Marine Mammal Surveys at the Klondike and Burger Survey Areas in the Chukchi Sea during the 2009 Open Water Season

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Executive Summary[1]

Marine mammal surveys were conducted in 2009 during the second of an anticipated three-year multidisciplinary research program in the Chukchi Sea during the open-water season, sponsored by ConocoPhillips Inc., Shell Exploration and Production Company, and Statoil USA E&P Inc. (Statoil). The purpose of the marine mammal research program was to develop baseline information on marine mammal use of the Klondike and Burger survey areas to aid in the development of National Environmental Policy Act (NEPA) documents and permits. The program also offers the opportunity to add to the existing knowledge base of marine mammal use of the Chukchi Sea.

Surveys were conducted by marine mammal observers (MMOs), who were trained biologists experienced in marine mammal surveys who had also participated in the 2008 research program. MMOs were at times assisted by Inupiat Communicators, who represented the local villages. Surveys were conducted from a vessel during three consecutive cruises, each approximately 20 days long, between 12 August 12 and 15 October 15, 2009. Surveys focused on two areas, Klondike and Burger, which are located over 100 km (62 mi) northwest of the village of Wainwright on the northwestern Alaska coast. Each area was surveyed during each of the three cruises. Surveys were conducted along transects that were 55.56 km (35 nm) in length along a north-south orientation and spaced 1.8 km (1 nm) apart across each survey area. Every other transect was designated as a primary transect line and alternate lines were designated as secondary transects. The study plan called for transit of primary transect lines during a survey; however, the secondary transect lines were surveyed opportunistically to increase sampling coverage when time allowed, or when weather prevented survey of a primary transect(s) under acceptable conditions. Two MMOs alternated observations approximately every 2 hr throughout the daylight hours. Data collected on marine mammals included species, number, location, behavior, distance from vessel, and age/sex (when possible), plus time, date, and observation conditions during surveys.

A total of 344 sightings of 589 marine mammals comprising at least nine species was observed during 434 hr of survey effort covering almost 6400 km (3977 mi) of transit lines at Klondike and Burger and areas outside the two survey areas. Pinnipeds comprised 84% of the recorded marine mammals, cetaceans 15%, and polar bears (*Ursus maritimus*) 1%. Seals were the most abundant pinniped, which included ringed (*Phoca hispida),* spotted *(Phoca largha),* and bearded *(Erignathus barbatus)* seals; no ribbon seals (*Histriophoca fasciata)* were encountered in 2009. The other pinniped recorded was the Pacific walrus *(Odobenus rosmarus)*. Twenty-seven calves or juvenile pinnipeds were recorded during the cruise, which included 25 walruses, one bearded seal, and one ringed/spotted seal; seals were placed in the latter category when ringed and spotted could not be distinguished to species.

Cetaceans were represented by four species including primarily gray whales (*Eschrichtius robustus),* followed by equal numbers of harbor porpoises *(Phocoena phocoena)* and bowhead whales *(Balaena mysticetus)*, and a few minke whales

[1] Citations for supporting statements in executive summary are provided in the body of the report.

(*Balaenoptera acutorostrata)*. Fin (*Balaenoptera physalus)* and humpback (*Megaptera novaeangliae*) whales and Dall's porpoises (*Phocoenoides dalli)* were observed in the southern Chukchi Sea on transits between Nome and the study area in late September or mid-October. No killer *(Orcinus orca)* or beluga whales (*Delphinapterus leucas*) were encountered during the research program, although they occur in the Chukchi Sea. Four polar bears, including one mother-cub pair were seen outside of Klondike and Burger,

The number and species composition of marine mammals varied between the two survey areas in 2009. All four species of pinnipeds were recorded at both survey areas with slightly more seals (90 vs. 78) and far more walruses (62 vs. 8) at Burger than Klondike; effort had little effect on the numbers, since it was essentially equal for the two areas. Small numbers of seals were recorded during each of the three cruises at Klondike (4-66 seals) and Burger (17-55), with more seals recorded at Burger than Klondike per cruise but for the last cruise. Approximately equal proportions of each seal species occurred in the two survey areas except for bearded seals, which were more common (22 vs. 7) at Burger than Klondike. However, differences were not consistent among cruises, and furthermore, the difference was statistically insignificant (confidence intervals for density overlapped) when the numbers were pooled across all cruises for each area. Most walrus observed at Burger occurred during the first cruise with few to none encountered during the last two cruises. Particularly large numbers of walruses were observed east and northeast of Burger near sea ice in early August and also Wainwright in the open water in late August and early September.

Of the four cetacean species observed during the program, only gray whales were recorded in both survey areas. Single gray whales were recorded at both survey areas, all three bowhead whales were observed at Burger and the one minke whale was observed at Klondike. All of the harbor porpoises were encountered outside of the survey areas close to the coast. All bowhead were observed in October, while most gray whales were observed during late August and mid-September, and near the coast. The other cetacean species were observed sporadically. Polar bears were observed only during the first cruise in remnant sea ice east of Burger. Only gray whales were observed feeding. Small numbers of seals, but most walruses and gray whales, were recorded outside of the two survey areas and near the coast. Observation conditions varied during each cruise but in all cases they were generally acceptable for effectively detecting marine mammals.

Sample sizes were too low to support the derivation of density estimates on a species-by-species basis for most marine mammals. Sample size was sufficient to calculate a statistically valid density estimates for walrus, and for seals when treated as a group. Density was estimated using the line-transect approach based on perpendicular distances of seals and walruses from the vessel. The small numbers of sightings reflected low seal densities for each cruise (0.003-0.078 seals/km^2 or 0.008-0.200 seals/mi^2); however, seal densities were significantly greater at Burger than Klondike during cruise 2 (0.056 vs. 0.003 seals/km^2 or 0.143 vs. 0.008 seals/mi^2). Seal density within Klondike was significantly greatest during Cruise 3, whereas seal density at Burger was greatest during Cruise 2, but there was no statistical difference ($P=0.05$) among the three cruises. Walrus densities were significantly greater at Burger than Klondike during Cruise 1, and density was equally low at both survey areas during Cruise 2; no walruses were encountered in either area during Cruise 3. Abundance estimates are not provided, since the numbers of missed seals or walruses are unknown, and there are no reliable correction factors for missed seals or walruses in open water.

Comparing the 2009 results with those achieved in 2008 and with existing literature show patterns of both similarities and differences, which are presented below. A more thorough and conclusive interpretation will evolve as the research program completes each year of the anticipated three-year program.

- Sea ice conditions were very different between the 2008 and 2009 research programs. Sea ice was prevalent at Klondike and Burger during the Cruise 1 and at Burger during the early part of Cruise 2 in 2008. Conversely, sea ice was absent during all of the 2009 cruises, which started three weeks later than in 2008 to minimize ice effects on the vessel access to survey areas. However, sea ice was encountered east and northeast of Burger by the research vessel in 2009 during the week before starting the Cruise 1 survey while deploying acoustic equipment. The different ice conditions between years likely influenced the results in the following way:

    - Seal densities were highly influenced by the presence of sea ice in the survey areas, although most seals were observed in the water. Densities were much lower in both 2009 (0.003-0.078 seals/km^2 or 0.008-0.200 seals/mi^2) and 2008 (0.041-0.075 seals/km^2 or 0.105-0.192 seals/mi^2) when Klondike and Burger were ice free than when sea ice was prevalent (0.133-0.381 seals/km^2 or 0.340-0.975 seals/mi^2) during Cruise 1 of 2008.

    - Seals showed no statistically significant preference for one survey area over the other between years. Klondike had the greatest density in 2008 and Burger in 2009. Nor was the seasonal pattern (reflected by density per cruise) of use recorded in 2008 repeated in 2009. In 2008 Cruise 1 had the greatest density at both Klondike and Burger, whereas in 2009, the greatest density in Burger was during Cruise 2 and in Klondike during Cruise 3. The results show that in the absence of sea ice, seal occurrence in the two survey areas was low, and the variability can probably be attributed to a number of currently possible influencing environmental factors that could include prey, currents, broad-scale movements, sample size, sea state, and greater dispersion of seals in the absence of ice.

    - Walrus occurrence of Burger was higher than in Klondike for 2008 and 2009, but numbers were much higher in 2008 (940 vs. 62 in 2009) when sea ice was present in Burger. Many more walrus were observed in 2009 east and northwest of Burger in or near remnant sea ice before the start of the first cruise as well as in open water near Wainwright. The higher walrus use of Burger during both years may be due to the higher abundance of benthic organisms (see beyond in report), and its close location to Hanna Shoal (historically used by walrus), as also possibly reflected by most 2009 walrus occurring in the northern half of Burger. The results also indicate a strong preference by walruses for sea ice. The reason for large numbers of walruses near Wainwright is unclear, but other researchers similarly encountered high walrus numbers in open water between Pt. Lay and Barrow in 2009 but not 2008.

- Broad movement patterns likely explain the differences in occurrence of cetaceans in the two survey areas in 2008 and 2009, with most differences probably associated with random occurrences of a given species at the time of a survey, particularly for minke whales, killer whales, and harbor porpoise. These animals are wide-ranging, few in number, and probably passing through one of the survey areas as they ranged over the Chukchi Sea in search of food. The situation may be different for gray and bowhead whales, which are seasonally abundant in the Chukchi Sea. Most gray whales occur close to shore so few would be expected in the two survey areas as shown in both 2008 and 2009. The two bowhead whales observed in 2008 and the three bowheads observed in October 2009 at Burger may have been fall migrants; Klondike was not surveyed in October in either year. While recent acoustic and satellite tracking data suggest that most bowheads migrate north of 71 N, which is north of the Klondike survey area but within the Burger survey area, historic data indicate that bowheads may also migrate in a southwesterly direction through both survey areas. Based on indications of on-going tagging studies and observation by local hunters, it is likely the majority of the bowhead fall migration in the Chukchi Sea occurred after the end of the research program each year as was likely the case also for beluga whales.

1.0 Introduction

The Chukchi Sea provides habitat to over ten species of marine mammals, some of which are key to the subsistence lifestyle of the coastal villages (Allen and Angliss 2010). Marine mammals migrate, summer, and reside year-round in the Chukchi Sea. Bowhead *(Balaena mysticetus)* and beluga (*Delphinapterus leucas*) whales migrate through the Chukchi Sea between summer and winter ranges (Allen and Angliss 2010) . Gray whales (*Eschrichtius robustus)*, minke whales (*Balaenoptera acutorostrata)*, and harbor porpoises *(Phocoena phocoena)* feed there during summer-fall (Allen and Angliss 2010). Use by spotted *(Phoca largha)*, ribbon (*Histriophoca fasciata)*, and most bearded *(Erignathus barbatus*) seals and walruses *(Odobenus rosmarus)* corresponds to the seasonal retreat and advance of the pack ice (Allen and Angliss 2010). Ringed seals, polar bears (*Ursus maritimus*), and a few bearded seals reside year-round (Allen and Angliss 2010). Other species occasionally found in the Chukchi Sea include small numbers of killer *(Orcinus orca)*, fin (*Balaenoptera physalus)*, and humpback (*Megaptera novaeangliae*) whales (Allen and Angliss 2010).

ConocoPhillips, Inc. (ConocoPhillips), Shell Exploration & Production Company (Shell), and Statoil USA E&P Inc. (Statoil) funded a multidisciplinary research program in the Chukchi Sea during the 2008 and 2009 open water seasons. The Chukchi Sea Environmental Studies Program integrates studies of marine mammals, seabirds, and fishes with physical, biological, and chemical oceanography and acoustics to build upon other research programs (e.g., Suydam et al. 2005, COMIDA 2009, Funk et al. 2009, Rugh et al. 2009) for developing a scientifically sound understanding of the ecology of the Chukchi Sea. This report addresses the marine mammal component of the 2009 program. The 2009 studies represent the second year of a three-year research program.

The purpose of the marine mammal program was to determine marine mammal use of the two oil and gas survey areas (Klondike and Burger) within Lease Sale Area 193 of interest to ConocoPhillips, Shell, and Statoil in the Chukchi Sea. The specific objectives of the program are to determine:

- Species composition, distribution, abundance, and density of marine mammals;
- Habitat use and behavior (e.g., feeding, mating, etc.) of marine mammals; and
- Influence of physical and biological oceanography on use by marine mammals.

2.0 Study Area

The study area is located in the northeastern Chukchi Sea over 100 km (62 mi) west of the village of Wainwright (Figure 1). Within the study area, the focus of the research was in two survey areas, Klondike and Burger. Each survey area was a 55.6 x 55.6 km (34.5 x 34.5 mi or 30 x 30 nm) box covering 3,091.4 km² (1,192 mi² or 900 nm²). The sizes and dimensions of the boxes (i.e., survey areas) were based on being large enough to include the areas of interest to ConocoPhillips, Shell, and Statoil and also large enough to provide meaningful research results. In addition, the areas transited to access the boxes from the village of Wainwright were surveyed, but they were ancillary to the main study area. Marine mammal sightings were linked to each area, and those sightings recorded outside but near a particular survey area were usually considered associated with that survey area, since the animal(s) were in areas assumed to be ecologically related to the survey areas.

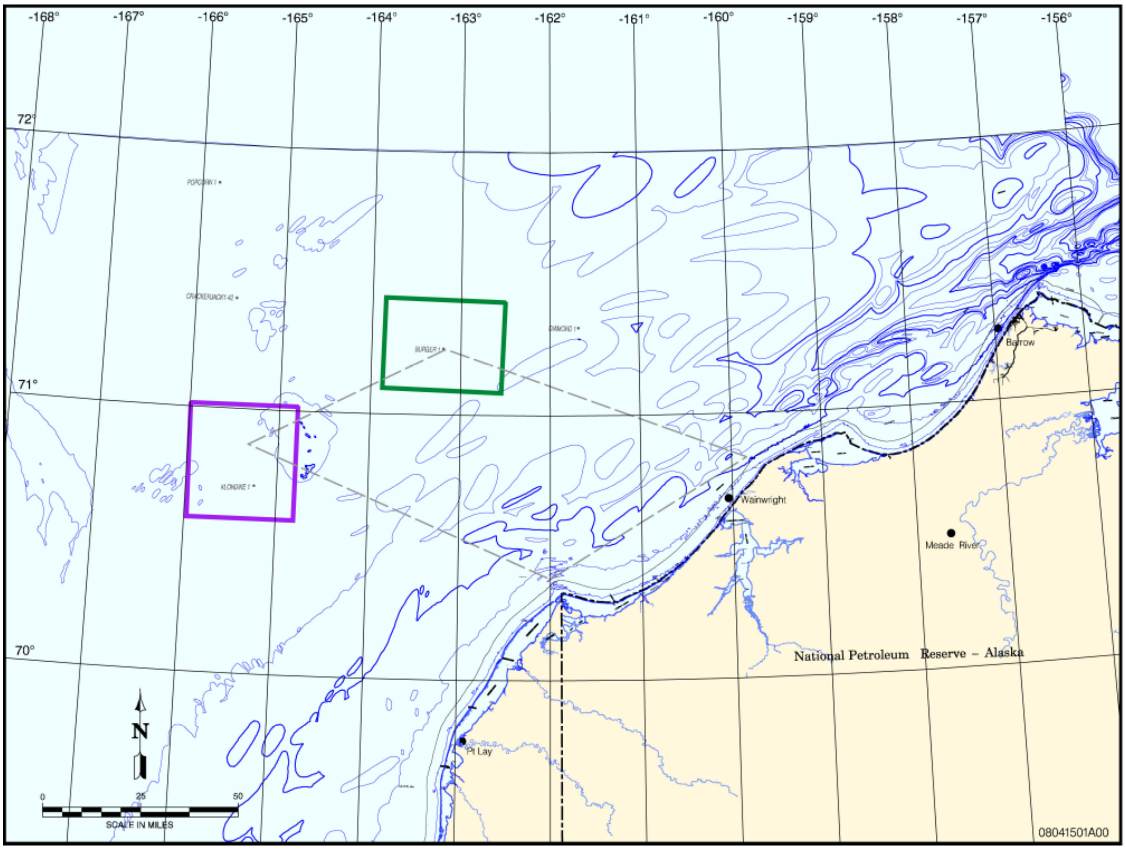

Figure 1. Study area showing the Klondike (purple) and Burger (green) survey areas.

The northeastern Chukchi Sea normally is ice covered from late fall to early summer and intermittently throughout summer in some years. Sea ice retreats northward through this area during approximately July and August and advances southward during November and December (Weingartner 2010). Ice movement largely is driven by the prevailing seasonal winds (Weingartner 2010). The dynamics of ice movement are highly variable among years in the Chukchi Sea, resulting in the pack ice at times moving beyond the shelf break during summer, as occurred in 2007, or remaining considerably south of the shelf break as occurring during more climatically severe years seen in the 1980's and early 1990's. This creates uncertainty about the length of time and duration ice may cover the two survey areas each year. Correspondingly, sea ice conditions can have a dramatic effect on the species abundance and composition of marine mammals inhabiting the survey areas (Brueggeman et al. 1990, 1991, 1992).

The two survey areas have different oceanographic characteristics that can affect use by marine mammals. The substrate at Klondike is sandier while Burger has more soft sediment, apparently creating better habitat at Burger for mollusks and other benthic organisms that inhabit soft sediments (Blanchard et al. 2009). Species composition of benthic organisms is similar between the two survey areas, but biomass and abundance are greater at Burger (Blanchard et al. 2009).

Oceanographic conditions at the two areas also suggest differences driven by currents and hydrography (Weingartner et al. 2005). Currents carry nutrients, carbon, heat, and animals from the Bering Sea to the Chukchi Sea and the Arctic Ocean (Weingartner et al. 2005). Within the Chukchi Sea, water inflows separate into three pathways: (1) a saline, western current flowing into the Hope and Herald Canyons; (2) a low saline eastern current moving to the east and into Barrow Canyon; and (3) a cold, highly saline current flowing northernly into the Central Channel and slowly over the southern flank of Hanna Shoal, ultimately joining waters exported into the basin of the Arctic Ocean through Barrow Canyon (Weingartner et al. 2005). Currents are affected by winds, which are the principal cause of flow variations, and can be substantial (Weingartner et al. 2005). Over the northeastern Chukchi Sea shelf, current fluctuations are coherent with variations with wind velocity over spatial scales of at least 300 km, with currents responding to wind variations in something less than a day (Weingartner et al. 2005). Such fluctuations can cause high interannual variability in the ecology of a given area, particularly at the geographic scale of Klondike and Burger recorded in 2008 and 2009 (T. Weingartner, Institute of Marine Sciences, University of Alaska, Fairbanks, AK, pers. comm. 2010). Distinctly different water masses occurred in Klondike and Burger in 2008, but they merged together in the two areas during 2009 (T. Weingartner, Institute of Marine Sciences, University of Alaska, Fairbanks, AK, pers. comm. 2010).

3.0 Methods

Survey Design and Procedures

Surveys were conducted from a research vessel within each survey area during three consecutive cruises from 12 August through 15 October 2009 (Figure 2); marine mammal observations also were conducted opportunistically between 8-10 August when deploying/retrieving acoustic equipment northeast and east of Burger, and 20-25 September and 15-16 October, when the vessel transited between Nome and the general survey area in the middle and again at the end of the research program. Each cruise was approximately 20 days long. Marine mammal observers (MMOs), trained biologists experienced in marine mammal surveys who also participated in the 2008 Chukchi Sea survey, recorded marine mammals along up to 31, 55.6 km (34.5 mi or 30 nm) long north-south transect lines equidistantly spaced 1.8 km (1.2 mi or 1 nm) apart across each survey area (Figure 2); MMOs were at times assisted by Inupiat Communicators, who represented the local villages. Every other line (high priority lines) was initially surveyed to ensure both survey areas were entirely covered during each of the three cruises. Skipped transect lines (low priority lines) were surveyed when time and conditions permitted to extend coverage within each survey area. Transect lines were surveyed sequentially to minimize fuel usage and maximize survey time whenever possible. For analytical purposes, north-south lines were called systematic, connecting east-west lines deadheads, and all other lines transits; transits between the survey areas and Nome were not included in the analysis beyond listing the species and number observed incidentally during the transits.

