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AERIAL SURVEYS OF BELUGA WHALES IN COOK INLET, ALASKA, JUNE 1996

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ABSTRACT

The National Marine Mammal Laboratory (NMML), in cooperation with the NMFS Alaska Regional Office, the Alaska Beluga Whale Committee (ABWC), and the Cook Inlet Marine Mammal Council (CIMMC), conducted an aerial survey of the beluga whale population in Cook Inlet, Alaska, during 11-17 June 1996. This provided a thorough coverage of the coasts around the entire inlet (1,388 km) as well as 1,538 km of offshore transects. Therefore, 100% of the coastal areas where belugas were expected to be during this season were searched one or more times, and 29% of the entire inlet was searched. The 40 hr survey was flown in a twin-engine, high-wing Aero Commander at 244 m (800 ft) altitude and 185 km/hr (100 kt). Throughout this survey, a test of sighting rates was conducted with multiple independent observers on the coastal (left) side of the plane, where most sightings occur. A single observer and a computer operator/data recorder were on the right side. After finding beluga groups, a series of aerial passes were made to allow at least two pairs of observers to make 4 or more counts of whales. Each pass was also videotaped for later analysis. The sum of the aerial estimates (using median counts from each site, not corrected for missed whales) ranged from 154 to 361 whales, depending on survey day. Estimates of group size ranged from 1 to nearly 300. Half (49%) of the initial sightings occurred more than 1.4 km from the aircraft - the perimeter of the standard viewing area. Of 40 groups recorded in 1994-96, 17 were reported by only one primary observer and missed by the other, while 23 groups were reported by both observers. Most (81%) of the beluga whales seen in Cook Inlet were in the upper Inlet near the mouth of the Susitna River, which is typical of their summer distribution.

INTRODUCTION

Beluga whales (*Delphinapterus leucas*) are distributed around most of Alaska from Yakutat to the Alaska/Yukon border (Hazard 1988). This species occurs in five apparent stocks around Alaska: Cook Inlet, Bristol Bay, Norton Sound, Eastern Chukchi Sea, and the Beaufort Sea (Hill *et al.* 1996) . The most isolated of these is the Cook Inlet stock, separated from the others by the Alaska Peninsula. The geographic and genetic isolation of the whales in Cook Inlet, in combination with their tendency towards site fidelity, makes this stock vulnerable to impacts from large or persistent harvest takes. Beluga whales in Cook Inlet are very concentrated in a few river mouths during parts of the year (as reviewed in Shelden 1994).

Aerial surveys are the established method used to collect distribution and abundance data for beluga whales in Cook Inlet (Klinkhart 1966; Calkins 1984; Calkins *et al*. 1975; Murray and Fay 1979; Withrow *et al*. 1994; Rugh *et al.* 1995, 1996). Traditionally, visual counts or estimates have been used to enumerate groups seen from the air, but they lack repeatability and have no direct measure of accuracy except through tests of independent, paired observers. However, prior to Rugh *et al.* (1995) there have been no documented tests of dual counting of beluga whales where two observers with nearly identical aerial views made independent searches and counts of whale groups. Barlow (1987, 1993), Øien (1990), Butterworth and Borchers (1988) and others have had independent observers search for cetaceans from ships. Rugh *et al*. (1990, 1993) conducted shore-based double counts of gray whales. Crete *et al*. (1991) made double counts from aircraft in surveys for polar bears, but paired observers did not have identical viewing areas. Forney and Barlow (1993) used a partially independent observer design for aerial surveys of cetaceans in which a second observer called out sightings only if they were missed by the primary observer, but the paired observers did not have identical viewing areas. We chose a survey design close to that recommended by Hiby and Hammond (1989) in which paired, independent observers have nearly identical search areas, and their counts are not compared until the research project is complete. Although we did break from the trackline each time a group of beluga whales was reported, it was only after the group was well behind the wing line.

Objectives

The objectives of the aerial surveys were to: 1) make a complete search for beluga whales around the perimeter of Cook Inlet; 2) conduct systematic transects through the center of Cook Inlet; and 3) circle groups of belugas for aerial estimations of group sizes and video documentation. Aerial survey procedures were kept similar to those used in previous studies (e.g., Rugh *et al*. 1995, 1996). Emphasis was placed on having independent searches and counts of belugas made by at least two observers on the same (nearshore) side of the aircraft. Tests of paired video cameras were run to improve post-season counts of whales (Waite and Hobbs 1995). Summary counts from the aerial effort, in combination with correction factors established through tests such as the paired observer effort, video documentation, and surface timings based on tagged whales, will be combined in a separate manuscript to calculate the total number of beluga whales in Cook Inlet.

METHODS

Survey Aircraft

The survey aircraft , an Aero Commander 680 FL (N7UP), has twin-engines, high-wings, 10-hr flying capability, and a five-passenger plus one pilot seating capacity. This aircraft has been enhanced for low-speed performance and increased range. There are bubble windows at each of the three primary observer positions, maximizing the search area. An intercom system allowed communication among the observers, data recorder, and pilot. A selective listening control device was used to aurally isolate the observer positions. Positional data were collected from the aircraft's Global Positioning System (GPS) interfaced with the laptop 386 computer used to enter sighting data.

