

**Marine Mammal Surveys at the Klondike and Burger Survey Areas in
the Chukchi Sea during the 2008 Open Water Season**

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Executive Summary¹

Marine mammal surveys were conducted during a multidisciplinary research program in the Chukchi Sea sponsored by ConocoPhillips Alaska, Inc. and Shell Exploration & Production during the 2008 open water season. The purpose of the marine mammal research program was to develop baseline information on marine mammal use of the survey areas that informs decision makers in the development of National Environmental Policy Act (NEPA) documents and ultimately permits. The program also offers the opportunity to add to the existing knowledge base of marine mammal use of the Chukchi Sea. Other disciplines addressed during the overall research program included physical, biological, and chemical oceanography, acoustics, and marine birds. The program is anticipated to continue for three consecutive years beginning in 2008. Reports of the results will be prepared each year culminating in a comprehensive report prepared at the end of the program.

Surveys were conducted by marine mammal observers (MMOs), who were trained biologists experienced in marine mammal surveys. Surveys were conducted from a vessel during three consecutive 32-day cruises beginning on July 23 and ending on October 16 with 1 to 2-day breaks between cruises to resupply the vessel. Surveys focused on two survey areas, Klondike and Burger, which are located over 100 km (62 mi) west of the village of Wainwright on the Alaska coast. Each area was surveyed during each of the three cruises. Surveys were conducted along transect lines that were 55.56 km (34.5 mi) in length along a north-south orientation and spaced 1.85 km (1.2 mi) apart across each survey area. Every other transect was designated as a primary transect line and alternate lines were designated as secondary transects. The basic study plan called for transit of primary transect lines during a survey; however, the secondary transect lines were surveyed opportunistically to increase area coverage when time allowed, or when sea ice presence did not allow access to all primary transects. Two MMOs alternated observations every two hours throughout the daylight hours. Data collected included species, number, location, behavior, distance from vessel, age/sex (when possible), as well as time, date, and observation conditions.

A total of 894 sightings of 2,149 marine mammals comprising 12 species was observed during 610 hours of survey effort covering almost 8600 km (5344 mi) of track line at Klondike and Burger, and areas outside the two survey areas. Pinnipeds comprised 97% of the marine mammals, cetaceans 2%, and polar bears (*Ursus maritimus*) 1%. Seals were the most abundant pinniped, which included ringed (*Pusa hispida*), spotted (*Phoca largha*), bearded (*Erignathus barbatus*), and ribbon seals (*Histiophoca fasciata*). The other pinniped recorded was the Pacific walrus (*Odobenus rosmarus*). Twenty-six calves or juvenile marine mammals were recorded during the cruise, which primarily included bearded seals and walrus but also ringed and spotted seals. Cetaceans were represented by six species including gray whales (*Eschrichtius robustus*), killer whales (*Orcinus orca*), harbor porpoise (*Phocoenaphocoena*), bowhead whales (*Balaena mysticetus*), minke whales (*Balaenoptera acutorostrata*), and Dall's porpoise (*Phocoenoides dalli*) in that order of abundance; the Dall's porpoise was observed off Point Hope on the return

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

trip to Nome in the fall. No beluga whales (*Delphinapterus leucas*) were encountered during the research program. One to three juvenile killer whales were observed in each of the two pods recorded during the surveys, which may have been the same group. There were also nine polar bears which did not include any mother-cub pairs in the study areas; however, a mother and two cubs were observed outside of the study areas swimming just offshore of Wainwright during a crew change.

The number and species composition of marine mammals varied between the two survey areas. All five species of pinnipeds were recorded at both survey areas but many more seals and far fewer walrus occurred at Klondike. Seals were recorded during all three cruises at each survey area with significantly more recorded during the first cruise when sea ice was present. Of the five cetacean species observed during the program, only gray whales were recorded in both survey areas. More gray whales were recorded at Klondike, but all bowhead and minke whales were recorded at Burger. Conversely, all harbor porpoise and killer whales were observed at the Klondike survey area. All bowhead and most gray whales were observed in the fall during the last cruise, while the occurrences of the other cetacean species were spread among the three cruises. Polar bears were observed only during the first two cruises when sea ice was present. Only gray whales were observed feeding. Relatively large numbers of seals, one walrus, and most gray whales were recorded outside of the survey areas toward the coast. Observation conditions varied during each cruise but in all cases they were predominantly acceptable for effectively detecting marine mammals.

Sample sizes were too low to support the derivation of density estimates on a species-by-species basis. When treated as a group, however, the total sample size for seals was sufficient to support a statistically valid density estimate. Density was estimated using the line transect approach based on perpendicular distances of seals from the vessel. Seal density estimates at both Klondike (0.381 seals/km²) and Burger (0.133 seals/km²) were statistically significantly greater (5 and 3 times, respectively) during Cruise 1 than Cruises 2 and 3. In addition, the density estimate was almost three times greater at Klondike than at Burger for Cruise 1, which was statistically significantly different. Density estimates for Cruises 2 and 3 were not statistically significantly different for either nor were they statistically significantly different between Klondike (0.060 seal/km²) and Burger (0.037 seal/km²). Consequently, density estimates were similarly low during Cruises 2 and 3 at both survey areas compared to being much higher during Cruise 1, especially at Klondike. Abundance estimates are not provided, since the number of missed seals is unknown, and there are no reliable correction factors for missed seals in open water.

Based on these results, the following preliminary conclusions can be provided to explain marine mammal occurrence in the survey areas and surrounding region. A more thorough and conclusive interpretation will evolve as the research program completes each year of the anticipated three-year program.

- Sea ice likely influenced the disproportionate use of the survey areas by seals among cruises and between survey areas. Seal occurrence was highest in each survey area

during Cruise 1 when sea ice was most prevalent. The reason for the much higher use of Klondike than Burger by seals during Cruise 1 is unclear.

- Sea ice similarly likely influenced the disproportionate use of the survey areas by walrus among cruises and between survey areas. Most walrus were encountered in association with scattered sea ice off the southern margin of the main pack ice. Higher but still relatively low occurrence of walrus at Burger than Klondike after the ice moved northward could be related to Burger's closer location to Hanna Shoals, a shallow area known to be used by walrus. Benthic communities, which provide the primary walrus prey, had statistically significantly higher abundance, biomass, and number of taxa at Burger than at Klondike according to results of benthic studies conducted in conjunction with the subject marine mammal surveys. This could have been due to differing substrates and other factors between the two areas.
- Broad movement patterns likely explain the differences in occurrence of cetaceans in the two survey areas, 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, 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. Most gray whales occur closer to shore so few would be expected in the survey areas. The two bowhead whales observed in Burger in October may have been fall migrants or possible summer residents. While recent 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 through both survey areas. It is likely the majority of the bowhead fall migration in the Chukchi Sea occurred after the research program ended in mid-October.

1.0 Introduction

The Chukchi Sea provides habitat to over ten species of marine mammals, which are key to the subsistence lifestyle of the coastal villages. Marine mammals migrate, summer, and reside year-round in the Chukchi Sea. Bowhead and beluga whales transit through the Chukchi Sea between summer and winter ranges. Gray whales, minke whales, and harbor porpoise feed there during summer-fall. Use by spotted, ribbon, and most bearded seals and walrus corresponds to the period encompassing the retreat and advance of the pack ice. Ringed seals and polar bears are the only year-round residents except for a few bearded seals. Other species occasionally found in the Chukchi Sea include small numbers of killer, fin (*Balaenoptera physalus*), and humpback (*Megaptera novaeangliae*) whales.

Managing oil and gas operations to maintain healthy marine mammal populations requires understanding the ecology of the Chukchi Sea. ConocoPhillips Alaska, Inc. (CPAI) and Shell Exploration & Production (Shell) funded a multidisciplinary research program in the Chukchi Sea during the 2008 open water season. The program integrates studies of marine mammals and seabirds with physical, biological, and chemical oceanography and acoustics to build upon other research programs (Rugh et al. 2009, Ireland et al. 2008, Suydam et al. 2005) for beginning to understand the ecology of the Chukchi Sea. This report addresses the marine mammal research element of the 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 Prospects) within lease sale area 193 of interest to CPAI and Shell in the Chukchi Sea. The specific objectives of the program were to determine:

- Species composition, distribution, and relative abundance of marine mammals
- Habitat use and behavior (e.g., feeding, mating, etc.) of marine mammals
- Influence of physical and biological oceanography on marine mammal use
- Contribution of acoustics in describing use of survey areas by bowhead and beluga whales

The 2008 program is the first of what is anticipated to be a three-year research program, after which a comprehensive report will be prepared integrating all of the elements of the research program to address the stated objectives.

2.0 Study Area

The study area is located in the eastern Chukchi Sea approximately 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 geographically defined as a 55.6 x 55.6 km (34.5 x 34.5 mi or 30 x 30 nm) block covering 3,091.4 km² (1,192 mn² or 900 nm²). The size and dimensions of the blocks were based on being large enough to include the areas of interest to CPAI and Shell and also large enough to provide meaningful research results. In addition, the areas transited to access the blocks, either between the blocks and to or from the village of Wainwright, were included in the study area, but they were ancillary to the blocks. 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.

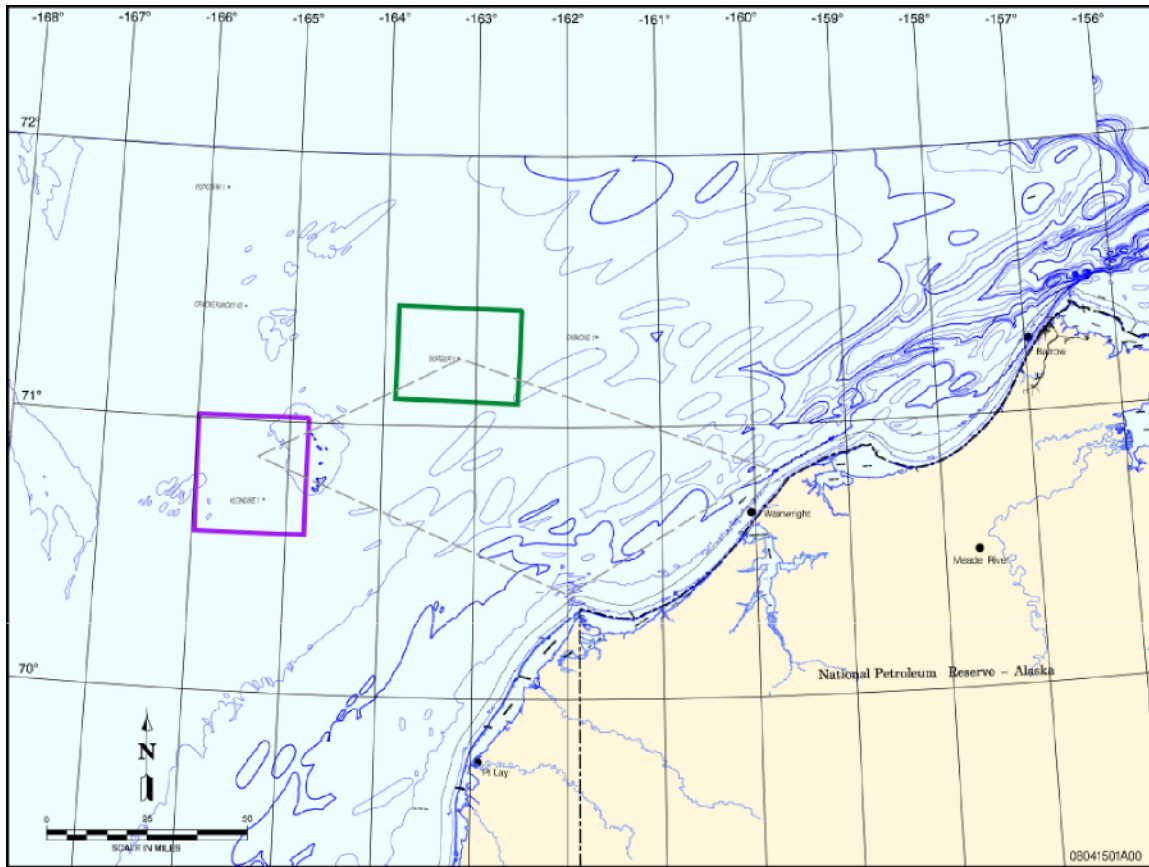


Figure 1 Study area showing the Klondike (purple) and Burger (green) survey areas

The study area is ice covered from late fall to early summer and in certain years intermittently throughout summer. The sea ice retreats northward through the study area during approximately July and August and advances southward during November and December. Ice movement is largely driven by the prevailing seasonal winds. 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 during more climatically severe years. This creates uncertainty about the time and duration ice may cover the survey areas each year. Correspondingly, environmental 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 substrate characteristics, possibly affected by oceanographic conditions. The substrate at Klondike is more gravelly, while Burger has more soft sediment, possibly creating better habitat at Burger for mollusks and other benthic organisms that inhabit soft sediments (Blanchard et al. 2009). Oceanographic conditions at the two areas are not well understood, but studies are currently underway to characterize the currents, temperature, and salinity. Understanding the oceanography and

substrate will provide a basis for better describing marine mammal use of the two areas. Water depths at the two survey areas are similar and range from approximately 25-40 m.

3.0 Methods

Survey Design and Procedures

Surveys were conducted from a research vessel within each survey area during three consecutive cruises from July 23 through October 16, 2008 (Figure 2). Each cruise was approximately 32 days long and separated by 1-2 days for crew change and to resupply the vessel. Marine mammal observers (MMOs), who were trained biologists experienced in marine mammal surveys, recorded marine mammals along 31, 55.6 km (34.5 mi or 30 nm) north-south transect lines equidistantly spaced 1.9 km (1.2 mi or 1 nm) apart across each survey area (Figure 2). Every other line was initially surveyed to better ensure each area was entirely surveyed during each 32-day period. Skipped transect lines were surveyed when time and conditions permitted to extend coverage within the survey areas. Transect lines were surveyed sequentially to minimize fuel usage and maximize time whenever possible; some modification was required to avoid sea ice. For analytical purposes, north-south lines were termed systematic, connecting east-west lines deadheads, and all other lines transits.

