Temporal-spatial distribution, movements and behavior of beluga whales near the Port of Anchorage, Alaska

Final Report

Edited by

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This work was done under contract with the Port of Anchorage and the U.S. Department of Transportation Maritime Administration (MARAD).

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Draft Final Report

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Introduction

This is the annual report of a study by LGL Alaska Research Associates, Inc., sponsored by Integrated Concepts and Research Corporation (ICRC), the Port of Anchorage (POA), and the U.S. Department of Transportation Maritime Administration (MARAD), to monitor beluga whale presence, habitat use and behavior in the Port of Anchorage area in 2006. Data were collected during this period to provide information on beluga whale presence and behavior within and near the Port of Anchorage Marine Terminal Redevelopment Project footprint prior to, and during, Phase I expansion activities. Sightings within the Marine Terminal Redevelopment Project footprint area were distinguished from data collected on beluga whale occurrence and behavior outside the project footprint.

This report covers field monitoring during April-November 2006. All measurements and observations were used to determine the frequency at which beluga whales were present in the area over time, and potential beluga whale responses to construction activities. The monitoring program also provided information in real time to construction crews for implementing mitigation measures. The research plan was developed following consultation with Integrated Concepts and Research Corporation ICRC, POA, and the National Oceanic and Atmospheric Administration (NOAA Fisheries). It was intended to meet the monitoring objectives set forth by NOAA Fisheries within the project scope agreed upon by POA, ICRC, NOAA Fisheries, and MARAD. MARAD is the federal funding agency for all work associated with the POA Expansion Project, including this monitoring program.

Program Objectives

Working with ICRC, POA, and MARAD, LGL Alaska Research Associates, Inc. (LGL) developed a monitoring plan to address the following objectives:

1) Estimate the frequency at which beluga whales are present in, and near, the Marine Terminal Redevelopment Project footprint, and how this varies temporally (seasonal, diurnal, and tidal patterns).

2) Provide information to ICRC and POA on the spatial distribution of beluga whale sightings relative to the Phase 1 North Backlands construction activities.

3) Characterize habitat use and behavior of beluga whales near the Port of Anchorage during ice free months.

Study Area, Sampling Effort, and Observation Stations

The study area included all water visible from the monitoring stations near the Port of Anchorage, within Knik Arm, upper Cook Inlet, just offshore of Anchorage, Alaska (Figure 1.1).

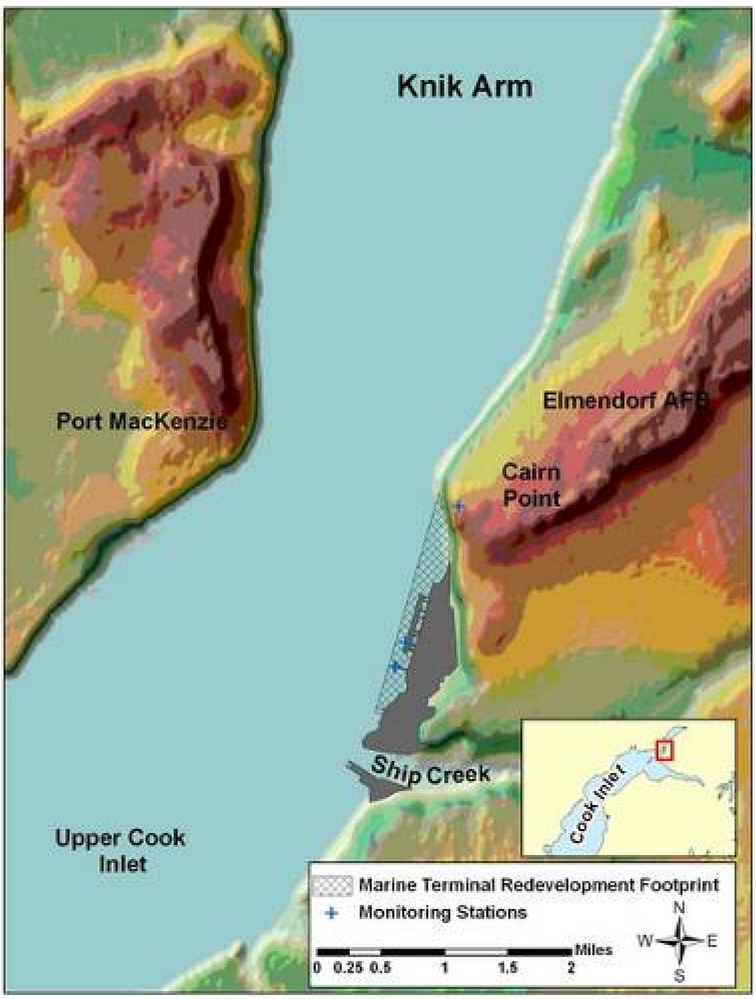

Figure 1.1. The study area is shown, with the Port of Anchorage in gray, the Marine Terminal Redevelopment Project Footprint shown in black hatch marks.

The focus of the study was the Marine Terminal Redevelopment Project Footprint, as defined by the Marine Terminal Redevelopment Environmental Assessment (Anchorage Port Expansion Team 2005, South End: X=1658512 feet, Y=2642136 feet. North End: X=1661550 feet, Y=2650479 feet; USACE SBC 1978, State Plane Coordinate System).

Monitoring was conducted four days per week, six hours a day, from April - November 2006. Observation shifts were scheduled to provide a sample of beluga whale use of the area under varying conditions (*e.g.*, noise, vessel traffic, environmental conditions), while accommodating logistical, safety, and security concerns of POA, EAFB, ICRC and LGL.

Observations were conducted by trained beluga whale biologists stationed at one of two shore sites overlooking the POA Phase 1 Expansion area: 1. the south facing bluff at Cairn Point, and 2. the northeast corner of the dock at the Port of Anchorage. These coastal observation platforms provided height above sea level near the shoreline and were used to maximize the probability of detecting beluga whales in and around the Port of Anchorage Marine Terminal Redevelopment Project footprint. The shore station at Cairn Point, located on Elmendorf Air Force Base (EAFB), was used for best sighting of whales in the northern part of the area. The second site, on the dock at the POA, was used when the Cairn Point site was not available due to logistical difficulties. These locations were selected in consultation with POA, MARAD and ICRC. POA consulted with EAFB for rights-of-entry onto military property. LGL field biologists cooperated with POA and EAFB personnel and underwent all necessary training to ensure compliance with Port and EAFB safety/security policies.

Sampling Protocol and Techniques

Environmental conditions

Environmental conditions that could affect observers' ability to sight whales were logged every hour during observation sessions. These conditions included wind speed, sea state, swell height, glare, percent cloud cover, and precipitation.

Port of Anchorage activities

The number, type, and activity of vessels at the Port were documented during observation sessions throughout the observation period. A combination of regular interval sampling, continuous monitoring, and theodolite tracking were used to monitor vessels around the Port. Port expansion activities were noted, in order to facilitate examination of beluga whale occurrence and behavior with respect to these activities.

Beluga whale observations

During the six-hour monitoring sessions, observers used methods described by Prevel Ramos *et al.* (2006), systematically scanning for whales during the entire observation session using the naked eye, Fujinon or West Marine 10 x 50 binoculars with an internal compass, and a spotting scope. Basic sighting information included date, time, number of whales sighted by age class (adult, subadult, calf, estimated by color), heading, primary and secondary activity, location, and group swimming formation (after Funk *et al.* 2005).

In addition to basic sighting information (date, time and number of whales), detailed data were collected regarding the locations, movements, and behavior of beluga whales near the Port. A surveyor's theodolite linked to a laptop computer was used to track group locations and movement patterns (Prevel Ramos *et al.* 2005). Using this technique, computer calculations provided accurate estimates of the distance of whales from the Phase 1 construction site in real time. When use of the theodolite was not practical due to logistical difficulties, a grid cell mapping system was used, with distances estimated by eye. Behavior of whales was documented by focal group sample.

Temporal analyses

Data were analyzed for seasonal and diurnal patterns, with comparisons of sighting rates and distribution made by month, time of day, and tidal state. Sighting rate data were standardized for effort by temporal period.

Theodolite tracking

To maximize the resolution of analyses of beluga whale occurrence and habitat use in the Marine Terminal Redevelopment Project footprint, the position of groups (longitude and latitude), surface speed, linearity, and orientation of whale group movements was monitored when feasible through the use of a surveyor's theodolite (Prevel Ramos *et al*. 2006). A theodolite measures horizontal and vertical angles, which can be used to triangulate whale location. Distance of whales from the Phase 1 expansion activities and vessels were measured using this technique in real time.

Use of a surveyor's theodolite to monitor the location and movement patterns of whales and dolphins is a well-established technique (reviewed by Samuels and Tyack 2000). First used in the 1970s (Würsig and Würsig 1979, 1980), this technique has proven effective in studies of a variety of cetacean species, including gray whales (*Eschrichtius robustus*), Southern right whales (*Eubalaena australis*), humpback whales (*Megaptera novaeangliae*), spinner dolphins (*Stenella longirostris*), dusky dolphins (*Lagneorhynchus obscurus*), and bottlenose dolphins (*Tursiops truncatus*) in locations around the world (*e.g.*, Argentina, Russia, Mexico, New Zealand, Australia, the United Kingdom, and the United States). Data collection protocols are well established and software for data collection and management are readily available. This technique has been found particularly effective for monitoring whales' and dolphins' distances from, and responses to, human activities in the coastal environment (*e.g.*, Russian gray whales and seismic exploration, New Zealand dusky dolphins and tourist vessels).

Horizontal (azimuth) and vertical (declination) readings from the theodolite were used to calculate the position of objects such as whales and vessels. Accurate assessment of whale group locations required input of station height and location, with tide tables showing variation during the sample. Measurement error generally decreases with increase in the height of the station, decrease in the distance to the object being fixed, and decrease in short-term variation of sea surface height (Würsig *et al*. 1991, Table 1.1).

Time-stamped positions of beluga whales and vessels, termed "fixes," were recorded using a theodolite linked to a laptop computer. Fixes of multiple objects provided information on distance between objects (*e.g.*, whales and the Phase 1 construction site). Horizontal and vertical angle-fix information was instantaneous downloaded and time stamped on computer. This information was collated with other observations (*e.g.*, group size, behavior, and environmental parameters); and rapid, real-time longitude-latitude position and movement pattern calculations were performed. GIS-compatible whale tracks provided distances between whales and shore, sources of noise, and vessels, as well as increased analytical power for examining sighting data and whale responses to expansion activities.

Table 1.1. Errors from incorrect measurement of theodolite height (Würsig et al. 1991).

Actual Cliff Height	**Approximate Error in Height**	**Distance Error (*ft*)** TRUE DISTANCE TO POSITION ON WATER		
		1,640 ft	**8,202 ft**	**16,404 ft**
42 feet	39 inches high	+112	+568	+1273
	4 inches high	+13	+56	+128
	4 inches low	-10	-56	-125
	39 inches low	-98	-564	-1243
98 feet	39 inches high	+56	+278	+587
	4 inches high	+7	+26	+59
	4 inches low	-7	-30	-56
	39 inches low	-56	-278	-581
148 feet	39 inches high	+39	+184	+384
	4 inches high	+7	+16	+39
	4 inches low	-3	-28	-36
	39 inches low	-36	-184	-381
328 feet	39 inches high	+16	+82	+167
	4 inches high	+3	+7	+16
	4 inches low	0	-9	-16
	39 inches low	-16	-82	-167

Equipment used in theodolite tracking included a tripod-mounted surveyor's theodolite, a computer download cable connecting the theodolite to a laptop computer, and a laptop computer with long-life batteries which allowed six hours of continuous data collection (Figure 1.2). Time-stamped horizontal (azimuth) and vertical (declination) readings from the theodolite were used to calculate the position of objects such as whales and vessels. A tripod-mounted Topcon DT-102 theodolite was connected to a Dell Inspirion 7500 laptop computer through a RS-232 cable (Figure 1.2). Data were collected and analyzed using Pythagoras (http://www.tamug.edu/mmrp/pythagoras/). Pythagoras displayed positions, movements, and distances in real-time; allowed input of sighting, environmental and behavioral data in a customized format; stored data in a Microsoft® Access database; and was GIS compatible.

(a)

(b)

Figure 1.2. These photographs show the monitoring stations at (a) Cairn Point and (b) the Port of Anchorage with the computer-linked theodolite facing in the direction of the Phase 1 North Backlands expansion site from both vantages.

The known surveyed heights of the monitoring stations were entered into the Pythagoras software. Eye height was measured to the nearest centimeter and entered daily into Pythagoras by the observer. Sea surface height was imported from tide tables (data from a tide level monitoring station located at the Port of Anchorage), generated with JTides 4.7 software (http://www.arachnoid.com/JTides), and input directly into Pythagoras. The theodolite was checked for balance every 20 minutes. Vessels were fixed once per hour and whale groups were fixed as frequently as possible as they passed through the study area. Other observations logged using Pythagoras included group size, whale behavioral state, and vessel activity.

500 m x 500 m grid mapping

During the past two years, LGL has developed and employed a grid system to monitor the locations and movements of beluga whales in Knik Arm (Funk *et al*. 2005). This system has proven effective for documenting whale group location and movements on a coarse scale (500 m x 500 m or 1 km x 1 km grids). These grid cell records of whale sightings can be input and analyzed using GIS for analyses of patterns, but cannot be used for accurate estimates of locations, distances, and movement patterns on a fine scale. In applying this technique, trained observers used a combination of compass bearings taken from binoculars and landmarks to place whale groups at any given time in a grid cell.

When a whale group was sighted, the location of the group was recorded using a 500 m x 500 m grid overlaid onto a base map of the study area. Grid cell locations were updated as the whales move through the area. A geo-referenced location grid map already developed and utilized for the Port of Anchorage area in 2005 (Figure 1.3) was used again for monitoring whale group locations in 2006 (Prevel Ramos *et al*. 2006). Grid cells D9 through I9 overlapped the Marine Terminal Redevelopment Project footprint (Figure 1.3).

Whale group size, age class composition, behavior, and movements

Focal group behavioral information (Mann 2000) was collected including behavioral state (traveling, milling, diving, resting, and feeding) and inter-individual distance/group spread. Predominant and secondary behaviors were recorded for each group sighted. Whale behavior within and outside the project footprint will was compared. Successive location fixes of whale groups with the theodolite provided estimates of parameters related to movement patterns (*e.g.*, speed, linearity, re-orientation rate, and bearing).

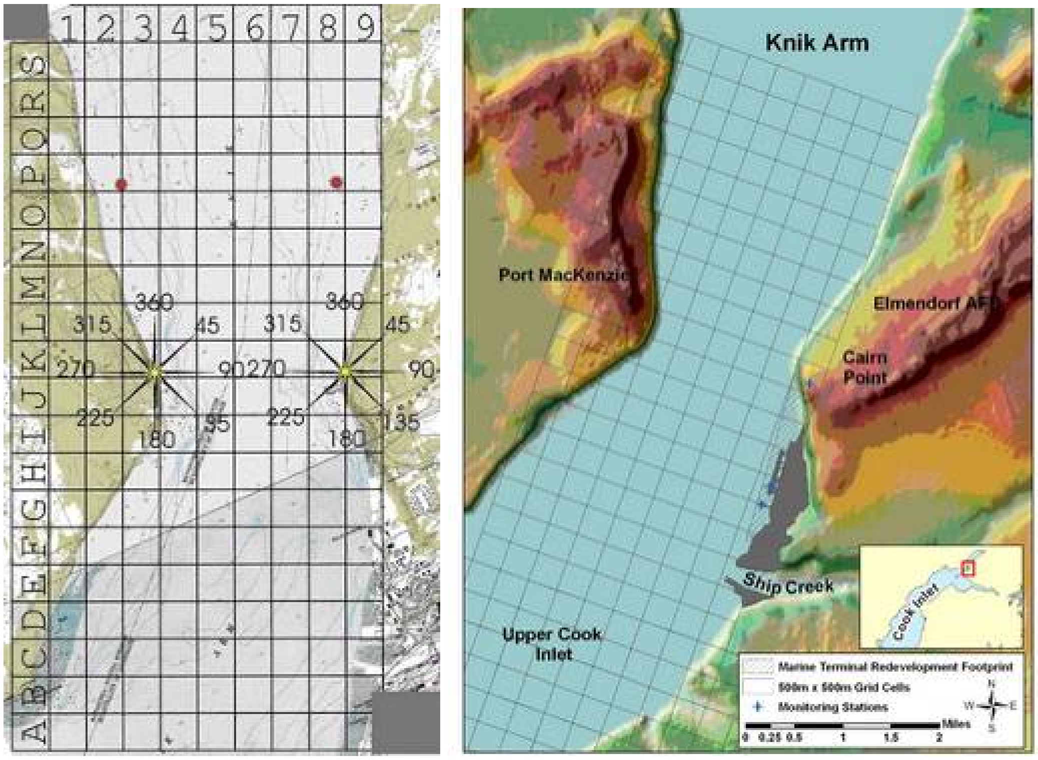

Figure 1.3. This 500 m x 500 m grid cell map (left) was used to document the location of beluga whale groups sighted from the Port of Anchorage and Cairn Point. For reference in the field, this map was oriented relative to magnetic north (compass bearings are shown at the center of the grid). The Port of Anchorage Marine Terminal Redevelopment Project footprint is located in grid cells D9 to I9. The grid cell map is shown in the context of the study area (right), with the Marine Terminal Project Footprint shown in black hatches.

Data Entry and Analyses

During observations without use of the theodolite, vessel activities, environmental conditions, and marine mammal data were collected using standardized paper datasheets. Upon completion of monitoring sessions, datasheets were checked for completeness and accuracy, and then used to enter data into a Microsoft® Access database. During theodolite tracking sessions, data were entered directly into a laptop computer in an Access database in the field. Both the grid-cell database and the theodolite database were checked for accuracy. Data were queried in Microsoft® Access, with means, standard errors and figures produced in Microsoft® Excel.

Summed beluga whale counts and sum of beluga whale groups per 500m x 500m grid cell were mapped for the study period by month and tide height. ArcView 3.2 GIS software was used to map whale grid-cell use, plot GIS-compatible whale tracks generated by Pythagoras from theodolite fixes, and calculate time spent inside versus outside the project footprint. Best counts across stations for each whale group were determined by choosing the count with the best age class representation. For groups whose best count was from a theodolite track, number of whales was included in totals of beluga whale use of overlapping grid cells (using GIS mapping). Summed number of group sightings and best whale counts per grid cell were mapped for April through November 2006, by month and by tide level. Beluga whale sighting rates were analyzed by month and day, with sightings inside the Marine Terminal Redevelopment Project Footprint distinguished from those outside the footprint.

Coverage of tidal levels during observation sessions, observed tidal levels during beluga whale sightings and timing of sightings from low tide were examined. Tide heights for Knik Arm, Alaska were obtained from JTides 4.7 software (http://www.arachnoid.com/JTides). The resulting tide tables were input into the Pythagoras software to adjust calculations for changing station height relative to sea level, and were used for tidal analyses. Levels of tides during observation sessions were obtained by querying tide levels for times between the observation start and end times on the date of all observation sessions. Tidal levels during sightings were obtained by querying JTides for the date and from the start to the end of each group observation in order to visualize our study's coverage of tidal levels.

From sighting records, mean percent values were calculated to examine age class representation and behavior in beluga whale groups. Focal group behavioral data were used to calculate whale activity budgets. Data analysis modules in Pythagoras were used to calculate mean time and distance between fixes, mean leg speed (speed of group between fixes), reorientation rate (magnitude of course changes along a track line), net and cumulative distance traveled, and linearity (measure of straightness of track line, with a value of one being a straight line).

