Distribution of Belugas, *Delphinapterus leucas*, in Cook Inlet, Alaska, During June/July 1993–2000

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ABSTRACT—Aerial surveys of belugas, Delphinapterus leucas, *in Cook Inlet were flown each year during June and/or July from 1993 to 2000. This project was designed to delineate distribution and collect aerial counts, elements critical to the management of this small, isolated stock that was subjected to a persistent harvest by Native hunters. The surveys provided a thorough, annual coverage of the coastal areas of the inlet (1,350 km of shoreline) and included roughly 1,000 km of offshore transects annually. Coastal transects were flown 1.4 km from the waterline, thus surveying most of the area within 3 km of shore. These, along with offshore transects, provided annual systematic searches of 13–33% of the entire inlet. The largest concentration of belugas (151–288 whales by aerial count) was in the northern portion of upper Cook Inlet in the Susitna River Delta and/or in Knik Arm. Another concentration (17–49 whales) was consistently found between Chickaloon River and Point Possession. Smaller groups (generally <20 whales) were occasionally found in Turnagain Arm, Kachemak Bay, Redoubt Bay (Big River), and Trading Bay (McArthur River) prior to 1995 but not thereafter. Over the past three decades, summer distribution has shrunk such that sightings now only rarely occur in lower Cook Inlet and in offshore areas. In the 1990's, most (96–100%) of the sightings were concentrated in a few dense groups in shallow areas near river mouths in upper Cook Inlet.*

Introduction

Belugas, *Delphinapterus leucas*, inhabit most of the Northern Hemisphere's Arctic and subarctic seas (Gurevich, 1980). In U.S. waters in the summer, they are distributed around much of mainland Alaska from the Gulf of Alaska to the Beaufort Sea (Hazard, 1988), and five discrete stocks are recognized, depending on their summer location: Cook Inlet, Bristol Bay, Norton Sound, the eastern Chukchi Sea, and the Beaufort Sea (O'Corry-Crowe et al., 1997).

The most isolated is the Cook Inlet stock, separated from the others by the Alaska Peninsula (>900 km long), with virtually no whales reported between Cook Inlet and the nearest stock in Bristol Bay (Laidre et al., 2000). Belugas in Cook Inlet are concentrated in the northern reaches of the inlet, at least during the spring (Huntington, 2000; Calkins[1]), and their natal homing behavior may have kept them separated from other beluga stocks long enough to effect evolutionary differentiation (O'Corry-Crowe et al., 1997).

The geographic isolation of these whales, in combination with their site fidelity, makes this stock vulnerable to impacts from large or persistent harvests by Alaska Natives (Hill, 1996) and anthropogenic environmental hazards (Moore et al., 2000; Calkins[2]). A very similar situation has occurred in the St. Lawrence River in eastern Canada, where a small, isolated stock of belugas suffered an intense harvest in the past without leaving the area, and it is now vulnerable to anthropogenic contaminants (Kingsley, 1998). Remarkable site tenacity despite hunting pressure was also demonstrated by belugas in a study conducted by Caron and Smith (1990) in eastern Hudson Bay, Canada.

Concern for the management of the Cook Inlet stock led to a project begun in 1993 with funding from the Marine Mammal Assessment Program of the National Oceanic and Atmospheric Administration (NOAA). This project was conducted by NOAA's National Marine Mammal Laboratory (NMML), Alaska Fisheries Science Center, National Marine Fisheries Service (NMFS), in cooperation with the NMFS Alaska Regional Office, the Alaska Beluga Whale Committee (ABWC), and the Cook Inlet Marine Mammal Council (CIMMC, which was established in 1994).

Basic to the assessment of the Cook Inlet stock was the documentation of the distribution and abundance of these whales. Aerial surveys are the established method for collecting these data (e.g. Calkins[1]; Klinkhart[3]; Murray and Fay[4]). Accordingly, the objectives of our

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[1] Calkins, D. G. 1984. Belukha whale. Vol. IX of Susitna hydroelectric project; final report; big game studies. Alaska Dep. Fish Game. Doc. 2328, 17 p.

[2] Calkins, D. G. 1983. Marine mammals of lower Cook Inlet and the potential for impact from Outer Continental Shelf oil and gas exploration, development, and transport. Research Unit 243; Final Rep. of Principal Investigators, Outer Continental Shelf Environ. Assessment Program, U.S. Dep. Commer., NOAA, Natl. Ocean Serv., Off. Oceanogr. Mar. Serv., Ocean Assessments Div. 20:171–263.

[3] Klinkhart, E. G. 1966. The beluga whale in Alaska. Alaska Dep. Fish Game, Juneau, Fed. Aid Wildl. Restor. Proj. Rep. Vol. VII, Proj. W-6-R and W-14-R, 11 p.

[4] Murray, N. K., and F. H. Fay. 1979. The white whales or belukhas, *Delphinapterus leucas*, of Cook Inlet, Alaska. Unpubl. pap. SC/31/SM12 pres. to Int. Whal. Comm. Sci. Committee, 7 p.

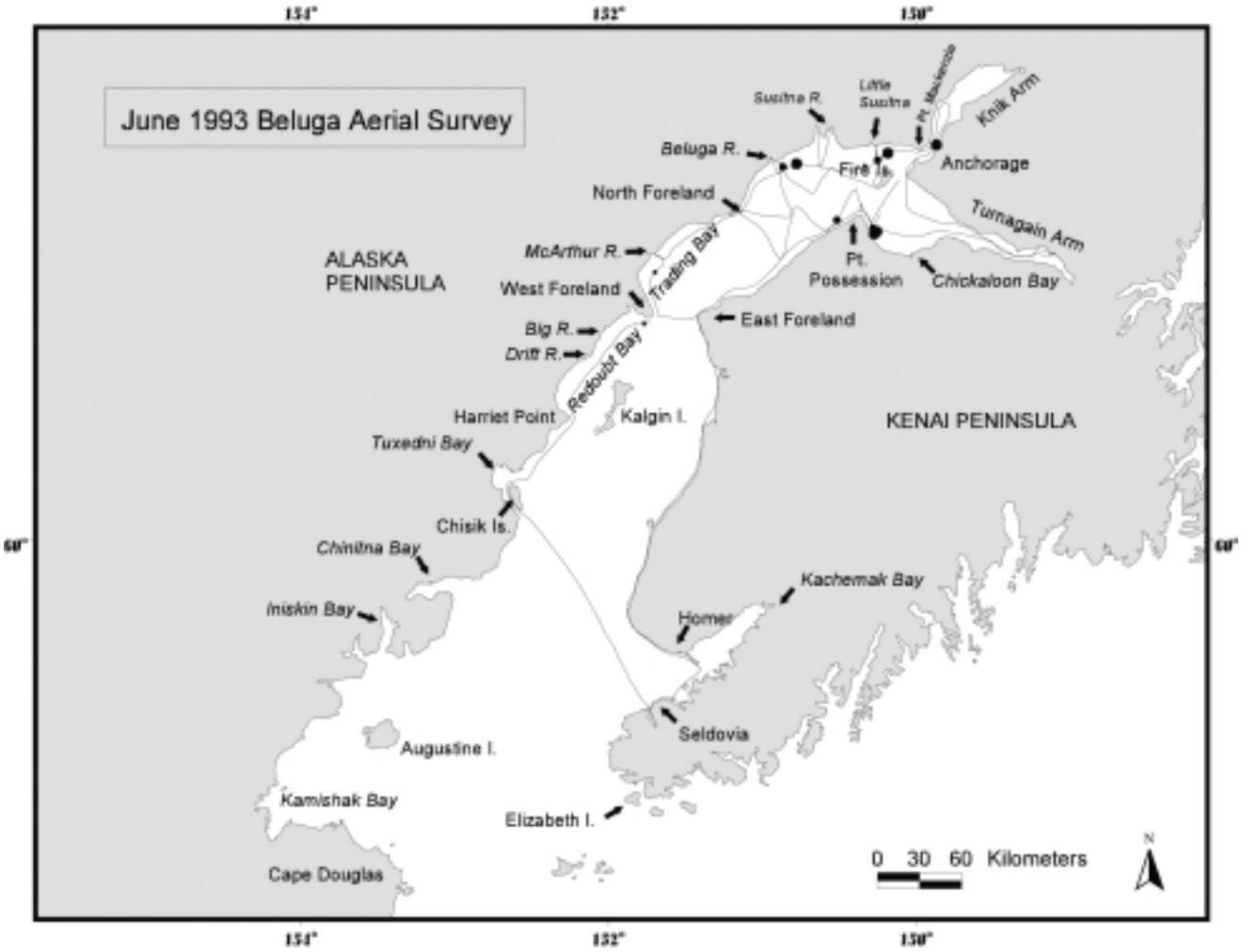

Figure 1.—Beluga groups seen 2–5 June 1993 during coastal and offshore aerial surveys of Cook Inlet, Alaska, with tracklines shown. In this and the subsequent maps, only one sampling from each area is represented, and poor viewing conditions were not included. Virtually all of the sightings were near shore or along the edge of mudflats in upper Cook Inlet, and 80% were between the Susitna Delta and Knik Arm.

field studies were to 1) make complete searches for belugas around the perimeter of Cook Inlet, 2) fly transects over the offshore waters of Cook Inlet, and 3) make systematic counts of belugas for aerial estimations of group sizes. Aerial survey procedures were refined from year to year, but the basic survey and counting methods were kept consistent.

The objectives of this paper are to: 1) describe distributional information on belugas in Cook Inlet during June/July, the optimal survey period (belugas outside the inlet are reported by Laidre et al. (2000)), 2) compare recent distributional data to data collected in previous surveys, and 3) provide group size estimates for calculations of stock size. Abundance estimates are presented in Hobbs et al. (2000a). These are based on summary counts from the aerial effort (reported here), in combination with correction factors using paired-observer effort (Hobbs et al., 2000b), video documentation (Hobbs et al., 2000b), and surfacing times of radio-tagged whales (Lerczak et al., 2000).