Aerial Records

General descriptions of the aerial operations (startup and shutdown times, names of participants, survey accomplishments, etc.) were kept in a master log maintained by the aerial project principal investigator or delegate. All other data and comment records were entered into the onboard computer. These data entries included routine updates of locations (via the aircraft GPS), percent cloud cover, sea state (Beaufort scale), glare (on the left and right), and visibility (on the left and right). Each start and stop of a transect leg was reported to the recorder. Observer seating positions were recorded each time they were changed, generally every 1-2 hrs to minimize fatigue.

Tides

Because of the broad geographical range of these surveys, and because tide heights in Cook Inlet are highly variable from place to place, our aerial surveys were not synchronized with the predicted low tide with the exception of five surveys that were timed to occur within one hour of low tide at the Susitna delta, and one survey that occurred there at high tide (Table 1). This effort to synchronize the counts of whales with low tide was based on the premise that the whales concentrated in narrow channels, making them easier to count than when they spread out at the higher tides. We also took advantage of lower tides in Knik and Turnagain Arms to reduce the effective survey area (at low tide, large areas of mudflats are exposed that would otherwise have to be surveyed), but the timing with the tidal cycle was more opportunistic here than was our timing at the Susitna delta.

Aerial Tracklines

Coastal surveys were conducted on a trackline approximately 1.4 km offshore. The objective was to find beluga whales in shallow, nearshore waters where they typically have been seen in summer (Calkins 1984). The trackline distance from shore was monitored with an inclinometer such that the waterline was generally 10º below the horizon while the aircraft was at the standard altitude of 244 m (800 ft). Ground speed was approximately 185 km/hr (100 knots). This coastal survey included searches up rivers until the water appeared to be less than 1 m deep, based on the appearance of rapids and riffles.

In addition to the coastal surveys, offshore transects were flown across the inlet. A sawtooth pattern of tracklines was designed to cross over shore at points approximately 30 km apart starting from Anchorage and zigzagging to the southern limits of Cook Inlet, between Cape Douglas and Elizabeth Island (Fig. 1).

Search Technique

Observers searched forward and laterally, but not behind the wing line. When away from shore, the search typically focused on a zone approximately 10° or more below the horizon (1-2 km from the aircraft) and 10° to 60° to the left (or right) of the trackline. This zone was considered to have a relatively good probability for detecting whales.

The search area for observers on the shore side of the aircraft was bounded by the shoreline, 1.4 km (10°) from the trackline. The steepest angles observers could search were 81-86°, depending on the height of the observer relative to the window frame, but typically there may have been little search effort expended at angles exceeding 75° (0.07 km off the trackline). This would mean there was a 0.14 km (140 m) wide blind zone along the trackline. When the search was concentrated in the typical viewing area, 10° to 60° off the trackline 1-2 km ahead of the aircraft, there would have been reduced effort within 0.4 km of the trackline, possibly lowering sighting rates in a 0.8 km wide swath under the aircraft.

Sighting Records

Immediately on seeing a beluga group, each observer reported the sighting to the recorder. As the aircraft passed abeam of the whales, the observer informed the recorder of the species, inclinometer angle, whale travel direction, and notable behaviors. With each sighting, the observer's position (left front, left rear, etc.) was also recorded. The recorder repeated these entries back to the observer to confirm accuracy. An important component of the effort by the observers on the left was that they not cue each other to their sightings. They had visual barriers between them, and their headsets did not allow them to hear each other, but they could be heard by the recorder, and the recorder was able to selectively confirm their sighting information. As these data were being entered, the aircraft continued past each whale group until it was out of sight; then the aircraft returned to the group and began the circling routine. If one observer missed seeing a group on transect, there was no cue to the sighting until the aircraft turned to circle the group. The pilot and data recorder did not call out whale sightings or in any way cue the observers to the presence of a whale group.

Distance to Sightings

The distance between the location of the aircraft when an initial sighting was made and the location of the whale group gave an indication of the observers' effective search perimeter. The whale group location was established at the onset of the aerial passes by flying a criss-cross pattern over the group, recording starts and stops of group perimeters. The perimeter point closest to the aircraft's location at the initial sighting was used to calculate the sighting distance.

Counting Techniques

The flight pattern used to count a whale group involved an extended oval around the longitudinal axis of the group with turns made well beyond the ends of the group. Whale counts were made on each pass down the long axis of the oval. Because groups were circled at least four times (4 passes for each of two pairs of observers on the left side of the aircraft), there were typically 8 or more separate counts per group. Counts began and ended on a cue from the left front observer, starting when the group was close enough to be counted and ending when it went behind the wing line. This provided a record of the duration of each counting effort. The paired observers made independent counts and wrote down their results

along with date, time, pass number, and quality of the count. The quality of a count (A through F) was a function of how well the observers saw a group, rated A if no glare, whitecaps, or distance compromised the counting effort, and rated down to F if it was not practical to count whales on that pass. These notes were not exchanged with anyone else on the aerial team until after all of the aerial surveys were completed. This was done to maximize the independence of each observer's estimates.