Reporting

Beluga whale presence was reported in real time to ICRC and/or POA-designated representatives. ICRC/POA personnel were notified when whales were first sighted, and again when whales were seen within each of the following distances from the Phase 1 North Backlands expansion site:

- 1 km (0.6 mi, 3,280 ft)
- 500 m (0.3 mi, 1,640 ft)
- 250 m (0.15 mi, 820 ft)
- 100 m (328 ft)
- 50 m (164 ft)

Monthly progress reports were supplied to ICRC following each month of field work. This report summarizes findings across the entire field season, and compares these results with those of previous studies in the area.

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Chapter 2: Temporal Distribution of Beluga Whale Sightings near the Port of Anchorage

Draft Final Report

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Introduction

Temporal patterns of animal distribution are related to temporal patterns of food, habitat, conspecifics, and predators. Temporal patterns may be diurnal (daily), seasonal, or tidal. Daily movement patterns are exhibited by spinner dolphins (*Stenella longirostris*) which move offshore at night to feed in deeper ocean waters, and rest in shallow near shore waters during the day to avoid predation from sharks (Norris *et al.* 1994). Seasonal patterns are seen in the migrations of humpback whales (*Megaptera novaengliae*) as they feed in prey-rich waters of Gulf of Alaska and calve and breed in the warm waters of the Hawaiian Islands (Baker *et al.* 1986). Movement patterns related to fluctuating water levels have been observed in the use of rivers and lakes by river dolphins (*Inia geoffrensis*) and their prey fish in South America (McGuire and Winemiller 1998).

The degree of temporal influence for many species is related to their geographic distribution; for example, tropical dolphins such as *Stenella* reproduce year-round (Barlow 1984), while at higher latitudes, reproduction in harbor porpoises (*Phocoena phocoena)* narwhales *(Monodon monoceros)* and belugas *(Delphinapterus leucas)* is highly seasonal (Leatherwood & Reeves 1983, Read 1990).

Temporal patterns in beluga whale distribution may be in response to several biotic and abiotic factors, including changes in water temperature, ice cover, hours of daylight, prey availability, habitat quality and quantity, predators, and social grouping patterns (Hobbs *et al.* 2006). Predators of beluga whales in Cook Inlet are killer whales (*Orcinus orca*) and humans. Although killer whale sightings in upper Cook Inlet are rare (Shelden *et al.* 2003), predation pressure in one area of their range may affect distribution of belugas in other areas of Cook Inlet.

Arial surveys (Hansen and Hubbard 1999, Rugh *et al.* 2000, 2002, 2004, 2005) satellite tracking of tagged whales (Hobbs *et al.* 2005), and land and boat-based observational studies (Funk *et al.* 2005) indicate that Cook Inlet belugas exhibit temporal patterns of distribution which vary with respect to season and tidal stage, although belugas do not appear to migrate into or out of the Inlet.

The overall objectives of the study presented in this report include estimating the frequency with which belugas are present in and around the Port of Anchorage and characterizing beluga habitat and behavior. This chapter focuses on temporal patterns of beluga distribution in and around the Port of Anchorage.

The questions addressed in this chapter are:

1) Do patterns of beluga distribution and abundance in and around the Port of Anchorage exist with respect to tidal cycle, season, and time of day?
2) When are belugas most likely to be present in and around the Port of Anchorage?
3) When are the greatest numbers of beluga whales present in and around the Port of Anchorage?

Methods

Observational effort

Observations were conducted by experienced observers at four shore stations located at (1) Cairn Point Station (CPS), (2) the Observation Deck at the Port of Anchorage (POA), (3) the northwest corner of the POA parking lot, and (4) the north east corner of the POA Dock. Each observation shift was six hours in length. For each observation shift, observations were conducted by a single observer at a given station, and use of stations varied according to month. During April, observations were conducted from the Observation Deck at the POA (while awaiting permission from Elmendorf Air Force Base to access Cairn Point). In May, paired observations (*i.e.*, simultaneous observations conducted by two observers, each located at a different station) were conducted from CPS and from the POA Sundeck for seven days, and for three days unpaired observations were conducted from CPS. Unpaired observations from June-August were conducted from CPS, with the exception of June 2 when paired observations were conducted from the POA observation deck and CPS. From August 23-31 (four days total), observers were not able to access the CPS station due to the presence of a bear in the area, and observations were conducted at the POA; two days of observations were conducted from the north west POA parking lot, and two days of observations were conducted from the north east corner of the POA dock (locations varied at the request of the POA). In September, observations were conducted from CPS, until the end of the month, when observers were again displaced by bear activity. Observations from September 27 through November 3 were conducted from the north east corner of the POA dock.

During the pre-construction phase (April 26-July 27), each six-hour observation shift was conducted independent of tidal stage. During the Phase 1 construction period (August 2-November 3), each six-hour observation shift was centered on the low tide (with some deviation due to shorter daylight hours during the fall months).

Vessel sightings

The number, type and activity of vessels were documented hourly during observations sessions. Observers noted if a vessel was within the Marine Terminal Redevelopment Footprint (hereafter referred to as the footprint).

Environmental conditions

Every hour, observers rated the overall sighting conditions and recorded the air temperature (measured with digital thermometer), type of precipitation, wind speed and direction (measured with anemometer), sighting distance, presence and angle of glare (angle measured with compass), swell height, and sea state.

Beluga sightings

Observers used binoculars (10 x 50 power), spotting scopes (20 power), and the naked eye to search for beluga whales and other marine mammals in the water around the POA, lower Knik Arm, and across upper Cook Inlet to Point MacKenzie and Fire Island. For every sighting of a beluga whale, observers recorded the date, time, and number of whales. Observers also recorded the times at which observation shifts began and ended; these times were used to calculate total effort by month and tidal stage. Beluga sightings and observational shifts were assigned to tidal stages. Tidal stages were derived from time of day and tide level data were generated with JTides software (http://www.arachnoid.com/JTides), using the Anchorage (Knik Arm) NOAA gauge located at the POA. Daily tidal cycles were divided into six tidal stages, each two hours long (Figure 2.1).

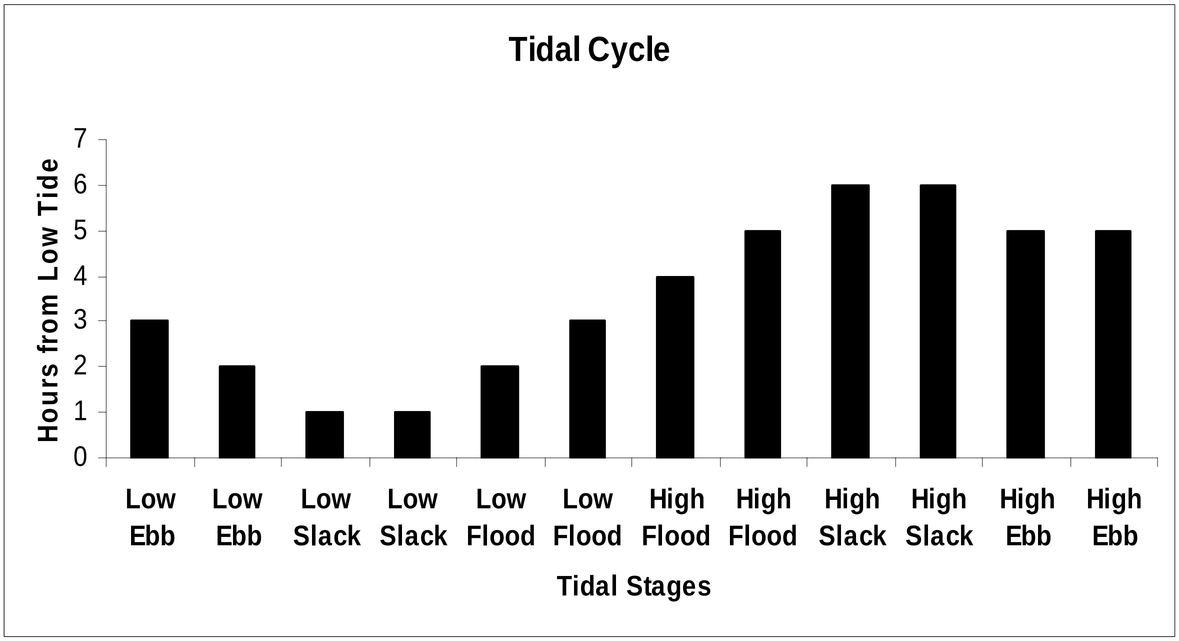

Figure 2.1. This schematic illustrates the classification of daily tidal cycle into six tidal stages of two hours each.

Sighting rates for numbers of whales and for numbers of groups of whales were calculated as mean number of whales per hour of effort and mean number of whale groups per hour of effort, respectively. The term *mean* is used to represent the arithmetic mean (often referred to as the average). Standard deviations about the mean are presented in parenthesis following the mean. Sighting rates are stratified according to month and tidal stage. A Kruskal-Wallis test (Zar 1984) was used to compare sample medians of beluga sighting rates among tidal stages. Results of statistical tests were considered significant at the $P \leq 0.05$ level.

Results

Beluga sightings according to month

Beluga whales were seen on 21 of 95 days (563.8 hours) of monitoring conducted between April 26 and November 3, 2006 (Table 2.1). Observers recorded a total of 25 beluga group sightings and a summed count 82 beluga whale occurrences (because individual belugas were not identified, individual belugas may have been re-sighted several times over the course of the study). Overall mean sighting rates were 0.14 (± 0.41 SD) whales per hour and 0.04 (± 0.09 SD) groups per hour.

Table 2.1. Observational sampling effort, number of beluga sightings and sighting rates are compare by month.

2006	**Observational Effort**		**Number of Sightings**			**Sighting Rates**	
Month	**Days**	**Hours**	**Number of days whales seen**	**Number of whale sightings**	**Number of groups**	**Whales/hour (± SD)**	**Groups/hour (± SD)**
April	2	12.0	1	1	1	0.08 (± 0.71)	0.08 (± 0.71)
May	10	60.0	3	7	3	0.12 (± 0.26)	0.05 (± 0.08)
June	18	108.0	3	8	4	0.07 (± 0.21)	0.04 (± 0.09)
July	14	84.0	2	2	2	0.02 (± 0.06)	0.02 (± 0.06)
August	16	92.1	4	36	6	0.39 (± 0.79)	0.07 (± 0.12)
September	16	96.0	6	26	7	0.27 (± 0.49)	0.07 (± 0.10)
October	16	96.0	2	2	2	0.02 (± 0.06)	0.02 (± 0.06)
November	3	15.7	0	0	0	0.00 (± 0.00)	0.00 (± 0.00)
Total	95	563.8	21	82	25	0.14 (±0.41)	0.04 (±0.09)

Whale sighting rates were highest in August and September (Figure 2.2), and group sighting rates were highest in August, September, and April, although monthly differences were not statistically significant (Kruskal-Wallis H = 6.44, P = 0.49; Kruskal-Wallis H = 5.92, P = 0.55, respectively). Whales were seen on more days during September than during any other month of the study, although more days of observational effort were expended in June.

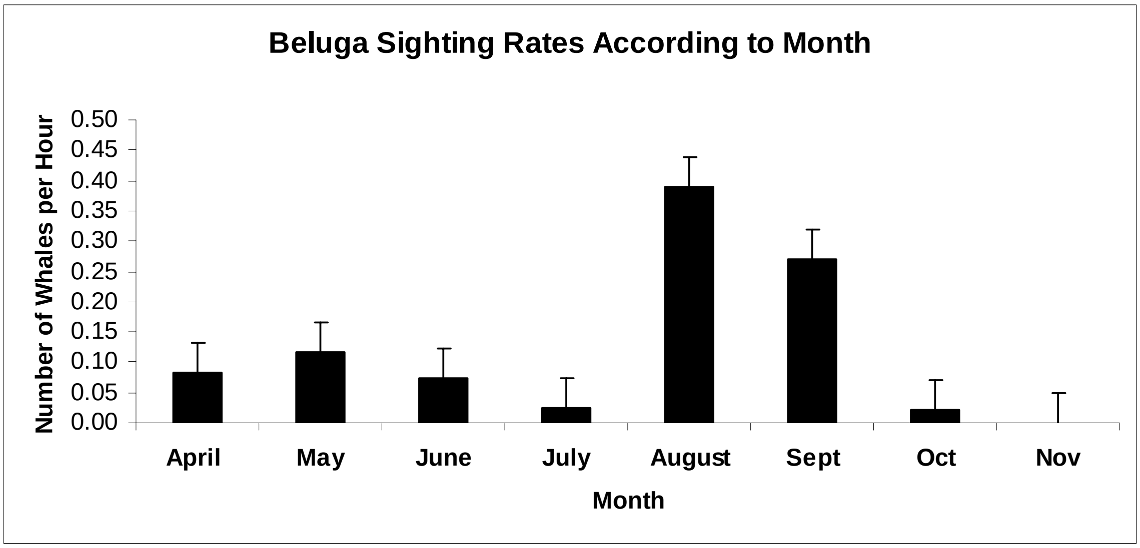

Figure 2.2. Mean beluga sighting rates (number of beluga sightings/hour) according to month of observation. Bars represent standard error about the mean.

Beluga sightings according to tidal cycle

Observations were conducted during all six stages of the tidal cycle (Figure 2.3). Differences in beluga sighting rates among tidal stages were statistically significant (Kruskal-Wallis H = 15.55, P = 0.008). Belugas were never seen during the high flood stage, despite 11% of the effort being expended during this stage (Table 2.2). Beluga sighting rates were greatest during the low slack and low ebb stages (Figure 2.4). Not only were more whales seen during the low slack stage, but whales were seen during more hours of the low slack tidal stage than of any other tidal stage.

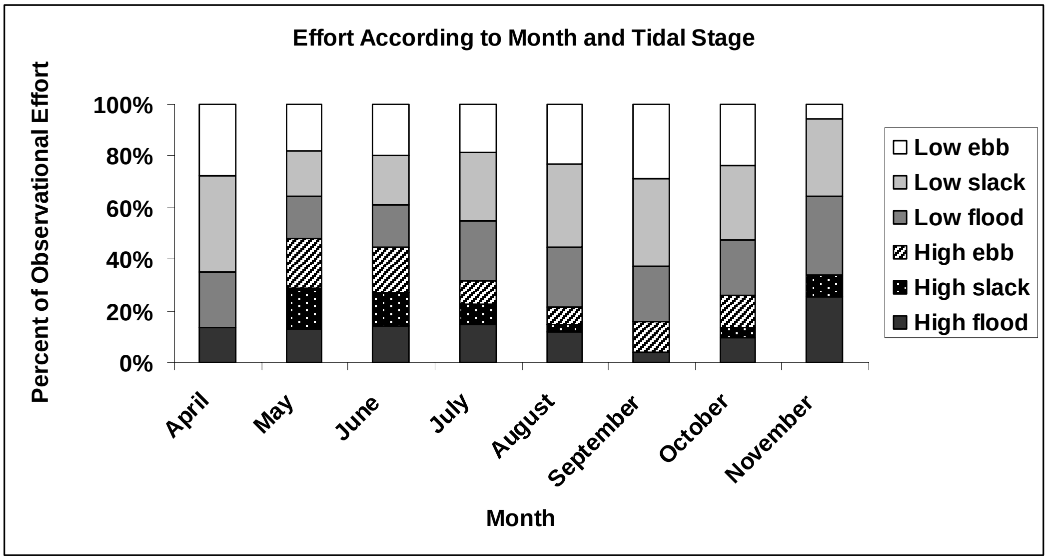

Figure 2.3. Percent of observational sampling effort according to month and tidal stage.

Table 2.2. Observational sampling effort, number of beluga sightings and sighting rates are compared by tidal stages.

Tidal Stage	Hours of observational effort (% of total)	Numbers of belugas sighted	Beluga sighting rate (belugas/hour) (± SD)	Total number of hours belugas sighted during tidal cycle	Percent of observation time with belugas (# hours with belugas/ # hours effort) x 100
Low ebb	116.5 (22%)	31	0.26 (± 1.06)	3.78	3.24 %
Low slack	143.5 (27%)	49	0.34 (± 1.51)	5.37	3.74 %
Low flood	110.4 (21%)	10	0.09 (± 0.95)	0.08	0.07 %
High flood	61.2 (11%)	0	0 (± 0.00)	0.00	0.00%
High slack	36.4 (7%)	5	0.14 (± 0.83)	0.20	0.55 %
High ebb	63.5 (12%)	4	0.06 (± 0.39)	0.07	0.11 %

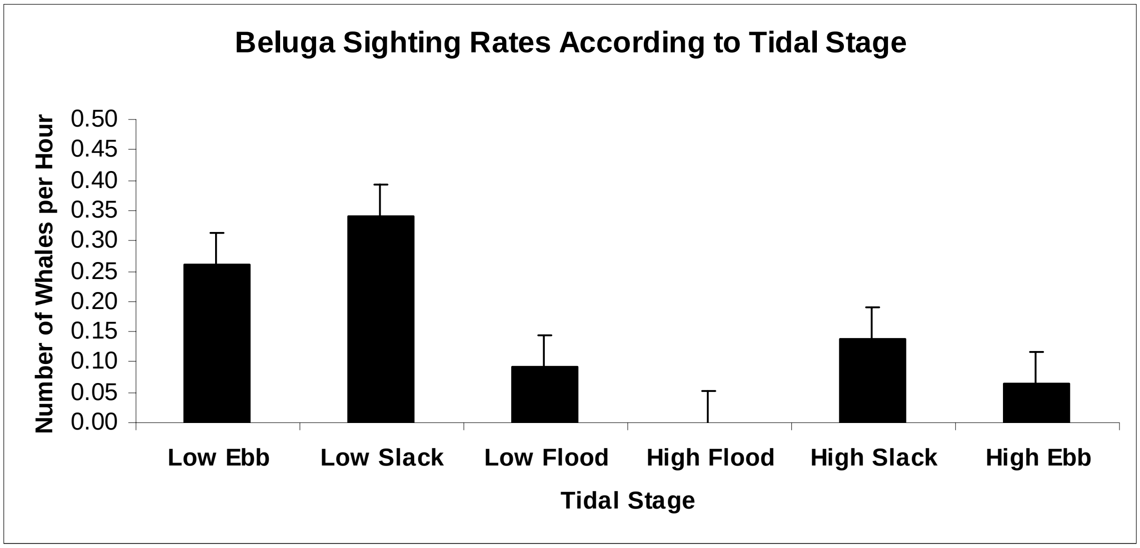

Figure 2.4. Mean beluga sighting rates (number of beluga sightings/hour) are shown by tidal stage. Bars represent standard errors about the mean. Belugas were not seen during the high flood stage.

Beluga sightings according to time of day

Shifts began as early as 07:10 and ended as late as 20:00. The majority (77%, *n*=434 hours) of hours of observational effort were conducted between 10:00 and 16:00. Although sixteen percent (*n*=93 hours) of all hours of observation were conducted before 11:00, whales were never seen before 11:00. After 11:00, group sighting rates remained constant (0.05 beluga groups per hour) throughout the sighting day.

Environmental conditions

Overall sighting conditions were classified as excellent to good in the majority (96.5%) of hours of effort (Table 2.3). Mean estimated maximum sighting distance was greatest between June and October. Mean wind speed was greatest in April and October. Sea state was most favorable for sighting conditions during April and May. August had the highest percentage of observation days with fog and rain. Snow fell in October but not November, although it remained on the ground during November. Sea ice was limited to the month of April.