Methods

Study Area

The study area, Cook Inlet, is a major marine feature in south-central Alaska, covering approximately 20,000 km^2 with 1,350 km of shoreline. The boundaries of this study area include all waters in the inlet north of an imaginary line from Elizabeth Island to Cape Douglas (Fig. 1) where belugas could occur, including rivers, shoals, and mudflats where the water appeared to be deeper than about 1 m. An imaginary line between East and West Foreland (at lat. 60° 43′N) made a convenient break between upper and lower Cook Inlet. This provided a division of the inlet for comparisons to previous surveys. Anchorage, the largest city in Alaska, is in the northeastern portion of the inlet and served as a convenient base of operations for these aerial surveys. A descrip-

tion of beluga habitat in Cook Inlet can be found in Moore et al. (2000).

The extremely turbid inlet waters in areas where belugas occur means that the whales are visible only when at the surface, unlike in the clear waters of the Arctic where whales are sometimes visible well below the water surface when seen from an aircraft. The young, gray individuals are especially difficult to see in the brown water of Cook Inlet.

Survey Protocol

The survey aircraft used on most flights from 1993 to 2000 was an Aero Commander 680 FL[5] with twin engines, high wings, 10-h flying capability, and seating capacity for five passengers and one pilot. The June 1997 survey was flown in a DeHavilland Twin Otter, which was larger but had similar characteristics to the Aero Commander. Both aircraft had large bubble windows at the forward observer positions. An intercom system allowed communication among the observers (2 on the left and 1 on the right), data recorder, and pilot. After 1993, a selective listening control-device was installed to aurally isolate the observers, who were also visually isolated from each other. This allowed for paired, independent observations as a check of sighting rates (Hobbs et al., 2000b). Most observers had previous experience on many marine mammal projects prior to flying with these surveys, and a core team flew on the Cook Inlet surveys for 7–8 seasons (see Acknowledgments).

Position data were collected from the aircraft's Global Positioning System (GPS) interfaced with a laptop computer used to enter sighting data. Data entries included routine updates of time and location at 1-min intervals and manual entries of percent cloud cover, sea state (Beaufort scale), glare (for each observer), visibility (on the left and right), and each beginning and end of a transect leg. Visibility was categorized into 5 subjective classes graded from excellent to useless based on sea state, glare, available light, and the condition of the observation window (whether it had rain, fog, or reflections). When survey conditions were considered poor or useless, they were treated in the analysis as unsampled areas. Observer seating positions were recorded each time they were changed, generally every 1–2 h, to minimize fatigue.

Tides

Tide heights in Cook Inlet were highly variable across the full geographical range of these surveys. No attempts were made to synchronize the flights with the predicted low tide, except in the Susitna Delta, because large groups of whales were found there consistently. The major advantage to surveying at low tide was that the effective survey area was greatly reduced in large parts of upper Cook Inlet dominated by extensive tidal flats.

Coastal Surveys

Coastal surveys were designed to maximize opportunities for finding belugas in shallow, nearshore waters where they typically range in summer (Calkins[1]). These surveys were conducted on a trackline about 1.4 km from the waterline. The trackline distance from shore was monitored by using an inclinometer to keep the water's edge 10% below the horizon while the aircraft was at the standard altitude of 244 m (800 ft). We found this altitude and the 10% search area to be a good compromise between maximal visual range and optimal sighting cue size without resulting in any evident disturbance to the animals. Ground speed was generally 170–185 km/h (90–100 kn), the minimum safe flying speed. Coastal surveys included searches of 5–20 km up each prominent river until the water appeared to be less than 1 m deep, based on the appearance of rapids or riffles. Distances flown up rivers were considered adequate according to Native hunters who flew with this project (see Acknowledgments).

Offshore Transects

In addition to the coastal surveys, offshore transects were flown across the inlet in most years (depending on available funds). A sawtooth pattern of tracklines was designed to cross shore at points about 30 km apart starting from Anchorage and zigzagging to the southern limits of Cook Inlet, between Cape Douglas and Elizabeth Island (Fig.1–9). Observers searched primarily within 1.4 km of the aircraft, but viewing conditions were usually so good they allowed for searches well beyond that distance.

Circling Over Whales

After a group of belugas was found, it was flown over at perpendicular angles to determine the perimeters of the group. This provided an accurate location of the group for mapping as well as a measure of group density by later comparing the number of whales relative to the total area in which the group was found. Next, a series of straight-line aerial passes was made on either side of the group until one or two pairs of observers could make at least four good counts each. The pilot was directed to fly close enough to the whales to optimize counting conditions (while maintaining an altitude of 244 m) but far enough away to keep the entire group in view. On each aerial pass, time spent counting was synchronized among the observers and recorded to the second. These counts were kept confidential until the season was over. A video camera documented most counting passes over each group of whales; this provided images for later analysis (Hobbs et al., 2000b). The observation time averaged about 0.5 h per whale group. In Cook Inlet, belugas were usually very concentrated, generally making it easy to define each group; however, when there were loose aggregations of whales, groups were defined as a function of convenience for counting while circling over them. This usually meant all whales within 100 m of each other were treated as a group for counting purposes.

Analytical Methods

Aerial counts used in this report are the medians of all of the primary observers' median counts made during multiple passes over a group. The process of using medians instead of means or maximum numbers reduces the effect of outliers (extreme counts) and makes the results more comparable to other surveys which lack multiple passes over whale

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

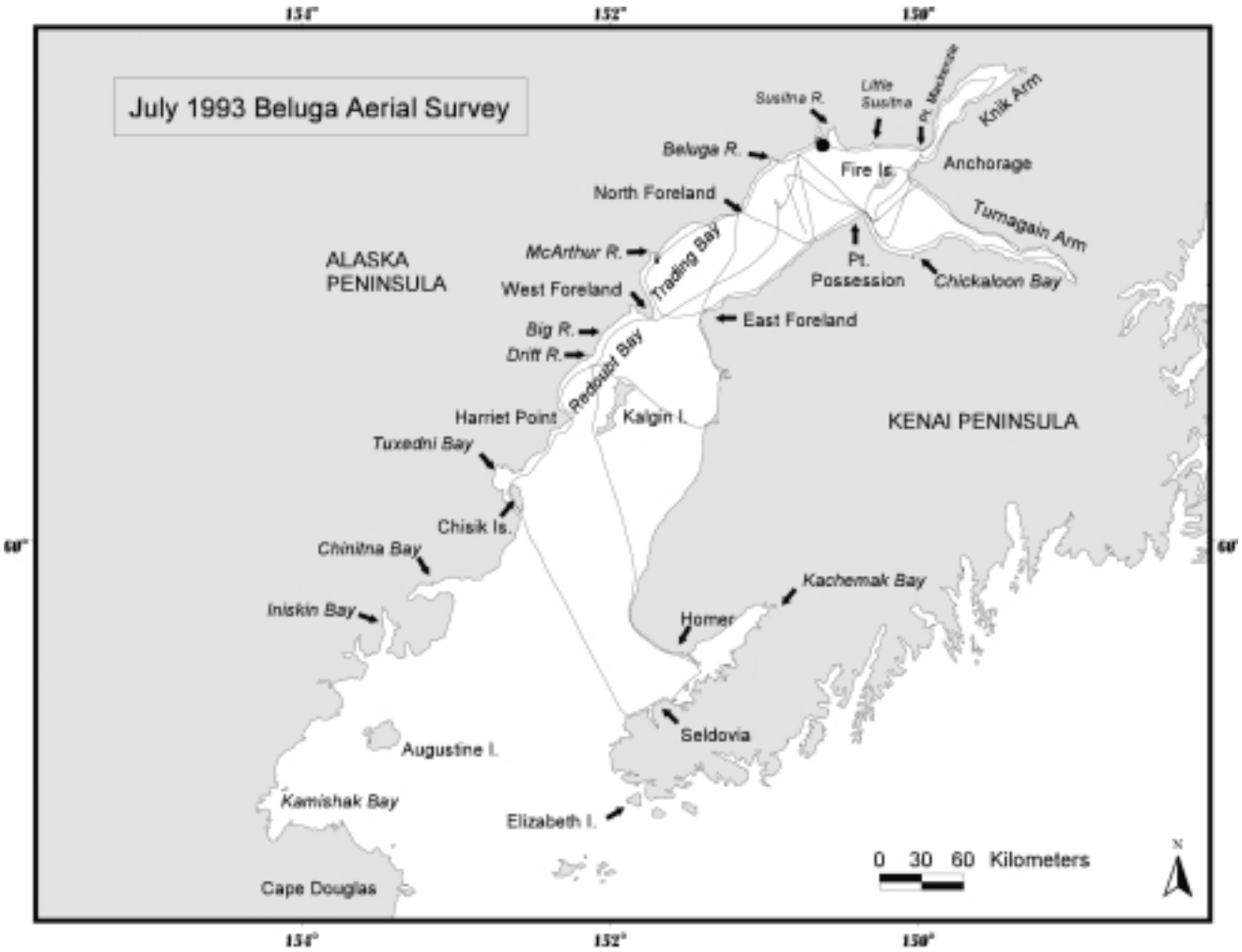

Figure 2.—Beluga groups seen 25–29 July 1993 during coastal and offshore aerial surveys of Cook Inlet. All of the sightings were near shore or along the edge of mudflats in upper Cook Inlet, and 82% were near the Susitna Rivers. (Only one day's sightings shown here.)

groups. The consistency of resightings between days, particularly of whales in the Susitna Delta and in Chickaloon Bay, allowed results to be combined between survey days, assuming whales did not travel long distances within each survey period.

Results

Survey Effort

Aerial surveys of Cook Inlet were flown in June or July of each year from 1993 to 2000, generally targeting 40 h per survey season (Table 1). In 1993, surveys were flown in June, July, and September to help establish optimal survey conditions and timing, as well as to refine survey methods. Of primary consideration was to take advantage of the predictable concentrations of belugas in a few river mouths and the ideal weather that is most likely to occur in early summer. Therefore, the June–July period was selected as the preferred time to survey (especially the first half of June), and only results from this period are reported here. Poor visibility interfered with survey effort during only 3% of the total effort during these months, and rarely were flights cancelled on account of weather.