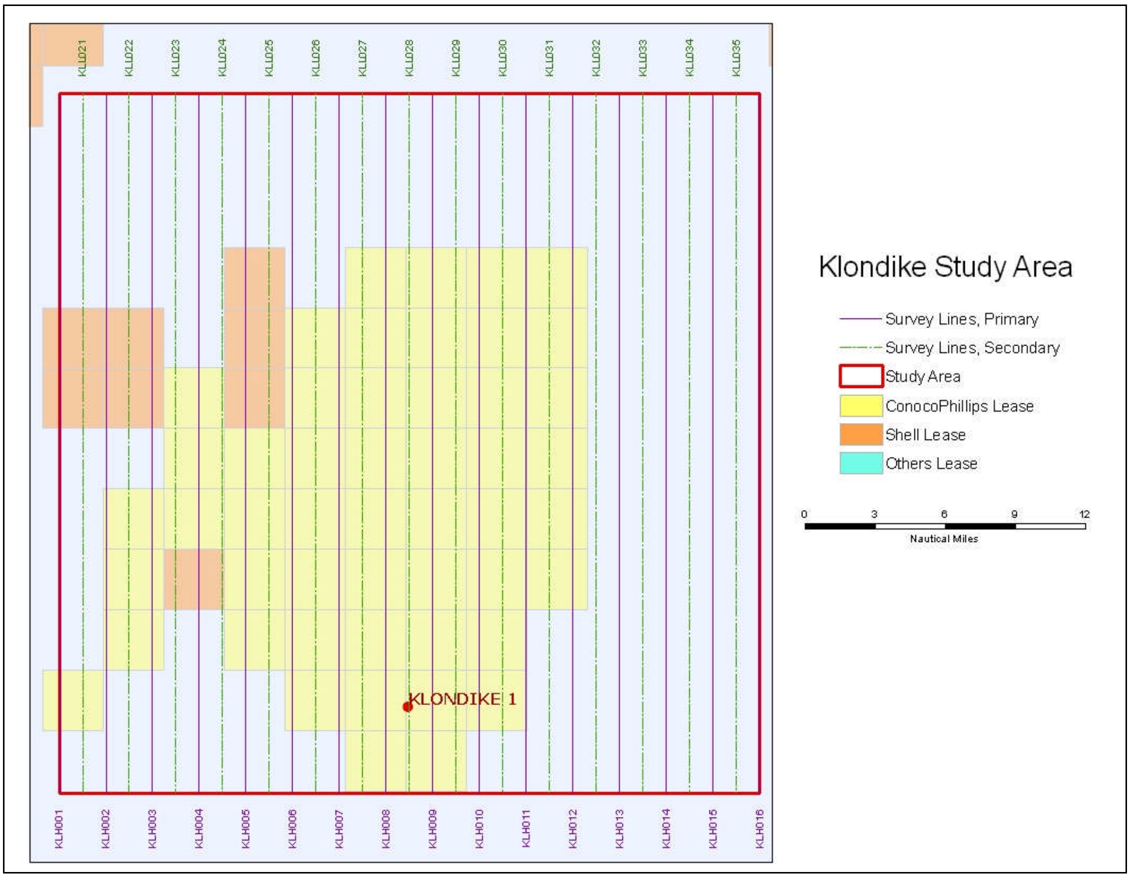

Figure 2. Klondike survey area showing transect line configuration.

Klondike and Burger were surveyed consecutively during each of the three cruises. The first area surveyed during the research program was Klondike and the last area surveyed was Burger, which resulted in only Burger being surveyed in October when bowheads begin to migrate through the Chukchi Sea. One survey area generally was completed before moving to the other survey area. A full survey at each survey area required a minimum of 6 days to complete, assuming a cruising speed of 8-10 kt. However, variation in suitability of weather between survey areas and cruises resulted in variation in the number of days required to complete a survey on a given survey area or cruise.

Marine mammals were observed from the bridge, the best available vantage point on the vessel. The biologists systematically scanned the survey area with the naked eye, aided by 7 X 50 Fujinon reticule binoculars, and used a set of high-powered stabilizing Fujinon binoculars for confirming species identification and behavior of the more distant animals, particularly during higher sea states. MMOs focused on the 180° area centered on the vessel's trackline to detect marine mammals, with occasional scans of the area behind the vessel to search for animals that may have been missed. Marine mammal observations occurred during essentially all daylight hours every day, depending on weather conditions with two observers alternating watches every 2 hr to minimize fatigue. Data were recorded on a handheld electronic tablet linked to an on-board computer system (Tiger). The tablet was preprogrammed with data fields, including pull-down menus for entering observations, which reduced data entry errors and maintained data consistency. A brief narrative was also recorded by biologists in field notebooks of more detailed observations of marine mammals or survey conditions.

When a marine mammal sighting was made, the following information about the sighting was recorded:

- Species, number, group size, age/size/sex categories (if determinable), behavior, direction of travel (cetaceans), and radial angle and distance from observer to sighting;
- Date, time, and location of the vessel;
- Sea state (Beaufort Wind Scale), ice cover (10% increments), visibility, and sun glare; and
- The positions of any other vessel(s) in the vicinity of the research vessel.

The ship's position and water depth, sea state, ice cover, visibility, and sun glare were recorded at the start and end of each transect line, every 30 min, and whenever there was a sighting or change in one or more of those variables. Location, time, and date were automatically linked by the computer system to the visual observations.

Distances to nearby marine mammals were estimated visually or with sighting aids (laser rangefinder, fixed points, clinometer, reticule in binocular). Observers used sighting aids to test and improve their abilities for visually estimating distances to marine mammals when conditions (no horizon) prevented using reticule binoculars. Surveys were generally not conducted during sea states exceeding a Beaufort 6, because marine mammals become too difficult to detect in seas this high (Barlow 2006; see Appendix A-1 for sea state descriptions). Field data were manually and electronically checked by biologists and a quality control specialist at the end of each day for accuracy, completeness, and consistency. Additional quality control of the data occurred after each cruise using a computer program before commencing analysis.

Analytical Procedures

Density was calculated for seals and walruses but not for each seal species, cetaceans, or polar bears, since there were insufficient sightings to obtain a meaningful density estimate. Density was calculated by using the line-transect estimation method (Burnham et al. 1980).

Density was calculated as follows:

$$D = \frac{n \times S \times f(0)}{2 \times L \times \mathrm{g}(0)}$$

where D = density of a species in number of animals/km^2

n	=	number of sightings
S	=	mean group size
f(0)	=	sighting probability density on the transect line
L	=	length of transect line completed (in km)
g(0)	=	probability of seeing a group directly on the transect line

The parameters f(0) and g(0) are correction factors to minimize biases in estimates of actual number of marine mammals. The parameter f(0) accounts for the reduced probability of detecting an animal as its distance increases from the transect line. The f(0) value used to calculate density was derived by using the software Distance 5, release 2 (Thomas et al., 2006). The parameter g(0) accounts for animals surfaced or sub-surfaced on the transect line but missed during the survey. The g(0) value used to calculate density was 1, which assumes the MMOs saw all animals on the transect line. Experiments were not conducted in the field to calculate the actual value of g(0), but it is likely that observers saw most, if not all, of the seals on the transect line due to the experience of the MMOs, height of the ship's bridge (survey platform), and generally good survey conditions.

Other variables analyzed included observation conditions, behavior, and distribution. Observation conditions were subdivided into sea state, visibility, and glare. Behavior was subdivided into a number of categories readily distinguished by the marine mammal observers and described under the results. Both spatial and temporal distribution was analyzed using graphical depictions of the marine mammal locations by cruise and number of marine mammals over time. Sample sizes were generally too small to conduct statistical analysis by species, so the results for the above mentioned variables were graphed as percentages of total number of groups or as total number of sightings per event. Seal species were pooled into a single group to increase sample size for most analyses.

4.0 Results

Species Composition and Numbers

A total of 344 sightings of 589 marine mammals of nine species was recorded in the study area during 2009 (Table 1). Seals were the most abundant pinnipeds, which included ringed/spotted and bearded seals in decreasing order of abundance; no ribbon seals were encountered in 2009. Ringed and spotted seals were combined into one group because of the frequent difficulty of distinguishing between the two species in open water; however, they were identified to species when possible. Approximately 25% of the seals were not identified to species and were listed as unidentified seals. The difficulty of distinguishing seal species in open water combined with occasional periods of marginal viewing conditions, brief surfacing, sightings at long distances from the vessel, and restrictions on the vessel to stop or deviate from a transect line because of mitigation measures instituted by ConocoPhillips, Shell, and Statoil, resulted in unidentified species. The remaining pinniped species observed during the cruise was the Pacific walrus, which numbered just over 300 animals or about 62% of the total number of pinnipeds. Small numbers of unidentified pinnipeds (10) were also recorded when conditions were not suitable for distinguishing pinniped species. Twenty-seven calves/juveniles were recorded during the cruise, which 25 walrus calves, one bearded seal, and one ringed or spotted seal.

Four species of cetaceans were recorded in the study area (Table 1). Gray whales were the most abundant (77) cetacean, followed by small numbers of harbor porpoises (3), bowhead whales (3), and minke whales (2). There were no beluga or killer whales observed during the cruises, although they occur in the Chukchi Sea (George and Suydam 1998, Suydam et al. 2005, Allen and Angliss 2010). There were two unidentified whales, of which one was dead and in an advanced state of decay, making species identification uncertain. There were also three sightings of four polar bears, including an adult with a cub.

Table 1. Sightings and numbers of marine mammals observed in northwestern Chukchi Sea, August-October 2009.

Species	All cruises							
	Klondike		Burger		Other		Total	
	No.	Sightings	No.	Sightings	No.	Sightings	No.	Sightings
Ringed/Spotted	36	32	31	30	2	2	69	64
Ringed Seal	6	6	11	11	1	1	18	18
Spotted Seal	7	7	5	5	3	2	15	14
Bearded Seal	7	7	22	21	4	4	33	32
Walrus	8	6	62	34	239	84	309	124
Unident seal	22	22	21	21	1	1	44	44
Unident pinniped	5	5	5	5	0	0	10	10
Gray Whale	1	1	1	1	75	24	77	26
Minke Whale	1	1	0	0	1	1	2	2
Bowhead Whale	0	0	3	2	0	0	3	2
Harbor Porpoise	0	0	0	0	3	2	3	2
Unident whale	0	0	2	2	0	0	2	2
Polar Bear	0	0	0	0	4	3	4	3
Total	93	88	163	132	333	124	589	344

The number and species composition of marine mammals differed between the two survey areas (Table 1). More seals, walruses, and cetaceans were at Burger, whereas all polar bears were encountered outside of the two survey areas as described below:

- All four species of pinnipeds were recorded at both survey areas, with slightly more of the seals (54% of 168 seals) but many more of the walruses (89% of 70 walruses) at Burger.

- All species of seals were similarly abundant at both survey areas except for bearded seals, which were more abundant at Burger; however, the differences in numbers were not statistically significant (95 % Confidence Limits) between Burger and Klondike.
- Of the four cetacean species observed in the two survey areas, only gray whales were recorded in both areas.
- Equal numbers of gray whales (1) were recorded at both survey areas, whereas all of the bowhead whales were recorded at Burger and the minke whale was recorded at Klondike.
- Small numbers of seals (6%), most walruses (77%), most gray whales (97%), all harbor porpoises, and one minke whale were recorded in areas outside of the survey areas on transits to and from Wainwright and when deploying acoustic equipment northeast and east of Burger during the week before the start of the first survey cruise. A large number (> 130) of walruses were encountered near Wainwright in late August and early September.

An additional 34 marine mammals were observed while transiting between the study area and Nome in late September and again in mid-October, which are not included in the table or the analysis provided in this report. They included 14 seals (ringed, spotted, bearded), 2 walruses, 2 unidentified pinnipeds, 5 Dall's porpoises, 4 humpback whales, 3 fin whales, 2 gray whales, 1 minke whale, and 1 unidentified whale. Humpback and fin whale and Dall's porpoise were recorded in the southern Chukchi Sea.

Survey Effort

A total of 434 hours of survey effort covering almost 6,400 km (3977 mi) of transect line was conducted for marine mammals at the Klondike and Burger survey areas, and areas outside of them, between 12 August and 15 October, 2009 (Table 2). Survey effort was essentially equal between the two survey areas. Less than about 6 % of the effort occurred during transits between the survey areas and Wainwright.

Table 2 Marine mammal survey effort during Chukchi Sea surveys, August –October 2009.

Location	Effort (hr)	% Effort	Effort (km)	% Effort
Klondike	203	47	3,060	48
Burger	206	47	3,128	49
Other	25	6	182	3
Total	434	100	6,370	100

Survey effort varied slightly among the three cruises (Figure 3). Effort was similar between the first and second cruises (35% of total survey effort), but slightly lower during the last cruise (30% of total survey effort) primarily due to inclement weather conditions that limited surveys (Figure 3). Percent effort was also similar at Klondike and Burger for each cruise, varying less than 10% per cruise (Figure 4). Effort in other locations represented a small percentage for each cruise, and there was no effort of that type during the last cruise, since the vessel headed directly for Nome.

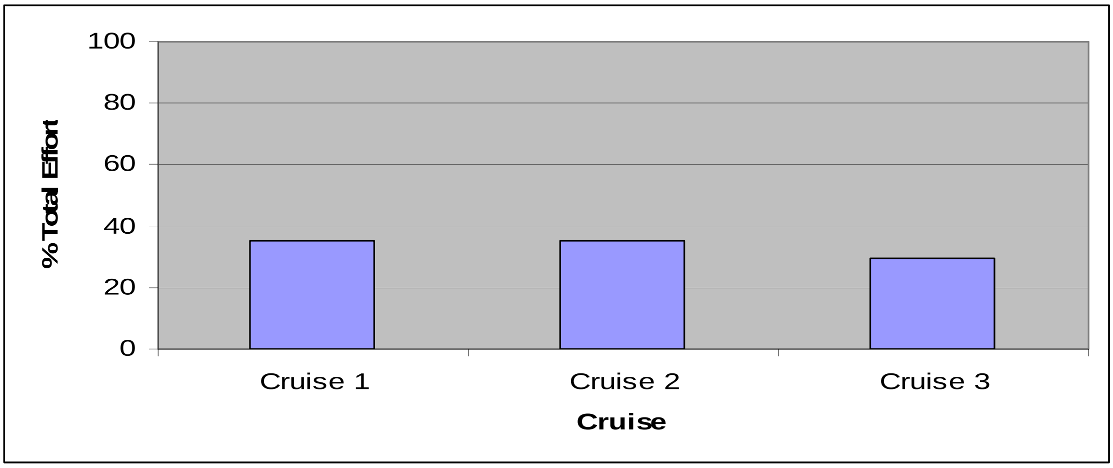

Figure 3. Survey effort in the northwestern Chukchi Sea August – October 2009, by cruise.

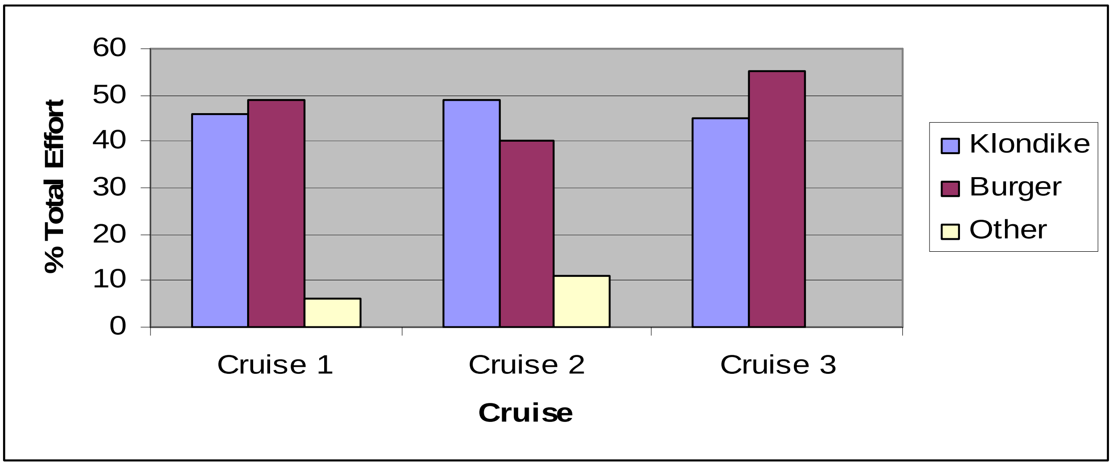

Figure 4. Survey effort at Klondike and Burger survey areas in the northwestern Chukchi Sea, August – October 2009, by cruise.

Survey Conditions

Sea state, visibility, and glare were recorded to gauge observation conditions during the marine mammal research program. High sea states, poor visibility, and severe glare can substantially reduce the effectiveness of detecting marine mammals, subsequently influencing the results of survey activities (e.g., density estimates) on marine mammals. Sea ice cover was also recorded, because it affects the species composition and abundance of marine mammals.

Sea state conditions of Beaufort six or less are typically considered acceptable for surveying marine mammals (Barlow 2006). Higher sea states make detecting a marine mammal difficult. Sea state conditions were acceptable (0-6) over 90% of the time at the two survey areas with 0-4 sea states occurring over 80% of the time (Figure 5). Sea states were proportionately lower during Cruise 2 at Burger and Klondike, higher during

Cruise 3 at both areas, and mixed (higher at Klondike and lower at Burger) during Cruise 1. Sea states ranging from 2 to 4 were most common in the two survey areas during each cruise. Low to moderate sea states (0-4) were most common on transits outside of the two survey areas.

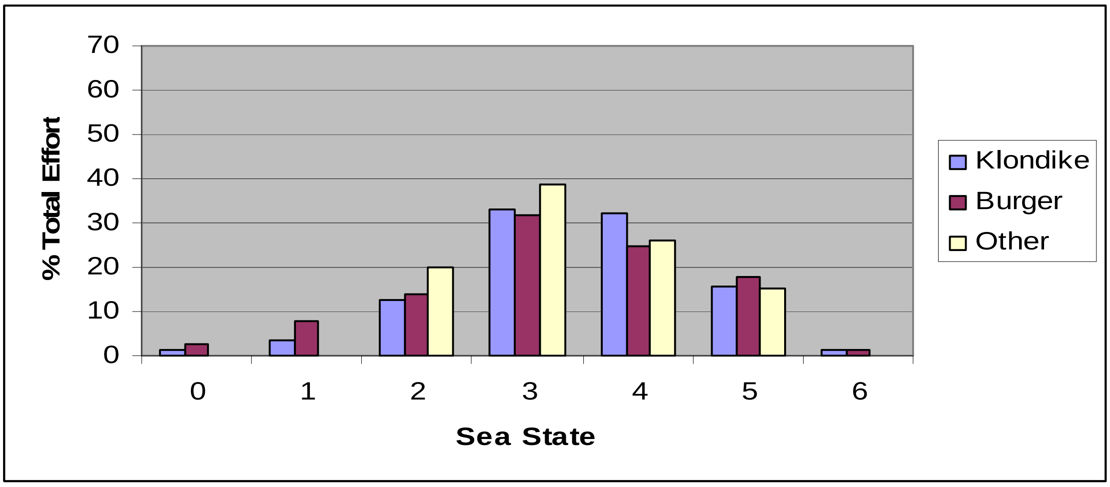

Figure 5. Sea state during marine mammal surveys in the northwestern Chukchi Sea, August – October 2009 (sea state descriptions in Appendix Table A-1)

Higher visibility enables a greater area to be monitored for marine mammals. Visibility from the vessel was greater than 1 km (0.2 mi) the majority (> 90%) of the survey effort at the two areas (Figure 6). The percentages of time visibilities exceeded 5 km (3.1 mi) were 95% at Klondike and 88% at Burger. Visibility was variable beyond 3.5 km (2.2 mi) from the vessel for Burger and Klondike < 20% of the survey time; this was a category used when visibility conditions frequently varied back and forth beyond 3.5 km (2.2 mi) from the vessel. A similar pattern occurred during each of the three cruises at the two survey areas, with almost all of the effort occurring at visibilities exceeding 5 km (3.1 mi). The only noteworthy difference in visibilities per cruise was during Cruise 1 at Burger when about 20% of the effort occurred during visibilities ≤ 3 km (1.9 mi compared with 1-6% for all other cruises. Visibility in areas outside of the two survey areas generally was similar to that recorded within them.

