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KILLER WHALE PREDATION ON BELUGAS IN COOK INLET, ALASKA: IMPLICATIONS FOR A DEPLETED POPULATION

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ABSTRACT

Killer whale predation on belugas in Cook Inlet, Alaska, has become a concern since the decline of these belugas was documented during the 1990s. Accordingly, killer whale sightings were compiled from systematic surveys, observer databases, and anecdotal accounts. Killer whales have been relatively common in lower Cook Inlet (at least 100 sightings from 1975 to 2002), but in the upper Inlet, north of Kalgin Island, sightings were infrequent (18 in 27 yr), especially prior to the 1990s. Beach cast beluga carcasses with teeth marks and missing flesh also provided evidence of killer whale predation. Most observed killer whale/beluga interactions were in the upper Inlet. During 11 of 15 observed interactions, belugas were obviously injured or killed, either through direct attacks or indirectly as a result of stranding. Assuming at least one beluga mortality occurred during the other four encounters, we can account for 21 belugas killed between 1985 and 2002. This would suggest a minimum estimate of roughly 1/yr and does not include at least three instances where beluga calves accompanied an adult that was attacked.

Key words: *Delphinapterus leucas*, *Orcinus orca*, beluga, killer whale, predator-prey interactions, stranding, mortality, Cook Inlet, Alaska.

A small, genetically distinct population of belugas (*Delphinapterus leucas*) inhabits the waters of Cook Inlet (O'Corry-Crowe *et al.* 1997, Rugh *et al.* 2000). During the first four years of thorough, systematic aerial surveys in Cook Inlet (1994–1998), the population declined by about 50% (653 whales, CV = 0.43 in 1994 to 347, CV = 0.29 in 1998; Hobbs *et al.* 2000), during which time there was unregulated hunting by local natives (Mahoney and Sheldon 2000). Since then there has been a very limited, regulated hunt, and the population decline has stopped (Hobbs *et al.* 2000). Because the whale population is so small and isolated, there is concern about all sources of mortality for this depleted stock and, in particular, predation by killer whales (*Orcinus orca*) (NMFS 2000).

Killer whale predation of belugas has been observed in arctic and subarctic waters of Greenland (Tomilin 1957, Heide-Jørgensen 1988), Canada (Sergeant and Brodie 1969, Reeves and Mitchell 1988), Russia (Sleptsov 1952 as cited in Kleinenberg *et al.* 1964), and western Alaska (Lowry *et al.* 1987, Frost *et al.* 1992, George and Suydam 1998).¹ Belugas and killer whales have inhabited Cook Inlet waters since prehistoric times. In lower Cook Inlet (defined here as south of Kenai, or about 60°33'N), in Tuxedni and Kachemak bays, rock paintings 1,000–3,000 yr old depict both of these species (Osgood 1937, deLaguna 1975, Klein 1981). Whale bones have also been found in middens in Native villages along Kachemak Bay *circa* 625–860 A.D. (Lobdell 1980). Although few of the bones could be identified to species, Lobdell (1980) concluded that “many of the vertebrae were quite small and likely represent the most common whale seen in Kachemak Bay, the beluga.” According to a Tanaina Indian interviewed in 1931, the killer whale was common in the lower Inlet, but was not eaten (Osgood 1937).

Killer whales are cosmopolitan, and in Alaskan waters they are widely distributed south of sea ice in the Chukchi Sea (Braham and Dahlheim 1982, Leatherwood *et al.* 1982). These whales generally occur in small pods, rarely with more than 40 individuals (Dahlheim and Heyning 1998). Although sometimes reported in the open ocean, killer whales are most abundant within 800 km of the continent (Heyning and Dahlheim 1988). For south-central Alaska, Matkin *et al.* (1999) indicated there were as many as 291 photographically identified whales in the Prince William Sound/Kenai Fjords region, some of which also range into Cook Inlet. Two sympatric, non-associating types of killer whales inhabit this region: resident whales that feed exclusively on fish, and transients that consume only marine mammals (Saulitis *et al.* 2000). Of the 291 identified whales in south-central Alaska, 54 are thought to be transients (Matkin *et al.* 1999). The occurrence of these transient whales is considered rare in southeast Alaska (Dahlheim *et al.* 1997), thus we assume that most transients found in Prince William Sound/Kenai Fjords range to the west, not to the east. Only four whales identified in Prince William Sound have been also identified in southeast Alaska (Matkin *et al.* 1999). Transients may have a very extensive range, for instance some were documented to have traveled 2,660 km from southeast Alaska to central California (Goley and Straley 1994). Also, we (M. Dahlheim) have recent photographic matches that show the same transients on the

¹ Burns, J. J., and G. A. Seaman. 1985. Investigations of belukha whales in coastal waters of western and northern Alaska. II. biology and ecology. Final report. U.S. Department of Commerce, NOAA, Outer Continental Shelf Assessment Program NA 81 RAC 00049. Alaska Department of Fish and Game, Fairbanks. 129 pp.

south side of the Kenai Peninsula and in the Bering Sea (1,060 km on a straight line, without allowing for land features).