The composite of these aerial surveys provided a thorough coverage for most waters within 3 km of Cook Inlet's shoreline (Fig.1–9). In addition, about 1,000 km of offshore aerial transects were flown each year (Table 1). Although the transect swath was 3 km wide, the effective search area is considered to be 2.0 km (1.4 km on each the left and right, less the 0.8 km blind zone beneath the aircraft). Therefore, the area covered by the coastal plus offshore tracklines each season ranged from 2,534 to 6,500 km^2 ($\bar{x}$ = 4,596 km^2), which means 13–33% ($\bar{x}$ = 23%) of the 19,863 km^2 surface area of Cook Inlet was surveyed annually (Table 1). 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; sometimes whales were seen over 6 km away. The distance between the aircraft

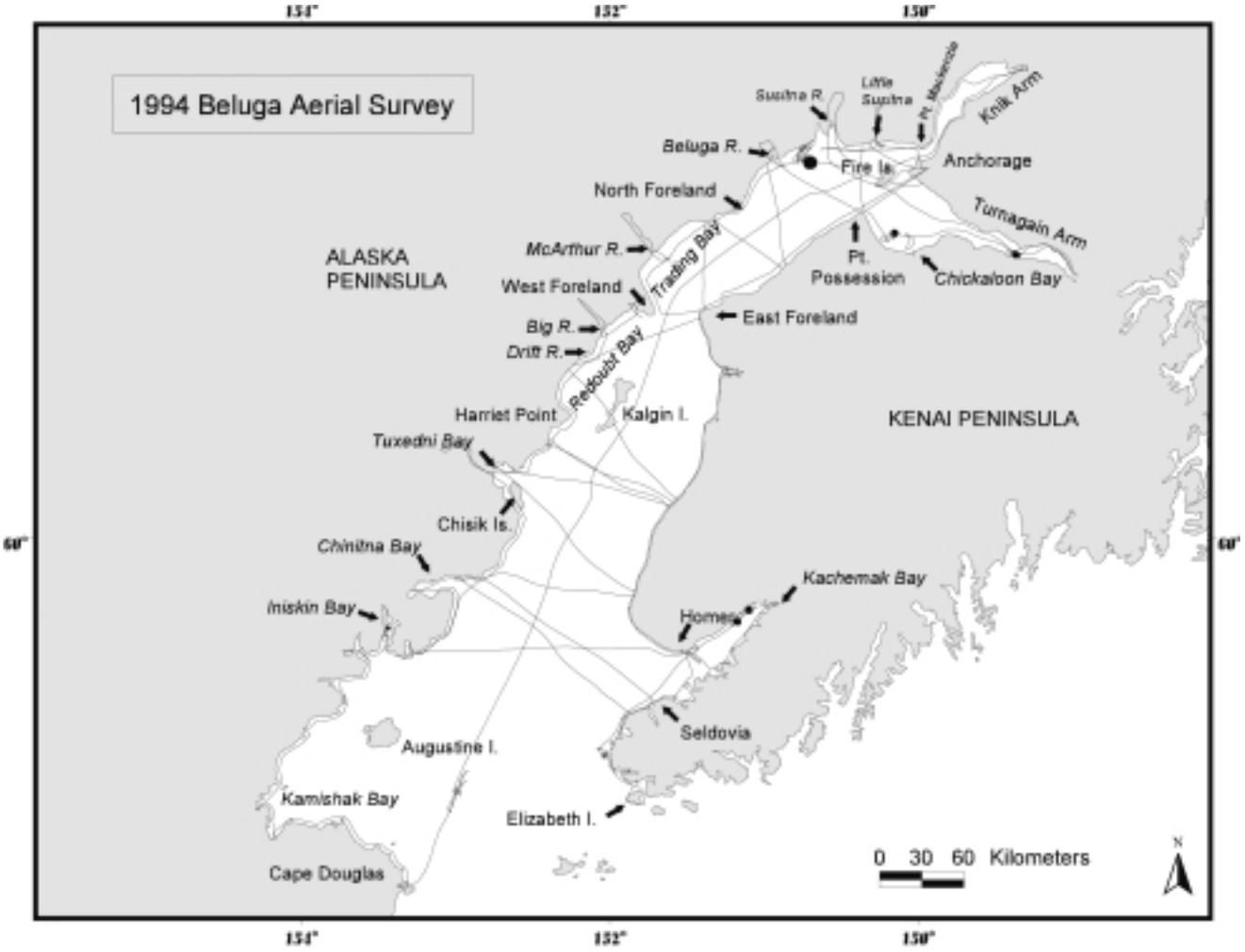

Figure 3.—Beluga groups seen 1–5 June 1994 during coastal and offshore aerial surveys of Cook Inlet. Virtually all of the sightings were near shore or along the edge of mudflats in upper Cook Inlet, and 88% were near the Susitna Rivers. Only 3 small groups were seen in the lower inlet (in Iniskin Bay and Kachemak Bay).

and a beluga group at the moment of the initial sighting ranged from 0.0 to 6.7 km, with a mean of 1.6 km (n = 90; SD = 1.2). Half (49%) of the initial sightings occurred beyond 1.4 km, considered the perimeter of the standard viewing area; therefore, the probability of making a sighting within 1.4 km was high. The correction factor for missed whale groups was only 1.015 (CV = 0.03; Hobbs et al., 2000a) based on results from the paired, independent searches. Although rivers were searched up to 20 km from the inlet, no whale groups were found beyond 4 km from river mouths. Therefore, these annual surveys covered virtually all of the coastal areas in which belugas might occur.

Whale Counts

Aerial counts of belugas in Cook Inlet in June–July during 1993–2000 ranged from 184 to 324 (Table 1). These counts are not corrected for missed whales. Estimations of numbers of whales missed, abundance calculations, and analysis of trends in abundance are presented in Hobbs et al. (2000a). Counts of belugas made in each area on each survey are shown in Table 2, and sighting locations are shown in Figures 1–9.

Sighting Locations

Most beluga sightings were close to the Cook Inlet shoreline or over shallow mudflats (such as over the Susitna Delta, in Knik Arm, or in Chickaloon Bay). Virtually all groups of more than one whale were sighted from the shore side of the aircraft (i.e. within 1.4 km of shore), although some whale groups were so large that they were visible from both sides of the aircraft.

Belugas were found with some consistency in only 3 of the 11 ad hoc areas listed in Table 2 (Fig.1–9). Virtually every summer, a large concentration

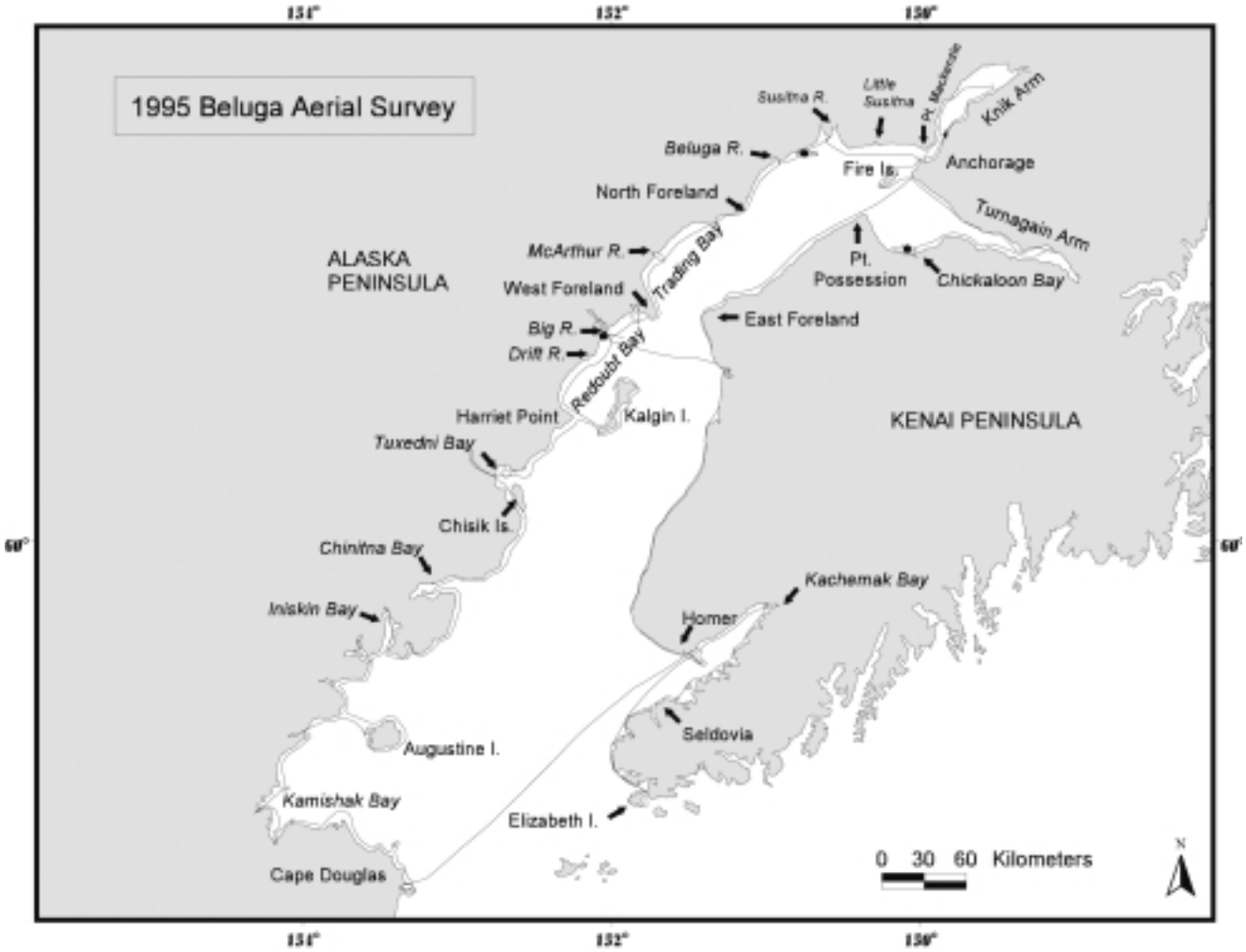

Figure 4.—Beluga groups seen 18–26 July 1995 during coastal and offshore aerial surveys of Cook Inlet. Virtually all of the sightings were near shore or along the edge of mudflats in upper Cook Inlet, and 89% were near the Susitna Rivers. Only 1 small group was seen in the lower inlet (at Big River).

of whales (151–288 by annual aerial counts) was found in the Susitna Delta, or the concentration was split between the Delta and Knik Arm. Whales apparently moved easily between the Susitna Delta and Knik Arm. Crane operators at the Port of Anchorage have also reported seeing several hundred whales at a time in Knik Arm (Smith[6]), and Natives describe how belugas tend to concentrate in Knik Arm later in the summer (Huntington, 2000). Although whales in the Susitna Delta were primarily in dense groups near river mouths, groups in Knik Arm were more dispersed across the tidal channels of the arm.