Typically, counting techniques involved a rapid tally from left to right across the whale group, mentally registering each surfacing whale as fast as possible or counting by fives or tens. Large groups were counted on a single visual pass across the group without looking back except slightly to include new surfacings close to the counting focus. This gave only a few seconds of search time on any particular beluga location. Dispersed or small groups allowed slightly longer counting efforts because it was easier to keep track of surfacings. Generally counts consisted of the number of visible whale backs, but if wakes, mud plumes ("contrails"), or other obvious indications of a whale's presence were included in a count, they were noted in comments. Aerial counts were of the number of sighting cues; later analysis would approximate the total number of whales present, whether or not they were visible from the aircraft.

When groups were circled, the right front observer moved to the co-pilot's seat and used a video camera through an open window to document the belugas. The camera was set on manual focus and operated at maximum useable shutter speeds (1/1000 to 1/10,000 sec, depending on available light). Date and time were recorded directly onto the video image. For compact groups of whales, magnification was adjusted to keep the entire group in view throughout the pass. Dispersed groups were better documented by maintaining the camera in a set position and at a constant magnification. As a study of the ability for the standard video (generally operated at 1 to 8 power) to capture whale images - especially gray juveniles, which are hard to detect - a paired video camera was operated at maximum magnification (15x). The two cameras were mounted on a board such that they had overlapping fields of view and were operated simultaneously during certain dedicated circlings over beluga groups.

On some tests, a still camera (Nikon F2) with 135 mm lens and Fuji 400 Provia film was used in the left rearmost position. This position had an opening window and allowed the camera to be fired perpendicular to the trackline. Prior to each aerial pass over a whale group, a photo of an identifiable marker (e.g., fingers held to show pass number) was taken by each camera.

Analysis

In each season from 1994-96, whale groups were systematically videoed whenever possible. These video images were studied in the laboratory, and counts of whales were made to compare to the infield counts (see Waite and Hobbs 1995). Analysis of both the aerial counts and counts from the video tapes are described in Hobbs *et al.* (1995) for 1994 data. Hobbs *et al.* (1995), Lerczak (1995), and Waite *et al.* (1995) describe tagging operations used to establish corrections for whales missed during aerial counts of beluga whales.

RESULTS

Survey Effort

A total of 39.73 hr of aerial surveys were flown around Cook Inlet 11-17 June 1996. All of these surveys (10 flights ranging from 1.7 to 6.1 hr) were based out of Anchorage. Systematic search effort was conducted for 20.60 hr, not including time spent circling whale groups, deadheading without a search effort, or periods with poor visibility. Visibility and weather conditions interfered with the survey effort during only 0.13 hr (0.6% of the total effort) when one or more observers considered the visibility poor or worse. There were 7.5 hr of video tape collected over whales. Results from video analysis will be reported in a separate document.

The first survey, on 11 June, was a reconnaissance flight targeting the delta of the Susitna River, an area where beluga whales have been found consistently during previous surveys. Counting techniques were practiced and dual videography was tested. Dual videography and photography tests were done again on whale groups in the Susitna delta on 17 June.

Stranded Belugas

We initiated a survey of upper Cook Inlet on 12 June, but the course was changed to study a group of stranded beluga whales, reported to us by a pilot in the Susitna area at 10:30. At the time of the report, the animals were already well above the waterline. We found the group on a mudflat south of the east margin of the Susitna River (61°11.24'N 150°32.96W). From 10:55 to 11:21, we circled the group to document the stranding on video and to make counts. A total of 63 whales (55-61 by aerial estimates) were together in one discontinuous group; at least half (n = 28) were white, half (n = 27) were gray, and 4 were calves. When we first saw the group, it was approximately 100 m from the waterline. Whales were still thrashing, and some amount of movement was seen occasionally over this and the subsequent observation periods, at 12:32-12:38 and 13:22-14:04. Many gulls were nearby, but none were seen on the whales. Blood was visible on or near several whales. We left the area temporarily, returning when the tide was rising. From 13:36-13:55, as the tide flooded the stranding site, the whales began swimming again and moved away. Low tide (-1.7 ft) was at approximately 11:30. The animals swam away when the tide was approximately +12 ft. If the stranding also occurred at this tide height, then the whales may have been stranded from 08:30 to 14:00, that is, for 5.5 hr. When the whales began to swim away, they moved slowly and went in different directions, but minutes later they came together and began traveling as a group going south toward deeper water. After the group swam free of the stranding, we conducted a series of standard aerial counts over the group. Using only A and B quality counts (some counts were compromised by glare), there were 21, 35, and 33 counted by one observer and 35, 32, and 32 counted by another. The median of these counts (33) is 52% of the known number (63) for the stranded group. It is not known how much the stranding may have affected the surfacing performance of these whales during the subsequent aerial counts.