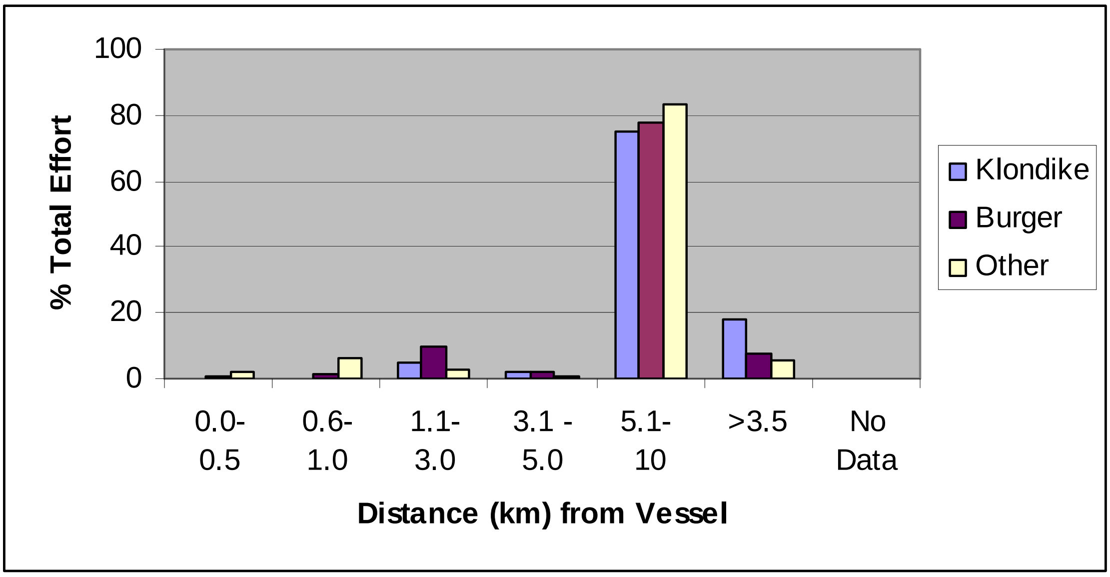

Figure 6. Visibility conditions during marine mammal surveys in the northwestern Chukchi Sea, August – October 2009.

Glare, like sea state and visibility, affects the ability to detect marine mammals by reducing the area effectively seen by an MMO. Glare conditions were largely acceptable (light to moderate) for conducting marine mammal surveys at both Klondike and Burger (Figure 7). Light to no glare conditions occurred most often during surveys at Klondike (76%) and Burger (80%), whereas severe glare occurred < 10% of the time and moderate glare occurred ≈ 6% of the time at each survey area. Glare was variable about 10% of the time. Conditions were acceptable during all three cruises except when glare was severe for about 20% of the survey time during Cruise 3 at Klondike compared to single digit values the rest of time in both survey areas. Glare was more prominent in areas outside of the two survey areas, particularly during the second cruise when moderate glare occurred at relatively large proportion (58%) of the time. In all cases where glare hindered observations, the area affected was generally a small proportion (< 10%) of the total area viewed by the observers, so most of the area was still effectively surveyed, even under severe glare conditions.

These results show that observation conditions as measured by glare, sea state, and visibility were variable but suitable for the observers to detect and observe marine mammals most of the time at both survey areas. Survey conditions during each cruise also varied, but there was no consistent pattern among the three metrics to distinguish one cruise from another. Any difference in one metric typically was balanced by variation in another metric. Therefore, observation conditions probably had little effect on the comparability of the results among the three cruises and between the survey areas.

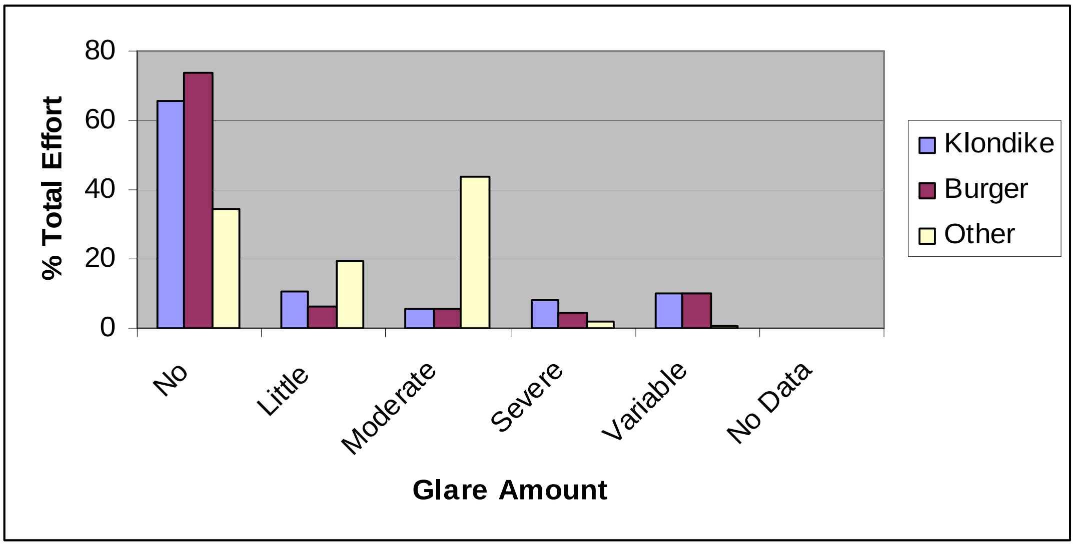

Figure 7. Glare conditions during marine mammal surveys in the northwester Chukchi Sea, August – October 2009. Glare was measured within the 180° viewing area centered on the bow of the vessel (no = none; light = easy to view survey area; moderate = see an animal's shape but not always able to distinguish species; severe = too bright to view the survey area in front of the vessel; variable = frequently changing glare conditions).

Sea ice was not present at Klondike or Burger during the survey, but ice was present immediately north of Burger during the first cruise based on satellite maps and observations by MMOs on the vessel. Sea ice had disappeared by the start of the surveys in early August. The research program ended in mid-October, before the pack ice advanced southward through the survey areas to the Bering Sea.

Spatial and Temporal Distribution

Seals were widely distributed in space and time throughout all of the areas surveyed during the research project (Figure 8). At Klondike, seals were recorded on about half (48%) of the total number (23) of survey days; highest numbers (51%) of seals were recorded near the end (September 28) of the program (Figure 9). There was no obvious spatial pattern of occurrence by any seal species or seals as a group in the survey area. A similar spatial pattern was observed at Burger for seals (Figure 8). Seals were recorded on 73% of the total number of survey days (22) (Figure 10). Most (61%) of the seals were recorded in mid-September (13-18), and daily counts averaged slightly higher (4.1 vs. 3.4 seals/survey day) at Burger than at Klondike. Each seal species was seen throughout the program, indicating no temporal pattern of use. In addition, most bearded seals occurred during the periods of highest seal numbers in each survey area, which was also associated with better viewing conditions due to lower sea states.

Outside of the survey areas on transits to Wainwright and elsewhere, seals were seen on 4 of the 14 survey days, spread across the research program (Figure 11). Most (55%) were recorded during mid-September (19th) similar to what was seen at Burger. Again, all three seal species were observed throughout the program. Three of four bearded seals were recorded in sea ice before the start of the first cruise. The results show that all three seal species were present in and outside of the two survey areas throughout the research program with most occurring during mid to late September in open water.

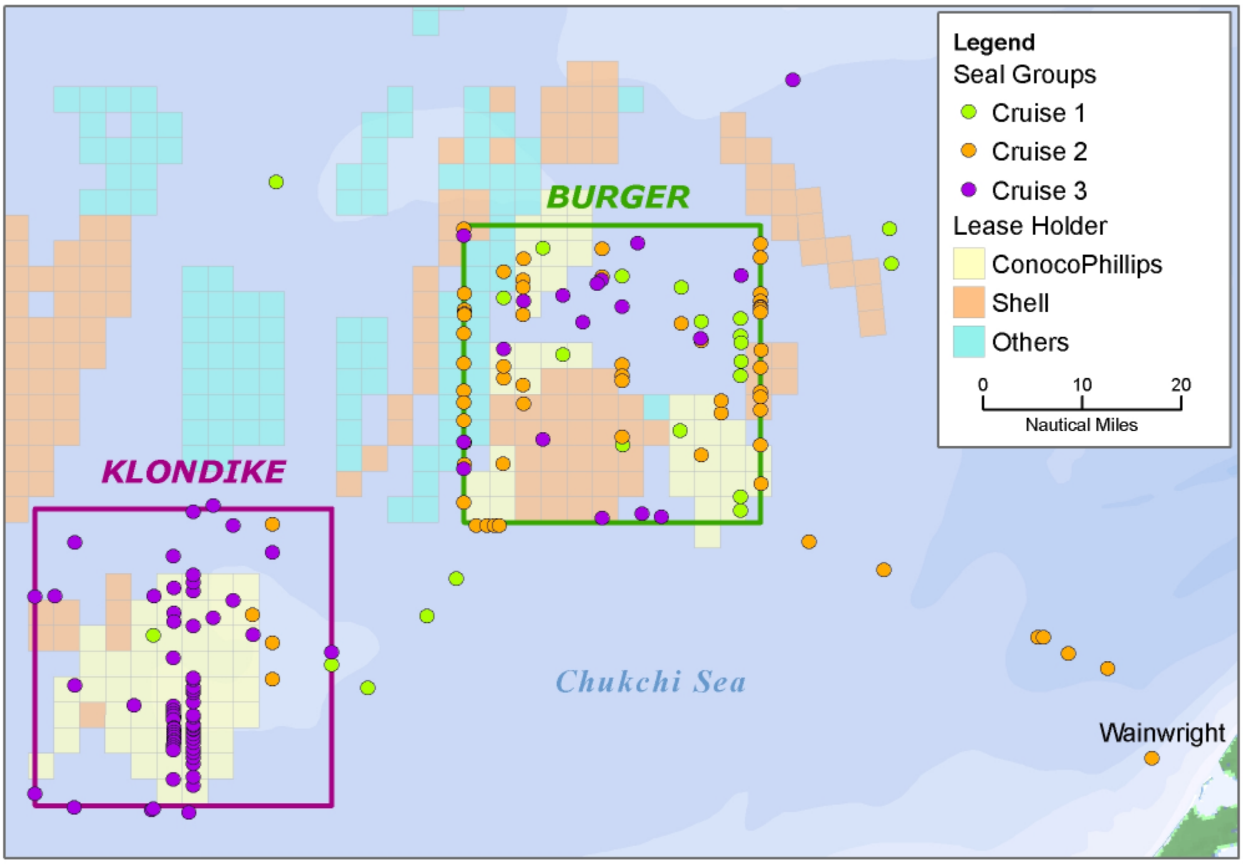

Figure 8. Seal sighting locations recorded at the Klondike and Burger survey areas, during transits to Wainwright, and when deploying/retrieving acoustic equipment during the three cruises in the northwestern Chukchi Sea, August – October 2009.

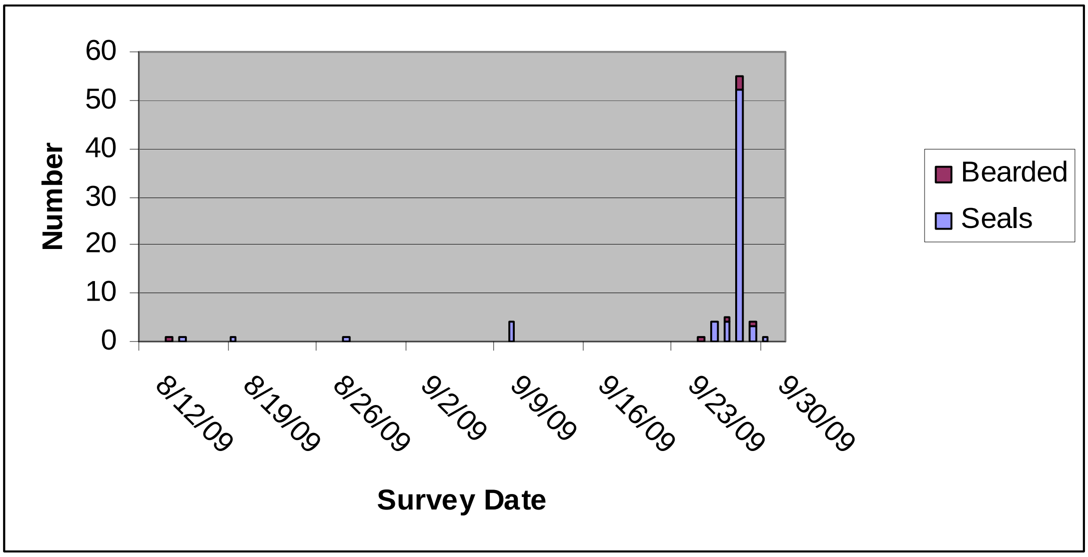

Figure 9. Number of seals (ringed and spotted seals) and bearded seals recorded at the Klondike survey area from 10 August to 1 October, 2009, by date.

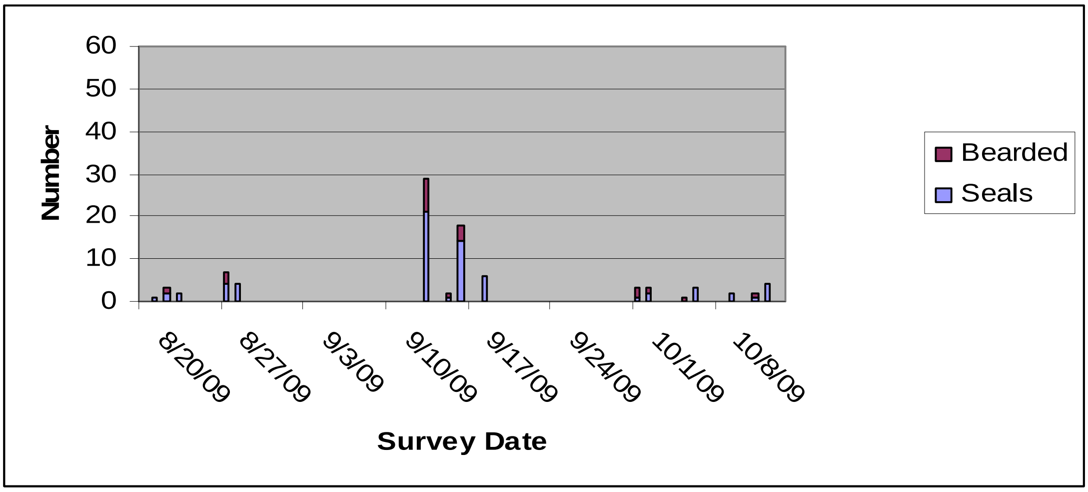

Figure 10. Number of seals (ringed and spotted seals) and bearded seals recorded at the Burger survey area from 20 August to 13 October, 2009, by date.

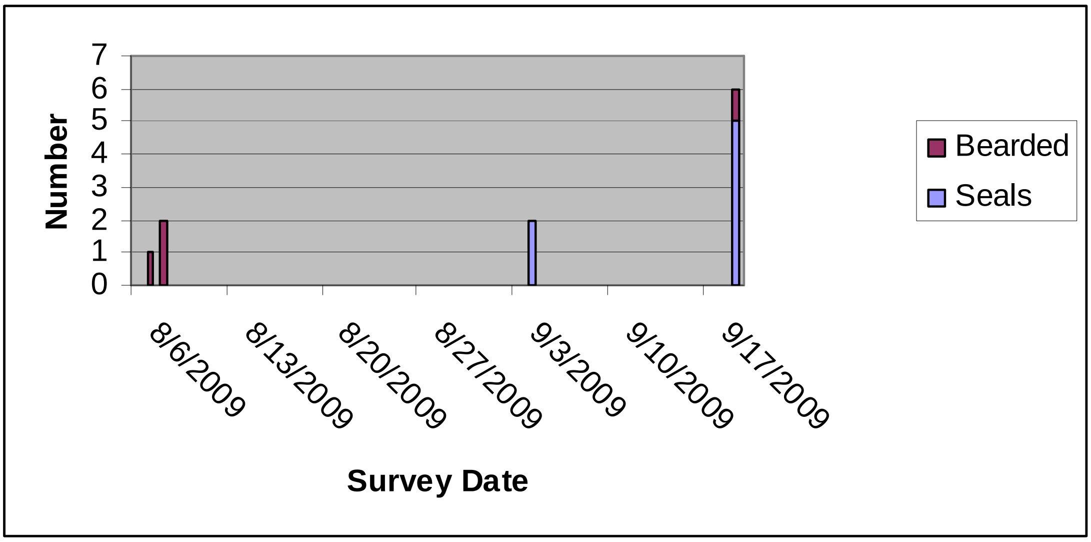

Figure 11. Number of seals (ringed and spotted seals) and bearded seals recorded outside of Burger and Klondike survey areas, August – October 2009, by date. Surveys were conducted outside the two survey areas on 8/6-10, 8/24-25, 8/30-31, 9/1-4, and 9/19/09.

The spatial and temporal distribution of walruses was more concentrated than seals in the study area during the research program (Figure 12). At Klondike, walrus were recorded during a small proportion (26%) of the total survey days between mid-August and mid-September (Figure 13); no more than two animals were seen on any given survey day. Conversely, walruses were observed at Burger on almost half (45%) of the survey days during essentially the same general time as those found at Klondike (Figure 13). No more than 21 animals were observed on any given day with most daily sightings totaling fewer than 10 walruses. At Burger, most walruses were recorded primarily in the northern half of the survey area, whereas there were too few sightings at Klondike to distinguish a spatial distribution pattern (Figure 12). Most walruses, however, were recorded outside of the two areas primarily northeast of Burger and near Wainwright during the period when walruses were recorded at the two survey areas. Daily counts averaged 21.7 (1-87 range) walruses outside of the survey areas, compared with 6.6 (1-21 range) at Burger and 1.2 (1-2 range) at Klondike. Particularly large numbers were recorded at the start of the program in early August, when ice was present while deploying acoustic equipment northeast of Burger. A smaller spike in walrus sightings occurred from late August to early September, both inside and outside of Burger, after sea ice had retreated much farther north. Some unidentified pinnipeds possibly were walruses, particularly where they were recorded at or near the time when walruses were seen in the survey areas.