Although only about 30 killer whale sightings (including many possible resightings) were reported from the southeastern Bering Sea between 1976 and 1990 (Lowry *et al.* 1987, Frost *et al.* 1992), five of these were associated with belugas or involved in evident attacks. The distribution of belugas may, in part, be an adaptation to avoid killer whale predation (Sergeant and Brodie 1969),² as has been suggested for the evolution of migration in baleen whales (Corkeron and Connor 1999). Cook Inlet, a semi-enclosed tidal estuary that is seasonally ice-covered, appears to be an environment ideal for evading killer whales. Although some killer whales, such as those in the Crozet Archipelago south of Africa, have been observed intentionally stranding themselves for brief periods on steep, wave-washed beaches when in pursuit of pinnipeds (*e.g.*, Guinet and Bouvier 1995), killer whales are vulnerable to unintentional stranding for extensive periods when they enter shallow, complex mudflats (Frost *et al.* 1992). In the northern portions of Cook Inlet dramatic tidal changes across extensive mudflats as much as 10 km across could provide some protection from killer whales. This may be one of the primary reasons that belugas are common there but relatively scarce in the southern parts of Cook Inlet where there are fewer apparent limitations to killer whale movements. During summer months, belugas congregate in the upper reaches of Cook Inlet in shallow water near major river outflows (Moore *et al.* 2000, Rugh *et al.* 2000), areas where prey availability is high and predator occurrence relatively low. In winter belugas are found in the upper or central parts of Cook Inlet (Rugh *et al.* 2000) in areas ranging from ice-free to 60% ice-covered (Hansen and Hubbard 1999) or even denser ice (Mahoney, personal observation). Murray (1979)³ concluded that killer whale predation on belugas in Cook Inlet was minimal given that belugas appeared to be spatially separated from killer whales. We present here the first assessment of killer whale predation on belugas in Cook Inlet.

METHODS

Records of killer whale sightings within Cook Inlet in the past 27 yr (1975–2002) were obtained from a number of sources, including systematic surveys and anecdotal accounts.

Systematic Surveys

Seabird and marine mammal surveys have been conducted frequently in different seasons and different parts of Cook Inlet. Aerial surveys to determine abundance and distribution of belugas occurred during the summers of 1964–1965,⁴

² Lowry, L. F. 1985. The belukha whale (*Delphinapterus leucas*). Pages 3–13 in J. J. Burns, K. J. Frost and L. F. Lowry, eds. Marine mammals species accounts. Alaska Department of Fish and Game, Game Technical Bulletin No. 7. 96 pp.

³ Murray, N. 1979. Belukha whales in lower Cook Inlet. Environmental Assessment of the Alaskan Continental Shelf, U.S. Department of Commerce, NOAA-ERL-AR-79-1:192–208.

⁴ Klinkhart, E. G. 1966. The beluga whale in Alaska. Federal Aid in Wildlife Restoration Project Report Volume VII: Projects W-6-R and W-14-R. Alaska Department of Fish and Game, Juneau, AK. 11 pp.

1974–1979 (Calkins 1983),⁵ 1982–1983,⁶ and 1993–2000 (Rugh *et al.* 2000). In 1997 winter surveys for belugas in ice-free areas of Cook Inlet were conducted from mid-February to mid-March (Hansen and Hubbard 1999). Aerial line transect surveys for harbor porpoise (*Phocoena phocoena*) were conducted 1–2 August 1991 (Dahlheim *et al.* 2000). Vessel surveys of seabirds and marine mammals in lower Cook Inlet, south of Kalgin Island, occurred in the summer of 1993 and winter of 1994 (Agler *et al.* 1995) and in late July to early August of 1995–1999 (Speckman and Piatt 2000).