Dead Belugas

On the same day, at 18:32 on June 12, a dead, floating beluga whale was seen in the Susitna delta 7.6 km north of the stranding site. Because the tide had been rising since the stranding, and the tide would carry flotsam to the north, it is possible this dead whale had been among the stranded animals. However, there was an extensive area of broken tissue on the exposed portion of the back (probably caused by the gulls seen on the carcass), and the carcass was floating, suggesting that the whale had been dead more than the 4.5 hr observed since the end of the stranding. This area, the Susitna delta, is heavily hunted for beluga whales.

Another dead beluga whale was seen on 14 June mid-way between Pt Possession and Anchorage. There was no evidence that the two sightings were or were not of the same animal.

Coastal Surveys

On 13 and 16 June, we flew coastal surveys of the perimeter of upper Cook Inlet north of East and West Forelands, including Knik Arm, Turnagain Arm, and the lower portions of the McArthur, Beluga, and Susitna Rivers. On 14 June, the survey covered the east shore of Cook Inlet from Pt Possession to Elizabeth Island followed by sawtooth transects across the open water portion of the inlet back to Anchorage. On 15 June, a second set of sawtooth transects were flown that criss-crossed the first set, followed by a survey of the west shore of Cook Inlet from Cape Douglas to West Foreland, including St Augustine and Kalgin Islands (Fig. 1).

Coverage

The composite of these aerial surveys provided a thorough coverage of the coast of Cook Inlet (1388 km) for all waters within 3 km of shore (Fig. 1). In addition, there were 1538 km of offshore aerial transects flown. Assuming a 2.0 km transect swath (1.4 km on the left plus 1.4 km on the right, less the 0.8 km blind zone beneath the aircraft), our coastal plus offshore tracklines covered 5852 sq km, which means approximately 29% of the 19,863 sq km surface area of Cook Inlet was surveyed. This calculation does not account for some intersections of offshore transect lines nor for the fact that observers generally searched well beyond 1.4 km. These surveys covered virtually 100% of the coastal area where beluga whales were expected.

Distance to Initial Sighting

Distances between the aircraft and a beluga group at the moment of the initial sighting ranged from 0.00 to 4.26 km (n = 47, combining data from 1994-96; Table 2 shows data from the 1996 survey). The mean sighting distance was 1.54 km (sd = 0.95). Half (49%) of the initial sightings occurred beyond 1.4 km, the perimeter of the standard viewing area. Distance to a group was positively correlated to the size of the group (Kendall distribution-free test for independence, $K^* = 1.95$, $p = 0.026$).

Distance at Closest Pass

Minimum distances between whale groups and the trackline ranged from 0.00 to 3.25 km, with a mean of 0.73 km (sd = 0.69; n = 50, combining data from 1994-96; Table 2 shows data from 1996). In 10 of 50 instances, the trackline went over a beluga group, and in 7 instances (14%) groups were more than 1.4 km from the trackline; 8% of small groups (<20 whales) and 22% of large groups were beyond 1.4 km at the closest pass.

Missed Groups

All four of the primary observers in 1996 had prior experience in surveying for beluga whales in Cook Inlet. Two other observers accompanied some of the flights, but they were not included in the inter-observer analysis because of the short time they were with the project. Results from June 1996 were combined with those from June 1994 (Rugh *et al.* 1995) and July 1995 (Rugh *et al.* 1996) to increase the sample size. These records do not account for the possibility of whale groups missed by all observers, a calculation which will be developed in a separate document.

Of 40 groups recorded in 1994-96, 17 were reported by only one primary observer and missed by the other, while 23 groups were reported by both observers. Whether or not an observer saw a whale group was affected in part by the size of the group. The mean group size of those missed by an observer ($\bar{x}$ = 23; s.d. = 37) and groups reported by both observers ($\bar{x}$ = 79; s.d. = 74) were significantly different ($z = -6.35$, $p << 0.01$). Most (70%) of the whale groups seen in the Susitna Delta area were large (>20), and most (93%) of the groups seen elsewhere in Cook Inlet were small.

Distance also affected the probability of missing a group. Of 5 recorded groups that were >1.4 km from the trackline at the closest pass, only 2 (30%) were seen by both observers; of 33 groups within 1.4 km, 18 (55%) were seen by both; of 13 groups within 0.5 km of the aircraft, 10 (77%) were seen by both observers.

Observer performance affected sighting rates (Table 3). Two observers (B and C) had higher missed rates (40-50%) compared to the other four observers (5-19%). Individual observer's sighting rates varied from a mean of 0.31 groups/hr (observer B) to 0.80 groups/hr (observer A), with three observers (C, D, E) having nearly identical sighting rates (.58-.59 groups/hr). However, the amount of paired, independent search effort has varied among observers from 10.4 to 31.0 hrs, and the sample size is considered too small to be conclusive with the number of observers and the number of covariates that should be treated in this analysis.

In summary, we have isolated three parameters that have the potential for significantly affecting whether or not a beluga group was seen: group size (<20 vs >=20), distance (<1.4 vs >=1.4 km), and observer. These parameters probably have interactive components, such as group size and distance as a function of where an individual observer tends to search; however, sample sizes are too small to adequately test all of these components and to provide corrections based on each observer's performance.