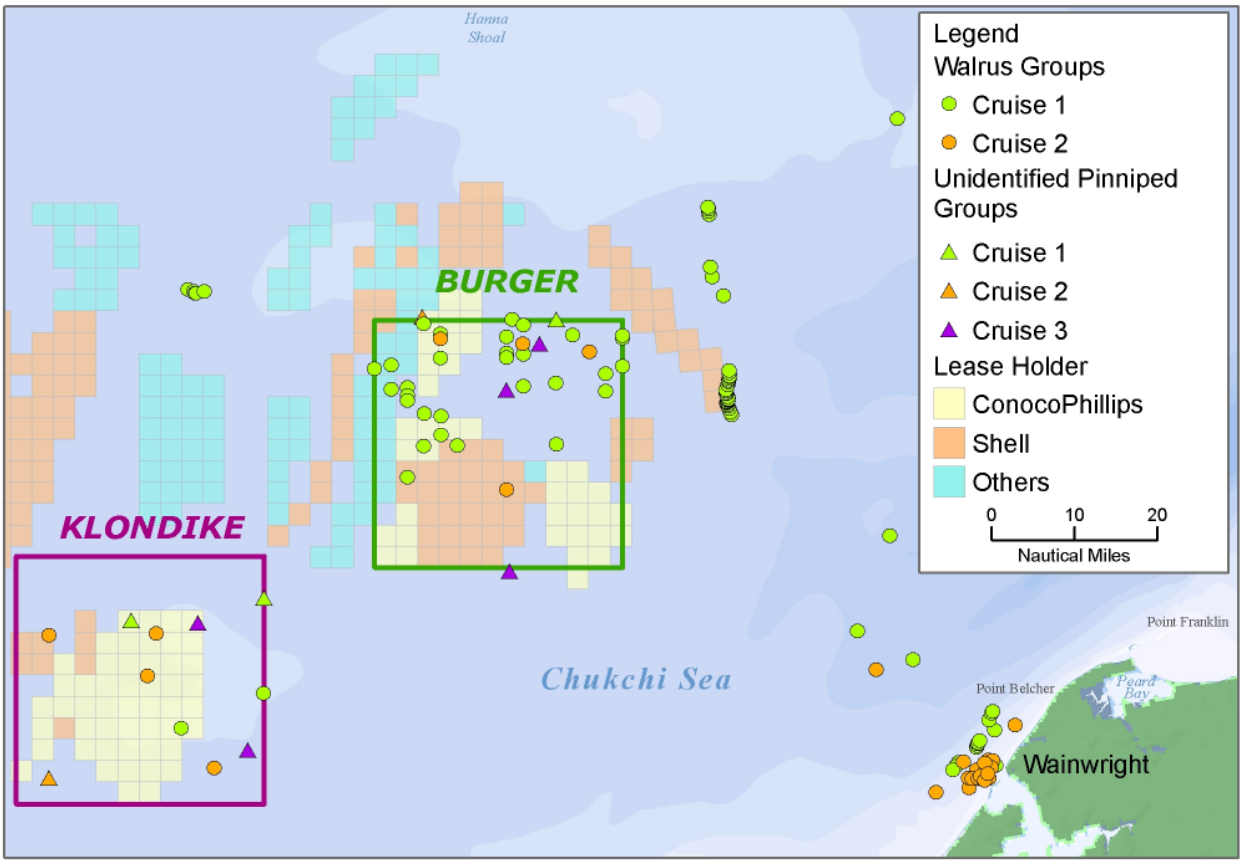

Figure 12. Walrus and unidentified pinniped sighting locations recorded at the Klondike and Burger survey areas, during transits to Wainwright, and when deploying/retrieving acoustic equipment during the three cruises in the northwestern Chukchi Sea, August – October 2009.

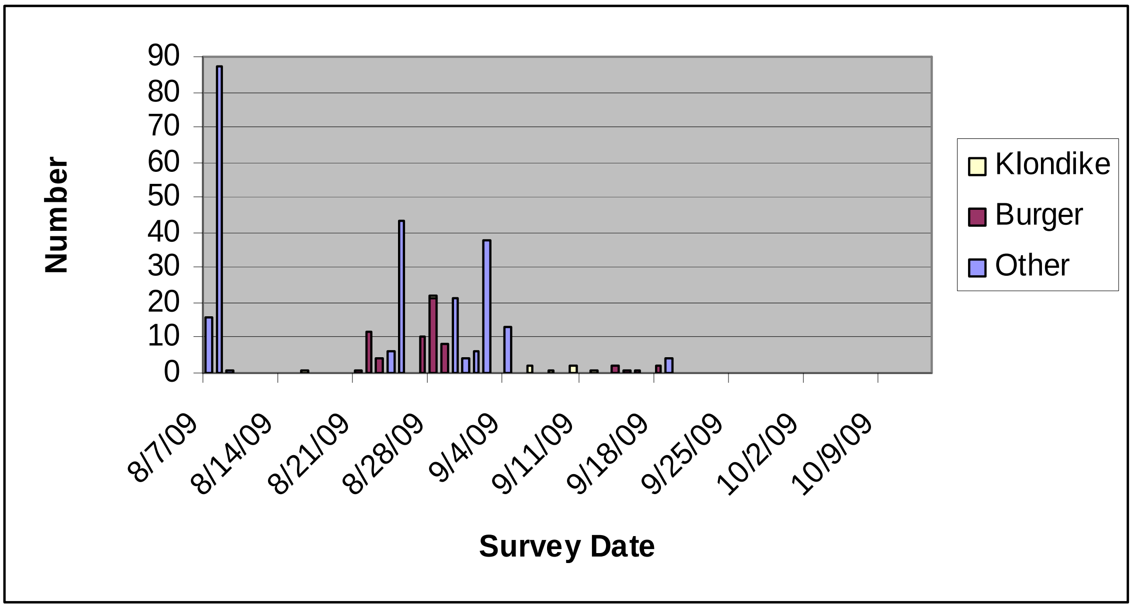

Figure 13. Number of walrus recorded at the Burger and Klondike survey areas from 20 August to 13 October, 2009, by date.

Cetaceans were widely scattered in time and space in the study area with specific differences among species (Figure 14). At Klondike, minke and gray whales were encountered during only 2 (9%) of the survey days, with all recorded in August. At Burger, cetaceans were recorded during 4 (18%) of the survey days; all but one cetacean (unidentified species) were recorded after October 1, including three bowhead whales, one gray whale, and one unidentified species. Outside of the two survey areas, cetaceans were recorded throughout the research program during each transit to Wainwright (Figure 14). Large numbers of gray whales were recorded in late August and again in mid-September within 48 km (30 mi) of the coast off Wainwright and Point Belcher (Figures 13 and 14). One minke whale was recorded in early August and harbor porpoises were recorded in late August and mid-September.

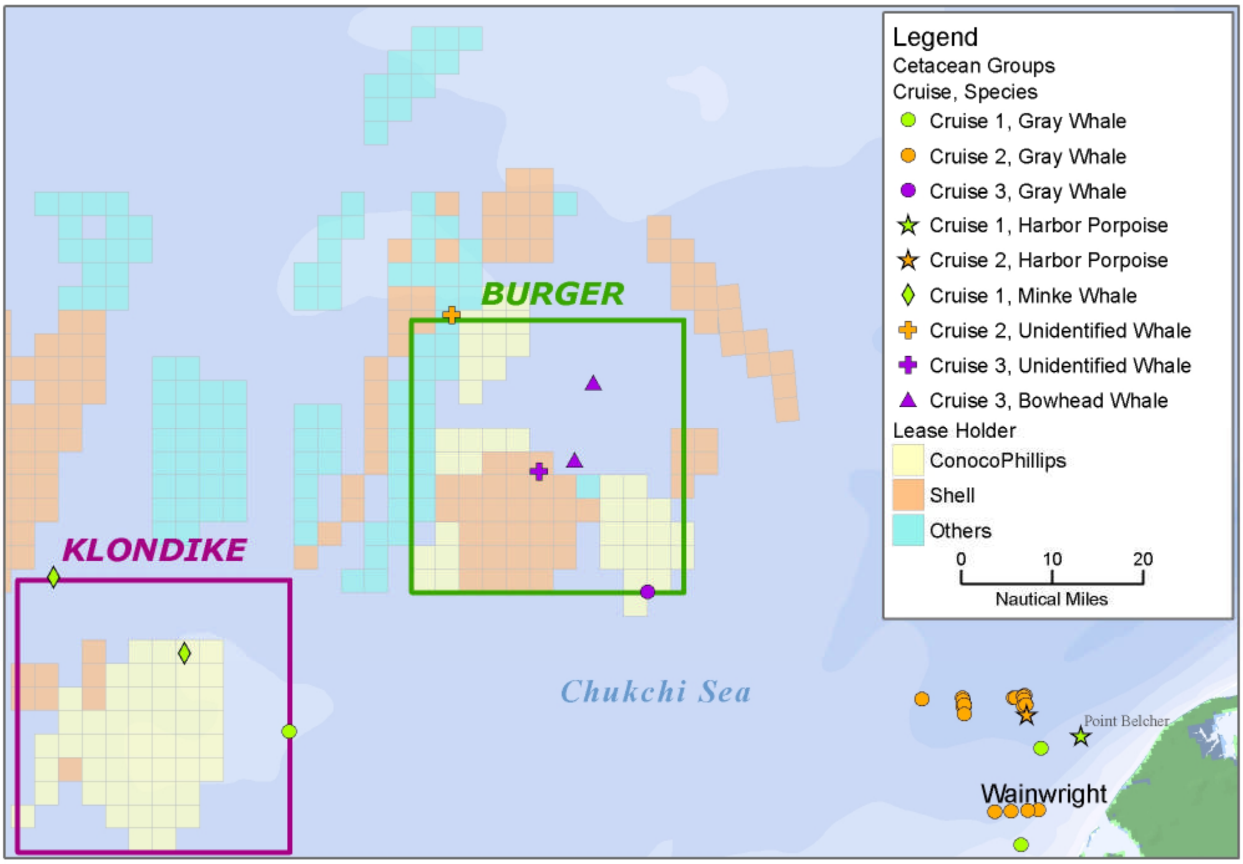

Figure 14. Cetacean sighting locations recorded at the Klondike and Burger survey areas, during transits to Wainwright, and when deploying/retrieving acoustic equipment during the three cruises in the northwestern Chukchi Sea, August – October 2009.

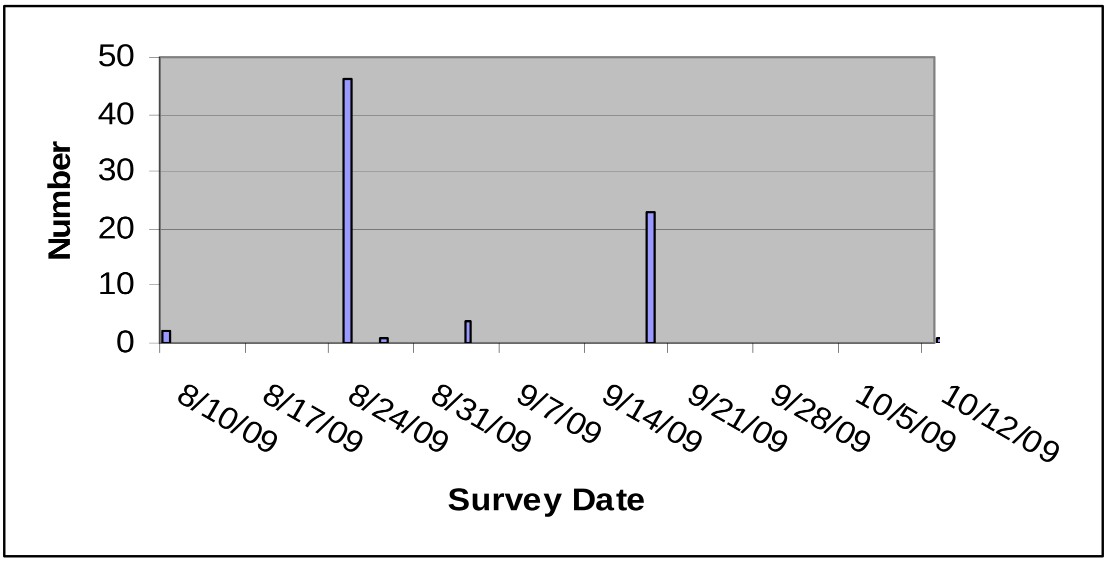

Figure 15. Number of gray whales recorded in the study area, August – October 2009, by date.

Polar bears were recorded outside of the two survey areas when sea ice was present during deployment of acoustic equipment before the start of Cruise 1 (Figure 16). All three sightings were recorded on ice east and northeast of Burger during three consecutive days in early August, and no bears were recorded after the sea ice moved north of the study area. The timing and spacing of locations suggests all three sightings were new bears and not duplicate counts, since two of the sightings occurred relatively close together (18 km or 11 mi) over a short period of time (24 hr) as the vessel traveled southwesterly, and the third sighting was too far away (93 km or 50 mi) and too close in time (within 24 hr) from the other sightings to be a duplicate bear.

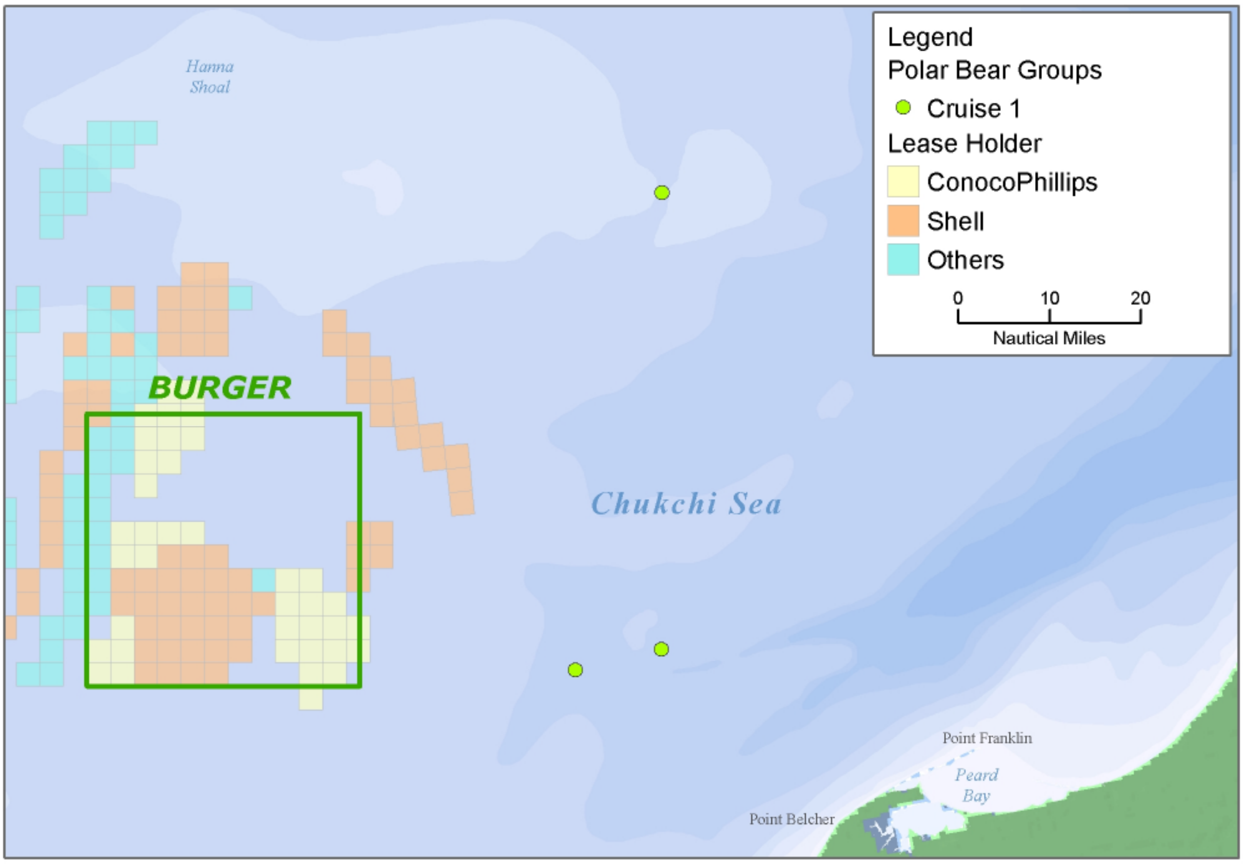

Figure 16. Polar bear sighting locations recorded at the Klondike and Burger survey areas, during transits to Wainwright, and when deploying/retrieving acoustic equipment during the three cruises in the northwestern Chukchi Sea, August – October 2009.

Behavior

Marine mammal behavior was recorded during the research program. Seal behavior primarily consisted of swimming, with lesser but similar proportions of seals looking and diving (Figure 17). This pattern was consistent among ringed/spotted seals, bearded seals, and all seals combined suggesting some seals may have been moving through the survey areas. No seals were observed feeding but a small proportion was recorded resting. A similar pattern of behavior occurred between survey areas and among survey periods, although the proportions varied among the three primary behaviors (Figure 18). At Klondike, sample sizes were sufficient only for analyzing behavior during the last cruise (n = 66 vs. 4 groups for each of Cruises 1 and 2), when seals displayed approximately equal proportions of swimming, looking, and diving. At Burger, swimming was the primary behavior during all cruises except Cruise 2 when diving was the primary behavior. Seal behavior in areas outside of the survey areas consisted primarily of swimming, diving, and also resting, but small sample sizes (0-7 seals/cruise) made interpretations of the observed variability in seal behavior between cruises unclear.

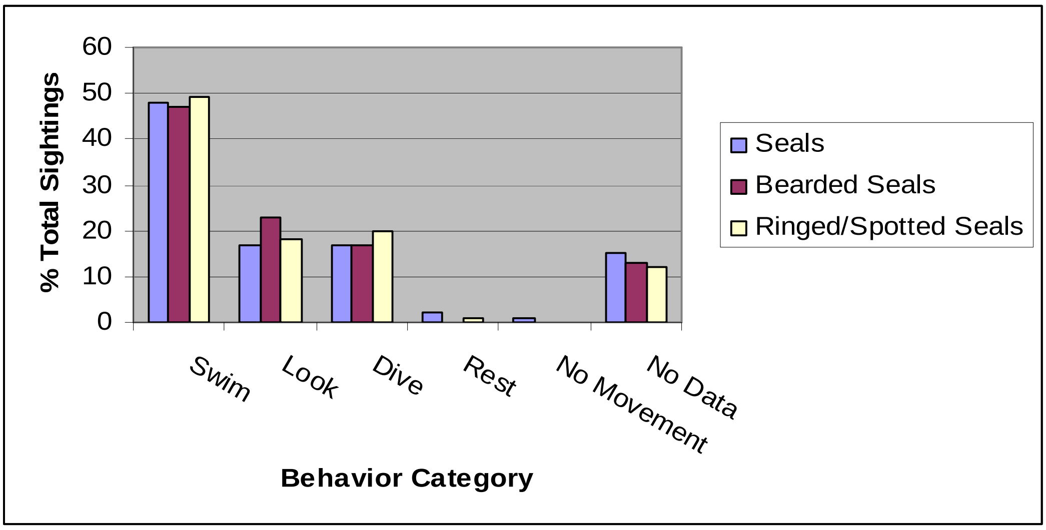

Figure 17. Behavior of seals recorded at both survey areas combined, August – October 2009.

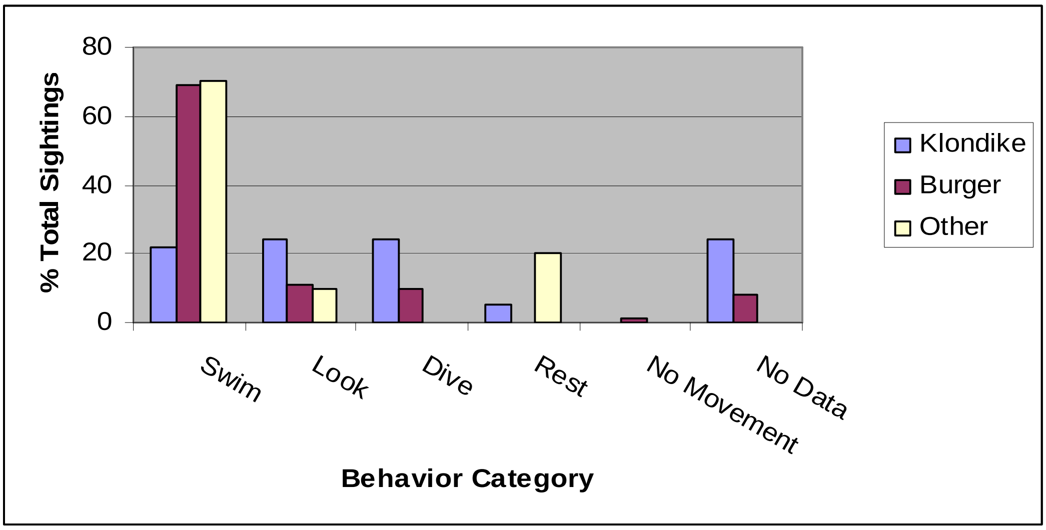

Figure 18. Behavior of seals recorded at Klondike, Burger, and other areas, August – October 2009.

