploy satellite transmitters and conduct counts, carcass surveys, and observations on haulouts that are encountered near villages in spring and fall. During the seven years (2009–2016) of this study titled, "*Village-Based Walrus Habitat Use Studies in the Chukchi Sea,"* we combined satellite-linked transmitter technology and the traditional knowledge and skills of Native subsistence walrus hunters to greatly increase our understanding of walrus movements and behavior. Satellite-linked transmitters placed on walruses provided information on movements, speed of travel, feeding areas, and haulout behavior. We documented intensive summer use of Chukchi Lease Sale Area 193, especially Hanna Shoal by female walruses with calves-of-the-year and females without calves. Local and traditional knowledge was documented at Point Lay, Point Hope, Wainwright, Barrow, Elim, and St. Michaels/Stebbins to further our understanding of walrus behavior and how it may be changing. This final report covers 2009–2016 and includes satellite tracking 82 walruses in the Bering, Chukchi, and Beaufort seas, terrestrial haulout surveillance, carcass surveys, necropsies and documentation of traditional knowledge. Activities were coordinated with the Eskimo Walrus Commission, North Slope Borough, U.S. Fish and Wildlife Service (USFWS), U.S. Geological Survey (USGS), and the villages of Barrow, Wainwright, Point Lay, Point Hope, Wales, Little Diomede, Gambell, and Savoonga.

We found that walruses migrating north with the receding sea ice were not limited to the marginal ice zone but traveled deep into the ice. Walruses migrated on both the U.S. and Russian sides of the Chukchi Sea, generally staying closer to shore (average 100 km, 62 miles) as they migrated north in June, and progressively moved farther from shore in the Chukchi Sea during July (average 119 km, 74 miles), August (average 138 km, 86 miles), and September (average 171 km, 106 miles).

The Hanna Shoal Walrus Use Area (HSWUA) is known to be important for walruses (Jay *et al.* 2012) and 59% of the walruses we tagged spent time there, presumably to forage. The average arrival date was 30 June and departure was 2 August. Prior to arriving in the HSWUA they traveled 49.5 km/day (30.7 miles/day), once within the area, however, travel rates slowed to about half that (25.7 km/day, 16.0 miles/day).

Females hauled out on ice a higher proportion of time when in Hanna Shoal than when in coastal foraging areas near Icy Cape. Specifically, haulout percentages of females with calves in Hanna Shoal were higher than females with calves near Icy Cape and higher than females with calves in the rest of the Chukchi Sea, as well as higher than females without calves in all areas. Haulout percentages were also highest during the day (0900–2000). For all females, dive duration was longest and dive rate was lowest in Hanna Shoal than in the rest of the Alaskan Chukchi Sea.

Not all walruses used the terrestrial haulouts at Point Lay during their southward migration. During the times when walruses hauled out in large numbers near Point Lay, two of seven tagged walruses used the haulout, and only in 2015.

Introduction

Pacific walruses (*Odobenus rosmarus*) are an important subsistence and cultural resource for coastal people of western Alaska and they are an important component of the Bering and Chukchi seas ecosystem. Walruses winter together in the Bering Sea but females with calves and subadults summer in the Chukchi Sea feeding on the sea floor in water less than 100 m and using sea ice as a resting platform; most adult males remain in the Bering Sea where they use terrestrial haulouts for resting. When the ice edge retreats too far north of the continental shelf it is no longer useable for resting between feeding bouts because the water is too deep for feeding. The rapid retreat of sea ice in recent years is changing walrus summer habitat in the Chukchi Sea and may be changing summer distribution and hauling out behavior, requiring that walruses haul out on land instead of ice. These ice conditions may require that females with calves and subadults feed near terrestrial haulouts, which may cause nearby feeding areas to be depleted and disturbance events on terrestrial haulouts can cause increased calf mortality. Walruses on ice floes can quickly get to deep water when disturbed, but on large land haulouts disturbances may lead to stampedes that cause calves and subadults to be trampled as the larger animals run over them to get to water. Polar bears congregate at terrestrial haulouts and can cause stampedes for the opportunity to prey on injured calves. Thus, the changes in the extent and duration of the sea ice in summer may be changing the distribution of females, calves, and subadults. For example, females with young calves may need to remain close to shore where calves can haul out to rest.

Due to these concerns walruses were petitioned for listing under the Endangered Species Act (ESA) in 2008. In 2011, although the population was not believed to be in decline, listing was determined to be warranted but precluded by other more urgent listing needs and the Pacific walrus was delegated as a candidate species. Court settlements have dictated that the Pacific walrus must either be listed under the ESA or removed as a candidate species by 2017. Concomitant with rapidly retreating summer sea ice, oil and gas activity increased in the Chukchi Sea until 2015 adding to the importance of understanding walrus movements, feeding areas, and habitat requirements necessary to plan lease sales, permit development activities, and design effective mitigation measures for better conservation and management of the species, however, substantial oil and gas activities in the near future appear unlikely.

During the seven years of this study (2009–2016) we learned about the movements and behavior of walruses during summer in the Chukchi Sea, including the amount of time spent in the Chukchi Lease Sale Area 193, which includes Hanna Shoal. We also learned about diving and hauling out behavior of adult females, both those with calves and those without calves, during a period of diminishing sea ice.

Goals and Objectives

This study was designed to work in close-cooperation with Native Alaskan subsistence hunters to deploy satellite-linked transmitters, conduct observations, document traditional knowledge regarding walruses, and to integrate our findings with concurrent research on walruses and other marine mammals in the Chukchi Sea Lease Sale area.

Objective 1**:** Estimate patterns of movement and behavior of walruses migrating to and moving within the Chukchi Sea Planning Area. Particular emphasis will be placed on estimating movements within industrial ship traffic lanes and between terrestrial haulout sites and feeding areas near Hanna Shoal and other potential oil and gas development sites.

Objective 2**:** Estimate and evaluate the effect of any changes in walrus behavior related to changes in ice coverage and ice quality in the Chukchi Sea.

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

Objective 4: Create a database of traditional knowledge of walrus behaviors including, but not necessarily limited to, movements, social behavior, and use of habitat including use of ice and land as haulout substrates.

Methods

Coordination

Meetings, workshops, other communication. Meetings with the Eskimo Walrus Commission (EWC), walrus hunters, Point Lay Community, U.S. Fish and Wildlife Service (USFWS), and U.S. Geological Survey (USGS) have been fundamental to this tagging project. We also co-sponsored and participated in the "Adapting to Climate Change: A Community Workshop on the Conservation and Management of Walruses on the Chukchi Sea Coast" held in Barrow in 2012 (Appendix A).

Tag development and deployment

We researched satellite-linked transmitters (tags) available for use on walruses, including those used by USGS. We chose a system of deployment and attachment developed by Mads Peter Heide-Jørgensen and Mikkel Jensen from the Greenland Institute of Natural Resources that has been used successfully with walruses in Alaska and Canada. These tags are manufactured by Wildlife Computers, Inc. and use the Argos system of satellites for data collection. Tags were deployed by crossbow with shafts modified for tag delivery. Crossbows were used to deploy tags only on adult walruses that were hauled out on ice or land. With the input of the walrus hunters, we developed a pole deployment system based on hunter harpoon methods to deploy tags on walruses that were either swimming at the surface of the water or were hauled out on sea ice. The pole was thrown (harpoon style) to tag walruses at a distance of 2–4 m.

We used two types of tags; 1) SPLASH tags (Model: SPLASH10, Dimensions: 5.5 x 3.0 x 2.5 cm) that provide both location and dive data and 2) SPOT tags (Models: SPOT5 during 2010–2014, 4.5 x 3.0 x 2.3 cm and SPOT6 during 2015, 5.2 x 3.0 x 2.0 cm) that provide location and haulout behavior (i.e., time wet and dry). Both tag types were mounted on top of a stainless steel shaft (7 cm long). The shaft has a cutting head and petal combination on the bottom (Fig. 1). The cutting head is designed to cut through the tough skin upon deployment and the petals are to impede the transmitter shaft from working out of the skin and blubber. The transmitter sits on top of the skin and serves as a stop during deployment. A (17 cm long) antenna wire protrudes from the top of the transmitter. The SPOT tags and shaft weighed 49 g in air, and the SPLASH tags and shaft weighed 63 g.

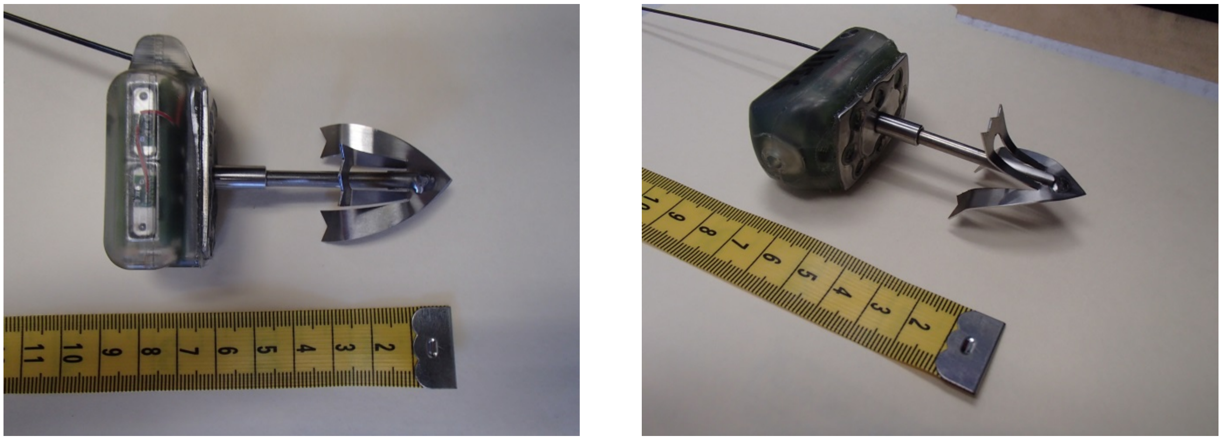

Figure 1. Satellite transmitter (Wildlife Computers SPOT tags) mounted on stainless steel shaft and cutting head and petals (made by Mikkel Jensen) used for tagging walruses. Ruler is in cm.

We attempted to minimize disturbance to non-target animals during all activities (e.g., see 2013 Research Permit Report, Appendix B). Walruses on the ice were approached very slowly from small boats with outboard motors. Walruses hauled out on land were approached from downwind by a person crawling on their stomach. Tagging and biopsy activities were not attempted on groups larger than 300 walruses to minimize injury from potential stampedes.

During 2010, we deployed two SPOT tags that were set to attempt 175 transmissions per day. Given that tags on walruses rarely transmit for more than a few months this limit was too conservative. For the remainder of the study, SPLASH and SPOT tags were set to attempt 250 transmissions per day. Tags were set to transmit all hours of the day and all days of the week; there was no "duty cycle" or "dead time." Tags only send data when at the surface and more than one transmission is required by Argos satellites to calculate a location. The number of transmissions received from tags was variable and likely dependent upon the position of the tag on the walrus (e.g., along the mid-line versus lower on the shoulder) in addition to the tag settings.

The SPLASH tags transmitted dive data in compressed and simplified histogram form, as well as more detailed dive information. Specifically, SPLASH tags collect the following forms of dive and haul out data:

1) *Maximum Dive Depth* data are a collection of accumulated dive depths during a 6-hr period. These histograms (DEPTH) tally the number of dives where the maximum depth recorded falls into pre-determined ranges or bins (0–5 m; 5–10 m; 10–20 m; 20–30 m; 30–40 m; 40–50 m; 50–60 m; 60–70 m; 70–80 m; 80–90 m; 90–100 m; 100–110 m; 110–120 m; and > 120 m).
2) *Dive Duration* data are a collection of accumulated dive durations during a 6-hr period. These histograms (DURATION) tally the number of dives where the dive duration of each recorded dive falls into pre-determined ranges or bins (0–2 mins; 2–

4 mins; 4–6 mins; 6–8 mins; 8–10 mins; 10–12 mins; 12–14 mins; 14–16 mins; 16–18 mins; 18–20 mins; 20–22 mins; 22–24 mins; 24–26 mins; and > 26 mins).

3) *Time-At-Depth* data are a collection of accumulated times the walrus spent at specific water depths during a 6-hr period. These histograms (TAD) store the data into pre-determined ranges or bins (0–5 m; 5–10 m; 10–20 m; 20–30 m; 30–40 m; 40–50 m; 50–60 m; 60–70 m; 70–80 m; 80–90 m; 90–100 m; 100–110 m; 110–120 m; and > 120 m).
4) *Hourly Timelines* summarize the proportion of each hour the tag reported being out of the water and dry (at the surface and dry or hauled out; PERCENT). A minute was classified as "dry" if the tag was dry for the entire minute. SPOT tags also collected these data.
5) *Dive Behavior* records the maximum depth and duration of a dive, along with its general shape. A walrus needed to go below 2 m for the behavior to be considered a dive. Possible dive profile shapes include "square," "V," or "U" shapes. This setting also records how much time is spent at the surface between dives.
6) *Dry-Deep-Neither* data classify the dominant behavioral state of the walrus for each hour and duplicated the chronologies of hourly haul-out and foraging state data collected by USGS. We collected this so that we could increase data available for USGS analyses. An hour was classified as "dry/hauled out" if the tag measured dry (out of the water) for more than 90% of the hour. An hour was classified as deep ("foraging") if it was deeper than 10 m for more than 50% of the hour. Otherwise the hour was classified as neither. The depth sensor was set to sample pressure every 1 second.

Genetic Samples

For our study, skin samples were only needed if sex was not evident from physical morphology. We collected a skin biopsy during tag deployment only when DNA was necessary to determine sex of the tagged walrus. Biopsy tips (manufactured by CETA-DART, Denmark) were a 2.5 cm-long, hollow, stainless steel cylinder, 0.6 cm diameter with internal barbs to retain the sample. When tagging with the crossbow, a biopsy was collected using a replaceable biopsy tip on a separate arrow shaft with a float and a retrieval string. When tagging with the pole system a replaceable biopsy tip was mounted next to the bolt holding the satellite transmitter. Penetration depth was controlled by a stopper on the plastic projectile when using the crossbow and by a plastic backing that holds the transmitter onto the pole. Skin biopsies from tagged walruses were provided to USFWS for their genetic mark-recapture study. If needed, DNA was extracted and analyzed to determine sex by genetics experts at the National Marine Fisheries Service, Southwest Fisheries Science Center and then archived.

Mapping

To keep all interested parties informed of the project and share the movements of any tagged walruses, we produced weekly maps and sent them to an extensive mailing list that included many subsistence hunters as well as agency and oil company personnel. ArcMap version 10.2 (ESRI Inc. 2012) was used for all mapping. We also created annual animations that depicted

daily walrus locations and sea ice concentrations throughout the monitoring period each year. The maps and information about the project are also posted at the Alaska Department of Fish and Game's (ADFG) website:
http://www.adfg.alaska.gov/index.cfm?adfg=marinemammalprogram.walrustracking

In addition to the general maps that included all tagged walruses and their movements, beginning in 2014, we also provided more detailed maps of tagged walruses in the active oil and gas lease areas near Hanna Shoal at the request of BOEM for weekly meetings with industry and agencies.

Movement and Dive Analyses

This report includes descriptive and quantitative analyses of walrus movements and behavior in the Chukchi Sea, from June through October, including their specific use of the Hanna Shoal Walrus Use Area (HSWUA; Jay *et al.* 2012; Fig. 2). These analyses include movement rates, distance from shore, density estimates highlighting high use and potentially important foraging areas, and haulout and diving behavior.

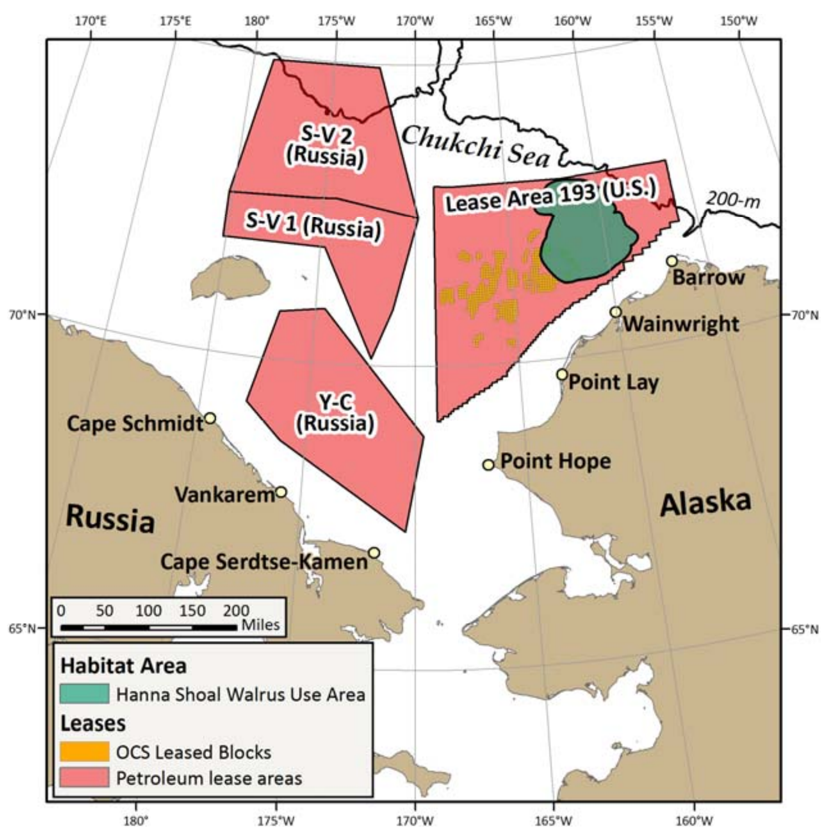

*Figure 2. Map of the Chukchi Sea with active U.S. and proposed Russian petroleum exploration/development lease areas (red), and Outer Continental Shelf (OCS) leased blocks (orange). Russian petroleum areas include: Severo-Vrangelevskiy 1 (S-V 1), Severo-Vrangelevskiy 2 (S-V 2), and Yuzhno-Chukotsky (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). (** OCS Leased Blocks associated with Chukchi Sea Lease Sale 193 were active during the study period; all but one lease block has been relinquished as of May 2016).*

Data Management and Location Processing

Location data were collected using the Argos system (Harris *et al.* 1990) and a copy of the raw data has been archived at ADFG in Fairbanks, Anchorage, and Juneau. Metadata, raw data files, and processed data files are archived on the State of Alaska web server. On this server (WinfoNet), we have an archival application specifically for the storage of data and the creation of metadata. The server is backed-up daily and cached in Fairbanks, Anchorage, and Juneau. Processed locations were imported into a geographic information system (ArcMap or R) for analysis. Location error 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/). Location qualities provided by Argos include B, A, 0, 1, 2, and 3 with 3 representing the highest quality and most accurate position.

To determine which locations to use for analyses we used a speed-distance-angle (SDA) filter (Freitas *et al.* 2008) in R version 3.1 (Package argosfilter) to remove less accurate locations. Walrus locations that resulted in swim velocities of >2.77 m/s (Udevitz *et al.* 2009) were removed unless they were within 5 km of the previous location. The angular component of the filter is used to remove locations with a high degree of location error that fall far from the 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., Keating 1994, Freitas *et al.* 2008). For location *i*, this deviation is measured as the angle between locations *i*-1, *i*, and *i*+1. 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 then removed locations that fell on land to establish the final set of locations used to determine walrus movements and areas of concentrated use.

For specific analyses, we also used a continuous-time, correlated random walk, state-space model to estimate the true locations and provide a single daily estimated location (Johnson *et al.* 2008) in R version 3.1 (Package crawl). In effect, the true location can be treated as an unknown variable and statistically estimated. The advantage of this technique is that all locations can potentially be used, regardless of location quality, and the estimated locations are more accurate than the raw data. Estimated locations of walruses were then used for analyses.

Movement Behavior of Tagged Walruses

We describe the seasonal movements of walruses in the Chukchi Sea during June through October. Because it is likely that walruses spend more time in higher quality foraging areas during summer, we compared movement rates and descriptive statistics of walruses in the HSWUA (Fig. 2) with the rest of the Chukchi Sea. We used all locations retained by the SDA filter in ArcMap 10.2 (ESRI Inc. 2012) to calculate minimum distances traveled and rates of travel (km/day). We recognize that rates of travel using Argos locations may be biased due to location error and gaps in data that result in failure to capture complete animal movements (i.e., rates of travel are likely underestimated for walruses with fewer locations). Therefore, distances traveled and rates of travel are minimum estimated values. We investigated whether movement rates differed by reproductive category (females with calves versus females without calves), area of use (whether the walrus was located in the HSWUA or in the rest of the Chukchi Sea), and year using a linear mixed model and SAS software, version 9.3 (SAS Institute, 2010; PROC MIXED). We also investigated whether the distance walruses were from shore changed while they were in the Chukchi Sea. For each walrus, we determined the distance between the daily estimated location from the correlated random walk, state-space model (Johnson *et al.* 2008) and the nearest shoreline in ArcMap 10.2 (ESRI Inc. 2012). We then tested if distances to shore differed by reproductive category, month, and year using a repeated measures linear mixed model (PROC MIXED) and SAS software. We included month as a covariate because it represented the stage of migration in the Chukchi Sea. We did not include male walruses in our analyses of movement rates or distance to shore because our sample size was insufficient.

Density Estimates

We were interested in identifying high use areas within the Chukchi Sea, by month, during June–October when we had walrus locations. We counted the number of locations within each cell of a 50 x 50 km gridded matrix that covered the Chukchi Sea to estimate the scaled probability of a walrus being located within each cell. We used R software to count the number of daily estimated locations from the correlated random walk, state-space model (Johnson *et al.* 2008) for each walrus that were located within each 50 x 50 km cell. Counts were made for each month of walrus locations (June–October). Next, we calculated the probability of finding a location in each cell by dividing the count of locations in each cell by the total number of locations. Finally, we estimated density contours, scaling the probability of finding a location in each cell by dividing the probability of finding a location in each cell by the overall maximal cell probability. Density contours were mapped in ArcMap 10.2.

Haulout and Diving Behavior

We investigated the haul out and dive behavior for female walruses while they were in the Chukchi Sea to determine if their behaviors differed by location or their reproductive category (i.e., whether or not the female had a calf of the year when tagged). The dive and haul out data collected by the tags (see *Tagging* section above) were organized into 6 and 24 hour histograms, respectively, and regularly did not have a location associated with them. Therefore, we used the correlated random walk, state-space model (Johnson *et al.* 2008) to estimate locations to match the time stamp of the haul out (every 24 hrs) and dive (every 6 hrs) data for each walrus (see *Movement Behavior of Tagged Walruses* section above). Next, we calculated density estimates (see *Density Estimates* section above) from the estimated haul out and dive locations and used estimates of 90% probability to identified potentially important foraging areas.

We were interested in the following behavior parameters: time hauled out (the proportion of an hour the walrus was hauled out (*Hourly Timelines*)), dive duration (*Dive Duration*), and dive rate (number of dives per hr). We calculated dive duration indices (used as response variables and derived from the data in the DURATION histograms) for each 6-hr histogram to allow statistical analyses and interpretation (Folkow and Blix 1999, Folkow *et al.* 2004; 2010).

$$Index_{Duration} = \sum (f_i M_i)$$

f_i : Proportion of dives assigned to the duration bin i,
M_i: Median duration value of bin i.

We defined the diving rate for each 6-hr histogram as the total number of dives in DEPTH Bins 2 through 14 divided by 6 hours. Although the depth resolution of the tags was small (±0.5 m), we excluded Bin 1 (0–2 m) to define a "dive" as >2 m to eliminate issues of wave height and near-surface behavior that are not likely to be related to foraging (Hastings *et al.* 2004, Folkow *et al.* 2010).

We used a linear modeling framework to examine haul out and dive parameters. For each parameter of behavior, we used model selection to examine the relationship between the behavior and reproductive category (females with calves versus females without calves), the area of use (whether the walrus was in an area identified as a potentially important foraging area or the rest of the Chukchi Sea), and time of day using a repeated measures, linear mixed model and SAS software, version 9.3 (SAS Institute, 2010). Time hauled out is proportional data (the proportion of an hour the walrus was hauled out), bound by 0 and 1, therefore we modeled these data using a logit link and a beta distribution as appropriate for proportional data with PROC GLIMMIX in SAS. We modeled dive duration and rate with PROC MIXED in SAS. To account for autocorrelated haul out and dive behavior and unequal time spacing among repeated measures within individuals, we used a spatial power covariance matrix structure (SP(POW)). For model selection, we fit repeated-measures mixed models with the REML method for estimating variances, and used a backward elimination procedure that sequentially eliminated statistically non-significant variables ($P > 0.05$) until only statistically significant variables remained ($P < 0.05$).