Anecdotal Reports

In addition to the marine mammal sightings reported during dedicated surveys (listed above), the National Marine Mammal Laboratory (NMML) maintains a database of marine mammal observations collected opportunistically (National Oceanic and Atmospheric Administration (NOAA) and U.S. Coast Guard personnel, fisheries observers, fisheries personnel, ferry operators, tourists, or other private boat operators). The Platforms of Opportunity Program (POP) database, with sightings dating since 1958, was reviewed for killer whale observations.

Separate from the POP collection at NMML, the National Marine Fisheries Services' (NMFS) Alaska Regional Office has collected anecdotal accounts of marine mammal sightings and strandings in Alaska since 1988. Sources include reports from fishing vessels, charter boat operators, aircraft pilots, NMFS enforcement officers, NMFS scientists, and the general public. Killer whales are relatively easy to identify, so these records can be used reliably.

Pod Size and Photo-identification

Photographs taken of killer whales during encounters with belugas were reviewed for possible matches in existing photographic catalogs (*e.g.*, Dahlheim 1997, Matkin *et al.* 1999). In instances where photographs were not available or could not be matched, pod type (resident *vs.* transient) was determined based on association with other marine mammals, pod size, saddle patch patterns, and/or dorsal fin shape (Bigg *et al.* 1987, Bain 1989, Baird 2000).

RESULTS

Systematic Surveys

Killer whale sightings were not reported during aerial surveys for belugas conducted prior to the 1990s.^{3,4,6} However, several systematic surveys conducted in the 1990s reported at least one sighting of killer whales. Each June or July of 1993–2000, NMFS aerial surveys searched for belugas over nearly 25% of the total water surface of Cook Inlet and almost 100% of the coastal areas (Rugh *et al.* 2000). Although the survey effort was focused on the upper Inlet, only two sightings of

⁵ Murray, N. K., and F. H. Fay. 1979. The white whales or belukhas, *Delphinapterus leucas*, of Cook Inlet, Alaska. Paper SC/31/SM12 presented to the Sub-committee on Small Cetaceans of the Scientific Committee of the International Whaling Commission. Unpublished. 7 pp. Available from AFSC, NMML Library, 7600 Sand Point Way N.E., Seattle, WA 98115.

⁶ Calkins, D. G. 1984. Belukha whale. Vol. IX of Susitna hydroelectric project; final report; big game studies. Alaska Department of Fish and Game Doc. 2328. 17 pp.

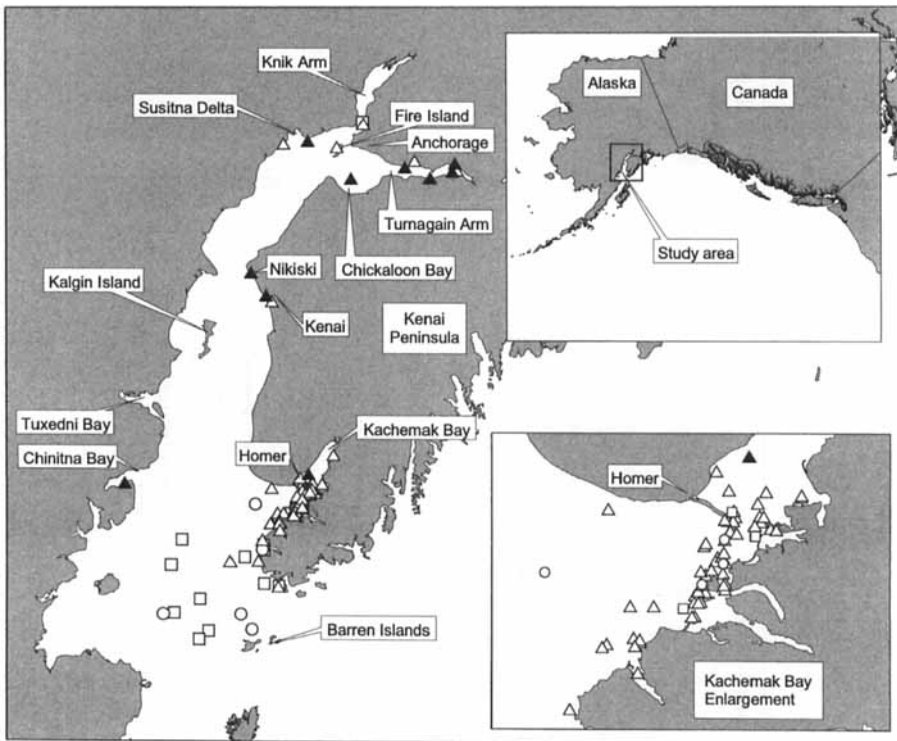


Figure 1. Sightings of killer whales in Cook Inlet, Alaska, from 1975 to 2002. Systematic surveys, Platforms of Opportunity Program data, and anecdotal accounts are shown as circles, squares, and triangles, respectively. Filled symbols indicate that belugas were present.