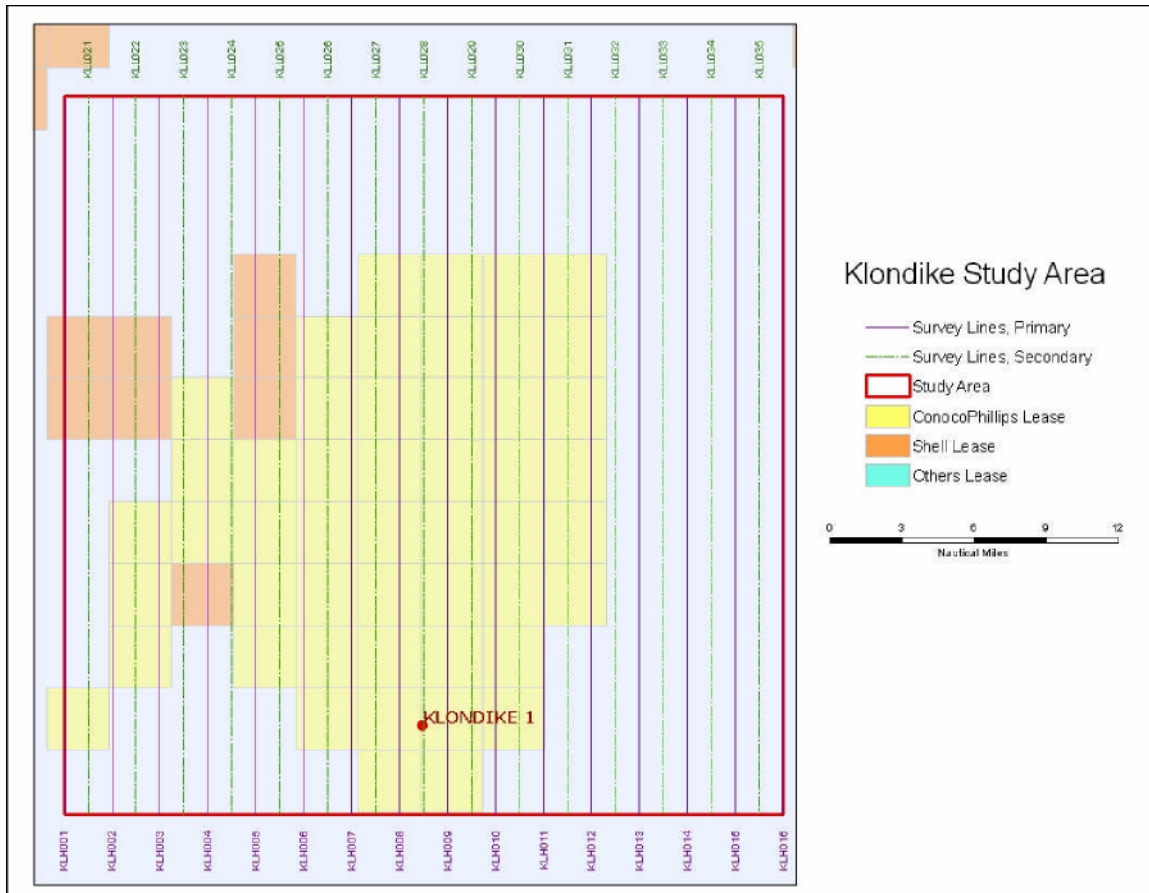


Figure 2 Survey design showing trackline configuration

Both survey areas were surveyed during each of the three cruises. One survey area was generally completed before transiting to the other survey areas. However, sea ice and weather conditions occasionally required the vessel to move between areas to circumnavigate these conditions and complete the surveys. A full survey required a minimum of five days to complete per area or 10 days for both areas, assuming a cruising speed of 8-10 kt. However, sea ice and weather increased the time to complete each survey area, resulting in the survey coverage varying between each area and cruises.

Vessel-based MMOs watched for marine mammals from the best available vantage point on the vessel, which was the bridge. The MMOs systematically scanned the survey area with the naked eye, aided by 7x 50 reticule binoculars; a spotting scope mounted on a gun-like stock was used for confirming species identification and behavior when sea states permitted. 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. Marine mammal observations occurred during essentially all daylight hours each day, depending on weather conditions. Two MMOs alternated 2-hour watches to minimize fatigue. Observations began about one hour before sunrise and ended about one hour before nightfall. Data were recorded on field forms and transferred to an Excel spread-sheet loaded into a laptop computer, which was transmitted to the principal investigator's land-based office daily or whenever possible. A brief narrative was also recorded in field

notebooks of more detailed observations by MMOs of marine mammals or survey conditions.

When a mammal sighting was made, the following information about the sighting was recorded on the field form:

- Species, number, group size, age/size/sex categories (if determinable), behavior, direction of travel (cetaceans), and perpendicular distance from vessel
- Date, time, and location of the vessel, sea state (Beaufort Wind Scale), ice cover (10% increments), visibility, and sun glare
- 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 minutes, and whenever there was a change in one or more of those variables. Location was obtained from either a hand-held GPS or the navigation system on the ship.

Distances to nearby marine mammals were estimated visually or with sighting aids (laser range finder, fixed points, clinometer, reticule in binocular, etc). MMOs used sighting aids to test and improve their abilities for visually estimating distances to objects in the water. Surveys were generally not conducted during sea states exceeding a Beaufort 6, since marine mammals become too difficult to detect in seas this high (Brueggeman et al. 1990; see Appendix A-1 for sea state descriptions).

Analytical Procedures

Density was calculated for seals but not for cetaceans, walrus, 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:

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

where D = density of a species in number of animals/km²
 n = number of sightings
 S = mean group size
 $f(0)$ = sighting probability density on the trackline
 L = length of trackline completed (in km)
 $g(0)$ = probability of seeing a group directly on the trackline

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 trackline. 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 trackline but missed during the survey. The $g(0)$ value used to calculate density was one, which assumes MMOs saw all animals on the trackline. Experiments were not conducted in the field to calculate the value, but it is likely that observers saw most if not all of the seals on the trackline due to the experience of the MMOs, height of the platform, and survey conditions.

4.0 Results

Species Composition and Numbers

A total of 894 sightings of 2,149 marine mammals comprising 12 species was observed during the research cruises (Table 1). Seals were the most abundant species of pinniped, which included ringed/spotted, bearded, and a few ribbon seals in that order of abundance. Ringed and spotted seals were combined because of the difficulty of distinguishing between the two species in open water. A large number of seals were not identified as to species. Most of these unidentified seals were encountered in large concentrations during the first three days of the cruise. The difficulty of distinguishing seal species in open water combined with encountering large concentrations viewed from a passing vessel unable to stop or deviate from a trackline because of mitigation measures instituted by CPAI and Shell resulted in high numbers of unidentified species. Species identification was further compromised by the challenge of obtaining a total count of large numbers of seals. The remaining pinniped species observed during the cruise was the Pacific walrus, which numbered almost 1000 animals or about 45% of the total number of pinnipeds. Small numbers of unidentified pinnipeds were also recorded but most were likely walrus, since they were observed near other walrus. Twenty-six calves/juveniles were recorded during the cruise, which primarily included bearded seals and walruses but also ringed and spotted seals.

Table 1 Sightings and numbers of marine mammals observed in Chukchi Sea research project

Species	Klondike		Burger		Other		Total	
	Sightings	Number	Sightings	Number	Sightings	Number	Sightings	Number
Ringed/Spotted	100	112	31	31	33	38	164	181
Ringed Seal	59	67	13	13	30	37	102	117
Spotted Seal	19	20	15	16	21	24	55	60
Bearded Seal	36	37	59	62	19	20	114	119
Ribbon Seal	4	4	2	2	0	0	6	6
Walrus	8	24	39	940	1	1	48	965
Unidentified Seal	205	309	49	49	83	249	337	607
Unidentified Pinniped	6	7	16	19	6	6	28	32
<i>Subtotal</i>	<i>437</i>	<i>580</i>	<i>224</i>	<i>1132</i>	<i>193</i>	<i>375</i>	<i>854</i>	<i>2087</i>
Harbor Porpoise	3	7	0	0	0	0	3	7
Gray Whale	2	3	1	1	12	18	15	22
Killer Whale	2	9	0	0	0	0	2	9
Bowhead Whale	0	0	2	2	0	0	2	2
Minke Whale	0	0	1	1	0	0	1	1
Dall's porpoise	0	0	0	0	1	1	1	1
Unidentified Whale	1	1	1	2	7	8	9	11
<i>Subtotal</i>	<i>8</i>	<i>20</i>	<i>5</i>	<i>6</i>	<i>20</i>	<i>27</i>	<i>33</i>	<i>53</i>
PolarBear	0	0	7	9	0	0	7	9
Total	445	600	236	1147	213	402	894	2149

Six species of cetaceans were recorded during the research cruises (Table 1). Gray whales were the most abundant, followed by killer whales, harbor porpoise, bowhead whales, one minke whale, and one Dall's porpoise. There were no beluga whales observed during the cruises, but they occur in the Chukchi Sea. There were eleven unidentified whales, which the majority was most likely gray whales. One to three juvenile killer whales were observed in each of two pods. There were also seven sightings of nine polar bears.

The number and species composition of marine mammals varied between the two survey areas (Table 1). Most seals and cetaceans but fewer walrus and no polar bears were observed at the Klondike as described below:

- All five species of pinnipeds were recorded at both survey areas but many more seals (86%) and far fewer walruses (3%) occurred at Klondike.
- All species of seals were more abundant at Klondike except for bearded seals; however, the large number of unidentified seals makes this comparison tenuous, although bearded seals are more recognizable than ringed and spotted seals in open water.
- Of the five cetacean species observed in the survey areas only gray whales were recorded in both areas.
- More gray whales (3 vs 1) were recorded at Klondike but all of the bowhead (2) and minke (1) whales encountered in the survey areas were observed at Burger.

- Conversely, all of the harbor porpoise and killer whales were observed at Klondike.
- Relatively large numbers of seals, one walrus, most (18 of 22) gray and unidentified whales, and the one Dall’s porpoise were recorded in areas outside of the survey areas on transits to and from Wainwright and the early part of the transit to Nome while still near the region of survey areas.

Survey Effort

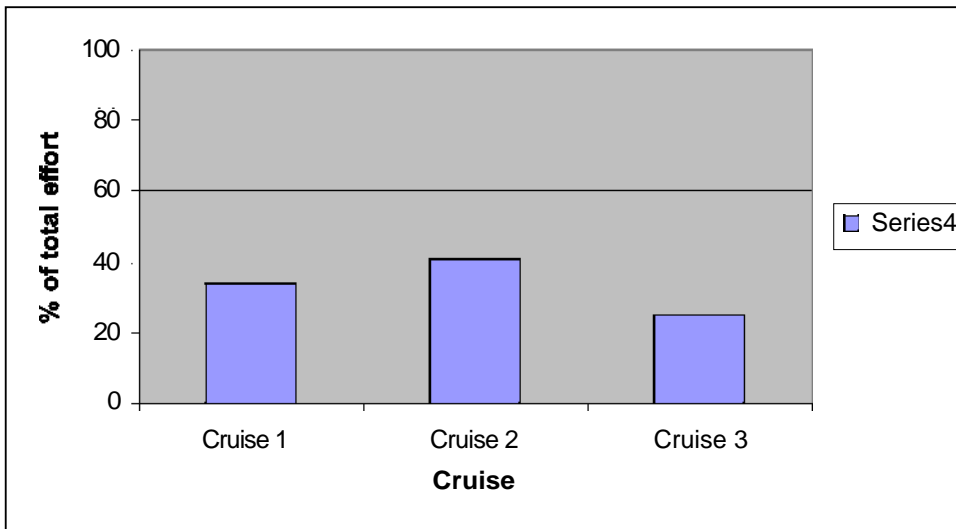
A total of 610 hours of survey effort covering almost 8600 km (5344 mi) of trackline was conducted for marine mammals at the Klondike and Burger survey areas, and areas outside of them, between July 23 and October 23, 2008 (Table 2). Survey effort was 13% higher at Klondike (54%) than the Burger survey area (41%). Five percent of the effort occurred in areas outside of the two survey areas, including transiting between Wainwright and the survey areas and also to Nome at the end of the research program.

Table 2 Marine mammal survey effort for Chukchi Sea research project

Location	Effort (hr)	% Effort	Effort (km)	% Effort
Klondike	328	54	4598	54
Burger	252	41	3558	41
Other	30	5	436	5
Total	610	100	8592	100

Survey effort varied during the three cruises (Figure 3). Effort was highest (41%) during the second cruise, lowest during the last cruise (25%), and intermediate during the first cruise (34%). Effort was consistently highest at Klondike for each cruise, but the difference was relatively small (10-19%) per cruise (Figure 4). Effort between survey areas was primarily affected by sea ice cover, which limited access to Burger more than to Klondike, particularly during the first two cruises.