Analysis of Time Spent Within Program Areas

We used all telemetry data collected between 2010 and 2015 to quantify when tagged walruses were present within petroleum areas. Transmitter locations were filtered as described above. When calculating the number of calendar days that walruses transmitted within various oil and gas exploration/lease areas we pooled all study years (i.e., 1 July 2013, 2014, and 2015 are all simply "1 July"). Although pooling across years provides a more general understanding of when walruses might be located within a petroleum area, it removes the ability to detect annual variability. Tags were deployed in May and June and few tags lasted longer than three months. Therefore documenting the range of days that walruses were present within an area will be a minimum because many tags likely went off the air while walruses were still in those areas. We examined walrus use of the following program areas (Fig. 2):

1. Alaskan Chukchi Sea: All of Lease Sale Area 193.
2. Russian Chukchi Sea: Russia's main oil and gas company, Rosneft, recently signed an agreement with ExxonMobil to explore three areas for liquefied natural gas (LNG) reserves (Appendix C). These areas include Severo-Vrangelevskiy 1, Severo-Vrangelevskiy 2, and Yuzhno-Chukotsky (Fig. 2).

Haulout Activities

Locate terrestrial haulouts

Traveling by boat, walrus hunters located terrestrial haulouts near their villages as they occurred so that they could be protected from disturbance. They reported the location and estimated number of animals to USFWS. Surveillance equipment (spotting scopes, blinds, cameras, and GPS units) was used to monitor numbers, determine the general sex and age composition, and identify animals that may be sick or injured. Hunters escorted researchers to and from the haulout and provided polar bear protection. Additionally, this project supported walrus hunters who assisted the Alaska SeaLife Center in the construction and maintenance of camera towers at walrus haul outs near Point Lay. Camera towers were designed to house cameras to document the formation, composition, and persistence of the terrestrial haulout and record causes and results of disturbances.

Carcass surveys

To quantify the number of walruses that died at haulouts and document their condition, the hunters also surveyed the beach after the walrus herd left the haulout. To avoid causing stampedes, carcass surveys were only conducted if they would not cause disturbance to the walrus herd. The hunters examined each carcass looking for signs of trauma such as tusk punctures, bullet wounds, broken bones, bruising, and blood from the nose and mouth. A data sheet was filled out for each carcass (Appendix D). Body length (straight line length from the nose to the tail tip) and blubber thickness (midline between the fore-flippers over the sternum) measurements were taken, sex was determined, and age was estimated by body size or tusk length (Fig. 3). Each carcass was photographed and marked with a durable numbered tag so that it did not get sampled more than once. These data were shared with USFWS.

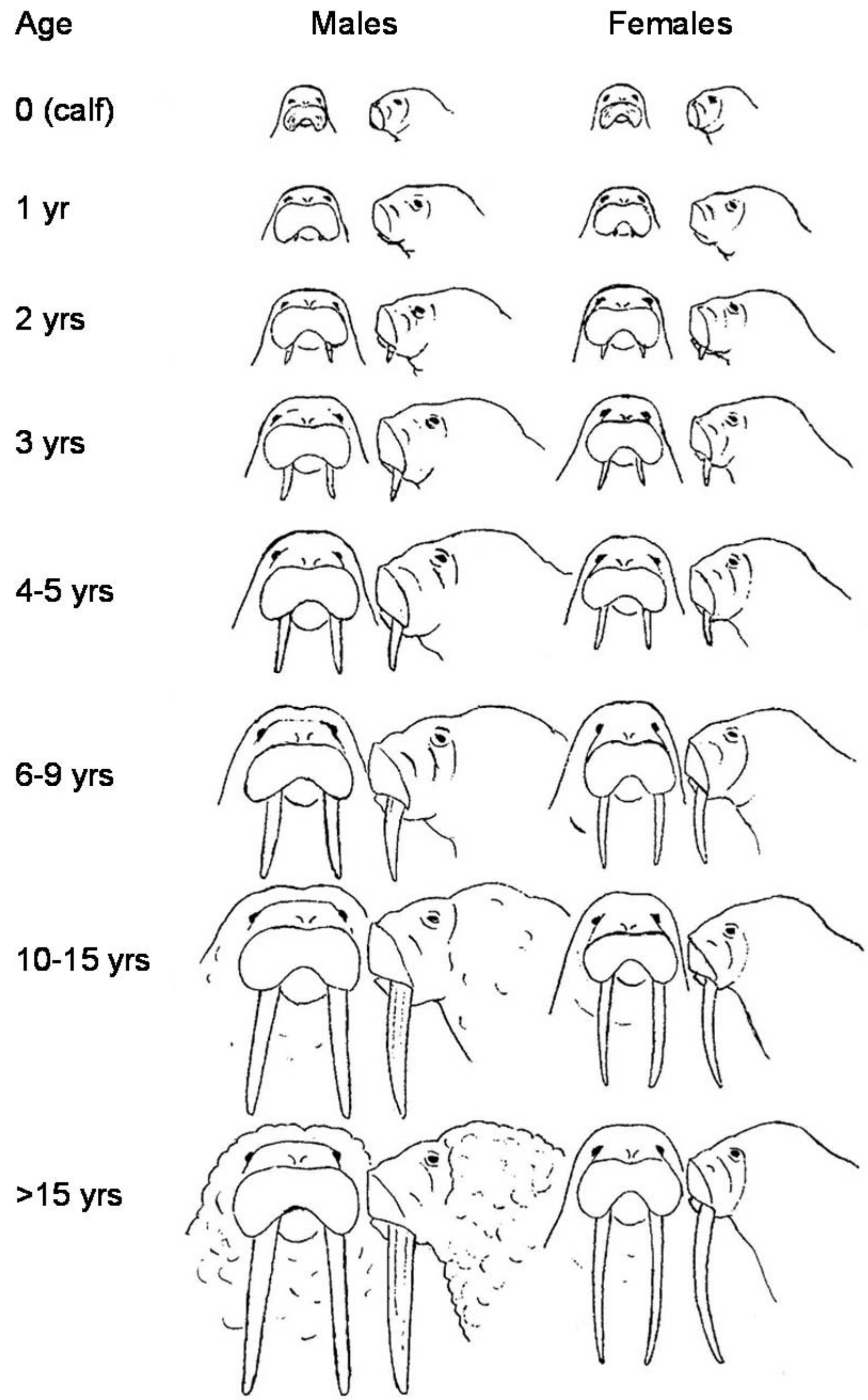

Figure 3. Average facial characters of walruses by sex/age classes used to classify tagged walruses. Age classification is based primarily on tusk size in relation to the width and height of the snout (Fay et al. 1986; Fay and Kelly 1989, published in Citta et al. 2013).

Local and Traditional Knowledge

Walrus hunters contributed local and traditional knowledge regarding walrus movements, timing of migration, and haul out behavior. Hunters shared their experiences of how to approach walruses on land, and in the water, without being detected, and their observations were critical to this study. Hunters also know when and where to look for walruses and how to approach them on the ice. We worked with EWC to identify walrus hunters with extensive knowledge that were interested in the project.

To collect local and traditional knowledge, interviews were conducted by Dr. Henry Huntington, a social scientist with experience in local and traditional knowledge studies and assisted by PI Quakenbush and by Mark Nelson. We used the same methods as those used by Noongwook *et al.* (2007); specifically, the semi-directive interview as described by Huntington (1998). Unlike Noongwook *et al.* (2007), however, our interviews were with one or two persons at a time, as well as with larger groups. In the semi-directive interview, researchers initiate a discussion around various topics of interest, but allow the person being interviewed to determine the order in which topics are discussed and to make connections among various topics that the researchers might not have anticipated. The interview is more fluid than would be a standardized questionnaire.

The persons interviewed were recommended by each community's representative to the EWC or by another participant's recommendation. The interviews were conducted in English, as all participants were comfortable in that language; occasionally terms were translated by participants for clarification. We brought maps of the region and local area and had participants draw walrus movements, haulouts, and other information directly on the maps, as they were being discussed during the interviews, to ensure that we accurately interpreted what was being described. We also recorded other information in notebooks. After information from the interviews was compiled, a draft report with annotated maps was sent to the interviewees to comment on for accuracy and for approval.

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 marine VHF handheld radios, satellite phones, personal satellite-linked locator beacons, and GPS units. Communication with a shore-base was coordinated prior to each trip.

Results

Coordination

We worked closely with EWC, local walrus hunters, USFWS, USGS, and BOEM. A chronology of the project history and accomplishments are included in Table 1. We maintained a webpage on the State of Alaska, Division of Wildlife Conservation website that explained the project and was updated weekly with a map of walrus movements (http://www.wildlife.alaska.gov/index.cfm?adfg=marinemammals.walrustracking). We also sent maps to an extensive list of interested entities including individual subsistence hunter, Village

Council Offices, EWC, USFWS, USGS, NSB (North Slope Borough), USCG (United States Coast Guard), and BOEM.

Table 1. Project history from July 2009 to June 2016.

Month	Year	Event
July	2009	Received contract from MMS (now BOEM). Submitted applications for research permits to USFWS and Animal Care and Use to ADFG.
September		Worked with USFWS and NSB to provide transportation for walrus hunters to conduct carcass surveys after a large (2,500–4,000) walrus haulout formed near Icy Cape and Wainwright. Gave project update to EWC Executive Committee in Anchorage. Purchased 15 satellite-linked transmitters. Received approved ADFG Animal Care and Use Protocol for walrus research.
October		Met with USFWS and USGS to discuss project during the 18th Biennial Conference of the Society for Marine Mammalogy in Quebec City, Canada.
December		Received research permit from USFWS to tag and biopsy walruses. Planned for travel to Pt. Hope, Pt. Lay, Wainwright, and Barrow in February to discuss monitoring terrestrial haulouts and tagging walruses.
January	2010	Submitted Annual Report to BOEM.
February		Traveled to Pt. Hope, Pt. Lay, Wainwright, and Barrow to discuss terrestrial haulouts and tagging activities as part of a visiting Chukotka hunter (Umpky Patrol) tour to share information about walrus and polar bear conservation (Appendix E).
June		Worked with hunters from Wales and Pt. Hope, but poor ice and weather conditions prevented tagging walruses.
September		Tagged two female walruses near Cape Lisburne (one with and one without a calf). Hunters from Pt. Lay monitored status of a large (25,000–35,000) walrus haulout near Pt. Lay and conducted carcass surveys.
October		Hunters from Pt. Lay on standby to conduct carcass surveys once herd left but a storm ended the haulout and washed the carcasses away. Submitted abstract for the Alaska Marine Science Symposium.
December		Provided a written project update to EWC in Anchorage (Appendix F-1).
January	2011	Poster presentation: *Results from village-based walrus studies in Alaska, 2010* at the Alaska Marine Science Symposium in Anchorage (Quakenbush et al. 2011; Appendix F-2). Submitted annual research permit report to USFWS.
March		Conducted traditional knowledge interviews in Pt. Lay and Wainwright.
June		Worked with hunters from Wales and Pt. Hope to tag but poor ice conditions and weather prevented tagging. Also tried to work with hunters from Little Diomede Island but travel to Diomede was restricted due to helicopter problems.
September		Pt. Lay hunters monitored ~22,000 walruses at the terrestrial haulout and conducted carcass surveys (Garlich-Miller et al. 2011; Appendix F-3).

October		Project update to EWC in Nome (oral update). Submitted abstract for the Alaska Marine Science Symposium.
November		Project update at hunter's meeting in Gambell and Savoonga.
January	2012	This study included in update to the Marine Mammal Commission on Arctic Marine Mammal research. Poster presentation: *Results from village-based walrus studies in Alaska, 2011* at the Alaska Marine Science Symposium in Anchorage (Crawford et al. 2012; Appendix F-4). Submitted annual research permit report to USFWS.
February		Co-sponsor of "A Community Workshop on the Conservation and Management of Walruses on the Chukchi Coast" workshop in Barrow (Garlich-Miller et al. 2012; Appendix A). Sponsored two hunters (Pt. Lay and Savoonga) to attend.
March		Provided project update to joint U.S.-Russian "Assessing Pacific Walrus Population Attributes from Coastal Haul-outs" workshop in Anchorage. Research permit amended to tag swimming walruses using "harpoon" method.
May		Worked with hunters to tag walruses near Little Diomede Island for three weeks but ice and weather conditions were unsafe until after walruses had migrated north of the island.
August		Worked with Pt. Lay to prepare for terrestrial haulout, reviewed traditional knowledge reports and provided update on the project and movements of tagged walrus. Supported Alaska SeaLife Center installing camera towers at walrus haulouts near Point Lay.
September		Pt. Lay hunters prepared to monitor haulout, but none occurred. Little Diomede Island hunters prepared to monitor haulout, conducted surveys for haulouts, but no haulouts occurred.
October		Conducted traditional knowledge interviews in Pt. Hope. Submitted abstract for the Alaska Marine Science Symposium.
November		Project update to EWC in Anchorage (oral update).
December		Final report on Pt. Lay and Wainwright traditional knowledge completed (Huntington et al. 2012; Appendix G-1).
January	2013	Poster presentation: *Results from village-based walrus studies in Alaska, 2012* at the Alaska Marine Science Symposium in Anchorage (Crawford et al. 2013; Appendix F-5). Submitted annual research permit report to USFWS.
February		Project update at hunter meetings in Gambell and Savoonga.
May		Cold water survival and tagging training for hunters participating in research cruise.
June		Tagged 34 walruses in Bering and Chukchi seas during walrus research cruise.
August		Trip to Pt. Lay to prepare for terrestrial haulout and update on project and tagged walrus movements. Supported Alaska SeaLife Center installing camera towers at walrus haulouts near Point Lay.
September		Included project in research summary for 40th Anniversary of the Environmental Studies Program, DOI, Anchorage, AK.

		Pt. Lay hunters monitored 2,000–10,000 walruses at the terrestrial haulout and conducted carcass surveys.
October		Submitted abstract for the Alaska Marine Science Symposium. Supported Alaska SeaLife Center maintenance of camera towers at walrus haulouts near Point Lay.
November		Final report on Pt. Hope traditional knowledge completed (Huntington and Quakenbush 2013; Appendix G-2).
December		Project update to EWC in Anchorage (Appendix F-6).
January	2014	Poster presentation: *Results from village-based walrus studies in Alaska, 2013* at the Alaska Marine Science Symposium (Crawford et al. 2014; Appendix F-7). Submitted research permit report to USFWS. Supported Alaska SeaLife Center maintenance of camera towers at walrus haulouts near Point Lay.
February		Project update presented at hunter meetings in Gambell and Savoonga.
April		Project end date extended to 30 June 2016 due to slow start with tagging. Coordination with USFWS and USGS for walrus research cruise.
May		Hunters in Gambell and Savoonga attempted to tag but were not successful due to ice conditions and weather.
June		Tagged 33 walruses in the Chukchi Sea during walrus research cruise.
August		Supported Alaska SeaLife Center installing camera towers at walrus haulouts near Point Lay.
September		Pt. Lay hunters monitored ~35,000 walruses at the terrestrial haulout and conducted carcass surveys.
October		Trip to Pt. Lay to assess carcasses, conduct necropsies, and collect samples from dead walruses (trampled) at the terrestrial walrus haulout north of the old village of Pt. Lay. In the field, we worked with NSB-DWM staff and Pt. Lay hunters (Appendix F-8). Submitted abstract for the Alaska Marine Science Symposium.
November		Supported Alaska SeaLife Center maintenance of camera towers at walrus haul outs near Point Lay.
December		Project update to EWC in Anchorage (Appendix F-8).
January	2015	Poster presentation: *Results from village-based walrus studies in Alaska, 2014* at the Alaska Marine Science Symposium (Crawford et al. 2015; Appendix F-9). Submitted research permit report to USFWS. Assisted with Alaska SeaLife Center's plans to erect camera towers for haulouts near Cape Lisburne.
February		Project update presented at hunter meetings in Gambell and Savoonga.
April		Project end date extended to 30 June 2016 due to slow start with tagging. Coordination with USFWS and USGS for walrus research cruise. Submitted abstract for the Society for Marine Mammalogy Conference.
May-June		Tagged 26 walruses in the Russian and U.S. Chukchi Sea during walrus research cruise.
August		Coordinated transfer of carcass surveys and haulout surveillance to USFWS due to end of BOEM project.

September		Pt. Lay had ~35,000 walruses on the terrestrial haulout.
October		Submitted abstract for the Alaska Marine Science Symposium.
December		Project update to EWC in Anchorage (Appendix F-10). Oral Presentation: *Using movement, diving and haul out behavior to identify the relative importance of foraging areas for walruses in the Alaskan Chukchi Sea* at the Society for Marine Mammalogy Conference (Crawford et al. 2015; Appendix F-11). Final report on Barrow traditional knowledge completed (Huntington et al. 2015a; Appendix G-3). Final report on Elim traditional knowledge completed (Huntington et al. 2015b; Appendix G-4). Final report on St. Michael and Stebbins traditional knowledge completed (Huntington et al. 2015c; Appendix G-5).
January	2016	Poster presentation: *Using movement, diving and haul out behavior to identify the relative importance of foraging areas for walruses in the Alaskan Chukchi Sea* at the Alaska Marine Science Symposium (Crawford et al. 2016; Appendix F-12).
February		Prepared manuscript on TEK including walrus TEK (Huntington *et al.* in press).
June		Final report on Kivalina traditional knowledge completed (Huntington *et al.* 2016a; Appendix G-6). Final report on Kotzebue traditional knowledge completed (Huntington *et al.* 2016b; Appendix G-7) Final report on Shishmaref traditional knowledge completed (Huntington *et al.* 2016c; Appendix G-8). Final Report

Tagging Walruses and Tag Performance

Our original goal was to tag walruses and work with hunters based from coastal villages. Our attempts to tag walruses included travel to Wales and Point Hope during 2010 and 2011, and travel to Little Diomede Island during 2012. In all three years, ice and weather conditions, primarily wind, near these coastal villages prevented safe travel by boat. Also, ice retreated north quickly, leaving no opportunities for tagging walruses. In 2012, we began exploring the option of ship-based tagging as part of multi-agency walrus research cruises with USFWS and USGS and started tagging walruses offshore, in the Bering and Chukchi seas in 2013, 2014, and 2015. We realized it would be important to the success of the research to have the expertise of the native subsistence hunters. Walrus hunters from Saint Lawrence Island, Clarence Irrigoo Jr. (2013–2015), Perry Pungowiyi (2013), and Edwin Noongwook (2014) taught the researchers how to approach most efficiently and safely with minimal disturbance to walruses.

Walruses have excellent hearing and are sensitive to noises, as well as to smells and movement, therefore approaching walruses on ice when they are resting is done quietly from downwind (Appendix G-1). Walruses are also sensitive to the type of noise and hunters say that speaking in a normal voice is less disturbing to walruses than whispering (Appendix G-3). The hunters know that walruses can be aggressive and can team up to attack small boats when disturbed from the ice (Appendices G-1 and G-3). Large herds and juvenile walruses can be especially dangerous to people. Females are protective of their calves and hunters have been cautioned by elders about females with calves. Elders know of times when hunters butchering a walrus on an ice floe have been surrounded by other walruses that put their tusks on the ice and chipped away at it (Appendix G-1). It is this knowledge and experience that was used to determine how and which groups the small boats could safely approach for tagging and biopsies. At times the reason to avoid a certain group of walruses was not known by the researchers, but their advice was heeded.

Recently, because of less ice, hunters have begun to harpoon walruses in the water when they cannot find them on the ice (Appendix G-1). The hunters helped us develop a harpoon style tag deployment system based on their hunting method.

We tagged a total of 95 walruses during this study between 2010 and 2015 (Table 2). Two walruses were tagged onshore near Cape Lisburne in September 2010 and 93 were tagged offshore, in the Bering and Chukchi seas, during walrus research cruises in June 2013 and 2014 and May and June 2015 (Fig. 4). Of the 95 walruses tagged, 86 were adult females (39 of which were accompanied by calves of the year) and nine were adult males (Table 2). We tagged some males to see if they summered in the Chukchi Sea with the females and young walruses or if they returned to the Bering Sea and to generally compare their behavior to females.

Of the 95 tags deployed on walruses; 56 were SPLASH tags and 39 were SPOT tags. In September 2010 we deployed two SPOT tags on adult female walruses, one with a calf and one without, hauled out near Cape Lisburne. No tags were deployed during 2011 and 2012. The rest of the tags were deployed in May and June 2013–2015; we deployed 38 transmitters on adult females with calves (28 SPLASH and 10 SPOT tags), 46 on adult females without calves (28 SPLASH and 18 SPOT tags), and 9 on adult males (9 SPOT tags). Not all tags transmitted data; 13 (5 SPLASH and 8 SPOT) did not transmit any data or only transmitted data for <24 hours after deployment due to an error in the tags' software or for other unknown reasons (Table 3). Therefore, our dataset includes data from 34 of 38 adult females with calves (28 of 28 SPLASH and 6 of 10 SPOT tags), 40 of 46 adult females without calves (23 of 28 SPLASH and 17 of 18 SPOT tags), and 6 of 9 adult males (all SPOT tags).

Tag longevity did not differ among females with calves, females without calves, and male walruses or among deployment years ($P > 0.53$). SPOT tags (mean duration 69.8 days, range 1–134 days) did transmit, on average, 25.8 days longer than SPLASH tags (mean duration 44.0 days, range 4–67 days, $P < 0.01$). Overall, fewer than 5 tags transmitted after 15 September (Fig. 5).

In 2013, three tags were lost during deployment attempts due to the fitting between the deployment rod and tag loosening in cold temperatures. The fitting was tightened by using a fabric tape that broke upon impact and no other tags were lost. In 2014, two tags were lost during deployment. In 2015, the first five tags deployed did not transmit after the first day of deployment (30 May) due to an error in the tag software. We were able to obtain new software to upload onto the remaining tags. The tags with the new software functioned properly after deployment so we were able to deploy the remaining 26 transmitters.

