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AERIAL SURVEYS OF BELUGA WHALES IN COOK INLET, ALASKA, JUNE 1997

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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 8-10 June 1997. This provided a thorough coverage of the coasts around the entire inlet (1,388 km). Therefore, 100% of the coastal areas where belugas were expected to be during this season were searched one or more times. The 23 hr survey was flown in a twin-engine, high-wing aircraft at 244 m (800 ft) altitude and 185 km/hr (100 kt) along a trackline 1.4 km from shore. Throughout most of this survey, a test of sighting rates was conducted with multiple independent observers on the coastal (left) side of the plane, where virtually all 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. The sum of the aerial estimates (using median counts from each site, not corrected for missed whales) ranged from 217 to 264 whales, depending on survey day. Only 1 beluga whale was found in lower Cook Inlet, 51-73 were counted near the Susitna River, 139-161 were seen in Knik Arm and 26-29 were counted in Chickaloon Bay. Combining data from 1994-97, almost half (46%) of the initial sightings occurred >1.4 km from the aircraft - the perimeter of the standard viewing area - with mean sighting distances of 1.2 km for small groups (<20 whales) and 1.9 km for larger groups (>= 20). In only 8 of 59 instances were whale groups >1.4 km from the trackline. Of 106 groups recorded by paired, independent observers in 1994-97, 20 were reported by only one primary observer, while 86 (81%) were reported by both observers.

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. Beluga whales in Cook Inlet are very concentrated in a few river mouths during parts of the year (as reviewed in Shelden 1994). 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. The Alaska Regional Scientific Review Group (ASRG) "felt very strongly that every effort should be made to survey this population every year" (letter from L. Lowry, Chair of ASRG, to S. Pennoyer, NMFS, dated 13 May 1997).

Since 1993, NOAA's National Marine Mammal Laboratory and its Alaska Regional Office have conducted annual aerial surveys to study the distribution and abundance of beluga whales in Cook Inlet (Withrow *et al*. 1994; Rugh *et al*. 1995, 1996, 1997). These studies have been in cooperation with the Alaska Beluga Whale Commission and the Cook Inlet Marine Mammal Council. Aerial surveys are the established method used to collect distribution and abundance data for beluga whales in Cook Inlet since the 1960's (Klinkhart 1966; Calkins 1984; Calkins *et al*. 1975; Murray and Fay 1979).

The objectives of the aerial surveys were to make a complete search for beluga whales around the perimeter of Cook Inlet and to 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 since 1994. 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.

METHODS

Survey Aircraft

The survey aircraft , a deHavilland Twin Otter, has twin-engines, high-wings and a seating capacity for six passengers plus two pilots. There are large bubble windows at two of the three primary observer positions (left and right front). An intercom system allowed communication among the observers, data recorder and pilots. During systematic search efforts, the two primary observers on the left side removed the cabling to their headset earphones such that they could not hear others report whales, but they could still be heard by the recorder, thereby allowing for independent search efforts. Positional data were collected from the aircraft's Global Positioning System (GPS) interfaced with the laptop computer used to enter sighting data. Data entries included routine updates of locations, 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 surveys timed to occur within one hour of low tide at the Susitna Delta, where most of the whales have been seen in the past. 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 dispersed 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 1997, no offshore transects were flown across the inlet. This was to maximize the efficiency of the survey by not searching away from the coast where whales have not been found during past surveys.

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 but not group size. With each sighting, the observer's position (left front, left rear, etc.) was also recorded. 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. As these data were being entered, the aircraft continued past each whale group until it was out of sight; then the aircraft retumed to the group and began the circling routine. 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.

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 tums 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 rear observer (whose peripheral search was limited by having a flat window instead of a bubble window), 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. Only quality A and B estimates were used in the analysis. Sighting 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.

Video images will be 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. Corrections for whales missed during aerial counts of beluga whales will be developed in a separate document.

RESULTS

Survey Effort

A total of 22.6 hr of aerial surveys were flown around Cook Inlet 8-10 June 1997. All of these surveys (4 flights ranging from 3.4 to 6.7 hr) were based out of Anchorage. Systematic search effort was conducted for 13.0 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 1.9 hr (9% of the total flight time) when the left-front observer considered the visibility poor or worse. There were 1.1 hr of video tape collected over whales. Results from video analysis will be reported in a separate document.