killer whales were made during this project, both in the lower Inlet (Fig. 1). No killer whales were seen during 1,873 km of aerial surveys for harbor porpoise in Cook Inlet in August 1991 (Dahlheim *et al.* 2000; NMFS, unpublished data). During vessel surveys of the lower Inlet, covering 17,452 km², observers reported killer whales on three occasions: one in the summer of 1993 and two in the winter of 1994 (Aglar *et al.* 1995). Similar vessel surveys in 1995–1999, covering 6,249 km of trackline (Speckman and Piatt 2000), encountered only three killer whale pods in lower Cook Inlet. During 9,406 km of aerial surveys in the winter of 1997, no killer whales were seen in Cook Inlet (Hansen and Hubbard 1999). In summary, during various extensive systematic surveys through the 1990s, few killer whale sightings ($n = 8$) occurred in Cook Inlet, all of which were in the lower Inlet (Fig. 1).

Anecdotal Reports

In the POP database, there were 15 killer whale sightings reported in Cook Inlet between 1975 and 1999 (Fig. 1). Only one of these sightings occurred in the upper Inlet: five whales seen near Anchorage in May 1982 (Table 1).

Most of the killer whale sightings and all records of interactions between killer whales and belugas (99 of 122 reports) came through the NMFS network for

Table 1. Killer whale sightings in upper Cook Inlet, Alaska, (north of 60°N) and any other killer whales associated with belugas in Cook Inlet. All of these are considered to be transient pods. Data on killer whale sightings in lower Cook Inlet (shown in Fig. 1) may be obtained by contacting the authors.

Date	Pod size	Location	Observations	Source
24 May 1982	5	Knik Arm (61.25°N, 149.90°W)	No comments recorded.	NOAA ship <i>Rainier</i> ^a
late spring/early summer 1985	1	Turnagain Arm (60.98°N, 149.61°W)	Observed a large group of belugas in a small bay off Gorilla Rock-Windy Pt. apparently feeding on culachon or salmon. Suddenly, the group disappeared, and the water went flat. Turbulent thrashing and violent splashing of brown water was then seen about 300–400 ft offshore. A large, black dorsal fin of a killer whale appeared several times in the area over the course of a few minutes. Others in the party reported seeing flashes of white and blood.	J. Yelverton ^b
July, early 1990s	4	Fire Island (61.17°N, 150.22°W)	In 20 yr of fishing off Fire Island 3–4 d/wk each summer, only observed killer whales one time. In July early in the 1990s, 4 whales, including one adult male, swam from North Pt. to Race Pt.	S. Braund ^c
September 1990	>3	Chickaloon Bay (61.00°N, 150.17°W)	While waterfowl hunting in the Anchorage Coastal Wildlife Refuge across from Potter's Marsh, observed several killer whales with a group of belugas. Mr. Hoffman's companion observed a killer whale chasing a beluga; the beluga leapt clear of the water followed by the killer whale which caught it in its jaws before both re-entered the water. Both men observed the resulting splash and churning water.	R. Hoffman ^d

Table 1. Continued.