*Table 2. Walruses instrumented with satellite-linked transmitters in the Bering and Chukchi seas in 2010, 2013, 2014, and 2015. Females with calves are noted by *. Tags that transmitted data for <24 hours after deployment due to an error in the tags' software or for other unknown reasons are noted by ⁺.*

Walrus Id	Date tagged	Latitude N	Longitude	Sex	Tag type	Tag duration (days)
W10-01	17-Sep-10	68.881	-166.194	F*	SPOT[1]	26
W10-02	19-Sep-10	68.861	-165.831	F	SPOT	2
W13-01	6-Jun-13	62.417	-168.827	F*	SPLASH[2]	53
W13-02	6-Jun-13	62.520	-168.799	F*	SPLASH	34
W13-03	13-Jun-13	68.234	-168.893	F*	SPOT	44
W13-04	13-Jun-13	68.233	-168.888	F	SPOT	26
W13-05	13-Jun-13	68.241	-168.889	F	SPOT	124
W13-06	13-Jun-13	68.253	-168.912	F*	SPOT	96
W13-07	13-Jun-13	68.278	-168.909	F	SPOT	88
W13-08	13-Jun-13	68.223	-168.907	F	SPOT	92
W13-09	13-Jun-13	68.228	-168.894	F	SPLASH	51
W13-10	13-Jun-13	68.226	-168.891	F	SPLASH	0⁺
W13-11	13-Jun-13	68.227	-168.895	F	SPLASH	34
W13-12	13-Jun-13	68.226	-168.901	F	SPLASH	45
W13-13	13-Jun-13	68.224	-168.890	F*	SPLASH	49
W13-14	13-Jun-13	68.225	-168.899	F	SPLASH	4
W13-15	13-Jun-13	68.217	-168.919	F*	SPLASH	55
W13-16	14-Jun-13	68.286	-169.086	F*	SPLASH	52
W13-17	14-Jun-13	68.286	-169.086	F*	SPLASH	56
W13-18	14-Jun-13	68.259	-169.321	F	SPLASH	0⁺
W13-19	16-Jun-13	68.828	-167.486	M	SPOT	86
W13-20	16-Jun-13	68.843	-167.461	F*	SPLASH	50
W13-21	17-Jun-13	68.811	-167.201	F*	SPLASH	29
W13-22	17-Jun-13	68.817	-167.201	F*	SPLASH	49
W13-23	17-Jun-13	68.816	-167.200	F	SPLASH	31
W13-24	17-Jun-13	68.825	-167.111	M	SPOT	0⁺
W13-25	17-Jun-13	68.824	-167.112	M	SPOT	63

W13-26	17-Jun-13	68.824	-167.112	M	SPOT	56
W13-27	19-Jun-13	69.662	-165.577	F	SPLASH	50
W13-28	21-Jun-13	69.438	-165.585	M	SPOT	0^{+}
W13-29	21-Jun-13	69.440	-165.600	F	SPLASH	56
W13-30	22-Jun-13	69.590	-164.964	F	SPOT	115
W13-31	25-Jun-13	69.424	-166.132	M	SPOT	0^{+}
W13-32	26-Jun-13	69.856	-165.891	F*	SPLASH	50
W13-33	26-Jun-13	69.861	-165.877	F	SPLASH	19
W13-34	27-Jun-13	70.246	-165.250	F*	SPLASH	33
W14-01	1-Jun-14	67.401	167.977	F	SPLASH	47
W14-02	1-Jun-14	67.401	167.977	F	SPLASH	7
W14-03	2-Jun-14	67.486	167.971	F	SPLASH	0^{+}
W14-04	2-Jun-14	67.482	168.008	F*	SPLASH	52
W14-05	5-Jun-14	68.338	167.844	F	SPLASH	47
W14-06	5-Jun-14	68.342	167.852	F*	SPLASH	44
W14-07	5-Jun-14	68.341	167.873	F*	SPLASH	7
W14-08	5-Jun-14	68.321	167.847	F*	SPLASH	47
W14-09	5-Jun-14	68.333	167.863	F	SPLASH	38
W14-10	5-Jun-14	68.333	167.891	F*	SPLASH	48
W14-11	5-Jun-14	68.333	167.891	F*	SPLASH	24
W14-12	5-Jun-14	68.328	167.979	F	SPLASH	28
W14-13	13-Jun-14	70.140	163.014	F*	SPLASH	53
W14-14	13-Jun-14	70.100	162.931	F	SPLASH	49
W14-15	13-Jun-14	70.091	162.894	F	SPLASH	48
W14-16	13-Jun-14	70.085	162.866	F	SPLASH	39
W14-17	13-Jun-14	70.053	162.773	F	SPLASH	58
W14-18	13-Jun-14	69.978	162.890	F	SPLASH	30
W14-19	15-Jun-14	70.432	162.897	F	SPLASH	55
W14-20	15-Jun-14	70.454	162.916	F*	SPLASH	66
W14-21	15-Jun-14	70.477	162.857	F*	SPLASH	55
W14-22	15-Jun-14	70.435	162.892	F*	SPLASH	7
W14-23	15-Jun-14	70.437	162.878	F*	SPLASH	46
W14-24	15-Jun-14	70.471	162.814	F	SPOT	62

W14-25	15-Jun-14	70.470	162.810	F	SPOT	49
W14-26	22-Jun-14	69.759	163.708	M	SPOT	53
W14-27	22-Jun-14	69.751	164.438	F	SPLASH	57
W14-28	21-Jun-14	69.813	163.581	M	SPOT	74
W14-29	22-Jun-14	69.813	163.581	F	SPOT	105
W14-30	22-Jun-14	69.813	163.581	F	SPOT	57
W14-31	22-Jun-14	69.813	163.581	F*	SPOT	80
W14-32	22-Jun-14	69.810	164.503	F	SPOT	40
W14-33	23-Jun-14	70.473	162.847	F	SPOT	92
W15-01	30-May-15	67.218	-171.125	F	SPOT	1^+
W15-02	30-May-15	67.298	-171.202	F*	SPOT	1^+
W15-03	30-May-15	67.305	-171.242	F*	SPOT	1^+
W15-04	30-May-15	67.308	-171.280	F*	SPOT	1^+
W15-05	30-May-15	67.308	-171.280	F*	SPOT	1^+
W15-06	4-Jun-15	67.995	-170.630	F	SPLASH	67
W15-07	4-Jun-15	67.947	-170.563	F*	SPLASH	37
W15-08	4-Jun-15	67.925	-170.683	F	SPLASH	53
W15-09	4-Jun-15	67.926	-170.684	F*	SPLASH	37
W15-10	4-Jun-15	67.914	-170.688	F*	SPLASH	54
W15-11	6-Jun-15	69.290	-175.559	F*	SPLASH	31
W15-12	7-Jun-15	69.436	-173.903	F	SPLASH	66
W15-13	7-Jun-15	69.439	-173.848	F*	SPLASH	57
W15-14	7-Jun-15	69.437	-173.824	F*	SPLASH	60
W15-15	16-Jun-15	71.835	-164.086	M	SPOT	39
W15-16	17-Jun-15	71.743	-164.028	F	SPLASH	35
W15-17	17-Jun-15	71.724	-164.018	F	SPLASH	0^+
W15-18	17-Jun-15	71.724	-164.018	F	SPOT	68
W15-19	17-Jun-15	71.720	-164.009	F*	SPOT	28
W15-20	17-Jun-15	71.727	-164.013	F	SPOT	1^+
W15-21	17-Jun-15	71.695	-164.035	F*	SPOT	97
W15-22	18-Jun-15	71.537	-164.402	F	SPOT	41
W15-23	18-Jun-15	71.543	-164.378	F*	SPOT	85
W15-24	18-Jun-15	71.543	-164.374	F	SPOT	35

W15-25	18-Jun-15	71.546	-164.364	F	SPOT	95
W15-26	18-Jun-15	71.549	-164.349	F	SPOT	134

[1] SPOT: Tag that provides locations and haul out timelines (*see Methods*).
[2] SPLASH: Tag that provides locations, haul out timelines, and dive data.

Table 3. Number of instrumented walruses whose tags successfully transmitted locations (i.e., number of tags that transmitted/total number of tags deployed) in the Bering and Chukchi seas in 2010, 2013, 2014, and 2015. Walruses are grouped by year tagged and reproductive category.

Year	Females with calves	Females without calves	Males	Total
2010	1/1	1/1	0	2/2
2013	13/13	13/15	3/6	29/34
2014	12/12	18/19	2/2	32/33
2015	9/13	9/12	1/1	19/26
Total	**35/39**	**41/47**	**6/9**	**82/95**

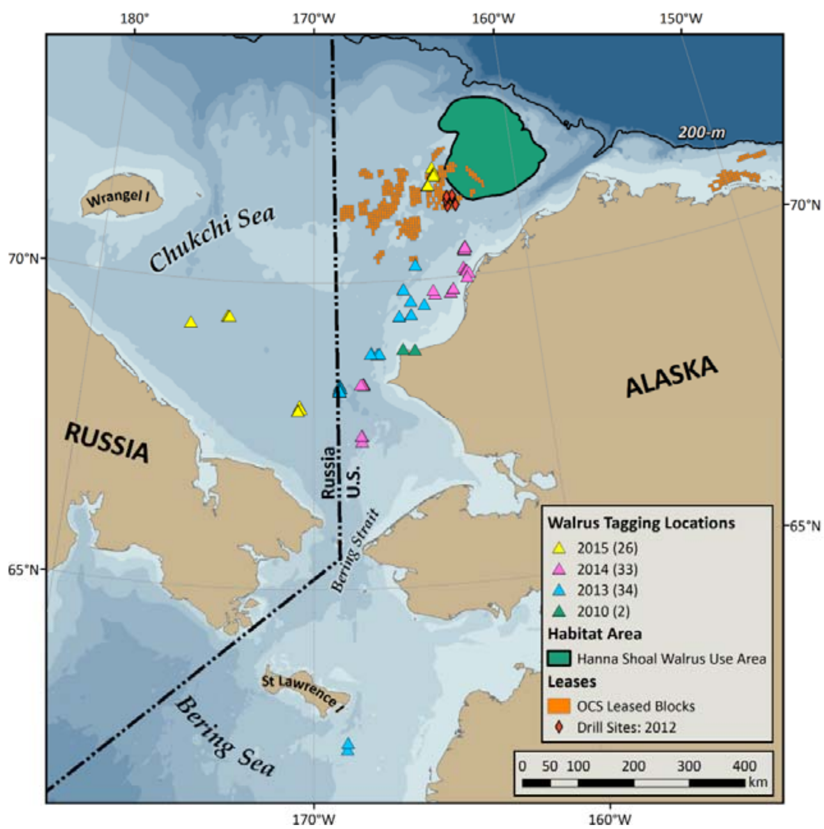

*Figure 4. Locations where satellite-linked transmitters were deployed on walruses in September 2010, June 2013 and 2014, and May and June 2015. (** OCS Leased Blocks associated with Chukchi Sea Lease Sale 193 were active during the study period; all but one lease block has been relinquished as of May 2016).*

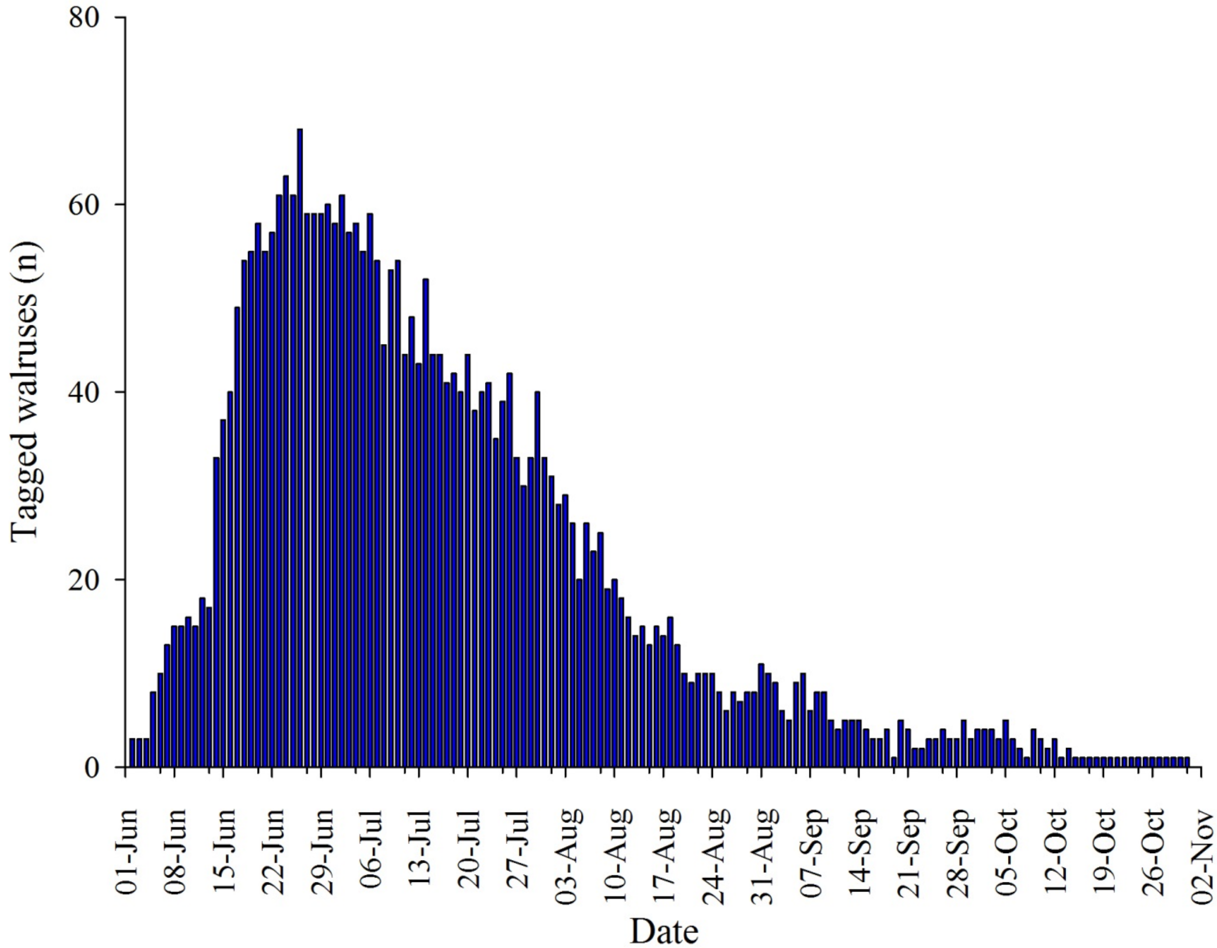

Figure 5. Number of tagged walruses that transmitted by day, all years combined (2010–2015).

Walrus Movements and Behavior

Walruses tagged during this study traveled an average minimum distance of 1,648 km, ranging from 21 to 4,457 km (Table 4). Although males traveled farther than females with and without calves, differences were not significant ($P = 0.37$). Annual movements of tagged walruses are shown in Figures 6–9. Satellite tracking has allowed us to identify variation in summer movements across the Chukchi Sea and unexpected movements by some individuals near coastal areas.

Table 4. Distances traveled by tagged walruses in the Bering and Chukchi seas during 2010, 2013, 2014, and 2015. Walruses are grouped by reproductive category.

	Females with calf (n = 35)	**Females without calf (n = 41)**	**Male (n = 6)**	**Total (n = 82)**
Ave. min. distance (km)	1,494	1,718	2,071	1,648
Min. distance (km)	175	21	1,289	21
Max. distance (km)	3,719	4,457	3,280	4,457

Sea ice conditions influence the movements and behavior of walruses. Summer sea ice conditions, both coverage and the ice receding patterns, in 2013, 2014 and 2015 were generally similar in the Bering and Chukchi seas, although there was slightly more ice in the central Bering Sea in 2013 during tagging in May and less ice in the central Chukchi Sea during the end of our research cruise in June 2015 (i.e., the research vessel was able to travel farther north in 2015). In all years, during late-May and June, the ice edge arched to the north, and generally was farther north in the mid Chukchi Sea between Vankarem, Russia and Point Hope, Alaska and ice continued to retreat northward until September. By September, the summer sea ice minimum was generally north of the continental shelf, delineated by the 200-m isopleth (Fig. 4).

Figure 6. Tracks of two tagged walruses in the Chukchi Sea from September through October, 2010. The tag deployed on the female without a calf (red "X") only transmitted locations for three days while the walrus was on shore near Cape Lisburne, Alaska.

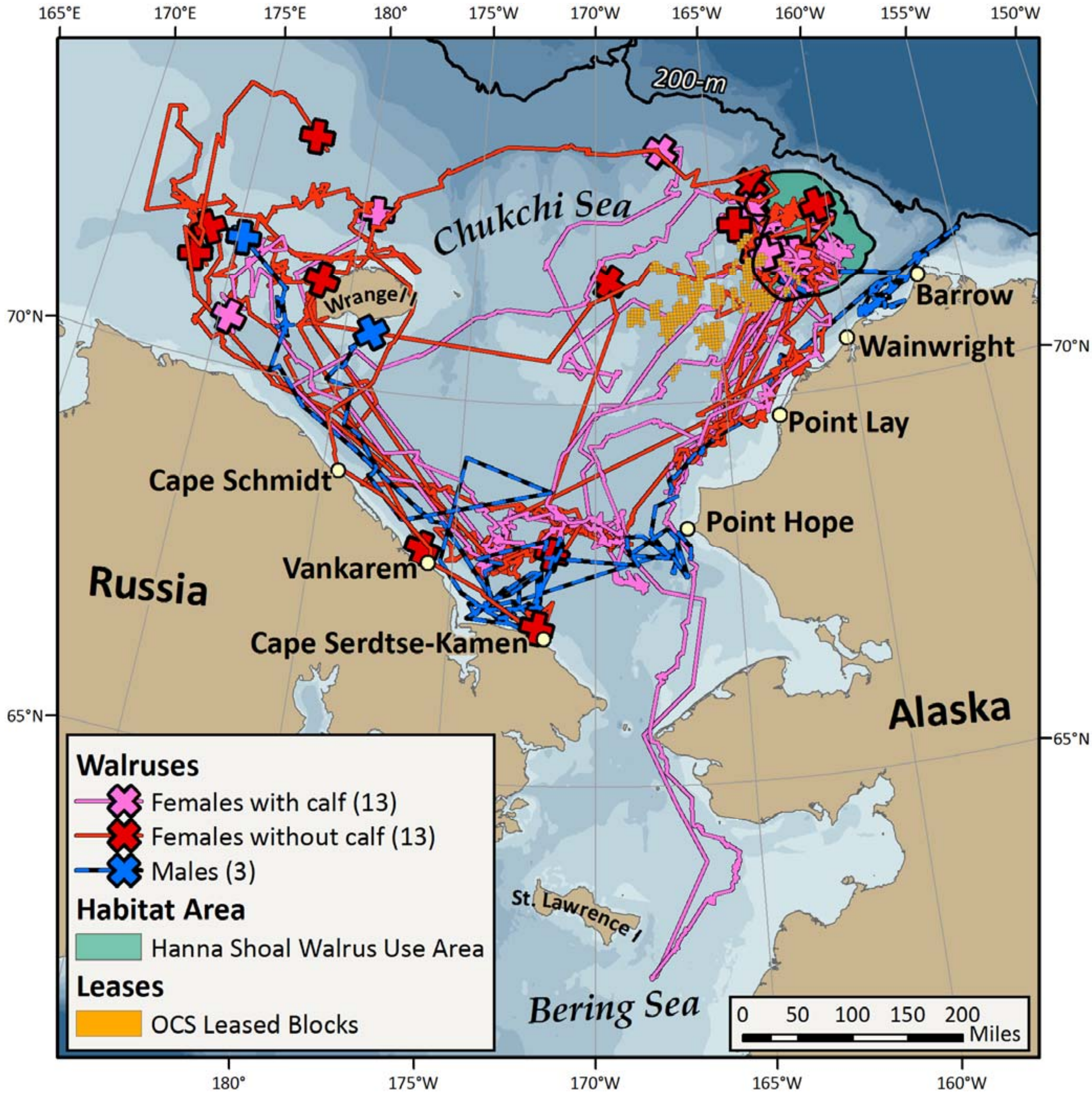

*Figure 7. Tracks of 29 tagged walruses in the Bering and Chukchi seas from June through October, 2013 relative to Outer-Continental Shelf Leased Blocks and the Hanna Shoal Walrus Use Area (Jay et al. 2012). Colored crosses are the location of the last transmission. (** OCS Leased Blocks associated with Chukchi Sea Lease Sale 193 were active during the study period; all but one lease block has been relinquished as of May 2016).*

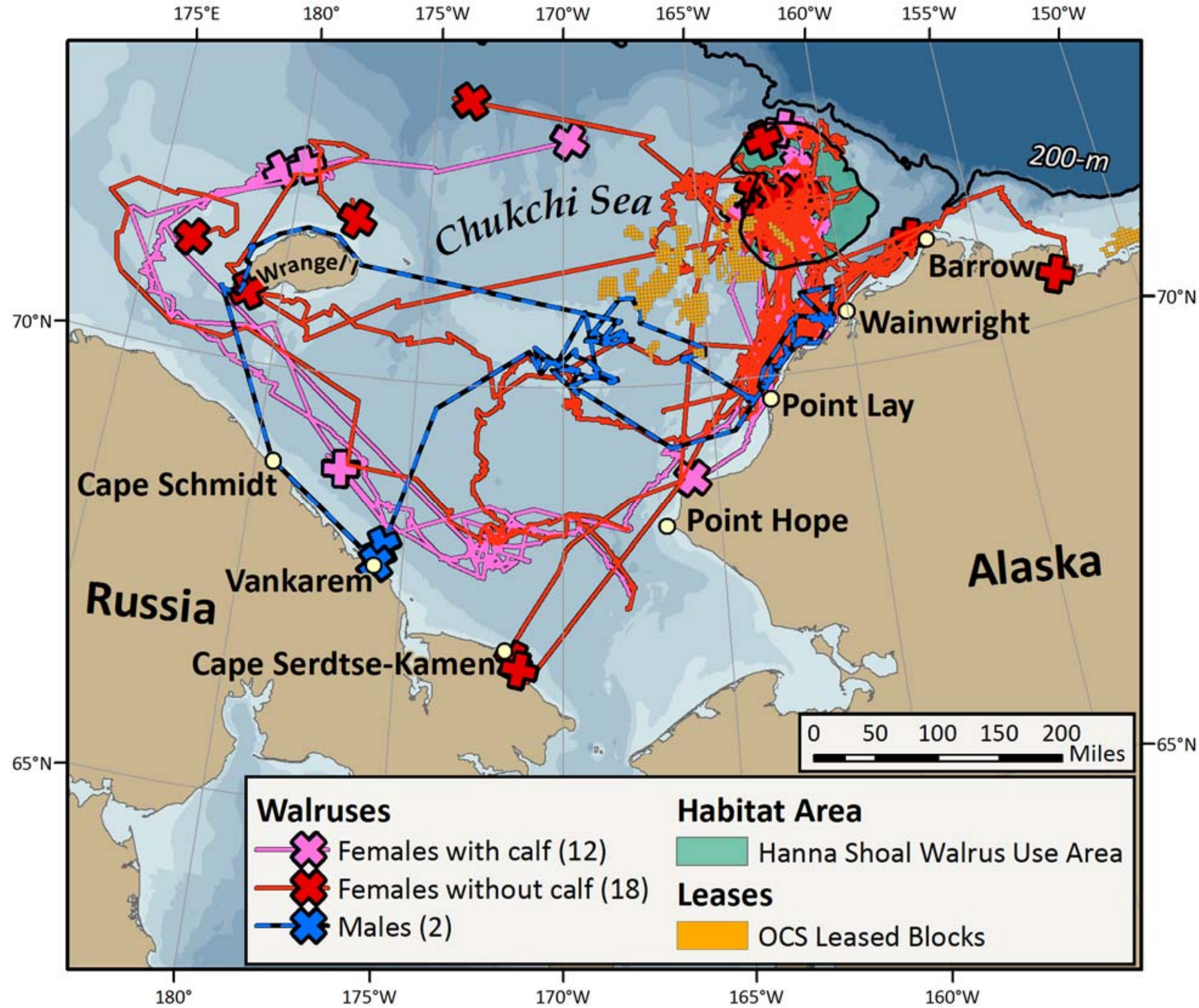

*Figure 8. Tracks of 32 tagged walruses in the Chukchi Sea from June through October, 2014 relative to Outer-Continental Shelf Leased Blocks and the Hanna Shoal Walrus Use Area (Jay et al. 2012). Colored crosses are the location of the last transmission. (** OCS Leased Blocks associated with Chukchi Sea Lease Sale 193 were active during the study period; all but one lease block has been relinquished as of May 2016).*

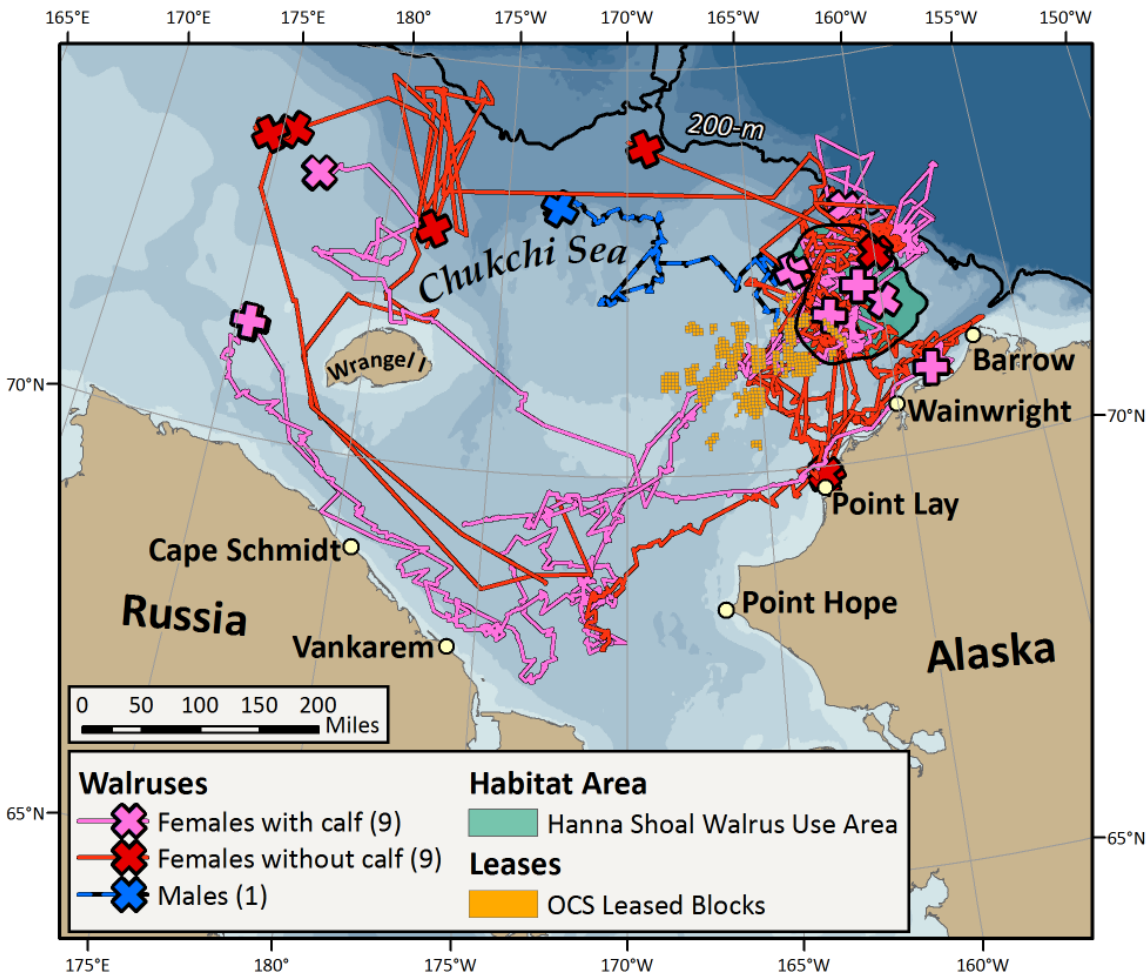

*Figure 9. Tracks of 19 tagged walruses in the Chukchi Sea from June through October, 2015 relative to Outer-Continental Shelf Leased Blocks and the Hanna Shoal Walrus Use Area (Jay et al. 2012). Colored crosses are the location of the last transmission. (** OCS Leased Blocks associated with Chukchi Sea Lease Sale 193 were active during the study period; all but one lease block has been relinquished as of May 2016).*

North Migration: Late May–June, Bering and Chukchi Seas

We tagged walruses opportunistically as they migrated from the Bering Sea, north through the Bering Strait, and into the Chukchi Sea during 2013–2015. Two walruses were tagged in the Bering Sea, both were females with calves tagged on the same day but in different groups. These two walruses migrated northward into the Chukchi Sea along similar paths through the eastern Bering Strait near Wales, Alaska. At ~100 km (62 miles) south of Point Hope, W13-01 turned west and traveled northwest along the Russian coast, while W13-02 continued northward past Point Hope toward Hanna Shoal (Fig. 7). Point Hope typically sees (and hears) walruses in May after the bowhead whaling season. Hunters say walruses make sounds like a dog with a sore throat. The spring migration includes all sexes and ages of walruses (male, female, old, and young); some migrate close to shore coming from the southeast either riding on the ice or swimming. (Appendix G-2).