Walrus behavior was dominated by swimming, followed by looking and diving (Figure 19). A similar pattern was observed outside of the survey areas where over 80% of the walruses were recorded swimming. Too few walruses occurred at Klondike or during Cruise 3 in both survey areas to warrant comparisons, but walruses inside and outside of Burger during the first two cruises primarily were recorded swimming. The high proportion of walruses swimming suggests that at least some were moving through the survey areas toward the main pack ice, which was located north of the survey areas. Four walruses were observed attempting to mate, but these probably were subadult males trying to mate unresponsive females; mating occurs in the Bering Sea, where adult males reside year round (Fay 1982). No walruses were observed feeding, but a small proportion was resting. Three dead walruses were recorded in the two survey areas in advanced stages of decay, with one of the three walruses possibly recorded twice.

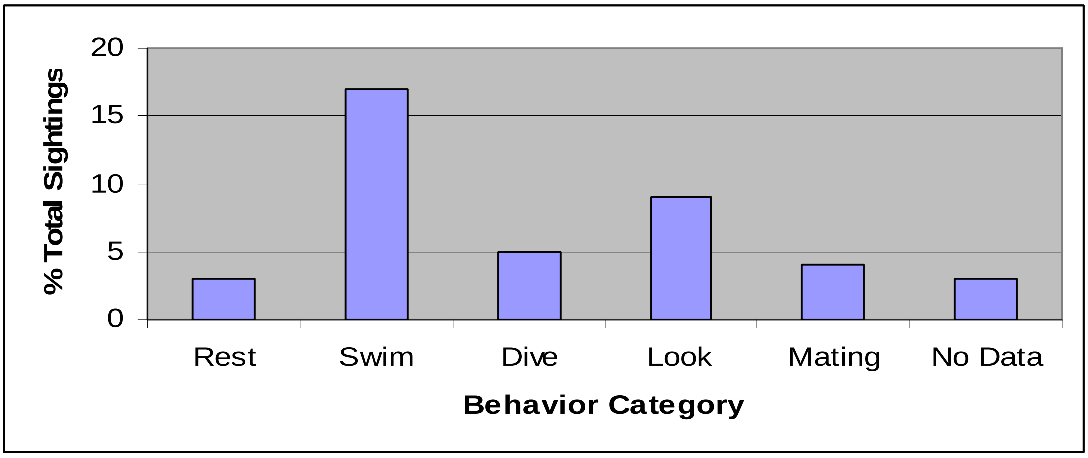

Figure 19. Behavior of walrus recorded at both survey areas combined, August – October 2009.

Meaningful analysis of cetacean behavior was limited to gray whales, because sample sizes for the other species were very small. Gray whale behavior primarily consisted of feeding, diving, and swimming (Figure 20); traveling and blowing also were recorded for about 10% of the gray whales. Gray whales most often were recorded feeding during Cruise 1, swimming more during Cruise 2, and Cruise 3 had too few gray whales (n=1) for analysis. Behavioral comparisons were not analyzed between survey areas, because too few whales were encountered in them to provide a meaningful interpretation of the data; therefore, all of the observations in the study area were pooled to analyze behavior.

Behavior of other cetacean species was also based on pooled observations from inside and outside of the survey areas to increase sample sizes for each species. Behaviors of these species included blowing and fluking for three bowhead whales traveling northward, resting and swimming for three harbor porpoises, and diving and swimming for two solitary minke whales. There was no evidence of feeding by any of these species of whales. The behaviors and small number of sightings suggest that most cetacean species were likely transiting through the general area `.

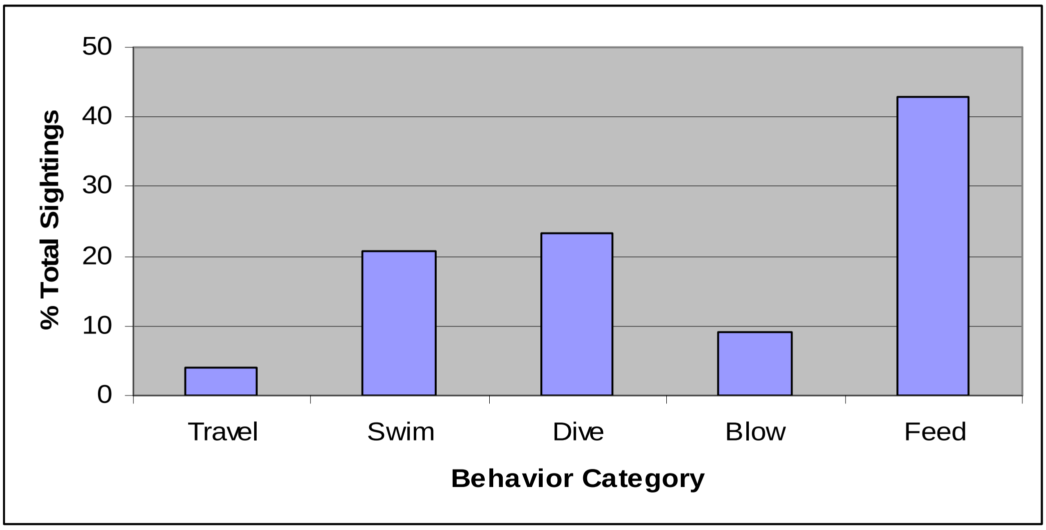

Figure 20. Behavior of gray whales recorded in all areas surveyed from August – October 2009. (almost all gray whales occurred outside of the two survey areas).

Behavior of the three sightings of four polar bears included two resting and one walking on the sea ice. The mother and cub rose from resting and walked away, once they noticed the approaching vessel, which was almost 1 km (0.62 mi) away. The vessel changed course upon sighting the movement of the bears.

Density

Data Characteristics

Sufficient sample sizes for reliably estimating density were available only for seals as a group and for walruses. Seals included all three species plus unidentified seals; unidentified pinnipeds were not included in the density calculations, because the category may have included both seals and walruses. Seal and walrus densities were calculated for Klondike and Burger by cruise except for Cruise 3 when no walruses were recorded in either survey area. Density was not calculated for the area outside of the two survey areas, because effort and area coverage were very limited and probably not representative of the broader area. Sightings of these animals occurred during sea state conditions ranging from Beaufort 0 to 7, but only sightings seen up to Beaufort 6 were used in the analysis.

Density was calculated by using only systematic (S) and transit (T) transect lines together (Table 3). These transect lines along with deadhead (D) transect lines and surveys between survey areas and Wainwright were only used to estimate detection functions for seals and walruses (see beyond). Deadhead lines were not used to calculate density, because they did not meet the assumption of line-transect theory that sightings are independent events (Buckland et al., 2001). Numbers of transect lines and effort/survey area are summarized in Table 3.

Table 3. Summary of transect lines and effort for the seal and walrus line-transect analysis.

Survey area	Area (km^2)	Number of transect lines and effort (km)		Total effort (km)
		Systematic lines	Transit lines	
CRUISE 1				
Burger	3087	19 (903.1)	4 (113.6)	1016.7
Klondike	3087	17 (900.6)	2 (29.6)	930.2
Total		36 (1803.7)	6 (143.2)	1946.9
CRUISE 2				
Burger	3087	20 (899.9)	2 (50.8)	950.7
Klondike	3087	19 (1003.6)	2 (58.7)	1062.3
Total		39 (1903.5)	4 (109.5)	2014.0
CRUISE 3				
Burger	3087	20 (918.6)	4 (112.2)	1030.8
Klondike	3087	17 (888.6)	1 (5.3)	893.9
Total		37 (1807.2)	5 (117.5)	1924.7
Total		112 (5514.4)	15 (370.2)	5884.6

Total effort on systematic and transit lines was 5514.4 km (3426 mi) and 370.2 km (230 mi), respectively. Total effort used to estimate abundance, therefore, varied between a little less than 5514 km (3426 mi, systematic lines only) and 5884 km (3656 mi, systematic and transit lines combined).

Two approaches were used in stratifying the sighting data for estimating density. Approach 1 assumed that both systematic and transit lines within Burger and Klondike were valid sampling units, so the two line types were pooled for analysis. In Approach 1, stratum-specific estimates were produced for all three cruises. Approach 2 was similar to Approach 1, except that only systematic lines in Burger and Klondike were used in estimating density. Estimates of density for walruses and seals were not significantly different between Approaches 1 and 2, so Approach 1 was used for the density estimates because it provided lower values of Coefficients of Variation due to higher effort.

Modeling Detection Probability

Exploratory analyses were conducted to investigate the best approaches to estimate detection probability. These analyses included various strategies for truncating and for binning perpendicular distance data. In addition, two conventional distance-sampling (CDS) models were used for fitting the data: the hazard-rate and the half-normal, both with cosine series expansions (Buckland et al. 2001).

The simplest modeling approach is to fit detection functions to untruncated and ungrouped (unbinned) data. This resulted in a poor fit of both hazard-rate and half-normal models, with the former being much better supported by the data according to the Akaike Information Criterion (AIC) analysis. Untruncated perpendicular-distance data implied that sightings up to 3.5 km (2.2 mi) from the transect line were used in the analysis. Alternative truncation points were explored, but best results were obtained at a truncation point of 1.5 km (0.9 mi).

Once the best truncation and binning strategy was found, more sophisticated models were used to fit perpendicular-distance data. In particular, multiple covariate distance-sampling (MCDS) models were tested in addition to CDS key functions (e.g., half normal, hazard rate, etc.). The following three covariates were included in the models: group size, seal species, and Beaufort sea state. The first covariant was fit as a continuous variable and assumes that detection probability increases linearly as group sizes increases. Species and Beaufort sea state were modeled as factor covariates. Species and sea state were modeled as individual values (i.e., one parameter was estimated for each Beaufort value or species) or as categories. The latter was done in order to pool across similar Beaufort sea states or species to reduce the number of parameters estimated by the models. One set of categorical data was created to model grouped sea state conditions ("BeaufCat", two levels, low = Beaufort 0-2 and high = Beaufort 3-5) and another was created to model grouped species ("SpeciesCat," two levels, seals = all seal species or walruses).

Models that did not conform to the detection probability hypothesis being presented were excluded from the analysis. For example, because detection probability is expected to increase as group size increases, the model was not considered if the parameters indicated otherwise. Model selection was made from AIC analysis, and inference was based on the model best supported by the data (e.g., the one with the lowest AIC score; note AIC values are negative so lowest score was -129.70).

Encounter Rate, Group Size Estimation, and Density Estimates

Encounter rate and its variance were empirically estimated from the data (Buckland et al., 2001; Innes et al., 2002).

For CDS models, size-bias regressions were computed to investigate whether group size influenced detection probability (Buckland et al., 2001). If the regression was significant at alpha = 0.15, then the size-bias regression coefficients were used to estimate average group size. Otherwise, a simple mean was computed. For MCDS models, group sizes were estimated by dividing the estimated density of individuals by the estimated density of groups in the study area (Marques and Buckland, 2003).

Density was estimated using CDS and MCDS modeling strategies, as presented in Buckland et al. (2001) and Marques and Buckland (2003). For the purpose of this analysis, detection probability on the transect line was assumed to be g[0]=1. All parameter estimates were computed with the function MRDS for the software R (J. Laake, pers. comm.; available for download with Program Distance).

Results are presented in Tables 4-6 and Figures 21-23. The hazard-rate model fit the data better than the half-normal model. The best supported model was the one with Beaufort sea state category (BeaufCat) and species (walrus and seals) as covariates (Table 4, Figure 21). The 2nd and 3rd best models were relatively well supported (Delta AICs $\leq$ 2, Table 4) and also had BeaufCat as covariate, emphasizing the importance of this covariate in the detection of seals and walruses in the survey areas. All other models had Delta AIC values greater than 2 and are not shown. Despite the differences in the AIC values, parameter estimates were similar across all models.

The results show that density estimates of walruses were significantly greater on Cruise 1 than Cruise 2 and greater in Burger than Klondike during Cruise 1 (Table 5, Figure 22). Estimation of density in the latter stratum is based on one sighting only and therefore is not reliable. It is presented here for completeness. No differences across strata were seen in Cruise 2. There were no sightings of walruses during Cruise 3; therefore, no estimates of density were computed.

Seal density estimates varied widely among cruises and survey areas (Table 6). Seal density was statistically significantly greater at Burger than Klondike during Cruise 2, but not between the two areas during the other two cruises (Figure 23). At Burger, seal densities were not significantly different among the cruises, although it was highest during Cruise 2. Conversely, density was significantly greater in Klondike during Cruise 3 than during Cruises 1 and 2, which were not significantly different.

Table 4. Model parameter estimates for estimating detection probability for the seal and walrus line-transect analysis.

Model	# par	Delta AIC	AIC	Average p	ESW (m)	ESW CV
Hazard rate with BeaufCat and species covariates	8	0.00	-129.70	0.36	540	0.06
Half normal with BeaufCat covariate	3	0.95	-128.75	0.31	465	0.06
Half normal with BeaufCat and speciesCat covariates	4	2.00	-127.69	0.31	469	0.06

# par = number of parameters, AIC = Akaike Information Criterion, p = detection probability,
ESW = effective search half-width, CV = coefficient of variation

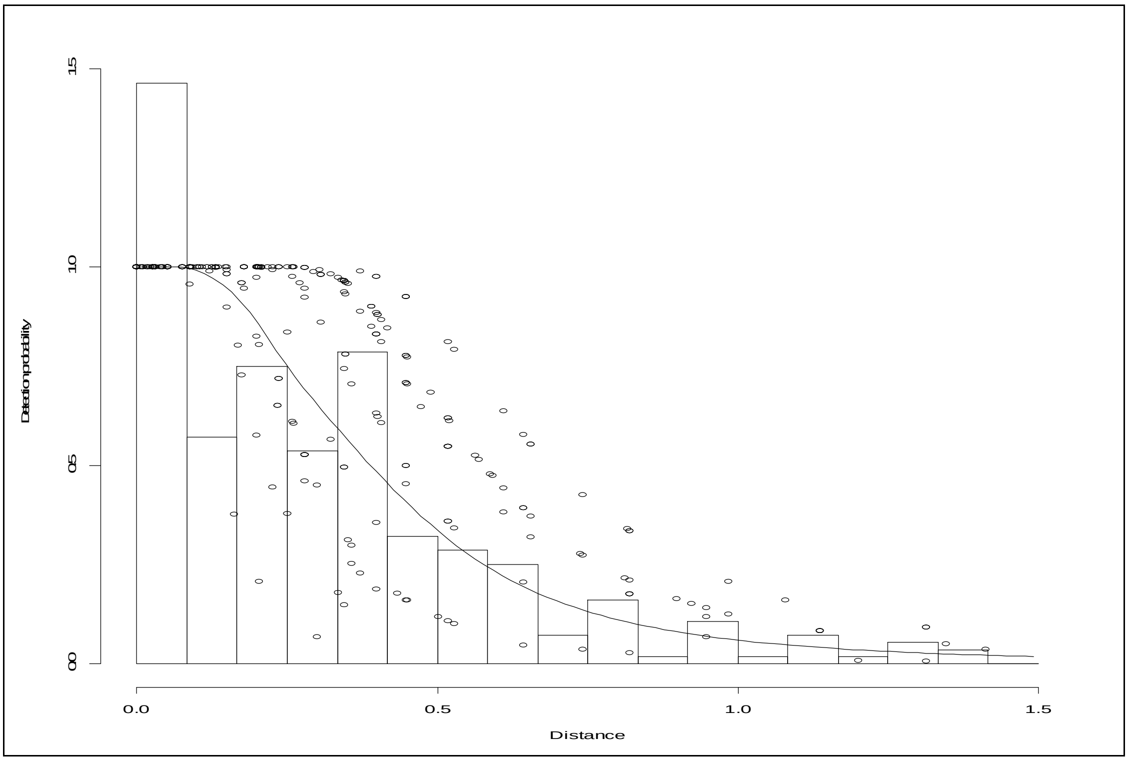

Figure 21. Selected detection probability function for the best fitting model (Hazard rate model with Beaufort Category and Species as covariates). The line represents the average detection probability and the dots the detection probability for each individual sighting (distance in km).

Table 5. Walrus density estimates using the best supported detection probability model from Table 4 (No walrus were encountered during Cruise 3).

Attribute	Cruise 1		Cruise 2	
	Burger	Klondike	Burger	Klondike
No. of sightings (n)	29	1	4	4
Encounter rate (ER)	0.053	0.001	0.006	0.006
ER CV	0.25	1.60	0.45	0.48
Mean group size	1.86	1	1.5	1.5
Group size CV	0.10	0.00	0.19	0.19
Density (ind/km^2)	0.061	0.001	0.007	0.007
	(0.156)[1]	(0.003)	(0.018)	(0.018)
Density 95% CI	0.036-0.103	0.000-0.016	0.003-0.019	0.002-0.019
CV	0.26	1.61	0.48	0.50

[1] Number in parenthesis is individuals per square mile

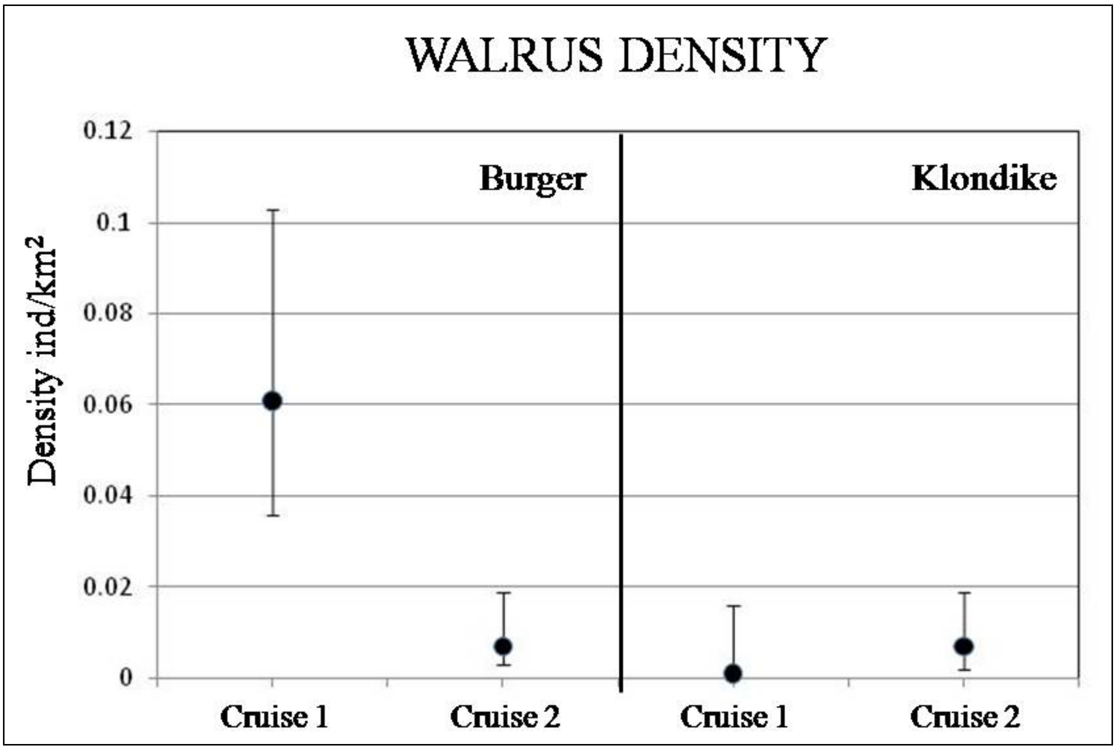

Figure 22. Walrus density at Klondike and Burger survey areas, August – October 2009 (no walrus were encountered during Cruise 3).