On 8 and 10 June, the survey area included 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 9 June, the survey covered the east shore of Cook Inlet from Pt Possession to Elizabeth Island and all of the west shore from Cape Douglas to Pt Mackenzie, including St Augustine and Kalgin Islands (Fig. 1).

The composite of these aerial surveys provided a thorough coverage of the coast of Cook Inlet (1388 km) for all waters within approximately 3 km of shore (Fig. 1). 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 tracklines covered 2,776 sq km, which is approximately 14% of the surface area of Cook Inlet; however, these surveys covered virtually 100% of the coastal area where beluga whales were expected. Most of upper Cook Inlet was surveyed three times, in particular the Susitna Delta where large groups of beluga whales have usually been found. Each of the surveys in this area were timed near the low tide (-0.6 to -0.4 m, with a maximum low of -0.7 m on 8 June; +2.0 to +2.3 m, with a maximum low of -0.3 m on 9 June; +0.6 to +0.3 m, with a maximum low of +0.2 m on 10 June).

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 = 59, combining data from 1994-97; Table 1 shows data from the 1997 survey). Almost half (46%) of the initial sightings occurred beyond 1.4 km, the perimeter of the standard viewing area, because observers searched well ahead of the aircraft. The mean sighting distance was 1.2 km (CI = 0.23) for groups with less than 20 whales and 1.9 (CI = 0.38) for groups of 20 or more (different at the $p = 0.005$ level, $F = 2.68$). Figure 2 demonstrates the frequency distribution of distances relative to whether the groups were small (<20) or large (>=20). This group size (20) formed a convenient definition because it split the sample size in half (30 of 59 groups in the sample had <20 whales each).

Distance at Closest Pass

Minimum distances between whale groups and the trackline ranged from 0.00 to 3.25 km. Figure 3 shows that these sighting distances were affected by whether whale groups were small (<20) or large (>=20)($p = 0.006$, $F = 2.67$; combining data from 1994-97; $n = 59$). Table 1 shows data from 1997. Mean distances were 0.63 km for small groups and 0.95 for large groups. In 20 of 59 instances, the trackline was within 0.5 km of a beluga group, including flying directly over it, and in 8 instances groups were more than 1.4 km from the trackline; 7% of small groups (<20 whales) and 20% of large groups were beyond 1.4 km at the closest pass, generally up rivers.

Missed Groups

All four of the primary observers in 1997 had prior experience surveying for beluga whales in Cook Inlet. One other observer accompanied one of the flights, but this effort was not included in the inter-observer analysis. Results from June 1997 were combined with those from 1994 to 1996 to increase the sample size of the test of paired, independent observers, many of whom flew with this project several seasons in succession. These records do not account for the possibility of whale groups missed by all observers.

Of 49 groups recorded in 1994-97, 18 were reported by only one primary observer, while 31 groups (63%) 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 ($\bar{x} = 23.4$; s.d. = 37.4) and groups reported by both observers ($\bar{x} = 67.3$; s.d. = 67.8) were significantly different ($F = 3.28$, $p = 0.009$).

Distance did not significantly affect the probability of missing a group ($F = 1.87$, $p = 0.110$ for initial sighting distances; $F = 1.00$, $p = 0.48$ for closest distances). However, of 14 recorded groups that were <0.5 km from the trackline at the closest pass, only 3 (21%) were missed by one observer, and 11 (79%) were seen by both. Of 4 groups that were beyond 1.4 km at the closest pass, 2 were missed by one observer, and 2 were seen by both.

Group size affected sighting rates ($F = 3.28$, $p = 0.009$) as evidenced by the low missed rate (3 out of 22, or 14%) for groups of >= 20 whales and the relatively higher missed rate for groups with < 20 whales (13 missed out of 25, or 52%).

Observer performance affected sighting rates. The summary of the 1994-97 data shows that inexperienced observers have higher missed rates (67%) relative to those who have already done aerial searches for beluga whales (19%). Furthermore, two of the experienced observers had higher missed rates (41%) compared to the other four primary observers (10%). However, 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.