Because U.S. research vessels were restricted from entering Russian waters in 2013 and 2014 and ice conditions limited travel in Russian waters when we were on board a Russian vessel in 2015, the majority of the walruses were tagged in the Alaskan Chukchi Sea (73 of the 82 (89.9%) tags that transmitted locations). Of the 73 walruses tagged in Alaskan waters, however, 32 (43.8%) spent some time in Russian waters, and of the 9 walruses tagged in Russian waters 4 (44.4%) spent some time in Alaskan waters.

During the northward migration (late-May and June), walruses spent time in three general locations; 1) southern Chukchi Sea, offshore and midway between Vankarem, Russia and Point Hope, Alaska; 2) northern Chukchi Sea nearshore between Point Lay and Wainwright (centered at Icy Cape); and 3) southern HSWUA (Fig. 10). During late-May and June, 16.2% of all daily locations were within the HSWUA. Point Lay hunters typically see walruses in May and early June traveling north on the ice, particularly during break-up when they are hunting for bearded seals (Appendix G-1). Female walruses moved an average of 49.5 km/day and were generally within 100 km of shore during the northward migration in June (Fig. 11).

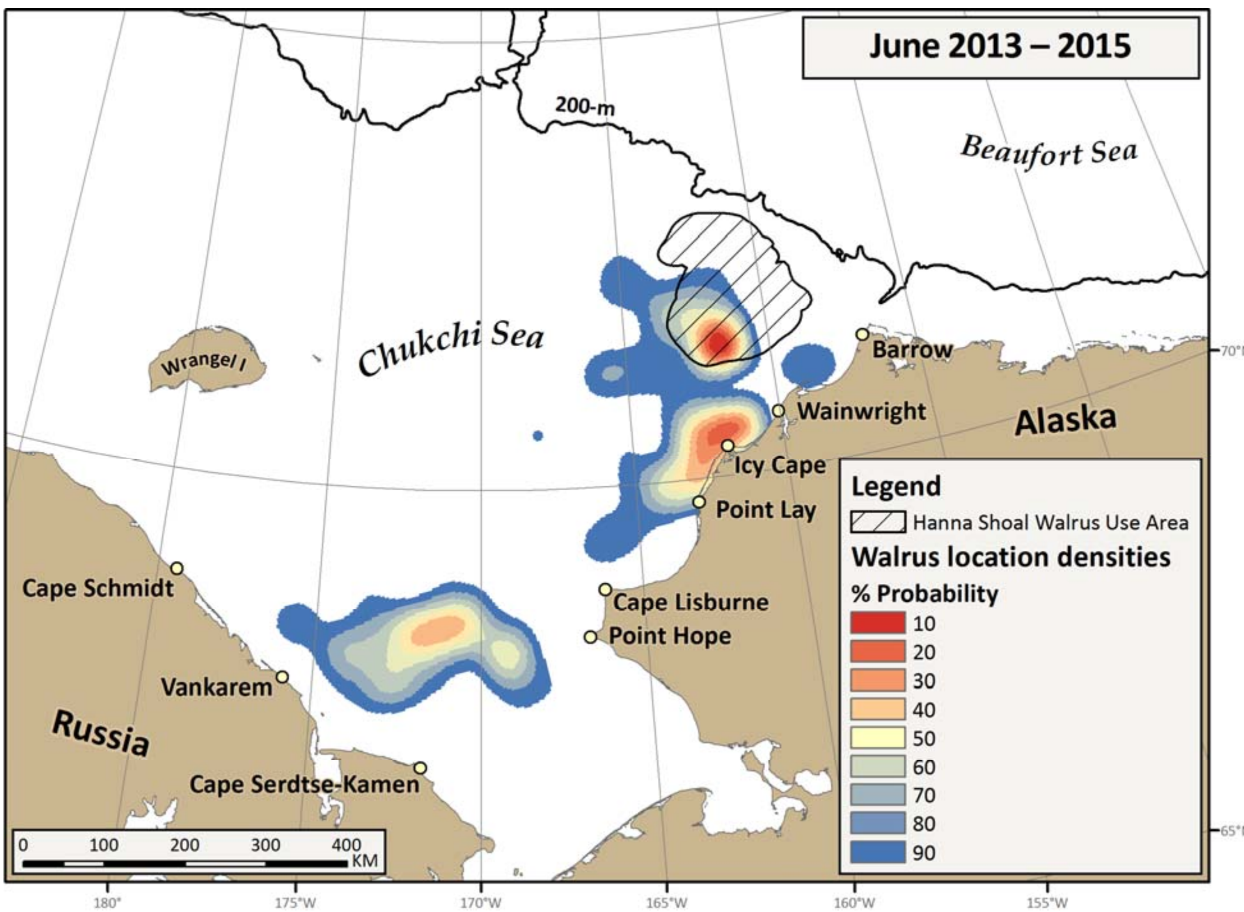

Figure 10. Contours showing probability of use (%) by tagged walruses in June using pooled location data (2013–2015; n = 82).

Summer Feeding: July–August, Chukchi Sea

In July and August, walruses generally continued to move north with the receding sea ice. Hunters from Wainwright rarely see walruses in July now that the ice breaks up earlier (in June) and does not return again, as it used to multiple times through the summer, bringing walruses close to shore (Appendix G-1). During these months, walruses were primarily located in or near the HSWUA (Figs. 11 and 12) having moved offshore from the Icy Cape area in late June. During July and August, 41.7 and 47.2% of all daily locations, respectively, were within the HSWUA and movement rates slowed to an average of 25.7 km/day. Walruses were farther offshore in August (average 138.2 km) than in July (average 119.2 km; Fig. 13), which was generally the same for females with calves, females without calves, and males (Fig. 11).

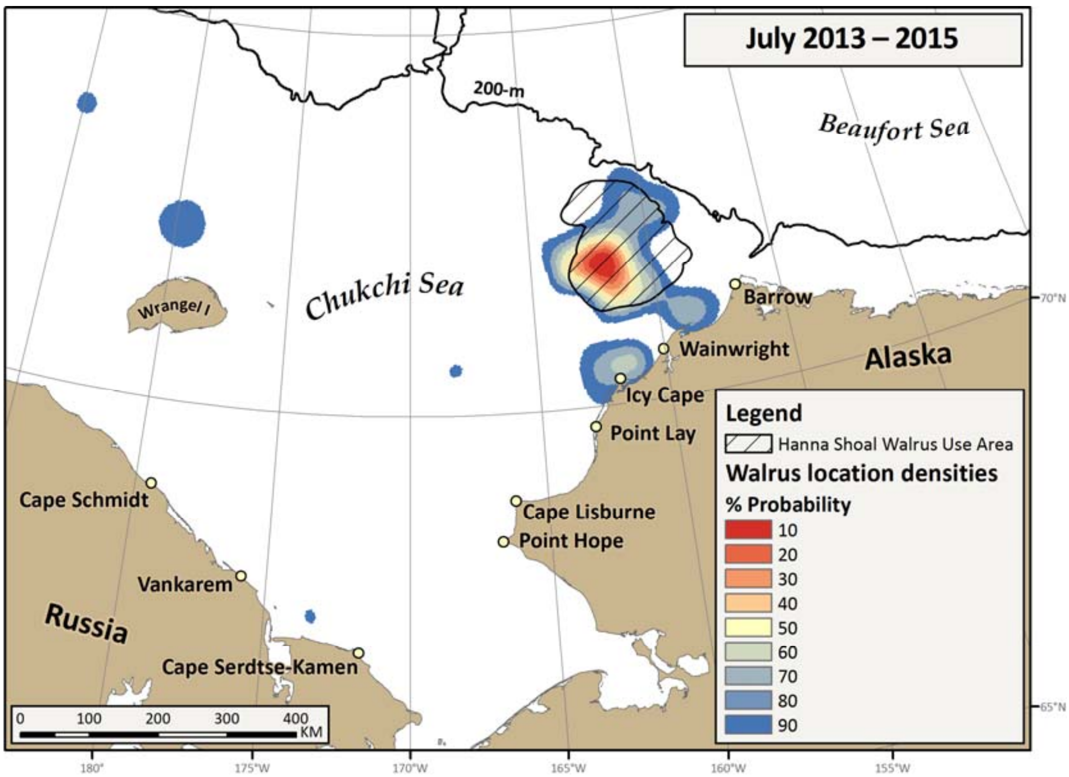

Figure 11. Contours showing probability of use (%) by tagged walruses in July using pooled location data (2013–2015; n = 74).

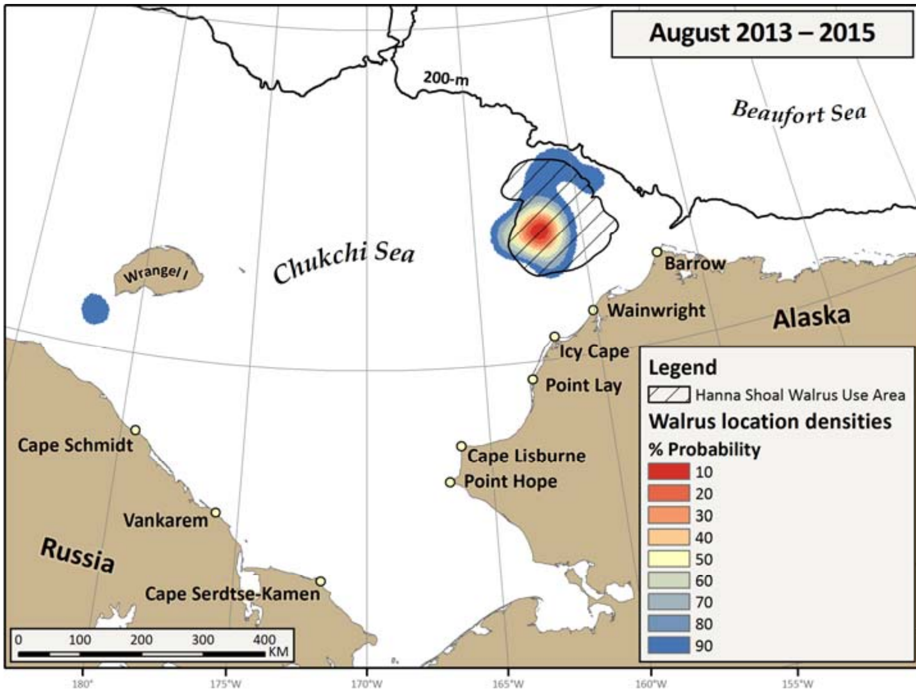

Figure 12. Contours showing probability of use (%) by tagged walruses in August using pooled location data (2013–2015; n = 40).

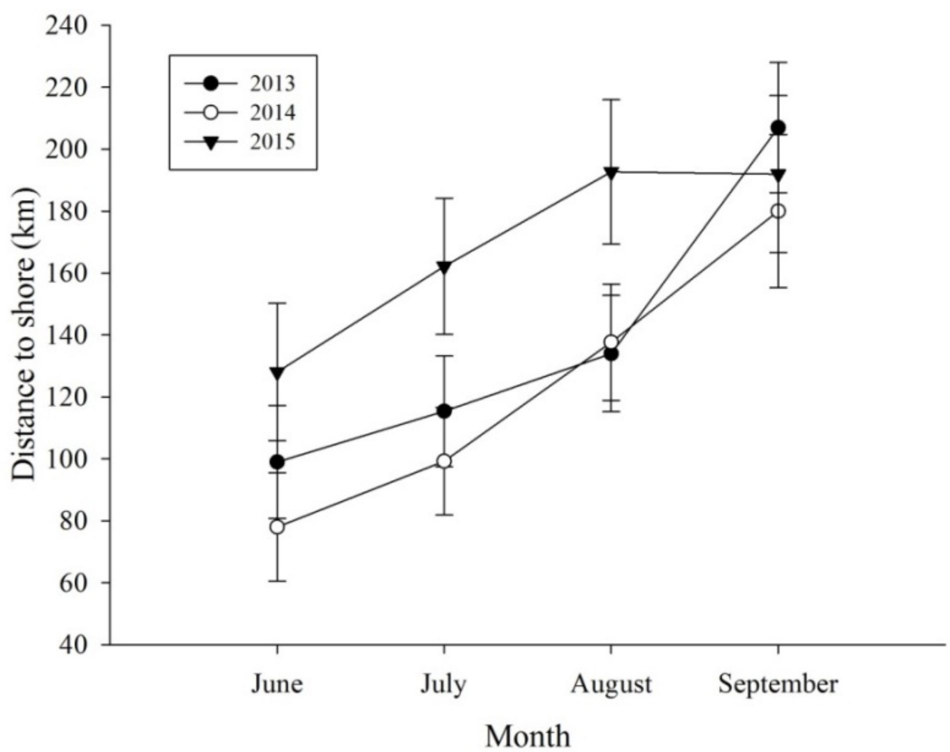

Figure 13. Average distance to shore by month for tagged adult female walruses in the Chukchi Sea, June through September of 2013–2015.

Hanna Shoal Walrus Use Area (HSWUA)

During our study, 20 of 34 (58.8%) females with calves and 26 of 40 (65.0%) females without calves spent an average of 35.2 and 31.6 days in the Hanna Shoal area, respectively (Table 5, Fig. 14). The first walrus entered the HSWUA on 18 June (average 30 June) and the last walrus left on 18 September (average 2 August). In general, walruses spent the entire month of July in the HSWUA. Distances traveled by females were lower within the HSWUA (average 25.7 km/day) than during migration (average 49.5 km/day). Within the HSWUA, the pattern of habitat use was generally the same for females with calves, females without calves, and males (although only one of six males used the HSWUA). The male that used the HSWUA (W13-26) entered on 8 August 2013 and stayed until at least 11 August, when the tag stopped transmitting. The percent of all daily locations within the HSWUA increased from mid-May and June (16.2%), peaked in July (41.7%) and August (47.2%), and decreased in September (18.4%).

Table 5. Summary of tagged walruses that entered the Hanna Shoal Walrus Use Area (HS) during 2013–2015. Average first and last days listed in the subtotal rows are average dates based on all individuals regardless of sex and reproductive category.

Year	Sex and reproductive category	# in HS	% tagged	Average first day in HS	Average last day in HS	Mean days in HS	Mean distance traveled in HS (km)	Mean rate of travel (km/day)
2013	Females with calf	9	69.2	30-Jun	29-Jul	29.1	639.5	22.0
	Females w/o calf	7	53.8	1-Jul	2-Aug	32.0	723.0	22.6
	Males	1	33.3	7-Aug	11-Aug	4.0	80.0	20.0
	Subtotal	**17**	**55.2**	**3-Jul**	**31-Jul**	**28.8**	**641.1**	**22.3**
2014	Females with calf	6	50.0	29-Jun	4-Aug	35.5	1,023.1	28.8
	Females w/o calf	12	66.7	4-Jul	2-Aug	29.1	782.8	26.9
	Males	0	0.0	-	-	-	-	-
	Subtotal	**18**	**56.3**	**3-Jul**	**3-Aug**	**31.2**	**862.9**	**27.6**
2015	Females with calf	5	55.6	22-Jun	6-Aug	45.6	1,032.4	22.6
	Females w/o calf	7	77.8	25-Jun	31-Jul	35.6	1,096.1	30.8
	Males	0	0.0	-	-	-	-	-
	Subtotal	**12**	**63.2**	**24-Jun**	**2-Aug**	**39.8**	**1,069.5**	**26.9**
Total	Females with calf	20	58.8	28-Jun	2-Aug	35.2	864.0	24.4
	Females w/o calf	26	65.0	1-Jul	2-Aug	31.6	851.1	26.9
	Males	1	16.7	7-Aug	11-Aug	4.0	80.0	20.0
	All	**47**	**58.8**	**30-Jun**	**2-Aug**	**32.5**	**839.6**	**25.7**

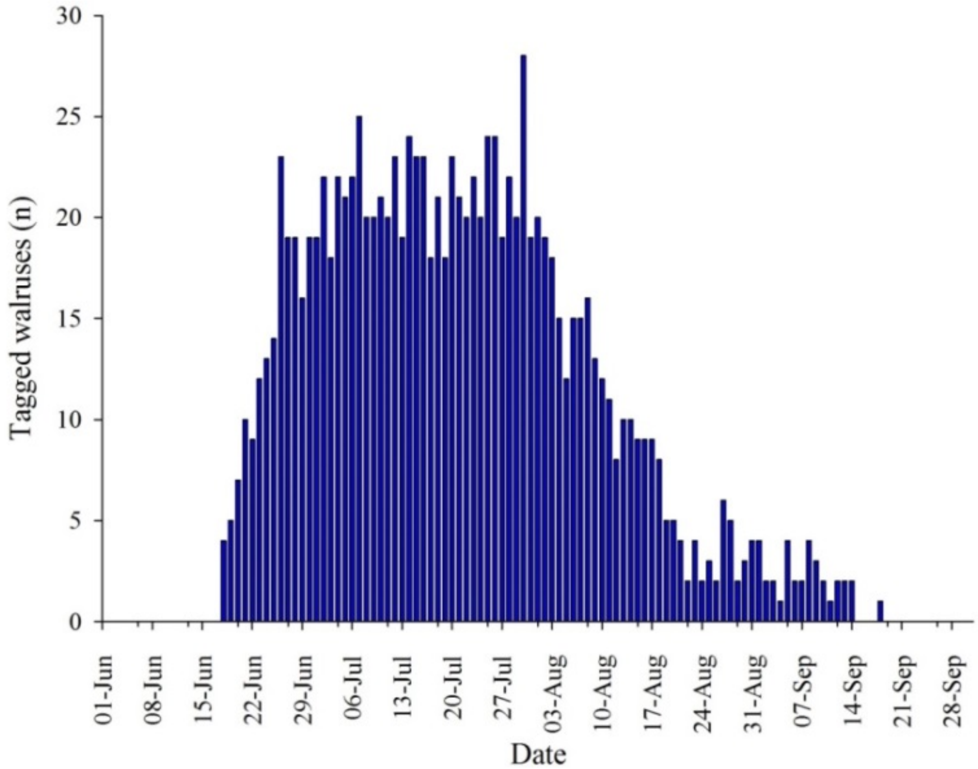

Figure 14. Number of tagged walruses that were in the Hanna Shoal Walrus Use Area (Jay et al. 2012) by day, all years combined (2013–2015).

In early August 2015, five tagged walruses were using the HSWUA when sea ice started to recede north of the continental shelf break (200 m isopleth). From 1 August through 20 September, four of these five walruses (two females without calves and two females with calves) made trips to the receding ice edge, north of the HSWUA (Fig. 15). Between 3 and 4 August, a female without a calf (W15-18) hauled out on ice ~20 km north of the shelf break (~50 km north of the HSWUA) for >24 hrs, (Fig. 15a). This same walrus also hauled out at the terrestrial haulout near Pt. Lay on 22 August (Figs. 15d and e; also see section *Use of Terrestrial Haulouts* and Fig. 18). A female with a calf (W15-23) hauled out on ice at the shelf break and ~30–100 km north of it on seven occasions: between 3 and 4 August (>29 hrs; Fig. 15a), between 6 and 7 August (>24 hrs), on 10 August (12 hrs; Fig. 15b), between 16 and 17 August (>24 hrs; Figs. 15b and c), on 18 August (9 hrs; Fig. 15c), on 20 August (7 hrs), and between 30 and 31 August (>18 hrs; 15e). Another female with a calf (W15-21) hauled out on ice ~45–100 km north of the shelf break on four occasions: between 21 and 22 August (>20 hrs; Figs. 15c and d), on 23 August (4 hrs; Fig. 15d), between 31 August and 1 September (>42 hrs; Fig. 15e) and between 15 and 16 September (>24 hrs; Fig. 15f). The second female without a calf (W15-26), hauled out on ice ~20 km north of the shelf break (~100 km north of HSWUA) between 15 and 16 August (>24 hrs; Fig. 15c) before moving west to an area north of Wrangel Island, Russia.

Although sea ice data derived from the Advanced Microwave Scanning Radiometer (AMSR2) depicted in the panels in Figure 15 show ice concentrations between 5 and 100%, AMSR2 ice data do not detect ice concentrations <15% accurately. Therefore, although the tracks of walruses appear to be in open water near the ice edge they apparently had access to ice in concentrations <15% that supported hauling out. Also, sea ice data depicted on the maps in Figure 15 are for the day that represents the mid-point for each time period (e.g., sea ice data for 4 August 2015 was used for mapping walrus tracks during 1–7 August 2015); therefore, the sea ice data may not represent the particular day when the walruses used the ice to haul out.

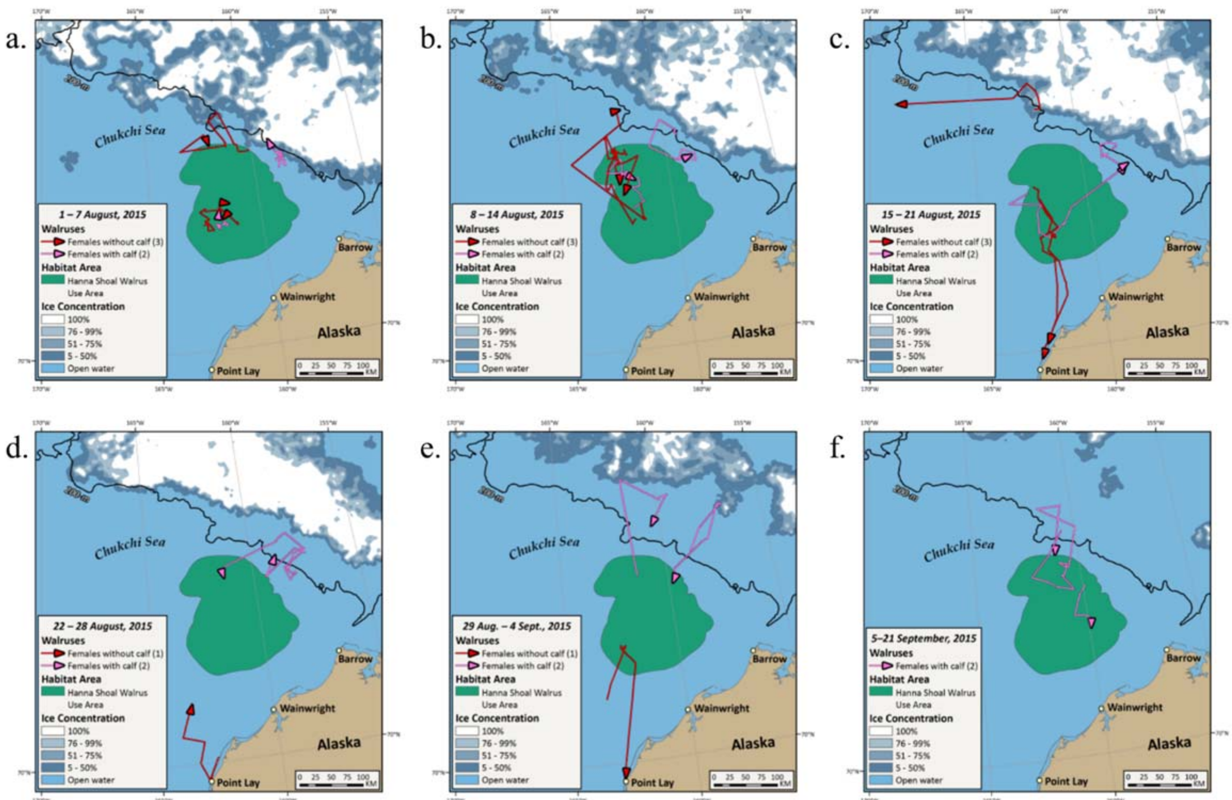

Figure 15. Tracks of five tagged walruses that traveled to and from the HSWUA and used sea ice north the continental shelf break (200 m isopleth) for resting during 1 August to 21 September 2015. One walrus used the ice north of the shelf break and the terrestrial haulout near Point Lay. AMSR2 sea ice data do not detect ice concentrations <15% accurately. Therefore, although walruses appear to be in open water when near the ice edge ice concentrations of <15% may have been present. Data from the tags were used to indicate when and where resting bouts occurred on top of ice. Figures 15a–e represent tracks during one week intervals and Figure 15f represents tracks during a two week interval.