Figure 3 Total survey effort per cruise



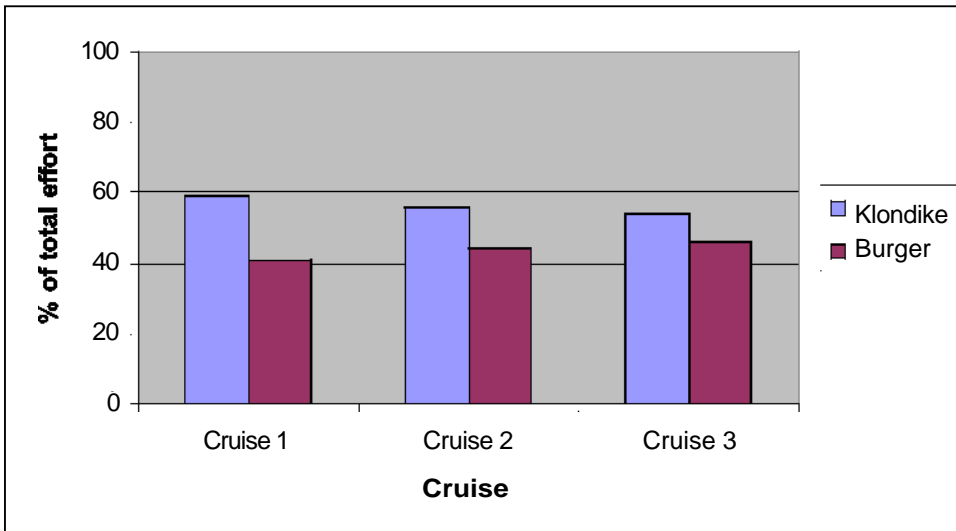


Figure 4 Survey effort at Klondike and Burger per cruise

Survey Conditions

Sea state, visibility, and glare were recorded to gauge observation conditions during the marine mammal research program at Klondike and Burger and areas outside of them. High sea states, poor visibility, and severe glare can substantially reduce the effectiveness of detecting marine mammals and subsequently influence the results of survey activities on marine mammals. Sea ice cover was also recorded, since it affects the species composition and abundance of marine mammals.

Sea state conditions of 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 over 90% of the time at the two survey areas but proportionally lower at Burger during the surveys (Figure 5). Sea states were lowest during Cruise 2 at Burger and Klondike, highest during Cruise 3 at both areas, and intermediate during Cruise 1. Sea states ranging from 2-4 were most common in the two survey areas during each cruise. Sea states were generally lower on transits outside of the survey areas.

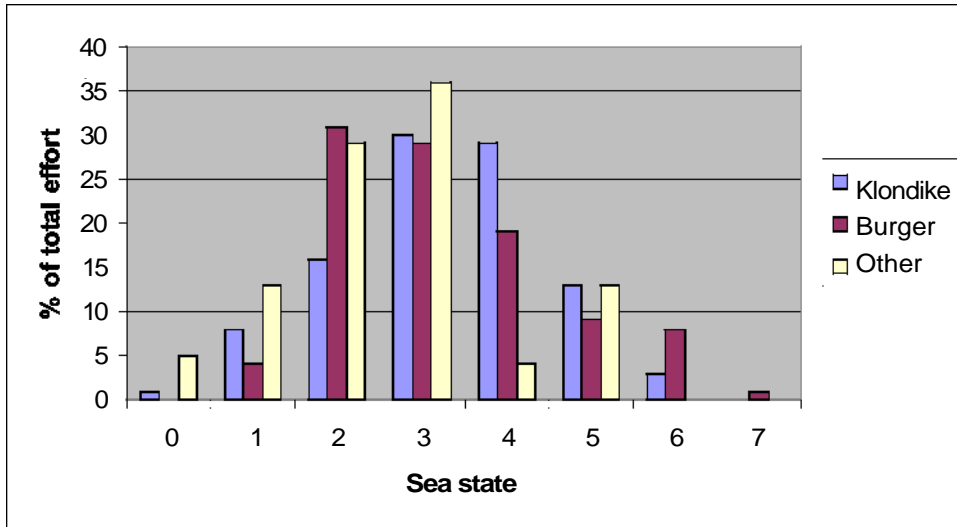


Figure 5 Sea states during marine mammal surveys (sea state descriptions in Appendix Table A-1)

Higher visibility enables a greater area to be monitored for marine mammals, which adds to the quality of the data. Visibility was very acceptable (>3 km or (>1.7 mi) for conducting marine mammal surveys at both areas, although the visibility was better at Klondike than Burger (Figure 6). Visibility from the vessel was greater than 1 km (0.2 mi) the majority (> 90%) of the survey effort at the two areas. The percentages of time visibilities exceeded 3 km (1.7 mi) and 5 km (3.1) were 95% and 80% at Klondike and 80% and 50% at Burger. About ten percent of the time visibility was variable 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 most of the effort occurring at visibilities exceeding 3 km (1.7 mi) and often 5 km (3.1 mi). The only noteworthy difference in visibilities per cruise was during Cruise 2 at Burger when 16% of the effort occurred during visibilities at 1 km (0.2 mi) or less compared to 0-3% for all other cruises. Visibility in areas outside of the two survey areas was generally similar to that recorded within them, although it was more variable beyond 3.5 km (2.2 mi) from the vessel; a category used when visibility conditions frequently changed beyond 3.5 km (2.2 mi) from the vessel.

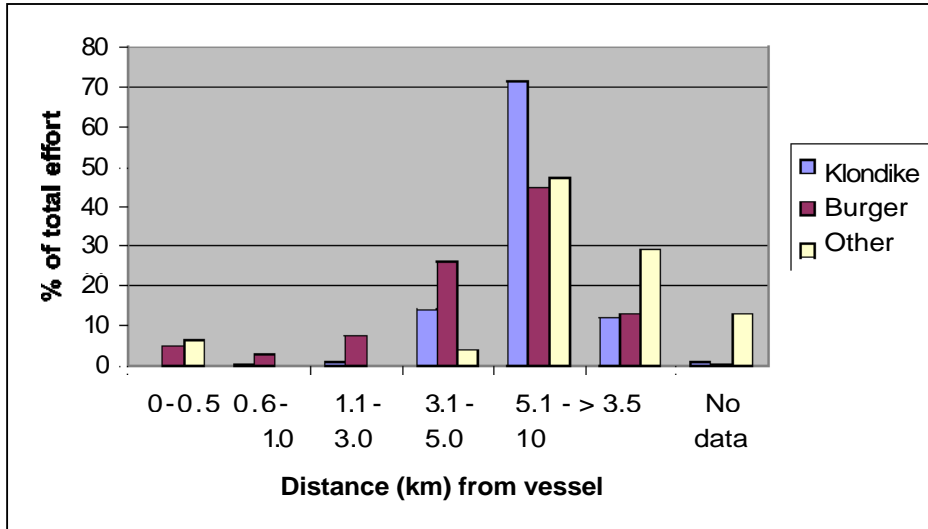


Figure 6 Visibility conditions during marine mammal surveys

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 acceptable (light to moderate) for conducting marine mammal surveys but they varied somewhat between survey areas (Figure 7). Light to no glare occurred most often during surveys at the Klondike (>45%) and Burger (>65%) survey areas, while severe glare occurred about 20% of the time and moderate glare 5% or less of the time at each survey area. Glare was variable 20% or less at the two survey areas. Conditions were generally acceptable during each of the three cruises except glare was severe for about 40% of the survey time during Cruise 2 at Klondike and about 30% of the survey time during Cruise 1 at Burger; severe glare was much lower (about <20%) during the other two cruises at each survey area. Conditions generally similar to the survey areas were encountered in areas outside of them.

These results show that observation conditions as measured by glare, sea state, and visibility were variable but suitable for the MMOs to effectively detect and monitor marine mammals the majority 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 was typically balanced by another metric. Therefore, observation conditions likely had little effect on the comparability of the results among the three cruises and between the survey areas.

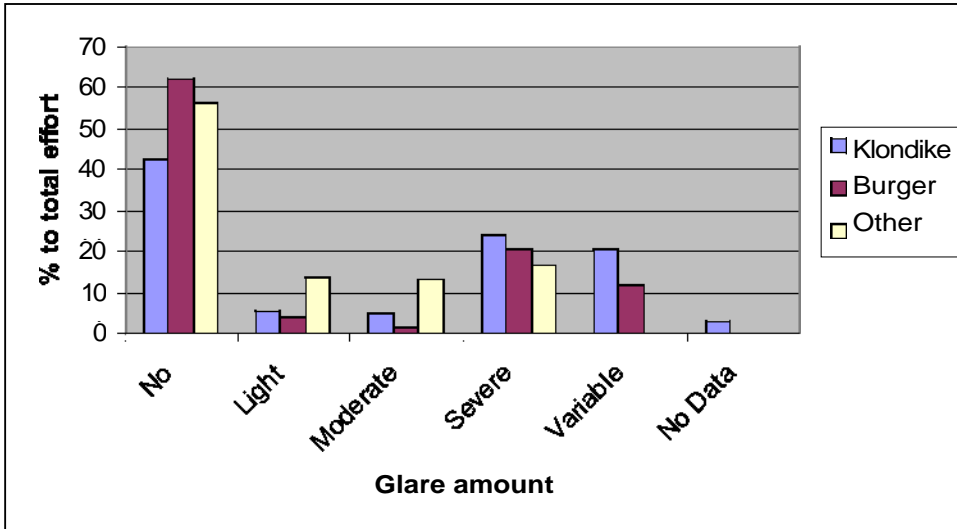


Figure 7 Glare conditions during marine mammal surveys within the 180° viewing area centered on the bow of the vessel (No = none, Light = easy to view survey area; Moderate = see an animal’s shape but not always able to distinguish species; Severe = too bright to view the survey area in front of the vessel; Variable= frequently changing glare conditions).

Sea ice was present in both survey areas, but more often at Burger based on satellite maps and observations by MMOs on the vessel. Sea ice cleared from Klondike after early September. Ice partially covered Klondike, primarily in the northern half. Burger was ice covered until the middle of September, after which the pack ice retreated northward out of the survey area. Sea ice covered most if not all of Burger when it was present. Burger was briefly ice-free during the first week of September when a tongue of ice shifted south back over the survey area before eventually retreating northward. Sea ice occurrence in both areas was generally reflected in the percent of daily survey effort. Sea ice was encountered in each area (Figures 8, 9); gaps in the time spans sea ice was present in each area were due to the specific location of the vessel in an area each day and which area was being surveyed by the vessel. Burger had a much greater number of days than Klondike when sea ice was encountered during most or all of the survey effort. The vessel was not able to survey far inside of the sea ice, which affected Burger during Cruise 1; this required adjusting the survey in concert with the northward retreat of the sea ice to cover all but the northeastern quarter of Burger.

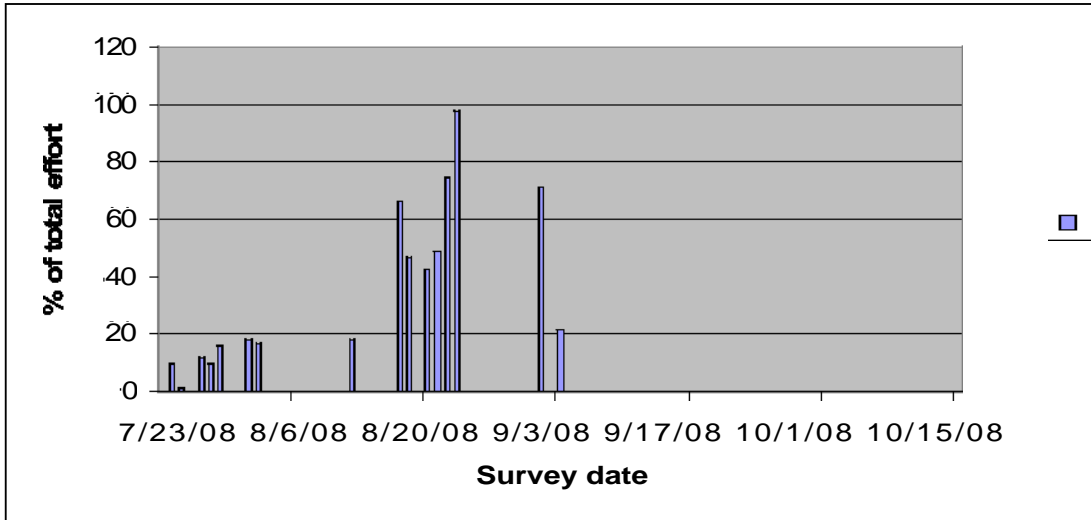
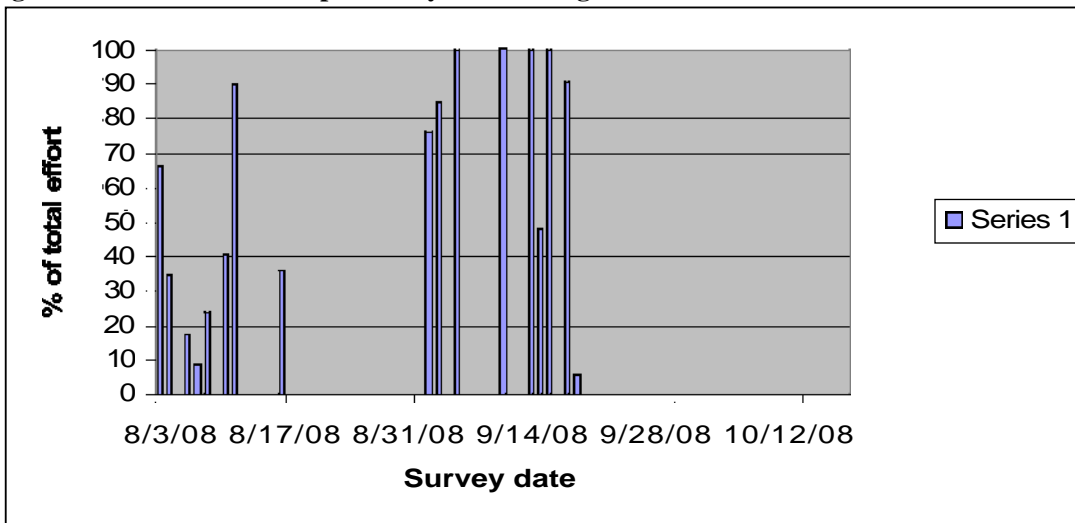


Figure 8 Percent of ice cover per survey date at Klondike area

Figure 9 Percent of ice cover per survey date at Burger



Spatial and Temporal Distribution

Seals were widely distributed in space and time throughout all of the areas surveyed during the research project (Figure 10). At Klondike seals were observed on almost 90% of the total number of survey days. Highest numbers (75%) of seals were recorded during the first five days (July 23-27) of the program after which daily numbers remained below about 20 seals and frequently below 10 seals (Figure 11). There was no obvious pattern of occurrence by any seal species in the survey area. A similar pattern was observed at Burger for seals, but the distribution was affected by sea ice limiting vessel access to parts of Burger, particularly during the first cruise (Figure 12). Seals were recorded on over 85% of the total number of survey days with most of the days of no seals associated with difficult observation conditions caused by high (> 5) sea states. Most (54%) of the

seals were recorded during the first six survey days (Aug 6-10), although daily counts (< 25 seals) were much lower than recorded at Klondike. Daily counts remained low the rest of the research program, commonly below 10 seals. Each seal species except ribbon seals was seen throughout the program, indicating no temporal pattern of use. Outside of the survey areas on transits to Wainwright and elsewhere, seals were seen on 6 of the 7 survey days, which spanned the research program (Figure 13). A particularly large number was recorded toward the end (Oct 22) of the program representing most (70%) of the total sightings. Again, all seal species except ribbon seals were consistently encountered during most survey days covering the span of time of the program. The results show that seal species were present in and outside of the two areas throughout the research program with most occurring during the early part of the survey program in each area. The large number of seals seen at the end of the program outside of the survey areas may have been due to sea ice, which seals used to haul out making them easy to count.