Aerial Estimates of Beluga Group Sizes

Aerial counts of beluga whales are shown in Table 2, 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 River, Knik Arm and in Chickaloon Bay, allowed us to combine results among survey days, assuming whales did not travel long distances within the 3 day survey period. Therefore, using median counts from each site, the sum of the counts

ranged from 217 to 264. 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), although in June 1997 the primary concentration was in Knik Arm. These concentrations of beluga whales apparently last from mid-May to mid-June (Calkins 1984) or later and are very likely associated with the migration of anadromous fish, particularly eulachon (*Thaleichthys pacificus*) (Calkins 1984; 1989). We did not find a change of the density of these whale groups between early June and late July, but there was some indication that the whales were dispersing out of the Susitna Delta, especially by the time we made observations in September. Elsewhere in upper Cook Inlet in June and July, we have consistently found a group of 20-50 whales in Chickaloon Bay. Groups seen in Knik Arm and Trading Bay may be associated with the large concentrations in the Susitna Delta, while whales seen in Turnagain Arm are thought to be a part of the concentration in Chickaloon Bay. All of these groups potentially interact to some degree, especially in the winter when much of this area is ice-covered, but the consistency of sightings in a few locations suggests there is some amount of territoriality. In lower Cook Inlet, we have occasionally seen small groups: 1 just south of West Foreland in 1993, 9 in Kachemak Bay in 1994, 2 in Iniskin Bay in 1994, 14 in Big River in 1995 and 1 in Tuxedni Bay in 1997. Only 0-4% of our sightings in June and July from 1993-97 have occurred in lower Cook Inlet (Table 3).

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." However, we have not found whales here in spite of excellent viewing conditions in some years.

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, NMFS, pers. commun.), 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 1997 study were developed from similar studies in 1993 (Withrow *et al*. 1994), 1994 (Rugh *et al*. 1995), 1995 (Rugh *et al*. 1996) and 1996 (Rugh *et al*. 1997). These studies were some of the most thorough and intensive surveys yet conducted for beluga whales in Cook Inlet. They 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 (Fig. 2) suggests there are whale groups that were 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 studies from 1994-97, there have been 106 sightings made while independent search efforts were underway. Of these, only 86 (81%) were seen by both primary observers. Inexperienced observers had lower sighting rates (33%), and there was some inconsistency in sighting rates among the experienced observers, but the sample size is too small to make different correction factors for each observer. These records do not include groups missed by both observers.

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, 1997) 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 1997 aerial observations in Cook Inlet ranged from 217 to 264 beluga whales. Using the same procedure of summarizing median estimates from the highest seasonal counts at each site, for June or July for each year 1993-97, there were, respectively, 344, 279, 338, 361 and 264 beluga whales (Table 3). 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. Initial sighting information on each group of beluga whales recorded during the June 1997 survey in Cook Inlet. Group size is the median estimate made by all observers doing counts on that pass. An x indicates which observer missed a sighting while on transect. Observers A, B, and C were in previous year's surveys and did not return in 1997. Dashes indicate that distance calculations could not be made due to irregularities in the flight path.

Date	Group	Location	Group size	Left Front obsv	Left Mid obsv	Right Front obsv	Initial Sighting Distance (km)	Closest dist. (km)
8 June	1	Knik Arm	14	G*	D*		0.90	0.78
	2	Knik Arm	43	E	F	D	1.16	0.58
	3	Knik Arm	42	D	G		1.60	1.34
	4	Knik Arm	1	D*	G*		0.62	---
	5+6	Knik Arm	38	D*	G*		---	---
	7	Knik Arm	2			D	---	---
	8	Chickaloon	16	Fx	E		1.16	0.75
	9	Chickaloon	13	F	E		1.26	0.43
	10	Susitna	72	G	D		1.71	0.83
9 June	1	Tuxedni Bay	1	E	---		---	---
	2	Susitna	51	Gx	E		0.56	0.47
10 June	1	Chickaloon	26	Ex[1]	D		1.74	1.05
	2	Susitna	73	F	G		1.18	1.10
	3	Knik Arm	109			D	2.55	2.41
	4	Knik Arm	46			D	1.00	0.53
	5	Knik Arm	1			D	---	---
	6	Knik Arm	5	D	E		---	---

*There was open communication between observers, so sightings were not included in inter-observer analysis.
[1] This whale group was missed during poor visibility conditions.