Aerial Estimates of Beluga Group Sizes

Aerial estimates of group size were reviewed for differences as a function of count quality, subjectively rated from A to F, in 1995 and 1996. Mean estimates of each quality rating were compared to all higher ratings. Accordingly, F quality estimates (n = 6) were on average 74% of A, B, C, and D estimates; D estimates (n = 23) were 59% of A, B, and C; C estimates (n = 38) were 86% of A and B; and B estimates (n = 38) were 91% of A quality estimates. Only quality A and B estimates were used in the following analysis.

Aerial counts of beluga whales are shown in Table 4, and sighting locations are shown in Figure 1. These counts are the medians of each primary observers' median counts on

multiple passes over a group. The consistency of locations of resightings between days, particularly the whales near the Susitna Rivers and whales in Chickaloon Bay, allowed us to combine results among survey days, assuming whales did not travel long distances within the survey period. Therefore, using median counts from each site, the sum of the counts ranged from 154 to 361. This sum is not corrected for missed whales. Calculations for whales missed during these aerial counts and an estimate of abundance will be developed in a separate document.

DISCUSSION

In Cook Inlet, beluga whales concentrate near river mouths during spring and early summer, especially in the northwest corner of the inlet between the Beluga and Little Susitna Rivers (Fig. 1), described here as the Susitna Delta. Fish also concentrate along the northwest shoreline of Cook Inlet, especially in June and July (Moulton 1994). Most of our of sightings of beluga whales have been in the Susitna Delta (56% in June 1993; 81% to 91% in June/July 1994-96). This concentration apparently lasts from mid-May to mid-June (Calkins 1984) or later and is very likely associated with the migration of anadromous fish, particularly eulachon (*Thaleichthys pacificus*) (Calkins 1984; 1989). We found that whales were more concentrated in June 1994 and June 1996 than in July 1995, perhaps evidence of this seasonal effect. Elsewhere in upper Cook Inlet in June and July, we have consistently found a group of 20-50 whales in Chickaloon Bay, and sometimes other groups have been seen in Knik Arm (1-80), Turnagain Arm (7), and Trading Bay (1-31) . In lower Cook Inlet, we have occassionally seen small groups: 1 just south of West Foreland in 1993, 9 in Kachemak Bay in 1994, 2 in Iniskin Bay in 1994, and 14 in Big River in 1995. Only 0-4% of our sightings in June and July from 1993-96 have occurred in lower Cook Inlet (Table 5).

Others who surveyed in June (Calkins 1984) also found the majority of animals in the northwest corner of the inlet (88% of the sightings made 1974-79), but far fewer in July (15% in 1974-79). Calkins (1984) reported seeing 26 beluga whales in Redoubt Bay and 25 whales south of Kasilof River in June. In July, 44% of his sightings were in the lower inlet. These were in groups ranging in size from 11 to 100 found between the Forelands and Tuxedni Bay, most well away from the coast. Calkins (1979:40) indicated that belugas were "seen throughout the year in the central and lower Inlet." Our records from June/July 1993-96 found only 0-4% of the whales in lower Cook Inlet.

In almost none of our survey years (1993-96) have we made sightings of beluga whales in deep water well away from shore. The furthest offshore sighting was a single whale 9.3 km offshore in 1996 in water 19 m deep. This whale was barely moving at the surface. In 1994, a group of beluga whales was seen 2.2 km from shore, but this was over shallow shelf waters listed as <1 m deep at lower low tides (NOAA Nautical Chart #16660). In every case, beluga whale groups of more than 1 animal were seen on the shore side of the aircraft; sometimes whale groups were so large they were seen from both sides of the aircraft, but only once - with the single whale mentioned here - was a group seen only on the open water side of our tracklines.

There have been sightings of beluga whales in the Gulf of Alaska outside of Cook Inlet.
Harrison and Hall (1978) saw belugas near Kodiak Island in March and July. Murray and Fay (1979) also found belugas near Kodiak Island, as well as in Shelikof Strait, south of Prince William Sound, and in Yakutat Bay. Leatherwood *et al.* (1983) recorded one beluga near the southwest entrance of Shelikof Strait on 6 August 1982, but no other belugas were seen by them on the north or south shores of the Alaska Peninsula. Some sightings have been made in Prince William Sound in March (Harrison and Hall 1978) and Yakutat Bay in May (Calkins and Pitcher 1977), September (R. Ream, NMFS, NMML pers. commun.), and February (B. Mahoney), perhaps as occasional visitors from Cook Inlet (Calkins 1989). These sightings indicate that at least some of the time there are beluga whales in the northern Gulf of Alaska outside of Cook Inlet. However, no sightings of belugas were made during many intensive aerial surveys around the Alaska Peninsula (Brueggeman *et al.* 1989; Frost *et al.* 1983; Harrison and Hall 1978; Leatherwood *et al.* 1983; Murie 1959; NMFS unpubl. data) supporting the hypothesis that the Cook Inlet stock is isolated from stocks in the Bering Sea, and that the Cook Inlet stock is not widely dispersed.