Table 2.3. Environmental conditions are compared by month.

2006	Rating of sighting conditions (hours)		Mean estimated maximum sighting distance	Mean wind speed and range	Sea State*	Mean air temperature and range	Percent of observation days with precipitation		
Month	**Good-excellent**	**poor**	**km**	**km/hr**	**Median Beaufort**	**(^{o}C)**	**fog**	**rain**	**snow**
April	12.0	0.0	5.0	5.0 (4-6)	1.0	7.0 (6-7)	0	0	0
May	60.0	0.0	7.0	3.0 (0-12)	1.0	13.0 (7-20)	0	0	0
June	105.0	3.0	9.0	1.7 (0-4)	1.8	19.0 (15-24)	5	33	0
July	81.0	3.0	9.0	2.0 (0-8)	1.6	22.8 (19-26)	7	29	0
Aug	92.1	0.0	8.5	1.3 (0-5)	1.5	17.6 (13-21)	25	44	0
Sept	93.0	3.0	9.0	1.5 (0-10)	2.0	15.3 (9-22)	12	44	0
Oct	87.0	9.0	9.0	4.6 (0-14)	2.0	7.9 (0-18)	0	38	12
Nov	13.7	2.0	7.0	0.8 (0-8)	1.5	$^{-}$2.8 ($^{-}$5-$^{+}$3)	67	0	0

** Beaufort Sea State scale: 0= mirror-like; 1=ripples without foam crests; 2=small wavelets, crests do not break; 3=large wavelets, scattered white caps; 4=small waves, fairly frequent white caps.*

Vessels in the study area

The number of vessels in the study area peaked between June and September (Table 2.4). The greatest number of vessels in the footprint and the greatest number of vessels engaged in noise producing activities (*e.g.*, dredging, moving, emptying dredge material, or stationary with motor on; Table 2.5) were recorded in August. More vessels were seen from the observation station at Cairn Point than from the observation stations at the Port of Anchorage.

Tugs, skiffs, and tugs with barges were the most commonly recorded vessels throughout the study, although there was some monthly variation in vessel types (Table 2.6). Tankers were the least common vessel type. Crane dredges were in the area from May through September, while the motor dredge remained present and active from May through November. Container ships were not recorded in October and November because, at the request of the Port of Anchorage, no observations were conducted on Tuesdays and Sundays, the days on which container ships were scheduled to be docked at the Port.

Table 2.4. Vessel sighting rates are compared by month and observation station. POA=Port of Anchorage; CPS=Cairn Point Station.

Month	Observation station	Mean number of vessels per hour observed in the study area	Mean number of vessels per hour observed in the footprint	Mean number of vessels per hour engaged in noise producing activities*
April	POA	2.3	2.3	0.1
May	CPS	6.0	5.3	2.0
May	POA	4.5	2.7	2.7
June	CPS	9.5	7.0	3.3
June	POA	5.8	4.5	2.0
July	CPS	10.0	8.2	3.8
August	CPS	9.0	7.0	4.0
August	POA	2.0	0.7	1.4
September	CPS	10.0	6.0	3.0
September	POA	1.5	0.7	1.4
October	POA	2.0	1.0	2.0
November	POA	2.0	1.0	2.0

** noise producing activities were defined as dredging, moving, emptying dredge material, or stationary with motor on.*

Table 2.5. Monthly vessel activity, expressed as a percent of vessels observed per month and observation station.

Month	Shore station	Docked	Moving	Stationary	Dredging	Emptying dredge	Anchored
April	POA	81	13	0	0	0	6
May	CPS	46	23	16	4	1	10
May	POA	37	35	5	14	5	4
June	CPS	49	16	15	11	1	8
June	POA	0	23	18	0	0	59
July	CPS	52	15	11	15	2	5
Aug	CPS	55	11	11	11	1	11
Aug	POA	25	25	25	25	0	0
Sept	CPS	65	13	5	13	2	2
Sept	POA	12	44	0	28	0	16
Oct	POA	0	50	0	50	0	0
Nov	POA	9	30	9	48	4	0

Table 2.6. Mean number of observed vessel types per hour according to month and observation station.

Month	Shore station	Tug	Skiff	Crane dredge	Motor dredge	Tug with barge	Container ship	Tanker	Other vessel
April	POA	0.1	0.0	0.0	0.0	0.0	0.0	1.5	0.8
May	CPS	1.1	1.8	0.4	0.1	2.2	0.2	0.1	0.2
May	POA	0.8	1.4	0.3	0.3	0.9	0.0	0.0	0.8
June	CPS	3.0	2.5	1.1	0.9	1.1	0.8	0.0	0.2
June	POA	1.7	0.7	0.7	0.0	2.8	0.0	0.0	0.0
July	CPS	3.8	2.6	1.0	1.0	0.9	0.8	0.0	0.1
Aug	CPS	3.0	2.0	1.0	1.0	0.5	1.0	0.0	1.0
Aug	POA	0.2	0.3	0.0	0.5	0.2	0.3	0.0	0.7
Sept	CPS	0.2	0.3	0.0	0.5	0.2	0.3	0.0	0.0
Sept	POA	3.5	2.5	1.0	1.0	0.5	1.0	0.0	0.5
Oct	POA	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0
Nov	POA	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0

Discussion

Seasonal patterns

Beluga populations elsewhere are known to undertake extensive seasonal migrations (Leatherwood and Reeves 1983), while the population of Cook Inlet belugas exhibit seasonal movements on a smaller scale within Cook Inlet (Hobbs *et al.* 2005). Observations in this study, conducted from late April to early November, offer a glimpse into half of the yearly seasonal cycle of belugas in the POA area of Upper Cook Inlet, and represent all of the ice-free months in this area. Beluga whale sighting rates remained low until late August and September, when they increased sharply. Sighting rates abruptly decreased in late September, and remained low for the rest of the season. Although sighting rates appear to be high for April, this was most likely a function of low observational effort (12 hours total) and only one whale was seen during this time.

This seasonal pattern is consistent with results from other studies of Cook Inlet belugas. In summer and early fall, belugas aggregate in river mouths or bays, where they are believed to feed on seasonal fish runs, such as euchalon (*Thaleichthys pacificus*) and salmon (*Oncorhynchus spp.:* Hobbs *et al.* 2005). Native hunters report that belugas follow monthly fish runs (Huntington 2000). Moore *et al.(*2000) state that in summer belugas prefer areas of shallow estuarine waters, where prey densities are high and predator densities are low. As fish runs decline by fall, belugas return to estuaries and bays (Hobbs *et al.* 2006). Funk *et al* (2005) reported that belugas spend August through mid-November in Knik Arm, and that spring and summer distribution is primarily at the mouth of the Susitna River, with some activity in the very southern reaches of Knik Arm (*i.e.*, near the POA study area). Between August and November 2005 at the POA, Prevel Ramos *et al.* (2006) reported that beluga sighting rates were highest in November, although belugas were seen on more days in August and September. Based on movements of animals tracked with satellite transmitters, Hobbs *et al.* (2005) reported that beluga movement patterns in November were similar to those in September.

When examining the seasonal patterns of beluga sightings, it is important to consider confounding factors, such as changes in observation station location and human activities within the study area (*e.g.,* vessel and construction activity). Station location may have affected the number of whales detected in the current study, and vessel and construction activities may have affected the number of whales detected, the number of whales present, and the amount of time whales spent in the study area. The majority of observational shifts between May and August were conducted from CPS, with a station height of 54.70 meters. The remaining observational shifts from late September through early November were conducted from the north east corner of the POA dock, with a station height of 12.56 meters. The higher vantage point of CPS afforded observers a better view of the study area, as demonstrated by the greater vessel sighing rates from CPS in comparison to vessel sighting rates from the POA on days in which observations were conducted from paired stations. The height of the Cairn Point station made it a better vantage point for viewing the waters around the POA, while much of the view of the water from the POA station was obstructed by the dock and vessels at the dock. Although beluga whale sighting rates were undoubtedly affected by station height, it is not clear to what extent. Station height may not have had as great an effect on beluga sighting rates as on vessel sighting rates, as the majority of belugas sighted from CPS were sighted in the area between CPS and the POA, which was also clearly visible from the POA station (see Chapter 3 for maps of beluga sightings).

In addition to having increased whale sighting rates, August and September were among the busiest month in terms of numbers of vessels in the study area, numbers of vessels in the Footprint, and number of vessels engaged in noise producing activities. Phase 1 Construction at the POA also began in August, and peak in-water construction activities were conducted during late August and all of September (see Chapter 3 for more details). It is unclear what, if any, effects activities from vessels and construction may have had on whale abundance and distribution at the Port of Anchorage.

Tidal patterns

Although belugas were seen during all tidal stages except high flood, they were seen in greater numbers and spent more time within the study area during low slack tide and low ebb tide. In several instances they appeared to travel with the falling tide from upper Knik Arm to the study area, and then travel back up Knik Arm with the rising tide. A similar pattern was reported by Funk *et al.* 2005, who reported that belugas travel up

Knik Arm during the flood tide from Six-mile Creek and Eagle River to Eklutna) and back down with the ebb tide. Prevel Ramos *et al.* (2006) observed that the majority of beluga sightings at the POA were during low tide (76.2% low tide, 14% mid-tide, and 9.5 % high tide). Native hunters report that belugas move with respect to the tides (Huntington 2000). While it appears that belugas track prey distribution and abundance on a seasonal scale (*i.e.*, in response to seasonal fish migrations and reproduction), belugas also track tidal patterns in order to gain access to prey-rich habitats; such tidal corridors allow access to feeding areas in Knik Arm, Turnagain Arm, Chickaloon River, and the Susitna River delta (Hobbs *et al.* 2005).

Distributional patterns associated with changes in water levels have been noted for other cetaceans. For example, during the low water season, river dolphins in the Amazon River are known to prefer confluence areas, where relatively deep waters and high density of prey provide important refuge to dolphins. Conversely, during high water, dolphins and their prey leave the confluence areas and follow the rising waters into lakes, tributaries and inundated forests (Martin and da Silva 2004, McGuire and Winemiller 1998).

Diurnal patterns

Distinct diurnal patterns in beluga distribution at the Port of Anchorage were not detected, except that whales were never seen before 11:00. Diurnal patterns may be difficult to detect and interpret due to stronger tidal and seasonal patterns. Diurnal patterns were examined with respect to time of day, but future studies may wish to consider examining time relative to sunrise and sunset instead, as hours of daylight varied substantially by month. Living in turbid waters and in latitudes with little daylight for much of the year, belugas rely primarily on echolocation rather than eyesight to navigate and hunt; it is therefore likely that if they are affected by daylight, it is indirectly and in response to diurnal patterns of their prey.

Summary

1) Temporal patterns of beluga distribution and abundance at the Port of Anchorage were observed with respect to tidal cycle and season. Diurnal patterns did not appear to be as strong.

2) Belugas were observed most often in and around the Port of Anchorage during the months of August and September, and during low slack and low ebb tidal stages.

3) Beluga abundance in and around the Port of Anchorage was greatest during August and September, and during low slack and low ebb tidal stages. Belugas were never seen during the high flood tidal stage.

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Chapter 3: Spatial Distribution of Beluga Whales near the Port of Anchorage

Draft Final Report

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Introduction

The spatial distribution of wildlife provides insight into habitat selection and the relative importance of given areas within an animal's home range. Habitat selection can be examined in an ecological context relative to foraging (Bernstein *et al.* 1991, Le Boeuf *et al.* 2000, Guinet *et al.* 2001, Boyd *et al.* 2002, Hastie *et al.* 2004), reproductive success (Boyd 1999, Van Parijs *et al.* 2000, Amstrup *et al.* 2001), and predator avoidance (Bernstein *et al.* 1991, Katnik 1997, Nordstrom 2002), among other things. This study was concerned with the spatial distribution of beluga whales (*Delphinapterus leucas*) in Knik Arm in Upper Cook Inlet as related to the expansion of the Port of Anchorage. As part of the monitoring program developed in coordination with NOAA Fisheries, beluga whale use of areas in proximity to current and planned construction activities, including the area of the Marine Terminal Redevelopment Footprint, was documented.

Although Cook Inlet beluga whales may not migrate outside of Cook Inlet, they shift their distribution within the Inlet seasonally. The whales aggregate near the Susitna Flats in May – July, and move into Turnagain and Knik Arms during August – November (Seaman *et al*. 1985, Moore *et al.* 2000, Funk *et al.* 2005, Hobbs *et al.* 2005, Rugh *et al.* 2005). Limited data from satellite tagging and aerial surveys indicate beluga shift their distribution to the south in the winter and are more dispersed in the upper to middle, and possibly the lower reaches of Cook Inlet (Angliss and Lodge 2004; Moore *et al*. 2000). NMFS has counted up to 190 beluga whales in Upper Cook Inlet in the summer during their annual aerial surveys (Rugh *et al.* 2006). Examination of spatial distribution data from these aerial surveys showed that the whales were highly concentrated in groups composed of more than 20 whales 71% of the time (n = 17; Rugh *et al*. 2000). However, these surveys were conducted when the whales were known to be grouped in seasonal feeding aggregations, and group size may be reduced at other times of the year. Smaller groups are also commonly observed in the Upper Cook Inlet, traveling or resting together (Hobbs *et al*. 2000b), suggesting that group size is variable and likely correlated with behavior. Several studies have reported that beluga whales appear to focus their foraging efforts at streams and rivers where fish are highly concentrated (Fried *et al*. 1979; Hazard 1988; NMFS 2005). Areas where beluga whales typically congregate in Cook Inlet in large numbers include Eagle Bay (Funk *et al*. 2005), the Susitna Delta (Rugh *et al.* 2005, Rugh *et al.* August 2006), and Chickaloon Bay (Rugh *et al.* 2005, Rugh *et al*. June 2006).

Several studies of marine mammals have employed land-based observers to collect data because observers based on land do not disturb the natural behavior of the animals (Würsig and Würsig 1979, Evans *et al.* 1996, Stockin and Weir 2002, Hastie *et al.* 2003, Funk *et al.* 2005). A surveyor's theodolite may be used to acquire location data for marine mammals observed at a distance (Würsig *et al.* 1991). This technique has been employed to study a variety of marine mammal species, including dolphins (Würsig and Würsig 1979, Bejder and Dawson 2001), harbor porpoise (Cox *et al.* 2001), killer whales (Williams *et al.* 2002), humpback whales (Noad and Cato 2000), and harbor seals (Suryan and Harvey 1999). Observers must be stationed at a known elevation, and as elevation increases, error decreases (Würsig *et al.* 1991).

Marine mammals are sensitive to underwater noise (Richardson *et al.* 1995) and NOAA Fisheries has specified that cetaceans should not be exposed to pulsed sounds exceeding 180 dB re 1 µPa SPL, *i.e.* root-mean-square value averaged over the pulse duration (NMFS 2000). The sound generated by pile driving at Port MacKenzie in Knik Arm in Upper Cook Inlet was measured and it was found that beluga whales at a depth of 1.5 m would be exposed to sound >180 dB re 1 µPa SPL if they were closer than 330 m to the sound source, and beluga whales at a depth of 10 m would be exposed to sound >180 dB re 1 µPa SPL if they were closer than 650 m to the sound source (Blackwell 2005). Because Port MacKenzie is only roughly 3 km away from the Marine Terminal Redevelopment Footprint at the Port of Anchorage, approximately the same values should apply.

The objective of this chapter was to document beluga whale presence in Knik Arm in the vicinity of the Port of Anchorage between late April and early November, 2006 in relation to the Port of Anchorage expansion. Observers recorded beluga whale locations and notified the client when whales were approaching the construction area. This information will serve as baseline data for examining the potential effects of future development at the Port of Anchorage on beluga whales.

Methods

Field data collection

A marine mammal observer stationed at either Cairn Point on Elmendorf Air Force Base or at the Port of Anchorage monitored beluga whales during a six-hour shift on an average 16 days per month between 26 April and 3 November, 2006. The observer scanned the water using a combination of the naked eye and 7 x 50 power binoculars and recorded the time, location, group composition, behavior and direction of travel of all beluga whale groups observed. Observers recorded the location of whales on a 500 m x 500 m grid. Environmental conditions recorded on an hourly basis included air temperature, could cover, wind speed and direction, estimated distance of visibility, precipitation, angle of glare, and Beaufort Sea state.

As detailed in Chapter 1, a surveyor's theodolite (Sokkia DT-5) was used to document (or "fix") the location of beluga whale groups whenever possible. The theodolite was connected to a laptop computer running Pythagoras, a computer program designed specifically to aid in tracking marine mammals (Gailey and Ortega-Ortiz 2000). The program output provided information on the distance between the whales and the observer and the whales and any other point the observer fixed, such as the location of ongoing construction activity in the Marine Terminal Redevelopment Footprint. It also provided data on the speed of beluga whale groups if multiple fixes were recorded.

The observer informed the client via telephone when beluga whales were first observed and again when they were sighted within 1 km, 500 m, 250 m, 100 m and 50 m of construction activities.

Analysis

Data recorded using Pythagoras were imported into a Geographic Information System (GIS) using ArcGIS 9 (ESRI 2005). The locations of all beluga whale groups were mapped relative to the Marine Terminal Redevelopment Footprint at the Port of Anchorage. Time spent within the footprint was calculated and indicated on GIS maps. Hawth's Animal Movement extension was used to convert point data to lines based on time to indicate the direction of whale travel. When theodolite data were unavailable, the locations of whale groups were mapped on the same geo-referenced 500 x 500 m grid used by field observers, with the number of sightings and summed whale counts per grid cell indicated by color scale in ArcGIS.

Results

Spatial distribution summary

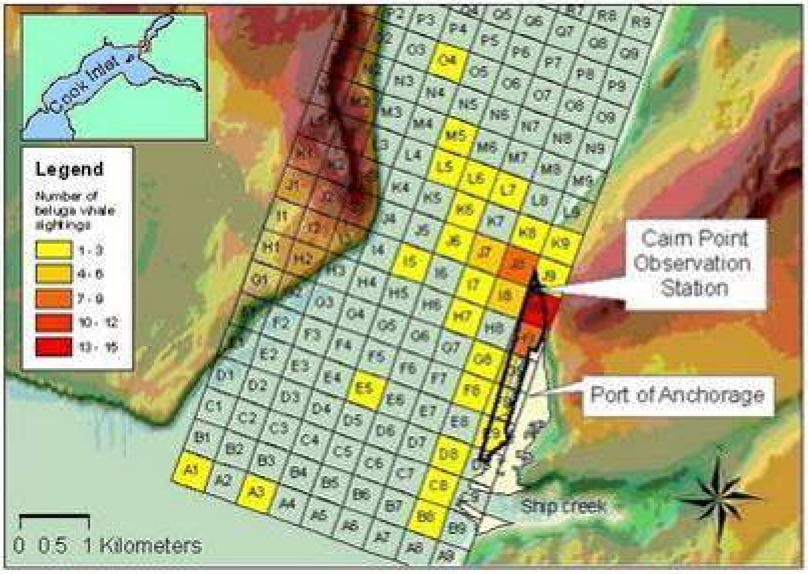
Beluga whales were observed near the Port of Anchorage on 25 occasions during 564 hours of effort between 26 April and 3 November, 2006 (Table 3.1). Eighty percent of beluga whale sightings occurred within 0.5 km^2 of the Marine Terminal Redevelopment Footprint at the Port of Anchorage. Sixty-four percent of groups were observed in the footprint (Figure 3.1a).