Date	Pod size	Location	Observations	Source
21 May 1991	6	Turnagain Arm (60.90°N, 149.20°W)	Six killer whales, including 2 adult males, 3 females, and 1 juvenile of unknown sex, stranded on the tide flats for 6 h southeast of Girdwood. Belugas were observed in the vicinity.	M. Opalka and NMFS unpublished data ^e
20 June 1991	?	Turnagain Arm (60.90°N, 149.40°W)	Dead beluga, unidentified sex, about 6 ft long, missing some of its tail; killer whale teeth marks evident.	Moore <i>et al.</i> 2000
6 October 1992	?	Kenai River (60.56°N, 151.29°W)	Found near MP 110.5 on Seward Hwy. Two male belugas stranded about 2 miles N. of the Kenai R. They were reportedly chased by killer whales and had been stranded for at least 3 d. When NMFS personnel arrived, one beluga had died and the other died when an attempt was made to return it to the water. Both had killer whale teeth marks on their flukes.	NMFS unpublished data ^f
24–27 August 1993	5	Turnagain Arm (61.00°N, 149.50°W)	During low tide on the 24th, five killer whales, including 1 adult male, 3 females, and a small male, stranded on the tide flats south of Bird Creek. The adult male was accessible to people and dogs while the rest of the pod was farther away and surrounded by water. The adult male regurgitated a large chunk of beluga blubber and a harbor seal paw, and later died. All were freed on the high tide.	NMFS unpublished data ^f
14 June 1994	?	Susitna Delta (61.23°N, 150.49°W)	186 belugas stranded on the tide flats. Unconfirmed report of killer whales in the area.	NMFS unpublished data ^f
August 1995	3	Ivan River (61.25°N, 150.73°W)	R. Johnson observed and photographed an adult male killer whale with an adult female (or subadult male) and a calf when departing his set net site on the Ivan River in the Susitna Delta. His father, P. Johnson, had fished the Ivan River since 1959 and never saw killer whales at his set net site until 5–7 yr ago. Since then, he has seen them at least once a year until 2000.	R. Johnson and P. Johnson ^g

Table 1. Continued.

Date	Pod size	Location	Observations	Source
29 August 1999	3	Turnagain Arm (60.90°N, 149.40°W)	Three killer whales seen chasing belugas roughly 2 h before about 60 belugas stranded on the tidal flat south of Bird Pt. At least five belugas died while stranded.	Moore <i>et al.</i> 2000
early September 1999	1	Chinitna Bay (59.83°N, 153.08°W)	One adult male was seen in about 10 ft of water towing a live, thrashing beluga to deeper water accompanied by a beluga calf. No blood was seen, but the beluga was held by its right pectoral and may have stopped thrashing while observed.	S. Fickes ^h
1st week September 2000	?	Nikiski (60.68°N, 151.38°W)	A dead beluga (sex unknown) with chunks of blubber and meat missing from its belly and possible orca teeth marks was found near the Unocal dock. Flukes and one pectoral fin were intact.	Moore <i>et al.</i> 2000
23–26 September 2000	3–5	Turnagain Arm (60.90°N, 149.40°W)	A male killer whale was seen among 40–50 belugas near Bird Pt on the 23rd. It separated one beluga from the group; then three other killer whales joined in a “vicious assault” on the beluga. No blood visible. On the 24th, a group of belugas was observed farther up the Arm at Girdwood, 3–5 killer whales were in a thin strip of water between tide flats near Peterson Creek, not far from the group. On the 25th, one killer whale stranded and later freed itself near Twentymile. Two belugas, both lactating females, were found dead (one on the 25th, the other on the 26th). Orca teeth marks were evident but appeared to be non-lethal. Internal organs were hemorrhaged suggesting deaths caused by an impact injury. Possible that beluga calves were consumed.	R. Yerena and K. Loberg, ⁱ NMFS unpublished data ⁱ

Table 1. Continued.

Date	Pod size	Location	Observations	Source
3 October 2000	3	Kenai River (60.53°N, 151.25°W)	A small, gray-colored beluga was observed up river of Ward's Cannery. It was injured (blood visible) and rarely submerged. Three submerged killer whales (dorsals visible) approached. There was a splash, churning red-colored water, then all the whales were gone.	J.R. Skrtha ^l
2000	1	Kachemak Bay (59.70°N, 151.30°W)	While boating and seal hunting on the east side of Kachemak Bay a couple of years ago (in 2000?) saw one killer whale chasing a beluga. Not sure of exact location and time of year.	T. Nuglene ^k
12 May 2001	1	Turnagain Arm (60.90°N, 149.20°W)	Observed two groups of belugas near Girdwood. One group of 48 animals was described as "casually feeding not stressed." Saw what appeared to be a killer whale "circling, cutting in water" where the second group of 30 belugas were "circling in same spot, splashing water."	B. Padgett ^l
25 May 2002	1	Turnagain Arm (61.00°N, 149.50°W)	A lone killer whale (subadult or female) was observed swimming among wind surfers. The person reporting the sighting (a friend of R. Maron) first heard the whale breathing before seeing it nearby. He was concerned that it might go after the wind surfers. Exact location of sighting not reported.	R. Maron ^m
27 August 2002	1	Turnagain Arm (60.90°N, 149.12°W)	Saw what appeared to be a stranded killer whale in mid-channel offshore of Girdwood.	D. Goldstein ⁿ
4 September 2002	1	Turnagain Arm (60.90°N, 149.17°W)	Observed one male killer whale among belugas swimming up Turnagain Arm near MP 93 on the Seward Highway.	L. Hibbs ^o

Table 1. Continued.