Survey methods for the 1996 study were developed from similar studies in 1993 (Withrow *et al*. 1994), 1994 (Rugh *et al.* 1995), and 1995 (Rugh *et al.* 1996). The 1994, 1995, and 1996 studies were some of the most thorough and intensive surveys yet conducted for beluga whales in Cook Inlet. These were also among the first aerial surveys for cetaceans in which paired, independent observation efforts were conducted systematically throughout the studies, with whale counts kept confidential until the field projects were concluded. It became evident that observers without previous experience had low sighting rates relative to experienced observers. This may in part be due to a need for developing appropriate search images and search patterns, and may also be a function of becoming familiar with the complex research protocol. Results from new observers may be compared to trained observers for use in future analysis for surveys that might be conducted without trained observers; however, more studies are needed to document the consistency of sighting rates or variances between observers. Details on survey protocol can be found in Rugh (1996).

Whale groups could sometimes be seen over 4 km away, but most initial sightings were at the limits of the typical search zone: 10˚ below the horizon or 1.4 km from the aircraft. By keeping the aerial trackline 1.4 km offshore, the survey optimized opportunities for seeing belugas. Calculations of initial sighting distances are conservative because inevitably a few seconds lapsed between the first sighting of the group, the reporting to the recorder, and the computer entry that grabbed the GPS position. At 185 km/hr, there would be a 50 m error for every 1 second delay. On the other hand, group locations were often determined as the center of the group because the perimeters are difficult to define. This potentially overestimated sighting distances if the initial sighting was actually on the near side of the group.

The distribution of intial sightings, particularly as a function of group size suggests there are whale groups that are not recorded. Differences in sighting rates between large and small groups is often more a function of the number of sighting cues available than the total

surface area of the group, except when a group is so dense it provides a large visual target. In our study in 1996, out of 14 whale groups recorded during systematic searches, 12 were seen by both of the primary observers. The groups seen by only one observer had counts of 7 and 41 whales respectively. In 1995, out of 14 groups, only 9 were seen by both observers; and in 1994, out of 15 groups only 6 were seen by both. These records do not include groups missed by both observers.

Aerial sightings of belugas were generally of white backs as the whales arched during a surfacing, although surface disturbances were included in the counts. Small, dark gray animals, such as calves or yearlings, were probably under represented in the aerial counts (see Hobbs *et al.* 1995 for calculations of number of animals missed in the aerial counts). The number of beluga whales counted at the surface was inconsistent between aerial passes. This was in part due to changes in visibility, such as glare, but also due to changes in the amount of time the group was counted. Although there was not a constant number of animals in view, as might be expected if there was a random surfacing rate, we did not observe an apparent synchrony in surfacings either. Calkins (1979) describes waves of three sub-groups surfacing in synchrony within a larger group such that the first group is resurfacing as the third group submerges. We did not see any patterned surfacings of this sort.

The proximity of the aircraft to belugas did not seem to reduce sighting opportunities as the whales showed no apparent reaction to the survey aircraft. This is consistent with observations in other years (Withrow *et al*. 1994; Rugh *et al.* 1995, 1996) and may be due to habituation to the dense air traffic in the area. Our aircraft was not a novel stimulus: during most of our surveys in Upper Cook Inlet, many other aircraft were in view at any one time.

The uncorrected sum of median estimates made from the June 1996 aerial observations in Cook Inlet ranged from 154 to 361 beluga whales. Using the same procedure of summarizing median estimates from the highest seasonal counts at each site, there were 344 beluga whales in June 1993, 287 in July 1993, 157 in September 1993, 279 in June 1994, 338 in July 1995, and 361 in June 1996 (Table 5). The process of using medians instead of maximum numbers reduces the effect of outliers (extremes in high or low counts) and makes the results more comparable to other surveys which lack multiple passes over whale groups. Medians or means are also more appropriate than maximums when counts will be corrected for missed whales. Not until the respective correction factors have been applied will absolute abundances or inter-year trends be calculated.

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Table 1. Tidal conditions at the Susitna River delta when counts of beluga whales were made. Tide times were estimated as 1.0 hr prior to reported times for the NOAA Harmonic Station in southern Knik Arm, near Anchorage (61˚14'N 149˚53'W).

Date (1996)	Survey time	Tide time	Tide height (ft)	Counts of belugas	Number of groups
11 June	11:50-13:42	low 11:00	-0.4	126	4
12 June	12:46-13:19	low 12:00	-1.7	160	4
12 June	17:39-18:29	high 17:30	+26.7	125	4
13 June	13:18-15:09	low 13:00	-2.1	154	3
16 June	14:39-16:36	low 14:00	-1.2	237	4
17 June	14:02-17:43	low 14:30	-1.0	291	4

Table 2. Initial sighting information on each group of beluga whales recorded during the June 1996 survey in Cook Inlet. Group size is the median estimate made by all observers doing counts on that pass. An underline indicates which observer first saw a group. An x indicates which observers missed a sighting while on transect. Observers A and B were in previous year's surveys and did not return in 1996; observers G and H flew on only a few of the surveys in 1996 and are not included in subsequent analysis.