Besides the groups in the Susitna Delta and Knik Arm, there was only one other group found consistently throughout these surveys. Generally 10–50 whales were counted in Chickaloon Bay, in the area between the Chickaloon River and Point Possession. Elsewhere, such as in Trading Bay (McArthur River), Turnagain Arm, Kachemak Bay, Redoubt Bay (Big River), and other parts of Cook Inlet south of North Foreland and Point Possession, small groups (generally <20 whales) were sometimes seen prior to 1995 but not since then, with the exception of 1 whale in Tuxedni Bay in 1997.

Group Size

Throughout the Cook Inlet surveys, whales were sighted in only 5–11 groups. Most whale groups were large (>20 each) in the Susitna Delta (71%; $n = 17$, using only one survey day per year), but relatively few groups were large elsewhere in upper Cook Inlet (24%; $n = 33$), and none of the 7 groups seen in lower Cook Inlet were large (only 1–14 whales each). All of the whales in the

[6] Smith, B. 1997. NMFS Regional Office, Anchorage, Alaska. Personal commun. via B. Mahoney.

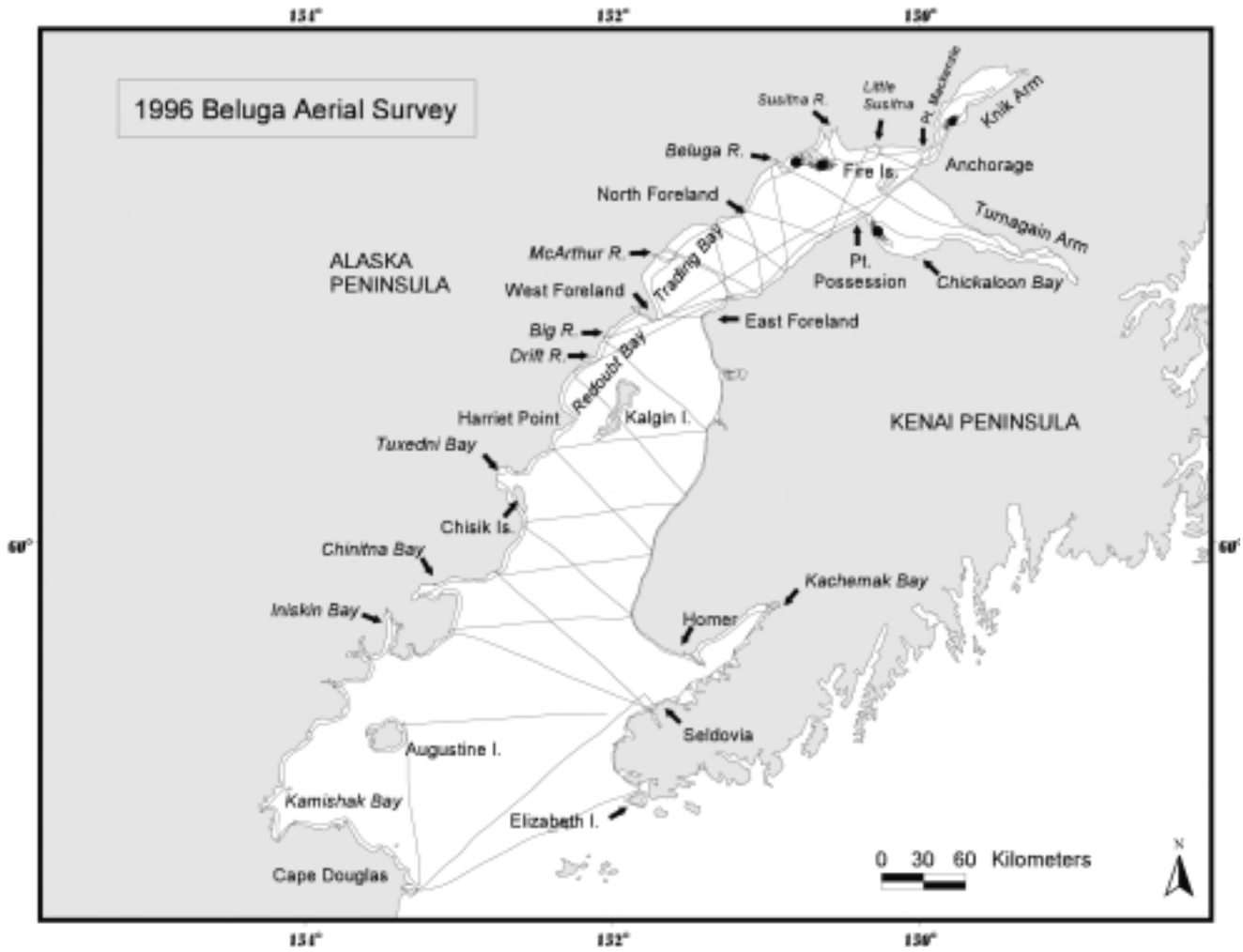

Figure 5.—Beluga groups seen 11–17 June 1996 during coastal and offshore aerial surveys of Cook Inlet. Virtually all of the sightings were near shore or along the edge of mudflats in upper Cook Inlet, and 77% were near the Susitna Rivers. No belugas were seen in the lower inlet.

Susitna Delta were usually concentrated in 1 or 2 large groups (6 of 8 years), but sometimes they split into as many as 4 or 5 groups. In Knik Arm, whales were not seen every year, but when they were, the groups were smaller than in the Susitna Delta and ranged from 1 to 7 subgroups. In Chickaloon Bay, almost all of the whales were in 1 or 2 groups, although sometimes a group was fairly dispersed.

The average density of whale counts within a group in Chickaloon Bay ($\bar{x}$ = 29.4 whales/km^2; SEM = 6.6) was lower (P = 0.003; F = 9.6) than averages in the Susitna Delta ($\bar{x}$ = 68.6; SEM = 7.9) and Knik Arm ($\bar{x}$ = 54.8; SEM =14.9); the Susitna and Knik densities were not significantly different (P = 0.40; F = 0.74). There was no evidence of seasonal changes in the density of whale groups within this sample set (P = 0.40; F = 0.74); mean densities (whales/ km^2 for each group) in the Susitna Delta and Knik Arm were 64 for 8–10 June (n = 10), 66 for 11–16 June (n = 27), and 69 for 18–24 July (n = 6). These date bins were post-stratified to best fit available data.

Lower vs. Upper Cook Inlet

Sightings in lower Cook Inlet (south of lat. 60° 43′N) occurred in low numbers (1–14 whales) from 1993 to 1995, but since then, no whales have been seen there (Table 2), with the exception of a lone whale in Tuxedni Bay in 1997 (Fig. 6) and a dead whale in the middle of the lower inlet in 1998 (Fig. 7). Furthermore, since 1995, only 1 other beluga has been seen south of Pt. Possession or North Foreland (lat. 61° 02′N) other than in Chickaloon Bay. Mean locations of whale groups (based on the most thorough sampling day per season) were weighted as a function of median aerial counts and compared among years (each whale represented by one latitude). This showed a regression northward within this sample period, from 1993 to 2000 (P = 0.054,

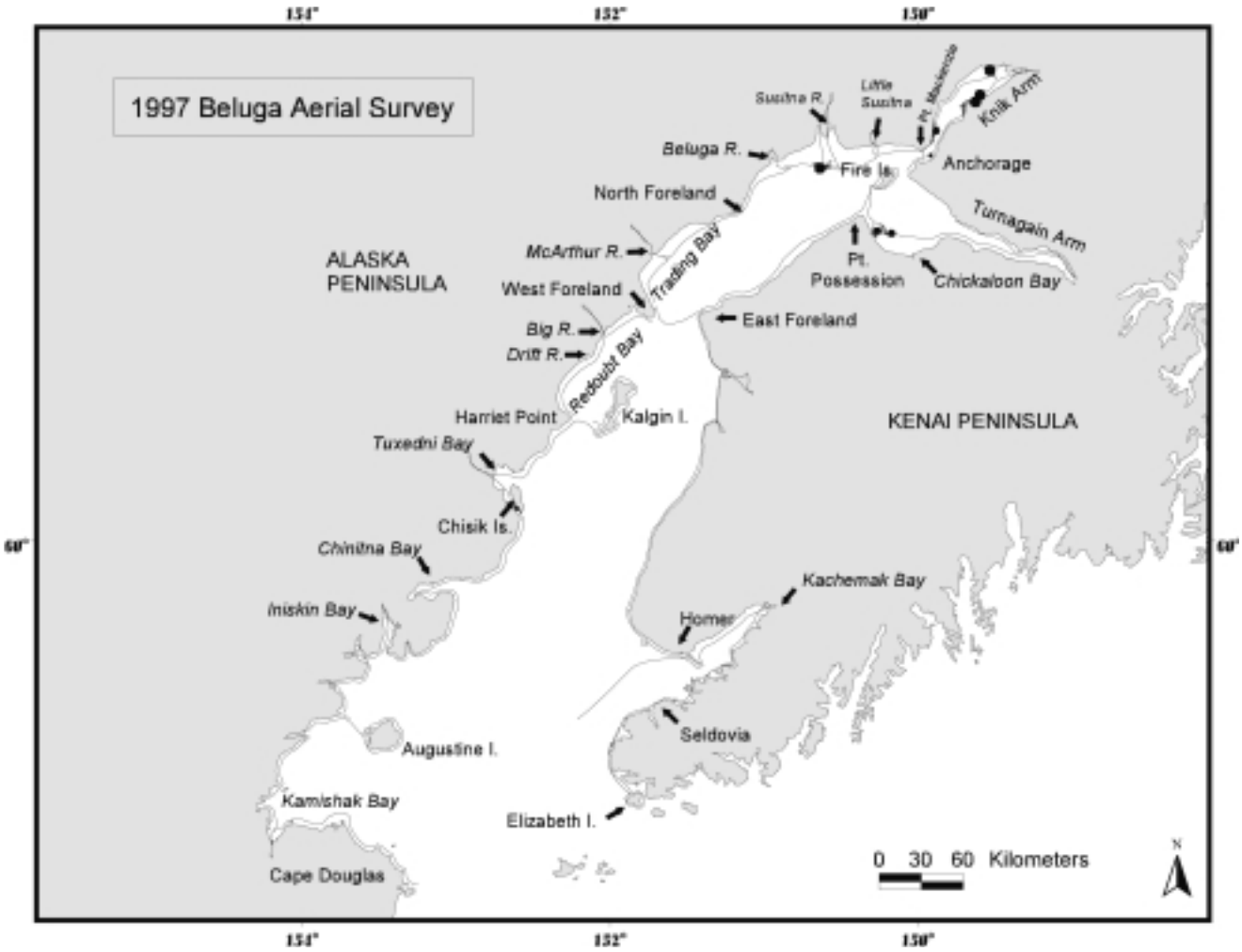

Figure 6.—Beluga groups seen 8–10 June 1997 during coastal aerial surveys of Cook Inlet. Virtually all of the sightings were near shore or along the edge of mudflats in upper Cook Inlet; only 1 whale was seen in the lower inlet (next to Chisik Island). Relatively fewer sightings (28%) were near the Susitna Rivers and more (61%) were in Knik Arm than in previous years.