Table 3.1. Summary of beluga whale sightings.

Date	Group	Time	Total length of observation (min)	Time within footprint (min)	Number of beluga whale sightings: Adult	Subadult	Calf	Unknown	Total
27 April	1	11:08 - 13:17	129	26	1	0	0	0	1
4 May	1	14:40 - 15:23	43	43	0	1	0	0	1
17 May	1	15:35 - 15:36	1	0	0	0	0	1	1
19 May	1	11:30 - 11:42	12	0	5	0	0	0	5
12 June	1	13:26 - 14:00	34	32	0	2	0	0	2
12 June	2	16:25 - 16:28	3	0	0	3	0	0	3
13 June	1	16:34 - 16:57	23	23	0	2	0	0	2
14 June	1	13:01 - 13:02	1	1	0	0	0	1	1
6 July	1	11:06 - 11:19	13	1	0	1	0	0	1
11 July	1	13:22 - 13:32	10	0	0	1	0	0	1
23 August	1	14:40 - 14:41	1	0	2	0	0	0	2
28 August	1	14:26 - 17:44	174	117	6	1	0	0	7
29 August	1	15:48 - 16:20	32	32	3	1	0	0	4
29 August	2	16:59 - 18:44	53	49	6	2	2	0	10
31 August	1	14:54 - 15:03	9	9	1	2	0	0	3
31 August	2	18:33 - 19:25 & 19:40 - 19:45	57	50	7	2	1	0	10
6 September	1	12:30 - 13:15	45	0	0	0	0	3	3
7 September	1	13:06 - 13:20	14	7	2	0	0	0	2
7 September	2	13:23 - 14:42	24	19	6	1	1	0	8
8 September	1	12:41 - 14:15	45	37	2	3	1	0	6
12 September	1	17:20 - 17:22	2	0	0	1	0	0	1
14 September	1	16:37 - 16:48	11	10	5	0	0	0	5
19 September	1	12:11 - 12:28	17	13	1	0	0	0	1
19 October	1	13:24 - 13:25	1	0	1	0	0	0	1
20 October	1	12:30 - 12:31	1	0	1	0	0	0	1

Theodolite tracks showed whale groups swimming the length of the Marine Terminal Redevelopment Footprint, entering just part of the footprint, and swimming just offshore of the footprint (Figure 3.1b).

(a) grid cell locations of all beluga whale sightings (n = 25)



(b) theodolite tracks of beluga whales (n = 7)

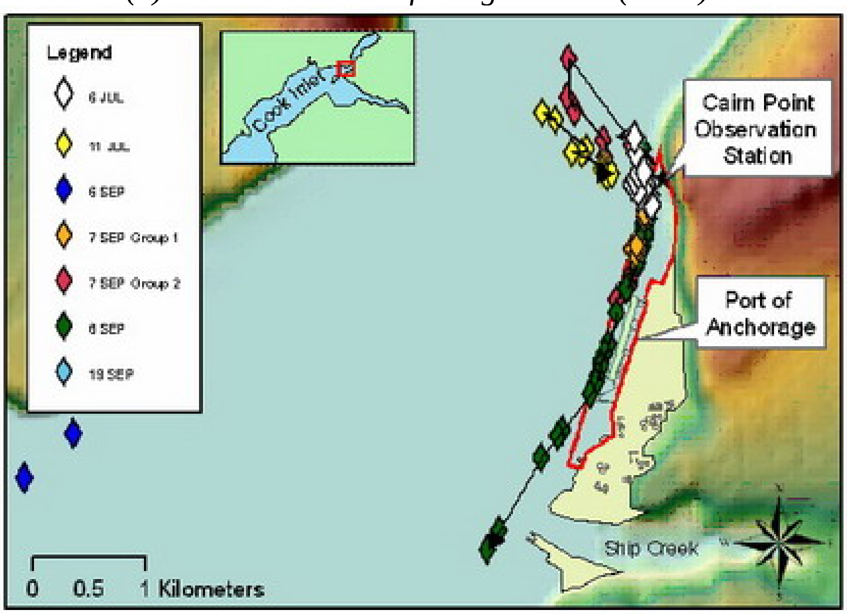


Figure 3.1. Locations of all beluga whale group sightings between 26 April and 3 November 2006 are shown by (a) grid cell map and (b) theodolite track lines relative to the Marine Terminal Redevelopment Footprint at the Port of Anchorage.

Summed beluga whale counts were highest at the northeast end of the Marine Terminal Redevelopment Footprint, closest to the observation stations and the area of Phase 1 construction (Figure 3.2).

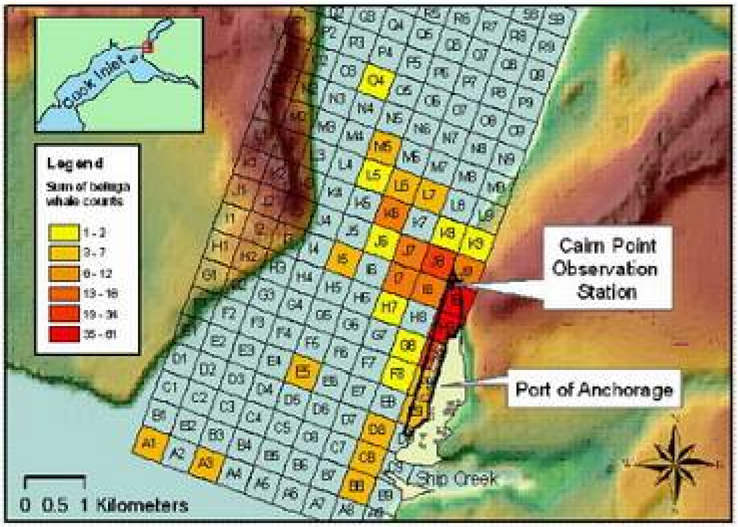


Figure 3.2. Summed counts of beluga whales from group sightings are shown by grid cell relative to the Marine Terminal Redevelopment Footprint (black outline) at the Port of Anchorage.

Beluga whales continued to enter the Marine Terminal Redevelopment Footprint during the period of Phase 1 construction in September (Figure 3.3).

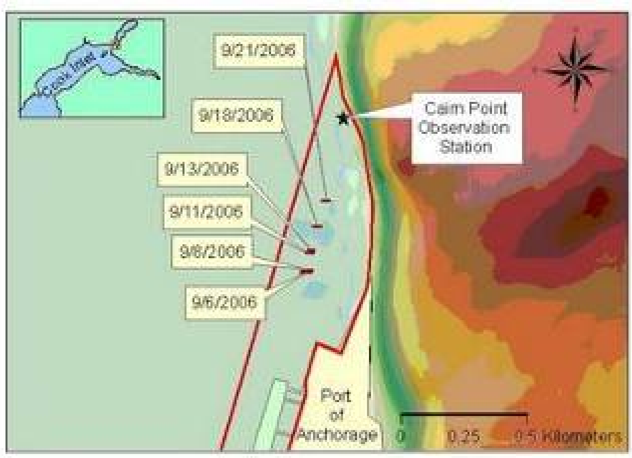


Figure 3.3. Progress of Phase 1 construction within the Marine Terminal Redevelopment Footprint (red outline) is shown by date at the Port of Anchorage. Red marks show the end of the dike being constructed by date.

Beluga whale calves were observed in close proximity to the construction site (within 150 m) on two occasions, on 7 September (group 2) and 8 September (group 1); however, in both instances the observer noted that construction was being conducted on land and not in the water because the tide was out.

Distribution of beluga whale sightings by date

April 2006

On 27 April a lone adult beluga whale was observed near the Port of Anchorage between 11:08 and 13:17 (Figure 3.4). It was observed within the Marine Terminal Redevelopment Footprint for a total of 26 minutes between 11:08 and 12:13, during the low ebb tidal stage. The observer noted frequent diving that might indicate foraging behavior. The whale was not observed between 12:15 and 13:17. A lone adult whale was observed swimming south in grid cell H7 at 13:17; the observer noted that it was likely the same whale observed earlier, however, it is possible that it was a different whale.

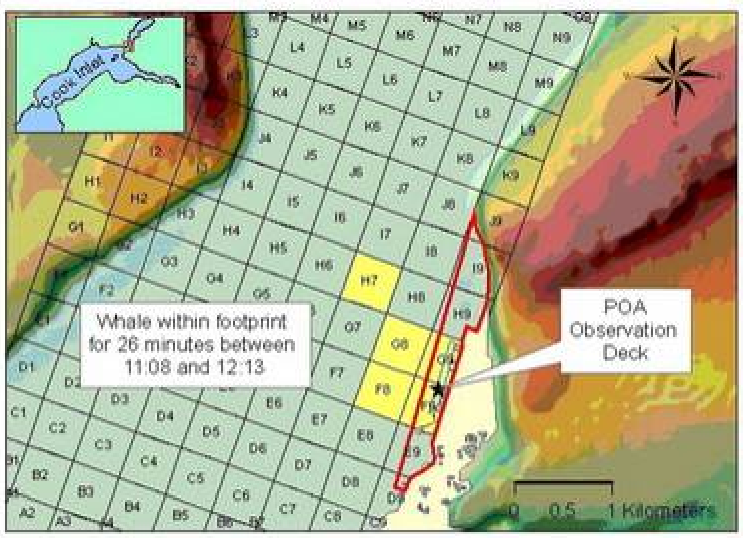


Figure 3.4. Locations of a lone adult beluga whale observed on 27 April are shown relative to the Marine Terminal Redevelopment Footprint (red outline) at the Port of Anchorage. The whale was observed within the footprint for a total of 26 minutes between 11:08 and 12:13.

May 2006

In May, there were just three beluga whale group sightings in the vicinity of the Port of Anchorage, one within the Marine Terminal Redevelopment Footprint, another nearby, and a third 3-4 km to the southwest (Figure 3.5).

A lone subadult beluga whale was observed within the Marine Terminal Redevelopment Footprint on 4 May from 14:40 to 15:23, during the high ebb tidal stage (Figure 3.5a). It was observed by two different observers, one at Cairn Point and one at the Port of Anchorage. The whale was diving and traveling north. During a 21-minute focal sample of the whale's diving behavior, dive durations averaged 2.6 minutes, with 2-3 seconds spent at the surface between dives. The observer at Cairn Point was able to observe the whale for a longer period of time than was the observer at the Port of Anchorage, despite the close proximity of the whale to the Port.

On 17 May a lone beluga whale of unknown age was observed briefly near the Port of Anchorage at 15:35, during the low ebb tidal stage (Figure 3.5b). The whale was not observed long enough to determine its age class or to classify its behavior.

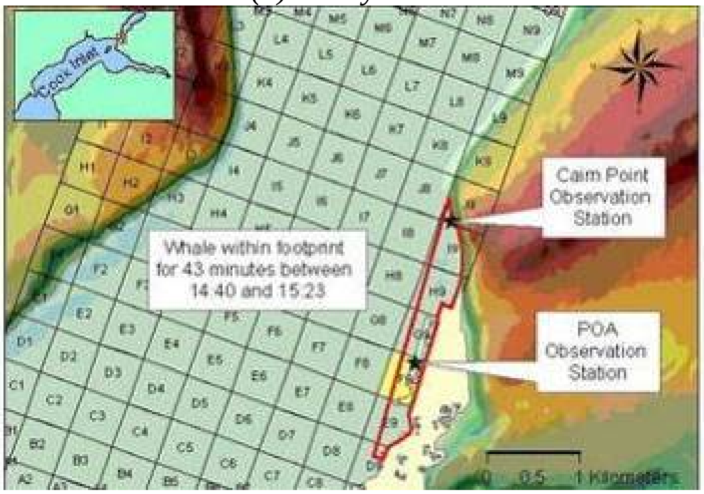
On 19 May a group of five adult beluga whales was observed at the entrance of Knik Arm, several kilometers from the Port of Anchorage, at high slack tide (Figure 3.5c). The whales were observed for 12 minutes, between 11:30 and 11:42. Their behavior was classified as traveling; they were headed west toward the Susitna Flats.

June 2006

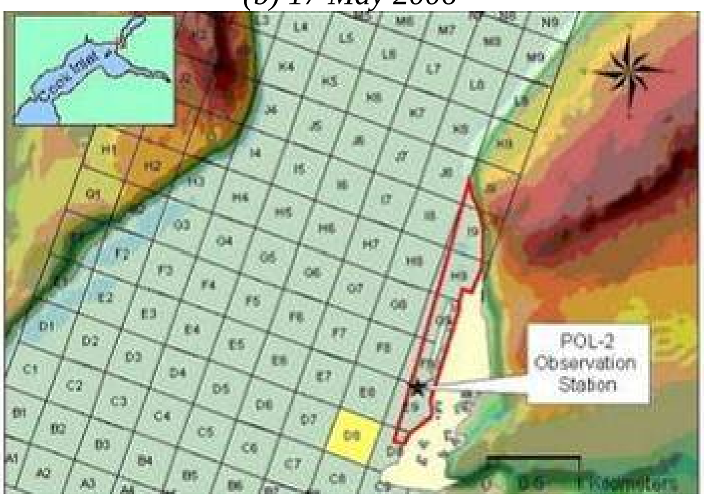
In June, there were four beluga whale group sightings near the Port of Anchorage, all within or immediately adjacent to, the Marine Terminal Redevelopment Footprint (Figure 3.6).

On 12 June, two subadult beluga whales were observed between 13:26 and 14:00, during the low ebb tidal stage. The whales were observed within the Marine Terminal Redevelopment Footprint for 32 minutes between 13:28 and 14:00. Their primary activity state was traveling and their secondary activity state was feeding suspected. The whales were separated from each other by 1 – 3 body lengths and were headed south.

(a) 4 May 2006



(b) 17 May 2006



(c) 19 May 2006

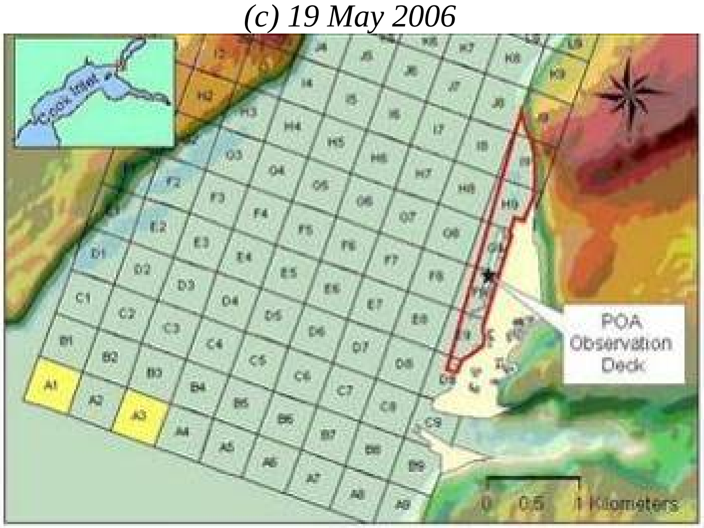


Figure 3.5. Locations of beluga whales observed in May 2006 are shown by date relative to the Marine Terminal Redevelopment Footprint (red outline) at the Port of Anchorage.

Later in the day on 12 June, three subadult beluga whales were observed near the base of Cairn Point, heading north, at low slack tide. They were only observed for 3 minutes (16:25 – 16:28); their activity state was recorded as traveling and they were spaced 1 – 3 body lengths apart. Two of the whales may have represented the same group seen earlier that day, however, it is possible that this second group was composed of entirely different individuals.

On 13 June, two subadult beluga whales appeared at the base of Cairn Point and swam south through the Marine Terminal Redevelopment Footprint. They were observed from 16:34 to 16:57, during low slack tide. They were spaced 1 – 3 body lengths apart and were traveling and diving; the observer noted feeding suspected as a secondary activity state. The whales disappeared from view at 16:57

On 14 June, a lone beluga whale of unknown age was observed briefly at the base of Cairn Point at 13:01, traveling north. The tidal stage at the time was high ebb. The whale was only observed for one minute before it swam up into Knik Arm and out of sight.

July 2006

In July, there were two beluga whale sightings, each of a lone subadult whale, tracked by theodolite in and slightly offshore of the Marine Terminal Redevelopment Footprint (Figure 3.7).

A lone subadult whale was observed on 6 July from 11:06 to 11:19, during low slack tide. The whale was within the Marine Terminal Redevelopment Footprint for 1 minute from 11:08 to 11:09. Its activity state was recorded as traveling.

On 11 July, a lone subadult beluga whale was observed from 13:22 to 13:32, during low ebb tide. The whale was not observed within the Marine Terminal Redevelopment Footprint and its activity state was recorded as traveling and milling.

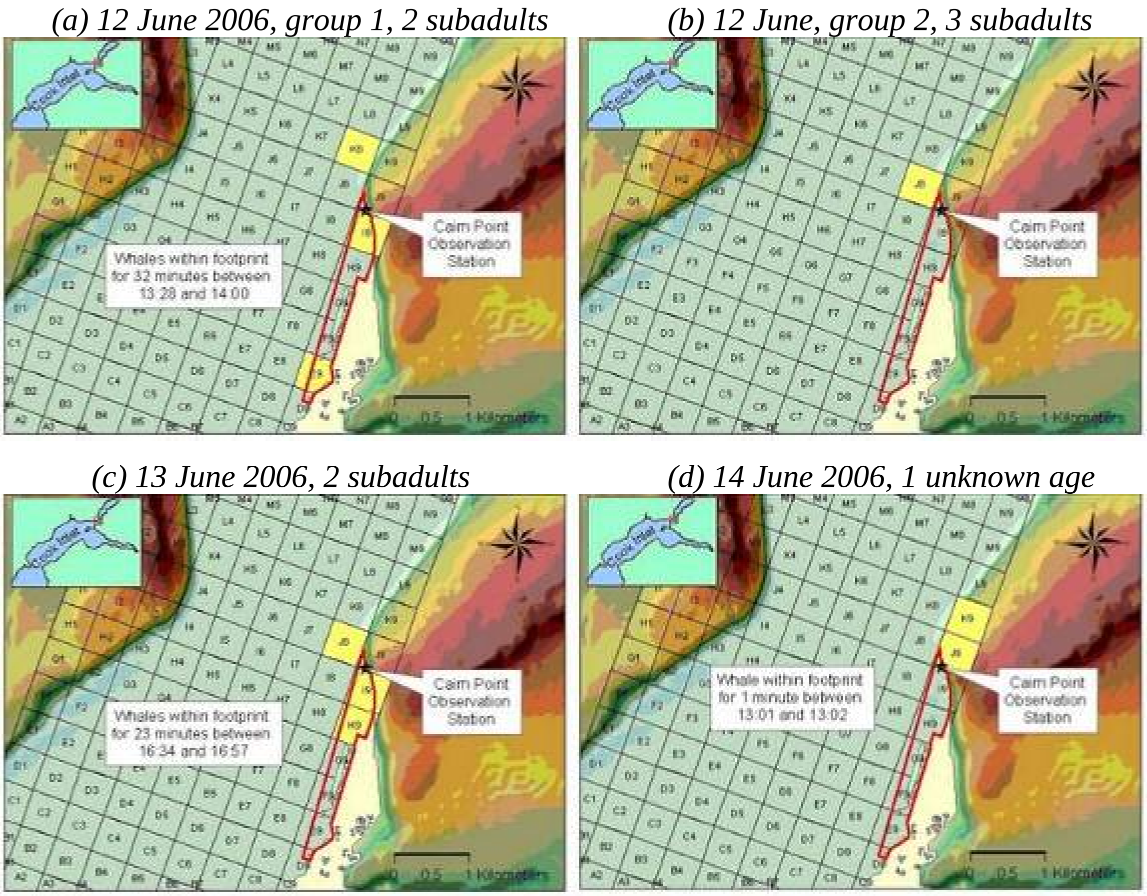


Figure 3.6. Locations of beluga whales observed during June 2006 are shown relative to the Marine Terminal Redevelopment Footprint (red outline) at the Port of Anchorage.