Date	Flt	Grp	Location	Group size	Left Front obsv	Left Mid obsv	Left Rear obsv	Right Front obsv	Initial Sighting Distance (km)	Closest dist. (km)
11 June	1	1	S of Beluga R.[1]	1	----	----	----	F	0.69	0.69
	1	2	Beluga R.	7	D	Cx	Gx	----	2.76	0.71
	1	3	Beluga R.[1]	1	----	----	----	F	----	----
	1	4	Theodore R.	4	D*	C*	G?*	----	1.10	0.00
	1	5	Lewis R.	113	D*	C*	G?*	F*	"	"
12 June	2	1	Knik Arm	6	E*	F*	G?*	----	1.22	0.13
	2	2	Knik Arm	2	----	----	----	C	----	----
	2	3	Stranded on Susitna Delta	61	----	----	----	----	----	----
	2	4	Pt Possession	----	E	Fx	Gx	----	2.39	0.97
	2	5	Lewis R.	127	----	----	----	C	0.53	0.53
	3	1	Theodore R.	19	F	C	G	----	0.99	0.82
	3	2	Lewis R.	14	F	C	G	----	----	----
	3	3	Big Su R.	92	F	C	G	----	1.23	0.00
13 June	4	1	Knik Arm	8	E	C	G	----	0.93	0.13
	4	2	Knik Arm	9	E*	C*	G*	----	----	----
	4	3	Pt Possession	41	Ex	C?	G	----	3.28	3.25
	4	4	Ivan R.	77	F	D	G	----	4.26	0.52
	4	5	Big Su R.	77	F*	D*	G*	----	----	----
14 June	5	1	Pt MacKenzie	20	----	----	----	E	2.57	2.27
16 June	9	1	Knik Arm	16	D*	C	H	----	0.47	0.37

	9	2	Knik Arm	13	D*	C	Hx	----	0.96	0.95
	9	3	Pt Possession	21	D	C	H	----	2.75[2]	1.84
	9	4	Lewis/Ivan R.	114	F	E	H	----	4.06	0.98
	9	5	Big Susitna	47	C	D	H	----	2.19	1.03
	9	6	Big/ Little Su	59	E	F	H	----	2.95	1.11
	9	7	Little Su Delta	17	E*	F*	H*	----	2.42	1.52
17	10	1	Ivan/Big Su R.	263	H*	E*	F*	D*	----	----
	10	2	Big Su R.	----	H*	E*	F*	D*	----	----
	10	3	Little Su R.	28	H*	E*	F*	D*	----	----
	10	4	Ivan/Big Su R.	78	H*	E*	F*	D*	----	----

[1] This "group" was a single whale near group 2.

[2] Observer "H" saw this group at 4.40 km but with the assistance of binoculars.

*There was open communication between observers, so sightings were not included in inter-observer analysis. In some cases, indicated by a question mark (?), it was not clear whether the respective observer saw the group independently.

Table 3. Pairings of primary observers A to F during aerial surveys over Cook Inlet in June/July 1994-96, showing the number of beluga whale groups reported by each observer while paired. Each of the observers in the top row was compared to the respective paired observer in the leftmost column.

		A	**B**	**C**	**D**	**E**	**F**
	1994	---	5	0	3	---	---
A	1995	---	0	0	2	2	---
	1996	---	---	---	---	---	---
	1994	5	---	0	0	---	---
B	1995	2	---	0	1	0	---
	1996	---	---	---	---	---	---
	1994	2	0	---	4	---	---
C	1995	2	0	---	1	3	---
	1996	---	---	---	3	1	3
	1994	2	0	2	---	---	---
D	1995	1	0	0	---	4	---
	1996	---	---	2	---	0	1
	1994	---	---	---	---	---	---
E	1995	3	0	3	3	---	---
	1996	---	---	2	0	---	2
	1994	---	---	---	---	---	---
F	1995	---	---	---	---	---	---
	1996	---	---	3	1	3	---
Total groups	1994	9	5	2	7	---	---
seen	1995	8	0	3	7	9	---
	1996	---	---	7	4	4	6
Total seen by	1994	12	7	6	7	---	---
one or both	1995	9	3	6	8	10	---
observers	1996	---	---	8	4	5	7
Groups missed	1994	3	2	4	0	---	---
	1995	1	3	3	1	1	---
	1996	---	---	1	0	1	1
Large groups (>20) missed		1	2	3	0	1	0
Percent missed		0.19	0.50	0.40	0.05	0.13	0.14
Hours surveyed	1994	14.2	9.7	10.2	11.8	0	0
while paired	1995	7.0	6.2	5.7	9.6	11.7	0
	1996	0	0	10.6	9.6	10.5	10.4
Groups/hour		0.80	0.31	0.45	0.58	0.59	0.58

Table 4. Summary of counts of beluga whales made during aerial surveys of Cook Inlet in June 1996. Medians from experienced observers counts were used from aerial passes where observers considered visibility good or excellent (conditions B or A). Dashes indicate no survey, and zeros indicate that the area was surveyed but no whales were seen. Sites are listed in a clockwise order around Cook Inlet.