Table 2. Summary of counts of beluga whales made during aerial surveys of Cook Inlet in June 1997. 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 1997						
Location	8 June median	high	9 June median	high	10 June median	high	Med-max Counts
Turnagain Arm (East of Chickaloon Bay)	0*		---		0*		0
Chickaloon Bay/ Pt. Possession	29	46	---		26	35	29-46
Pt. Possession to East Foreland	0		0		0		0
Mid-inlet east of Trading Bay	---		0		---		0
East Foreland to Homer	---		0		---		0
Kachemak Bay	---		0		---		0
W side of lower Cook Inlet (Tuxedni only)	---		1*		---		1
Redoubt Bay	---		0		---		0
Trading Bay	0		0		0		0
Susitna Delta (N Foreland to Pt. Mackenzie	72	95	51	95	73	97	73-97
Fire Island	0		---		---		0
Knik Arm	139	259	---		161	227	161-259
						Total =	264-403

* Visibility compromised in some area due to high winds.

Table 3. 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
1997	June 8-10	264	0	28	72

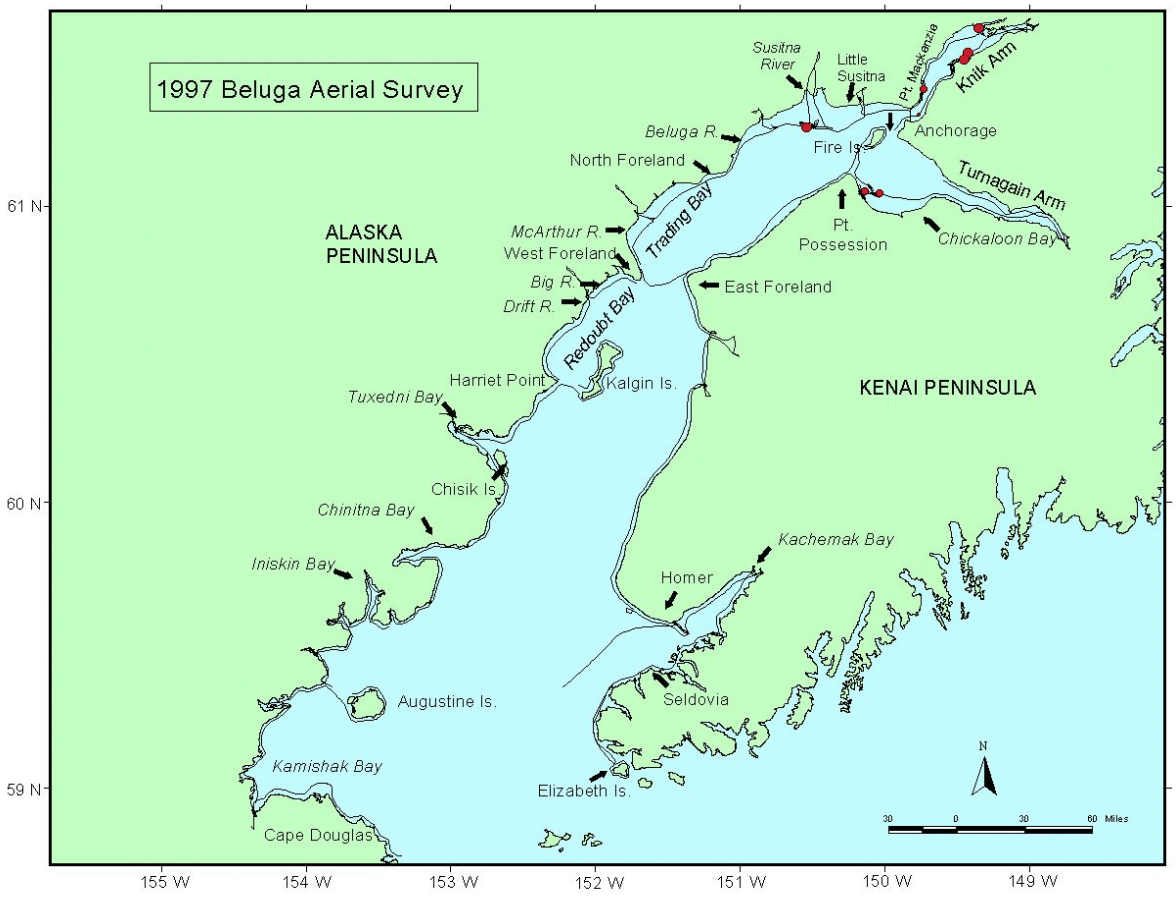

Fig. 1. Aerial survey tracklines for 8-10 June 1997 covering the coastal areas of Cook Inlet. All beluga whale sightings occurred in the upper inlet.

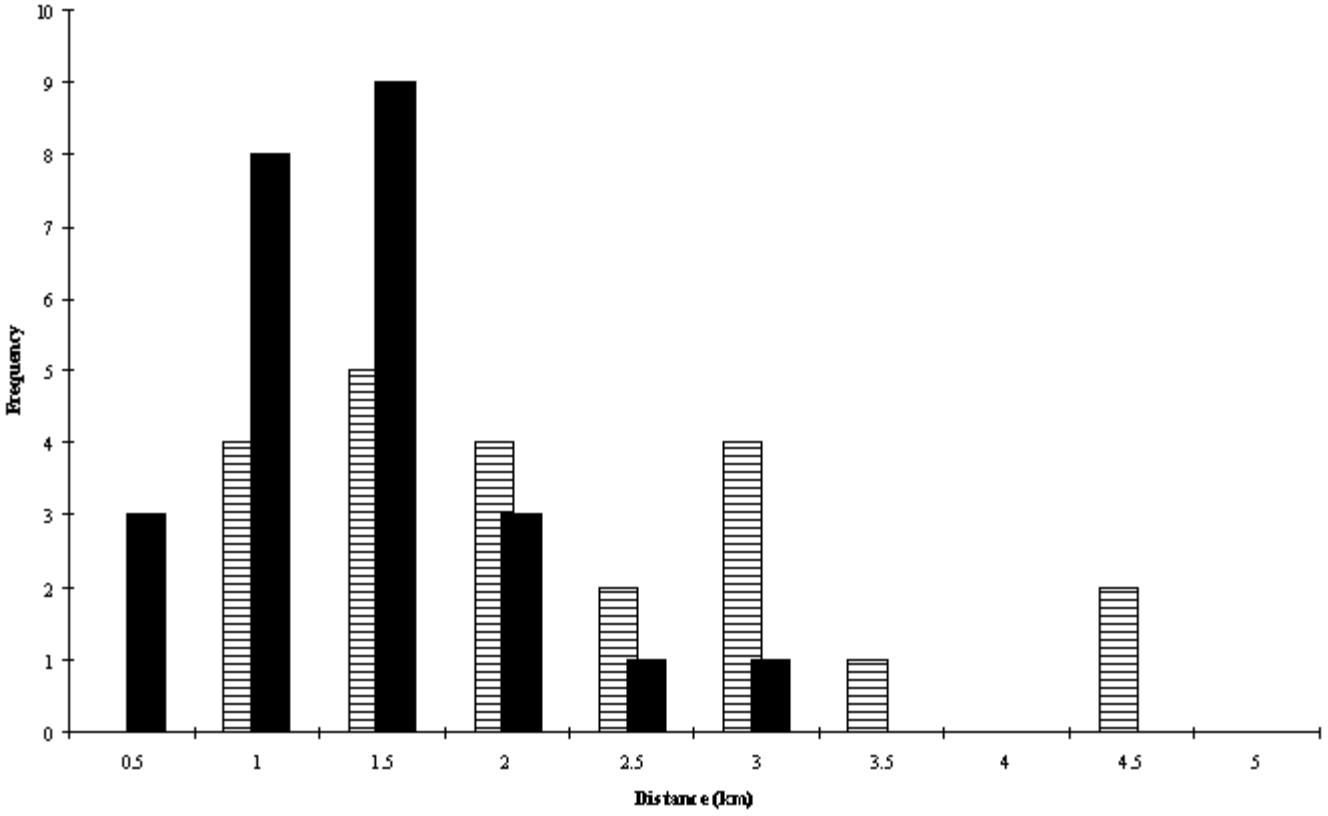

Fig. 2. Distance between the aircraft and beluga groups when they were initially sighted. Solid bars indicate groups of less than 20 animals each; stripped bars indicate groups of more than 20.