Table 6. Seal density estimates using the best supported detection probability model from Table 4.

Attribute	Cruise 1		Cruise 2		Cruise 3	
	Burger	Klondike	Burger	Klondike	Burger	Klondike
No. of sightings (n)	16	4	49	4	17	61
Encounter rate (ER)	0.016	0.004	0.055	0.004	0.016	0.073
ER CV	0.41	0.51	0.34	0.74	0.24	0.49
Mean group size	1	1	1.04	1	1	1.07
Group size CV	0	0	0.03	0	0	0.03
Density (ind/km^2)	0.018 (0.046)[1]	0.005 (0.013)	0.056 (0.143)	0.003 (0.008)	0.030 (0.077)	0.078 (0.200)
Density 95% CI	0.009-0.036	0.002-0.013	0.029-0.108	0.001-0.012	0.017-0.053	0.030-0.166
CV	0.35	0.47	0.32	0.71	0.28	0.42

[1] Number in parenthesis is individuals per square mile

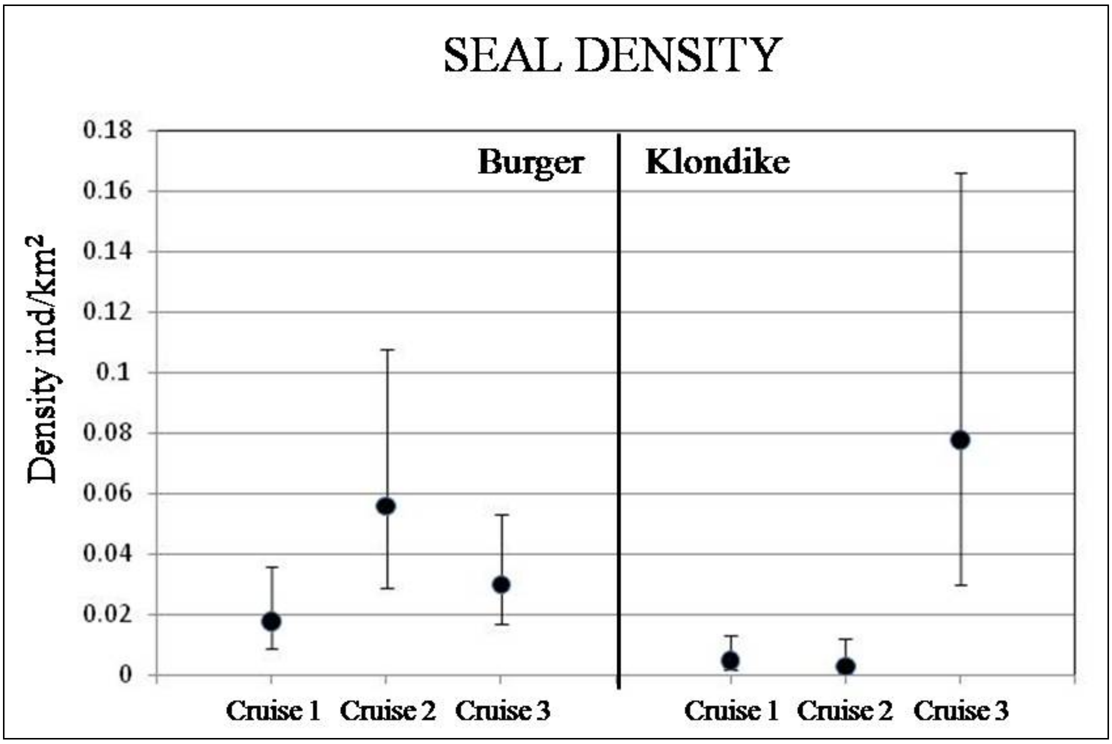

Figure 23. Seal density at Klondike and Burger survey areas, August – October 2009.

5.0 Discussion

The following discussion separately addresses whales, seals, walruses, and polar bears and compares the 2009 results with those of 2008. The literature is summarized for each species and compared to the results of the research cruises. A brief discussion about weather conditions is initially presented since they were quite different between 2008 and 2009. General conclusions about marine mammal use of the survey areas are provided at the end of the section.

Environmental Conditions

Environmental conditions were quite different between 2008 and 2009, which likely affected the spatial and temporal distribution and abundance of marine mammals. In 2009, the two survey areas were ice free during the three cruises; however, ice was briefly present north and east of Burger when the vessel was deploying acoustic equipment the week before the Cruise 1 survey began. In 2008, sea ice was present in both survey areas through August, after which sea ice remained in Burger until mid-September before moving northward for the remainder of the 2008 research program. The difference in occurrence of sea ice in the survey areas between years was primarily due to the 2009 program starting almost three weeks later than the 2008 program. Seal and walrus numbers are typically higher near sea ice than open water, which is further discussed in the following section.

Whales

Bowhead Whales

Bowhead whales migrate in spring through the Chukchi Sea to summer feeding areas and in fall to the Bering Sea wintering area with a relatively small number possibly staying in the Chukchi Sea throughout the summer (Moore and Reeves 1993; Brueggeman 1982). The spring migration is well documented with whales following the open leads in the sea ice running parallel to the Chukchi Sea coastline before veering eastward through the Beaufort Sea (Braham et al. 1984; Moore and Reeves 1993). Most whales pass through the Chukchi Sea by late June as documented from traditional Eskimo knowledge and research (Huntington and Quakenbush 2009). Eskimo whalers believe the spring migration occurs earlier than in the past (Huntington and Quakenbush 2009).

The fall migration has only recently been more specifically documented by tracking over 20 satellite-tagged bowhead whales from Barrow through the Chukchi Sea into the Bering Sea (Quakenbush et al. 2009, 2010). Most of the whales migrated westward above 71º N latitude from Barrow to Wrangel Island and then down the Chukota Coast before entering the Bering Sea (Quakenbush et al. 2009, 2010, Figure 24). Some whales migrated in a more southwesterly direction from Barrow to the Chukota Coast, crossing through or near the survey areas. Aerial and vessel surveys conducted in the Chukchi Sea over the last 30 years also suggest a southwesterly route based on scattered bowhead whale sighting locations (Ljungblad et al. 1984, 1986, 1987; Brueggeman et al. 1990, 1991, 1992; Figure 25). Recent acoustic studies conducted from 2007 to 2009 indicated calling bowheads migrated across the Chukchi Sea in both a westerly direction following the 71° N latitude and a less defined route after leaving the Barrow area (Hannay et al 2009; Martin et al. 2008). Eskimo whalers report whales travel westward and later during light ice years and southwestward during heavy ice years (Figure 26, Huntington and Quakenbush 2009). These collective results suggest the location of the fall migration route may comprise a variety of paths across the Chukchi Sea. The fall migration of bowheads through the Chukchi Sea generally begins in early October and ends sometime in December, as sea ice advances into the Bering Sea.

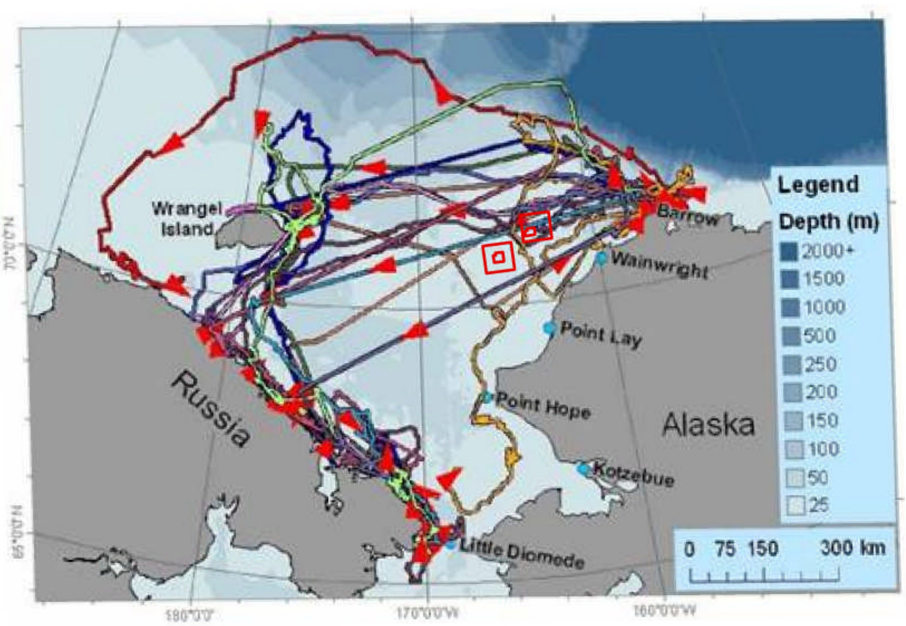

Figure 24. Tracklines of satellite-tagged bowhead whales in the Chukchi Sea during fall; the straighter the lines the fewer the location points and less certain the actual trackline (Figure prepared by Alaska Department of Fish and Game). Red boxes are the Klondike (lower) and Burger (upper) survey areas.

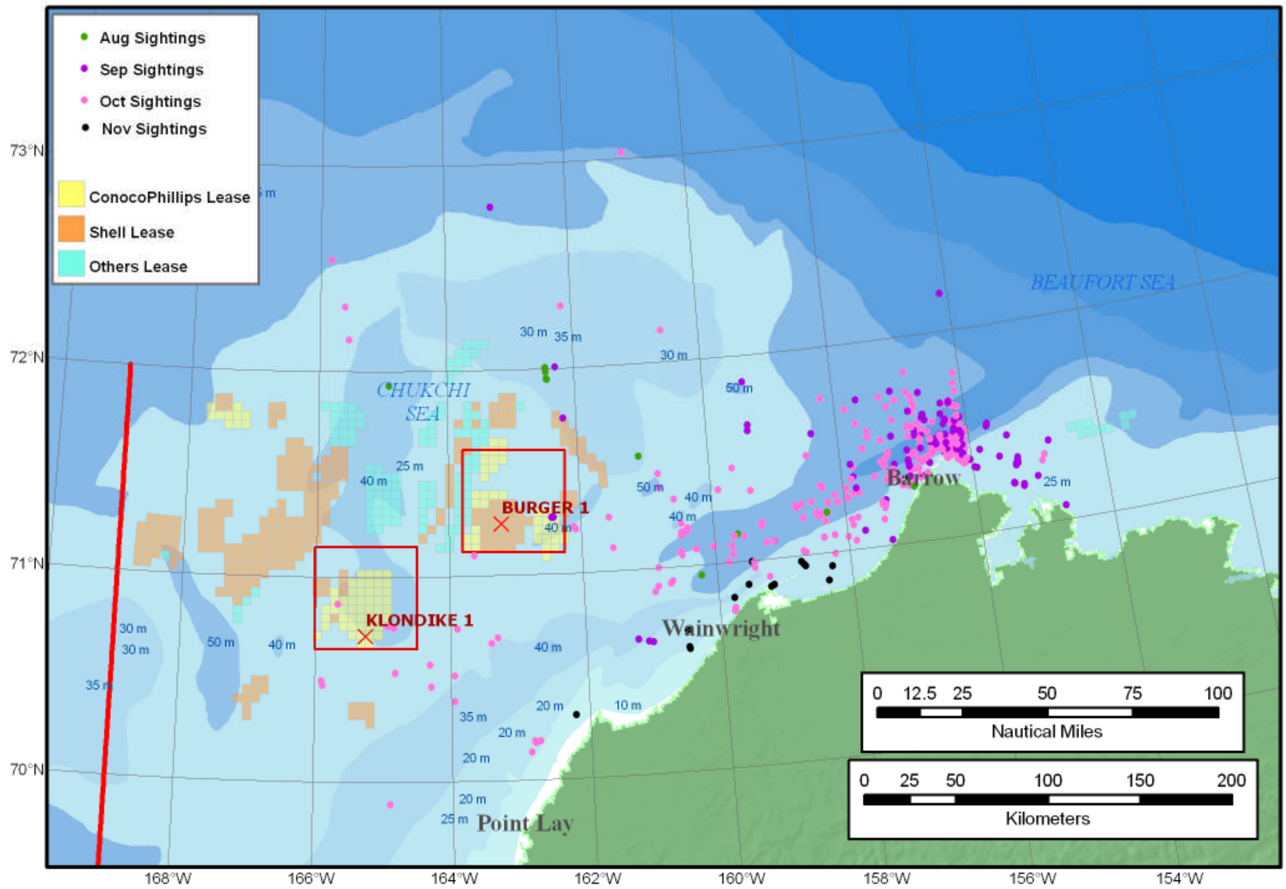

Figure 25. Bowhead whale locations recorded during aerial surveys conducted from 1979 to 2008. Areas without sightings may reflect a lack of survey effort. Sources are NMFS provided by Janet Clark, Funk et al. (2009), Brueggeman et al. (1990, 1991, 1992), and the current research program.

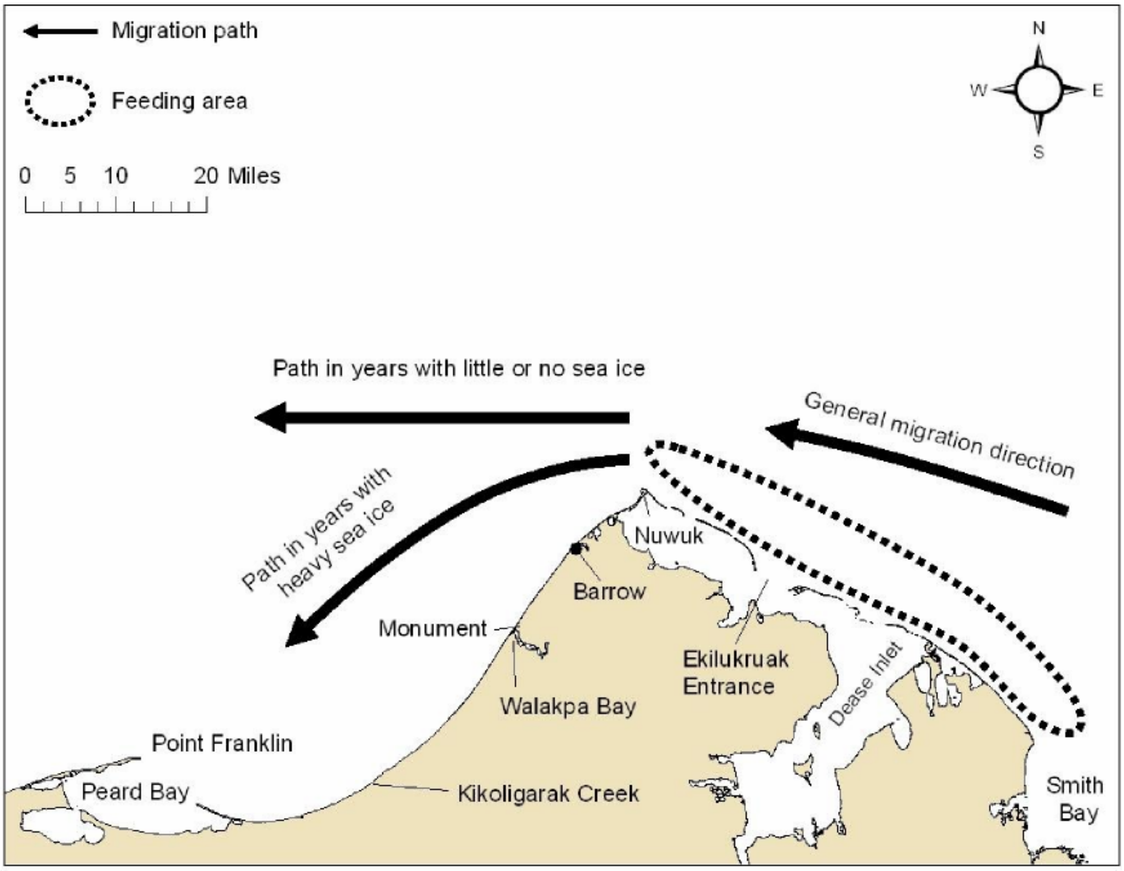

Figure 26. Bowhead fall migration routes based on traditional Eskimo knowledge (map taken from Huntington and Quakenbush 2009).

Acoustic studies indicate bowheads may inhabit the Chukchi Sea for more of the year than previously thought; however, most pass through in the spring and fall during migration between the Bering Sea and Canadian Beaufort Sea (Moore et al. 2010). Calling bowheads have been recorded in the Chukchi Sea during summer and winter (Berchok et al. 2009, Funk et al. 2009). A recent acoustic study monitoring for bowhead calls in the western Beaufort Sea and northeastern Chukchi Sea between October and May reported calling bowhead whales during October and November but not again until late March (Moore et al. 2010), indicating most bowheads do not overwinter in this region. It has been suggested that some bowheads summered in the Chukchi Sea before commercial exploitation began, and that these animals were killed off as the whaling industry moved north into the Beaufort Sea (Moore and Reeves 1993). It is possible that as the bowhead whale population has increased in recent time (> 10,500 animals in 2002 with a 3.4% annual rate of increase) to pre-exploitation levels (Gerber et al. 2007; George et al. 2004 a, b), and some of these areas may be becoming reoccupied by bowheads as has been observed in gray whales (Moore et al. 2010; Townsend 1935). Small numbers of bowheads have been recorded visually (COMIDA 2008, 2009), acoustically (Hannay et al. 2009, Martin et al. 2008), and from traditional Eskimo knowledge (Huntington and Quakenbush 2009) in the Chukchi Sea between July and September. Most of the potential summering whales have not been observed feeding nor have any cow-calf pairs been observed during this time period (Funk et al. 2009). However, COMIDA (2009) reported several bowheads feeding southwest of Barrow in September 2009, possibly early fall migrants.

A single and pair of bowheads observed at Burger in October were likely early fall migrants. The brief observations of each whale indicated they were moving in a northerly direction. These sightings complement the two 2008 sightings of single bowhead whales in Burger, also in October. No bowheads were observed before October in either 2008 or 2009 or in Klondike; however, Klondike was not surveyed in October during either year, which could account for the absence of bowheads. Whales have been reported by various investigators occurring in and near Burger and also Klondike during fall (Brueggeman et al. 1992; Quakenbush et al. 2009; COMIDA 2009), although none were seen during a shallow hazards survey conducted at Klondike by ConocoPhillips from early September to the end of October in 2008 (Brueggeman et al. 2009). Acoustic recorders detected bowhead calls during 29% of 35 days from September 9 to October 13 at Klondike and during 60% of 35 days from September 10 to October 14, 2008 at Burger; the calls could not be converted to bowhead numbers (Cornell University 2010). These results show some bowheads migrate through the two survey areas during fall, but the number likely represents a small proportion of the population given the wide range of documented locations of fall migrants. Most bowheads likely migrated through the Chukchi Sea after the research program ended in mid-October as indicated by acoustic studies and government-conducted aerial surveys (Funk et al. 2009; Goetz et al. 2009). No mother-calf pairs were observed during the three cruises.

Gray Whales

Gray whales summer in the Chukchi Sea where they feed before returning to Mexico wintering grounds (Rugh et al. 1999, Rugh et al. 2001). Gray whales occupy the Chukchi Sea during the open water season, generally arriving behind the retreat of the sea ice and leaving ahead of the advance of the ice (Clarke et al. 1989; Brueggeman et al. 1992; Funk et al. 2009; Goetz et al. 2009). Gray whales are widespread in the Chukchi Sea but most occur near shore (< 40 km or 25 mi from shore) between Wainwright and Barrow with highest concentrations north of Wainwright (Figure 27). Smaller numbers of gray whales concentrate in the region of Hanna Shoal, north of the Burger survey area between 160º and 165º W (Figure 27). Gray whale movements vary annually depending on prey abundance and distribution (Nerini 1984). Gray whales feed in soft sediments which contain their primary prey, benthic ampeliscid amphipods (Nerini 1984). Gray whales are the most abundant cetacean reported in the Chukchi Sea during summer (Funk et al. 2009, Brueggeman et. al. 1990, 1991, 1992; Janet Clark pers. comm. 2009**).** Recent acoustic data suggest some gray whales may over-winter in the Chukchi Sea, but the numbers are likely small (Moore et al. 2006).

