Assessment of Remote Video for Monitoring Beluga Whales, *Delphinapterus leucas,* of Cook Inlet, Alaska

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Introduction

In 1979, Alaska's Cook Inlet beluga whale, *Delphinapterus leucas*, population was estimated to be 1,300 animals (Calkins[1]). Abundance surveys in the early 1990's indicated a 47% decline, and in response to this decline, NOAA's National Marine Fisheries Service (NMFS) designated the stock as depleted under the Marine Mammal Protection Act on 31 May 2000 (NOAA, 2000). On 22 October 2008 NMFS listed the Cook Inlet beluga whale as an endangered species under the Endangered Species Act (NOAA, 2008; NMFS[2]). Since then, aerial surveys have shown a continued decline to an abundance recently estimated at 312 animals (Hobbs et al., 2015). As part of the requirements of the ESA listing process, NMFS designated critical habitat for Cook Inlet beluga whales and is developing a recovery plan for the conservation and survival of this species.

One of the challenges facing managers, scientists, and others interested in the recovery and conservation of Cook Inlet beluga whales is the dearth of information about habitat use and requirements. Ongoing aerial and vessel surveys coupled with photographic identification, land-based observer efforts, and passive acoustic monitoring have provided useful insights into the Cook Inlet beluga whale occurrence and behaviors in summer months (Moore et al., 2000; Goetz et al., 2007; Funk et al.[3]; Markowitz and McGuire[4]; Markowitz et al.[5]; McGuire et al.[6,7];

[1]Calkins, D. G. 1989. Status of belukha whales in Cook Inlet. *In* L. E. Jarvela and L. K. Thorsteinson (Editors), Proceedings of the Gulf of Alaska, Cook Inlet, and North Aleutian Basin Information Update Meeting, Anchorage, AK, Feb. 7–8, p. 109–112. U.S. Dep. Commer., NOAA, OCSEAP Rep., Anchorage.

[2]NMFS. 2008. Conservation plan for the Cook Inlet beluga whale (*Delphinapterus leucas*). U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv. Reg. Off., Juneau, AK, 122 p.

[3]Funk, D. W., T. M. Markowitz, and R. J. Rodrigues (Editors). 2005. Baseline studies of beluga whale habitat use in Knik Arm, Upper Cook Inlet, Alaska: July 2004–July 2005. Rep. from LGL Alaska Res. Assoc., Inc., Anchorage, with HDR Alaska, Inc., Anchorage, for Knik Arm Bridge and Toll Authority, Anchorage, Dep. Transp. Public Facil., Anchorage, and Fed. Highway Admin., Juneau, Alaska, 232 p. (http://www.knikarmbridge.com/Tech_Reports/Boiler%20QC/Baseline%20Studies%20of%20Beluga%20Whale%20Habitat%20Use%20in%20Knik%20Arm.pdf).

[4]Markowitz, T. M., and T. L. McGuire (Editors). 2007. Temporal-spatial distribution, movements and behavior of beluga whales near the Port of Anchorage, Alaska. Rep. from LGL Alaska Res. Assoc., Inc., Anchorage, for Integrated Concepts and Res. Corp. and U.S. Dep. Transp. Marit. Admin., 73 p. http://alaskafisheries.noaa.gov/protectedresources/whales/beluga/development/portofanc/poa2007tempspacialmovements.pdf)

[5]Markowitz, T. M., T. L. McGuire, and D. M. Savarese. 2007. Monitoring beluga whale (*Delphinapterus leucas*) distribution and movements in Turnagain Arm along the Seward Highway. Final Rep. from LGL Alaska Res. Assoc., Inc., Anchorage, for HDR and Alaska Dep. Transp. and Public Facil., 42 p.

[6]McGuire, T. L., C. C. Kaplan, and M. K. Blees. 2009. Photo-identification of beluga whales in Upper Cook Inlet, Alaska. Final Rep. Belugas re-sighted in 2008 prep. by LGL Alaska Res. Assoc., Inc., Anchorage, for Natl. Fish Wildl. Found., Chevron Corp., and ConocoPhillips Alaska, Inc., 42 p.

[7]McGuire, T., M. Blees, and M. Bourdon. 2011. Photo-identification of beluga whales in Upper Cook Inlet, Alaska. Final Rep. Field activities and belugas resighted in 2009 prep. by LGL Alaska Res. Assoc., Inc., Anchorage, for Natl. Fish Wildl. Found., Chevron Corp., and ConocoPhillips Alaska, Inc., 53 p. (www.cookinletbelugas.org).

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ABSTRACT—Alaska's Cook Inlet beluga whales, Delphinapterus leucas*, an endangered species, were estimated by the National Marine Fisheries Service, NOAA, at a mere 312 animals in 2012. Understanding the habitat use and defining critical habitat for these whales is crucial for their conservation. The Little Susitna River Delta is thought to be an important summer foraging, mating, and calving habitat area for the species. To investigate the efficiency of new methodologies and increase our understanding of habitat use, the Alaska SeaLife Center initiated the Cook Inlet beluga whale remote monitoring pilot study in the summer of 2011 using video monitoring. Observers used two remotely controlled video cameras mounted on a 9 m tower approximately 1.5 river miles from the confluence of the Little Susitna River and the waters of Cook Inlet. Belugas were observed through the cameras from May to August 2011 as they entered the river mouth and traveled upstream past the camera site. The remotely captured behavioral information in this secluded location added finer-scale information about habitat use and behavior to the existing body of knowledge about Cook Inlet belugas. Behaviors observed and video-recorded included typical beluga behaviors (e.g., travelling, milling, and suspected feeding) along with a higher-than-anticipated occurrence of other behaviors (e.g., breaching, spyhopping, mother/newborn interactions). Additionally, detailed group composition, distribution, and duration of sighting data was collected, proving both the effectiveness and value of this monitoring method.*