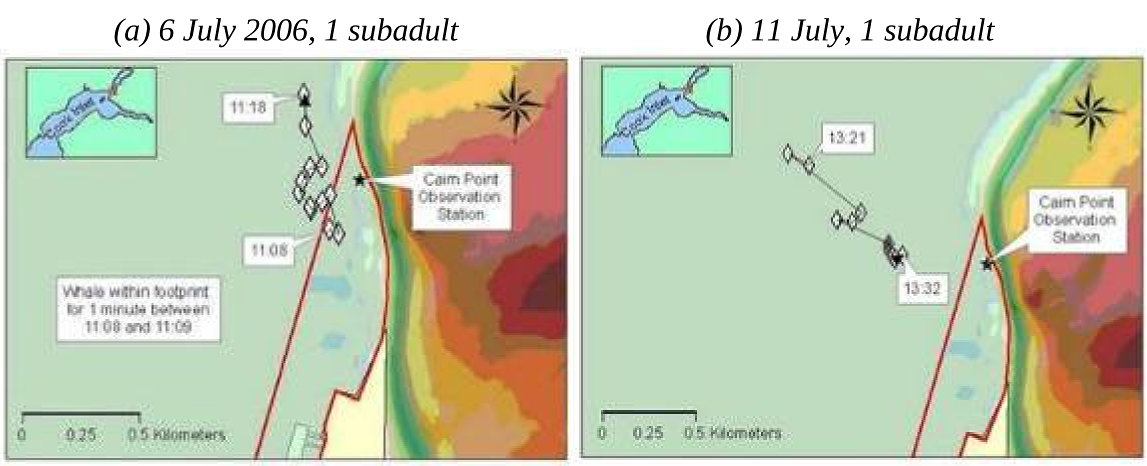


Figure 3.7. Locations of beluga whales tracked using a surveyor's theodolite (white diamonds) in July 2006 are shown relative to the Marine Terminal Redevelopment Footprint (red outline) at the Port of Anchorage. Black arrows represent the direction of travel.

August 2006

In August, beluga whale groups were sighted near the Port of Anchorage six times in or adjacent to the Marine Terminal Redevelopment Footprint (Figure 3.8)

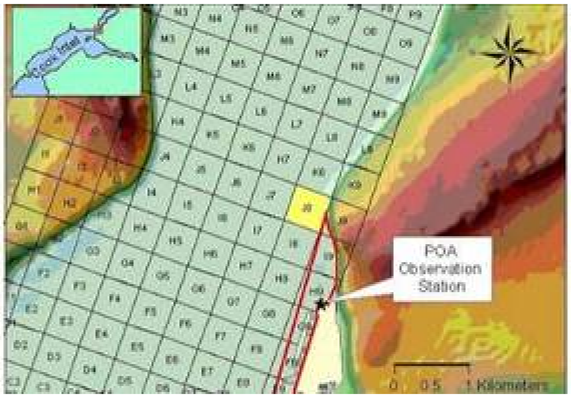
Two adult beluga whales were observed briefly on 23 August from 14:40 to 14:41, during low slack tide. They were diving and traveling less than a kilometer from Cairn Point and were spaced 1 – 3 body lengths apart.

A group of seven beluga whales (6 adults, 1 subadult) was observed on 28 August between 14:26 and 17:44, during low ebb and low slack tide. The whales generally traveled south (although no clear swimming direction was noted) and were observed within the Marine Terminal Redevelopment Footprint for 117 minutes between 15:03 and 17:44. They were spaced approximately 3 body lengths apart (range 1 – 7); their primary activity state was diving and their secondary activity state was feeding suspected.

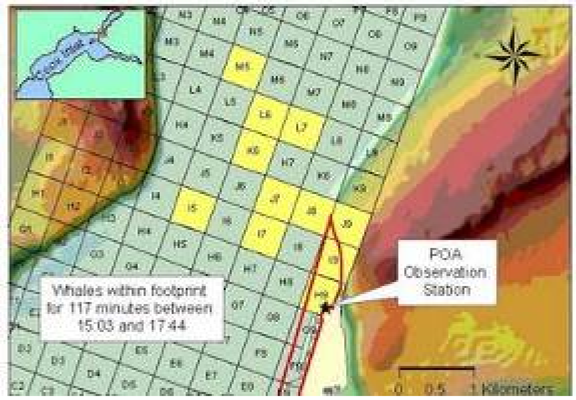
On 29 August 2006, a group of four whales (3 adults, 1 subadult) was observed within the Marine Terminal Redevelopment Footprint for 32 minutes from 15:48 – 16:20, during low ebb tide. On the same day, a second group of ten beluga whales (6 adults, 2 subadults, 2 calves) was observed also within the Marine Terminal Redevelopment Footprint for 49 minutes between 16:59 and 18:44. The whales traveled south from 16:50 to 17:24 (low slack tide), then north between 18:06 and 18:44 (low slack to low flood tide).

On 31 August, a group of three beluga whales (1 adult, 2 subadults) was observed within the Marine Terminal Redevelopment Footprint between 14:54 and 15:03, during high ebb tide. They were spaced 4 – 7 body lengths apart and were traveling south. On the same day, a second group of ten beluga whales (7 adults, 2 subadults 1 calf) was observed beginning at 18:33, during low slack tide. The whales were observed within the Marine Terminal Redevelopment Footprint for a total of 50 minutes between 18:33 and 19:45, excluding when they were not seen at all between 19:25 and 19:40. The whales were generally spaced 7 body lengths apart (range 1 – 12) and were traveling south. Activity states recorded included traveling, diving and feeding suspected.

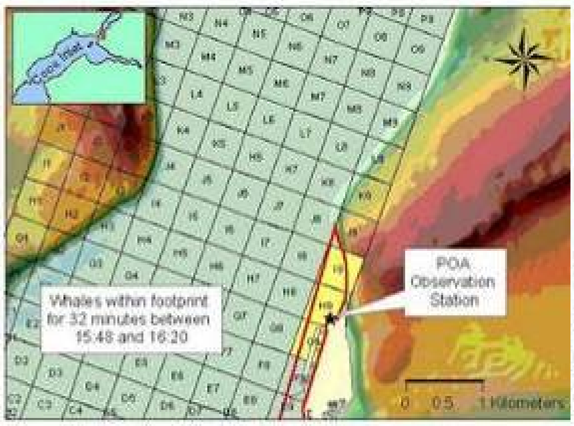
(a) 23 August 2006, 2 adults



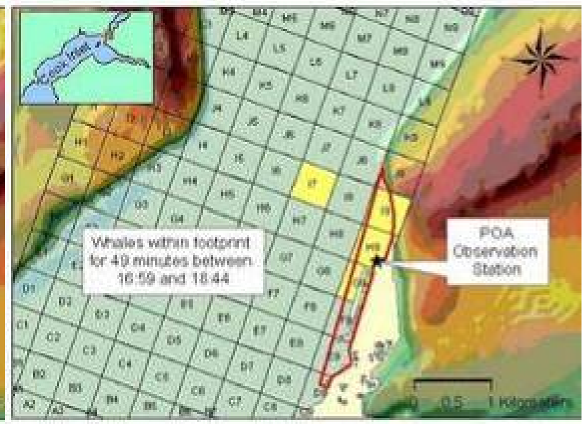
(b) 28 August 2006, 7 whales



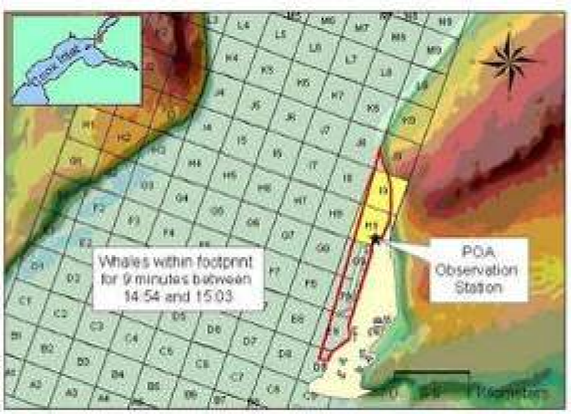
(c) 29 August 2006, 4 whales



(d) 29 August 2006, 10 whales



(e) 31 August 2006, 3 whales



(f) 31 August 2006, 10 whales

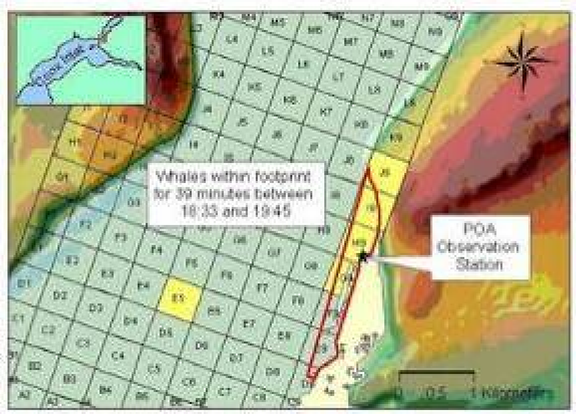


Figure 3.8. Locations of beluga whales observed during August 2006 are shown in relation to the Marine Terminal Redevelopment Footprint (red outline) at the Port of Anchorage.

September 2006

In September, beluga whale groups were sighted seven times near the Port of Anchorage. During five of these observations, whales were observed within the Marine Terminal Redevelopment Footprint (Figure 3.9)

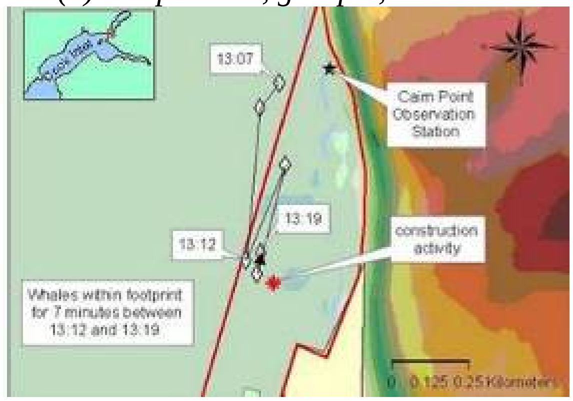
On 6 September a group of three beluga whales of unknown age were observed near the entrance of Knik Arm during low slack tide. A vessel observed the whales at 12:30 however, the land-based observer at Cairn Point did not observe them until 12:56. The whales were diving and were seen again briefly at 13:15.

A group of two adult beluga whales was observed on 7 September from 13:06 to 13:20, during low ebb tide. The whales were located within the Marine Terminal Redevelopment Footprint for 7 minutes between 13:12 and 13:19. The whales were spaced 4 – 7 body lengths apart and were traveling south until 13:16. At 13:16, as they neared the construction, they reversed direction and disappeared from view.

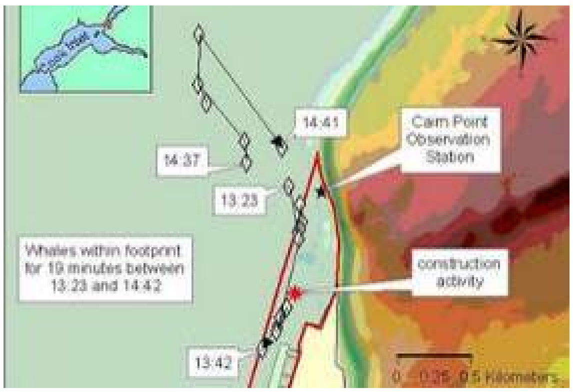
A second group of eight beluga whales (6 adults, 1 subadult, 1 calf) was observed on 7 September from 13:23 to 14:42, during low slack tide. They were located within the Marine Terminal Redevelopment Footprint for 19 minutes between 13:23 and 14:42. The whales were generally spaced 4 – 7 body lengths apart, although towards the end of the observation they were spaced only 1 – 3 body lengths apart. Their activity state was recorded as traveling, diving and feeding suspected. They were traveling south from 13:23 to 13:42; they disappeared from view from 13:42 to 14:37; at 14:37 they were observed traveling north and disappeared at 14:42. The observer used the surveyor's theodolite to mark the location of dumping activity at 12:49; that location (red asterisk) is shown relative to the whales in Figure 3.9 below. The observer noted that by 13:42 the construction activity was being conducted on land because the tide had gone out.

(a) 6 September, 3 whales

(b) 7 September, group 1, 2 whales

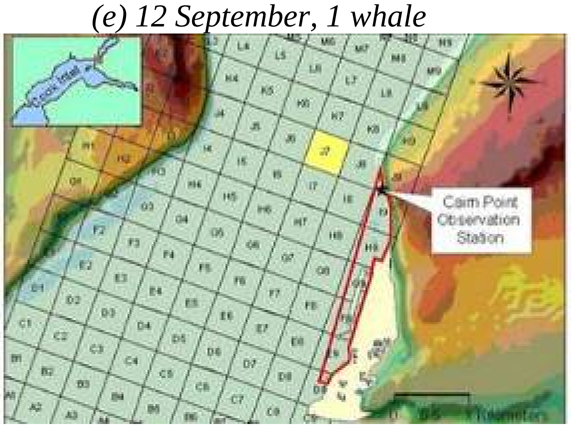


(c) 7 September, group 2, 8 whales

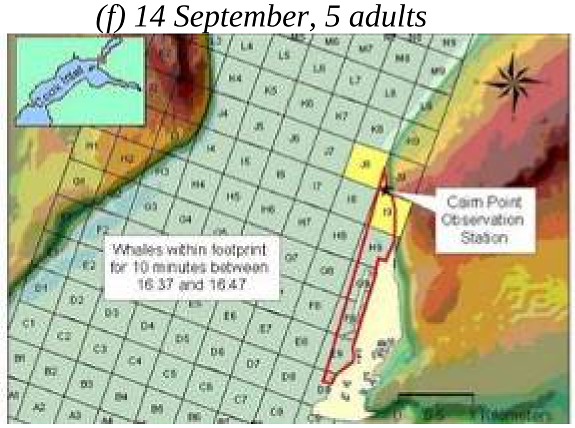


(d) 8 September, 6 whales

(e) 12 September, 1 whale



(f) 14 September, 5 adults



(g) 19 September, 1 adult

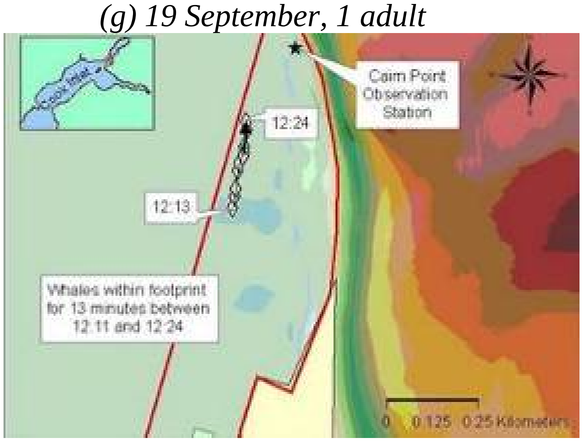


Figure 3.9. Locations of beluga whales (white diamonds) tracked using a surveyor's theodolite and mapped with grid cells (yellow squares) during September 2006 are shown relative to the Marine Terminal Redevelopment Footprint (red outline) at the Port of Anchorage. Black arrows represent direction of travel. Red asterisks show the location of construction activity.

A group of six beluga whales (2 adults, 3 subadults, 1 calf) was observed on 8 September between 12:41 and 14:15, during low ebb tide. The whales were located within the Marine Terminal Redevelopment Footprint for a total of 27 minutes between 12:41 and 13:41. They were spaced 1 – 3 body lengths apart and their activity states were recorded as diving, traveling, and feeding suspected. They were observed traveling north from 12:41 to 13:12; they disappeared from view from 13:12 to 13:31; and they were observed traveling south from 13:31 to 14:15. Although the general direction of travel between 12:41 and 13:12 was north, the whales reversed direction several times, displaying behavior that suggested foraging. The observer used the surveyor's theodolite to mark the location of dumping activity at 12:43; that location (red asterisk) is shown relative to the whales in Figure 3.8 below. The observer noted that the construction activity was occurring on land because the tide was out.

A lone subadult beluga whale was observed briefly on 12 September at 17:20, during low slack tide. The whale was traveling north and was not observed within the Marine Terminal Redevelopment Footprint.

A group of five adult beluga whales was observed within the Marine Terminal Redevelopment Footprint on 14 September during low ebb tide. The whales initially appeared near Cairn Point and swam south toward the end of a dike at the Port of Anchorage where construction activities were being conducted (Figure 3.8). The whales remained within the Marine Terminal Redevelopment Footprint for 10 minutes, from 16:37 to 16:47. At 16:47 a marked behavior change was noted as the whales began swimming rapidly north, away from the construction activity.

A lone adult beluga whale was observed on 19 September from 12:11 to 12:28, during low slack tide. It was located within the Marine Terminal Redevelopment Footprint for a total of 13 minutes between 12:11 and 12:24. The whale was traveling and diving and reversed its direction of travel twice within the observation period. When it disappeared from view at 12:28 it was headed north.

October 2006

In October, lone adult beluga whales were sighted on just two occasions, approximately 2-3 km to the northwest of the Marine Terminal Redevelopment Footprint (Figure 3.10). The two whale sightings occurred on two consecutive days, in similar locations, around the low tide.

A lone adult beluga whale was observed briefly outside of the Marine Terminal Redevelopment Footprint on 19 October at 13:24, during low slack tide. The whale surfaced twice, approximately one minute apart. Its activity state was recorded as diving.

On 20 October a lone adult beluga whale was observed briefly outside of the Marine Terminal Redevelopment Footprint at 12:30, during low ebb tide. The whale was observed at the beginning of the observer's shift and may have been in the area before 12:30. Its activity state was recorded as diving.

(a) 19 October 2006, 1 adult *(b) 20 October 2006, 1 adult*

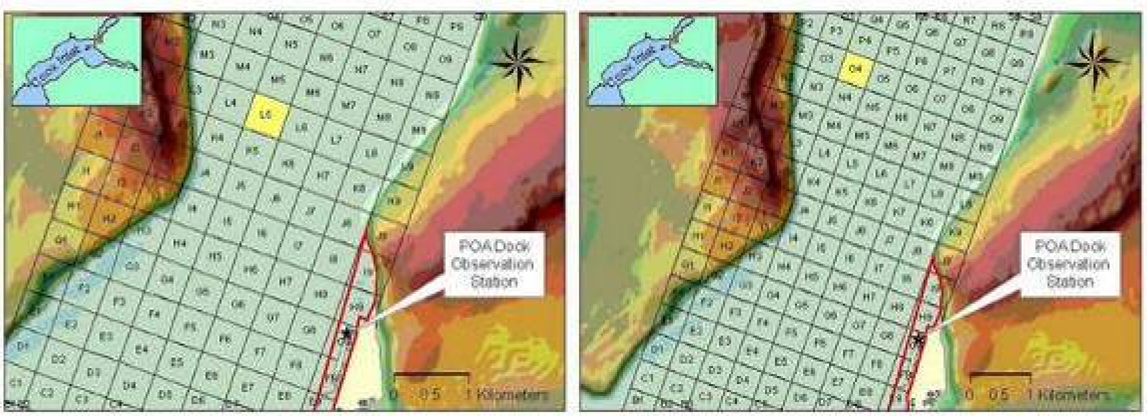


Figure 3.10. Locations of beluga whales observed during 20 October 2006 are shown relative to the Marine Terminal Redevelopment Footprint (red outline) at the Port of Anchorage.