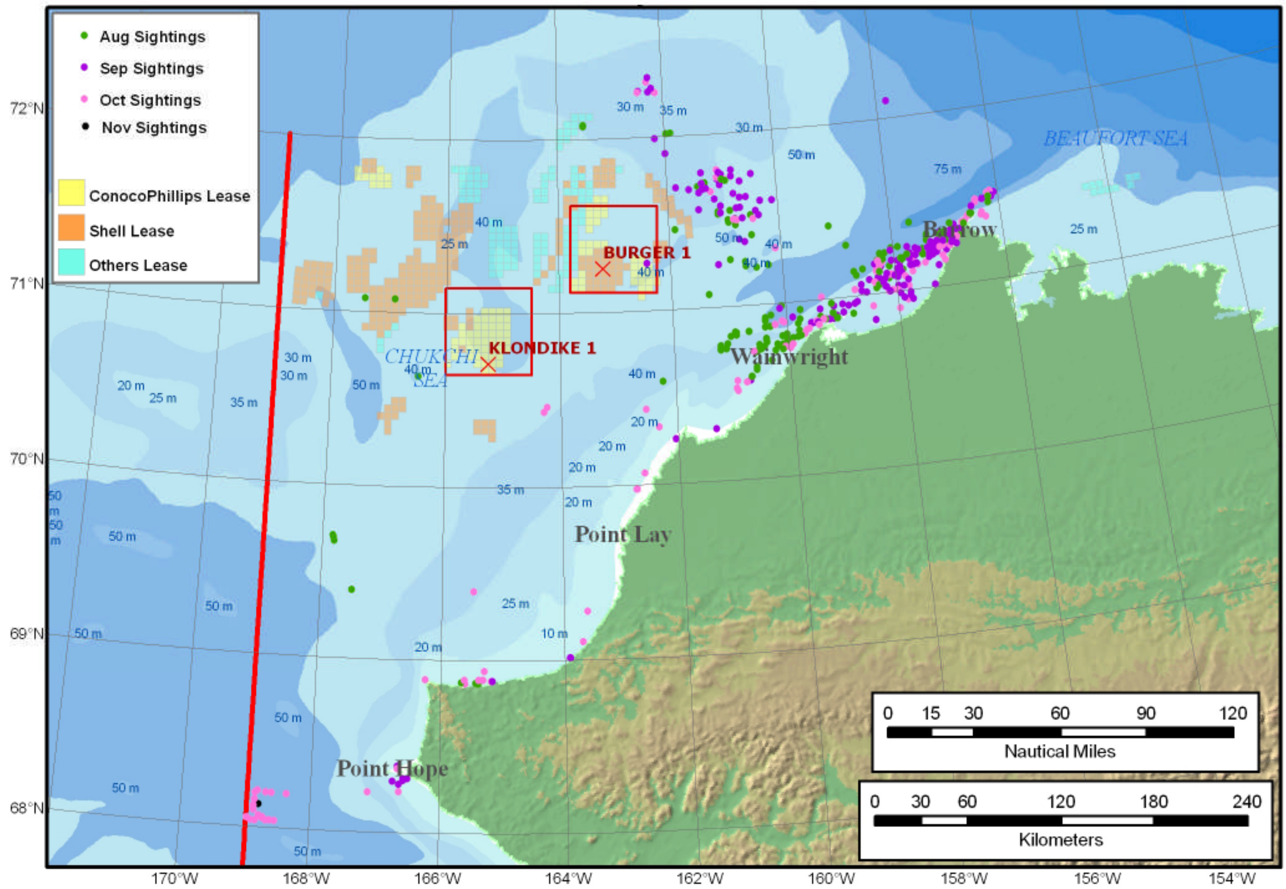

Figure 27. Gray whale locations recorded during aerial surveys conducted from 1979 to 2008. Areas without sightings may reflect a lack of survey effort. Sources are NMFS provided by Janet Clark, Funk et al. (2009), Brueggeman et al. (1990, 1991, 1992), and the current research program.

The pattern of gray whale occurrence during the research program is consistent with the reported research on gray whales in the Chukchi Sea. Gray whales were widespread in the study area during the span of the research program with small numbers in each survey area, but most occurred nearshore between Wainwright and Cape Belcher during both 2008 and 2009. Gray whales observed during a shallow hazards survey conducted by ConocoPhillips at Klondike and a coring program between Klondike and the coast in 2008 were entirely nearshore (Brueggeman et al. 2009). Similarly, the 2009 COMIDA (2009) surveys found most gray whales feeding nearshore between Pt. Lay and Barrow from June to October with none observed in or near Burger or Klondike. No calves were observed during the three cruises in 2008 or 2009, although others have reported calves with groups observed eastward from the two survey areas (COMIDA 2009). These collective results indicate the primary habitat for gray whales in the northeastern Chukchi Sea is considerably east of Burger and Klondike; Hanna Shoal has also been historically used by gray whales, but none were seen there during the 2009 COMIDA surveys.

Other Cetaceans

Small but unknown numbers of other cetacean species (harbor porpoise, minke whales, and killer whales) observed in the study area during 2008 or 2009 regularly occur in low numbers in the Chukchi Sea during the open water season (Clarke et al. 1998; Funk et al. 2009). Minke whales and harbor porpoise were observed in both survey years, while killer whales were only observed in 2008.

Harbor porpoise are the most commonly recorded of the three species in the northeastern Chukchi Sea, followed by minke whales, and lastly killer whales, based on surveys by other investigators (Funk et al. 2009). Killer whales have been primarily observed near the coast rather than farther offshore (Brueggeman et al. 1992, George and Suydam 1998), possibly due to a higher chance of encountering them from more human activity nearshore. Conversely, acoustic recorders detected killer whale calls in 2007 and 2009 offshore between Cape Lisburne and Barrow from July until October (Hannay et al. 2009, Martin et al. 2008, Delarue and Martin 2010). The combination of acoustic and visual data suggests killer whales occur both offshore and near shore with no clear inshore/offshore trend. Brueggeman et al. (1990, 1991, and 1992) did not observe any of these three species in the survey areas when surveyed in 1989 and 1990, but they did record one minke whale in the Popcorn Prospect in 1990. The low numbers of these three species reported by other investigators are confirmed by the few animals observed inside and outside of the survey areas in 2008 and 2009. It is likely that small numbers of all three species transit through the survey areas as they feed in the Chukchi Sea during summer.

Three cetacean species not observed in the study area were observed south of Point Hope during the transit to Nome. Dall's porpoise were observed in 2008 and 2009, while fin whales and humpback whales were observed only in 2009. Fin whales were also acoustically detected off Pt. Lay and Cape Lisburne from early August to mid-September in 2007 and late August in 2009 (Hannay et al. 2009; Martin et al. 2008; Delarue and Martin 2009; D. Hannay pers. comm. 2010). Fin and humpback whales are uncommon in the eastern Chukchi Sea, but in the 1930s and 1940s humpbacks commonly inhabited the southern Chukchi Sea off the Chukotka Peninsula of eastern Siberia (Tomilin 1937; Sleptsov 1961). Humpback whale numbers were reduced in the 1950s and 1960s (Melnikov; and others 2000). By the mid-1990s, sizable numbers (70) of humpbacks were reported off the peninsula, which was attributed to a population recovery from an end of commercial whaling initiated in the 1930s (Melnikov; and others 2000). Recently, humpback and fin whales have been reported in the eastern Chukchi Sea (humpback between Ice Cape and Wainwright in late July, 2009) and also Beaufort Sea (humpback cow with calf in 2007) by several investigators (COMIDA 2009; Funk et al. 2009), suggesting they may be becoming more common, possibly corresponding to a rise in sea surface temperatures (Hashagen et al. 2009).

Cetaceans Not Observed

Cetaceans not observed in the study area in 2008 or 2009, but are seasonally present, include beluga whales. Two beluga whale populations migrate through the Chukchi Sea in the spring and fall: the eastern Beaufort Sea population and the eastern Chukchi Sea population (O'Corry-Crowe et al. 1997). The former population summers in the Canadian western Beaufort Sea and winters in the Bering Sea (Allen and Angliss 2010). It normally follows the ice lead systems during the spring migration and the advance of the ice in the fall migration, which typically occur outside of the time period of the research cruises.

The eastern Chukchi Sea beluga population also summers in the Beaufort Sea and winters in the Bering Sea, but a large segment of the population inhabits Kasegaluk Lagoon near Pt. Lay in June and July, where they are harvested by Pt. Lay hunters (Suydam et al. 2001). These animals leave the lagoon after mid-July and continue north to summer feeding grounds (Suydam et al. 2001). Recent studies using satellite-tagged belugas found that most of these belugas summer north of the outer continental shelf in the Chukchi Sea and along the Beaufort Sea, at times penetrating areas of 90% sea ice cover as far as 80º north (Suydam et al. 2001). They return south of the outer continental shelf break in October to December as the ice retreats toward the Bering Sea.

A compilation of sightings recorded during aerial and vessel surveys conducted between 1979 and 2008 shows belugas were widespread in the Chukchi Sea, particularly during fall, with some sightings overlapping the survey areas (Figure 28). Included in these sightings were recent vessel and aerial surveys conducted from 2006-2008 by Funk et al. (2009), which encountered few or no belugas south of the outer continental shelf during late summer and fall; most belugas were observed near the coast in July as they migrated north from Kasegaluk Lagoon (Funk et al. 2009). Also included in the sightings were surveys conducted from 1989 to 1991 by Brueggeman et al. (1990, 1991, and 1992) when they frequently encountered belugas during August to early October 1991 at or near other survey areas (Crackerjack and Diamond), which geographically bound the Klondike and Burger survey areas. However, they encountered many more belugas near Pt. Lay and northward off the coast in June, but only one beluga whale at the Klondike survey area in late June in 1989 and none at Burger. No belugas were observed during a shallow hazards survey conducted at Klondike by ConocoPhillips from early September to late October in 2008 (Brueggeman et al. 2009); extensive aerial surveys conducted jointly by the NMFS and MMS in 2009 did not encounter any belugas in August or September but belugas were observed in October when most were recorded north of Pt. Barrow (COMIDA 2009). Acoustic studies conducted in 2007 rarely detected belugas until mid-September when increasing numbers of calls were recorded off Barrow, likely corresponding to the start of the fall return to the Bering Sea (Hannay et al. 2009, Martin et al. 2008).

The differences in results in the survey area region over the almost 30-year time span represented by the sightings on the map are likely due to annual variation in the location and extent of sea ice cover occurring during summer and fall. This is somewhat confirmed by the surveys conducted by Brueggeman et al. (1991), where 72% of the belugas recorded away from Kasegaluk Lagoon were in pack ice. Consequently, the occurrence of belugas in or near the survey areas may largely depend on sea ice conditions, although recent acoustic surveys suggest small numbers of belugas may summer in the region (Chris Clark pers. comm. 2009, Dave Hannay pers. comm. 2010). The fall migration to the Bering Sea wintering grounds generally corresponds to the advance of the sea ice in November and December.

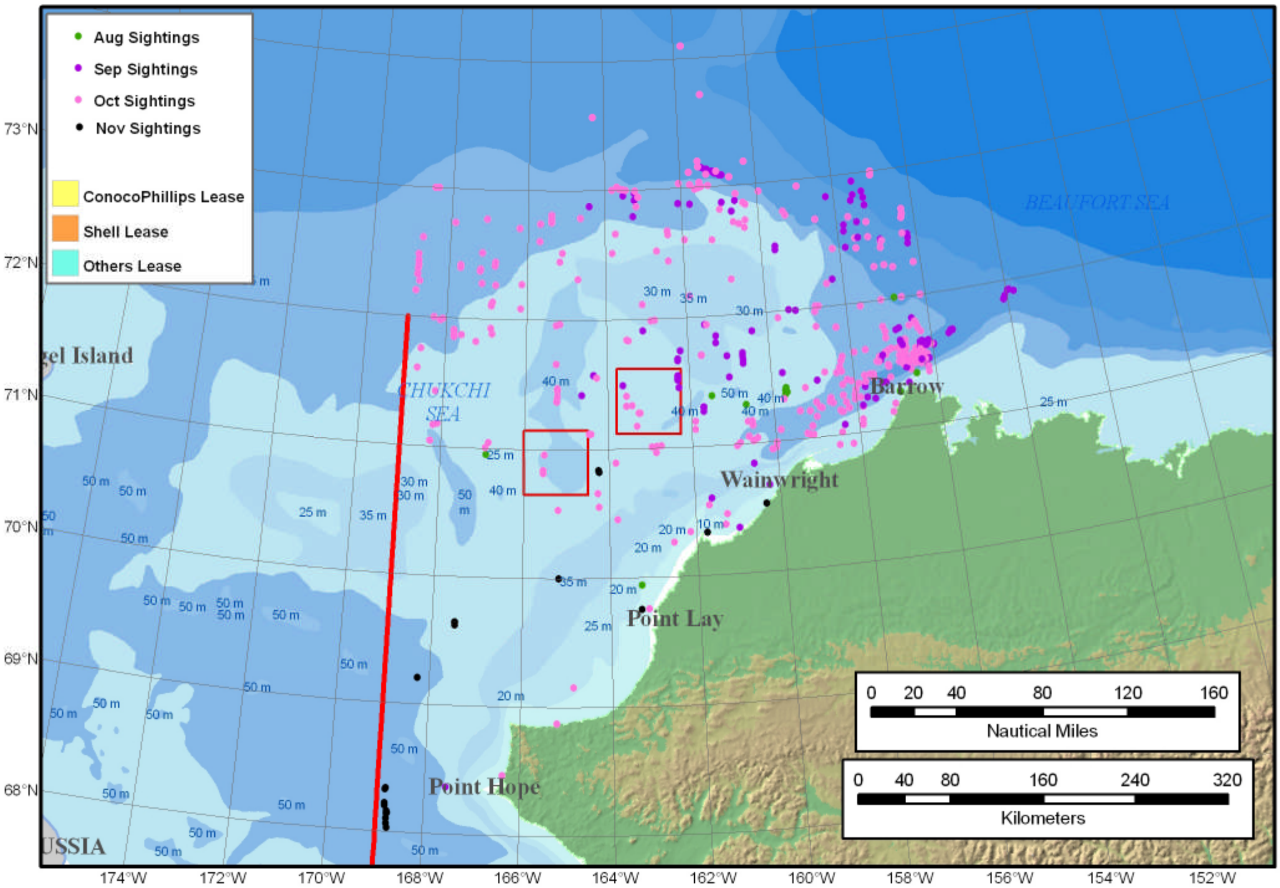

Figure 28. Beluga whale locations recorded during aerial surveys conducted from 1979 to 2008. Areas without sightings may reflect a lack of survey effort. Sources are NMFS provided by Janet Clark, Funk et al. (2009), Brueggeman et al. (1990, 1991, 1992), and the current research program.

Seals

Seals are the most prominent marine mammal in the Chukchi Sea during the open water season (Funk et al. 2009). They are widespread over the outer continental shelf in the Chukchi Sea (Allen and Angliss 2010). Highest seal abundance is associated with sea ice, but all four species also occur in open water as the sea ice retreats northward during summer (Allen and Angliss 2010; Burns et al. 1980 cited in USDI MMS 2003). Ringed and bearded seals are more closely associated with sea ice than spotted and ribbon seals (Allen and Angliss 2010; Burns 1981). Recent satellite tracking studies cooperatively developed by the Native Village of Kotzebue with several government agencies show widespread seasonal movements of ringed and bearded seals from the Bering Sea into the Beaufort Sea with bearded seals more closely associated with the coast than ringed seals. Spotted seals appear to be more often near shore where they are known to haul out, particularly along the Beaufort Sea (USDI MMS 2003). Bearded seals require relatively shallow water, since they primarily feed on benthic mollusks (Burns 1981). The other species are less restricted by water depth, since they feed on fish and zooplankton (Kelly 1988; and Reeves et al. 1992 cited in USDI MMS 2003). All four species calve on the sea ice in the spring (Quakenbush 1988; Rugh et al. 1997; Kovacs et al. 1996 cited in USDI MMS 2003). Calves are weaned 6-8 weeks after birth when they become independent of the mother, which makes them hard to distinguish from adults during summer and fall.

Density estimates of seals during the open water season in the Chukchi Sea are only available for the group and not individual species. The estimates provide a rough index for comparison but weaknesses in the estimates prohibit using them to estimate population size. Prominent among these weaknesses is no statistically valid correction factor for missed animals. Lacking such a correction factor results in underestimating density by some unknown but significant amount. Recognizing the weaknesses, comparing estimates of uncorrected densities among studies provides some measure of relative abundance.

Seal densities for the Chukchi Sea during the open water season have only been reported by Funk et al. (2009). The estimates, based on vessel surveys, ranged between 0.0402 to 0.1924 seals/ km^2 (0.1029-0.4925 seals/mi^2) during Jun-Aug and 0.0602 to 0.05045 seals/ km^2 (0.1541-0.1292 seals/mi^2) during Sept-Oct for 2006-2008. Densities were substantially higher in the fall than summer periods for all years except 2008, when they were higher in the summer than fall, apparently due to less effort and higher sea states in the fall. Estimates were for conditions without seismic activity and were corrected for f(0) and g(0). However, there were no confidence intervals or coefficient of variations provided for the estimates to assess uncertainty.

The results differed between the 2008 and 2009 research programs as well as those reported by Funk et al. (2009). The differences and similarities are discussed below:

- Spotted, ringed, and bearded seals were encountered in Burger and Klondike during every cruise in 2009. These seal species were similarly temporally and spatially widespread in 2008 and 2009. Ribbon seals were observed in 2008 but not 2009; however, so few ribbon seals occur in the study area that there is a high likelihood of not encountering this species.
- Seal densities in 2009 likely reflected the lack of sea ice during the three cruises when compared to 2008. Densities during open water cruises in 2008 and 2009 were much lower than during the first cruise in 2008 when sea ice was present. Densities during open water cruises ranged from 0.003 - 0.078 seals/km^2 (0.008-0.200 seals/mi^2) compared to 0.133 - 0.381 seals/km^2 (0.340-0.975 seals/mi^2) when sea ice was prevalent. The differences were significant between all of the open water densities and the upper range of the ice present density.

- Seal density per cruise was not significantly different between Klondike and Burger except during Cruise 2 in 2009 when density was significantly greater at Burger and during Cruise 1 in 2008 when density was significantly greater at Klondike. Ice was prevalent in Klondike and Burger during Cruise 1 in 2008, and both Klondike and Burger were in open water during Cruise 2 in 2009. The biological reasons for this inconsistency are not clear but possibly due to small sample sizes in 2009.
- The highest seal densities at Burger and Klondike varied among cruises in 2009, whereas the highest densities for the two areas were during the same cruise in 2008. Densities among cruises were significantly greatest at both Burger and Klondike during Cruise 1 in 2008, and Klondike during Cruise 3. Density was highest at Burger during Cruise 2 but not significantly different from the other two cruises in 2009. While the high densities in the survey area during 2008 are explainable by the presence of sea ice, the reasons for the differences in 2009 are uncertain. Funk et al. (2009) similarly found a wide range of seal densities that varied by season (cruise) and year and were influenced by sea ice.
- More bearded seals were observed at Burger than Klondike during both 2008 and 2009 for all three cruises taken together, but the differences were not consistent between cruises for the two survey areas or statistically significant. Acoustic studies found bearded seals called more consistently at Burger than Klondike in 2009, but the calls could not be converted into number of animals to compare relative use of the two areas (Dave Hannay pers. comm. 2010). While Burger has been shown to have a higher abundance and biomass of prey (benthic organisms) than Klondike, it does not appear to have clearly affected bearded seal distribution in 2008 or 2009.
- Seal behavior in 2008 and 2009 was dominated by swimming followed by looking and diving. Feeding was not observed during either year. Nor was any unusual behavior encountered such as unusually large groups of seals or interactions between species. One interesting observation was when relatively large numbers of seals were encountered on a given survey day, the species composition usually included all three species in larger numbers than on days with few seals. Sightings of large numbers of mixed species of seals were associated with low sea states (0-1).
- Small numbers of juvenile seals were recorded in 2008 and 2009, which included primarily bearded seals. The larger size disparity makes distinguishing between juvenile and adult bearded seals easier than for other seal species. Distinguishing adults from juveniles for all seal species was difficult given juveniles were several months old and independent of their mothers at the time of the surveys.