Theil's nonparametric test for the slope coefficient). Using the same test but with unweighted mean latitudes (each group of whales represented by one latitude) also indicates that there has been a perceptible continuation of the northwardly concentration (P = 0.09), although the trend has not been as pronounced since 1995.

Discussion

Seasonal Distribution Change

Belugas are known to be in upper Cook Inlet between April and November (Huntington, 2000), and because of the predictability of their distribution, most surveys are conducted in summer. June and July are favored for surveying belugas because the whales are more concentrated than at other times of the year and because the lack of sea ice and relatively benign weather maximize the probability of seeing whales. In the past, belugas were more concentrated in the upper inlet in June than in July (Table 3): in the 1970's, the percent of sightings in the upper inlet relative to the lower inlet dropped from 86% in June to 52% in July (averages of two data sets; Calkins[1] and NMFS[7]); and in the 1980's, percentages dropped from 100% in June to 32% in July (NMFS[7]); but in the 1990's, this annual shift in distribution was no longer evident (from 99% to 98% for both June and July).

As summer progresses, whales may disperse away from the uppermost portions of the inlet. For instance, of 157 belugas seen in Cook Inlet during 11 hours of aerial surveys in September 1993, only 73% were in the upper inlet (Withrow et al.[8]). This dispersal

[7] NMFS. 1997. Unpubl. data on file at Platforms of Opportunity Program, NMML, NMFS, NOAA, 7600 Sand Pt. Way, N.E., Seattle, WA 98115.

[8] Withrow, D. E., K. E. W. Shelden, D. J. Rugh, and R. C. Hobbs. 1994. Beluga whale, *Delphinapterus leucas*, distribution and abundance in Cook Inlet, 1993. *In* H. Braham and D. DeMaster

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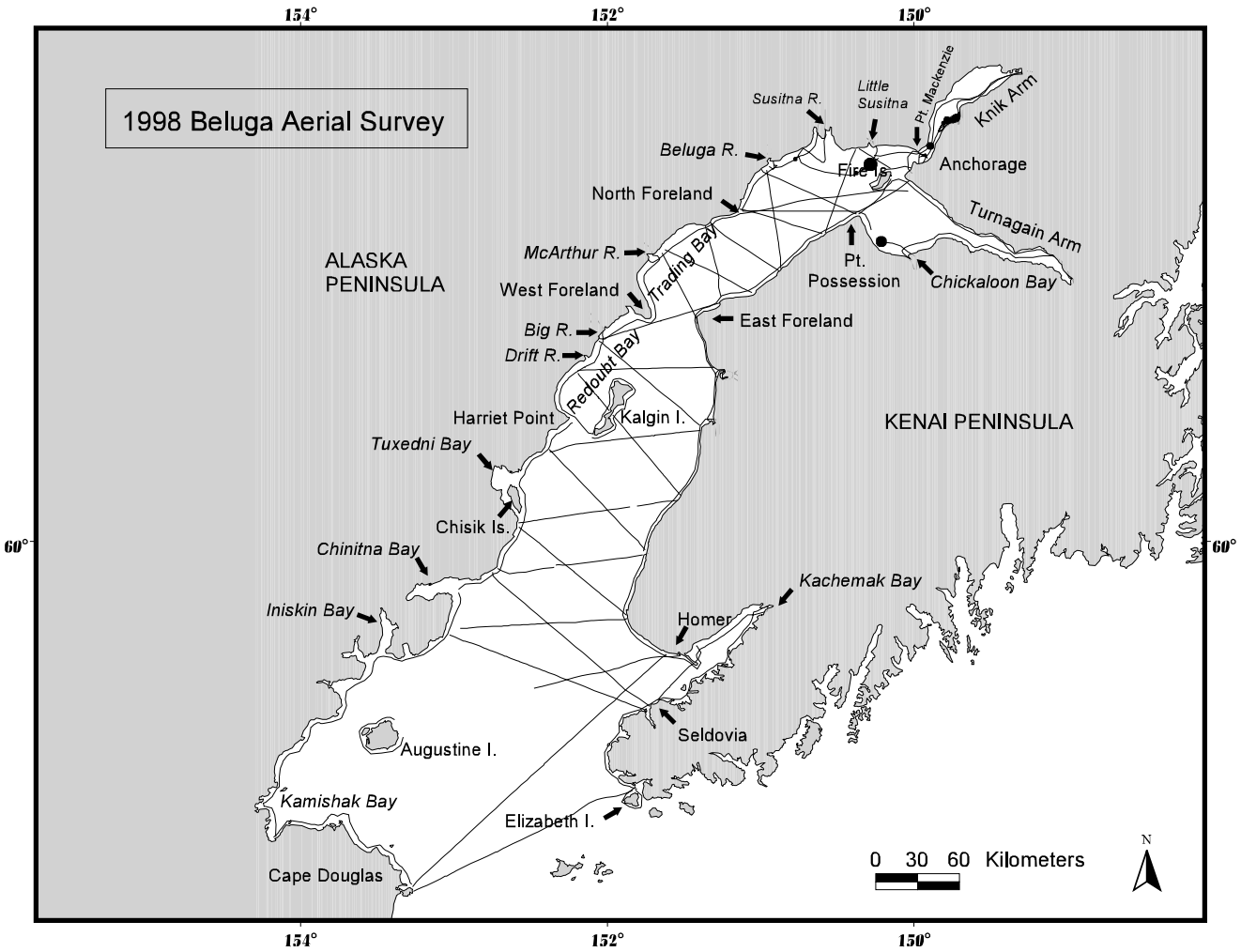

Figure 7.—Beluga groups seen 9–15 June 1998 during coastal aerial surveys of Cook Inlet. Virtually all of the sightings were near shore or along the edge of mudflats in upper Cook Inlet; only 1 (dead) whale was seen in the lower inlet. Most of the whales were near the Little Susitna River and in Knik Arm (78%).

of belugas to other parts of Cook Inlet was also evidenced by sightings in August 1978 of concentrations of 150 belugas in the central part of the inlet (Murray and Fay[4]) and by aerial counts of 160–200 in September 1994, 1995, and 1996 in Tuxedni Bay (Bennett[9]).

A tagged beluga stayed in upper Cook Inlet throughout the period it was monitored, from 31 May to 17 September 1999 (Ferrero et al., 2000). It remained close to the mouth of the Little Susitna River in early June, and then moved into other parts of the upper inlet through the summer, spending time in Knik and Turnagain Arms in September.

There have been very few surveys in Cook Inlet between November and April, and the distribution of belugas has been somewhat enigmatic (Huntington, 2000). There has been a common belief that in winter belugas migrate out of the inlet—or at least out of the upper inlet (Calkins[2]), not because there were sightings elsewhere, but because there were very few sightings in the upper inlet. This was probably just a function of low survey effort in winter and the difficulty of seeing belugas in icy waters. In fact, Native hunters have reported seeing belugas near Tyonek and the Susitna Delta in November (Huntington, 2000). Sightings from drilling platforms in Trading Bay were not uncommon during January (Dahlheim[10]), and reports from a variety of sources (Priewe[11] and several citations in Hansen

[8] *(cont.)* (Editors), Marine Mammal Assessment Program: status of stocks and impacts of incidental take; 1993, p. 128–153. Annu. Rep. submitted to Off. Protected Resour., NMFS, NOAA, 1335 East-West Highway, Silver Spring, MD 20910.

[9] Bennett, A. J. 1996. Physical and biological resource inventory of the Lake Clark National Park-Cook Inlet coastline, 1994–96. Lake Clark Natl. Park and Preserve, Kenai Coastal Off., P.O. Box 2643, Kenai, AK, 99611. Unpubl. manuscr., 137 p.

[10] Dahlheim, R. F., Jr. 16126 Dubuque Road, Snohomish, WA 98290. Personal commun.

[11] Priewe, R. 1997. Priewe Air Service, Anchorage, Alaska. Personal commun. via B. Mahoney.