Date	Pod size	Location	Observations	Source
21 September 2002	1	Knik Arm (61.24°N, 149.04°W)	One male killer whale seen about 1500 ft. off the small boat launch at Ship Creek swimming at a steady pace north into Knik Arm.	C. Anderson ^f
30 September 2002	2	Chuitna River (61.09°N, 151.12°W)	A Tyonek villager reported seeing two killer whales at the mouth of the Chuitna River.	P. Merryman ^g

^a Observations from the Platforms of Opportunity Program database, National Marine Mammal Laboratory, NOAA, NMFS, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, Washington 98115-6349 U.S.A.

^b Personal communication, Joe Yelverton, Mountain Safety Research, P.O. Box 24547, Seattle, Washington 98124-0547 U.S.A., 1 August 2001.

^c Personal communication, Steve Braund, Braund and Associates, 308 G St., Anchorage, Alaska, 99513 U.S.A., June 2001.

^d Personal communication, Robert Hoffman Jr., 7761 Ingram St., Anchorage, Alaska, 99502 U.S.A., 30 October 2001.

^e There are conflicting reports as to when this event occurred. An unpublished document (NMFS, 1992. Status report on Cook Inlet belugas (*Delphinapterus leucas*) (prepared by NMFS, Alaska Region, 222 W. 7th Ave. #43, Anchorage, Alaska 99513 U.S.A. 22 pp.) describes the stranding on 15 May 1991. Stranding reports from the NMFS Alaska Region office list the date as 21 May 1991. Reported by Mike Opalka, Alaska State Trooper, P.O. Box 663, Girdwood, Alaska 99587 U.S.A.

^f Unpublished data, Barbara Mahoney and Brad Smith, National Marine Fisheries Service, 222 W. 7th Ave. #43, Anchorage, Alaska 99513 U.S.A.

^g Personal communication, Ross Johnson, Fisherman, 9845 Greenhouse St., Eagle River, Alaska 99577 U.S.A., and Preston Johnson, Fisherman, Eagle River, Alaska 99577 U.S.A., 13 December 2001.

^h Personal communication, Steve Fickes, Great Alaska Adventure Lodge, P.O. Box 1051, Sterling, Alaska 99672 U.S.A., 30 January 2002.

ⁱ Personal communication, Robert Yerena, Enforcement Officer, National Marine Fisheries Service, Alaska Enforcement Division, 230 Railway Seaview Plaza, Suite 125, Seward, Alaska 99664 U.S.A. and Kenneth Loberg, 2221 Muldoon Rd, Anchorage, AK 99504 U.S.A., 26 September 2000.

^j Personal communication, Joseph R. Skrha, Kenai, Alaska, 99611 U.S.A., October 2000.

^k Personal communication, Albert (Tom) Nuglene, Marine Mammal Hunter, 3206 East 11th Ct., Anchorage, Alaska, 99508 U.S.A., 13 July 2002.

^l Personal communication, 1st Lt. Ben Padgett, Civil Air Patrol, Polaris Composite Squadron, Anchorage, Alaska, 99501 U.S.A., May 2001.

^m Personal communication, Rick Maron, Land Surveyor, Bureau of Land Management, 222 W. 7th Ave, Box 13, Anchorage, Alaska 99513 U.S.A., May 2002.

ⁿ Personal communication, Dave Goldstein, Prince William Sound Eco-charters, Whittier, Alaska 99693 U.S.A., 30 August 2002.

^o Personal communication, Liz Hibbs, Alaska State Trooper Dispatch, P.O. Box 663, Girdwood, Alaska 99587 U.S.A., 3 October 2002.

^p Personal communication, Carl Anderson, Owner, Cook Inlet Tug and Barge Co., Anchorage, Alaska 99501 U.S.A., 23 September 2002.

^q Personal communication, Peter Merryman, Chief, Native Village of Tyonek, Tyonek, Alaska 99682 U.S.A., 11 October 2002.

collecting anecdotal accounts. The majority of killer whale sightings in the lower Inlet ($n = 75$) were provided by charter boat operators out of Homer, in Kachemak Bay (Fig. 1).