November 2006

No whales were observed during November 2006. Observations were discontinued with the end of construction and increasing sea ice concentration.

Spatial distribution by tidal stage

The distribution of beluga whale sightings by tidal stage is presented in Figure 3.11 below. As detailed in Chapter 2 of this report, beluga whale sighting rates per hour of monitoring effort were much higher during low ebb and low slack tides than during other tidal stages. Whales were observed within the Marine Terminal Redevelopment Footprint during all tidal stages except high slack and high flood; however, these were the stages with the least amount of monitoring effort.

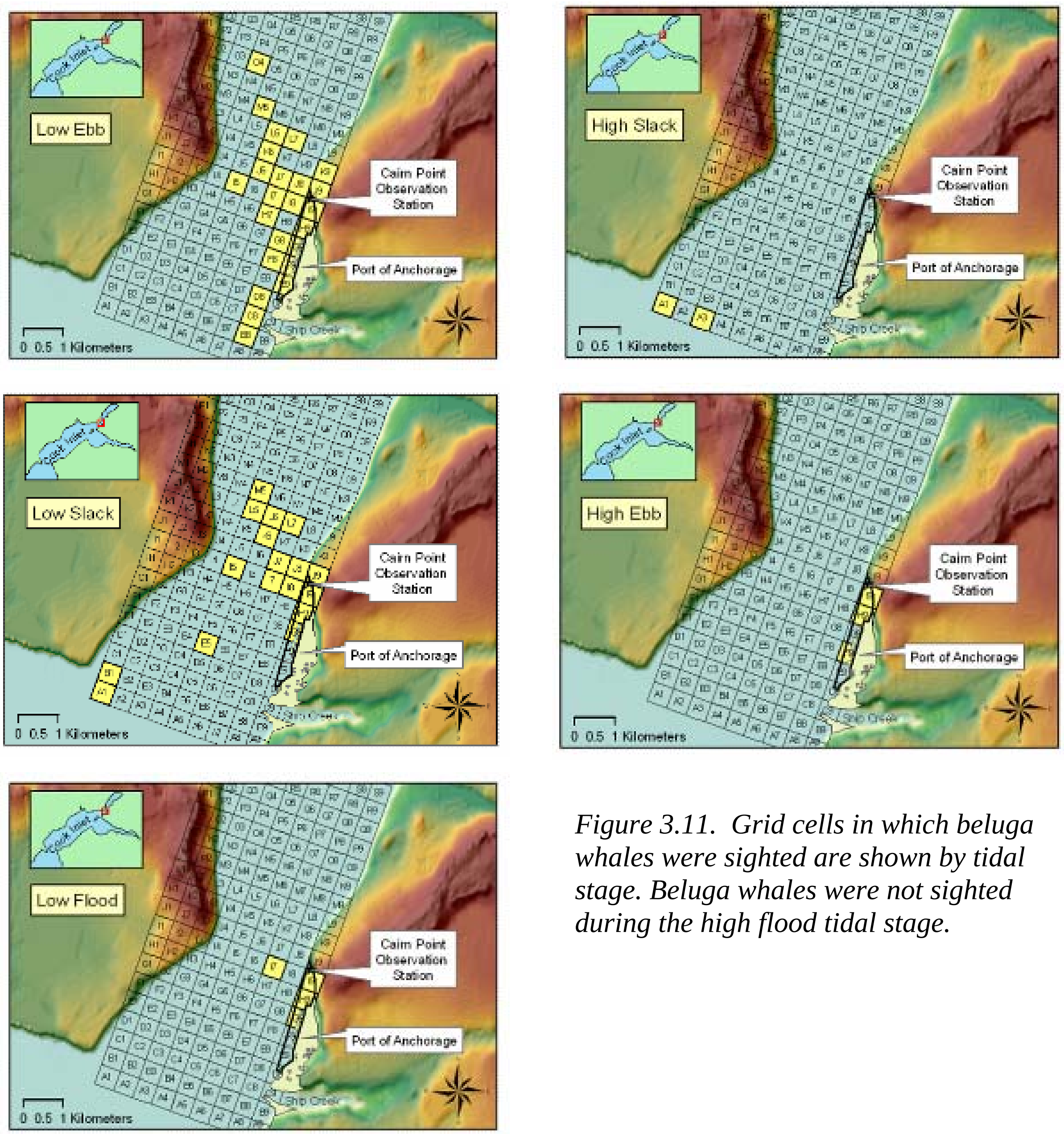


Figure 3.11. Grid cells in which beluga whales were sighted are shown by tidal stage. Beluga whales were not sighted during the high flood tidal stage.

Discussion

As detailed in Chapter 2, beluga whale presence in Knik Arm peaked in late August to mid-September, consistent with the seasonal distribution patterns previously reported for this population (Seaman *et al*. 1985, Moore *et al.* 2000, Funk *et al.* 2005, Hobbs *et al.* 2005, Rugh *et al.* 2005). A high proportion of the beluga whales observed (79%) entered the Marine Terminal Redevelopment Footprint at the Port of Anchorage and the whales continued to frequent the area near the footprint during the time that construction of a dike was occurring. Beluga whale group sizes tended to be highest near shore and calves were observed in the area during the construction activity. Moore *et al.* (2000) postulated that Cook Inlet beluga whales have become habituated to human activity. Eighty percent of beluga whale groups were observed within 0.5 km of the footprint, which is within the estimated180 dB re 1 µPa SPL sound radius based on measurements at Port MacKenzie (Blackwell 2005).

One explanation for the repeated observation of beluga whales within the Marine Terminal Redevelopment Footprint south of Cairn Point is the presence of an eddy during ebb tide that may serve to concentrate prey (Ebersole and Raad 2004). The hydrography described by Ebersole and Raad (2004) also explains why belugas were observed swimming north near Cairn Point several times during ebb tide, a behavior that seems counter-intuitive given that Funk *et al.* (2005) reported beluga whales in Knik Arm generally swim south with the ebbing tide. The eddy forces a northerly flow of water near shore past Cairn Point during ebb tide so beluga whales may have followed this northward flow in pursuit of prey.

Although Cook Inlet beluga whales apparently prefer the near shore environment (Moore *et al.* 2000), the effect of vantage cannot be discounted. The probability of observing an animal is directly related to its distance from the observer. Because the observers in this study were stationed relatively close to the Marine Terminal Redevelopment Footprint, it follows that the greatest number of whale observations would be recorded in close proximity to the footprint. Funk *et al.* (2005) calculated a detection function for beluga whales in Knik Arm and found that although detection probability was equal to 1.0 at a distance of 1 km, at a distance of 2 km it decreased to

0.85, and at a distance of 3 km it dropped to 0.4. The fact that 80% of beluga whale group sightings occurred within 0.5 km^2 of the Marine Terminal Redevelopment Footprint may have been influenced by the proximity of our observers to the footprint. However, 20% of beluga whale groups were first detected at a distance >3 km, demonstrating that observers did have the ability to detect whales at greater distances. The detection probability should serve as a reminder that our observations are minimum estimates of whale presence in the area and it is likely that more beluga whales were present further offshore that were undetected.

Elevation also directly affects an observer's ability to detect whales at a distance. Observers stationed at the Port of Anchorage, a lower vantage point than Cairn Point, would have been more likely to detect whales in close proximity to the Port than at a distance. Elevation is directly related to the accuracy of theodolite data as well (Würsig *et al.* 1991). The error associated with theodolite data collected at the Port of Anchorage would have been greater than that associated with the data collected at Cairn Point because of the difference in elevation. All theodolite data reported here were collected at Cairn Point.

Our examination of beluga whale spatial distribution relative to the Port of Anchorage expansion indicates that whales use nearshore areas proximate to, and including, the Marine Terminal Redevelopment Footprint, but not to the same extent as some other areas in Knik Arm (Funk *et al*. 2005). Beluga whales observed near the Port of Anchorage did not show signs of avoiding vessels or construction activities.

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Chapter 4: Beluga Whale Grouping, Behavior, and Movements near the Port of Anchorage

Draft Final Report

by

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Introduction

Understanding the behavioral ecology of beluga whales can help inform management and mitigation of potential impacts of human activities in the near shore environment, providing insight for example into the relative importance of various habitat areas (NMFS 2005). In addition to the temporal and spatial patterns of beluga whale sightings in the Port of Anchorage area (Chapters 2 and 3 of this report), we examined how whales used the area. To fulfill this objective, beluga group size and age class composition, behavior and movement patterns were documented. This chapter focuses on these details of how beluga whales were grouped and behaved as they moved through the area near the Port of Anchorage, including areas within the Marine Terminal Redevelopment Footprint.

Social grouping

Beluga whales are highly social, found in groups ranging from a few to hundreds of individuals (Leatherwood and Reeves 1983). Lone belugas are also sometimes observed, often adult whales diving in deeper water (Funk *et al.* 2005). Although calves apparently remain with their mothers until adulthood, adults may segregate at least during some parts of the year by sex (Norris 1994), with males and females using different habitats during part of the summer (Suydam *et al*. 2003, Richard *et al*. 2001) and feeding on different prey (Lowry *et al*. 1985). This chapter investigates social group size and age class composition for whale groups sighted near the Port of Anchorage.

Reproduction

As in other locations throughout the arctic and subarctic, beluga whales in Cook Inlet exhibit seasonal reproduction. Female age at first parturition typically ranges from 5 to 8 years and estimated gestation length is 11-16 months for beluga whales in Alaska (Burns and Seaman 1985, Heide-Jørgensen and Teilmann 1994). The calving season in Cook Inlet has been estimated to last from May to July (Calkins 1983). At birth, calves are roughly 10-20% of adult female body mass, but grow rapidly during the first weeks of life as they nurse on energy-rich milk containing up to 27% fat by volume (Martin 1996). Female beluga whales nurse their calves for about two years, and the median estimated inter-birth interval is 3 years (Reeves *et al*. 2002). However, inter-birth intervals of 2 years are also common (Sergeant 1973).

Harvested beluga whales with near-term fetuses in May and neonates observed from May-July in the Susitna River Delta indicate the area is used for calving and nursing newborn calves (Huntington 2000). Such shallow estuaries, often used by beluga whales during the summer, may act as thermal refuges, reducing heat energy loss by calves (Connor 2000). Following the summer, beluga whales move into Knik Arm in greater numbers (Funk *et al*. 2005), which may act as a nursery area for groups with maturing calves (NMFS 2005). This chapter investigates the use of the area near the Port of Anchorage, including the Marine Terminal Redevelopment Footprint by mothers with maturing calves.

Behavioral ecology

Beluga whales are commonly found in shallow estuaries in summer months, but are also found in deep submarine canyons, diving to depths of > 2,600 ft (800 m, Reeves *et al*. 2002). Like other deep-diving marine mammals, the beluga whale has a relatively high blood volume (Elsner 1999).

The diet of beluga whales varies with season and location and includes fish, crustaceans, marine worms and cephalopods (Kleinenberg *et al*. 1964, Burns and Seaman 1985). Beluga whales feed throughout the water column, and on the sea floor, often congregating at river mouths and estuaries during seasonal fish runs (Kingsley *et al*. 2001, Martin 1996). In captivity, beluga whales may consume a daily average of 2.5-3% of their body weight in fish (NMFS 2000).

Although the area immediately adjacent to the Port of Anchorage does not appear to be a concentration area for beluga whale foraging activity (*i.e.*, searching for, chasing, capturing, and ingesting prey), whales have been noted to forage and feed near shore and in the mid-channel areas of Knik Arm near the port (Prevel Ramos *et al*. 2006, Funk *et al*. 2005). During the fall, some whales travel into and out of this area on the tides, where they rest or mill around low tide (Funk *et al*. 2005).

Chapter 4 research objectives

The purpose of this chapter is to examine how beluga whales used the habitat near the Port of Anchorage, including the Marine Terminal Redevelopment Footprint, during the ice free months of 2006. Specific objectives are:

1) To investigate social group size and age class composition, including use of the area by mothers with maturing calves
2) To examine beluga whale behavior including feeding/foraging activity, and
3) To assess beluga whale movement patterns, such as speed, distance traveled.

Methods

Temporal and spatial analysis of data

Behavioral data were compared by month and tidal state (as detailed in Chapter 2). In some cases, tidal stage was simply divided into high versus low (*i.e.* times within three hours of the low tide versus those within three hours of the high tide). Whale behavioral data were also examined with respect to the location of whales inside versus outside the Marine Terminal Redevelopment Footprint (Chapter 3 details the methods used to assess the location and spatial distribution of beluga whale sightings).

Group size and age class distribution

Group size and age class distribution was examined based on minimum best counts of whales by age class from each beluga whale group sighting (Funk *et al*. 2005, Prevel Ramos *et al*. 2006). Beluga whales are born dark gray and gradually lighten as they mature, becoming white as adults (Martin 1996). Age class was assigned as adult, subadult, calf, or unknown based on the size and coloration of individuals (Figure 4.1).

(a) adult *(b) subadult* *(c) calf*

Figure 4.1. These sample photograph show typical differences in coloration by age class (a. adult, b. subadult, c. calf, photographs taken on 31 July 2005, 15 September 2005, and 7 Aug 2006 by T.M. Markowitz under General Authorization for Scientific Research from NOAA Fisheries, Letter of Confirmation Number 481-1795).

Group behavior

Groups were defined by spatial and temporal proximity using a 50 m chain rule (Mann 2000). In order to examine the dispersion or spread of beluga whales within groups, the distance between individuals was noted during group sightings, using an adult whale body length (approximately 4 m or 13 ft) as a reference. Mode (predominant) inter-individual distance was recorded in the following categories: < 1 adult whale body length, 1-3 body lengths, 4-7 body lengths, 8-12 body lengths, or > 12 body lengths.

Primary and secondary behavioral states (Shane 1990) recorded during focal beluga whale group observations (Mann 2000) were defined as follows:

Travel – Movement in a linear or near linear direction, transiting through an area

Mill – Non-linear, weaving movement within an area

Dive – Movement directed downward through the water column

Feed – Chasing or apparently chasing fish, as evidenced by bursts of speed and/or focused diving in a particular location.

Group and individual movement patterns

Analyses of beluga whale group movement patterns based on theodolite tracks (*n = 7*) were conducted using the track line analysis module of Pythagoras (Gailey and Ortega-Ortiz 2002). Leg speed was calculated by dividing the distance between two consecutive fixes by the time between them. Percent linearity was calculated by dividing the distance between the initial and end points of a track line (*i.e.* distance made good) by the total sum of distances between consecutive points along the track (*i.e.* total distance traveled). Re-orientation rate, a measure of the magnitude of course changes along each track line, was calculated by summing all course changes (in degrees) along the track line, and dividing that value by the total duration (minutes) of the track.

Statistical analyses

Results were tabulated, summary statistics (*e.g.* means, standard deviations) calculated, and data figures produced in Microsoft® Excel. Non-parametric statistical tests were used to compare values in SPSS, with significance reported at the $P < 0.05$ level.

Results

Use of the Marine Terminal Redevelopment Footprint and adjacent areas

Behavioral data were collected from 25 beluga whale group sightings on 21 of 95 total days of observation. During sixteen of these sightings (64%) whales were observed to enter the Marine Terminal Redevelopment Footprint. Whales were monitored for a total of 14.2 hours near the Port of Anchorage, and were observed within the Marine Terminal Redevelopment Footprint for a total of 7.9 hours (56%). By month, the average duration groups remained in the footprint ranged from 0-41 minutes representing 0-74% of the time they were monitored in the area (Figure 4.2). Lone whales and groups ranging in size from two to ten whales used the area within the Marine Terminal Redevelopment Footprint.

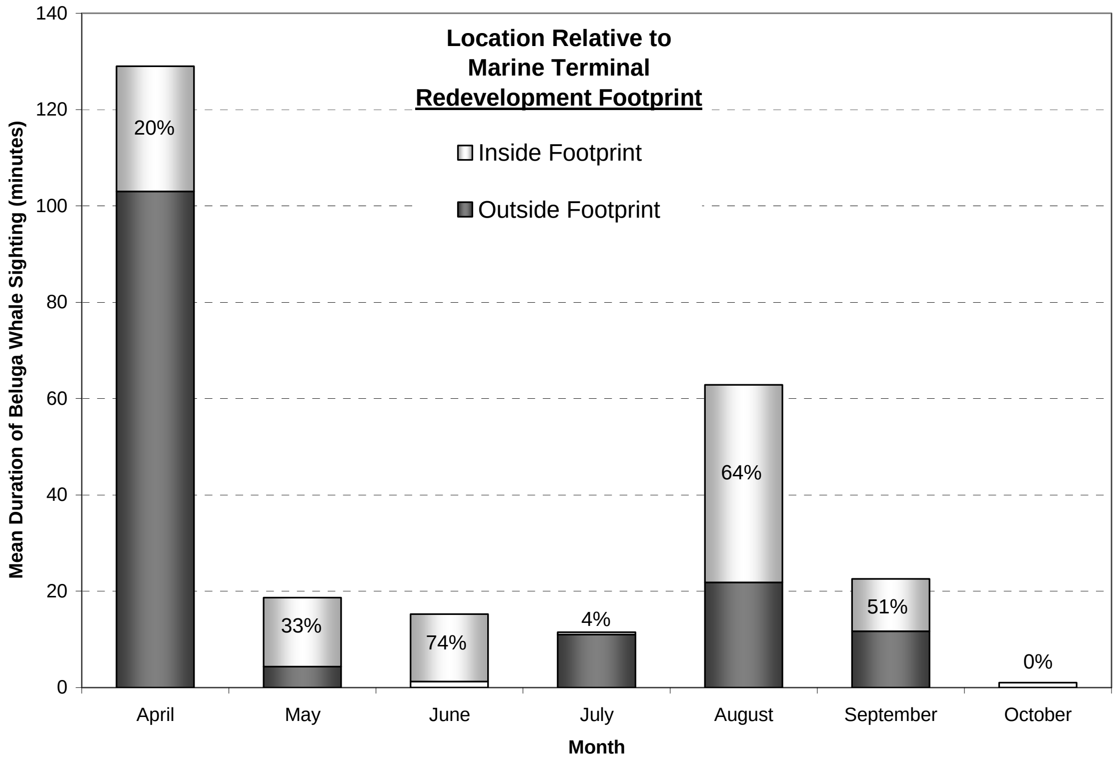

Figure 4.2. The mean duration of whale sightings near the Port of Anchorage is shown per month, divided into time whales were observed inside versus outside the Marine Terminal Redevelopment Footprint. Data labels show the mean percent time groups monitored near the Port of Anchorage were observed inside the footprint.

Group size, age class composition, and dispersion

Generally, the size of beluga whale groups observed near the Port of Anchorage was small. Mean group size was three whales, comprised of two adult whales and one subadult whale on average. Ten of the twenty five beluga sightings were of lone whales (four adult, four subadult, and two of unknown age). In April, July, and October, only lone whales were observed. In other months, mean group sizes ranged from two to six whales, with a maximum group size of 10 whales noted on two days in August (Figure 4.3).