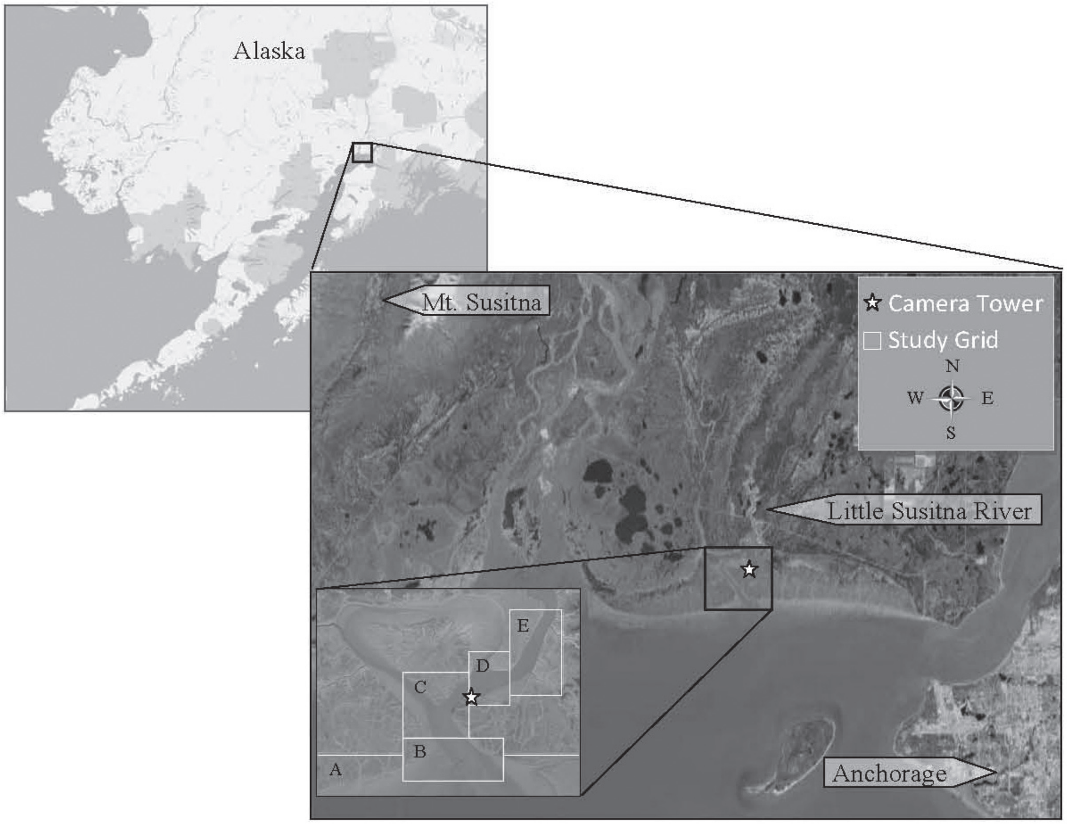

Figure 1.—Alaska with a detailed map of the Little Susitna River study area and surrounding area including Upper Cook Inlet waters adjacent to the city of Anchorage. The study area is shown with distances to landmarks visible through monitoring cameras. The inset is a close up view of the river delta study area with map subdivisions from A to E. Base map source: "Little Susitna River" (lat. 61°16′22.41″ N, long. 150°15′34.32″ W, Google Earth, 15 April 2011).

McGuire and Bourdon[8,9]; Small[10]). However, these approaches are all limited in various ways (e.g., cost, opportunity, weather). None of the visual approaches provides continuity of observations at any spatial scale.

As one solution, remote video monitoring can provide a constant platform for collecting continuous occurrence (diurnal, tidal, seasonal) movement and behavior data during ice-free months from focal areas known to be important to Cook Inlet beluga whales. Remote monitoring offers the benefit of monitoring Cook Inlet beluga whales without human-caused disturbance that may result from boat-based surveys and from low-flying survey aircraft. Remote monitoring can provide longer term behavioral observations, group composition information, and has the potential for photo-identification. Remote monitoring has been used by the Alaska SeaLife Center for over a decade to monitor behavior, site fidelity, and pupping of endangered Steller sea lions, *Eumetopias jubatus*, at the Chiswell Islands (Maniscalco et al., 2002, Parker et al., 2008, Maniscalco et al., 2010) and abundance and behavior of harbor seals, *Phoca vitulina*, in Aialik Bay (Hoover-Miller et al., 2011).

Information gathered from remote video monitoring could similarly provide fine-scale details on the Cook Inlet beluga whale use of critical habitat, including diurnal, tidal, and seasonal patterns of habitat use, which scientists and managers can utilize for conservation decisions. This study tested the efficacy of remote video monitor-

[8]McGuire, T. L., and M. L. Bourdon. 2009. Pre-deployment visual monitoring for beluga whales in and near the Cook Inlet tidal energy project proposed deployment area, June–November 2009. Rep. prep. by LGL Alaska Res. Assoc., Inc., Anchorage, for Ocean Renewable Power Co., Anchorage, 36 p. (www.fakr.noaa.gov/protectedresources/whales/beluga/development.htm).

[9]McGuire, T. L., and M. L. Bourdon. 2011. Pre-deployment visual monitoring for beluga whales in and near the Cook Inlet tidal energy project proposed deployment area, May–November 2010. Rep. prep. by LGL Alaska Res. Assoc., Inc., Anchorage, for Ocean Renewable Power Co., Anchorage, 36 p. (www.fakr.noaa.gov/protectedresources/whales/beluga/development.htm).

[10]Small, R. J. 2010. Project title: Acoustic Monitoring of Beluga Whales and Noise in Cook Inlet. Final Rep. to NMFS for Grant No. NA07NMF4390364, 2 p. (www.fakr.noaa.gov/protectedresources/whales/beluga/research.htm).

Figure 2.—Tower and mounted cameras used to monitor Cook Inlet beluga whales in the Little Susitna River. Arrows indicated the location of the two cameras mounted near the top of the tower.

ing to study belugas during ice-free months in Cook Inlet.

Methods

Location

The study site was located near the mouth of the Little Susitna River, Upper Cook Inlet, Alaska. The video cameras and tower were located at (lat. 61°16′22.41″ N, long. 150°15′34.32″ W), approximately 2.4 km from the confluence of the Little Susitna River and the waters of Cook Inlet, at mean low tide (Fig. 1). This site is located in the designated critical habitat for Cook Inlet beluga whales and was selected based on results of previous Cook Inlet beluga whale studies in the area that identified it as an area of persistent beluga occurrence during the ice-free months (e.g., Hobbs et al., 2015; McGuire et al.[6,7]; McGuire and Bourdon[8,9]).

Equipment

The video camera system utilized remotely operated analog high resolution (640 x 480) camera technology made from basic Sony camera component with custom upgrades and housing (SeeMore Wildlife Systems, Homer, AK[11]). The cameras allowed an observer in an office to remotely manipulate the cameras in real-time via a microwave link. This technology has proven to be reliable for remote observations during daylight, which can approach 20 h per day in summer (Maniscalco et al., 2002; Hoover-Miller et al., 2004).

The camera system consisted of two cameras mounted to a 9 m steel tower embedded in the ground at the study site (Fig. 2). Two cameras were used to increase coverage with overlap in visual range. Only one camera feed could be utilized at a time. Each camera was equipped with a 12–18x optical and 180–300x digital zoom lenses mounted in weather proof housings and with remotely controlled pan, tilt, zoom, and windshield wiper/washer functions. Video signal was transmitted approximately 15 miles via microwave transmission. The cameras and tower were powered by a 12-volt battery system charged by solar power.

In the office, the signal was viewed and recorded in real time with typical television monitors and digital recorders. The commands for controlling the cameras were sent from custom-made software running on a desktop computer. Batteries, electronics, and the recharging system to run the cameras were located in a hard case mounted at the base of the steel tower, and the live image from the cameras was transmitted via microwave signal to a receiver. The receiver was located 15 km away on the ConocoPhillips building in Anchorage which had a line-of-sight relay for the remote acquisition of video data. The analog signal was transmitted to the receiver and required digital compression for transmission to an Anchorage-based office complete with computer, recorder, and editing equipment.