Walrus

Walrus winter in the Bering Sea and summer in the Chukchi Sea except for a small number that summer in the western extreme of the Beaufort Sea (Fay 1982). Adult males reside in the Bering Sea year-round while females, calves, and subadults migrate north into the Chukchi Sea (Fay 1982). Migration corresponds with the spring retreat and fall advance of the pack ice (Fay 1982). Walrus ride the pack ice northward, which provides a platform for feeding, resting, calving, and molting (Fay 1982). Most walrus also summer in the pack ice although a few occur in open water. Walrus swim ahead of the pack ice during the southward fall migration, since the pack ice at that time is too thin to provide a stable platform (Fay 1982). Walrus summering in the Chukchi Sea are restricted to the relatively shallow shelf waters, since they are benthic feeders preying on clams and other mollusks (Fay 1982).

Walrus summering in the Chukchi Sea are widespread in the pack ice extending between the Alaska coast and Wrangel Island (Gilbert 1989, Gilbert et al.1992). The last comprehensive surveys of walrus distribution were conducted over 20 years ago by Estes and Gilbert (1978), Johnson et al. (1982), and Gilbert (1989). These studies involved aerial surveys that broadly overlapped the region of the Klondike and Burger survey areas (approximately 162º 50´ to 166 º 00´ W longitudes). In 1975, Estes and Gilbert (1978) censused the open water and pack ice between 156º and 174º W longitude in early September and found the highest walrus densities between 162º and 165º W. In 1980, Johnson et al. (1982) surveyed the pack ice near the ice edge from 153º to 172º 30´ W longitude in mid-September. Walrus were encountered throughout the area, but the density was highest between 160º 30´ and 166º 30´ W. In 1985, Gilbert censused the pack ice near the ice edge between 156º 30´ and 174º W longitude in late September and early October. Walrus were widespread in this area, but the density was generally highest between 165º and 174º W. The ice edge during these three surveys was generally between 70º and 73º N latitude. These surveys combined with several vessel surveys by Johnson et al. (1982) show that walrus were widespread across the southern margin of the pack ice and, more specifically, they occurred in the region of the two survey areas (162º 50" to 166º 00" W), which when sea ice is present may contain relatively high but variable densities each year. Gilbert (1998) suggested that this spatial variability may reflect a westward movement of walrus in September.

More recently, Brueggeman et al. (1990, 1991, 1992) conducted aerial and vessel surveys at Klondike, Burger, Crackerjack, Popcorn, and Diamond Prospects and the area from the prospects to the Alaska coast from Wainwright northward during 1989, 1990, and 1991. Diamond is about 49 km (30.5 mi) east of Burger, and Crackerjack and Popcorn are over 74 km (46 mi) north and west of Burger. Surveys were conducted to assess impacts of drilling operations on walrus. In 1989, surveys were conducted at the Klondike, Burger, and Popcorn Prospects. Large numbers of walrus migrated through at least one prospect and a small number of walrus summered in open water within all three prospects. The spring migration corresponded to the northward retreat of the pack ice as it passed through the Klondike Prospect, which was the only prospect surveyed as ice retreated through each prospect. Densities were relatively high compared to the range of densities reported by Gilbert (1989) for the ice from the Alaska coast to Wrangel Island. It is very likely walrus also migrated through the other prospects with the retreat of the sea ice given the reported spring migration pattern. During the fall migration, walrus were encountered on pack ice near the Popcorn Prospect, which was the only prospect surveyed at that time because it was the location of drilling activity.

In 1990, surveys were conducted at Popcorn, Burger, and Crackerjack Prospects. However, the pack ice remained north of the prospects when the surveys began in late June. Most walrus were in the marginal ice between Popcorn and Burger Prospects (162º

-165º W longitude). Small numbers of walrus were observed near the Crackerjack Prospect in late September swimming southward of the pack ice, considerably ahead of the pack ice. Although the pack ice was approximately 185 km (115 mi) north of the prospects, various US and USSR investigators conducting aerial surveys during October concluded that the pack ice was too dispersed to support large numbers of walrus and the heavier pack ice was beyond the outer continental shelf, in waters too deep for walrus to feed. The location of these walrus was uncertain, but large numbers of walrus were observed by Soviet scientists along the western Chukchi Sea coast and associated islands. Funk et al. (2009) reported large numbers of walrus were hauled out on the Alaska side of the Chukchi Sea in 2007 when sea ice was north of the outer continental shelf.

In 1991, surveys were conducted at Crackerjack and Diamond Prospects. As in previous years, walrus movements through the prospects were transitory and associated with the retreat of the pack ice. Crackerjack appeared to be on the western periphery of the main walrus concentration during the northward migration, summer-early fall feeding period, and southward migration. Conversely, walrus were numerous in the region of the Diamond Prospect from the northward and southward migrations. The location of the Diamond Prospect is closely associated with Hanna Shoal, a region of relatively shallow water presumed to be an important walrus feeding ground (J. Burns, pers. comm. 2009; Phillips 1987). Walrus were observed in the same general region over the entire course of the survey period at Diamond regardless of the daily shifts of the pack ice. Consequently, the region of the Diamond appears to be within the walrus feeding grounds when pack ice is present.

These collective results shown in Figure 29 confirm that the Klondike and Burger survey areas occur within the broad scale area used by walrus in the Chukchi Sea, which may support a relatively high density of walrus when ice is present; note that gaps in the mapped walrus distribution may reflect no or low survey coverage. Relatively large numbers of walrus likely migrate through the Klondike and Burger survey areas during the spring and also during the fall migration, although the relative numbers are less certain. Small numbers of walrus occur in open water between the spring and fall migration, while most summer in the pack ice. Occurrence in the survey areas is largely transitory with the period of occupancy dependent on the time and duration of pack ice in the survey areas. Severe ice years could result in walrus occupying one or both survey areas for all or most of a summer as was observed at Diamond in 1991.

The 2008 and 2009 results are consistent with each other and with those reported in the literature summarized above. Substantially more walrus occurred in Burger than Klondike both years. While many more walrus were observed in Burger in 2008 (940) than in 2009 (62), approximately equal proportions of total walrus occurred in Burger in 2008 (98%) and 2009 (89%) relative to Klondike. Most walrus recorded in Burger in 2008 occurred near sea ice, whereas there was no sea ice in Burger during the three 2009 cruises. Acoustic studies similarly found more calling walrus at Burger than at Klondike (Hannay et al. 2009, Martin et al. 2008). Most (77%) walrus in 2009 were observed outside of the survey area with about half east and northwest of Burger in sea ice during early August and the rest in open water near Wainwright in late August and early

September. COMIDA reported large numbers of walrus between Pt. Lay and Barrow during this time period. The consistently higher occurrence of walrus at or near Burger may be related to its higher abundance and density of their primary prey (benthic organisms) and closer proximity to Hanna Shoal, an area of historic use by walrus (Blanchard et al. 2009, Sheffield and Grebmeier 2009). As reported in the literature above, many more walrus likely pass through Burger and Klondike as the pack ice advances in the spring and retreats in the fall, which are time periods outside of the research program.

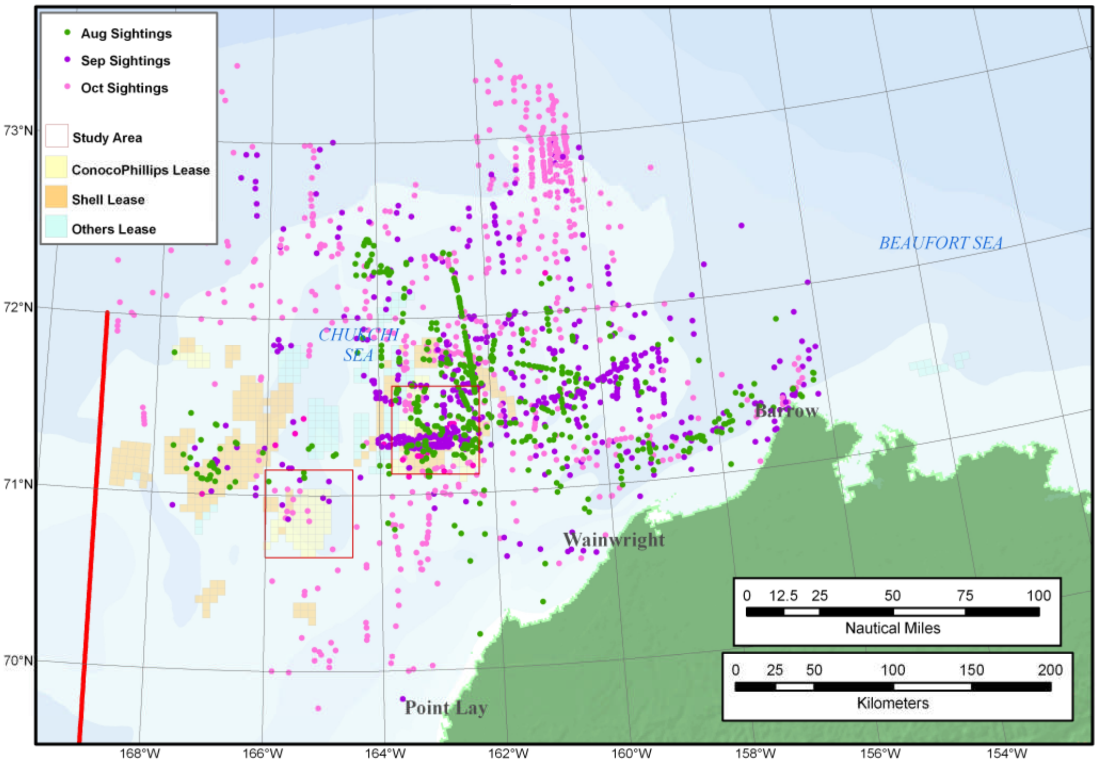

Figure 29. Walrus locations recorded during aerial surveys conducted from 1979 to 2008. Areas without sightings may reflect a lack of survey effort. Sources are NMFS provided by Janet Clark, Funk et al. (2009), Brueggeman et al. (1990, 1991, 1992), and the current research program.

Polar Bears

Polar bears are widespread in the sea ice in the Chukchi Sea (Figure 30). Bear locations coincide with the retreat and advance of the pack ice (Schleibe et al. 2006). There are no discernible east-west movement patterns by bears in the sea ice from past and more recent surveys (Figure 30). Most observations are of single bears, adult with a subadult or mother with cub. Bears have seldom been recorded in open water far from the pack ice (Ferguson et al. 2000). Instances of such occurrences are likely related to bears stranded on sea ice detached from the main pack ice due to shifting winds. Our 2009 observations differ from those in 2008 in number and location. Fewer bears were observed in 2009 (4) than 2008 (9). All nine bears in 2008 were observed in Burger and all 2009 bears were observed a considerable distance east and northeast of Burger. All of the 2009 bears were observed in the pack ice as were the 2008 bears. Most sightings were single bears during both years except for an adult with cub in 2009, and two pairs in Burger and a mother with two cubs near Wainwright in 2008. The behavior of the bears was similar during the two survey years, which included resting and walking except one bear swimming between ice floes in 2008.

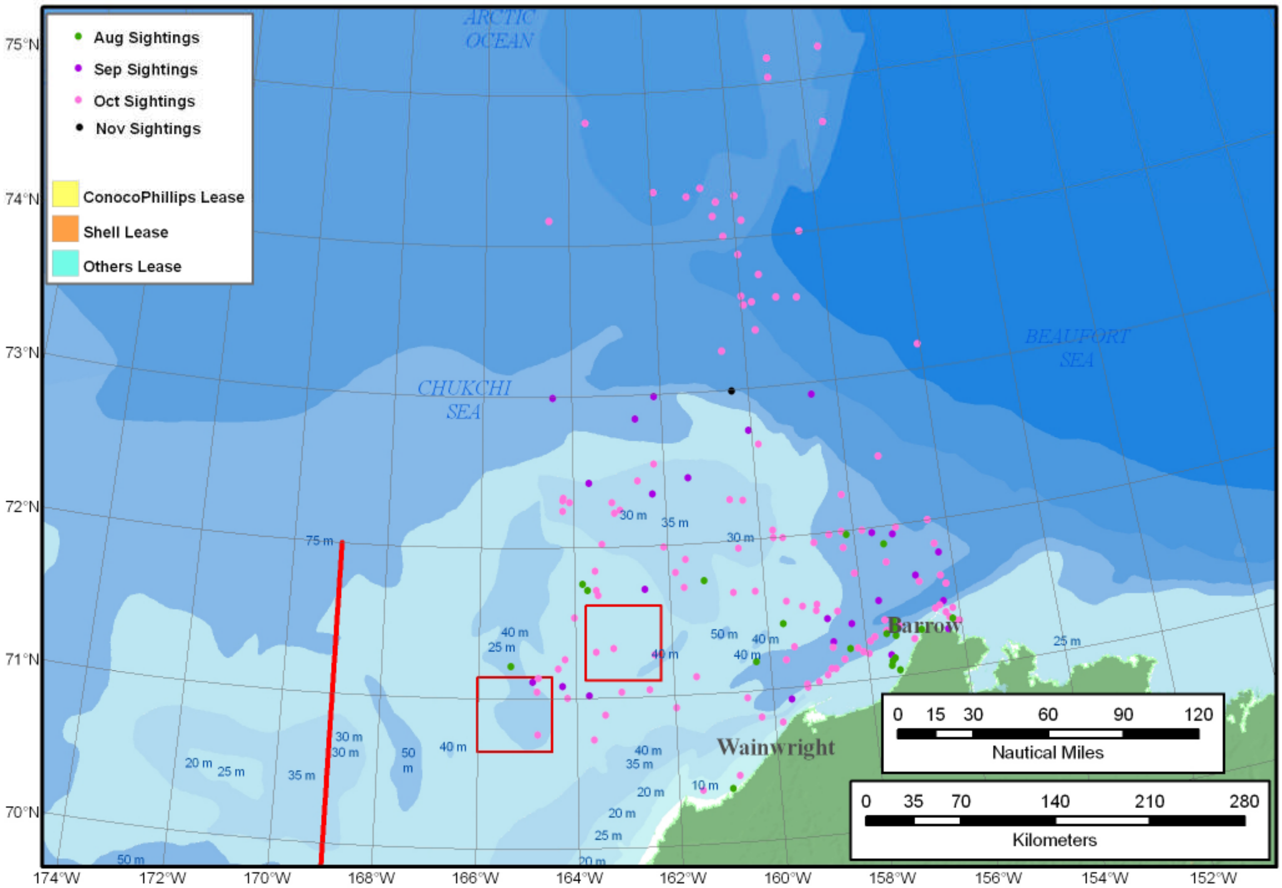

Figure 30 Polar bear locations recorded during aerial surveys conducted from 1979-2008. Areas without sightings may reflect a lack of survey effort. Sources are NMFS provided by Janet Clark, Funk et al. (2009), Brueggeman et al. (1990, 1991, 1992), and the current research program

General Conclusions

Comparison of the 2009 results with those in 2008 and the literature show similarities and differences, which are presented below. A more thorough and conclusive interpretation will evolve as the research program completes each year of the anticipated three-year program.

- Sea ice conditions were very different between the 2008 and 2009 studies. Sea ice was widespread at Klondike and Burger during the entire first cruise and at Burger during the early part of the second cruise in 2008. Conversely, sea ice was absent during all of the 2009 cruises, which started three weeks later than in 2008. However, sea ice was encountered east and northeast of Burger by the research vessel the week before starting the Cruise 1 survey when deploying acoustic equipment. The different ice conditions between years likely influenced the results in the following ways:

    - Seal densities were highly influenced by the presence of sea ice in the survey areas. Densities were much lower in both 2009 (0.003-0.078 seals/km²) and 2008 (0.041-0.075 seals/km²) when Klondike and Burger were ice free than when sea ice was present (0.133-0.381 seals/km²) during the first cruise of 2008.

    - Seals showed no preference for one survey area over the other between years. Klondike had the greatest density in 2008 and Burger in 2009. Nor was the seasonal pattern (reflected by density per cruise) of use recorded in 2008 repeated in 2009 reflecting the different environmental conditions. The first cruise had the greatest density at both Klondike and Burger in 2008, whereas the greatest density in Burger occurred during Cruise 2 and in Klondike during Cruise 3. The results show that in the absence of sea ice, seal occurrence in the two survey areas was low, and the variability attributed to probably natural environmental factors, which could include prey, currents, sea state, broad-scale movements, and possibly sample size.

    - Walrus use of Burger was higher than Klondike in both 2008 and 2009, but numbers were much higher in 2008 (940) than 2009 (62) when sea ice was present in Burger. Many more walruses were recorded in 2009 east and northwest of Burger in or near sea ice before the start of the first cruise as well as in open water near Wainwright. Walruses were detected more frequently by acoustic recorders at Burger than Klondike by JASCO in 2009. The higher walrus use of Burger may be due to higher abundance and density of benthic organisms there, and its location near Hanna Shoal as also possibly reflected by most walrus occurring in the northern half of Burger. The results also indicate a strong preference by walrus for sea ice, consistent with the literature. The reason for large numbers of walrus near Wainwright is unclear, but other researchers similarly encountered high walrus numbers in open water between Pt. Lay and Barrow.

- Broad movement patterns likely explain the differences in occurrence of cetaceans in the two survey areas in 2008 and 2009, with most differences probably associated with random occurrences of a given species at the time of a survey, particularly for minke whales, killer whales, and harbor porpoise. These animals are wide ranging, few in number, and they were likely passing through one of the survey areas as they ranged over the Chukchi Sea in search of food. The situation may be different for gray and bowhead whales, which are more seasonally abundant in the Chukchi Sea. Most gray whales occur closer to shore so few would be expected in the two survey areas as shown in both 2008 and 2009. The two bowhead whales observed in 2008 and the three bowheads observed in 2009 at Burger in October may have been fall migrants or possible summer residents. While recent acoustic and satellite tracking data suggest that most bowheads migrate north of 71 N, which is north of the Klondike survey area but within the Burger survey area, historic data and traditional Eskimo knowledge indicate that some bowheads may also migrate southwest ward through both survey areas. It is likely the majority of the bowhead fall migration in the Chukchi Sea occurred after the end of the research program each year as was likely the case also for beluga whales.

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Appendix Table A-1 Sea state descriptions

The Beaufort Scale: Sea-based specification

Sea State Code (Force)	Speed (10 m above ground)		Description	Specifications for use on land
	Miles per hour	knots		
0	0-1	0-1	**Calm**	Sea like a mirror
1	1-3	1-3	**Light air**	Ripples with the appearance of scales are formed, but without foam crests.
2	4-7	4-6	**Light Breeze**	Small wavelets, still short, but more pronounced. Crests have a glassy appearance and do not break.
3	8-12	7-10	**Gentle Breeze**	Large wavelets. Crests begin to break. Foam of glassy appearance. Perhaps scattered white horses.
4	13-18	11-16	**Moderate Breeze**	Small waves, becoming larger; fairly frequent white horses.
5	19-24	17-21	**Fresh Breeze**	Moderate waves, taking a more pronounced long form; many white horses are formed. Chance of some spray.
6	25-31	22-27	**Strong Breeze**	Large waves begin to form; the white foam crests are more extensive everywhere. Probably some spray.