Number of Killer Whale Sightings

The number of killer whale accounts ($n = 122$) may be positively biased as there were apparent cases of multiple reports of the same pod seen over several days. For instance, pod AD5 was reported six times in Kachemak Bay between late July and mid-September 1998 (47 d). Of the 122 sightings, 48 occurred within one week of each other and in the same general vicinity (<40 km between apparent resightings). None of these sightings could be considered unique based on time and distance between sightings (*i.e.*, apparent swim speed) alone, because all pairwise comparisons of sequential sightings indicate that whales could have easily traveled between the sighting locations at <2 km/h. Therefore, it is not evident how many different pods might have entered Cook Inlet.

Since 1985, there have been 11 confirmed sightings of killer whales with belugas, one unconfirmed sighting (in 1994), and evidence of three other encounters (*i.e.*, two stranded belugas with teeth marks and a killer whale regurgitating beluga flesh) in the waters of Cook Inlet (Table 1).

Pod Size and Identity

Pod sizes of killer whales observed in the lower Inlet ranged from 1 to 40 animals and included both transient and resident whales. For example, one pod identified in Kachemak Bay was AD5, a pod of 17 resident whales most often observed in the Kenai Fjords region (Matkin *et al.* 1999). The smallest resident pod in the lower Inlet consisted of five individuals (perhaps only a portion of the AD5 pod). In the upper Inlet pods ranged in size from one to six animals (Table 1). The consistently small size of these pods in the upper Inlet, their interactions with other marine mammals, as well as photographs of pod members with pointed dorsal fins and closed saddle patches, suggests they were transients (Baird and Dill 1996, Baird 2000, Saulitis *et al.* 2000).

Photographs taken of killer whales that stranded in Turnagain Arm in 1991 (six whales), 1993 (five whales), and 2000 (three–five whales) (Table 1) provided one match of an adult male in 1991 and 1993. Poor quality of additional photographs hindered the ability to identify other individuals, but it does appear that the composition of the killer whale pod during these three encounters was similar. No matches were found between the images of killer whales in Turnagain Arm and those in all available catalogs for Alaska south to Mexico.⁷

Location

Most killer whale sightings in Cook Inlet occurred in the lower Inlet, despite the strong bias towards reports from high-traffic areas, such as near Anchorage. Of the 122 reported sightings, 81% were south of $60^{\circ}33'N$. In the upper Inlet there were only 18 sightings of killer whales in the past 27 yr, plus two reports of dead belugas

⁷ Personal communication from David Ellifrit, Center for Whale Research, 1359 Smuggler's Cove Road, Friday Harbor, WA 98250, 1 May 2002.

with killer whale rake marks (Fig. 1, Table 1). People who have fished the upper Inlet for 20–50 yr⁸ reported few if any sightings of killer whales, and nearly all of these were in the 1990s. In his study of traditional ecological knowledge, Huntington (2000) interviewed Alaska native beluga hunters who reported that killer whales were rarely seen in the upper Inlet or near belugas.

Of the sightings in the lower Inlet, 90% were east of 152°15'W, near the Kenai Peninsula. This sighting distribution is biased upward by the high amount of tourist and fishing activity on the east side of the Inlet, especially near Homer, thereby increasing the probability of sightings being reported.

Timing

Sighting rates through the seasons seem to be correlated with increased traffic: only one sighting was reported from lower Cook Inlet from December to January; only 2–8 sightings per month were reported for February, March, April, and October; whereas 12–24 per month were reported from May through September when more boats may have been on the water. All of the upper Inlet sightings occurred from May through September and were spread fairly evenly (about three sightings per month) through this period. This could either be a function of reduced search effort between fall and early spring, or it could, in part, represent killer whale seasonal occurrence. Sea ice is usually present between November and April (Mulherin *et al.* 2001), a period which correlates with reduced observational opportunities and, thus, the absence of sightings in the upper Inlet.

Only two sightings were recorded in the upper Inlet prior to 1990, but since then sightings have been more frequent. Some people have said killer whales were seen at least once a year in upper Cook Inlet since the mid-1990s.⁹

DISCUSSION

This study of belugas and killer whales in Cook Inlet parallels reports by Lowry *et al.* (1987) and Frost *et al.* (1992) from the southeastern Bering Sea, particularly Bristol Bay. Bristol Bay is separated from Cook Inlet by the Alaska Peninsula, and similar to Cook Inlet, belugas regularly feed on fish in river mouths over shallow mudflats—areas sometimes invaded by killer whales.