The viewing area covered by both cameras spanned from the confluence of the Little Susitna River and the waters of Cook Inlet to approximately 3 river miles upriver at mean low tide. Within the viewing area, the river width ranged from 0.1 to 0.3 miles wide.

Observing and Data Collection Protocol

Scanning Protocol

The observer monitoring effort was conducted from May to August 2011. Observations occurred during daylight hours, 5–7 days a week, with hours varied to cover different tidal stages but primarily targeting high-tide stages. Tides in this region can vary by as much as 9 m. Scans of the study area were conducted every 20 min throughout each monitoring shift (8 h). For each scan, the observer would position the camera at the farthest south or north position and slowly move the camera through the study area. Movement of the camera for observations were incremental instead of continuous, to allow for detailed observation. With each movement of the camera (~ 300 m increments), the observer paused long enough to determine if whales were present in the field of view before moving it again. Scans usually lasted between 10 and 15 min, but they were longer if belugas were present to facilitate accurate data collection.

Data Collection and Video Archiving

Data for each scan were recorded on standardized data sheets and subsequently entered into a Microsoft Office Access database. Occurrence, number, and durations of observa-

[11]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

tions of boats, harbor seals, or other river activity were recorded in the database with the beluga data. Video was recorded during the observer's shift, and video segments with belugas, boats, harbor seals, or other river activity were archived. Date and time of the footage was archived as part of the file. Video without animals or humans was discarded.

Beluga Data Collection

During real-time monitoring, when belugas were present, observers noted group location, group size, composition (i.e., color of whales and presence of dark gray calves), and behaviors. To accurately capture the dynamic movements of whales within the study area, without inflating total numbers of whales reported, a two-tiered data collection scheme was implemented. Consistent with protocols used by other beluga monitoring studies in Cook Inlet (Pinney[12]), upon sighting a group of whales for the first time the observer would keep them in view long enough to accurately assess location, composition, and behavior (tier 1, initial sighting).

After recording these data, the observer would continue to scan the study area for the presence of other groups of whales. On successive scans whales sighted were assigned a new group number and a new line of data was recorded, with the observer again documenting composition, location, and behavior, and any comments on the data sheet to indicate if this was most likely the same group as previously recorded (tier 2). Data were recorded and maintained in a database. Data entry and group coding, as well as a comparison among real-time monitoring through the systems with video recordings, are detailed in a project report (Easley-Appleyard et al.[13]).

[12]Pinney, L. 2011. GIS assessment of Cook Inlet beluga whales (*Delphinapterus leucas*) habitat parameters in the Knik Arm area of Anchorage, AK. MSc thesis, Univ. Alaska Anchorage, 91 p.

[13]Easley-Appleyard, B., L. Pinney, L. Polasek, J. Prewitt, and T. McGuire. 2011. Alaska SeaLife Center Cook Inlet beluga whale remote monitoring Pilot Study. Final Rep. from Alaska SeaLife Center, Seward, 49 p. (http://www.fakr.noaa.gov/protectedresources/whales/beluga/survey/cib_susitna093011.pdf).

Group location was documented using a grid system consisting of five grids (A, B, C, D, E) covering all portions of the study area visible through the camera (Fig. 1). Grid A consisted of an array of 117 500-m x 500-m cells (2.93 x 10^7 m^2). Grids B, C, D, and E consisted of arrays of 100m x 100m cells (144 total cells; 4.44 x 10^6 m^2). Each group was assigned a code and movement noted among grids to track the spatial arrangement of belugas (Fig. 1).

Behaviors

Beluga behavior was assessed for primary, secondary, and tertiary behaviors. Primary behavior was the main activity of the groups. Secondary and tertiary behaviors were less frequent activities observed sporadically in the midst of the primary activity. Primary behaviors included traveling (movement in a singular direction), milling (movement in multiple directions), and unknown. Secondary behaviors were milling, traveling, feeding suspected (bursts of speed and or localized diving), diving (arched back with brief tail fluke before submerging), spyhopping (head out of water vertically), and other. Tertiary behaviors were traveling, feeding suspected, diving, spyhopping, tail slapping, and other. Secondary or tertiary activities under the category of "other" included headstands, bobbing, listing while showing pectoral fins, and excessive splashing. Details on behaviors can be found in Easley-Appleyard et al.[13]

Nightly Reviewed Video

When conditions were acceptable, the video cameras were left on to record at the end of an observer shift and programmed to turn off at 2200 h, when diminishing daylight reduced visibility. The cameras were pointed northeast and primarily covered Grid D. Recorded video was reviewed for presence of belugas, humans, and other marine mammals, and video of any significant events was archived.

Environmental Conditions

Environmental conditions were recorded for every hour of observation during the project. Environmental data collected through visual observations included the presence (yes or no) and direction of glare within the study area, Beaufort Sea state (0 to 5), the presence of whitecaps (yes or no), percent cloud cover, and precipitation (scale of 0 to 3). The overall monitoring conditions were ranked as excellent, moderate, or poor, based on the presence of wind, whitecaps, sun glare, rain, haze, smoke, snow, and fog. Wind direction, wind speed, and air temperature were collected from the Anchorage airport station on the Weather Underground website (http://www.wunderground.com/US/AK/Anchorage.html).

Tidal Stages

Tidal stages were calculated by finding the difference between when the consecutive high and low tides occurred as reported by NOAA, Tide and Currents verified data for Anchorage (http://tidesandcurrents.noaa.gov/geo.shtml?location=99501). The number was then divided by the six tidal stages that make up a tidal cycle and times for tidal stages were calculated. Cook Inlet has 12-h tidal cycles. For the purpose of this study, the tidal stages were divided into six equal stages, averaging about two hours per stage. Being the first study of this kind on belugas, a wide variety of tidal stages were monitored. The stages used for analysis include: low ebb, low slack, low flood, high flood, high slack, and high ebb. During analysis, a tidal stage was considered covered by monitoring if there was monitoring for at least 45 min of the tidal stage.

Spatial Distribution

All grid cell locations recorded for each group sighting were tabulated at the end of each month. Total sightings for each grid cell were imported into ArcGIS ArcInfo 10.0 (ESRI, Redlands, Calif.). Cells were color coded based on the total number of group sightings

Table 1.—Monitoring effort in 2011 by month. Monitoring effort was defined as the time when observers conducted regular scans over the entire survey area. Because the camera was positioned in one location for nightly video, effort and results from nightly reviewed video was not included in regular monitoring effort and beluga whale presence.

Month	No. of monitoring days	Total monitoring hours (h:min)	% Month covered by monitoring effort (24/7)	Mean per day covered by monitoring effort	Mean monitoring effort h/day
May	10	42:33	18%	18%	4:15
June	30	255:06	35%	35%	8:30
July	29	222:28	30%	32%	7:40
August	24	199:24	27%	33%	7:58
Total	93	719.3			

Table 2.—Monthly observation effort and Cook Inlet beluga whale sightings by group and with calves using live-feed video monitoring from May to August 2011.