Southern Migration: Fall (September–October) Chukchi Sea

During September, walruses were primarily located in the north central and northeastern Chukchi Sea near the shelf break, in the HSWUA, and at coastal haulouts near Point Lay and Cape Lisburne, Alaska (Fig. 16). Tagged walruses began to move south in September, leaving the HSWUA and the central Chukchi Sea prior to the formation of sea ice. This southern migration generally started 1–2 weeks before the ice edge advanced north of the continental shelf (200 m isobath). During September, walruses were on average 171.1 km offshore (Fig. 11) and by October, were primarily located north of Wrangel Island and along the Russian coastline (Fig. 17). Walruses that used the HSWUA migrated south by one of three routes: 1) directly south toward Point Lay (n = 3), 2) directly south toward Cape Lisburne (n = 3), and 3) west toward Wrangel Island and then south (n = 4). Walruses near Wrangel Island migrated south by traveling along the north coast of Russia (n = 4). The one walrus that left Point Lay (W14-29) traveled toward Cape Lisburne. The two walruses that left Cape Lisburne (W10-01 and W14-29) crossed the Chukchi Sea to the haulout at Cape Serdtse-Kamen, Russia. This pattern of movement was generally the same for females with calves, females without calves, and males. We did not receive locations often enough in October to estimate a movement rate for that month, however for the months after moving away from the HSWUA, walruses averaged 55.1 km/day, which did not differ among reproductive categories or sexes (P = 0.57). We received locations for only one male (W13-19) during September; he was west of Wrangel Island until at least 9 September, when the tag stopped transmitting.

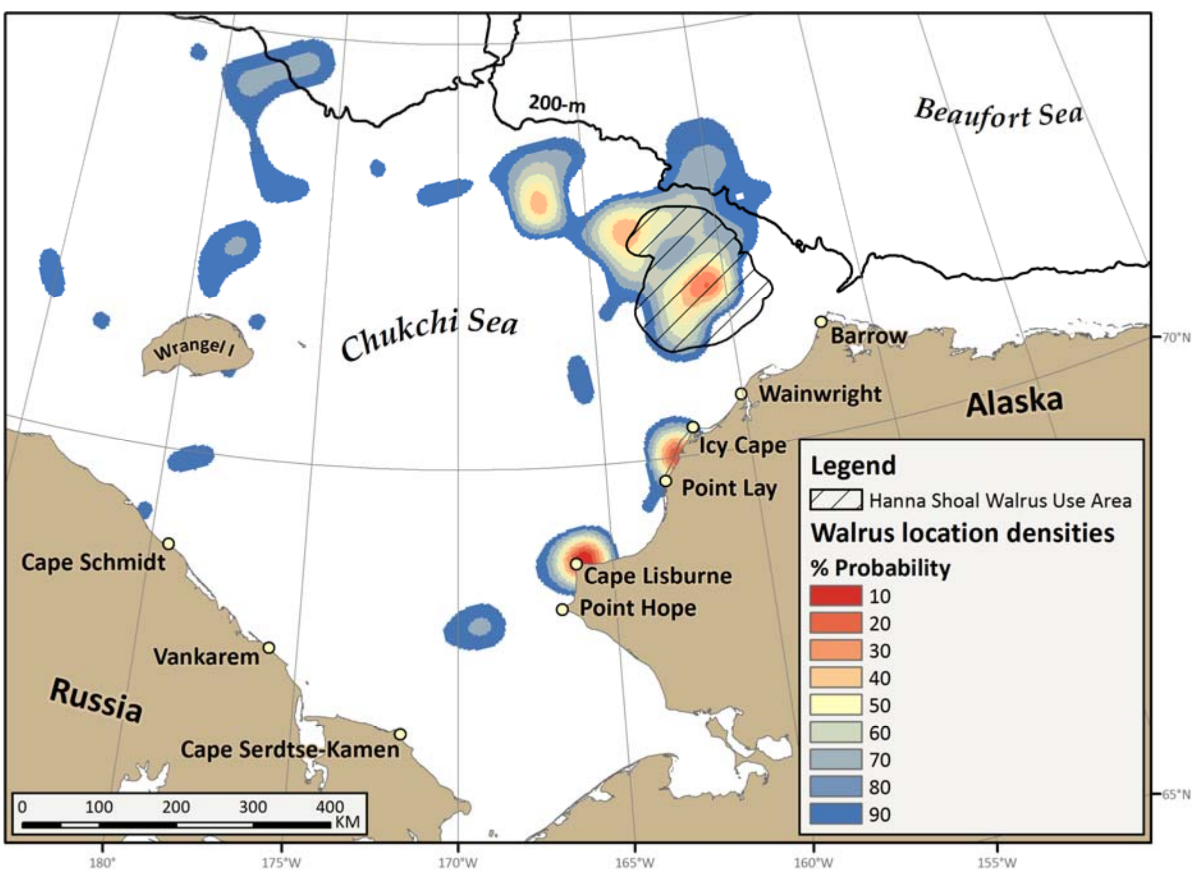

Figure 16. Contours showing probability of use (%) by tagged walruses in September using pooled location data (2013–2015; n = 15).

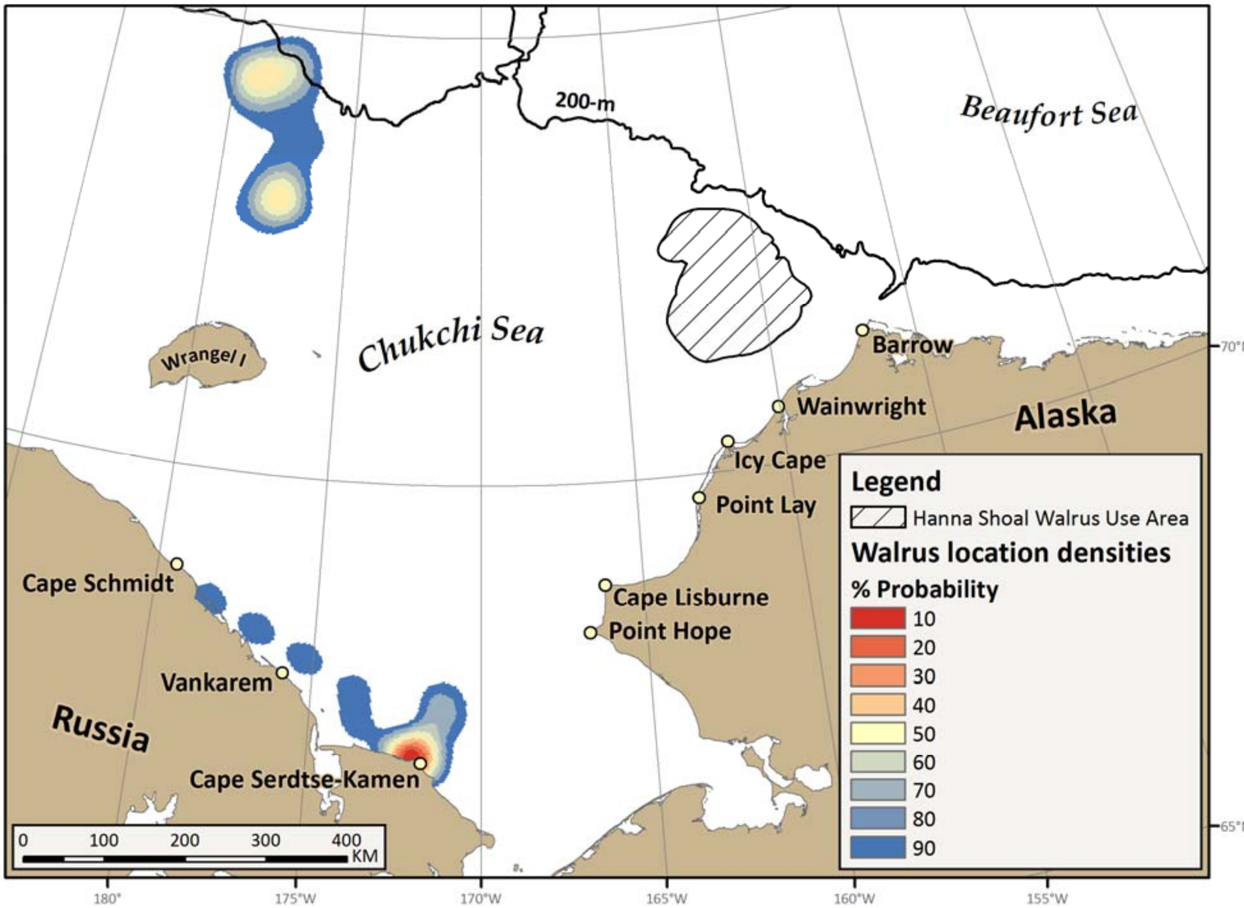

Figure 17. Contours showing probability of use (%) by tagged walruses in October using pooled location data (2013–2015; n = 5).

Use of Terrestrial Haulouts.
Terrestrial haulouts formed in Alaska or Russia in late summer in all years in which we tagged walruses (2010, 2013, 2014, and 2015). In five of the seven years of our study, walruses formed large terrestrial haulouts (1,500–35,000 walruses) near Point Lay, Alaska. Large terrestrial haulouts (2,000–>100,000 walruses) also occurred near Cape Serdtse-Kamen, Russia every year. Despite the large numbers of walruses observed at these haulouts, only 8 of 28 (29%) walruses with tags that were active when the haulouts formed hauled out on land (Table 6).

Walruses regularly haul out on shore in small numbers and hunters reported this activity in Norton Sound, near Point Hope, Point Lay, Wainwright, and Barrow (Appendices G-1–G-5). Walruses sometimes haulout in small numbers between Cape Thompson and Cape Lisburne, but regularly haul out by the dozens near Cape Lisburne. However, fewer walruses have hauled out near Cape Lisburne recently, possibly because barges sometimes wait there for better ice or weather conditions (Appendix G-2). In the past, typically a few walruses were seen at various locations on the islands in Kasegalek Lagoon. Large numbers were seen on shore between Point Lay and Wainwright in the 1950s, but much larger numbers began hauling out on the Alaskan coast in 2007 (Appendix G-1).

Large terrestrial haulouts have regularly occurred on Russian Islands and coasts for decades (e.g., Tomilin and Kibal'chich 1975), however even larger numbers have been reported during the 2000s. For example, Cape Serdtse-Kamen was documented as a terrestrial haulout as early as 1927 (Arsen'ev 1927), again in 1937 (Nikulin 1941), and during all of the aerial survey years; 1960, 1964, 1975, 1980, 1985, and 1990 (Fedoseev 1966, Gol'tsev 1968, Fedoseev 1981, Estes and Gol'tsev 1984, Fedoseev and Razlivalov 1986, Gilbert *et al.* 1992). Although numbers on haulouts have also been large in the past (9,000 to 12,000 in 1975 and >12,000 in 1990) they were much larger in 2009 (97,000) and 2011 (115,000) (Kochnev, unpubl. data).

During 2010, one of one tagged walruses hauled out at Cape Serdtse-Kamen in October (Table 6). In early September 2013, one of six tagged walruses hauled out at Vankarem on the Russian coast. In mid-September, none of the three walruses with active tags hauled out near Point Lay. From 27 September to 9 October, one of two walruses with active tags, W13-30, moved southwest along the Russian coast, hauling out at Cape Schmidt, Vankarem, and Cape Serdtse-Kamen over the course of 13 days. During 2014, only two of five tagged walruses hauled out at terrestrial haulouts. During August, one of five walruses with active tags hauled out at Russian haulouts, including the southeastern shore of Wrangel Island (18–22 August) and Cape Schmidt (29–30 August) (Table 6). In September, one of two hauled out near Cape Lisburne, Alaska, and none hauled out near Point Lay. Also in 2014, two walruses approached terrestrial haulouts, W14-31 near Point Lay and W14-33 near Cape Lisburne, but stayed in the water and did not haul out.

During 2015, two of four tagged female walruses hauled out near the Point Lay haulout (Table 6, Fig. 18). Both of these walruses left the HSWUA and followed relatively direct paths for ~180 km to the Point Lay haulout; W15-18 took three days traveling at 60.5 km/day while W15-25 took six days traveling at 29.2 km/day. W15-25 first arrived at the Point Lay haulout on 24 August and spent 1.5 days there. This walrus then left Point Lay, traveling for 4.4 days at 55.2 km/day, to return to the HSWUA where she spent four days before leaving on 3 September to return to the Point Lay haulout on 4 September, traveling for 1.7 days at 99.4 km/day. W15-25 then stayed on land for at least three days before we received the tag’s last signal on 6 September. During our study, two of seven walruses (29%), whose tags were still transmitting when terrestrial haulouts formed near Point Lay, hauled out there; both in 2015.

Table 6. Tagged walruses that hauled out at terrestrial haulouts during 2010 and 2013–2015.

Year	**Dates**	**Location**	**# Walruses hauled out (%)**[a]	**Walrus IDs**	**# Walruses transmitting**[b]
2010	4–8* Oct	Cape Serdtse-Kamen, Russia	1 (100%)	W10-01	1
2013	4–8 Sept	Cape Vankarem, Russia	1 (17%)	W13-07	6
	12–27 Sept	Point Lay, Alaska	0 (0%)	-	3
	27 Sept–1 Oct	Cape Schmidt, Russia	1 (50%)	W13-30	2
	4–5 Oct	Vankarem, Russia	1 (50%)	W13-30	2
	8–9* Oct	Serdtse-Kamen, Russia	1 (50%)	W13-30	2
2014	18–22 Aug	SE Wrangel Island, Russia	1 (20%)	W14-28	5
	29–30 Aug	Cape Schmidt, Russia	1 (33%)	W14-28	3
	5 Sept	Cape Lisburne, Alaska	1 (50%)	W14-31	2
	25 Sept–5 Oct	Point Lay, Alaska	0 (0%)	-	1
2015	22–24* Aug	Point Lay, Alaska	2 (50%)	W15-18	4
	24–25 Aug			W15-25	4
	4–6* Sept	Point Lay, Alaska	1 (33%)	W15-25	3
	1–4* Oct	Cape Serdtse-Kamen, Russia	1 (100%)	W14-29	1
Total			**8[c] (29%)**		**28[d]**

* Last date located at haulout was the last day we received a location from the tag.
[a] Percentage of walruses hauled out from the total number of walruses whose tags were still transmitting when the haulout formed
[b] Number of walruses whose tags were still transmitting when the haulout formed.
[c] Total number of unique walruses that hauled out at terrestrial haulouts.
[d] Total number of unique walruses whose tags were transmitting when haulouts formed.

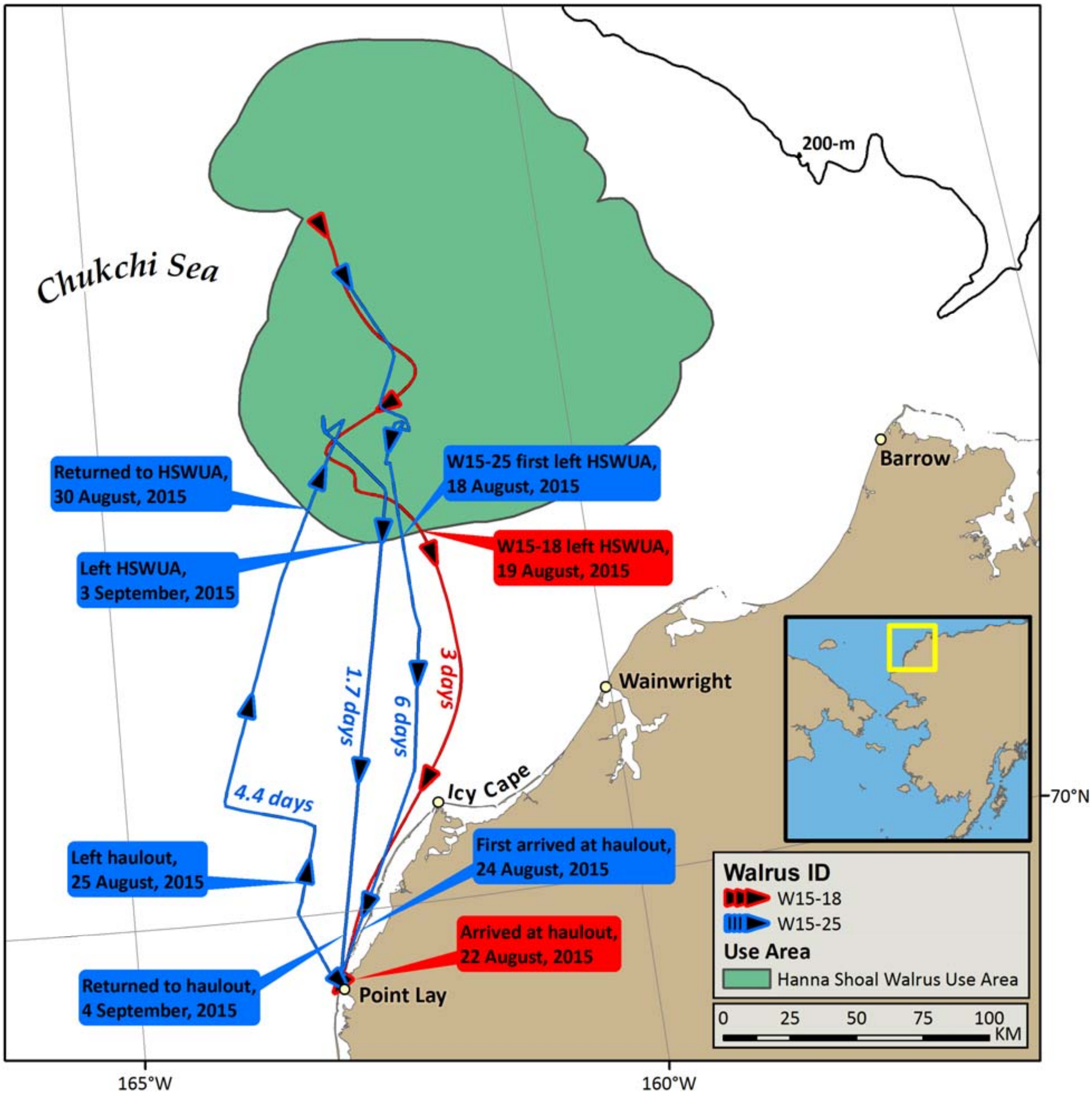

Figure 18. Tracks of two walruses tagged in the Chukchi Sea that hauled out at the terrestrial haulout near Point Lay, Alaska, between 14 August and 6 September, 2015. The number of transit days between the HSWUA and the haulout near Point Lay are listed next to each walrus track. Walrus W15-25 made two trips to the haulout.

Movement Analyses

During the northward migration in June, female walruses traveled farther per day (49.5 km/day) than walruses using the HSWUA in July and August (25.7 km/day; $P < 0.01$) and farther than walruses that did not enter the HSWUA in July and August (46.5 km/day; $P = 0.03$). During July and August, walruses outside the HSWUA traveled farther per day than walruses inside the HSWUA ($P < 0.01$). Movement rates did not differ between females with calves and females without calves ($P = 0.39$). Males on northward migration traveled twice as far per day (45.4 km) as the one male that used the HSWUA (20 km/day), but our sample size of male locations was too small to quantify statistical significance.

Movement rates of females during the southern migration (55.1 km/day) did not differ from rates during the northern migration (49.5 km/day; $P = 0.96$). Migration movement rates, however, were higher than rates in July and August, regardless of whether walruses had entered the HSWUA ($P < 0.01$).

During late-May and June, walruses generally were closer (within 100 km) to shore than during July to September (Fig. 13). Distance to shore was best explained by a model that only included month ($P < 0.01$) and was not different by reproductive or sex category ($P = 0.57$).

Prior to this study, no male walruses had been tagged in the Chukchi Sea. Large, male only terrestrial haulouts occur in the Bering Sea in summer and males are seen and harvested in the Chukchi Sea in summer, but male movement behavior in the Chukchi Sea in summer is not well understood. Although many males spend the summer in the Bering Sea using terrestrial haulouts along the Russia coast and in Bristol Bay, Alaska, hunters in the Bering and Chukchi seas see adult male walruses migrating north in the spring (Appendix G-2 and G-5). Point Hope hunters see fewer males and fewer walruses overall passing by, possibly due to noise from ships, smells from engines, or changes in sea ice. Ships traveling north and south in Alaskan Chukchi Sea pass closer to Point Hope than other villages along the coast because Point Hope is located at the end of Lisburne Peninsula. Therefore, if walruses are currently following ice breakers north in the spring they may pass Point Hope farther from shore than they did in the past (Appendix G-2). In September and October most walruses migrating from the north near Point Hope are older males. Overall, fewer walruses are seen in fall than in spring. In the past, most of the walruses that hauled out on land near Point Hope were males (Appendix G-2).

We tagged six males in the Chukchi Sea in June; during July and August, three stayed in the central Chukchi and three moved north; one along the Alaskan and two along the Russian coast. Two males had active tags in late August 2013; one was in the HSWUA and the other was between Wrangel Island and the northern Russian coast. By late-August 2014, two male walruses moved south from Wrangel Island to the Russian coast and hauled out on land near Cape Schmidt.

Walruses tagged in previous telemetry studies in the Chukchi Sea had not traveled east of Barrow (Anthony Fischbach, USGS, personal communication; Jay et al. 2012, Fig 2). Barrow hunters say walrus hunting occurs in the Chukchi Sea but not in the Beaufort Sea. Hunters travel west or south then west from Barrow (Appendix G-3). Only occasionally are walruses seen in the Beaufort Sea, east of Point Barrow. However, a female without a calf (W14-17) that was tagged in the Chukchi Sea in June 2014 moved north and east of Barrow, Alaska into the Beaufort Sea on 14 July 2014. On 23 July, this walrus moved into Kogru River Inlet, roughly 180 km east of Barrow. Based on the dive and haulout data collected from the Kogru River Inlet, this walrus continued to dive in the inlet and haul out on land until its last transmission on 10 August.

Walrus Presence and Timing within Program Areas

Most walruses tagged during 2013–2015 (77 of 80, 96%) entered at least one of the active or proposed program areas in the Chukchi Sea (Fig. 19), 56 of 80 (70%) entered the general Lease Area 193 in the U.S. and 43 of 80 (54%) entered leased blocks within the larger Lease Area 193. We documented the timing of use of these active and proposed program areas and show the days for which tagged walruses were present in active (Fig. 20) and proposed program areas (Fig. 21). Because we combined all years and not all tags transmitted locations for the same length of time, the histograms show the general use period and the peak of use, but do not show residence time for individuals. Hence, reporting the range of days that walruses were present within a program area is more informative than the actual number of walruses, which would be an underestimate.