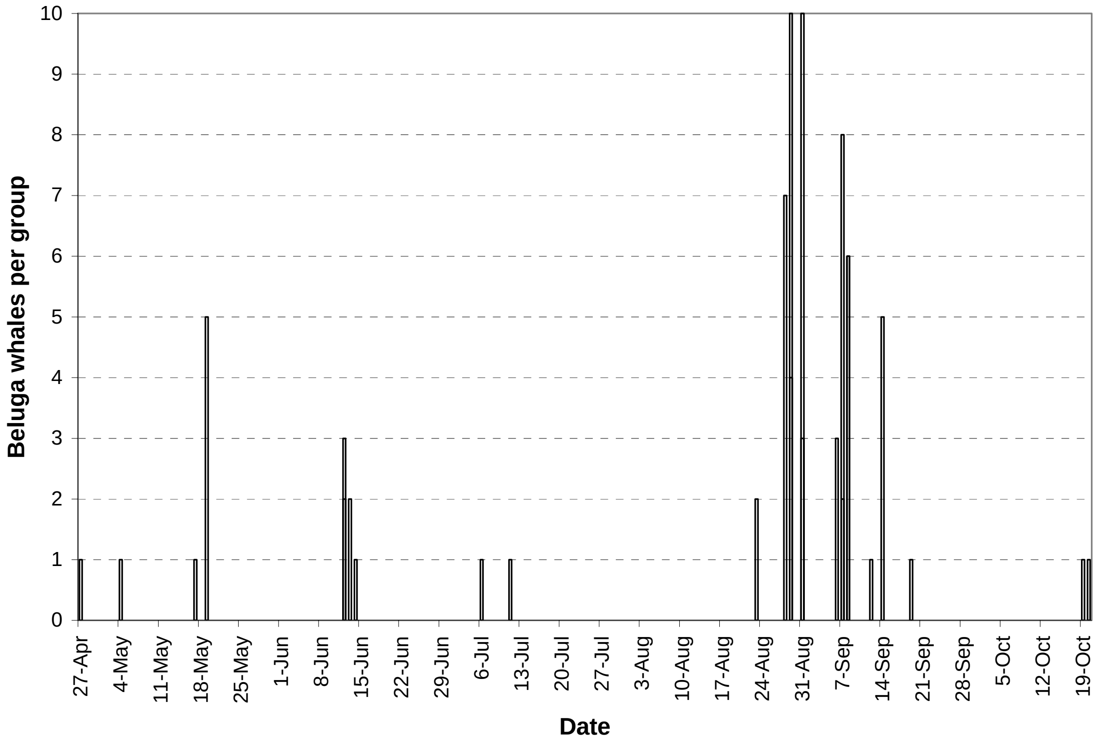

Figure 4.3. The number of beluga whales counted per group sighted near the Port of Anchorage is shown by date (n = 25 whale group sightings).

Calves were observed in groups sighted near the port of Anchorage on just five of 95 total days of observation effort, all of them during the fall (Figure 4.4). Mean group size was significantly larger (Mann-Whitney, $U = 2.0$, $P = 0.004$) when calves were present (mean = 8, sd = 2.0) than when calves were not present (mean = 3 whales, sd = 1.6). Just one calf was observed in each of four groups and two calves were observed in one group.

All five groups with calves (nursery groups) were observed to enter the Marine Terminal Redevelopment Footprint, and all five were sighted at either low ebb or low slack tide. These nursery groups were observed for periods ranging from 19 to 49 minutes (mean = 32 minutes) in the Marine Terminal Redevelopment Footprint, representing 47-79% of the time they were observed (mean = 63%). Eight of 10 small groups without calves were observed at low tide, and 8 of 10 lone whales at low tide. Half of the lone whales sighted and half of the groups without calves entered the Marine Terminal Redevelopment Footprint.

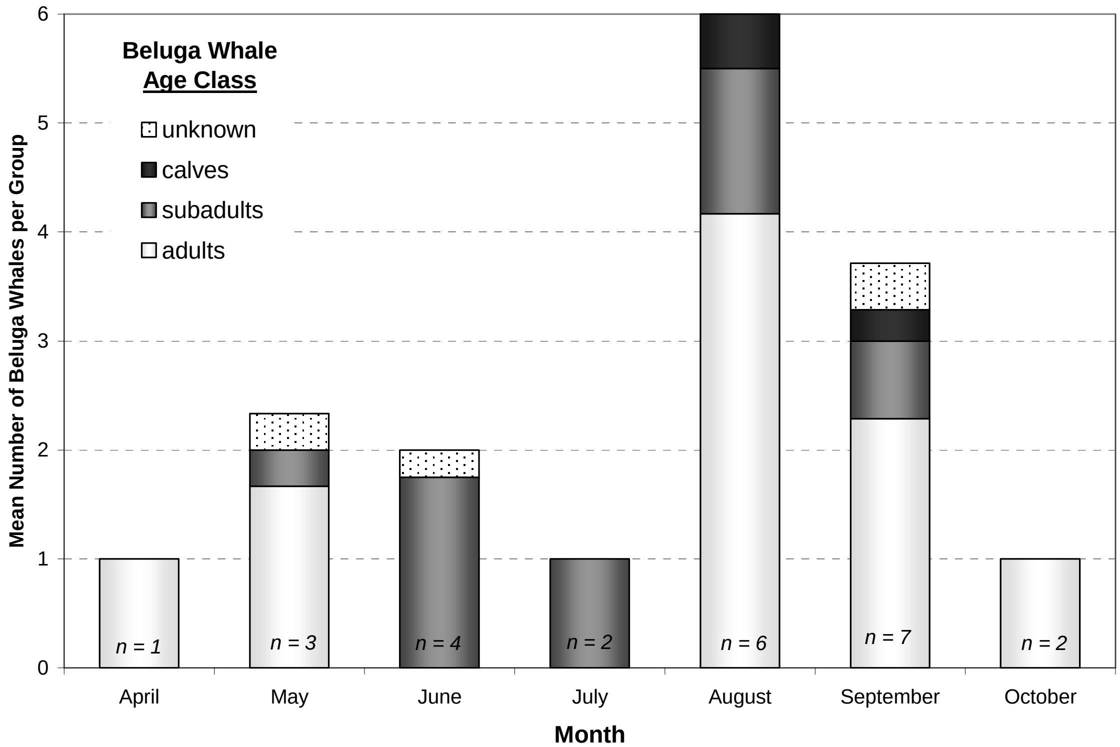

Figure 4.4. Age class composition of beluga whale groups sighted near the Port of Anchorage during April-October 2007 is shown, with the mean number of adults, subadults, calves, and whales of unknown age class shown by month (n = number of group sightings per month).

Group behavior

Both groups with and without calves observed near the Port of Anchorage were often tightly grouped. The spacing between individuals in nursery groups was no less than that observed in other groups (Figure 4.5).

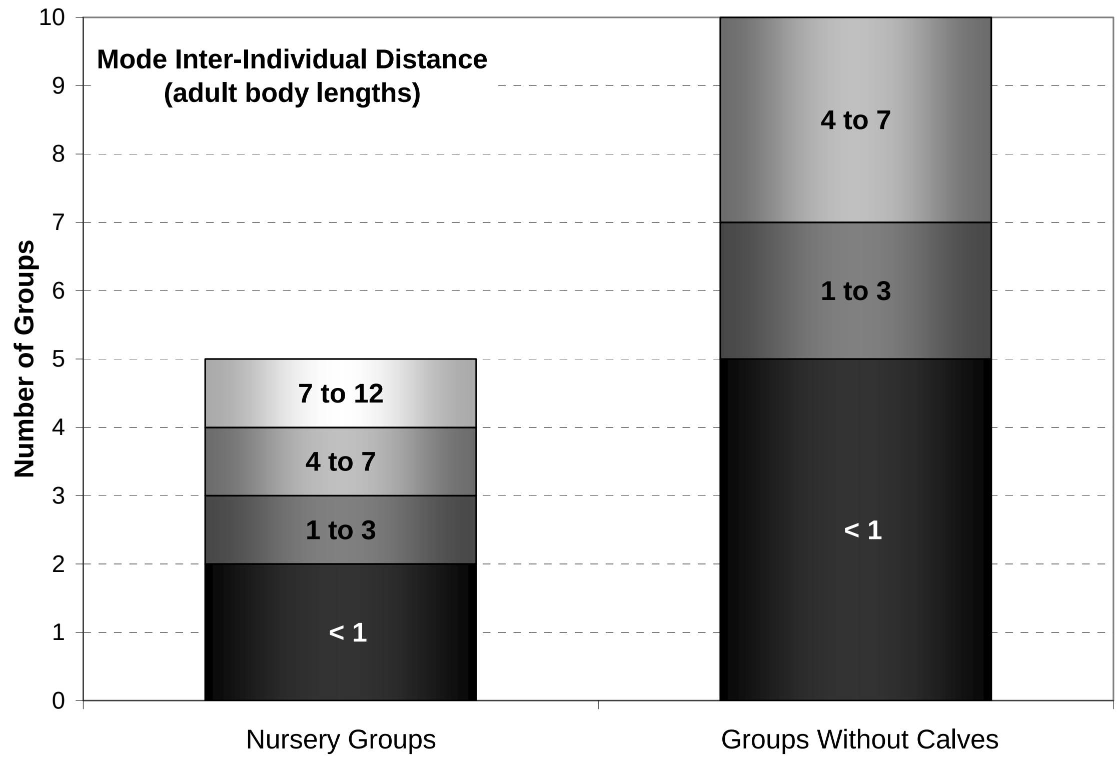

Figure 4.5. Group dispersion (mode inter-individual distance in adult body lengths) is compared between groups with and without calves.

Feeding activity (suspected or confirmed) and diving which could indicate foraging were commonly noted during observations of beluga whales near the Port of Anchorage (Table 4.1). Whales were also observed traveling through the area during most months (Figure 4.6).

Table 4.1. Percent of beluga whale sightings during which behavior was observed (Percentages may sum to > 100% when groups were engaged in multiple activities).

State	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Overall**
Traveling	0	33	75	100	50	57	0	52
Diving	100	33	25	0	83	71	100	60
Milling	0	0	0	50	17	14	0	12
Feeding	100	33	50	0	50	29	0	36
n sightings	*1*	*3*	*4*	*2*	*6*	*7*	*2*	*25*

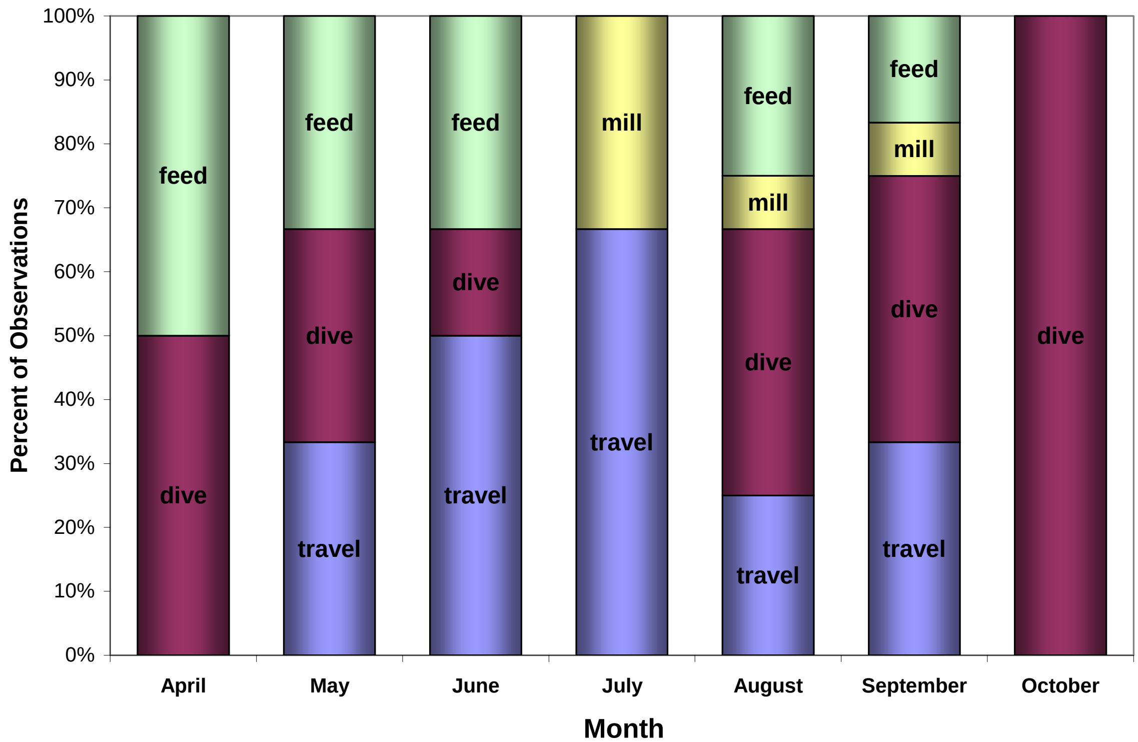

Figure 4.6. The mean proportion of behavioral states noted during beluga whale group observations near the Port of Anchorage is compared by month for April-October 2007.

Whale behavior was similar between high and low portions of the tidal cycle, with traveling noted 30-40%, diving noted 35-40%, and feeding noted 20-23% of the time (Figure 4.7). As noted in Chapter 2, beluga whales were most commonly observed near the Port of Anchorage around the low tide (21 of 25 group sightings).

Feeding activity was more commonly noted during observations of nursery groups than during observations of lone whales and groups without calves (Figure 4.8). Traveling and diving were less commonly noted in observations of nursery groups than during observations of lone whales and groups without calves (Figure 4.8).

Feeding was more commonly noted inside the Marine Terminal Redevelopment Footprint (nine of 16 groups, 28% of behaviors noted) than outside the footprint (no groups, Figure 4.9).

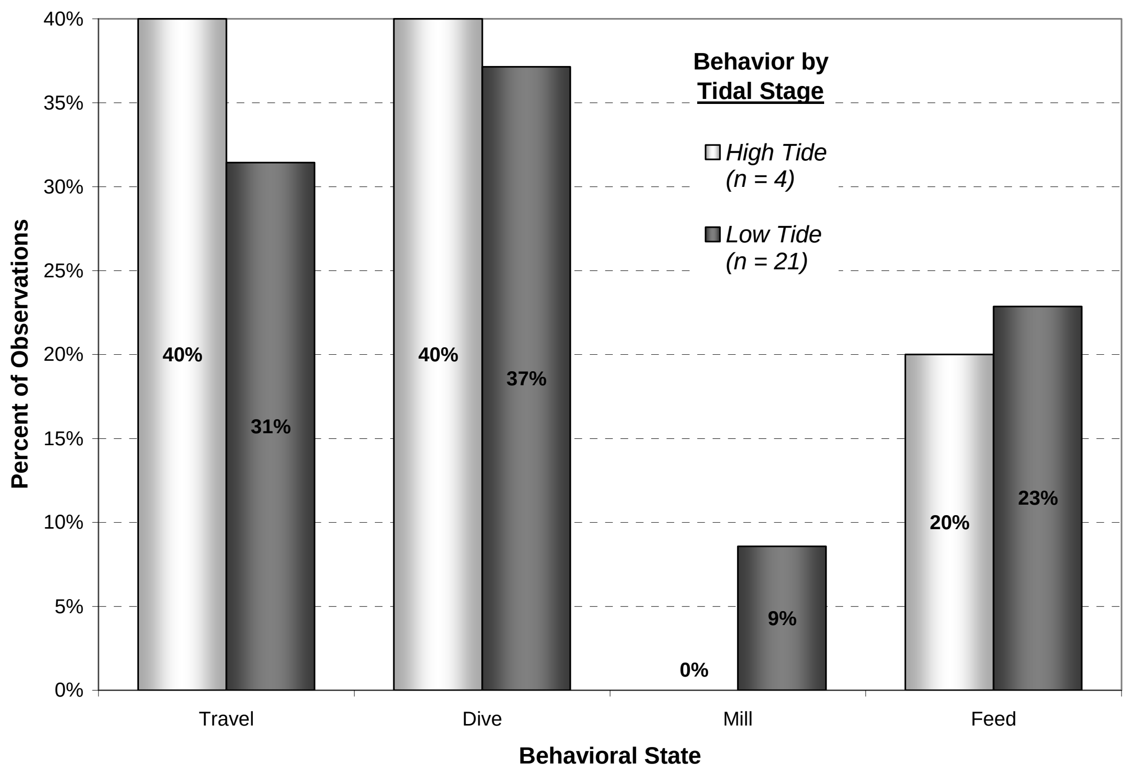

Figure 4.7. Beluga whale behavioral state is compared by tidal stage.

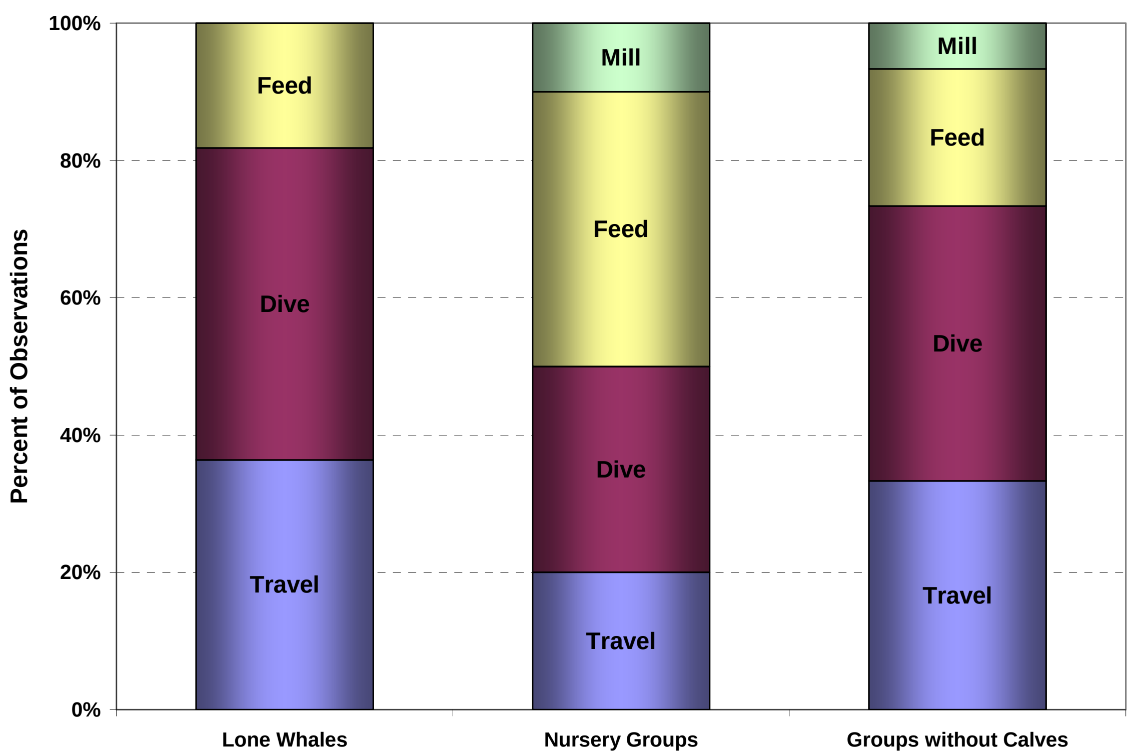

Figure 4.8. Activity budgets are compared between lone whales, nursery groups, and groups without calves.