Month	No. of monitoring days	No. of days belugas observed	% Observation days belugas observed	Total monitoring hours	No. of hours belugas observed	% Monitoring hours belugas observed	No. of beluga groups observed	No. of groups with calves
May	10	2	20%	42.6	3.0	7%	11	6
June	30	11	37%	255.1	18.2	7%	16	2
July	29	5	17%	222.5	9.4	4%	8	0
August	24	20	83%	199.8	91.0	45%	34	13
Total	93	38		720.0	121.6		69	21

for that location. Specific locations for behaviors of note (suspected feeding, diving, spyhopping, breaching, bobbing, showing pectoral fins, and excessive splashing) and presence of calves (confirmed by dark color and relative size) were tabulated for the entire season, imported into ArcGIS, and color coded based on total number of sightings of each for each grid cell.

Results

Monitoring Effort

In total 720 h of monitoring, time when observers conducted regular scans over the entire survey area, were conducted over 93 days from 22 May 22 to 31 August. Throughout the project the average percentage of the day that was covered by monitoring over a 24 hour period was 32% (Table 1). Night video was not included in regular monitoring effort because cameras were positioned in one location overnight.

Equipment Function

Over the entire project period, image quality and clarity was lower than anticipated, which prevented the identification of individual beluga whales. On several occasions (<10) the cameras lost connection, lost movement, or provided significant static to prevent data collection. In most cases camera function was fully restored within the hour by restarting the system, but on more than one instance connection was lost for more than 12 h. These complications resulted in lost video footage for several days each month.

Image resolution was lower than anticipated for the project due to degradation of signal transmission within the office building. Installation of high frequency signal transmission cables was not possible in the office space used. Therefore the signal had to be compressed and image resolution was reduced to 300 x 225 pixels.

Beluga Observations

Belugas were observed on 38 of the 93 days during the May–Aug. study period. In total, 69 groups of beluga whales were observed within the study area. Belugas were seen most often in August, with belugas seen on 83% of observations days, and least often in July, with sightings on only 17% of observation days (Table 2). Calves were observed in 30% of the groups, and the greatest number of groups with calves (13 groups) was observed during August (Table 2). Groups ranged in size from 1 to 59 whales. Time that groups remained in the study area ranged from 1 to 498 min (8.3 h; Table 3). More than half of groups observed (52%) remained in the study area for less than one hour.

Spatial Distribution

Beluga whales were observed throughout the study area in all study grids. A majority of groups (39 of 69 or 57%) were observed either spread across or traveling through multiple study grids. Grids C and D were closest to the camera and therefore provided the greatest detail within beluga groups. Sighting rates were highest in grid D and lowest in grid E (Fig. 3). Groups containing calves were seen more often in grids C and D, 14 and 16 groups, respectively, than they were elsewhere in the study area (Fig. 4).

Tidal and Temporal Beluga Presence

Although belugas were seen during all tidal stages, after standardizing for unequal monitoring effort, during daylight hours belugas were seen most

Table 3.—Monthly summary of beluga whales per group sighting data 22 May–31 Aug. 2011. Activity codes: 0=Unknown, 1=Traveling/moving, 2=Diving, 3=Mating, 4=Spyhopping, 5=Breaching, 6=Feeding observed, 7=Feeding suspected, 8=Milling, 9=Startled effect, 10=Tail slapping, 11=Avoiding predation, 12=Calving, 13=Abrupt dive, 14=Disperse, 99=Other.

Month	Max. sighting duration/ group (min)[1]	Locations by grid	Max. group size	Max. no. calves/ group	1° Activity	2° Activity	3° Activity
May	33	A,B,D,E	30	6	1,8	1,2	-
June	344	A,B,C,D,E	46	3	0,1,8	1,2,7,8	1,2
July	158	B,C,D	14	0	1,8	1,7,8	7
August	498	A,B,C,D,E	59	3	0,1,8,99	1,2,4,7,8,99	1,2,4,7,10,99

[1]Maximum sighting duration is the maximum length of time belugas were seen continuously and may include more than one group.

Table 4.—Tidal stages with monitoring effort and beluga presence, using live-feed video monitoring, from 22 May–31 Aug. 2011.

Tide	No. of tide stages covered by monitoring effort[1]	No. of tidal stages with beluga presence	Beluga presence relative to monitoring effort
Low ebb	55	11	20%
Low slack	38	3	8%
Low flood	50	9	18%
High flood	85	21	25%
High slack	94	32	34%
High ebb	73	20	27%

[1]Tidal stages per tidal type, 2011, 24 h/day (22 May 2011–31 Aug. 2011). Tidal stage was considered covered by monitoring if there was monitoring of at least 45 min of the tidal stage.