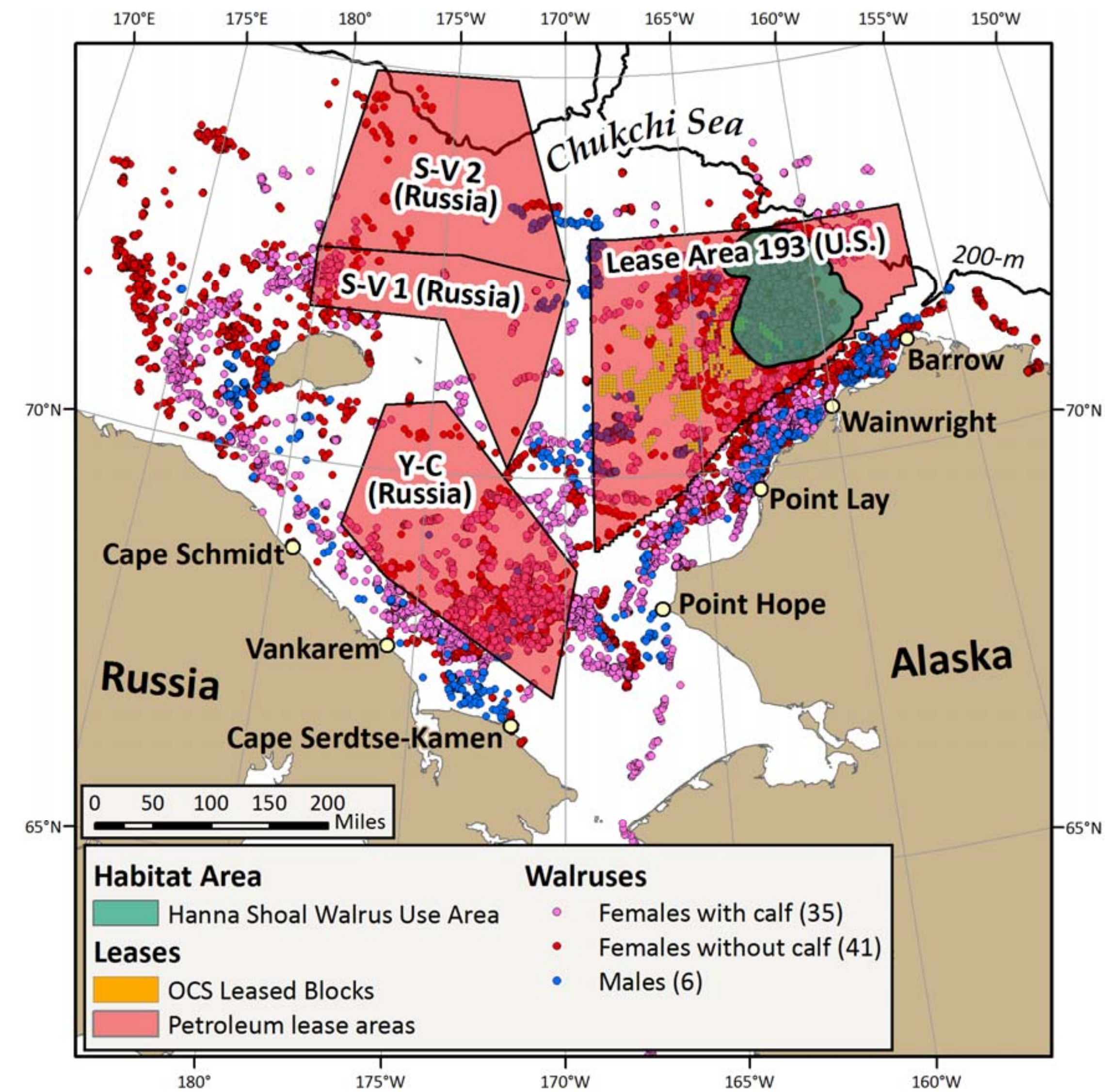

*Figure 19. Locations of 82 tagged walruses in the Chukchi Sea from June through October 2010–2015 relative to active and proposed program areas: Yuzhno-Chukotsky (YC) and Severo-Vrangelevskiy (SV) areas 1 and 2. (** OCS Leased Blocks associated with Chukchi Sea Lease Sale 193 were active during the study period; all but one lease block has been relinquished as of May 2016).*

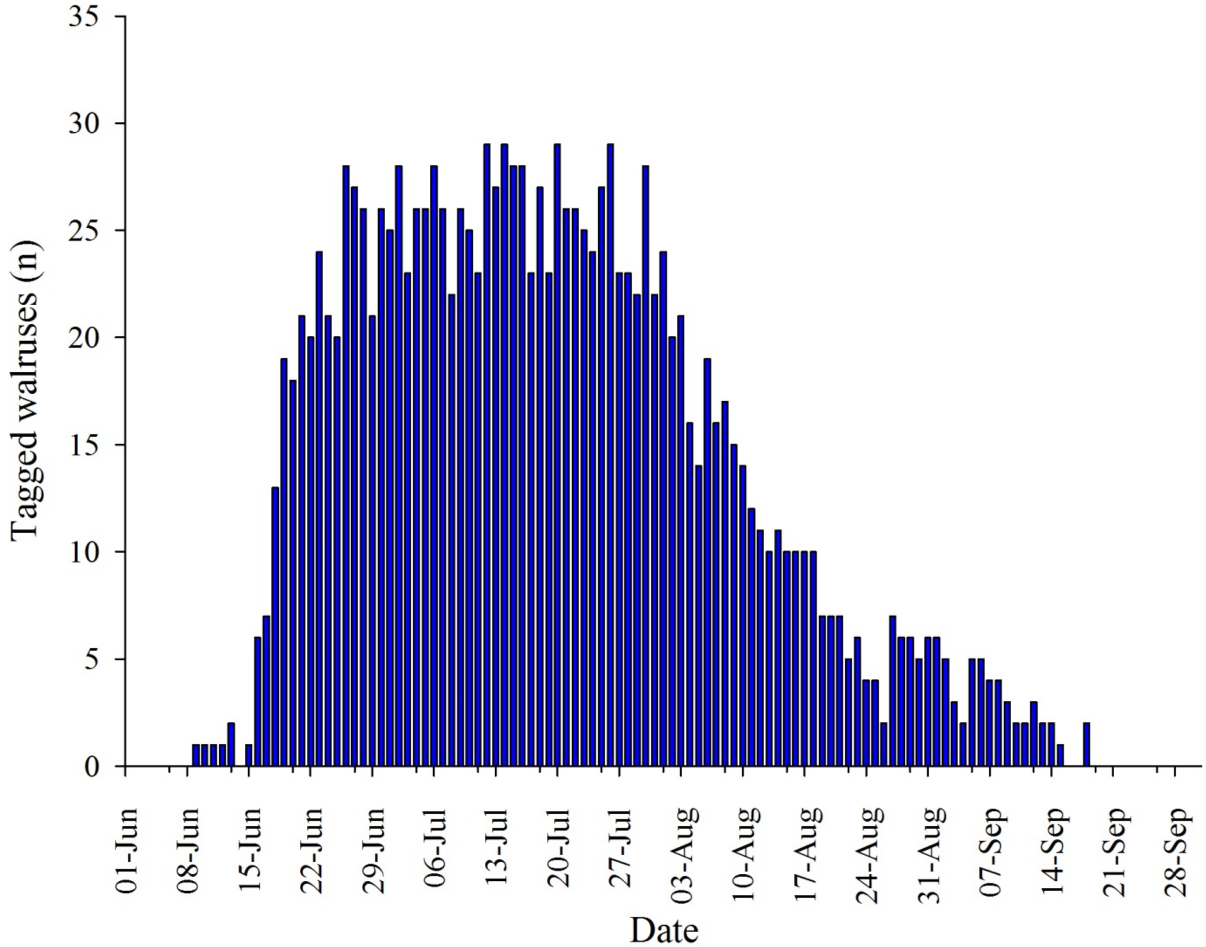

Figure 20. Number of tagged walruses that were in the Lease Area 193 program area in Alaskan waters by day, all years combined (2013–2015).

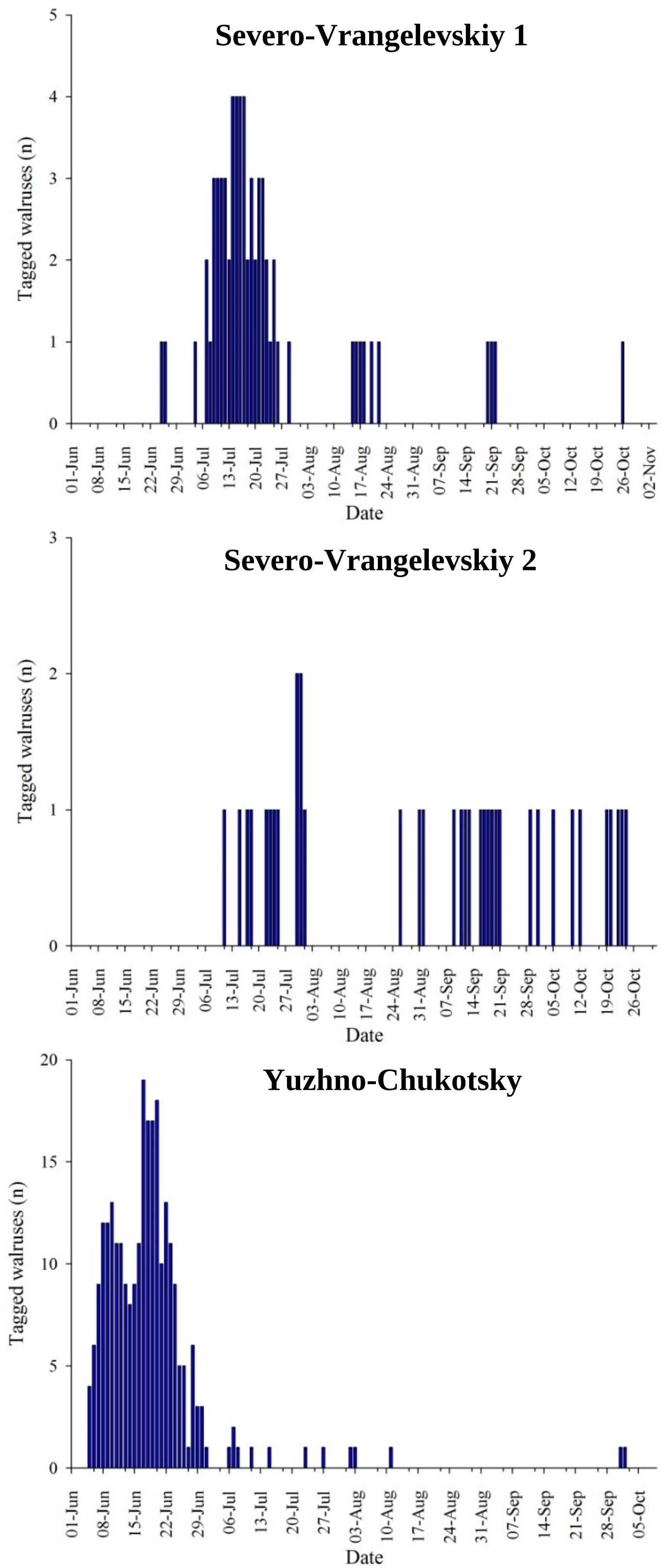

Figure 21. Number of tagged walruses that were in proposed program areas in Russian waters by day, all years combined (2013–2015).

Chukchi Sea Lease Area 193. From 2013 to 2015, 56 of 80 (70%) tagged walruses entered Chukchi Sea Lease Sale Area 193 and the leased blocks. We did not include the two walruses tagged in 2010 in this summary because they had likely migrated south of Area 193 prior to being tagged at Cape Lisburne in late September. For walruses migrating north in the Alaskan Chukchi Sea, the spring migration followed the coast and some walruses entered the Area 193 and the leased blocks as they followed the receding ice north. However, the majority of walruses that entered Area 193, and the leased blocks, did so when they moved into the HSWUA, which is wholly contained within the boundaries of Area 193 (Fig. 19). Walruses were located within Area 193 between 9 June and 18 September, however >50% of the walruses that entered Area 193 were present between 19 June and 8 August (Fig. 20). On average, tagged walruses were located within Area 193 for 35 days (range = 1–93 days, n = 56 walruses).

Residence patterns within the leased blocks were similar to those within the larger Area 193 (Fig. 19), except that the leased blocks represent a small area, thus fewer walruses were located within the block boundaries (43 of 80, 54%) and those that were in the leased blocks were there for a shorter period of time (17 June–10 September). On average, tagged walruses were located within the leased blocks for 18 days (range = 1–71 days, n = 43 walruses), however, because the leased blocks are relatively small areas, residence time in the overall lease area is likely more representative of when walruses might be found within leased blocks than the data from leased blocks alone.

Program Areas in Russia. Although most walruses (73 of the 82 (89.9%)) were tagged on the U.S. side of the international dateline, they used U.S. and Russian waters. Specifically, 43 of 82 (52%) spent some time in Russian waters and 33 of 82 (40%) entered the Yuzhno-Chukotsky (YC) Area. Use of the YC, however, is expected because of its location in the southern Chukchi Sea, just north of Bering Strait, and walruses migrating north generally travel through this area during June (Figs. 10 and 21) before following either the Alaskan or Russian coast to continue their northward migration. Similarly, walruses will also travel through this area during their southern migration. Tagged walruses were located within the YC Area between 5 June and 2 October (Fig. 21). On average, tagged walruses were present within the YC Area for 11 days (range = 1–34 days, n = 33 walruses). Fewer walruses entered the Severo-Vrangelevskiy (SV) 1 and 2 Areas, located in the central Chukchi Sea, east and north of Wrangel Island where fewer tagged walruses were located overall (Figs. 10, 11, 12, 16, 17, 19). During this study, only 14 (18%) and 6 (7.5%) tagged walruses entered the SV Areas 1 and 2, respectively. Walruses transmitted within the SV 1 Area between 25 June and 26 October (Fig. 21). On average, tagged walruses were present within the SV 1 Area for 8 days (range = 1–29 days, n = 14 walruses). Walruses transmitted within the SV 2 Area between 11 July and 24 October (Fig. 21). On average, tagged walruses were present within the SV 2 Area for 17 days (range = 1–59 days, n = 6 walruses).

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 walrus communication, navigation, and movements. Walruses have good hearing and are sensitive to noise, especially when they are on land (Appendix G-1). Noise or noise in combination with movement is known to cause disturbance related stampedes on terrestrial haulouts (Tomilin and Kibal'chich 1975, Ovsyanikov *et al.* 1994).

Although tagged walruses were located within an active program area during summer and fall of 2013–2015, we found only one 2D operation in 2013 that overlapped in space and time with walrus locations. Although we have made contact with the company that performed the operation we have not been successful in acquiring the information need to overlay walrus locations with the seismic operation to conduct an analysis of walrus behavior before, after, and during the survey.

Haulout and dive behavior
Using the 90% probability density estimates of the estimated haulout and dive locations, we identified two potentially important foraging areas within the Alaskan Chukchi Sea in summer (June–September). One area overlapped the HSWUA and the other was offshore of Icy Cape, between Point Lay and Wainwright, Alaska (Fig. 22). Walruses began using these two areas around 26 June in all years. For this analysis we did not include any dive or haulout behavior of walruses using terrestrial haulouts (n = 2).

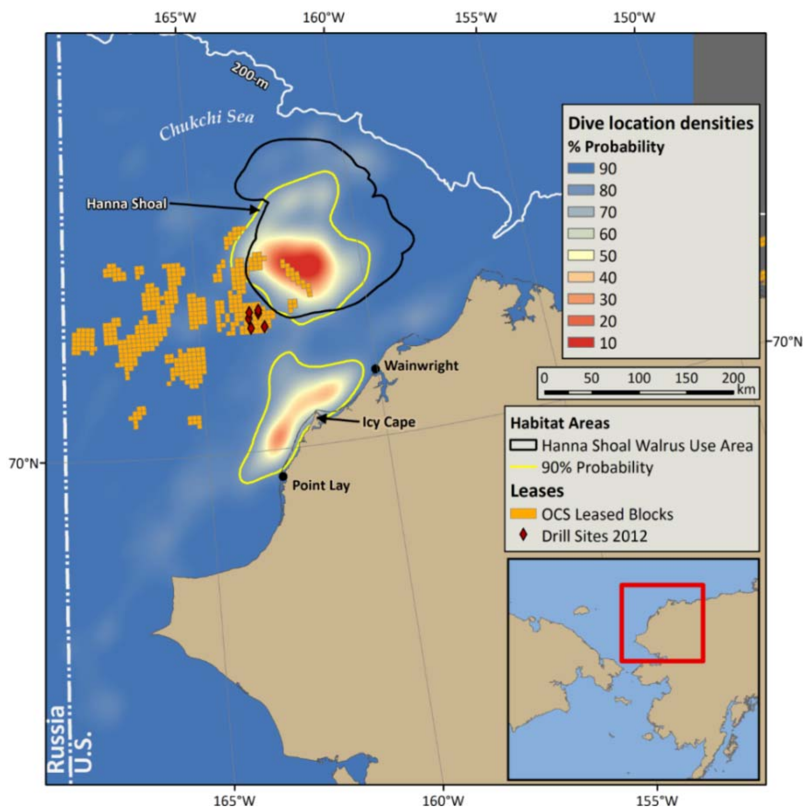

*Figure 22. Densities of dive locations of tagged female walruses using ice as a haulout platform from June–September during 2013–2015 (n = 82). Yellow polygons in Hanna Shoal and near Icy Cape contain areas with >90% probability of diving locations and thus were considered potentially important foraging areas. (** OCS Leased Blocks associated with Chukchi Sea Lease Sale 193 were active during the study period; all but one lease block has been relinquished as of May 2016).*

The model that best approximated the proportion of time hauled out (i.e., haulout percentage) included area of use, reproductive category, and time of day (Area × Reproductive Category + Time) (Figs. 23 and 24). For all females, haulout percentage was, on average, 10% higher in Hanna Shoal than in Icy Cape after controlling for reproductive category and time of day ($P < 0.01$; Fig. 25). Specifically, haulout percentages of females with calves in Hanna Shoal was higher than females with calves in Icy Cape and the rest of the Chukchi Sea and higher than all females without calves in all areas ($P < 0.01$). Within Hanna Shoal and Icy Cape, haulout percentage was, on average, 4.4% higher for females with calves than females without calves ($P < 0.01$). However, in the rest of the Alaskan Chukchi Sea, haulout percentages did not differ by reproductive category ($P = 0.65$).

Haulout percentages of female walruses also differed by time of day (Fig. 24). Walruses hauled out, on average, 6.3% longer between 0900 and 2000 than during the rest of the day ($P < 0.01$). Although the best model did not indicate that hourly differences in haulout percentages were different for females with and without calves ($P = 0.99$) (i.e., the best model did not include an interaction term with Reproductive category and Time of day), we plotted the hourly haulout percentages of each category separately because our data suggest there may be slight differences between categories, especially between 1300 and 1600, and survey-related studies are interested in specific hourly differences in haulout percentages between each category to adjust those analyses for time of day.

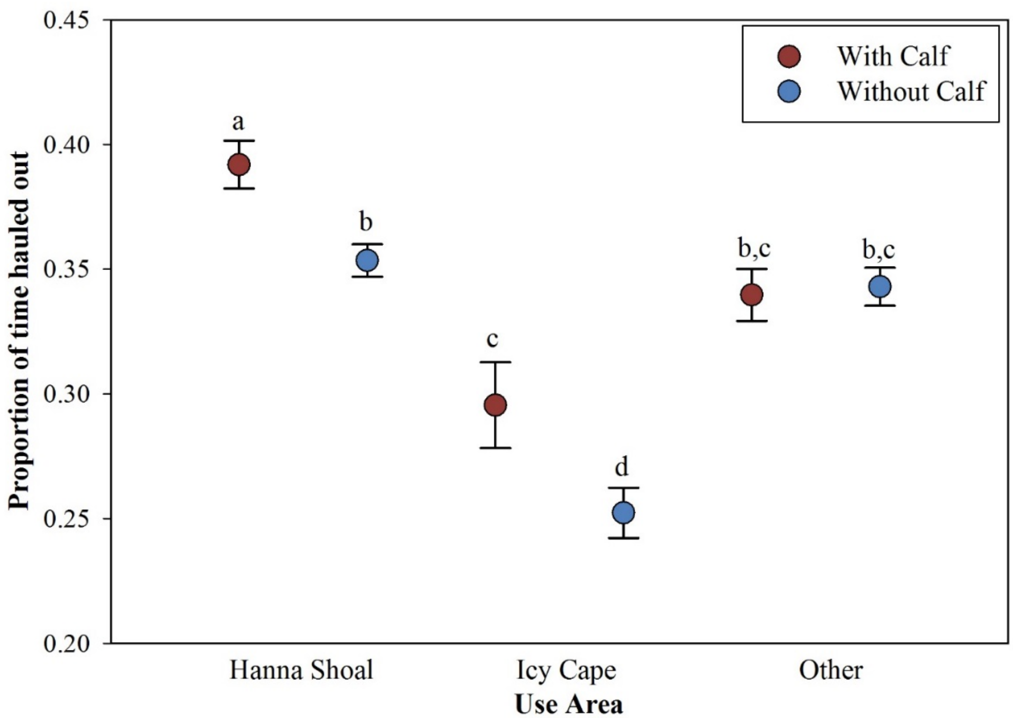

Figure 23. Proportion of time hauled out on ice by reproductive category for tagged female walruses in the Alaskan Chukchi Sea from June–September during 2013–2015. Error bars represent 95% confidence intervals and letters on error bars that are different denote statistically significant differences. Hanna Shoal and Icy Cape were identified as potentially important foraging areas based on 90% density probability of haulout locations. "Other" represents the rest of the Alaskan Chukchi Sea.

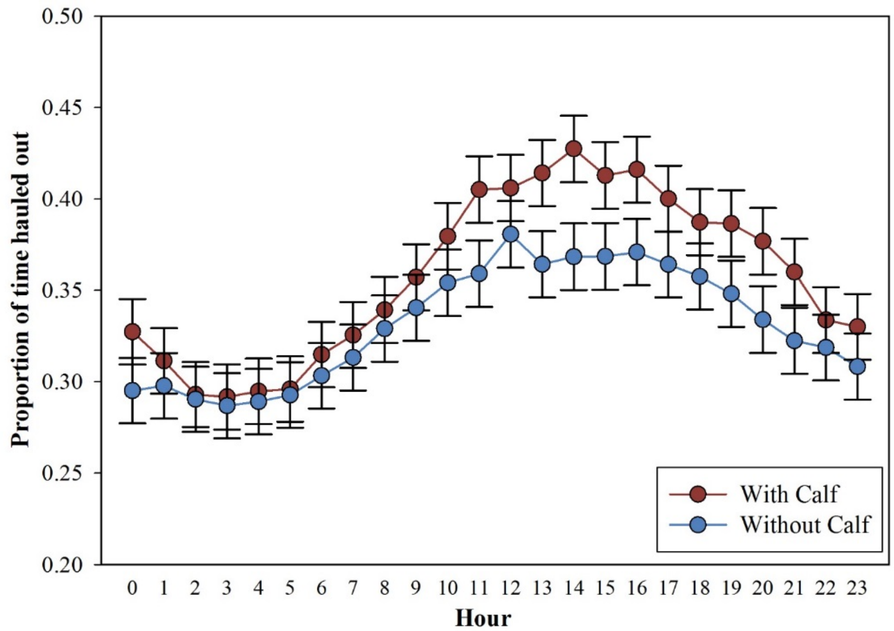

Figure 24. Proportion of time hauled out on ice by hour for tagged female walruses (with and without calves) in the Alaskan Chukchi Sea from June–September during 2013–2015. Error bars represent 95% confidence intervals.

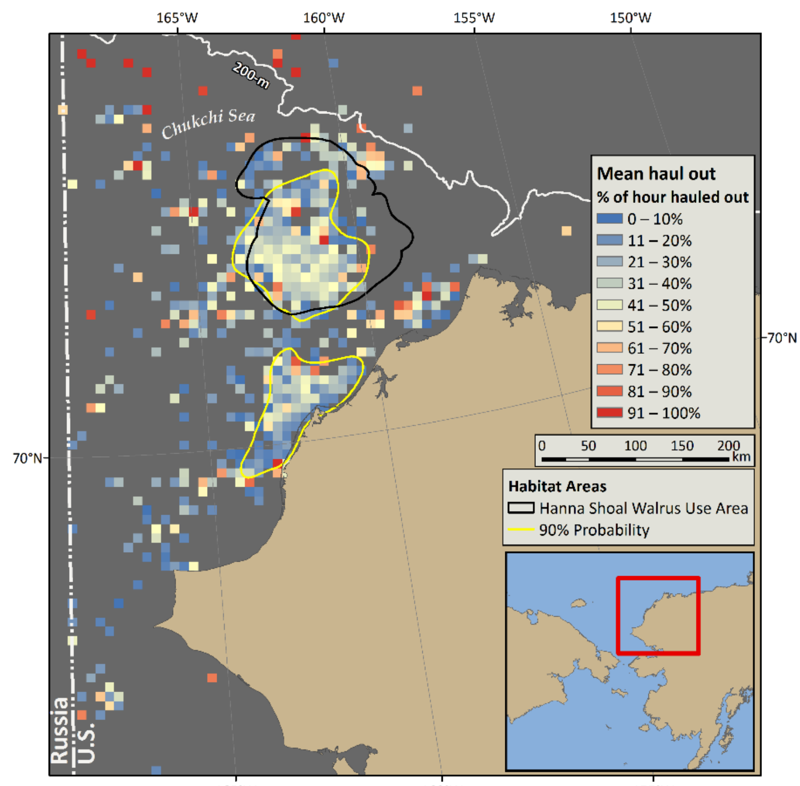

Figure 25. Spatial representation of mean haul out percentages for tagged female walruses on ice from June–September during 2013–2015. Yellow polygons in Hanna Shoal and near Icy Cape contain areas identified as potentially important foraging areas based on 90% density probability of on ice haulout locations.

The model that best approximated dive duration included area of use and time of day (Area + Time) (Fig. 26). Dive durations of all females were 1.6 minutes longer when in Hanna Shoal than Icy Cape and the rest of the Alaskan Chukchi Sea ($P < 0.01$); which did not differ ($P = 0.99$; Figs. 26 and 27). After controlling for the area used, walruses dove longer in the morning (0300–0859) than midday (0900–1459; $P < 0.01$) and evening (1500–2059; $P = 0.02$; Fig. 28). Dive durations at night (2100–0259), however, did not differ from any other time of day ($P > 0.36$).