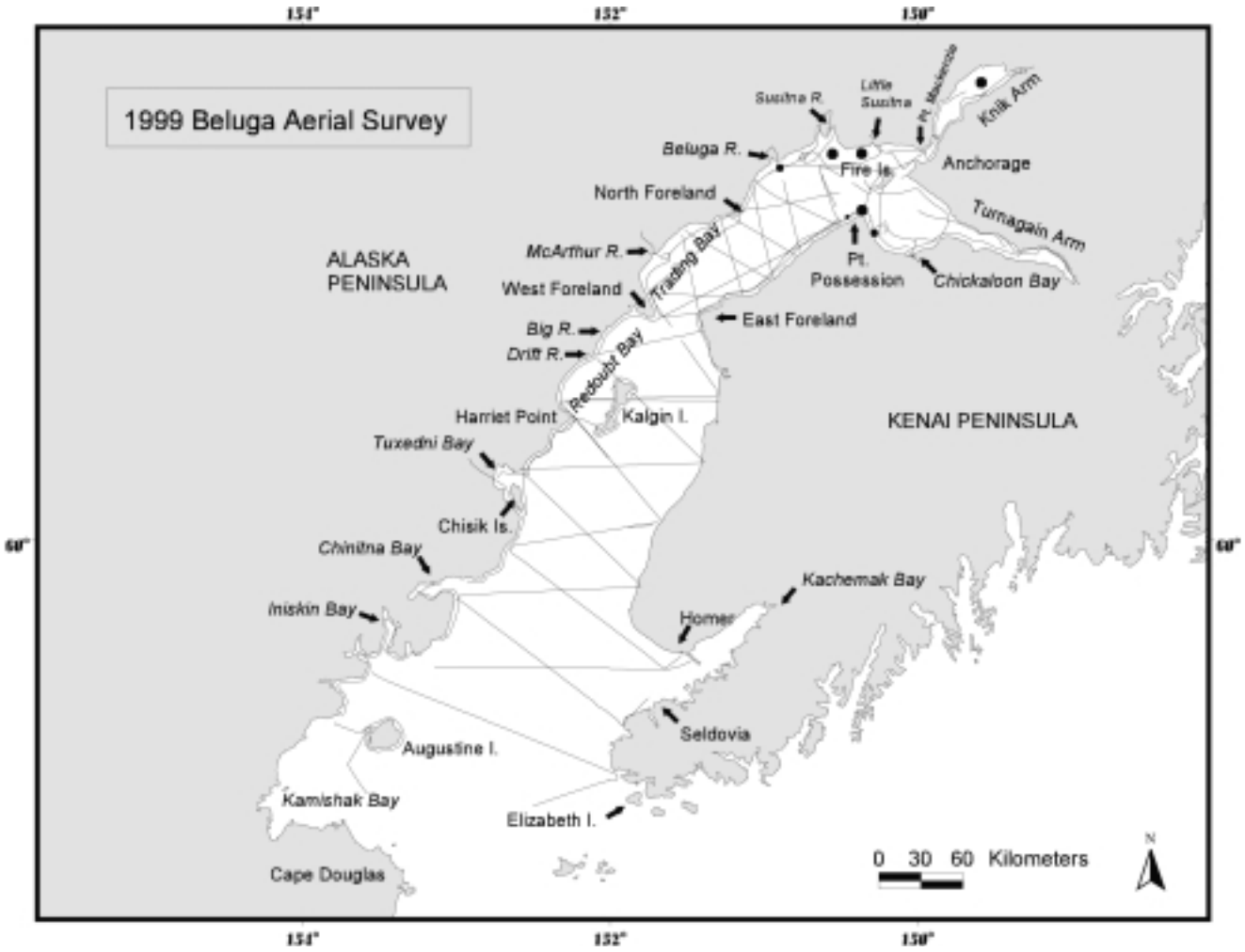

Figure 8.—Beluga groups seen 8–14 June 1999 during coastal aerial surveys of Cook Inlet. Virtually all of the sightings were near shore or along the edge of mudflats in upper Cook Inlet; no belugas were seen in the lower inlet. Most of the whales were between the Susitna Delta and Knik Arm (86%).

and Hubbard, 1999) indicate that belugas have been observed north of the Forelands throughout the winter, even in areas with considerable ice coverage. Calkins[2] concluded that belugas were present in all seasons in the inlet, based on his own sightings. To date there has been only one systematic survey for belugas in Cook Inlet in winter: Hansen and Hubbard (1999) flew 40 h in February and March 1997, counting 150 belugas in 10 sightings, including resightings, mostly in the central parts of the inlet north of Kalgin Island. The theory that the upper inlet is used by belugas even in the winter was substantiated by two whales carrying satellite tags from September 2000 to January 2001 (NMFS[12]). Both whales stayed in upper Cook Inlet throughout this period, almost never going south of the Forelands. These tagged whales, along with the surveys and opportunistic sightings, indicate that waters in central and northern Cook Inlet may be an important winter habitat for these belugas.

Distributional Factors

Lowry (1985) listed four factors that influence seasonal distribution of belugas: 1) access to air (regarding extent of ice cover), 2) water quality and characteristics, 3) access to food, and 4) freedom from excessive predation and other disturbance factors.

Access to Air

Relating these factors to our observations in Cook Inlet, it appears that access to air as a function of sea ice (Factor 1) is not an immediate determinant in beluga distribution in June and July, but it may be in winter. There are variable amounts of sea ice in upper Cook Inlet in winter (Moore et al., 2000). Belugas have been observed in 40–60% ice cover in mid February and in open water in late February and March (Hansen and

[12] NMFS. Maps presented on the web page for Natl. Mar. Mammal Lab. (http://nmml.afsc.noaa.gov/WhatsNew/news.htm).

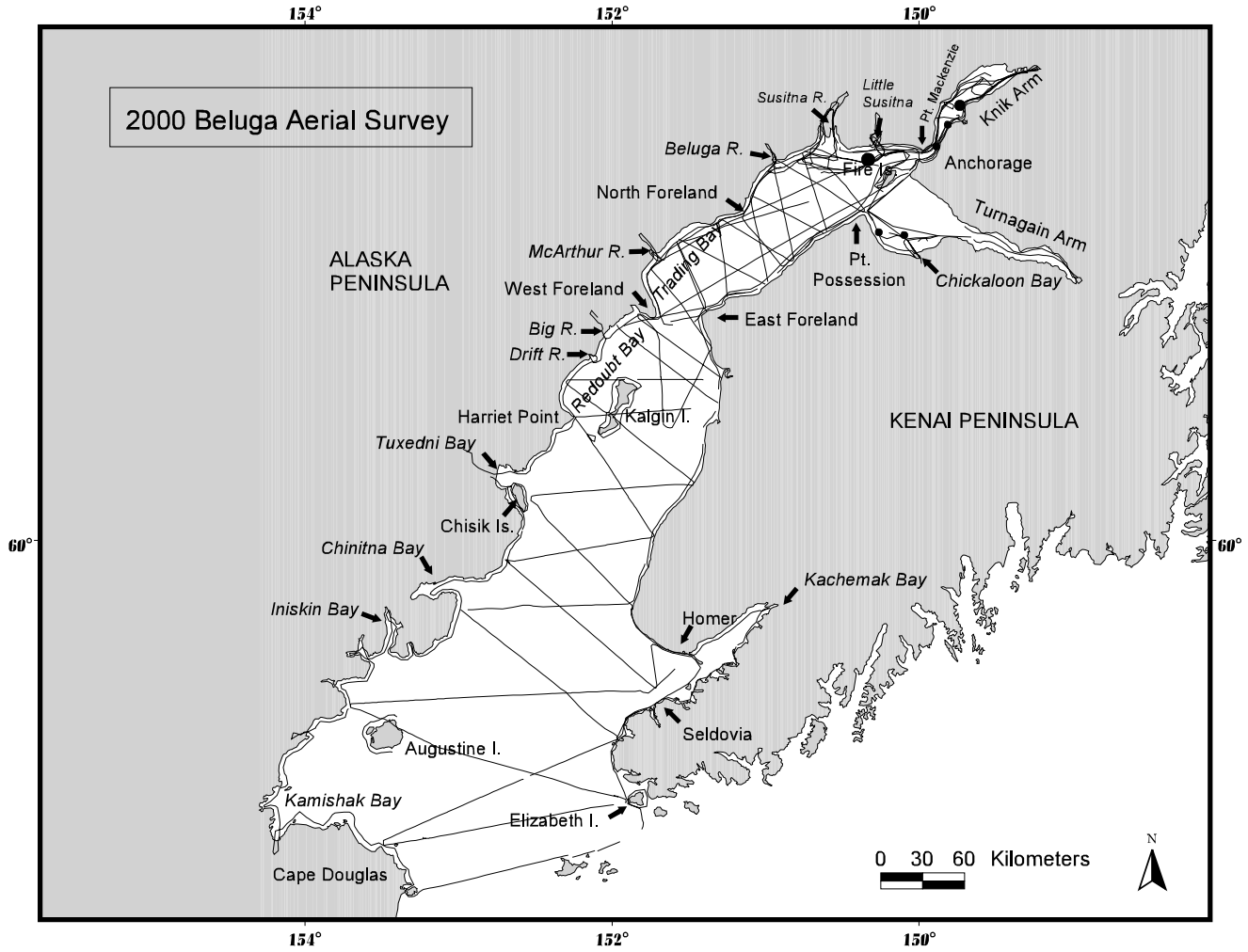

Figure 9.—Beluga groups seen 7–13 June 2000 during coastal aerial surveys of Cook Inlet. Virtually all of the sightings were near shore or along the edge of mudflats in upper Cook Inlet; no belugas were seen in the lower inlet. Most of the whales were between the Susitna Delta and Knik Arm (85%).

Hubbard, 1999). It has been commonly held that belugas retreat from dense ice by moving south to the lower parts of the inlet (Hansen and Hubbard, 1999; Calkins[1]); however, sightings have been made in the upper inlet even with considerable amounts of ice (Priewe[11]), and elsewhere in Alaska, belugas commonly occur in ice-permeated waters (Hazard, 1988).

Water Quality

Water quality (Factor 2) in Cook Inlet is strongly influenced by glacial silt that discolors the water of the upper inlet to the point of appearing as liquid mud. At low tide, this siltation may extend south to the mouth of the lower inlet (Moore et al., 2000). Belugas have obviously developed a tolerance of not being able to see in opaque water with varying salinity, which is characteristic of upper Cook Inlet (Moore et al., 2000). Water quality would probably have only an indirect influence on whale distribution by affecting the distribution of their prey.

Water temperatures range from 8–12°C in early June to 14–16°C in mid July (Moulton[13]). In other areas, such as the Mackenzie Delta of the Beaufort Sea and Kasegaluk Lagoon in the northeastern Chukchi Sea, belugas concentrate in the relatively warm waters of estuaries (as much as 10°C above ocean waters) where prey is not a factor (Hazard, 1988). Because the waters of Cook Inlet are tidally mixed at a high rate (Moore et al., 2000), in June and July belugas do not have distinct thermal advantages in one area over another.

Access to Food

Access to food (Factor 3) may be the overriding element in beluga distribution in June and July (Moore et al., 2000), as described by Natives in Cook Inlet (Huntington, 2000). The consis-

[13] Moulton, L. L. 1994. 1993 northern Cook Inlet smolt studies. ARCO Alaska Sunfish Proj. Rep. prep. for ARCO Alaska, Inc., 700 G St., Anchorage, AK 99510, 100 p.

tency of whale concentrations at river mouths can best be explained as an efficient way for the whales to feed. These coastal concentrations apparently last from April until November (Huntington, 2000) and are very likely associated with the migration of anadromous fish, particularly eulachon, *Thaleichthys pacificus*, and Pacific salmon, *Oncorhynchus* spp. (Moulton, 1997; Huntington, 2000; Moore et al., 2000; Calkins[1,14]; Bennett[9]). However, it is unknown why belugas concentrate at only a few of the many rivers in Cook Inlet and why they are not found at other rivers where presumably fish runs are adequate for their needs.