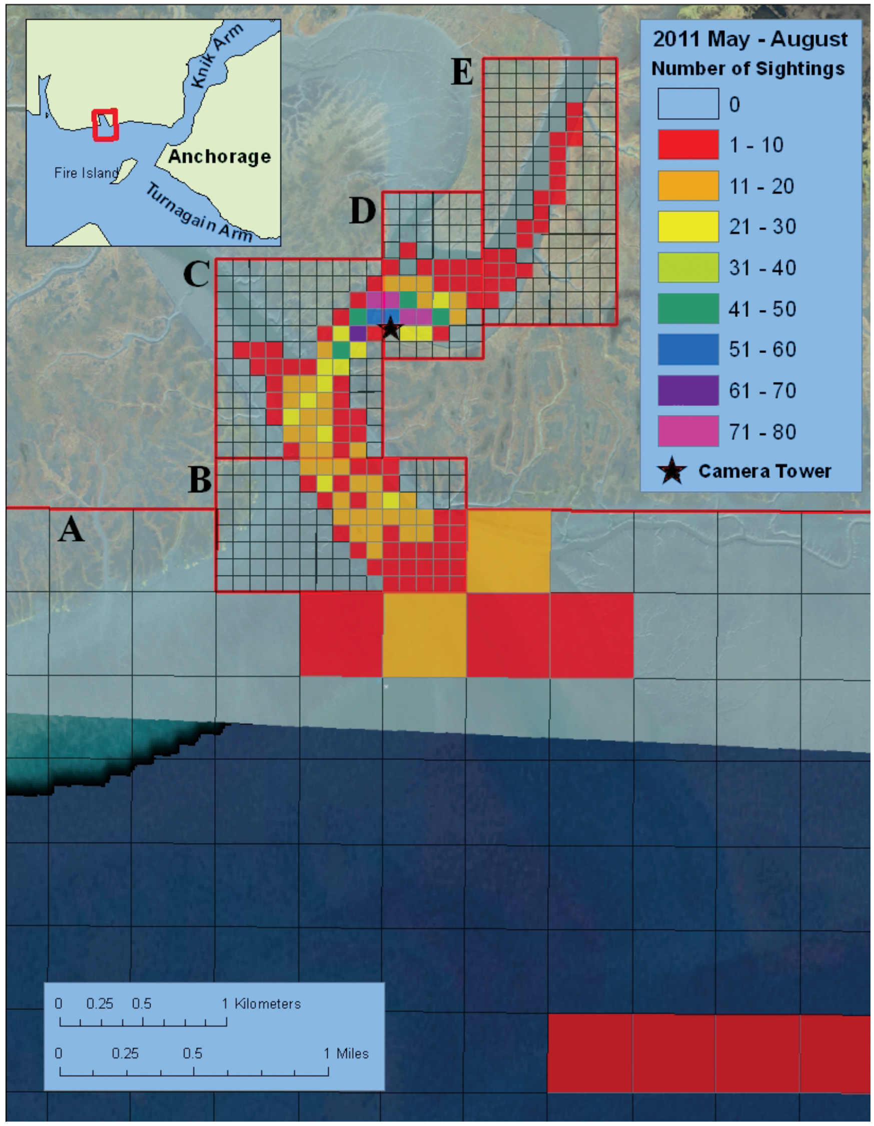

Figure 3.—Spatial distribution of sightings of beluga whale archival groups in May–Aug. 2011 with an inset of the relative position of the study area within Upper Cook Inlet. A sighting is defined as the presence of beluga whales during the duration of a single scan. Highlighted grid cells represent locations where beluga whale groups were observed. Color scale indicates total number of group sightings in each grid cell during 2011. Beluga whales were observed in grids A, B, C, D, and E. Group sighting rates were highest in grids C and D.

often during high tides and less frequently during low tide stages. Within tidal stages, belugas were more often seen in high slack tide (i.e., peak water levels; 32 out of 96 sightings) and least often during low slack tide (i.e., lowest water levels; 3 out of 96 sightings; Table 4). Belugas were seen throughout daylight hours in which monitoring occurred (0645 h to 2024 h). Nightly video, in a following section, indicated that belugas were present up the river during all but low ebb tides.

Behavior

In all months, May through August, primary behaviors included traveling and milling (36% and 59% of total primary behaviors, respectively). In June and August some behaviors were noted as unidentifiable due to poor visibility (Table 3). Secondary behaviors included traveling (28% of total secondary behaviors) and diving (17%) in all months, except no diving was recorded in July. Secondary behaviors also included suspected feeding (34%) and milling (20%) (June–Aug.), as well as spyhopping, tail stands, and some unknown behaviors (2%) (Aug.). Additionally, extended adult/calf interactions were observed, but this was not part of our directed behavioral observations and is therefore ancillary. Suspected feeding and diving behaviors were seen most frequently in grids C and D (Fig. 5, 6). Spyhopping was observed in grids B, C, and D. Tail slapping was recorded once in grid C. Headstands occurred in grids B, C, and D. Bobbing and showing pectoral fins occurred in grid C. Vigorous splashing occurred in grid B.

Other Marine Mammals

Harbor seals, *Phoca vitulina richardsi,* were observed on 91 of the 93 days of monitoring. An average of 10 harbor seals were observed during a scan. The largest group of harbor seals recorded in a scan was 42, with 40 seals hauled out at the mouth of the river and two seals in the water near belugas. Harbor seals were observed with fish in their mouths 18 times on 15 days during the study. Harbor seals were observed within

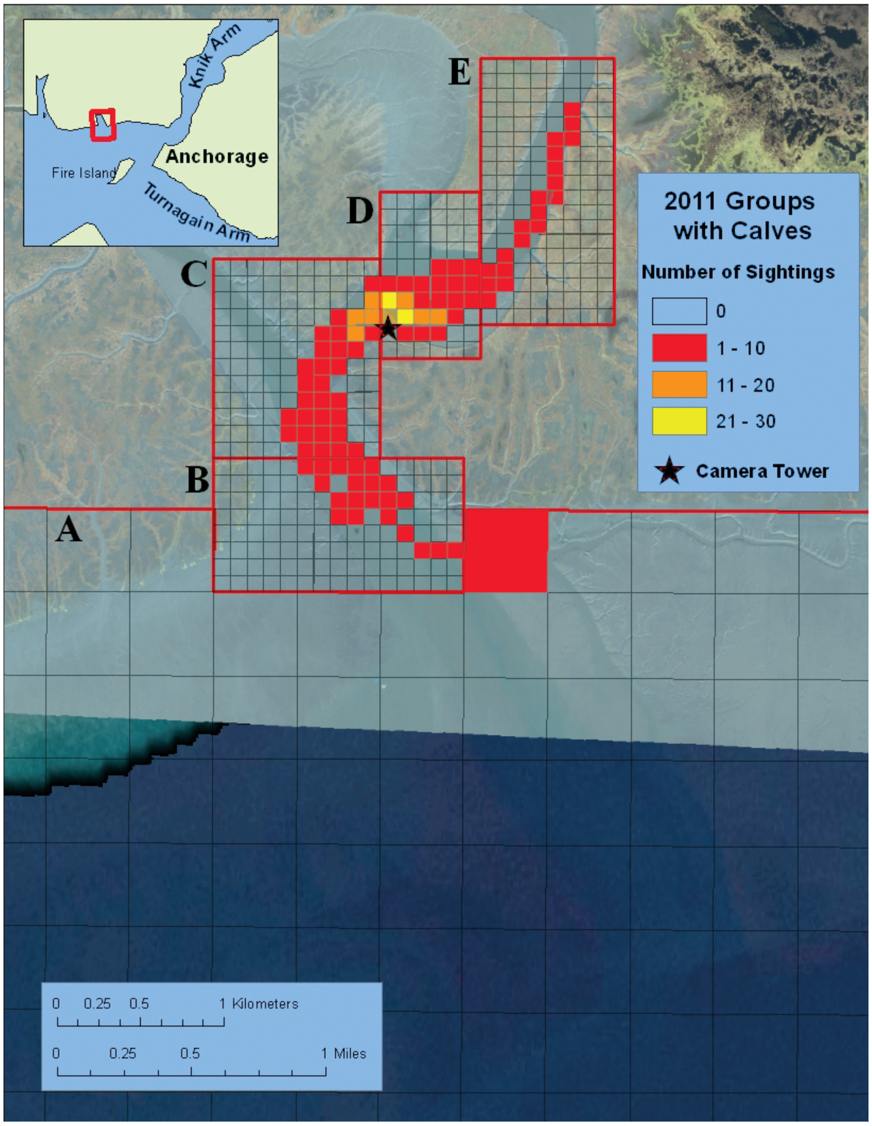

Figure 4.—Spatial distribution of sightings of beluga whale groups with calves in May–Aug. 2011 with an inset of the relative position of the study area within Upper Cook Inlet. A sighting is defined as the presence of beluga whales during the duration of a single scan. Highlighted grid cells represent locations where beluga whale groups with calves were observed. Color scale indicates total number of sightings in each grid cell during 2011.