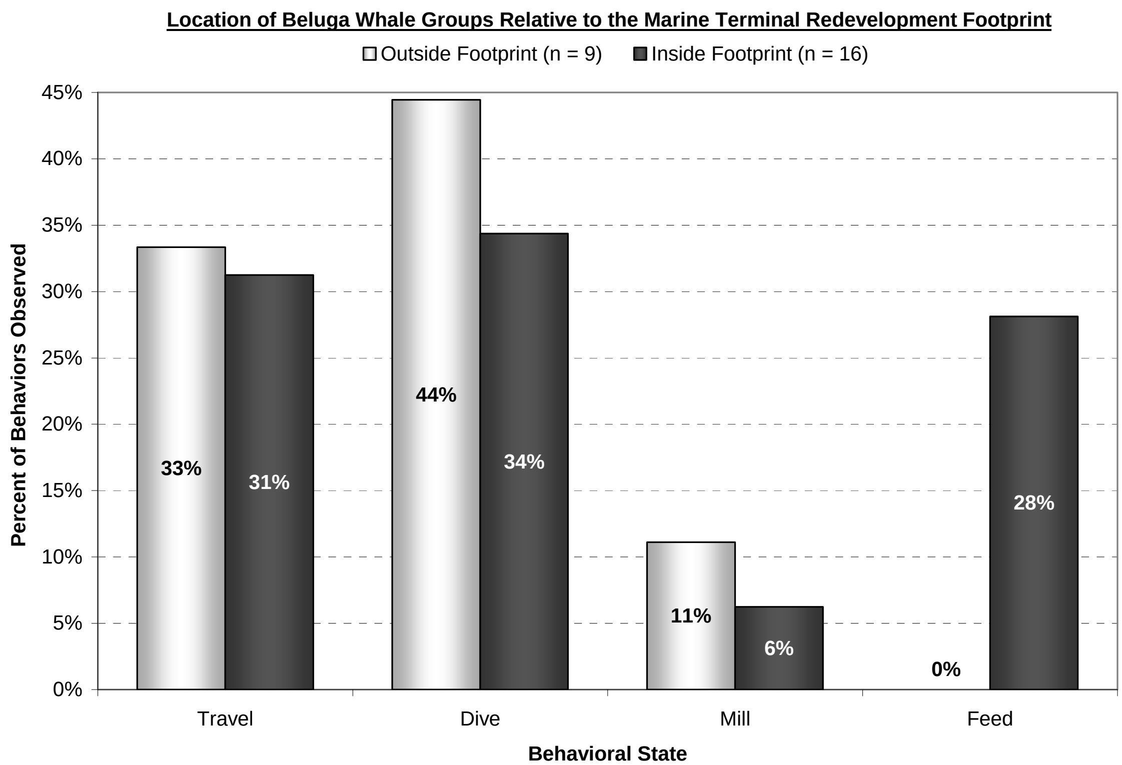

Figure 4.9. Behavioral states of beluga whales sighted near the Port of Anchorage are compared for whale groups observed outside versus inside the Marine Terminal Redevelopment Footprint (values shown represent the percent of behaviors noted).

Movement patterns

Table 4.2 shows summary statistics regarding the movement patterns of beluga whale groups tracked with a theodolite near the Port of Anchorage. Whales were tracked for time periods ranging from 11- 89 minutes (mean = 33 minutes), with total track line distances ranging from 0.4 to 6.1 km (mean = 2.3 km). The net distance whales were tracked by theodolite (*i.e.* "distance made good") ranged from 224 m to 2.7 km.

Mean estimated horizontal swimming speed of whales tracked was 5.8 km/hr, with a range of 1.8 to 10.7 km/hr. Swimming speeds ranged from 3.3 to 5.9 km/hr for lone whales, 5.0 to 8.3 km/hr for nursery groups, and 1.8 to 10.7 km/hr for groups without calves. The slowest leg speed (1.8 km/hr) was recorded for a group of three whales observed diving near the entrance to Knik Arm on 6 September; however, as only two location fixes were obtained of this group and as these fixes were nearly twenty minutes apart, this is likely an underestimate of the actual horizontal swimming speed of the whales. Also as these whales were diving, their swimming speeds including the vertical dimension were likely much greater. The next slowest mean leg speed (3.3 km/hr, Table 4.2) was recorded for a lone adult whale tracked in the Marine Terminal Redevelopment Footprint on 19 September that was also noted to be diving. The fastest mean leg speed (10.7 km/hr) was exhibited by a group of two adult beluga whales that traveled south through the Marine Terminal Redevelopment Footprint toward the construction then turned and headed back to the north on 7 September (Table 4.2, see also Chapter 3, Figure 3.9).

The most linear travel (74%) was documented for a group tracked outside the Marine Terminal Redevelopment Footprint on 11 July (Table 4.2). Groups tracked inside the Marine Terminal Redevelopment Footprint swam in a relatively non-linear manner (mean = 43% linearity) at a mean speed of 6.5 km/hr.

Table 4.2. Movement parameters calculated in Pythagoras are shown for all days during which whales were tracked with a theodolite.

Variable	**6-Jul**	**11-Jul**	**6-Sep**	**7-Sep**	**7-Sep**	**8-Sep**	**19-Sep**	**Mean**
Group #	1	1	1	1	2	1	1	
Total Time (min)	11	11	20	12	78	89	11	**33**
Total Distance Traveled (m)	846	1,086	583	1,366	5,544	6,139	362	**2,275**
Distance Made Good (m)	480	800	583	563	271	2,773	224	**814**
Mean Time Btw Fixes (min)	0.9	0.8	19.5	2.4	2.0	2.3	1.8	**4**
Mean Leg Speed (km/hr)	5.9	5.4	1.8	10.7	8.3	5.0	3.3	**5.8**
Mean Inter-fix Distance (m)	65	78	583	273	230	157	52	**205**
Percent Linearity	57%	74%		41%	5%	45%	62%	**47%**
Re-orientation Rate	65	67		46	22	48	33	**47**

Discussion

Use of the Marine Terminal Redevelopment Footprint and adjacent areas

Beluga whales were observed to use areas near the Port of Anchorage, including the Marine Terminal Redevelopment Footprint, at a relatively low sighting rate compared with what was previously documented for areas further to the north. During the fall of both 2005 (Prevel Ramos *et al*. 2006) and 2006, 0.3-0.4 whales per hour were sighted at the Port of Anchorage versus 3-5 whales per hour at Eklutna, 20-30 whales per hour at Birchwood, and 3-8 whales per hour at Cairn Point in the earlier study (Funk *et al*. 2005). During 95 six-hour monitoring shifts in 2006 (570 hours total effort), whales were observed in the area just 25 times on 21 days, remaining in sight for a total of 14.2 hours (2.4%), and inside the Marine Terminal Redevelopment Footprint for a total of 7.9 hours (1.4%). More than half of the whale groups sighted (16 groups) entered the Marine Terminal Footprint, but the length of time they were observed in the footprint was generally short, ranging from one minute to just over two hours, and averaging 33 minutes. Taken together with research conducted in 2005 (Prevel Ramos *et al*. 2006), these findings support the interpretation that the Port of Anchorage is a relatively low use area for beluga whales.

Group size and age class composition

Group sizes were generally small, with counts averaging just three whales per group. Ten sightings were of lone whales and the remaining15 sightings of groups of ten or fewer whales. Five groups with calves were sighted, and all of them entered the Marine Terminal Redevelopment Footprint. In all but one case, only one calf was observed. Average group size was more than twice as large in groups with calves as in groups without calves.

These data provide further support for the notion that relatively few whales use the area. The tendency of groups with calves to enter the Marine Terminal Redevelopment Footprint even when construction was occurring (see also Chapter 3) indicates that there is some use of the area by mothers with calves; however, the very low rate of use suggests that during the study period it was likely not being used as a crucial nursery area by Cook Inlet beluga whales.

Group behavior

Group dispersion samples generally indicated that whales spread out within the area, including those in nursery groups. This may be related to foraging activity as both diving and feeding activity were commonly noted. These results suggest that the area, while not used frequently or by many whales, is apparently used for foraging. Whales apparently feeding were noted both inside and outside of the Marine Terminal Redevelopment Footprint.

Movement patterns

Mean leg speed (an estimate of horizontal swimming speed) was generally low averaging 1-10 km/hr for lone whales and groups tracked with the theodolite. This may be related to the predominant use of the area by the whales being around the low tide (Chapter 2, Funk *et al*. 2005, Prevel Ramos *et al*. 2006). Beluga whales traveling on the changing tide past locations such as Birchwood at the middle of Knik Arm or Girdwood at the middle of Turnagain Arm have been monitored moving at an apparently faster horizontal speeds at times exceeding 15 km/hr (Funk *et al*. 2005, Markowitz *et al*. unpublished data). If the Port of Anchorage area is one that whales occasionally visit further down Knik Arm from their usual low tide concentration areas (*e.g.* Eagle Bay and Sixmile Creek), then slower movements may indicate a brief resting or milling period around the low tide before traveling with the rising tide back up the arm.

The apparent use the area by the whales for foraging, with diving frequently noted, may also explain the low horizontal speeds as the whales are moving vertically through the water more than horizontally. Other studies have shown that typical foraging dives occur at a speed of 1-2 m per second and last 12-20 minutes, with roughly 5 minutes between dives (Martin 1996).

The relatively non-linear movement of the whales tracked in the area also suggests the whales may linger briefly, resting or foraging for a short while before traveling out of the area on the tide.

Summary

Taken as a whole, data on beluga whale grouping, behavior and movements near the Port of Anchorage indicate that it is a relatively low use area, occasionally visited by lone whales or small groups of whales (most often around low tide in the fall, see Chapter 2). Although groups with calves were observed to enter the area, including the Marine Terminal Redevelopment Footprint, our data do not support the interpretation that it is an important nursery area. Similarly, while feeding activity was often noted, our data do not support the notion that it is an important feeding concentration area such as the Susitna River area.

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Chapter 5: Summary, Conclusions and Recommendations

Draft Final Report

by

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Report Summary

Temporal patterns

Seasonal patterns of habitat use are often related to prey availability, reproduction, and predator avoidance. In the case of beluga whales, sea ice cover, water temperature, and fish abundance influence seasonal movement and residency patterns. In summer, Cook Inlet beluga whales gather to feed at large fish runs at the Susitna River and likely use the shallow river flats as a thermal refuge for newborn calves. In the fall, as the calves mature, the whales move into Knik Arm and Turnagain Arm. Beluga whales can be found in Knik Arm year-round (NMFS 2005), but the number of whales using the area appears to be relatively low in seasons other than the fall (Funk *et al*. 2005).

During the fall, in both Knik Arm and Turnagain Arm, beluga whales ride the tidal currents, generally moving into the upper arms around high tide, and moving into low tide holding and foraging areas at low tide (NMFS 2005). Previous studies have shown that in Knik Arm, whales generally are found in the Palmer Slough-Eklutna-Knik River area near high tide, and in the Eagle Bay-Sixmile Creek area around the low tide (Funk *et al*. 2005). Relatively few whales apparently travel down Knik Arm as far as the Port of Anchorage (Prevel Ramos *et al*. 2006).

This study further investigated temporal patterns of beluga whale use of the area near the Port of Anchorage during ice free months (summer to fall). Specific objectives included confirming whether there are predictable seasonal, diurnal, and temporal patterns in beluga whale use of the area, providing information to predict when beluga whales are most likely to be present, and when the number of beluga whales present is likely to be highest.

Observations were conducted from April-November from either Cairn Point on Elmendorf Air Force base, or from the Port of Anchorage dock. Prior to Phase 1 construction, observations were conducted independent of tidal state. During Phase 1 construction, observations were centered on the low tide, daylight allowing. Data were collected on environmental conditions and vessel activity as well as on beluga whale occurrence.

Sighting rates were highest in August and September, with the mean number of whales sighted per hour in these months (0.4 and 0.3 whales per hour) more than double that in other months. Beluga whale sighting rates also varied significantly by tidal state, peaking at low ebb and low slack, when whales were observed during 3-4% of the time, as compared to <1% of the time at all other tidal states. Whales were more commonly sighted in late morning-afternoon than during early morning. This diurnal pattern was less prominent than the tidal pattern. Environmental conditions were rated good-excellent during 96.5% of observation hours. Mean wind speed ranged from 0.8-5.0 km/hr and median Beaufort Sea State ranged from 1 to 2. The number of vessels observed in the Port of Anchorage peaked between June and September, with the greatest number of vessels present in the Marine Terminal Redevelopment Footprint during August.

The observed seasonal and tidal pattern of beluga whale distribution documented during this study in 2006 is generally consistent with that documented near the Port of Anchorage during 2005 (Prevel Ramos *et al*. 2006) and throughout Knik Arm during 2004-2005 (Funk *et al*. 2005). In both 2005 and 2006, beluga whale monitoring at the Port of Anchorage yielded mean sighting rates during ice free months in the fall centering on 0.3 whales per hour. In 2006, sighting rates dropped in October and November, showing some inter-annual variability. Whether this change is due to Phase 1 construction activities in 2006 or environmental differences between the two years is unknown. There was also a difference in sampling effort between the two years, with relatively few monitoring sessions conducted in November 2006 due to an earlier onset of sea ice than in 2005. During spring-summer (April-July) 2006, mean sighting rates were just 0.02-0.12 whales per hour. In both years, sighting rates around low tide were 3-4 times those at other tidal stages.

Spatial distribution

An important component of the beluga whale monitoring program was documenting the spatial distribution of beluga whales near the Port of Anchorage. Beluga whale distribution in Cook Inlet varies seasonally, with whales gathering in large aggregations to feed at the mouths of rivers and streams during summer and fall. Areas where the whales are concentrated include the Susitna River delta, Eagle Bay, and Chickaloon Bay. In order to assess potential effects of the Port of Anchorage expansion on beluga whales, the distribution of whales relative to the area of construction was assessed, with particular attention to whale use of the Marine Terminal Redevelopment Footprint.

Data on beluga whale locations were collected by shore-based observers using geo-referenced grid cell maps (Funk *et al*. 2005) and a computer-linked surveyor's theodolite (Prevel Ramos *et al*. 2006). During Phase 1 construction, LGL field biologists informed ICRC-designated personnel in real time when whales were first sighted and when the whales approached within 1 km, 500 m, 250 m, 100 m, and 50 m of construction activities. Positions were calculated from theodolite angle fixes using Pythagoras software, and input into ArcGIS where whale group positions were plotted for each day relative to the Marine Terminal Redevelopment Footprint. The number of group sightings and summed whale counts per grid cell were displayed using color scales in ArcGIS.

Eighty percent of beluga whale sightings occurred within 500 m of the Marine Terminal Footprint, and 64% of groups sighted were observed in the footprint. Theodolite tracks showed whale groups swimming the length of the footprint as well as entering the footprint only briefly or staying just outside the footprint. Sighting rates and summed whale counts were highest in the northeast part of the Marine Terminal Redevelopment Footprint, in the area closest to the observation stations and Phase 1 construction. Beluga whale groups with calves were observed within 150 m of the Phase 1 construction sight on two consecutive days in September. Whales were observed in the Marine Terminal Redevelopment Footprint once in April, once in May, three times in June, once in July, five times in August, five times in September, and never in either October or November. Whales were documented using the largest area including the Marine Terminal Redevelopment Footprint during low ebb and low slack tides. Whales were also observed in the Marine Terminal Redevelopment Footprint at low flood and high ebb tides when they were seen across a smaller range.

Although a large proportion of sightings occurred within, or in close proximity to, the Marine Terminal Redevelopment Footprint, this may be due to the effect of distance on sighting rates, especially from the relatively low vantage of the observation station at the Port of Anchorage. Funk *et al*. (2005) examined the effect of distance on sighting rates, and concluded that sighting rates dropped substantially at distances > 3 km. In this Port of Anchorage monitoring effort, 20% of sightings occurred at distances > 3 km.

Sighting rates of beluga whales from shore-based monitoring stations overlooking the Port of Anchorage were much lower than those from shore-based monitoring stations and vessel surveys further up Knik Arm in 2004-2005 (Funk *et al*. 2005). Beluga whales were not generally concentrated in the vicinity of the Port of Anchorage, but occasionally could be found in the area in relatively low numbers.

Grouping, behavior and movements

To provide a more comprehensive assessment of how beluga whales use the Port of Anchorage area, we examined group size and age class composition, behavior, and movement patterns. Particular attention was given to use of the Marine Terminal Redevelopment Footprint by mothers with maturing calves and by feeding/foraging whales. Movement patterns, such as distances covered by the whales per unit time (horizontal swimming speeds), were examined to provide information for estimating the time whales take to move through areas.

Data were organized temporally and spatially as detailed in the previous chapters. Group size and age class distribution was estimated based on minimum best counts of adults, subadults, and calves, which were discriminated based on coloration and size. Mode inter-individual distance and behavioral state were recorded during each focal group observation. Leg speed, percent linearity, total distance traveled, distance made good, and re-orientation rate of beluga whale groups were calculated using the track line analysis module of Pythagoras. Results were tabulated in Excel and non-parametric statistical comparisons computed in SPSS.

The mean duration whales were observed in the Marine Terminal Redevelopment Footprint varied across months, ranging from 0-41 minutes, representing 0-74% of the time they were seen in the Port of Anchorage area. Group sizes were generally small.

Forty percent of sightings were of lone whales (*n* = 10), and the average group size was just three whales. Group sizes peaked in August and September, with a maximum of ten whales counted on two days in August. Calves were observed in five groups (20% of sightings), and group size was significantly larger in these nursery groups (mean = 8 whales) than in other groups (mean = 3 whales). All five nursery groups were sighted at either low ebb or low slack tide, and all entered the Marine Terminal Redevelopment Footprint for time periods ranging from 19-49 minutes (mean = 32 minutes).

Beluga whale groups sighted near the Port of Anchorage were generally fairly dispersed, whether or not calves were present in the groups. Frequently observed behaviors included confirmed or suspected feeding activity as well as diving behavior possibly indicating foraging. Feeding was more commonly noted inside the Marine Terminal Redevelopment Footprint than outside the footprint.

Whale groups were tracked with the theodolite for time periods ranging from 11-89 minutes, traversing horizontal distances of up to 6 km. Mean leg speed (horizontal swimming speed) was 6 km/hr, and whales tracked in the Marine Terminal Redevelopment Footprint moved in a generally non-linear manner.

Beluga whales used the Port of Anchorage area at a relatively low rate and only in small groups. Although feeding activity and some groups with calves were noted, the area around the Port of Anchorage did not appear to be a major foraging or nursery area for beluga whales. Whales were observed in the Marine Terminal Redevelopment Footprint a relatively small proportion of the time, less than one out of every four days, and remained in the footprint for a period of less than one hour on average.

Conclusion and Recommendations

Based on sighting rates from monitoring over the past two years, it appears that beluga whales are present in the Port of Anchorage area at a relatively low rate, with sporadic visitation by lone whales and small groups most often around low tide during the fall. With careful monitoring and mitigation plans, harassment of whales due to construction activities related to the Port of Anchorage expansion could be effectively minimized. One strategy likely to reduce the effects of construction on beluga whales would be to schedule pile driving (particularly impact pile driving) for time periods other than the low tide in the fall.

Although sighting rates were generally low, we caution that those whales sighted often entered or approached quite close to the Marine Terminal Redevelopment Footprint (80% of groups came within 500 m of the footprint and 64% entered the footprint). Therefore, early detection and construction shutdowns may be necessary to lessen the number of beluga whale takes by harassment. To insure all whales entering the area are detected, we recommend that monitoring from multiple vantage points be conducted by dedicated, trained observers during all hours of construction. This will be particularly advantageous if whale detection over a broader range is deemed important due to the transmission of in-water noise related to pile driving.

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