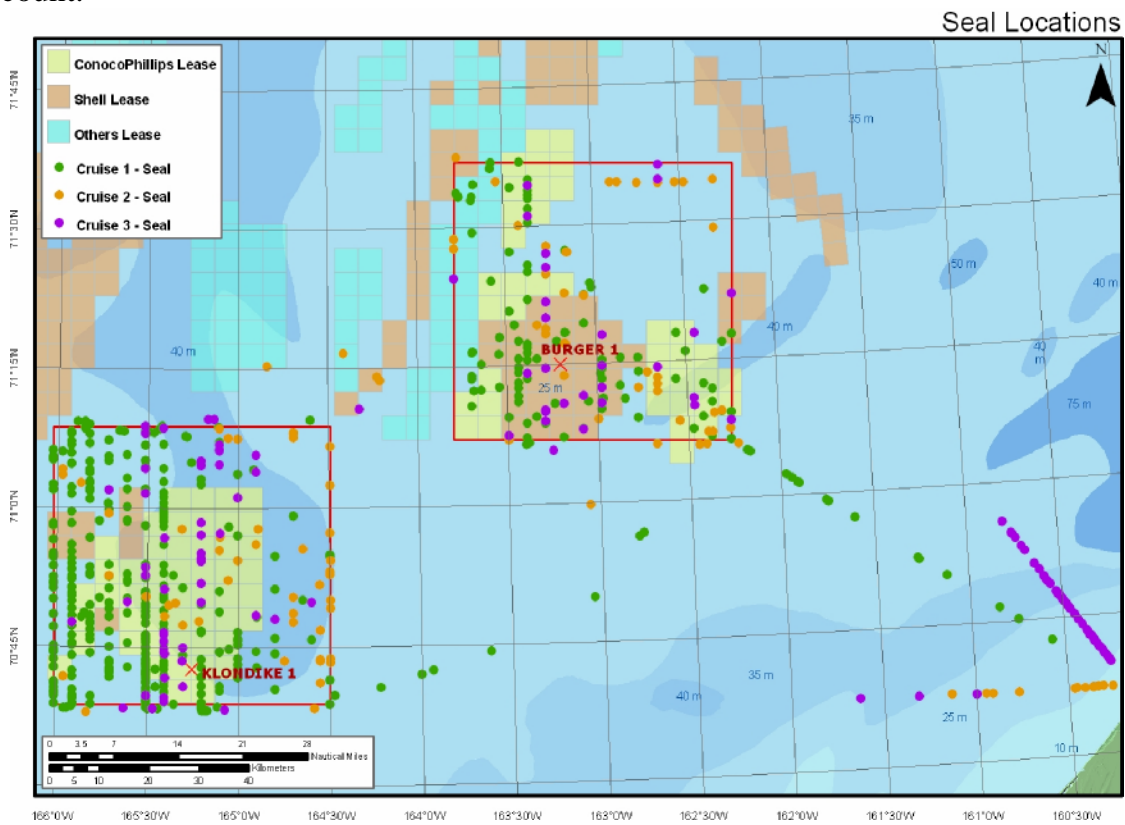


Figure 10 Seal sightings at the Klondike and Burger survey areas during the three cruises

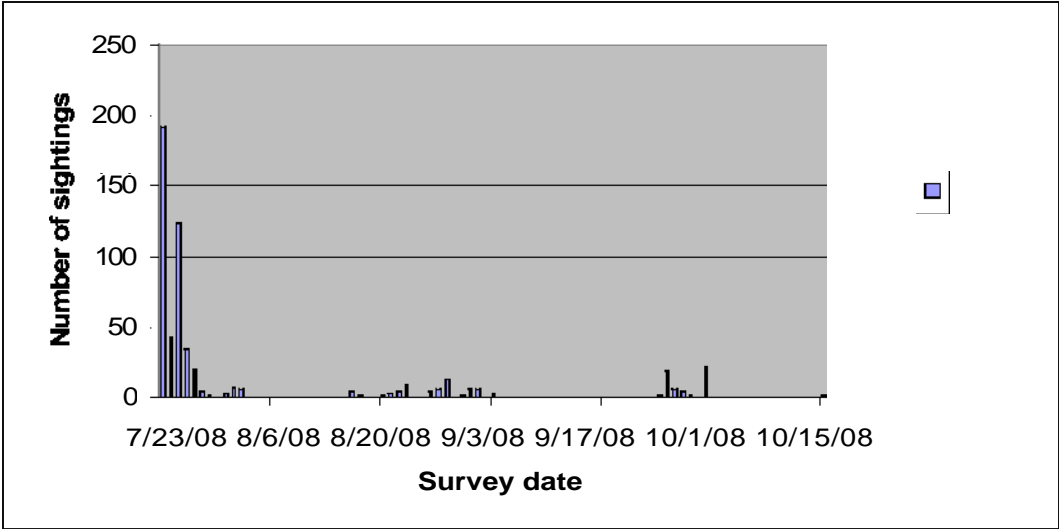


Figure 11 Number of seal sightings per survey date at Klondike from July 23-Oct 15, 2008

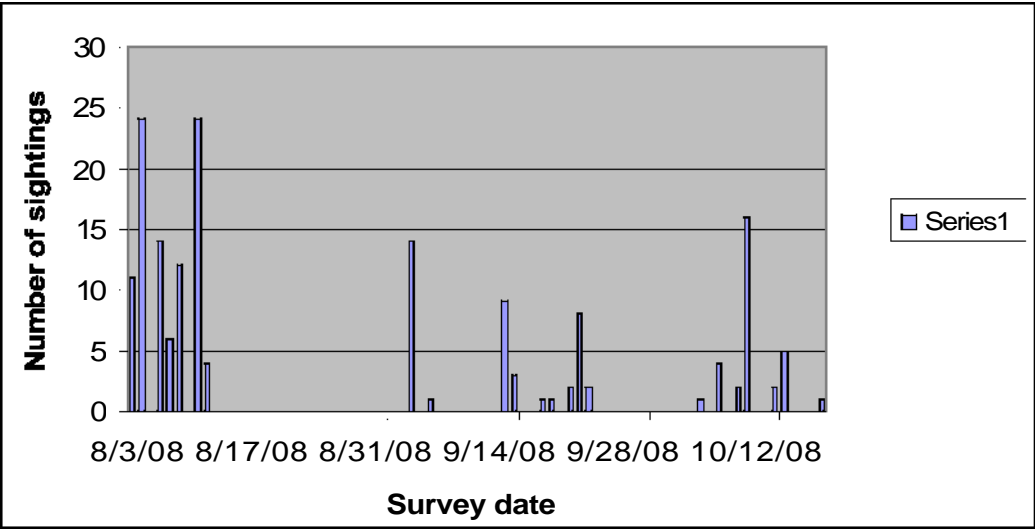


Figure 12 Number of seal sightings per survey date at Burger from Aug 30-Oct 16 2008

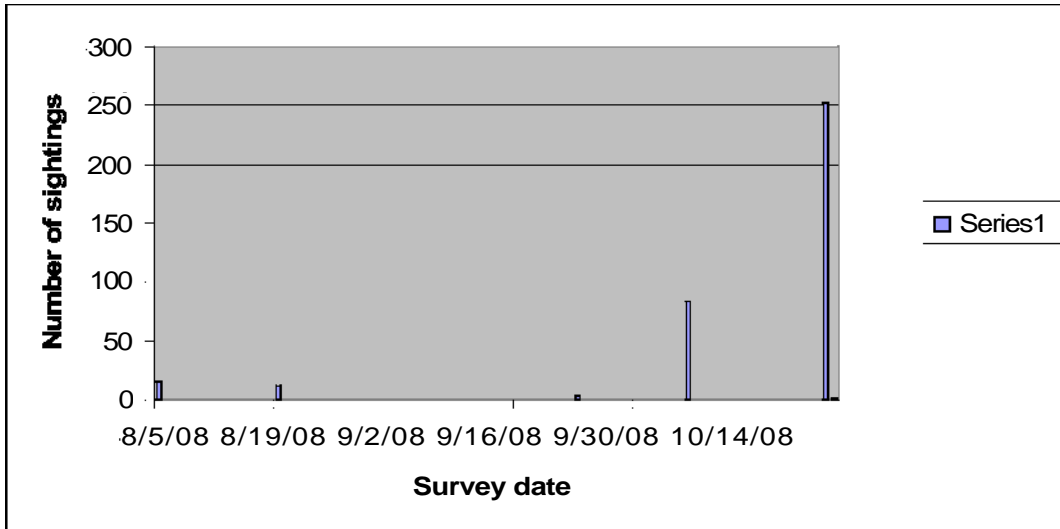


Figure 13 Number of seal sightings per survey date outside of the survey areas from Aug 5-Oct 23 2008

Walrus were more concentrated in their spatial and temporal distribution during the research program than seals (Figure 14). At Klondike, walrus were recorded during a small proportion (17%) of the total survey days with all but one occurring after Sept 24. No more than 10 animals were seen on any given survey day. Conversely, walrus were observed at Burger on over a third (38%) of the survey days spread throughout the survey period (Figure 15). Except for one day in the middle of September (13th) when there were over 900 walrus, the daily numbers were consistently below 10 animals. At both Burger and Klondike most walrus were primarily observed in the northern halves of each survey area (Figure 14). Only one walrus was recorded outside of the two areas during the latter half of September. Most of the unidentified pinnipeds were likely walrus, since many were recorded at or near the time walrus were in the survey areas, thereby reflecting similar temporal distribution patterns to walrus in the program area.

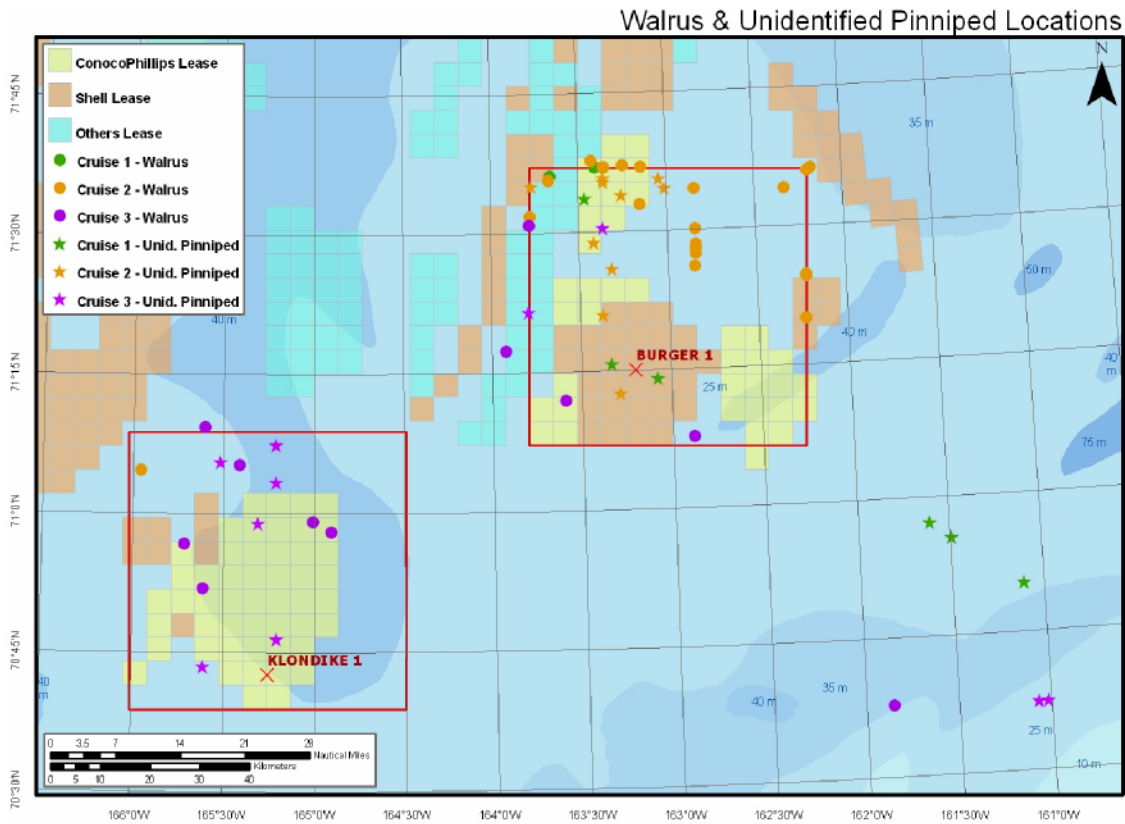


Figure 14 Walrus sightings at the Klondike and Burger survey areas during the three cruises