100 m, and as close as 1 m, of belugas during 49 of the scans and on 20 of the monitoring days. Other marine mammals known to inhabit Cook Inlet, such as killer whales, *Orcinus orca;* Steller sea lions, harbor porpoise, *Phocoena phoconea;* and Dall's porpoise, *Phocoenoides dalli,* were not observed.

Environmental and Equipment Conditions

Environmental conditions that hindered monitoring effort included: high winds, low tide, and glare (reflection of sunlight off of the water). High winds caused the camera to shake, which resulted in poor and sometimes obstructed visibility. Monitoring conditions often deteriorated during low tide due to low water levels and higher possibility of reflection off the surface of the water. There were also instances when glare was not present, but low or poor light levels along the water decreased visibility. Environmental conditions during the scans were noted and did not necessarily hinder monitoring of the entire study area.

Human Activity

Thirty-five independent sightings of vessels were observed in the Little Susitna River during May through August monitoring efforts. Vessel sightings ranged from small boats to skiffs and jet skis, and in numbers from one to three at a time. Most of the vessels were traveling through the study area and did not remain in view for more than a few minutes. In most cases, but not all, vessel operators slowed down when whales were present.

Nightly Reviewed Video

A total of 67.5 h of video recorded over 13 nights was reviewed for presence of belugas, humans, and other marine mammals. On 5 of the 13 nights belugas were seen in the video viewing area. On all five nights that belugas were observed during nightly reviewed video, belugas were also observed during high tide earlier in the day during scheduled monitoring efforts. Belugas were observed during all tidal stages except low ebb; however low ebb only occurred twice in the nightly reviewed video. During nightly sightings belugas were seen milling the majority of the time; however, diving, breaching, and a tail slap were also recorded. Vessel traffic was observed on five of the nights, and vessels traveled both up and down stream. Harbor seals were viewed swimming in the area on nine of the nights, with one record of a harbor seal swimming near belugas.

Discussion

We were able to document the occurrence, relative abundance, and surface behavior of beluga whales near

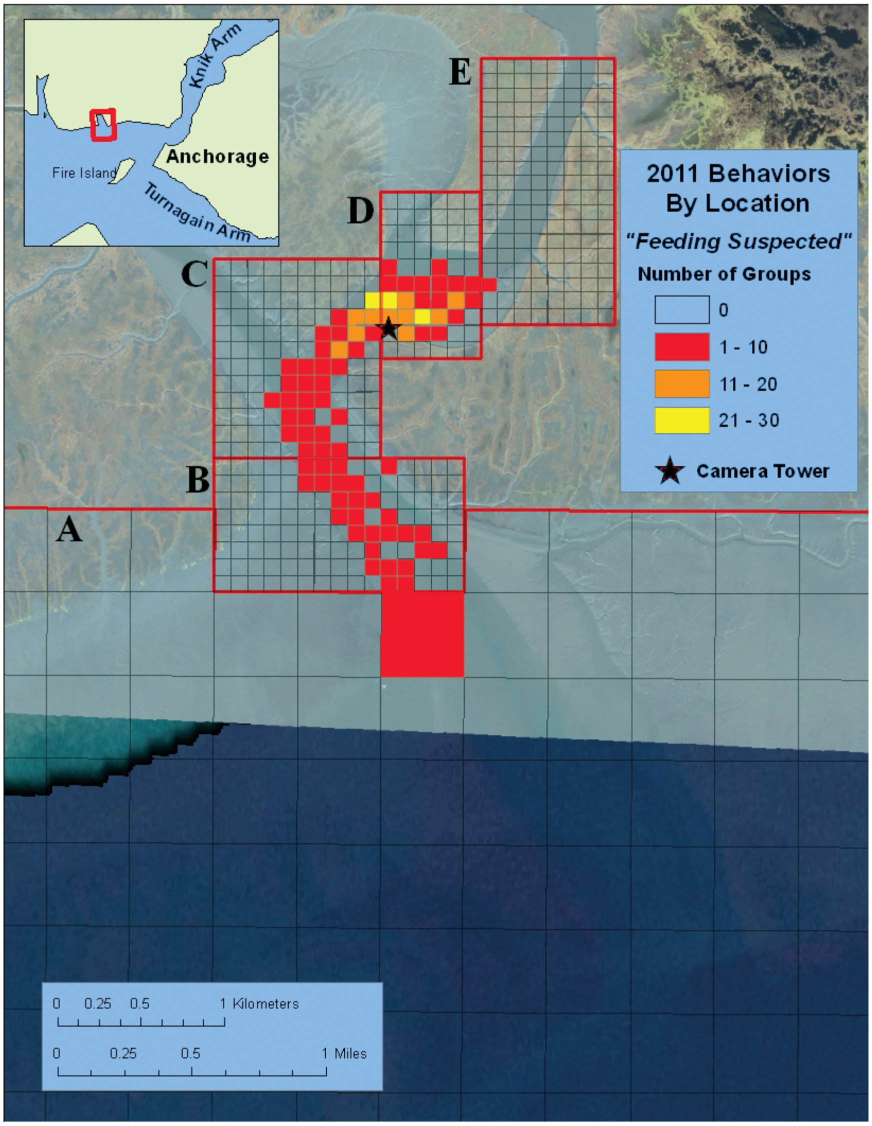

Figure 5.—Spatial distribution of sightings of beluga whale groups engaged in suspected feeding behavior in May–Aug. 2011 with an inset of the relative position of the study area within Upper Cook Inlet. Highlighted grid cells represent locations where beluga whale groups were observed engaged in suspected feeding behavior. Color scale indicates total number of sightings in each grid cell during 2011. Beluga whales were observed engaged in suspected feeding behavior in grids A, B, C, D, and E. Suspected feeding behavior was observed most often in grids C and D.

the mouth of the Little Susitna River during the ice-free months of 2011.

Beluga Observations

Spatial Distribution of Beluga Whales

Groups were seen through all grid areas; however belugas were seen most often and in the greatest detail and numbers in grids C and D. Calves were more often identified in grids C and D as well, most likely because grids C and D were closest to the camera and therefore provided the greatest detail within beluga groups. However, the ability to see beluga whales was not equal in the different grids due to distance from camera and environmental conditions. Sighting rates were lowest in grids A and B due to distance from the camera and visibility in grid A of the study area was often poorer than other grids, making comparisons between grids problematic

Beluga groups were observed to spend longer periods of time near shore than in mid-river. For example, belugas were seen near shore in grids C and D, which are situated in a bend of the river. The hydrodynamics of this location may have caused fish to become disoriented and/or concentrated, making them easier for belugas to capture compared to other locations in the study area.

The greatest numbers of calves were observed in grids C and D; however these grids were also the areas closest to the camera. Calves may have been underrepresented in grids A, B, and E, because of calf coloring (gray calves blend in with the turbid gray water of Upper Cook Inlet), greater sighting distance, and the resulting diminished image quality.