Table 1.—Summary of aerial survey effort conducted by NMFS in Cook Inlet, Alaska, searching for belugas. Counts are the highest of the daily medians of multiple-observer counts for each site for each season.

Dates	Flight hours	Total coverage[1]	Offshore transects	Total groups[2]	Total counts	Upper Cook Inlet counts[3]
1993 June 2–5	13.4	2,534 km^2 (13%)	410 km	11	304	303 (99.7%)
1993 July 25–29	14.8	2,660 km^2 (13%)	557 km	6	271	271 (100.0%)
1994 June 1–5	25.2	4,872 km^2 (25%)	1,129 km	9	281	271 (96.4%)
1995 July 18–26	40.0	4,139 km^2 (21%)	493 km	7	324	310 (95.7%)
1996 June 11–17	39.7	5,852 km^2 (29%)	1,538 km	8	307	307 (100.0%)
1997 June 8–10	22.6	2,894 km^2 (15%)	86 km	10	264	263 (99.6%)
1998 June 9–15	39.4	5,709 km^2 (29%)	1,320 km	9	193	193 (100.0%)
1999 June 8–14	41.5	6,200 km^2 (31%)	1,790 km	7	217	217 (100.0%)
2000 June 7–13	43.0	6,500 km^2 (33%)	1,841 km	7	184	184 (100.0%)
Averages	31.1	4,596 km^2 (23%)	1,018 km	8	261	258 (98.9%)

[1] Coverage is calculated from flight distance times a 2 km-wide swath, a modest estimate of the effective viewing area. Most coastal areas were surveyed several times each season, but coverage calculations included each area only once. Offshore transects are included in this calculation. Percent coverage is based on 19,863 km^2 total surface area of Cook Inlet.

[2] Excluding recounts of groups.

[3] Parenthetic numbers indicate the percentages in the upper inlet relative to the lower inlet.

Predation

Freedom from excessive predation and other disturbances (Factor 4) may be important considerations for beluga distribution in Cook Inlet. The upper inlet experiences extreme tidal fluctuations, and belugas are at risk of becoming stranded (Moore et al., 2000) owing to the inherent risks associated with feeding in opaque waters with rapid changes in depth and strong tidal currents over shallow deltas. However, in spite of these objective hazards, the whales are rarely caught in a stranding by accident (Huntington, 2000), but strandings have occurred when killer whales, *Orcinus orca*, were in the area (Huntington, 2000; Moore et al., 2000). Perhaps the shallow waters of upper Cook Inlet provide some degree of protection, even though strandings may result. Although killer whales may be a primary cause for most baleen whale migrations (Corkeron and Connor, 1999), it is unknown how much their predation affects beluga distribution in Cook Inlet.

Another hazard is beluga philopatry to areas accessible to hunters (Caron and Smith, 1990). Perhaps, because of their need to rebuild fat reserves in the spring, belugas have such a strong drive to feed on fish runs that they remain in feeding areas, even when pursued by hunters (Nuglene[15]). By late June or July, the whales become increasingly more wary of approaches by boats; we have observed entire groups leaving an area when a boat was near. This change in sensitivity may be correlated to changes in fish runs in that the belugas may be relatively tolerant of boats when fish are abundant and easy to catch.

Aircraft, on the other hand, pose no apparent threat to the whales, as they have habituated to the aerial traffic generated by several major airports around upper Cook Inlet. Caron and Smith (1990) observed no changes in swim directions of belugas in eastern Hudson Bay, Canada, when aircraft passed >300 m overhead. Our surveys were consistently flown near 244 m, but belugas did not exhibit overt avoidance behaviors. Sometimes whale groups split or merged, but it did not seem to be in response to the aircraft. In fact, often whales were swimming in the same direction and speed throughout the aerial circling procedure, without any apparent change in activity.

Reproductive Condition

Reproductive condition is an additional factor potentially affecting whale distribution. Although small, dark beluga calves and young were observed during the summer surveys, no apparent pattern indicated calving areas. Natives describe a calving period from April through August (Huntington, 2000), and they indicate that calving areas include most of the areas where belugas concentrate. The southernmost beluga sighting in Cook Inlet in our study was of an adult with a calf or yearling in a fiord (Iniskin Bay) far from other groups. Elsewhere, calves were seen in very large groups of adults and juveniles in upper Cook Inlet. Calves are so much more difficult to see than adults (Hobbs et al., 2000b) that sighting records from the aerial surveys are not considered an optimal mechanism for assessing the proportion of calves to adults.

Sightings in Lower Cook Inlet

The concentrations of belugas observed in upper Cook Inlet during June and July 1993–2000 were similar to reports from previous studies (e.g. June sightings in Calkins[1]), but our low sighting rates in lower Cook Inlet were in

[14] Calkins, D. G. 1989. Status of belukha whales in Cook Inlet. *In* L. E. Jarvela and L. K. Thorsteinson (Editors), Proceeding of the Gulf of Alaska, Cook Inlet, and North Aleutian Basin Information update meeting, 7–8 Feb. 1989, Anchorage, Alaska, p. 109–112. U.S. Dep. Inter., Minerals Manage. Serv., OCS Study, MMS 89-0041.

[15] Nuglene, A. 1997. Subsistence hunter. Personal commun. via B. Mahoney.

Table 2.—Counts of belugas made during NMFS' aerial surveys of Cook Inlet in June/July 1993 to 2000. When multiple surveys were done in an area, median counts from each survey day (typically based on 4 counts from each of 2–4 observers) are shown on separate lines. Counts here do not indicate the number of groups seen in the respective area on each day. Dashes indicate no survey, and zeros indicate that the area was surveyed but no whales were seen. Summary figures use the highest medians from each area (or combination of medians between neighboring areas) for the respective season (in bold).

Survey area (in clockwise order)	June 1993	July 1993	June 1994	July 1995	June 1996	June 1997	June 1998	June 1999	June 2000
Upper Cook Inlet									
Trading Bay	1	**30**	0	0	0	0	0	0	0
(McArthur R.)	**3**	0	0	**4**	0	0	0	0	
	0	0	0	0		0	0	0	
		29		0[1]					
				2					
Susitna Delta	**163**	59	197	**287**	124	72	59	89	100
(N Foreland to	122	150	119	140	159	51	57	75	104
Pt. Mackenzie)	166[2]	**221**	244	178	138	**73**	69	**160**	**114**
	100	184	**248**	190	157		**109**	109	67
		201		199	**237**				
Fire Island	0	0	0	0	0	0	11[2]	0	0
	3[2]	0		0	0		0		0
	0	0		0	0		0		0
				0					
Knik Arm	**80**	0	0	0[3]	7	139	83[2]	43[2]	24
	0	0	0	0	17	**161**	71[2]	**27**	**42**
		0		**1**	20		**42**	14	65[2]
					29				
Turnagain Arm	0	0	**5**	0[1]	0	0[1]	0	0	0
(east of Chickaloon Bay)	**8**	0	0	0[1]	0	0[1]	0		
				0[1]	0		0		
Chickaloon Bay/	**49**	0	15	17	17	**29**	23	17	6
Pt. Possession	29	**20**	11	16	**41**	26	**42**	**29**	**28**
	0		**17**	10	21		41		
				18					
Pt. Possession to	0	0	0	0	0	0	0	0	0
East Foreland	6[2]	0	0	0	0	0	0	0	0
	0	0	**1**	0	0	0	0	**1**	0
	0	0		0				0	
Lower Cook Inlet									
East Foreland to Homer	0	0	0	0[1,3]	0	0	0	0	0
Kachemak Bay	0[4]	—	**8**	0[1]	0	0	0	0	0
West side lower Cook Inlet	—	—	**2**	0	0	**1**[1]	0	0	0
Redoubt Bay (Big R.)	**1**	0	0	**14**	0	0	0	0	0
				2					
Sum of highest medians	**304**	**271**	**281**	**324**	**307**	**264**	**193**	**217**	**184**

[1] Visibility was compromised due to weather conditions.
[2] Not used in the summaries because these groups may have already been included in other areas on other days, or a higher count was obtained by combining two neighboring areas.
[3] Possible sighting of a beluga.
[4] Incomplete survey of this area.

Table 3.—A comparison of June and July sightings of belugas in upper Cook Inlet relative to the lower inlet. Counts are cumulative across several survey seasons in the respective categories.

	June counts			July counts		
		Upper Cook Inlet			Upper Cook Inlet	
Dates	Total (sample size)	counts	percentages	Total (sample size)	counts	percentages
1970's[1]	419	368	88%	789	438	56%
1970's[2]	64	48	75%	578	276	48%
1980's[2]	238	238	100%	257	82	32%
1990's[3]	1,750	1,738	99%	595	581	98%

[1] ADFG data (Calkins, text footnote 1), 1974–79.
[2] NMML unpublished data in Platforms of Opportunity database (NMFS, text footnote 7), 1980–88.
[3] Data from the current study (sum of annual medians), 1993–2000.

contrast with other reports (Calkins[1]; NMFS[7]; Fig. 10). In fact, since 1995, we have seen only one live and one dead beluga south of the Forelands in the lower inlet. This drop in sighting rates was despite our emphasis on completing thorough, annual circuits of the entire coastline, searching specifically for belugas. The paucity of beluga sightings here was not simply an issue of poor visibility, because other marine mammals, such as sea otters, *Enhydra lutris*; harbor seals, *Phoca vitulina*; Steller sea lions, *Eumetopias jubatus*; and harbor porpoise, *Phocoena phocoena*, were seen in abundance in the lower inlet.