	Flight dates in June 1996							
Location	11 June	12 June	13 June	14 June	15 June	16 June	17 June	Min-max Counts
Turnagain Arm	---	0	0	---	---	0	---	0
Chickaloon Bay	---	*	41	---	---	21	---	21-41
Kenai River	---	---	---	0	---	---	---	0
Kachemak Bay	---	---	---	0	---	---	---	0
Iniskin Bay	---	---	---	---	0	---	---	0
Big River	---	---	---	---	0	---	---	0
McArthur River [a]	---	---	0	---	---	0	---	0
Big Su Delta [b]	126	160 (or 125)	154	---	---	161	263	125-291
Little Su River	0	0	0	---	---	76	28	(b)
Knik Arm [c]	---	8	17	20	---	29	---	8-29

Total = 154-361

* Beluga group seen but not counted.

(a) Includes all of Trading Bay.

(b) Includes all groups between Beluga River and Little Susitna River.

(c) Includes Pt Mackenzie.

Table 5. Summary of beluga whale sightings made during aerial surveys of Cook Inlet. Medians were used when multiple counts occurred within a day, and the high counts among days were entered here.

			Percent Sightings		
Year	Dates	Counts	Lower Cook Inlet	Susitna Delta	Elsewhere in Upper Cook Inlet
1993	June 2-5	344	0	56	44
1993	July 25-29	287	0	74	26
1993	Sept 3, 19	157	9	16	75
1994	June 1-5	279	4	91	5
1995	July 18-24	338	4	89	7
1996	June 11-17	361	0	81	19

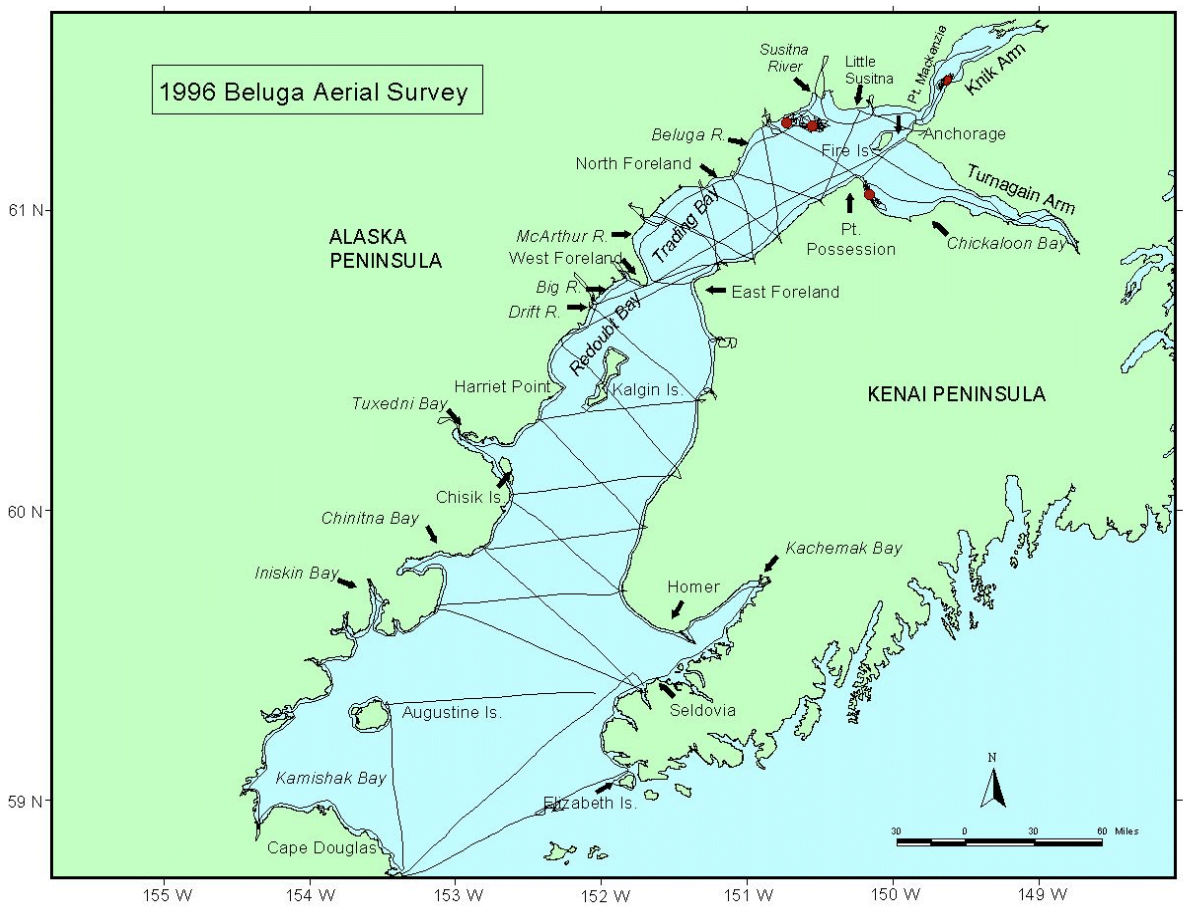

Fig. 1. Aerial survey tracklines for 11-17 June 1996 covering the coastal and offshore areas of Cook Inlet. Dashed areas indicate mud flats exposed at low tide.