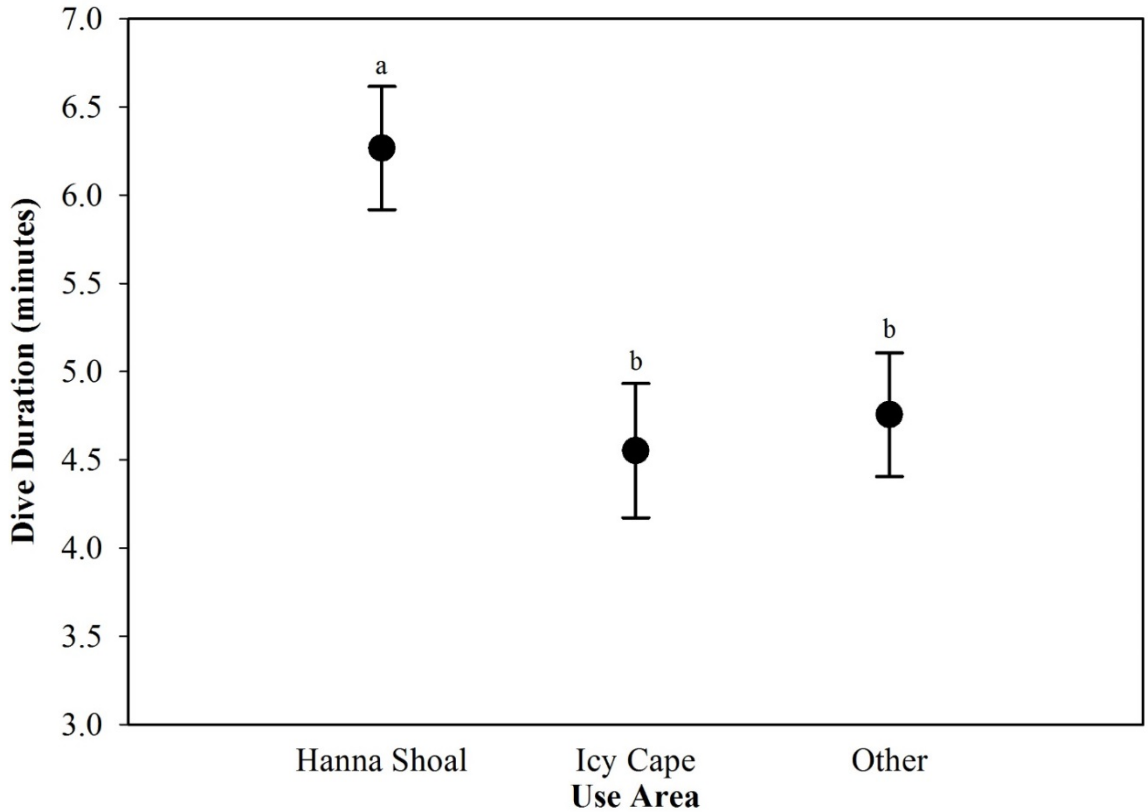

Figure 26. Mean dive durations (in minutes) by use area for tagged female walruses using ice as a haulout platform in the Alaskan Chukchi Sea from June–September during 2013–2015, after controlling for time of day. Error bars represent 95% confidence intervals and letters on error bars that are different denote statistically significant differences. Hanna Shoal and Icy Cape were identified as potentially important foraging areas based on 90% density probability of dive locations. "Other" represents the rest of the Alaskan Chukchi Sea.

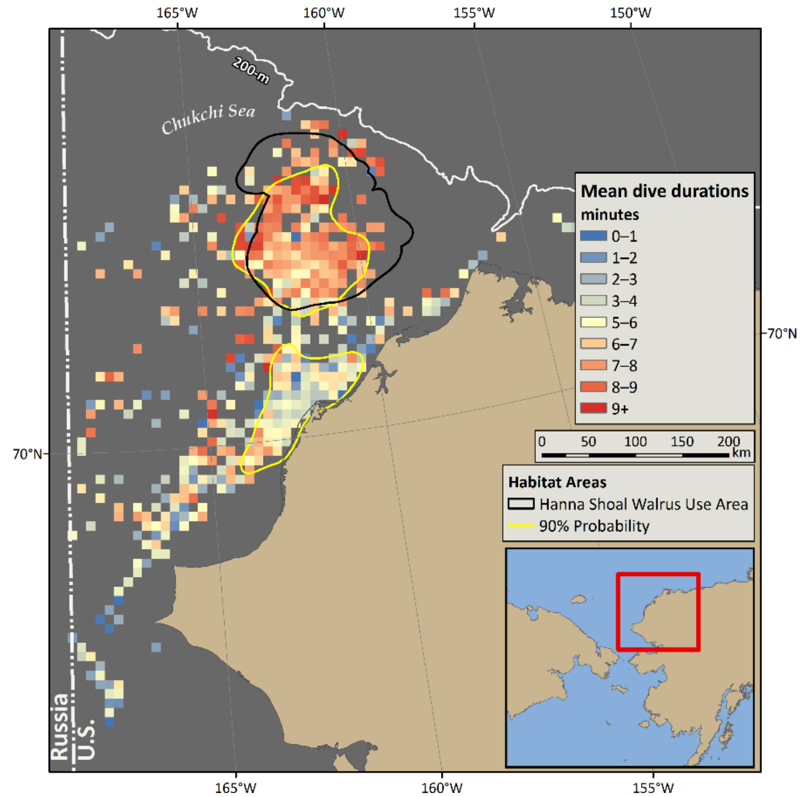

Figure 27. Spatial representation of mean dive durations for tagged female walruses using ice as a haulout platform from June–September during 2013–2015. Yellow polygons in Hanna Shoal and near Icy Cape contain areas identified as potentially important foraging areas based on 90% density probability of dive locations.

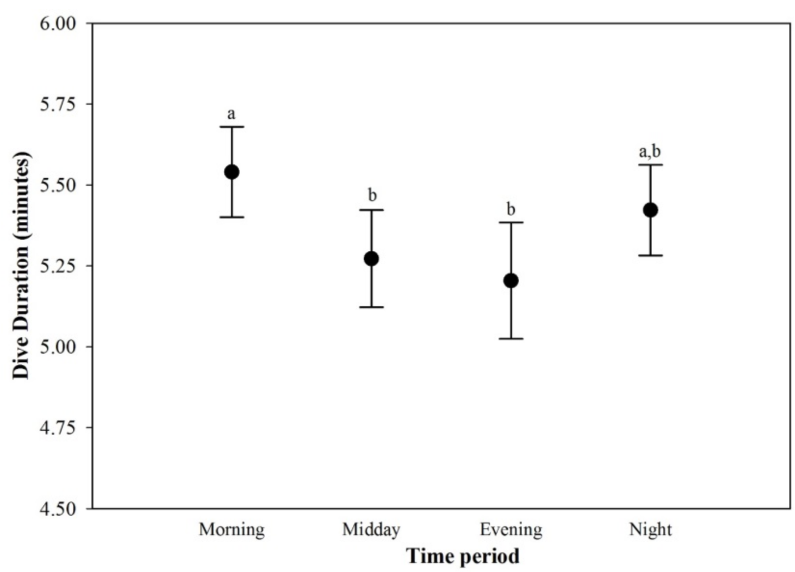

Figure 28. Mean dive durations (in minutes) by time of day (Morning: 0300–0859, Midday: 0900–1459, Evening: 1500–2059, Night: 2100–0259) for tagged female walruses using ice as a haulout platform in the Alaskan Chukchi Sea from June–September during 2013–2015, after controlling for area used. Error bars represent 95% confidence intervals and letters on error bars that are different denote statistically significant differences.

The model that best approximated dive rate included area of use and reproductive category (Area × Reproductive Category) (Fig. 29). When in Hanna Shoal, females made 1.4 fewer dives per hour than when in all other areas ($P < 0.01$; Fig. 30). When in Hanna Shoal ($P = 0.84$) and Icy Cape ($P = 0.41$), the dive rate of females with calves and without calves did not differ. However, in the rest of the Alaskan Chukchi Sea, females with calves made 1.25 more dives per hour than females without calves ($P = 0.04$; Fig. 29).

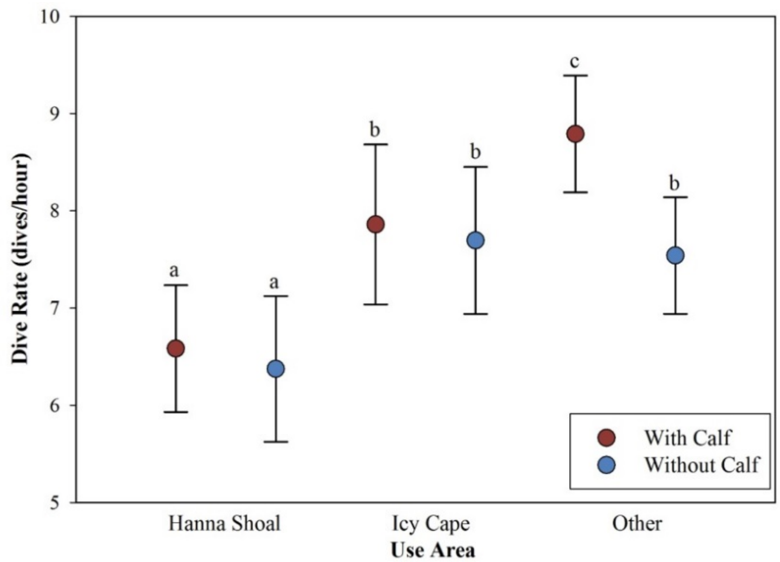

Figure 29. Mean dive rate (dives/hour) by use area for tagged female walruses using ice as a haulout platform in the Alaskan Chukchi Sea from June–September during 2013–2015. Error bars represent 95% confidence intervals and letters on error bars that are different denote statistically significant differences. Hanna Shoal and Icy Cape were identified as potentially important foraging areas based on 90% density probability of dive locations. "Other" represents the rest of the Alaskan Chukchi Sea.

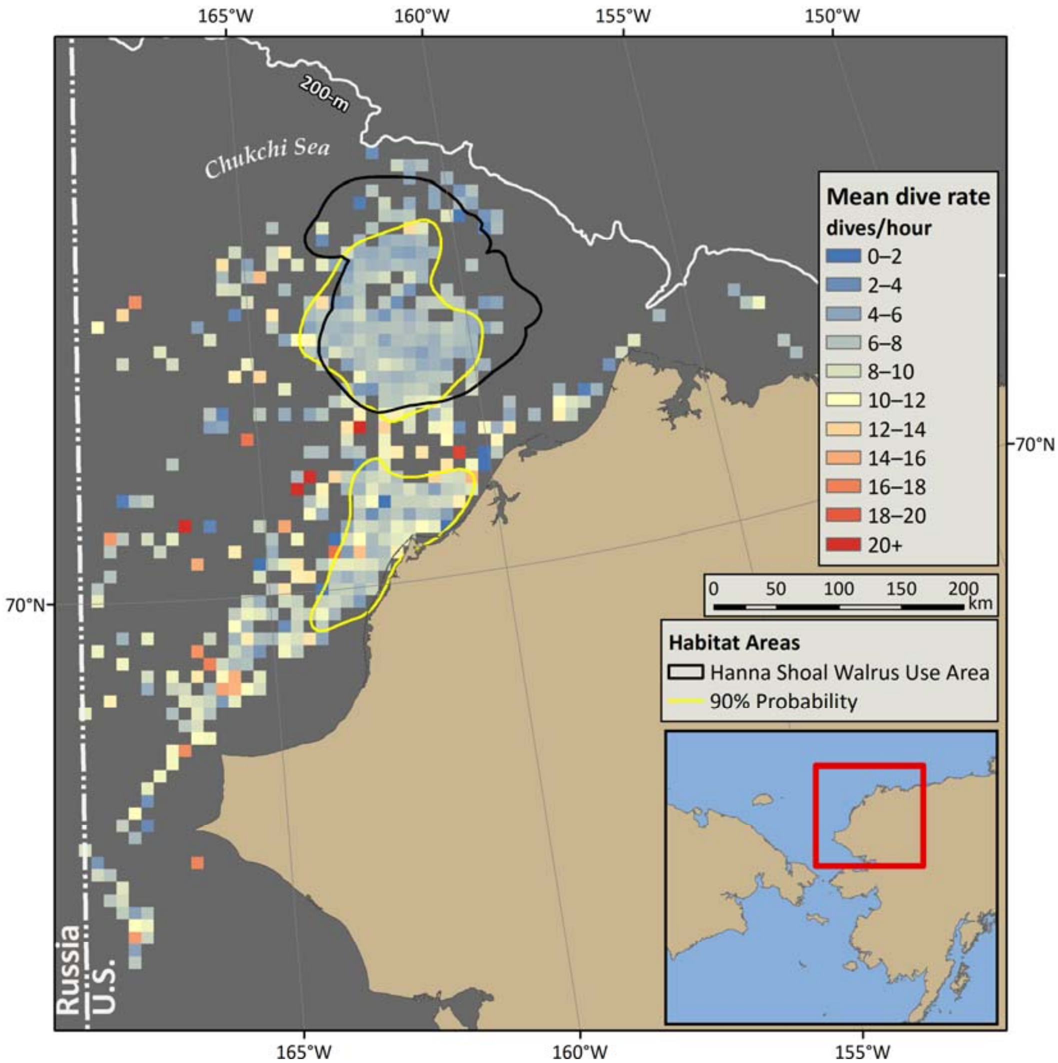

Figure 30. Spatial representation of mean dive rates for tagged female walruses using ice as a haulout platform during 2013–2015. Yellow polygons in Hanna Shoal and near Icy Cape contain areas identified as potentially important foraging areas based on 90% density probability of dive locations.

Surveys and other Activities at Terrestrial Haulouts

Hunters in Point Lay conducted haulout and carcass surveys during 2010, 2011, 2013, and 2014 (Table 7) and assisted ADFG and NSB biologists with carcass surveys in 2014 (Table 8). Although one of our objectives was to conduct shore-based surveys of demographic classes of walruses hauled out, often the risk of disturbance was determined to be too high. From USGS activities (i.e., tagging Jay *et al.* 2012) and high altitude helicopter gimbal photography (Monson *et al.* 2013) however, it was well established that the herds were mostly females with dependent young and juveniles.

Calves were the most frequently identified age class of walrus carcasses surveyed, 49 of 111 (44.1%), and calves were observed with symptoms of trauma more often, 36 of 49 (73.5%), than older age classes (Table 9). Each subsequently older age class; yearlings, subadults, and adults, had a smaller proportion of individuals showing signs of trauma.

Table 7. Walrus carcass survey results from Point Lay, Alaska, September and October 2010, and September 2011, 2013, and 2014. Signs of trauma included blood from the nose and mouth, symptomatic of trampling as the cause of death. Fresh, moderate, advanced, and mummified carcass conditions refer to the level of decomposition observed; advanced and mummified (skeletal) decomposition suggests the walrus died the previous year.

Year	**Sample ID**	**Carcass condition**	**Sex**	**Age class**	**Body condition**	**Length (cm)**	**Signs of Trauma**	**Skin lesions**
2010	PLW10-001	Moderate	F	Calf	Robust	155	Y	N
	PLW10-002	Fresh	F	Calf	Robust	144	Y	N
	PLW10-003	Fresh	M	Calf	Emaciated	135	Y	N
	PLW10-004	Moderate	M	Calf	Robust	142	Y	N
	PLW10-005	Fresh	F	Calf	Robust	132	Y	N
	PLW10-006	Fresh	M	Calf	Robust	126	Y	N
	PLW10-007	Moderate	F	Calf	Robust	127	Y	N
2011	PLW11-001	Moderate	M	Yearling	Robust	163	U	Y
	PLW11-002	Mummified	F	Adult	Unknown	U	U	U
	PLW11-003	Moderate	F	Calf	Unknown	146	U	N
	PLW11-004	Mummified	U	Adult	Unknown	U	U	U
	PLW11-005	Moderate	F	Calf	Robust	123	Y	Y
	PLW11-006	Fresh	M	Yearling	Robust	154	Y	Y
	PLW11-007	Advanced	F	Adult	Unknown	U	U	U
	PLW11-008	Fresh	M	Subadult	Robust	215	Y	Y
	PLW11-009	Moderate	F	Calf	Emaciated	123	U	Y
	PLW11-010	Fresh	F	Adult	Robust	277	Y	Y
	PLW11-011	Moderate	M	Yearling	Unknown	147	N	Y
	PLW11-012	Fresh	F	Calf	Emaciated	121	N	Y
	PLW11-013	Moderate	F	Yearling	Unknown	135	Y	Y
	PLW11-014	Fresh	F	Adult	Robust	269	Y	N
	PLW11-015	Fresh	M	Calf	Robust	145	Y	Y
	PLW11-016	Moderate	F	Calf	Robust	142	Y	Y
	PLW11-017	Moderate	U	Calf	Emaciated	130	Y	N
	PLW11-018	Moderate	F	Yearling	Robust	138	Y	Y
	PLW11-019	Advanced	U	Yearling	Unknown	U	U	U
	PLW11-020	Moderate	F	Adult	Emaciated	279	Y	N
	PLW11-021	Advanced	F	Calf	Unknown	127	N	U
	PLW11-022	Advanced	U	Calf	Unknown	U	U	U
	PLW11-023	Advanced	F	Yearling	Unknown	140	U	U
	PLW11-024	Advanced	F	Calf	Unknown	140	U	U
	PLW11-025	Advanced	U	Calf	Unknown	U	U	U
	PLW11-026	Moderate	F	Adult	Unknown	U	U	N
	PLW11-027	Moderate	F	Calf	Emaciated	U	N	Y
	PLW11-028	Fresh	M	Subadult	Emaciated	178	N	Y

2013	PLW13-001	Advanced	M	Adult	Robust	366	N	U
	PLW13-002	Advanced	M	Adult	Robust	274	N	U
	PLW13-003	Advanced	U	Adult	Unknown	396	N	N
	PLW13-004	Fresh	F	Yearling	Robust	170	Y	N
	PLW13-005	Moderate	M	Calf	Emaciated	155	Y	N
	PLW13-006	Fresh	F	Calf	Robust	185	Y	N
	PLW13-007	Fresh	F	Yearling	Robust	218	Y	N
	PLW13-008	Fresh	F	Calf	Robust	157	Y	N
	PLW13-009	Fresh	U	Subadult	Robust	272	N	N
	PLW13-010	Fresh	M	Calf	Emaciated	178	Y	Y
	PLW13-011	Fresh	U	Yearling	Robust	191	Y	N
	PLW13-012	Fresh	U	Calf	Robust	145	Y	U
	PLW13-013	Fresh	U	Yearling	Robust	185	Y	U
	PLW13-014	Fresh	F	Yearling	Robust	198	N	N
	PLW13-015	Fresh	M	Adult	Robust	284	N	N
	PLW13-016	Fresh	U	Calf	Robust	160	N	N
2014	PLW14-001	Advanced	F	Calf	Robust	153	U	U
	PLW14-002	Advanced	U	Yearling	Unknown	U	U	U
	PLW14-003	Moderate	U	Adult	Unknown	235	U	U
	PLW14-004	Moderate	U	Yearling	Unknown	202	U	U
	PLW14-005	Moderate	U	Subadult	Unknown	223	U	U
	PLW14-006	Fresh	F	Adult	Unknown	315	Y	N
	PLW14-007	Fresh	F	Adult	Robust	318	Y	N
	PLW14-008	Fresh	M	Calf	Robust	186	Y	N
	PLW14-009	Fresh	U	Subadult	Robust	264	Y	N
	PLW14-010	Fresh	M	Calf	Robust	179	Y	N
	PLW14-011	Fresh	M	Calf	Robust	192	Y	N
	PLW14-012	Fresh	F	Adult	Robust	300	Y	N
	PLW14-013	Fresh	F	Adult	Robust	310	Y	N
	PLW14-014	Fresh	M	Calf	Robust	216	Y	N
	PLW14-015	Fresh	F	Calf	Robust	U	Y	N
	PLW14-016	Fresh	F	Calf	Robust	178	Y	N
	PLW14-017	Fresh	F	Calf	Robust	165	Y	N
	PLW14-018	Fresh	U	Calf	Robust	169	Y	N
	PLW14-019	Fresh	F	Adult	Robust	310	Y	N
	PLW14-021	Fresh	M	Calf	Robust	145	Y	N
	PLW14-022	Fresh	F	Calf	Robust	140	Y	N
	PLW14-023	Fresh	F	Yearling	Robust	170	Y	N
	PLW14-024	Advanced	U	Yearling	Unknown	180	N	N
	PLW14-025	Fresh	U	Calf	Robust	105	N	N
	PLW14-026	Fresh	U	Subadult	Robust	240	Y	N
	PLW14-027	Fresh	F	Calf	Robust	160	Y	N
	PLW14-028	Fresh	M	Calf	Robust	145	Y	N
	PLW14-029	Fresh	F	Calf	Robust	151	Y	N
	PLW14-030	Fresh	F	Yearling	Robust	183	Y	N

U: Unknown

Table 8. Walrus carcass survey results from Point Lay, Alaska, 3–4 October 2014 and conducted in cooperation with the North Slope Borough, Department of Wildlife Management. Signs of trauma included blood from the nose and mouth, symptomatic of trampling as the cause of death. Moderate and advanced carcass conditions refer to the level of decomposition observed; advanced decomposition suggests the walrus died the previous year.

Sample ID	Carcass condition	Sex	Age class	Body condition	Length (cm)	Signs of Trauma	Skin lesions
PLW14-031	Unknown	F	Adult	Unknown	281	N	N
PLW14-032	Unknown	F	Calf	Unknown	170	Y	N
PLW14-033	Unknown	F	Adult	Unknown	281	N	N
PLW14-034	Unknown	F	Adult	Unknown	270	N	N
PLW14-035	Unknown	F	Adult	Unknown	302	N	N
PLW14-036	Unknown	F	Adult	Unknown	274	N	N
PLW14-037	Unknown	F	Adult	Unknown	318	N	N
PLW14-038	Unknown	F	Subadult	Unknown	251	N	N
PLW14-039	Moderate	F	Yearling	Unknown	191	Y	N
PLW14-040	Unknown	F	Adult	Unknown	279	N	N
PLW14-041	Advanced	F	Subadult	Unknown	201	Y	N
PLW14-042	Unknown	F	Adult	Unknown	286	N	N
PLW14-043	Moderate	F	Adult	Unknown	310	Y	N
PLW14-044	Unknown	F	Adult	Unknown	284	N	N
PLW14-045	Unknown	F	Adult	Unknown	287	N	N
PLW14-046	Advanced	U	Calf	Unknown	U	Y	N
PLW14-047	Advanced	U	Calf	Unknown	163	Y	N
PLW14-048	Advanced	F	Calf	Unknown	157	Y	N
PLW14-049	Unknown	F	Subadult	Unknown	221	N	N
PLW14-050	Unknown	F	Calf	Unknown	U	Y	N
PLW14-051	Unknown	F	Adult	Unknown	290	N	N
PLW14-052	Unknown	M	Calf	Unknown	141	Y	N
PLW14-053	Unknown	F	Yearling	Unknown	196	Y	N
PLW14-054	Unknown	U	Subadult	Unknown	241	Y	N
PLW14-055	Unknown	F	Adult	Unknown	259	Y	N
PLW14-056	Advanced	F	Adult	Unknown	297	N	N
PLW14-057	Fresh	M	Yearling	Unknown	183	Y	N
PLW14-058	Unknown	M	Calf	Unknown	147	N	N
PLW14-059	Unknown	M	Calf	Unknown	154	Y	N
PLW14-060	Moderate	U	Subadult	Unknown	251	Y	N
PLW14-061	Unknown	F	Calf	Unknown	149	N	N

U: Unknown

Table 9. Summary of walrus carcasses that were observed with symptoms of trauma in 2010, 2011, 2013, and 2014.

Age class	No. sampled	Signs of Trauma (%)
Calf	49	36 (73.5%)
Yearling	20	12 (60.0%)
Subadult	11	6 (54.6%)
Adult	31	10 (32.3%)
Total	**111**	**64 (57.7%)**

Determining the duration of occupancy at haulout locations and follow-up carcass surveys were problematic at Point Lay. In the late fall, the water level drops in the lagoon between the village of Point Lay and the haulout on the barrier island making boating difficult. As the temperature drops there is a period when neither boats nor 4-wheelers or snowmachines can be used for access. During this period when access is limited, high winds can cause the haulout beaches to be inundated. The high water and wave action simultaneously displaces the herd and washes away unsurveyed carcasses that were too close to the herd to be visited when the haulout was active. For these reasons demographic data, duration of haulout occupancy, and carcass surveys are incomplete.

Surveys for newly formed haulouts were conducted regularly by boat, both north and south, of Point Lay. Haulout surveys were also conducted during 2012 on Little Diomede Island at an area known to be used but no walruses were found hauled out on land.

An important part of the surveillance of the Point Lay haulout was done by camera as part of a project conducted by the Alaska SeaLife Center. Point Lay hunters supported by this project assisted in the construction and maintenance of camera towers. In 2015, two of the camera towers got pushed over by walruses as the haulout hit its maximum size. Tens-of-thousands of photos were taken and researchers at the Alaska SeaLife Center are currently examining these photos and plan to produce a final report by October 2016.