Tidal and Temporal Beluga Presence

With this project in its pilot year, observer monitoring shifts were scheduled around high tide, in anticipation that river levels during other tidal stages would be too low to allow belugas to safely navigate the relatively shallow river. During high tides belugas have been seen to move into narrower channels in the inlet, departing during ebb tides (Moore et al., 2000; Ezer et al., 2008). Belugas were seen most often and in the largest groups during peak water levels (even after standardizing for the greater monitoring effort made during this tidal stage), but belugas were observed in the river during low tidal stages as well.

The occurrence and number of beluga whales increased drastically in August, as did the number of groups containing calves and the observance of rare behaviors. Beluga sightings in August occurred almost every day of monitoring effort and for longer durations than sightings in May, June, and

July. Calf sightings are likely to have increased, since all animals would have calved by of the end of August; calves are larger and coloring is more detectable with age. These factors all facilitate higher detections rates for calves. We speculate higher adult counts may be due to greater fish presence in the river. The river may also provide calmer and narrower waters for calf care.

Beluga Behavior

One aspect of behavior that is important to managers when evaluating the value of habitat to beluga whales is feeding behavior. Although actual feeding could not be observed in the turbid waters, behaviors that were suspected to be feeding were documented. Suspected feeding was documented if behaviors were indicative of chasing prey with burst speeds, lunges and/or diving in a focused location. Often these behaviors were observed in proximity to seals surfacing or foraging with fish in their mouth.

These behaviors of interest were most often seen in grids C and D, which may indicate these areas are preferred feeding habitats within the study area. The observations of these behaviors that were recorded as part of this study could be due in part to the sheltered, low-disturbance, and abundant forage fish qualities of the Little Susitna Delta. Nearshore travel and slower transit time is suggestive of foraging behavior and has been shown in higher frequency in the Little Susitna and Susitna river areas (Goetz et al.[14]) However, these areas were also the closest to the camera and thus may have afforded a better view. This method did provide finer detailed information to the existing body of knowledge about this species by allowing focused long term observations with no disturbance to the animals.

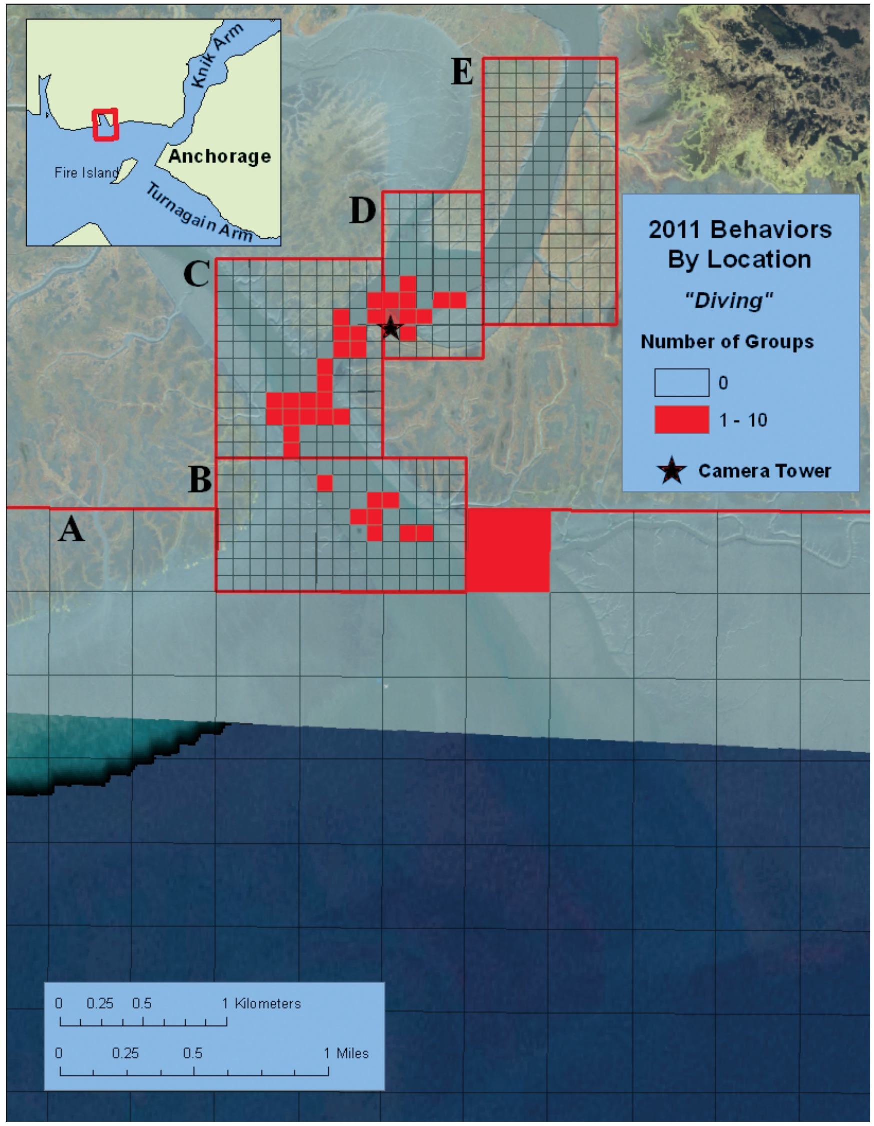

Figure 6.—Spatial distribution of sightings of beluga whale groups engaged in diving behavior in May–Aug. 2011 with an inset of the relative position of the study area within Upper Cook Inlet. Highlighted grid cells represent locations where beluga whale groups were observed engaged in diving behavior. Color scale indicates total number of sightings in each grid cell during 2011. Beluga whales were observed engaged in diving behavior in grids A, B, C, and D.

Behaviors seldom observed during other beluga whale studies, such as breaching and spyhopping, in the Cook Inlet population were documented during this study. These behaviors were on the nightly reviewed video on two separate days. The behaviors only occurred in grids C and D. Again, this could be due to better visibility and closer proximity to the camera. It could also be because the behaviors were seen up the river, away from the mouth, near the camera site, which was sheltered and had fewer disturbances in comparison to the river mouth. Other studies within Cook Inlet also note spyhops as uncommon occurrences and do not note breaches (Markowitz and McGuire[4];

[14]Goetz, K. T., P. W. Robinson, R. C. Hobbs, K. L. Laidre, L. A. Huckstadt, and K. E. W. Shelden. 2012. Movement and dive behavior of beluga whales in Cook Inlet, Alaska. AFSC Processed Rep. 2012-03, 40 p. Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE, Seattle WA 98115 (http://www.afsc.noaa.gov/Publications/ProcRpt/PR2012-03.pdf).

Goetz et al.[14]; Cornick and Kendall[15]; USAG-Alaska[16]), nor do studies outside Cook Inlet, although their primary focus was diving behavior (Martin et al., 1998; Kingsley et al., 2001; Martin et al., 2001).