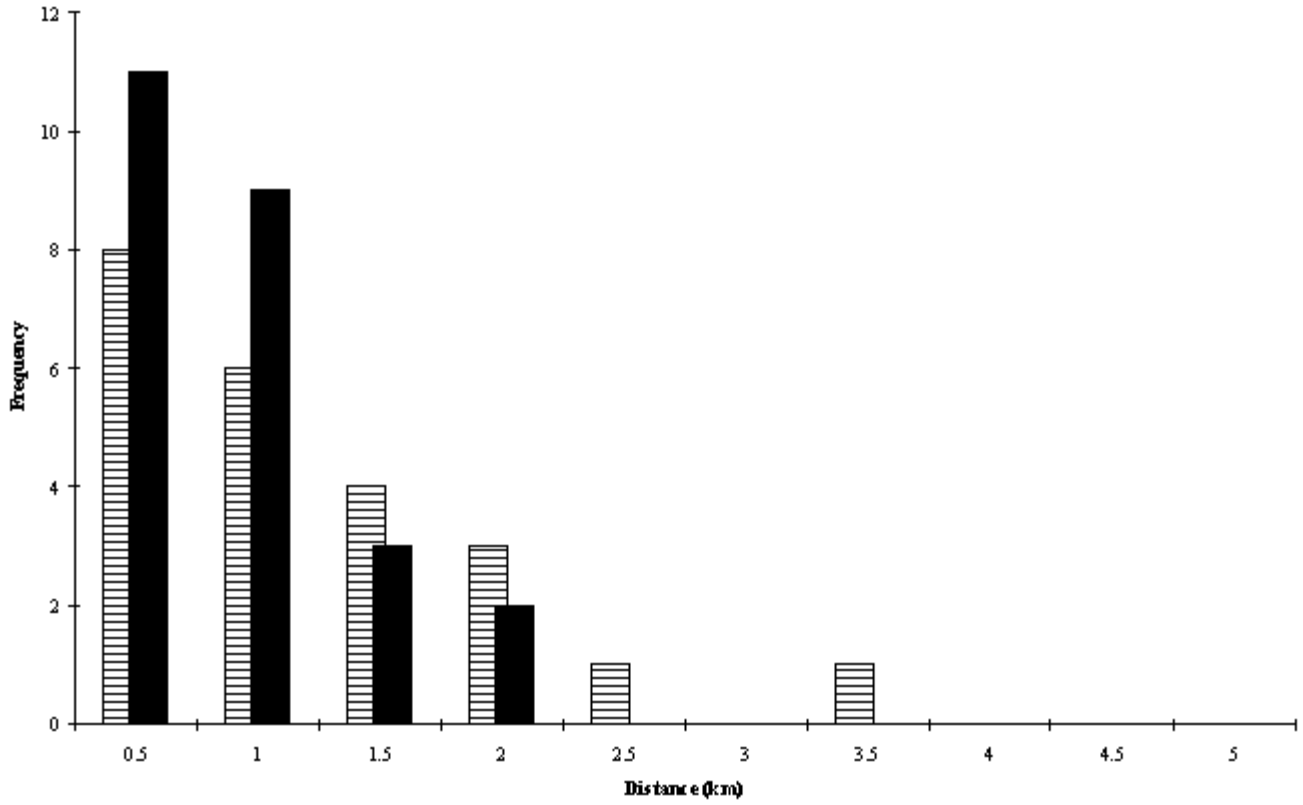

Fig. 3. Distance between the aerial trackline and beluga groups at the closest pass. Solid bars indicate groups of less than 20 animals each; stripped bars indicate groups of more than 20.