During vessel operations conducted in offshore waters of Cook Inlet in June and July 1974 to 1979 (Fig. 10; NMFS[7]), 50% of the 642 recorded belugas were in the lower inlet. In the 1980's, 35% of 495 recorded belugas were in the lower inlet, compared with only 1% of the 2,345 sightings in the 1990's (Tables 2, 3). Sighting effort was not well documented in previous studies, so if there had been more surveys in the upper inlet than the lower inlet

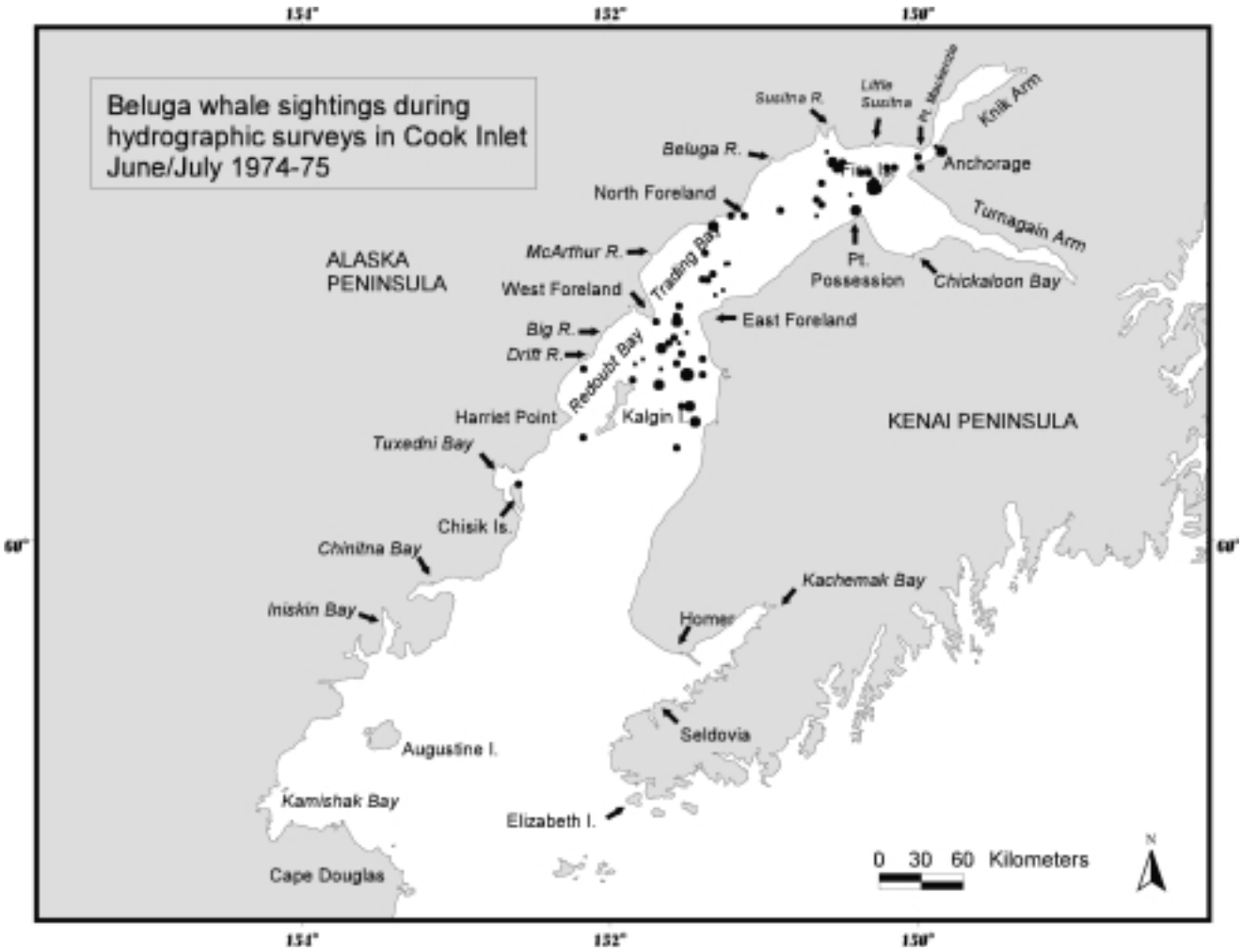

Figure 10.—Beluga sightings during hydrographic surveys in Cook Inlet during June and July 1974–75 (NMFS, text footnote 7). Note that most of the sightings were well offshore, and many sightings occurred in lower Cook Inlet, in contrast to sightings made in the 1990's.

(which is likely because almost all aerial surveys in this area were based out of Anchorage, and virtually all of the surveys targeted areas in the upper inlet where belugas were known to occur), the decline in sightings has been underestimated.

Calkins[2] (p. 40) indicated that belugas were "seen throughout the year in the central and lower inlet, with heaviest use occurring in the central area." Whales are known to concentrate in Tuxedni Bay, based on 11 years of observations by seasonal coastal rangers working for the National Park Service (Bennett[16]). Bennett[16] observed small numbers (up to 38) daily in Tuxedni Bay in June and July 1992, but no whales were seen during his surveys from 1 May to late-August 1994 to 1996 (Bennett[9]). This is a further indication that beluga sightings in the lower inlet in summer have become rare. Others report seeing hundreds of belugas continuously throughout Cook Inlet in the 1970's and 1980's, including areas where few are now found (Foster[17]).

Native hunters reported seeing large groups of belugas in the Kenai River in the 1930's, but the numbers have decreased over the decades, and great numbers occurred in Trading Bay until 10–15 years ago (Huntington, 2000). Belugas were seen regularly in Kachemak Bay until about 1996, according to Jack Montgomery, a local tour guide who has logged about 14,000 km/yr over the past 18 years in that area (Adamson[18]). Intense surveys for marine birds and mammals conducted during 1995–99 in late July and early August did not find any belugas in lower Cook Inlet (Speckman and Piatt, 2000).

[16] Bennett, A. 1993. Wildlife Biologist, Lake Clark Natl. Park and Preserve. Letter to D. Rugh, 14 Dec. 1993.

[17] Foster, S. 1997. Pilot. Personal commun. via B. Mahoney.

[18] Adamson, C. 1998. Where are Cook Inlet belugas? Peninsula Clarion (Soldotna Alaska), 11 Dec. 1998, No. 477:2–3.

Because there was poor or no documentation of effort in previous surveys of Cook Inlet, we used a simple, straightforward approach of comparing proportions of sightings north and south of the Forelands in the middle of the inlet. From casual observations, opportunistic records, and dedicated surveys, it was very apparent that many belugas were seen in the lower inlet in the past where currently almost none are found despite increased search intensity. The differences between reports from the 1970's and 1980's relative to the 1990's, as well as our interannual data through the 1990's, indicate that the distribution of belugas has declined significantly.

Sightings in Offshore Areas

Changes may have occurred in the offshore waters of the upper inlet as well. Some of Calkins'[1] June sightings and most of his July sightings from 1974 to 1979 were well offshore. Also, NOAA data from June and July 1974–75 (Fig. 10) (NMFS[7]) show all but a few of the sightings were offshore. In part this is because the latter data were collected from vessel operations, but whales were also observed along the shore during these surveys (Segur[19]). In contrast, our surveys found almost no live belugas in the center of the inlet in spite of excellent viewing conditions and extensive offshore search efforts. Virtually all of our sightings were shoreward of the 10 fathom (18 m depth) line, whereas the preponderance of the reported sightings in the 1970's (Calkins[1]; NMFS[7]) were beyond this depth.

Sightings Beyond Cook Inlet

There have been some sightings of belugas in the Gulf of Alaska outside of Cook Inlet (Laidre et al., 2000); however, considering the amount of effort expended by aerial surveys and extensive vessel operations in the Gulf of Alaska, it is remarkable how few beluga sightings have been recorded. The lack of sightings along the southern side of the Alaska Peninsula indicate that the Cook Inlet stock is not widely dispersed and is isolated from stocks in the Bering Sea. This hypothesis is supported by mitochondrial DNA analyses which show distinct differences between belugas in Cook Inlet relative to other stocks around Alaska (O'Corry-Crowe et al., 1997). Native hunters have also remarked on how distinct the belugas in Cook Inlet are (Huntington, 2000).

Previous Beluga Counts

The number of whales counted during our aerial surveys (184–324) from 1993 to 2000 is roughly 60–80% of Klinkhart's[3] estimates of 300–400 in 1963 and 1964. Similar numbers (about 400) were seen in 1976–78 (Calkins[2]), with the highest count (479) made on 21 August 1979 (Calkins[14]). Murray and Fay[4] counted only 150 on three consecutive days in the central inlet, but these counts did not include the upper inlet. Counts ranged up to 335 in the upper inlet in June and July 1982 and up to 176 in June and July 1983 (Calkins[1]). During a 40-h survey specifically searching for belugas throughout upper Cook Inlet in June 1991 (NMFS[20]), the highest one-day count was 242 whales. Counts of 200 in June 1991 and 255 in June 1992 were made during aerial surveys of upper Cook Inlet while survey teams were en route to or returning from other projects (NMFS[21]). However, prior to our surveys starting in 1993, most counts were not based on systematic surveys for belugas throughout the entire inlet (Calkins[1]). Current counts have resulted from more intensive and focused surveys than were previously conducted. Analysis of trends in recent abundance estimates (1994–2000) with corrections for missed whales are presented in Hobbs et al. (2000a). Declines evident in these abundance estimates are probably reflected in the declines in distribution reported here. There is no evidence that the belugas of Cook Inlet have dispersed to other areas (Laidre et al., 2000) in response to the persistent harvest by Native hunters (Mahoney and Shelden, 2000), so it is evident that this stock was in decline during this period.

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[19] Segur, G. V. 1975. Marine Mammal Officer, NOAA Ship *McArthur*. Memo. to Chief, Fish. Br., PMC Operations Div., Seattle, Wash., 27 Aug. 1975.

[20] NMFS. 1992. Status report on Cook Inlet belugas (*Delphinapterus leucas*). Rep. prep. by Alaska Reg., Natl. Mar. Fish. Serv., 222 W. 7th Ave., Anchorage, AK 99513-7577, 22 p.

[21] NMFS. 1997. Unpubl. data on file at NMML, NMFS Alaska Fish. Sci. Cent., NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

Whale Commission and NMFS Alaska Regional Office (AKR) provided partial support for some of the CIMMC observers. Kristin Laidre (NMML) provided data and sighting maps from NOAA's Platforms of Opportunity Program and produced all of the maps used in this publication. Flights were conducted under Scientific Research Permits No. 791 (P771#63) and No. 782-1360. Document reviews were provided by Rod Hobbs (NMML), Brad Smith (AKR), Marcia Muto (NMML), David Withrow (NMML), Gary Duker (AFSC Publications Unit), and three anonymous reviewers.

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