In August 2015, in anticipation of the end of this project, we transferred carcass survey and haulout surveillance responsibilities to the USFWS. Data was shared with USFWS and USGS throughout the project.

Local and Traditional Knowledge

The contribution of walrus hunters including local and traditional knowledge regarding walrus movements, timing of migration, and haulout behavior was a valuable contribution of this study. Information from interviews in Point Lay, Wainwright, Point Hope, Barrow, Elim, St. Michael, Stebbins, Kivalina, Kotzebue, and Shishmaref, during this study (2010–2015) are contained in reports made for the communities and incorporated into the results of this final report. Final reports are available from interviews in Point Lay and Wainwright (Huntington *et al.* 2012; Appendix G-1), Point Hope (Huntington and Quakenbush 2013; Appendix G-2), Barrow (Huntington *et al.* 2015a; Appendix G-3), Elim (Huntington *et al.* 2015b; Appendix G-4), St.

Michaels and Stebbins (Huntington *et al.* 2015c; Appendix G-5), Kivalina (Huntington *et al.* 2016a; Appendix G-6), Kotzebue (Huntington *et al.* 2016b; Appendix G-7), and Shishmaref (Huntington *et al.* 2016c; Appendix G-8) are available on the Alaska Department of Fish and Game's webpage at
http://www.adfg.alaska.gov/index.cfm?adfg=marinemammalprogram.traditionalknowledgereports. Some of the information contained in these reports is also presented in a peer-reviewed publication in Biology Letters (Huntington *et al.* in press). Details of the communities, topics, and numbers interviewed are presented in Table 10 and all traditional knowledge reports are included as Appendices G-1–G-8.

Hunter experience in approaching walruses on land without being detected was critical to the success of tagging and observations done during this study. Hunters also know when and where to look for walruses and how to approach them on the ice. We worked with the EWC to identify walrus hunters that had extensive knowledge and were interested in the project.

Walrus hunters Clarence Irrigoo, Perry Pungowiyi, and Edwin Noongwook, all from Saint Lawrence Island, taught us about walruses and sea ice during the walrus research cruises in 2013–2015. During the walrus research cruises, when the ship was between concentrated ice and the shore the hunters were consulted about the best course to take relative to the prevailing wind and currents.

Table 10. Summary of traditional ecological knowledge interviews and final reports.

Community	Year	Species discussed	No. interviewed	Reference
Point Lay and Wainwright	2012	Walrus and seals	5 13	Huntington *et al.* 2012; Appendix G-1
Point Hope	2013	Walrus, seals, bowhead whales, and beluga whales	8	Huntington and Quakenbush 2013; Appendix G-2
Barrow	2015	Walrus, seals, polar bears, bowhead whales, and beluga whales	10	Huntington *et al.* 2015a; Appendix G-3
Elim	2015	Walrus, seals, and beluga whales	8	Huntington *et al.* 2015b; Appendix G-4
St. Michael and Stebbins	2015	Walrus and seals	8 2	Huntington *et al.* 2015c; Appendix G-5
Kivalina	2016	Walrus, seals, bowhead whales	5	Huntington *et al*. 2016a; Appendix G-6
Kotzebue	2016	Walrus, seals	6	Huntington *et al.* 2016b; Appendix G-7
Shishmaref	2016	Walrus, seals	5	Huntington *et al.* 2016c; Appendix G-8
Total 10 communities	**4 years**	**7 species**	**70 interviews**	**8 reports**

Accomplishment of Objectives and Tasks
Overall Objective: The overall objective of this study was to work with subsistence hunters to deploy satellite transmitters and conduct observations on walruses in order to collect data that can be used to accomplish the following specific objectives.

Between 2009 and 2016 we worked with subsistence hunters from Gambell, Savoonga, Diomede, Wales, Point Hope, Point Lay, Wainwright, and Barrow to deploy satellite transmitters, conduct observations, carcass surveys, and TEK interviews.

Objective 1**:** Estimate patterns of movement and behavior of walrus migrating to and moving within the Chukchi Sea Planning Area. Particular emphasis will be placed on estimating movements within industrial ship traffic lanes and between terrestrial haulout sites and feeding areas near Hanna Shoal and other potential oil and gas development sites.

The greatest potential for overlap with ship traffic not related to oil and gas activities would occur during September and October when walruses are migrating south and ships are still traveling through Bering Strait. Although our tag data did not cover those months well because most tags were deployed in June and did not last through September, the data we have for September and October indicate that walruses would be near the coast of Chukotka and using terrestrial haulouts there. The potential danger of ship strikes to walruses is probably far less than if ships came close enough to shore to disturb large haulouts.

Use of the Chukchi Sea Planning Area 193 was high with 56 of 80 (70%) tagged walruses entering the area with most using the Hanna Shoal area (Fig. 19). Although >50% of the walruses that entered Area 193 were present between 19 June and 8 August (Fig. 20), the earliest day of use was 9 June and the latest was 18 September. On average, tagged walruses were located within Chukchi Sea Planning Area 193 for 35 days between June and September (range = 1–93 days, n = 56 walruses) with the highest density of use in the HSWUA.

Residence patterns within the leased blocks were similar to those within the larger Area 193 (Fig. 19), except that the leased blocks represent a smaller area, thus fewer walruses were found within the block boundaries (43 of 80, 54%) and those that were in the leased blocks were there for a shorter period of time (17 June–10 September). On average, tagged walruses were located within the leased blocks for 18 days (range = 1–71 days, n = 43 walruses).

Although terrestrial haulouts occurred on Russian and Alaskan coasts each year of tagging, few tagged walruses used terrestrial haulout sites. Only 8 of 28 (29%) tagged walruses used any terrestrial haulout (Table 6), and only two used the Point Lay haulout on the Alaskan coast (Fig. 18). During our study, two of seven walruses (29%), whose tags were still transmitting when terrestrial haulouts formed near Point Lay, hauled out there; both in 2015 (Fig. 18).

Objective 2**:** Estimate and evaluate the effect of any changes in walrus behavior related to changes in ice coverage and ice quality in the Chukchi Sea.

Tagged walruses arrived in the HSWUA in spring when ice was present, often traveling through the pack ice and north of the retreating ice edge to access the HSWUA. They did not begin to haulout at Point Lay until most of the ice had retreated north of the Chukchi Shelf, however some walruses continued to use ice that did not show up on satellite images and ice that was north of the shelf, over water deeper than 200 m (Fig. 15).

Whether walruses have always moved ahead (northward) of the retreating ice in the spring is not clear, however, the intensive use of the HSWUA in late June and early July when most walruses were still in the Bering Sea in the past (Fay 1982) indicates that the spring migration is earlier now than described by Fay (1982).

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

The terrestrial haulout at Point Lay was used by all demographic classes beginning in late August and continuing into September until winds from fall storms brought waves crashing on the haulout beach and walruses would leave. The waves also removed the carcasses that were too near the haulout to be counted and evaluated when walruses were present, preventing a complete count.

Carcasses were mostly calves and yearlings indicating that females and dependent young used the haulout. Photographs and observations of the haulout indicated that older juveniles and adult males were also present (Monson *et al.* 2013).

Objective 4: Document traditional knowledge of walrus behaviors including, but not necessarily limited to, movements, social behavior, and use of habitat including use of ice and land as haulout substrates.

Interviews involving 70 people from 10 coastal Alaska communities produced valuable information that were presented in eight final reports to EWC and the communities. Final reports are available on ADFG and BOEM websites, and are included in this document as Appendices G-1–G-8.

TEK findings specific to walrus behavior included their excellent hearing and sensitivity to smells and movement. Females are protective of their calves and have been known to attack boats and hunters. Hunter knowledge of how to work around large groups of walruses, including many females with calves was important to this study.

Walruses regularly haul out on shore in small numbers and hunters reported this activity in Norton Sound, near Point Hope, Point Lay, Wainwright, and Barrow (Appendices G-1–G-5). Walruses sometimes haulout in small numbers between Cape Thompson and Cape Lisburne, but regularly haul out near Cape Lisburne by the dozens. However, fewer walruses have hauled out near Cape Lisburne recently, possibly because barges sometimes wait there for better ice or weather conditions (Appendix G-2). In the past, typically a few walruses were seen at various locations on the islands in Kasegalek Lagoon. Large numbers were seen on shore between Point Lay and Wainwright in the 1950s, but the much larger numbers began hauling out on the Alaskan coast in 2007 (Appendix G-1).

Task 1 – Data Review and Hypothesis Development. We reviewed available data on walruses throughout the project. In addition to examining our own data, we peer reviewed manuscripts and read published literature on walrus movements and behavior to refine and develop working hypotheses.

Task 2 – Experimental Design and Field Work. We continued to develop our collaborations originally established during "The Planning Phase" of this study that begun as a University of Alaska Coastal Marine Institute Study in 2008. We worked with the walrus hunters, EWC, USFWS, and USGS to address objectives. We worked with walrus hunters from Point Lay to conduct carcass surveys and to make observations of the terrestrial haulout when it formed and to look for other haulouts. We worked with hunters from Wales, Diomede, and Point Hope to tag walruses from shore during the spring migration but the weather and ice conditions prevented any tag deployments. Hunters from Gambell and Savoonga were critical members of the walrus research cruises in the Bering and Chukchi seas (2013–2015). We avoided conflicts with subsistence hunting by allowing each community to determine if tagging activities conflicted with their hunting.

We tracked 82 walruses for a maximum of 134 days. Tag longevity was limited by retention or antenna durability and not battery longevity. We coordinated with USGS to match the data collection parameters of the tags both agencies deployed on walruses so that data collected by both agencies were comparable and could be combined for some analyses. This was accomplished even though we used a different tag manufacturer and attachment anchor.

Task 3 – Data Analysis and Reporting. We used findings from this study to test and refine hypotheses. We provided weekly maps of all tagged walruses by reproductive category (i.e., females with and without calves) to interested parties via an extensive email list and an additional map focused on the Chukchi Leases and the Hanna Shoal area for BOEM to accommodate weekly meetings that BOEM held with industry in order to provide the most recent locations of tagged walruses for near real-time evaluations of walruses and industry. We also supplied density estimate maps and maps that depicted walrus movements relative to the Distributed Biological Observatory areas in the Bering, Chukchi, and Beaufort seas for BOEM presentations at workshops. We have presented research results at six Alaska Marine Science Symposiums (2011–2016) and at the Society for Marine Mammalogy Biennial Conference in 2015. We have begun to prepare manuscripts on dive and haulout behavior, and movements relative to ice concentration. We intend to continue collaborations with USFWS, USGS, and others on data analyses and products that will improve our understanding of walrus behavior and ecology.

Task 4 – Integration of Findings with other Tasks. Walrus movement data from this study will be included in a Synthesis of Arctic Research (SOAR) publication that will overlay the distribution of marine mammal use of the Chukchi Sea (Citta *et al.* In prep.)

We have accommodated many requests for data to augment other projects and efforts. Although we anticipated contributions to the U.S. Coast Guard efforts for planning shipping lanes in Bering Strait the date of tagging and the longevity of the tags have not provided sufficient data in Bering Strait. We make our maps and other products available through our website and many consulting companies and other entities use them for their reports. We have offered data to USGS to augment their studies.

Task 5 – Data Management and Archival. We have maintained an archive of all data collected during this study. We have ensured that all data are properly recorded, validated, backed up, and archived in order to be available to BOEM and other investigators after the objectives and obligations of this project are met. Location data from Argos have been downloaded weekly from the Argos webpage and complete summaries have been received monthly. Metadata, raw data files, and processed data files are archived on the State of Alaska web server. On this server (WinfoNet), we have an archival application specifically for the storage of data and the creation of metadata. The server is backed-up daily and cached in Fairbanks, Anchorage, and Juneau, Alaska. Processed locations were imported into a geographic information system (ArcMap or R) to analyze location and dive data that we plan to present in future manuscripts. Our 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. We coordinated with EWC and the local communities for tagging, haulout monitoring, and traditional knowledge interview activities. We provided handouts at annual EWC meetings (Appendices F-1, F-6, F-8, and F-10). Our primary method of outreach consisted of sending weekly project updates and maps to a list of interested persons, including subsistence hunters, scientists, industry, and managers. Updates included a map with the most recent tagged walrus locations, a description of sea ice conditions, and a description of any additional pertinent information. Recipients often responded and generated real-time discussions regarding walrus movements. Maps were then posted on the ADFG website, where they are available along with other information about the walrus tagging project. We also prepared posters and gave presentations in coastal communities. We held two Federal Walrus Research Permits from USFWS (MA220876 and MA57198B) and used a permit issued to USFWS in 2015 (MA039386). We also maintained Institutional Animal Care and Use Committee (IACUC) protocols from ADFG approved annually for our research (2010-13R, 2012-020, 2013-20, 2014-03, and 2015-25).

Task 7 – Logistics/Safety Plan. Safety plans were developed specific to each tagging effort based on local logistics, infrastructure, and measures already in place. Safety equipment was 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 present on all tagging boats.

Discussion

Coordination

Collaboration between walrus hunters, walrus hunting communities, EWC, USGS, USFWS, and BOEM was important for tagging and exchanging information during this study. Our original study design was for ADFG to tag from coastal communities with local walrus hunters because USGS had been focused on tagging offshore from ships. When this project began in 2009, however, large numbers of walruses were hauling out at Point Lay and USGS began an onshore tagging effort there. Although we were working with Point Lay for haulout surveillance and carcass surveys we did not tag there and instead tried to work from other village locations including Point Hope, Little Diomede, and Wales, but weather and ice conditions were not conducive to tagging. All of these tagging attempts were coordinated with the communities so that tagging operations would not interfere with walrus hunting.

In order to keep the EWC informed of the study progress and for them to relay questions and concerns we made regular oral presentations at EWC meetings and provided handouts for EWC commissioners. In order to keep as many people informed as possible we sent weekly maps of the locations and movements of tagged walruses to partners and anyone that expressed an interest in receiving them. The e-mail list included >200 addresses; many people also forward our maps to their own list of addresses.

Upon receiving maps, recipients often replied to the list with their thoughts, questions, or other information about current walrus observations. This often stimulated a mini-discussion that provided valuable real-time information with perspective on the movements of the tagged walruses relative to the rest of the population and allowed us to clarify some confusion about USGS versus ADFG tagging activities.

After the maps were distributed to the e-mail list they were placed on the ADFG website for people without e-mail addresses and for archiving. We know that the website was checked regularly because we received inquiries if we were slow to post a map. We also posted 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.

We coordinated with research conducted by USGS and USFWS and participated in joint research cruises where all but two of our tags were deployed. We produced maps specific to the regulatory needs of BOEM to use for meetings with oil companies and other agencies.

Tagged Walruses, Biopsy and Tag Performance

The amount of data collected from each tag varied greatly and was dependent on many factors, some of which are impossible to identify with certainty. Although the tags we deployed had relatively good tag longevity for walruses (mean tag duration; SPOT tags: 69.8 days; SPLASH tags: 44.0 days), walruses do not retain tags very long for reasons we do not completely understand, but are possibly related to how walruses lay and roll on their backs and on each other when hauled out, potentially breaking the antenna from the tag, crushing the tag's circuitry, or shearing the tag off of the anchor plate. Very few tags have been observed attached to walruses after being deployed so there is little information available for improving tag attachment design for longevity and for further minimizing effects to the walrus. A walrus was harvested by Point Hope hunters in fall 2011 that had a satellite transmitter and the walrus was healthy with no apparent problems on the skin near the transmitter attachment location (Appendix G-2).

Most tags performed well and collected reliable data, however in trying to provide USGS with equivalent behavioral data to those collected by their Telonics tags, we worked with engineers at Wildlife Computers to develop a new setting to collect these data on SPLASH tags. In 2013, this behavioral setting did not collect the data properly, although location, dive, and haulout information were not affected. After the research cruise in 2013, we worked with Wildlife Computers again to fix this setting and the problem was resolved prior to deploying tags in 2014 and the additional behavioral data was collected in 2014 and 2015. We checked all tags thoroughly before deployment by dunking them in salt water to be sure they will activate once deployed and to confirm battery strength. Of 95 tags deployed, 13 did not transmit any data or only transmitted data for <24 hours after deployment due to an error in the tags' software or for other unknown reasons (Table 3).

During this study (2009–2016), we deployed 95 tags on walruses (39 on females with calves, 47 on females without calves and 9 on males). These are the first data collected on Pacific walruses where it is known if females had calves when they were tagged, and therefore allows comparisons between females with and females without calves to be made, although it is unknown if any calves were lost after tagging. Because we only deployed tags on nine male walruses, and only six of these tags transmitted data, results of our analyses between sexes (e.g., tag longevity, travel distances, distance to shore) may be a function of the small sample size of males tagged. The success of this program was largely due to the partnership with Native walrus hunters. Walrus hunters could safely approach walruses and deploy tags accurately using a crossbow or a traditional harpoon style delivery with minimal disturbance to the group and maximal safety for the taggers.

Conclusions

This project collected important information about walruses during spring and summer in the Chukchi Sea. We worked with Native subsistence hunters to develop new study objectives and to deploy tags. We worked with tag manufacturers to make our data compatible with those collected by USGS and to improve longevity of the tags. We shared our results with the EWC, subsistence hunters, and their communities, scientists, oil company personnel, agency personnel, and other interested parties by sending out weekly maps and information updates. We have offered to share data with USGS and USFWS. We maintained an active website that allowed public access of our data products. This website was used by many entities for diverse purposes, including species and habitat maps, environmental assessments, biological opinions, incidental harassment applications and authorizations. We made numerous oral and poster presentations at conferences, symposia, and meetings (Appendices F-1–F-13) and general summer distribution data will be published in a peer-reviewed scientific publication in 2016 (Citta *et al.* In prep.). We also intend to publish manuscripts on migration, diving and haulout behavior, and habitat use.

This project has contributed a greater understanding of the distribution, movements, and habitat use of Pacific walruses by combining data collected by satellite transmitters with Traditional Ecological Knowledge. These include, but are not limited to:

1. Further documentation of the spring, summer, and fall distribution of walruses, including migratory routes and summer movements by reproductive category.

2. Documentation of the relative importance of feeding areas. Specifically we compared Hanna Shoal, Icy Cape, and the rest of the Chukchi Sea and, based on walrus behavior, found indications that Hanna Shoal is likely the most important of these areas.

3. Documentation of the use and timing of sea ice, terrestrial haulouts, and foraging areas.

4. We have documented walrus presence within U.S. and Russian program areas in the Chukchi Sea. Based on movements and behavior of tagged walruses from all years, the greatest potential for anthropogenic disturbances from industrial activities, including local shipping, occur near Hanna Shoals Walrus Use Area from June–September.

5. We deployed tags in U.S. (*n* = 81) and Russian waters (*n* = 14) and, although the sample size in Russian waters was small, found that walruses often crossed the International Date Line and movements on both sides were generally similar

Recommendations

1. Further analyze available telemetry data to determine if female walruses with calves exhibit movements (e.g., southern migration), diving, and haulout behavior that are different from females without calves. Include an analysis of difference between using terrestrial haulouts vs. sea ice.

2. Conduct a comprehensive analysis of walrus interactions with seismic activities. Walrus tracks that spatially and temporally overlap with seismic operations need to be analyzed to learn about walrus behavior near seismic activities. Oil and seismic companies need to be forthcoming with their program tracklines (location and time) for this analysis to occur.

3. Investigate the combination of satellite telemetry and acoustic technology to directly monitor noise levels that walruses are exposed to and how walrus vocalizations change with level. This knowledge could then be used to better interpret passively monitored acoustic information.

4. Conduct a comprehensive analysis of terrestrial haulout (historic and recent) use patterns to better anticipate their use in the future. Using historic information about how many consecutive years particular haulouts were used may help predict how long Point Lay will be used and where the next haulout might form.

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List of Project Reports, Presentations, and Products

Project update to EWC Executive Board, 28–29 September 2009 in Anchorage
Project update to EWC Full Board, October 2011 in Nome
Project update to EWC Full Board, November 2012 in Anchorage
Project update to EWC Full Board, December 2013 in Anchorage
Project update to EWC Full Board, December 2014 in Anchorage
Project update to EWC Full Board, December 2015 in Anchorage
Annual Research Permit Reports to U.S. Fish and Wildlife Service

Garlich-Miller, J., W. Neakok, and R. Stimmelmayr. 2011. Field Report: walrus carcass survey, Point Lay Alaska, September 11–15, 2011. (Appendix F-3)

Quakenbush, L., J. Crawford, A. Bryan, M. Nelson. 2011. Results from village-based walrus studies in Alaska, 2010. Alaska Marine Science Symposium, 17–21 January, Anchorage, AK. (Abstract and poster; Appendix F-2)

Crawford, J. A., W. Neakok, M. A. Nelson, J. Garlich-Miller, and L. Quakenbush. 2012. Results from village-based walrus studies in Alaska, 2011. Alaska Marine Science Symposium, 16–20 January, Anchorage AK. (Abstract and poster; Appendix F-4)

Garlich-Miller, J. 2012. Adapting to climate change: a community workshop on the conservation and management of walruses on the Chukchi Sea coast. Feburary 24–24, Barrow, Workshop Proceedings prepared by USFWS, Anchorage, 41 pp.

Huntington, H. P., M. Nelson, and L. T. Quakenbush. 2012. Traditional knowledge regarding walrus near Point Lay and Wainwright, Alaska. Report to the Eskimo Walrus Commission and the Bureau of Ocean Energy Management for contract #M09PC00027. 11 pp. (Appendix G-1)

Crawford, J. A., W. Neakok, M. A. Nelson, J. Garlich-Miller, and L. Quakenbush. 2013. Results from village-based walrus studies in Alaska, 2012. Alaska Marine Science Symposium, 21–25 January, Anchorage AK. (Abstract and poster; Appendix F-5)

Huntington, H. P., and L. T. Quakenbush. 2013. Traditional knowledge regarding walrus near Point Hope, Alaska. Report to the Native Village of Point Hope, Alaska and Bureau of Ocean Energy Management for contract #M09PC00027. 9 pp. (Appendix G-2)

Crawford, J. A., L. Quakenbush, C. Irrigoo, P. Pungowiyi, W. Neakok, W. H. Lampe, and J. Garlich-Miller. 2014. Results from village-based walrus studies in Alaska, 2013. Alaska Marine Science Symposium, 20–24 January, Anchorage AK. (Abstract and poster; Appendix F-7)

Crawford, J. A., L. T. Quakenbush, C. Irrigoo, E. Noongwook, and J. Garlich-Miller. 2015. Results from village-based walrus studies in Alaska, 2014. Alaska Marine Science Symposium, 19–22 January, Anchorage, AK. (Abstract and poster; Appendix F-9)

Crawford, J. A., L. T. Quakenbush, J. J. Citta, C. Irrigoo Jr. and P. R. Lemons. 2015. Using movement, diving and haul out behavior to identify the relative importance of foraging areas for walruses in the Alaskan Chukchi Sea. 21th Biennial Conference on the Biology of Marine Mammals. 14–18 December, 2015. San Francisco, CA, USA. (Abstract and presentation; Appendix F-11)

Crawford, J. A., L. T. Quakenbush, J. J. Citta, C. Irrigoo Jr. and P. R. Lemons. 2016. Using movement, diving and haul out behavior to identify the relative importance of foraging areas for walruses in the Alaskan Chukchi Sea. Alaska Marine Science Symposium, 25–29 January, Anchorage, AK. (Abstract and poster; Appendix F-12)

Huntington, H. P., M. Nelson, and L. T. Quakenbush. 2015a. 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. 8 pp. (Appendix G-3)

Huntington, H. P., M. Nelson, and L. T. Quakenbush. 2015b. Traditional knowledge regarding ringed seals, bearded seals and walrus near Elim, Alaska. Final report to the Eskimo

Walrus Commission, the Ice Seal Committee, and the Bureau of Ocean Energy Management for contract #M13PC00015. 7 pp. (Appendix G-4)

Huntington, H. P., M. Nelson, and L. T. Quakenbush. 2015c. Traditional knowledge regarding ringed seals, bearded seals, and walrus near St. Michael and Stebbins, Alaska. Final report to the Eskimo Walrus Commission, the Ice Seal Committee, and the Bureau of Ocean Energy Management for contract #M13PC00015. 7 pp. (Appendix G-5)

Huntington, H. P., M. Nelson, and L. T. Quakenbush. 2016a. Traditional knowledge regarding ringed seals, bearded seals, and walrus near Kivalina, Alaska. Final report to the Eskimo Walrus Commission, the Ice Seal Committee, and the Bureau of Ocean Energy Management for contract #M13PC00015. 8 pp. (Appendix G-6).

Huntington, H. P., M. Nelson, and L. T. Quakenbush. 2016b. 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. 11 pp. (Appendix G-8).

Huntington, H. P., M. Nelson, and L. T. Quakenbush. 2016c. Traditional knowledge regarding ringed seals, bearded seals, and walrus near Shishmaref, Alaska. Final report to the Eskimo Walrus Commission, the Ice Seal Committee, and the Bureau of Ocean Energy Management for contract #M13PC00015. 8 pp. (Appendix G-7).

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