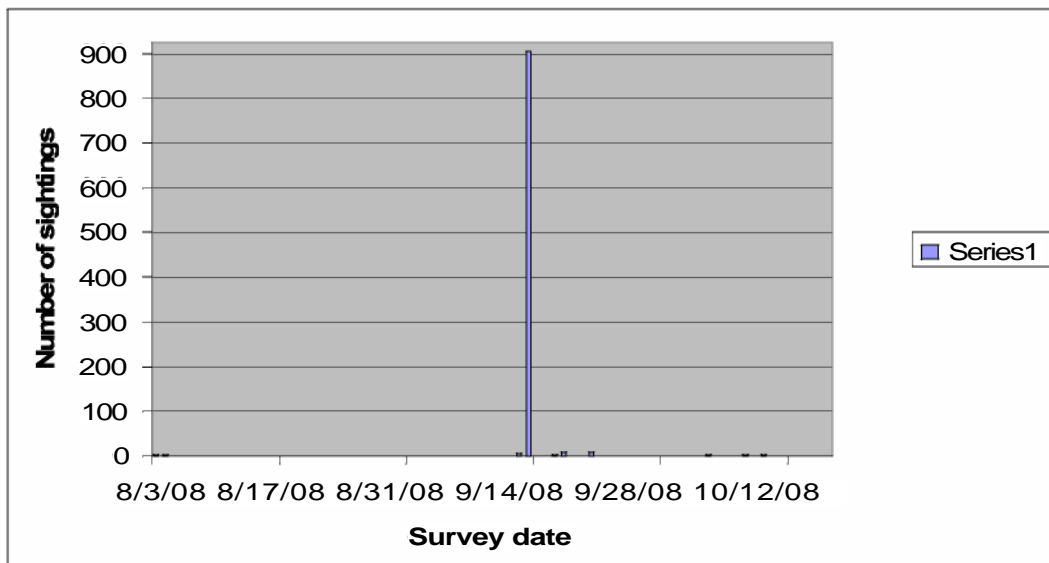


Figure 15 Number of walrus sightings per survey date at Burger (there is no graph for Klondike due to low number of sightings)

Cetaceans were widely scattered in time and space in the program area (Figure 16). At Klondike, cetaceans were encountered during fewer (22%) than a quarter of the total survey days. Except for two unidentified cetacean sightings, all were recorded during

July and August, which included all four species observed at Klondike. At Burger, cetaceans were recorded during a small proportion (14%) of the total survey days. Most of the cetaceans were recorded after October 1, including two bowhead whales and one gray whale. Outside of the survey areas, most of the cetaceans were recorded after October 1 including all but one of the gray whales and all of the unidentified whales, which were most likely gray whales given most were seen at or near the same time and location of the gray whales.

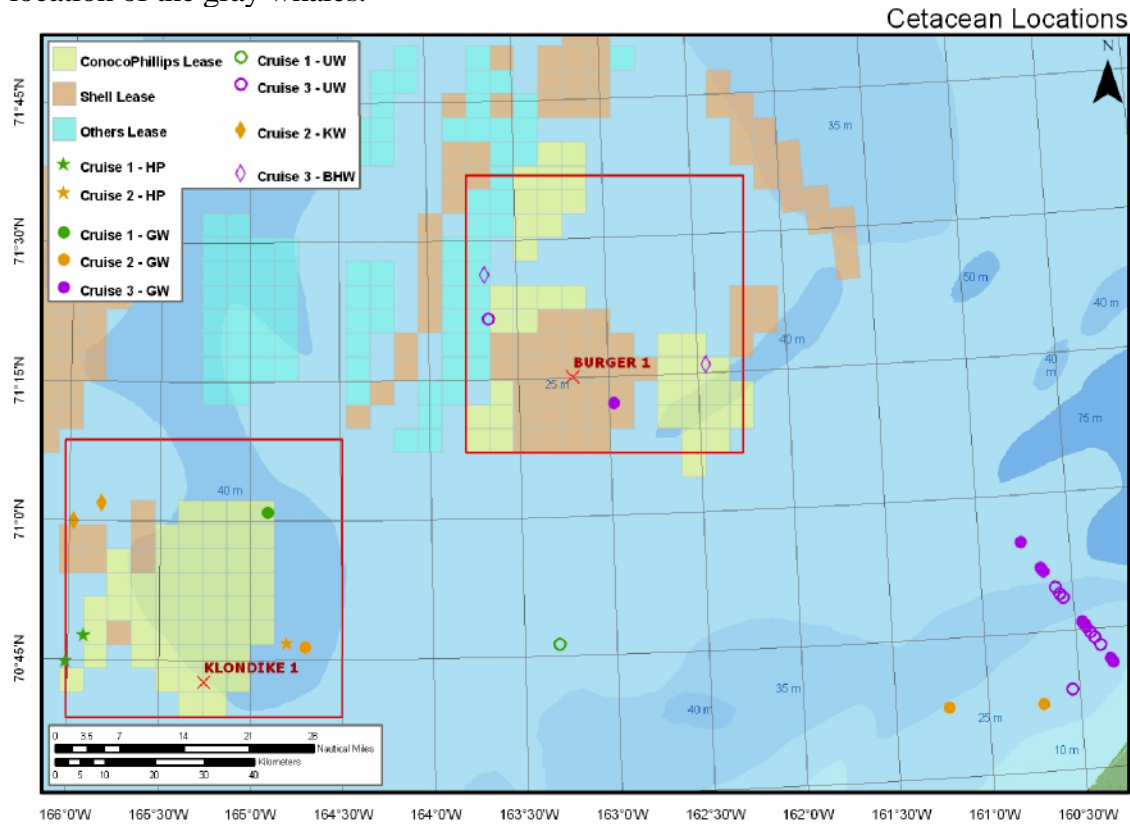


Figure 16 Cetacean sightings at the Klondike and Burger survey areas during the three cruises

Polar bears were only seen at Burger where they were geographically widespread (Figure 17). All were recorded during Cruise 2 except for one bear observed during Cruise 1. The latter was seen in mid-August and the others in mid-September (9/12-14). One of the nine bears observed was swimming in the water toward several ice floes, while the others were on the sea ice. No bears were recorded after the sea ice moved north of the survey areas. The close timing and wide spacing of locations suggests most of the bears were new bear sightings and not duplicate counts.

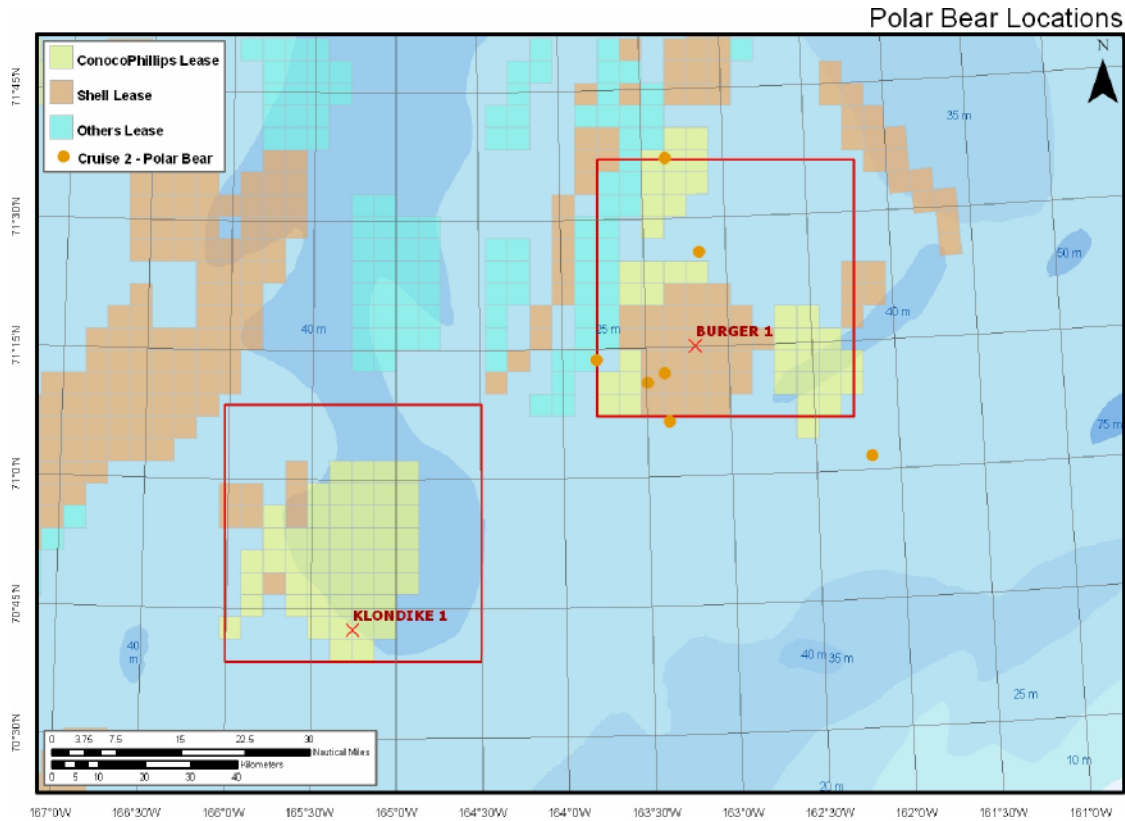


Figure 17 Polar bear sightings at the Klondike and Burger survey areas during the three cruises

Behavior

Marine mammal behavior was recorded during the research program. Seal behavior primarily consisted of three behaviors; swimming, looking, and, less often, diving (Figure 18). Ringed/spotted seals had a higher proportion of looking than bearded seals when separating the species for all seals but the result is inconclusive given the high proportion of these species likely within the unidentified seal category. No seals were observed feeding. This pattern was similar between survey areas and among survey periods. Seal behavior in areas outside of the survey areas was generally dominated by these three behaviors; however, there was a higher proportion of diving than observed in the two survey areas.

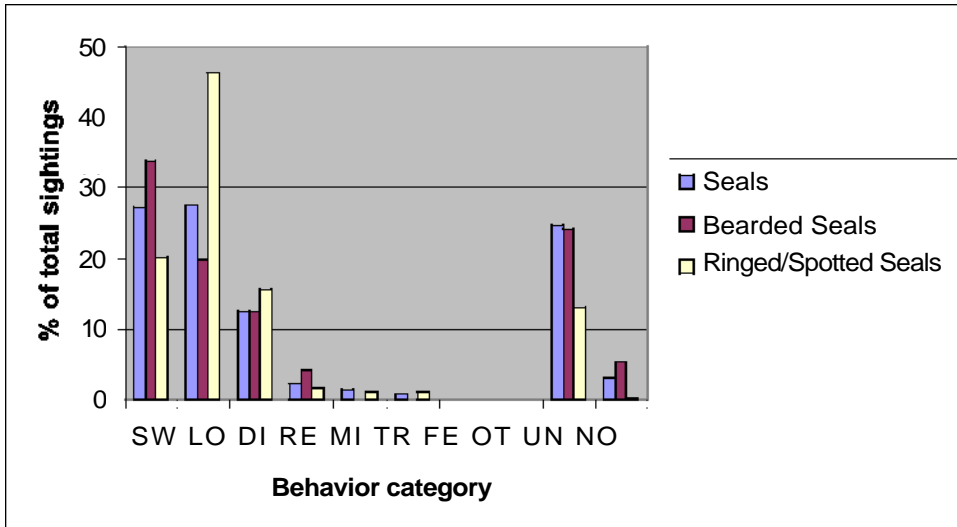


Figure 18 Behavior of seals at both survey areas (SW=Swim, LO=Look, DI=Dive, RE=Rest, MI=Mill, TR=Travel, FE=Feed, OT=Other, UN=Unknown, and NO=No Reaction)

Walrus behavior was dominated by swimming followed by diving, resting, and looking (Figure 19). This pattern suggests that at least some walrus were likely moving through the survey areas with the retreating sea ice. The number of walrus observed outside of Burger was too few to warrant comparing behavior between survey areas or elsewhere, so the data were combined into one analysis. Correspondingly, most walrus were seen during the second cruise, so no comparisons were made among cruises. Walrus were not observed feeding.