Reviewed Video

One added advantage of this project is the ability to review recorded video. Real-time beluga whale data collection presents a time-restricted atmosphere as observers document accurate numbers, behaviors, and group composition before whales disappear from view. Collecting data from video of previously recorded beluga groups allowed observers to review events as many times as necessary and on slow playback to achieve highly accurate documentation.

Many interesting beluga whale behaviors happen in a flash and are therefore likely to be missed by observers in real time. The ability to pause video when taking notes increases the likelihood of catching these elusive events. For example, a tail slap and a startled response were documented in recorded video from May and June, although these behaviors were not captured in real-time data from the same time period.

When in the field and monitoring in real-time it is often difficult to recall exactly when a beluga sighting ends. Frequently observers find themselves waiting a few minutes or more to be sure that a sighting was actually the last observation of a particular group. Because of the ability to rewind video, resulting sighting times and durations are thought to be more precise. One caveat, however, is that an observer collecting data from previously recorded video would have no way of knowing if whales were present before or after video clips unless noted.

Picture quality was lower than anticipated and therefore recorded images from only one individual beluga whale were of sufficiently high image quality to allow for positive identification through LGL's Cook Inlet beluga photo-identification project (McGuire et al.[7]). With increased image quality, photo-id of belugas would be more feasible. The full project report (Easley-Appleyard et al.[13]) provides a more detailed review of live video feed versus recorded video footage.

Nightly Reviewed Video

Although the entire study area was not captured in nightly video, night recordings provided valuable information about beluga presence outside of standard monitoring efforts. Nightly video revealed that belugas travel within the study area during both high tides of the day. Although nightly video was captured during other tidal stages, no overnight activity was observed except during high tide. Behaviors not seen during daytime monitoring efforts (e.g., breaching) were captured during nightly video. Vessel traffic was also noted, and nighttime monitoring was helpful in determining if there were changes in vessel traffic during times when observers were not on shift.

Other Marine Mammals

This study was as useful for monitoring harbor seals as it was for monitoring belugas. Harbor seals were often seen feeding on fish, presumed to be Pacific salmon, *Oncorhynchus* spp., based on the size and shape of the fish, within 1 m of belugas. The harbor seal and its confirmed prey could be used as a proxy for suspected feeding behavior of beluga whales. Density of harbor seals coincided with density of belugas during the months of monitoring.

Human Activity

This study was useful for monitoring the interaction between human activities and belugas. On the occasions when vessels and beluga whales were present, vessel operators usually slowed or stopped; however, on two occasions vessels failed to slow or yield when belugas were in close proximity. It is possible that operators were unaware of the presence of whales at these times. Monitoring vessel activity in critical areas can help guide decisions on how to best educate boaters about endangered wildlife.

Project Challenges

As with any method of marine mammal monitoring and data collection, there were advantages and disadvantages to this method, and they became apparent over the course of the season.

One disadvantage of remotely-operated video camera systems is the lack of peripheral vision. The field of view available through the human eye is much wider than through the camera lens. On-site observers are able to survey more of any study site without losing sight of whales in view. The limited view through the camera forces observers to move the camera away from groups of whales periodically to ensure that no other groups are present within the study site.

A second challenge was that smaller darker animals may have been underestimated at the edge of the camera boundaries. This is most likely due to low contrast between the water color and calf color. This was increasingly challenging in the more distant grids. The addition of a second camera with a wider field of view with higher resolution that can be run concurrently with the camera focused on the whales would potentially address these issues.

Lastly, as previously mentioned, resolution was lower than anticipated which limited animal identification. Increased camera resolution or installation of high frequency signal transmission cables at the receiver site may help improve signal reception.

Conclusions and Recommendations

Several unique benefits from video monitoring became apparent through the course of the season. Observers actively manipulating the cameras were able to capture extreme close-ups of

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[15]Cornick, L. A., and L. Saxon Kendall. 2008. Distribution, habitat use, and behavior of Cook Inlet beluga whales in Knik Arm, fall 2007. Rep. prep. for Integrated Concepts and Research Corporation, Port of Anchorage, and U.S. Dep. Transp. Marit. Admin., Alaska Pacific Univ., Anchorage, 29 p. (https://www.alaskafisheries.noaa.gov/protectedresources/whales/beluga/development/portofanc/poa2007habitatknikarm.pdf).

[16]USAG-Alaska. 2010. Beluga observational studies on Eagle River Flats, Fort Richardson, Alaska 2009. Fort Richardson, Alaska,

individual whales, including newborn calves, and rare behaviors with absolutely no physical disturbance to these animals. One of the most rewarding and valuable aspects of this project has been video recording of behaviors rarely seen by observers in the field, such as breaching, spyhopping, and extended video of adult and newborn calf interactions. Many of these observations were captured when cameras were left on overnight. This was also beneficial for determining beluga presence while observers were not on shift.

Although the greatest number and highest frequency of belugas were seen during high tidal stages, belugas were also seen in the river during low tides as well. Unless future research study objectives are framed around high tide, future monitoring efforts would be best if they were evenly distributed across all tidal stages so the river in low tidal stages is not under documented. The addition of a second camera with a wider field of view and higher resolution would also be recommended for future work.

The ability to review archived video for data collection and validation purposes resulted in a more accurate dataset than could be captured in real-time. In the future and with improved image quality, archived video could be used to train future observers, educate the public, and for a wealth of potential research questions. Remote observations allow for a more-comfortable work environment for observers, which may reduce observer fatigue, compared to observers stationed at the field site. Field safety protocols are not necessary with remote monitoring. Combined, these factors allow a single observer to monitor for up to 8 h without excessive fatigue or threats to physical safety. Aside from the initial camera installation at the site, there is no travel time or cost associated with remote monitoring which would be incurred by observers operating in remote locations.

Because of the nature of beluga whales and the endangered status of the Cook Inlet population, an increased effort toward educating boaters about wildlife awareness would be beneficial. Monitoring vessel activity in critical areas can help guide decisions on how to best educate boaters about endangered wildlife. On a broader scale, compiling a comprehensive habitat-use assessment of Cook Inlet is difficult in general, and impossible for any single monitoring program or research method. Land-based visual observations, aerial surveys, satellite tagging, acoustic surveys, and photo-identification studies are all adding valuable pieces of information to this effort.

Through this pilot study, remote video monitoring has demonstrated its value as a method to provide habitat use data on Cook Inlet beluga whales. Information provided by remote video monitoring in the 2011 field season includes spatial and temporal distribution patterns of belugas in the Little Susitna River during ice-free months. This type of observation method, could add finer detailed information to the existing body of knowledge about this species including potential nursery and foraging habitat use. The use of remote video monitoring in other areas in upper Cook Inlet with similar physical qualities could be very beneficial to a more comprehensive understanding of the relationship between Cook Inlet belugas and their habitat.

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