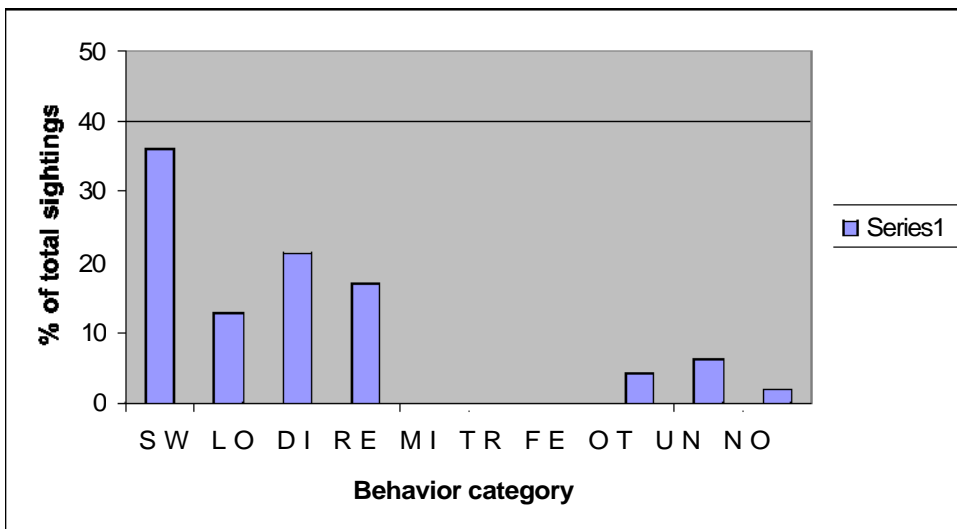


Figure 19 Walrus behavior at both survey areas (SW=Swim, LO=Look, DI=Dive, RE=Rest, MI=Mill, TR=Travel, FE=Feed, OT=Other, UN=Unknown, and NO=No Reaction)

Meaningful analysis of cetacean behavior was limited to gray whales, since sample sizes of the other species were very small. Gray whale behavior predominantly consisted of fluking, swimming, and diving (Figure 20). Feeding was also observed among a small percentage (< 10%) of gray whales, but also suggested from other recorded behaviors

(e.g. diving). Gray whale behavior was generally not discernible in the survey areas, since the few whales encountered were typically too far from the vessel to observe behavior, so most behavioral observations were of gray whales outside of the survey areas. The behavior of other cetacean species was based on pooled observations from inside and outside of the survey areas to increase sample sizes for each species. Behaviors of these species included diving and fluking for two single bowhead whales, and swimming for three single harbor porpoises, two groups of killer whales, and a single minke whale. There was no evidence of feeding by any of these species of whales. The behavior suggests that most cetacean species were likely transiting through the survey areas, which were within a much broader area they inhabit during the open water season.

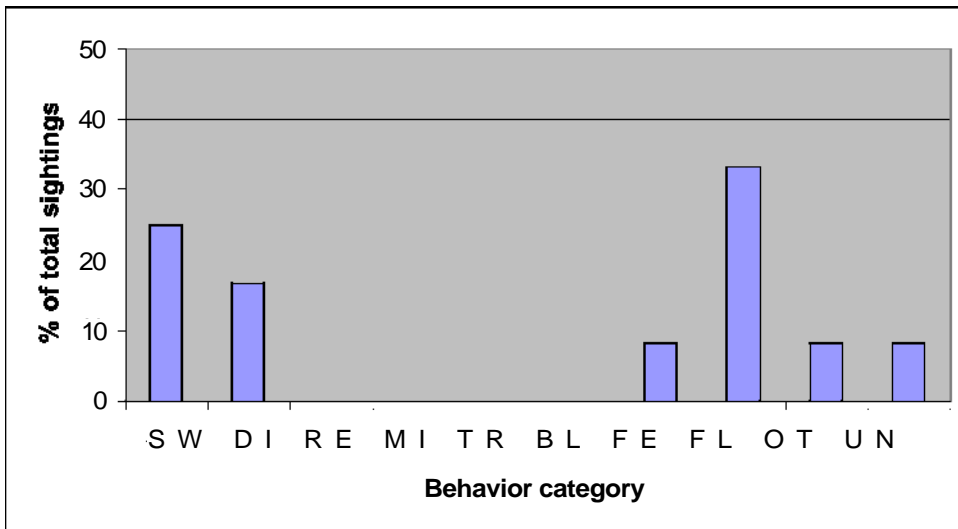


Figure 20 Gray whale behavior observed outside of survey areas (SW=Swim, DI=Dive, RE=Rest, MI=Mill, TR=Travel, BL=Blow, FE=Feed, FL=Fluke, OT=Other, UN=Unknown)

Density

Data Characteristics

Sufficient sample sizes for reliably estimating density were available only for seals and walrus. However, considering that two sightings of the latter species corresponded to large aggregations (100 and 700 individuals), fitting detection probability functions to perpendicular distance data proved difficult and results were unreliable. Therefore, density estimates were computed for seals as a group, rather than individual species. Sightings were detected in sea conditions ranging from Beaufort 0 to 7, but only sightings seen up to Beaufort 6 were considered in the analysis.

Four approaches were used in stratifying sighting data for estimating density. Approach 1 assumed that both systematic (S) and transit (T) tracklines within the Burger and Klondike survey areas were valid sampling units so the two transect types were pooled for analysis. Sightings in all other transects (deadheads) were used in estimating detection probability, but not density. In Approach 1, survey-area-specific estimates were produced for all three cruises. Approach 2 was similar to Approach 1, except only S tracklines at

Burger and Klondike were used in estimating density. Approach 3 also used only S tracklines, but pooled data from Cruises 2 and 3 to compute density since sighting rates were similar for the two cruises. Approach 4 used S and T tracklines, but pooled data from Cruises 2 and 3 to compute density for the same reason as stated for Approach 3.

Modeling Detection Probability

Exploratory analyses were conducted to investigate the best approaches to estimate detection probability; detection probability values are specific to each survey and not comparable to surveys conducted by other researchers because of differences in observer skills, vessel height, and observation conditions. 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.

The simplest modeling approach is to fit detection functions to untruncated and ungrouped (unbinned) data. This resulted in poor fits of both half normal and hazard rate models, with the latter being much more supported by the data according to the Akaike Information Criterion (AIC). Untruncated perpendicular distance data implied that sightings up to 2 km (1.2 mi) from the trackline were used in the analysis. Alternative truncation points (1.5 km or 0.9 mi, 1 km or 0.6 mi, and 0.75 km or 0.5 mi) were explored, but best results were obtained at a truncation point of 1 km (0.6 mi). The fit of detection functions was also relatively poor if data were left ungrouped. Therefore, after some exploration of binning intervals, data were grouped in 10 equal intervals of 0.1 km (0.06 mi) width.

Once best truncation and binning strategy were 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. The following covariates were included in the models: group size, seal species, and Beaufort sea state. The first was fit as a continuous variable and assumes that detection probability increases linearly as group sizes increase. Species and Beaufort sea state were modeled as factor covariates. Sea state was modeled as individual values (i.e. one parameter was estimated for each Beaufort reading) or as categories. The latter was done in order to pool across similar Beaufort sea states in order to reduce the number of parameters estimated by the models. Two sets of categorical data were created to model grouped sea state conditions. The first (Beaufort sea state Category 1) had three levels: “low” (Beaufort sea state 0-2), “medium” (Beaufort 3-4), and “high” (Beaufort sea state 5-6). The second (Beaufort sea state Category 2) had two levels: “low” (Beaufort sea state 0-3) and “high” (Beaufort sea state 4-6).

Models that did not conform to the detection probability hypothesis being presented were excluded from the analysis. For example, detection probability is expected to increase as group size increases. However, if model parameters indicated otherwise, models were not considered.

Encounter Rate, Group Size Estimation, and Density Estimates

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

For CDS models, size bias regressions were computed to investigate whether group sizes were influencing detection probability (Buckland et al. 2001). If the regression was significant to an $\alpha=0.15$ level, 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 trackline was assumed to be unit ($g[0]=1$). All parameter estimates were computed using the software Distance 5, release 2 (Thomas *et al.*, 2006).

Results are presented in Tables 3 and 4 and Figure 21. One model was well supported by the data and contained species and Beaufort sea state Category 1 as covariates. The next two best models were not well supported (Delta AIC = 3.86 and 4.42, respectively), but are presented here for comparison. All other models had Delta AIC values greater than 13 and therefore were not well ranked at all (and therefore are not shown). Despite the differences in the AIC values, parameter estimates were similar across all models.

Density estimates including systematic (S) and transit (T) tracklines did not differ statistically from those using only S transects. However, the coefficients of variation were smaller when combining data from S and T track lines, so these data were used for the density estimates. Density estimates for seals at Klondike (0.381 seals/km^2) and Burger (0.133 seals/km^2) were much greater (5 and 3 times, respectively) during Cruise 1 than Cruises 2 and 3 (Table 4). These differences were statistically significantly different as confidence intervals of density estimates for Cruise 1 do not overlap those for Cruises 2 or 3. In addition, the density estimate was almost three times greater at Klondike than at Burger for Cruise 1, which was statistically significantly different. Finally, density estimates for Cruises 2 and 3 were not statistically significantly different for either survey area nor were they statistically significantly different between Klondike (0.060 seal/km^2) or Burger (0.037 seal/km^2). Consequently, density estimates were similarly low during Cruises 2 and 3 at both survey areas compared to being much higher during Cruise 1, especially at Klondike. Abundance estimates are not provided, since the number of missed seals is unknown and there are no reliable correction factors for missed seal in open water.

Table 3 Model parameter estimates for estimating detection probability in the line transect analysis for seals

Model #	Model	# par	Delta AIC	AIC	pdf(0)	ESW (m)	ESW CV
1	Hazard rate with Species and Beaufort Category 1 covariates	9	0.00	2412.95	3.07	325	0.03
2	Half normal with Species and Beaufort Category 2 covariates	7	3.86	2416.81	3.39	290	0.03
3	Half normal with Species and Beaufort Category 1 covariates	8	4.42	2417.37	3.40	290	0.03

par – number of parameters, AIC – Akaike Information Criterion, pdf(0) – probability density function evaluated at zero distance, ESW – effective search half-width, CV – coefficient of variation

Table 4 Seal density and abundance estimates using the best supported detection probability model for Approaches 1 and 4 highlighted above.

<i>Approach 1</i>	Cruise 1		Cruise 2		Cruise 3	
	Burger	Klondike	Burger	Klondike	Burger	Klondike
Encounter rate(ER)	0.087	0.180	0.024	0.029	0.027	0.049
ERCV	0.14	0.19	0.29	0.21	0.25	0.28
Group Size	1	1.39	1.09	1.02	1	1
Group Size CV	0	0.04	0.04	0.02	0	0
Density (ind/km ²)	0.133	0.381	0.041	0.046	0.041	0.075
Density 95% CI	(0.100, 0.179)	(0.259, 0.562)	(0.023, 0.073)	(0.030, 0.070)	(0.025, 0.067)	(0.043, 0.131)
<i>Approach 4</i>	Cruise 1		Cruise 2 +3			
	Burger	Klondike	Burger	Klondike		
Encounter rate(ER)	0.087	0.180	0.025	0.036		
ERCV	0.14	0.19	0.20	0.17		
Group Size	1	1.39	1.06	1.01		
Group Size CV	0	0.04	0.03	0.01		
Density (ind/km ²)	0.133	0.381	0.041	0.057		
Density 95% CI	(0.100, 0.179)	(0.259, 0.562)	(0.028, 0.061)	(0.041, 0.080)		

Hazard rate model with Species and Beaufort Category 1 as covariates

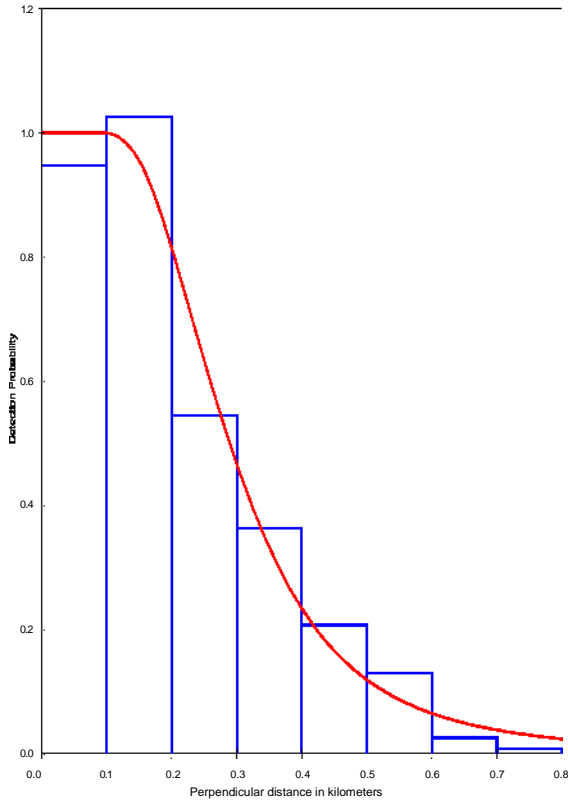


Figure 21 Average detection probability for seals

5.0 Discussion

The following discussion separately addresses whales, seals, walruses, and polar bears. The literature is summarized for each species and compared to the results of the research cruise. General conclusions about marine mammal use of the survey areas are provided at the end of the section.

Whales

Bowhead whales

Bowhead whales migrate through the Chukchi Sea in spring 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 coast line 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. The fall migration has only recently been more specifically documented by tracking 20 satellite-tagged bowhead whales from Barrow through the Chukchi Sea into the Bering Sea (Quakenbush et al. 2009). Most of the whales migrated westward above 71° N latitude from Barrow to Wrangel Island and then down the Chukota Coast before entering the Bering Sea (Figure 22). Some whales may have 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; and others; Figure 23). However, it is possible some of these whales eventually reverse course northward and follow a more westerly route across the Chukchi Sea as has occurred among some satellite-tagged whales. 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.

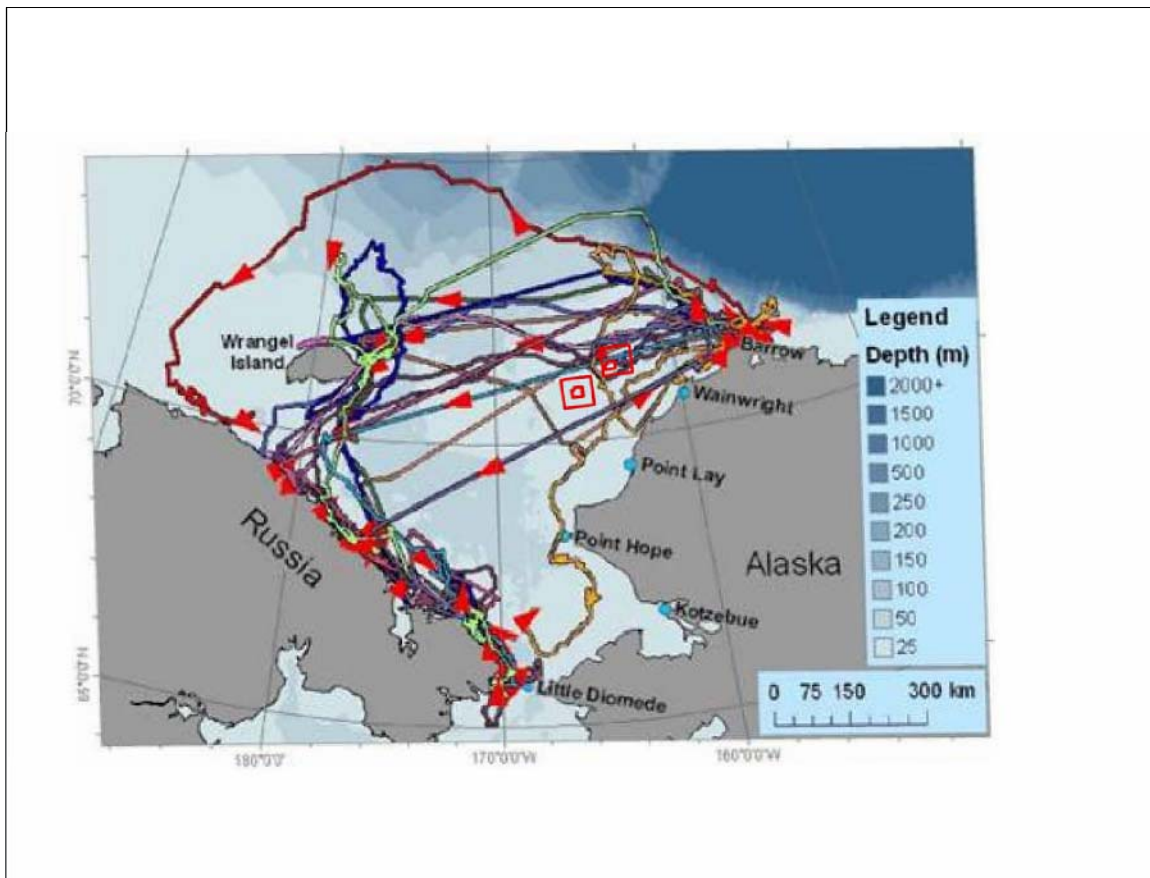


Figure 22 Tracklines of satellite-tagged bowhead whales in the Chukchi Sea during fall; the straighter the lines the fewer the location points and less certain the actual trackline (Figure prepared by Alaska Department of Fish and Game). Red boxes are the Klondike (lower) and Burger (upper) survey areas.

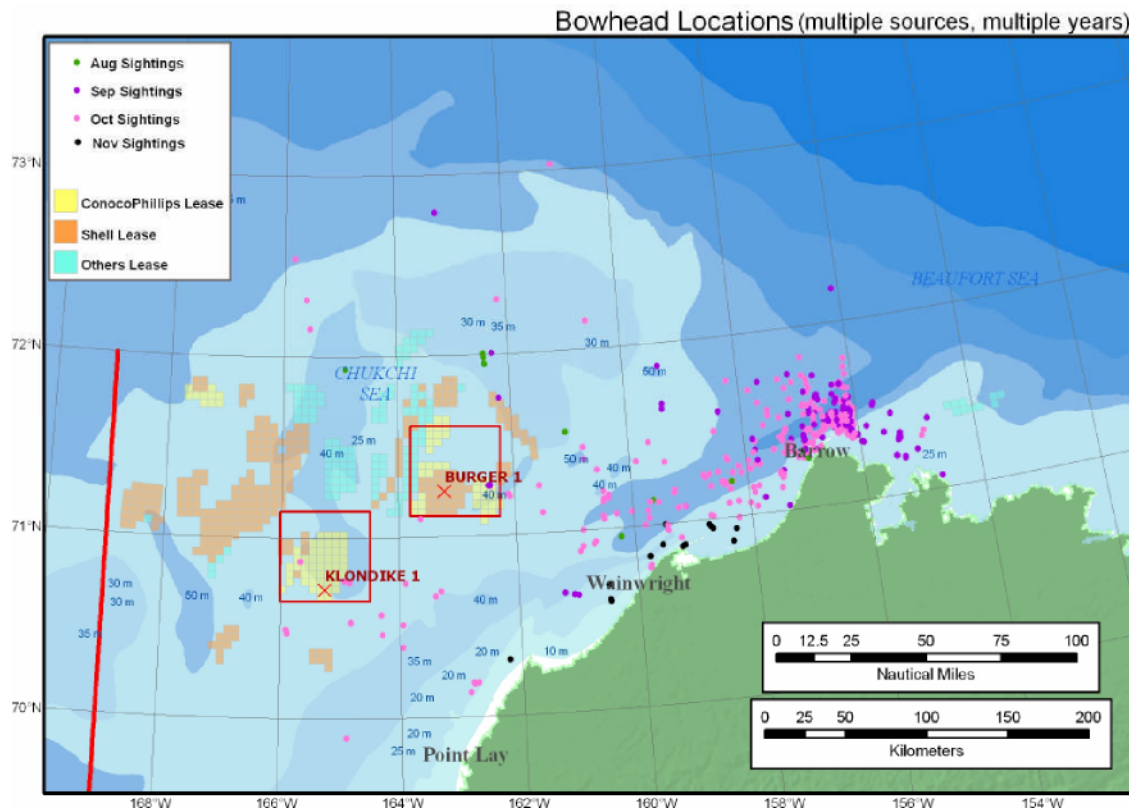


Figure 23 Bowhead whale locations recorded during aerial surveys conducted from 1979-2008. Areas without sightings may reflect a lack of survey effort. Sources are NMFS provided by Janet Clark, Ireland et al. (2009), Brueggeman et al. (1990, 1991, 1992), and the current research program.

Acoustic studies indicate bowheads may inhabit the Chukchi Sea year-round. Calling bowheads have been recorded in the Chukchi Sea during summer and winter (Ireland et al. 2009). The number of whales is not known but most whales likely summer and winter in the areas historically occupied after commercial exploitation. 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 (> 10,500 animals in 2002 with a 3.4% annual rate of increase) in recent time to pre-exploitation levels (George et. al. 2004 a,b), and some of these areas may be becoming reoccupied by bowheads as has been observed in gray whales (Townsend 1935). Small numbers of bowheads have been recorded in the Chukchi Sea between July and September (Figure 23). None of the potential summering whales have been observed feeding nor have any cow-calf pairs been observed during this time period (Ireland et al. 2009).

The two single bowheads observed at Burger in October were likely early fall migrants. The brief observation of each whale did not provide any directional information to indicate migration. However, whales have been reported by various investigators occurring in and near Burger and Klondike during fall (Brueggeman et al. 1992, Quakenbush et al. 2009), although none were seen during a shallow hazards survey

conducted at Klondike by CPAI from early September to the end of October in 2008 (Brueggeman et al. 2009). It is likely some bowheads migrate through and briefly occupy the two survey areas during fall but numbers may be considerably less than those using the more westerly route based on the proportion of satellite-tagged whales using the two routes, provided the data accurately reflect movement by the majority of the population. 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 (Ireland et al. 2009, Goetz et al. 2008). No calves 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; Ireland 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 24). Smaller numbers of gray whales concentrate in the region of Hanna Shoals, north of the Burger survey area between 160° and 165° W (Figure 24). 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 (Ireland et al. 2009, Brueggeman et. al. 1990, 1991, 1992; Janet Clark [pers. com.](#) 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).

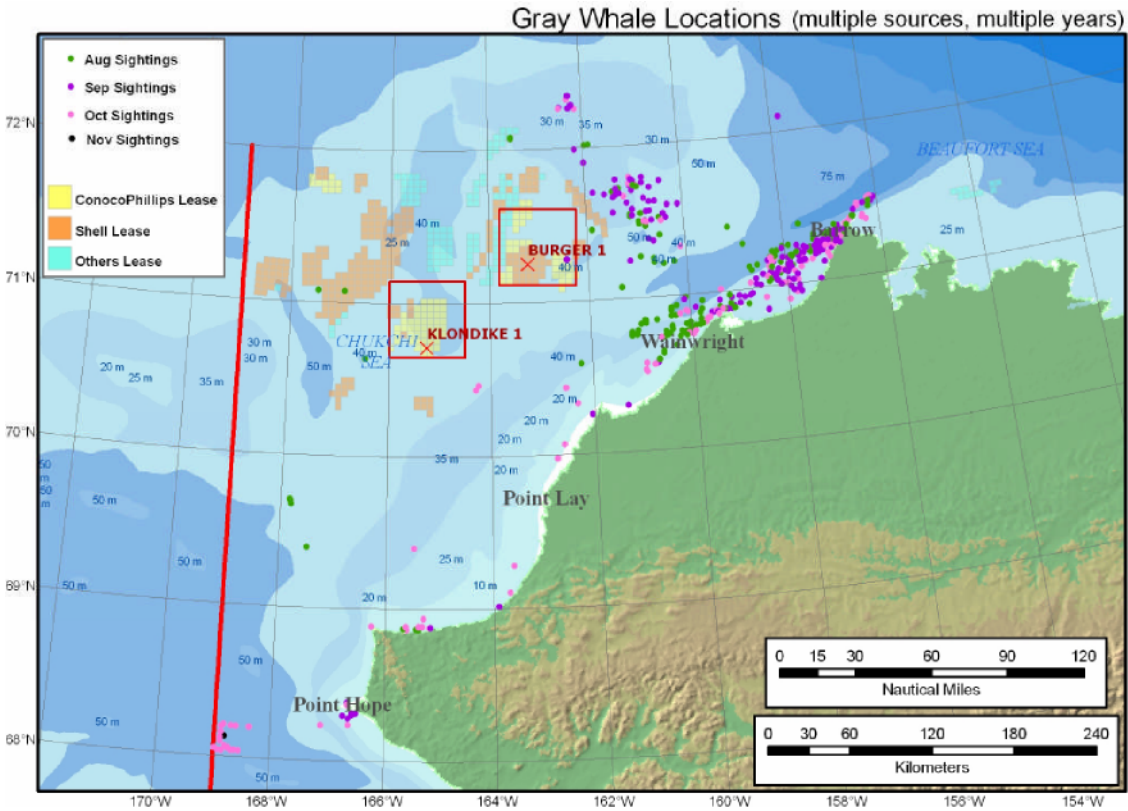


Figure 24 Gray whale locations recorded during aerial surveys conducted from 1979-2008. Areas without sightings may reflect a lack of survey effort. Sources are NMFS provided by Janet Clark, Ireland et al. (2009), Brueggeman et al. (1990, 1991, 1992), and the current research program.

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 program area with small numbers in each survey area but most occurred nearshore between Wainwright and Barrow; a similar pattern occurred with the unidentified whales, which most likely were primarily gray whales; gray whales observed during a shallow hazards survey conducted by CPAI at Klondike and a coring program between Klondike and the coast in 2008 were entirely nearshore (Brueggeman et al. 2009). Gray whales were observed during all three cruises, although not consistently in each survey area but in the program area, confirming gray whales are present throughout the summer at the latitudes coincident from the survey areas eastward to shore. No calves were observed during the three cruises.

Other Cetaceans

Small but unknown numbers of the other cetacean species (harbor porpoise, minke whales, and killer whales) observed in the program area regularly occur in the Chukchi Sea; Dall's porpoise was observed outside of the program areas, south of Pt. Hope on the transit to Nome. All three species are widespread in the Chukchi Sea during the open water season (Clarke et al. 1998; Ireland et al. 2009). Harbor porpoise are the most

commonly recorded of the three species, followed by minke whales, and lastly killer whales, based on surveys by other investigators (Ireland et al. 2009). Killer whales have been primarily recorded near the coast than farther offshore (Brueggeman et al. 1992, George and Suydam 1998). This may be due to higher prey densities of marine mammals near the coast but also more human activity for encountering killer whales. 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. It is likely that small numbers of all three species transit through the survey areas as they feed in the Chukchi Sea during summer.

Cetaceans Not Observed

Cetaceans not observed in the program area but seasonally present include fin, humpback, and beluga whales. Fin and humpbacks 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 and also Beaufort Sea (humpback cow with calf in 2007) by several investigators (Janet Clark, [pers. com.](http://pers.com) 2009, Ireland et al. 2009), suggesting they may be becoming more common, possibly corresponding to a rise in sea surface temperatures (Hashagen et al. 2009). While humpbacks as well as fin whales are still relatively uncommon in the Chukchi Sea, belugas are very common but typically not present during the period of the subject research cruises.

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 (Angliss and Outlaw 2008). 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 and along the Beaufort Sea, at times penetrating areas of 90% sea ice cover as

far as 80° 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 show belugas were widespread in the Chukchi Sea, particularly during fall, with some sightings overlapping the survey areas (Figure 25). Included in these sightings were recent vessel and aerial surveys conducted from 2006-2008 by Ireland 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 (Ireland 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). 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. com.](#) 2009). The fall migration to the Bering Sea wintering grounds generally corresponds to the advance of the sea ice in November and December.

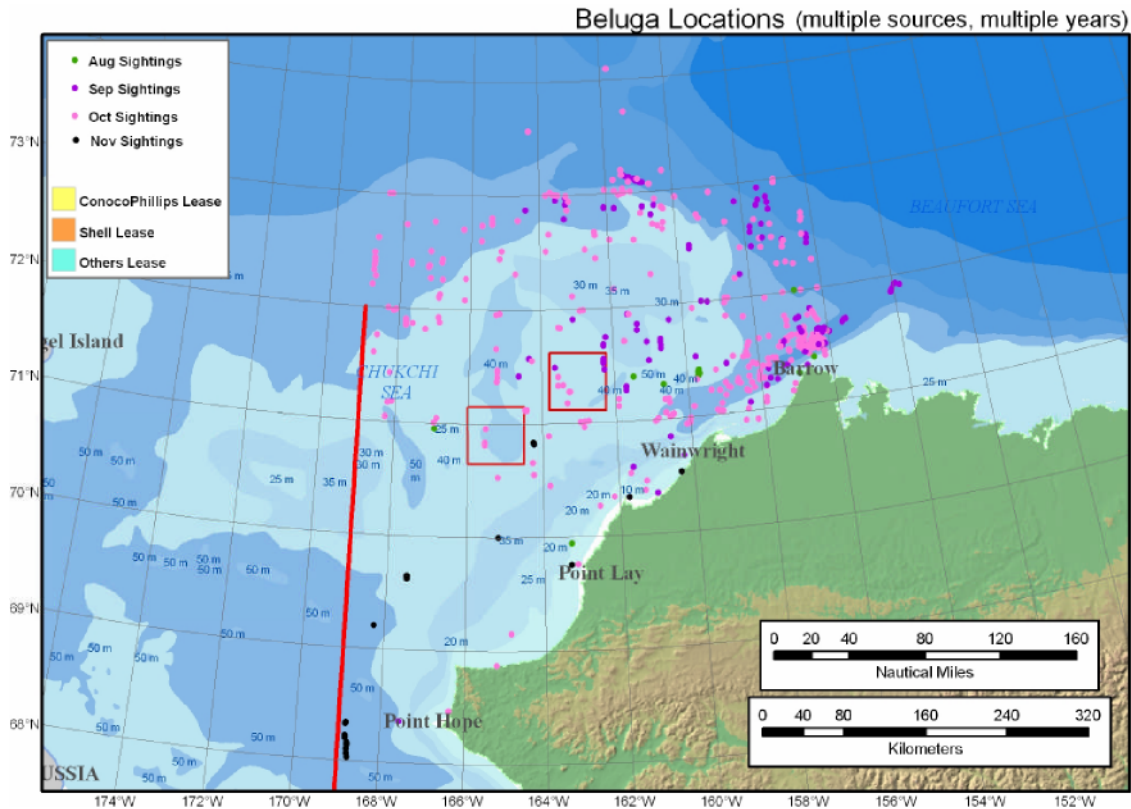


Figure 25 Beluga whale locations recorded during aerial surveys conducted from 1979-2008. Areas without sightings may reflect a lack of survey effort. Sources are NMFS provided by Janet Clark, Ireland et al. (2009), Brueggeman et al. (1990, 1991, 1992), and the current research program.

Seals

Seals are the most prominent marine mammal in the Chukchi Sea during the open water season (Ireland et al. 2009). They are widespread over the outer continental shelf in the Chukchi Sea (Angliss and Outlaw 2008). 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 (Angliss and Outlaw 2008; 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 (Angliss and Outlaw 2008; Burns 1981). 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 Ireland et al. (2009). The estimates, based on vessel surveys, ranged between 40.2 to 192.4 seals/1000 km² during Jun-Aug and 60.2 to 504.5 seals/1000 km² 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 of this research program had some similarities but also differences to those reported by Ireland et al. (2009). Seals were similarly widespread in the program area but densities were statistically significantly higher in the summer (Cruise 1, 133 seals/1000 km² @ Burger and 381 seals/1000 km² @ Klondike) than in the fall (Cruises 2 and 3 combined, 41 seals/1000 km² @ Burger and 57 seals/1000 km² @ Klondike), which is opposite from that reported by Ireland et al. (2009) except for 2008, possible due to differing ice regime years. The higher densities observed in the summer occurred when sea ice was present in or near the survey areas. Ireland et al. (2009) also found more seals near sea ice than away from it. They also reported relatively few juveniles due to the time of the surveys and looking as a prominent behavior.

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 and resting, calving, and molting (Fay 1982). Most walrus also summer in the pack ice although 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 for walrus (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 162° 50' to 166° 00' W longitude). In 1975, Estes and Gilbert (1978) censused the open water and pack ice between 156° and 174° W longitude in early September and found the highest walrus densities between 162° and 165° W. In 1980, Johnson et al. (1982) surveyed the pack ice near the ice edge from 153° to 172° 30' W longitude in mid-September. Walrus were encountered throughout the area, but the density was highest between 160° 30' and 166° 30' W. In 1985, Gilbert censused the pack ice near the ice edge between 156° 30' and 174° W longitude in late September and early October. Walrus were widespread in this area, but the density was generally highest between 165° and 174° W. The ice edge during these three surveys was generally between 70° and 73° 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 (162° 50' to 166° 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 30 nm east of Burger, and Crackerjack and Popcorn are over 40 nm 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 (162° -165° 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.

Ireland 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 Shoals, a region of relatively shallow water presumed to be an important walrus feeding ground (J. Burns, [pers. com.](#) 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 26 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.

These results are consistent with those reported above, in that walrus occurred in both survey areas but highest numbers were associated with the presence of sea ice. Sea ice was present when most, including over 900, walrus were recorded at Burger in September (Figures 9 and 15). Small numbers of walrus occurred in both survey areas, particularly Burger, after the sea ice moved north, carrying most of the walrus to more northern feeding grounds. The fall migration likely occurred after the research program ended in mid-October.

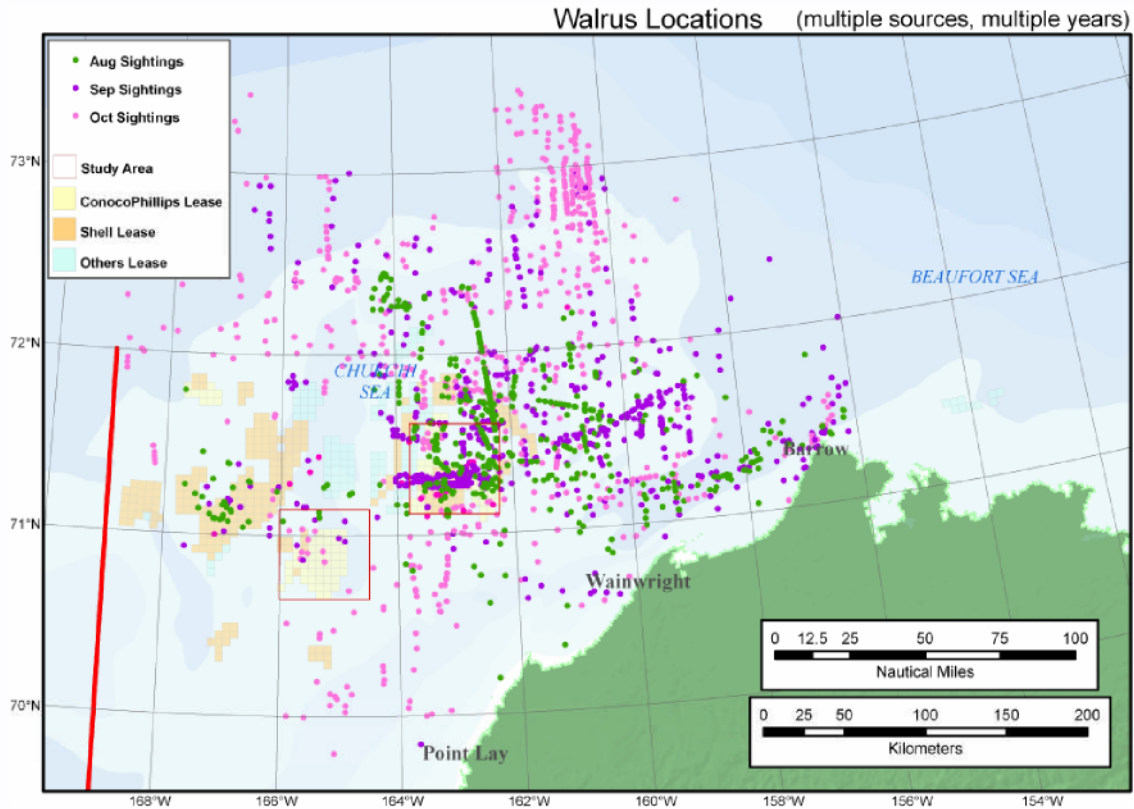


Figure 26 Walrus locations recorded during aerial surveys conducted from 1979-2008. Areas without sightings may reflect a lack of survey effort. Sources are NMFS provided by Janet Clark, Ireland et al. (2009), Brueggeman et al. (1990, 1991, 1992), and the current research program.

Polar Bears

Polar bears are widespread in the sea ice in the Chukchi Sea (Figure 27). 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 27). 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 often related to bears stranded on sea ice detached from the main pack ice due to shifting winds. Our observations correspond to these findings, including that all bears were observed on pack ice or swimming between ice floes as singles or pairs. There were no observations of mother-cub pairs in the program area, except a mother with two cubs immediately off Wainwright observed during a crew change.

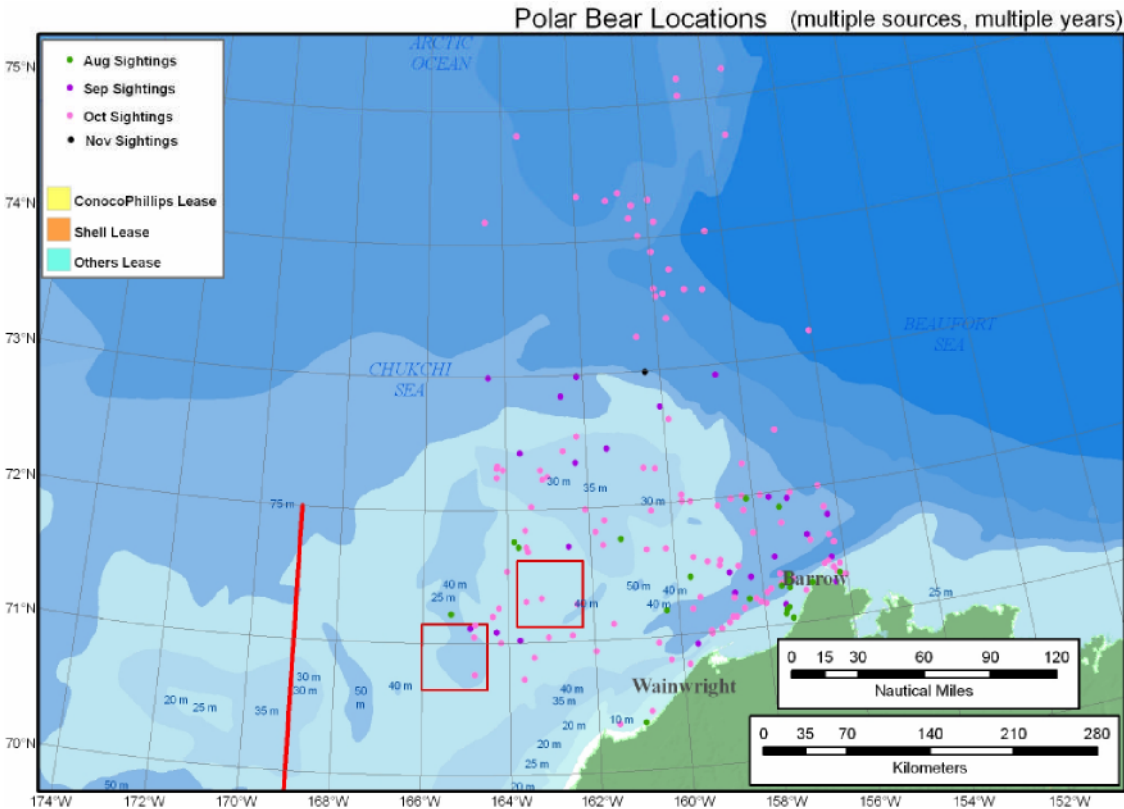


Figure 27 Polar bear locations recorded during aerial surveys conducted from 1979-2008. Areas without sightings may reflect a lack of survey effort. Sources are NMFS provided by Janet Clark, Ireland et al. (2009), Brueggeman et al. (1990, 1991, 1992), and the current research program.

General Conclusions

- Sea ice likely influenced the disproportionate use of the survey areas by seals among cruises and between the two survey areas. Seal occurrence was highest in each survey area during Cruise 1 when sea ice was most prevalent. The reason for the much higher use of Klondike than Burger by seals during Cruise 1 is unclear.
- Sea ice similarly likely influenced the disproportionate use of the two areas by walrus among cruises and between survey areas. Most walrus were encountered in association with scattered sea ice off the southern margin of the main pack ice. Higher but still relatively low occurrence of walrus at Burger than Klondike after the ice moved northward could be related to Burger's closer location to Hanna Shoals, a shallow area know to be used by walrus. Benthic communities, which provide the primary walrus prey, had statistically significantly higher abundance, biomass, and number of taxa at Burger than at Klondike (Blanchard et al. 2009). This could have been due to differing substrates and other factors between the two areas (Blanchard et al. 2009).

- Broad movement patterns likely explain the differences in occurrence of cetaceans in the two survey areas, 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 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. Most gray whales occur closer to shore so few would be expected in the survey areas. The two bowhead whales observed in Burger in October may have been fall migrants or possible summer residents. While recent 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 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.

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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	Ripple 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.