Strandings of belugas and killer whales on these mudflats appear to be associated with these attacks. Killer whales have stranded at least four times in Turnagain Arm (21 May 1991, 24–27 August 1993, 25 September 2000, and 27 August 2002; Table 1), and strandings of killer whales have also been reported elsewhere, such as in Bristol Bay (Lowry *et al.* 1987, Frost *et al.* 1992). Only once did a stranding in Cook Inlet result in a known death (Table 1).

Beluga deaths during strandings appear to be rare, seen during only 4 of 14 documented events (total known mortalities = 12 belugas out of 650 belugas that have been seen stranded since 1988, Moore *et al.* 2000). Five of these deaths occurred during one event when killer whales were present (29 Aug 1999, Table 1).

⁸ Personal communications from Steve Braund, 308 G St., Anchorage, AK 99510, June 2001; David Ring, 5033 W 80th Ave, Anchorage, AK 99502, 14 June 2001; Nancy Lord, P. O. Box 558, Homer, AK 99603, 12 July 2001; Dan Billman, 13740 McDonell Road, Anchorage, AK 99516, 12 July 2001; and Ross Johnson, 9845 Greenhouse St., AK 99577, 13 December 2001.

⁹ Personal communication from Preston Johnson, Eagle River, AK 99577, 13 December 2001.

There were no recorded sightings of killer whales in upper Cook Inlet in the 1970s and only two in the 1980s. However, from 1990 to 2002 there were 18 records of occurrence. In the lower Inlet sightings increased by similar proportions: 14 prior to 1990 to 88 after 1990, a six-fold increase. This is probably a function of observational effort: it is likely that most whales were missed prior to the 1990s when there were fewer observers and no formal network for reporting sightings (the anecdotal reports collected by NMFS in Cook Inlet began in 1988). Current sighting networks are so wide, and interest among the public is so high, that relatively few killer whale occurrences near traffic centers go unreported, especially when there are encounters with belugas. Encounters in the upper Inlet (and in more recent times) are more likely to be reported because there is road access along much of the northeast portion of Cook Inlet, boat traffic is common in the upper Inlet, and there are many sightseers in low-flying aircraft based out of Anchorage.

The documented change in beluga distribution between the 1970s and 1990s (Rugh *et al.* 2000) has resulted in fewer belugas in the lower Inlet in recent years. Consequently, when killer whales could no longer find belugas in the lower Inlet, they might have increased their visits to the upper Inlet, in spite of the hazards of shallow tidal areas, rapid currents, and seasonal sea ice.

Killer whale predation on Steller sea lions (*Eumetopias jubatus*) and harbor seals (*Phoca vitulina*) may have provided these whales with a reliable food source (Corkeron and Connor 1999), given the large numbers of these pinnipeds prior to the 1980s and their predictable use of haul-out sites (Braham *et al.* 1980, Loughlin *et al.* 1984). However, declines in abundance of sea lions (Loughlin *et al.* 1992) and harbor seals (Frost *et al.* 1994) in Alaska to less than one-half of their original numbers may have forced killer whales to search for alternate food sources in recent years. This possible switch in prey base correlates with the apparent rise in killer whale encounters in upper Cook Inlet (reported here) and in Bristol Bay (Frost *et al.* 1992), as well as the increased take of sea otters, *Enhydra lutris* (Estes *et al.* 1998, Hatfield *et al.* 1998). Of the 54 transient whales identified in the Gulf of Alaska, it is likely that very few visit the upper Inlet and pursue belugas.¹⁰ However, Estes *et al.* (1998) calculated that the entire sea otter decline observed recently over large areas in western Alaska could have been caused by less than four killer whales. The relatively smaller area of Cook Inlet and the low number of belugas involved makes it plausible that only a small number of killer whales could be responsible for all of the predation of belugas there.

Killer whales in upper Cook Inlet were probably members of a transient pod. Of the 15 observed interactions, 11 included reports of beluga injuries or mortalities. On every occasion when killer whales were seen in Turnagain Arm, belugas were chased, stranded, consumed, or later found dead. There have been at least 11 observed beluga deaths (*i.e.*, stranded animals that died ($n = 5$) or carcasses found with rake marks ($n = 6$)) caused by killer whales in the upper Inlet between 1991 and 2000, eight of which occurred in Turnagain Arm.

The most recent observed deaths (23–26 September 2000; Table 1) were of two lactating belugas in Turnagain Arm. Neither of the females were eaten, instead only parts of their flippers or flukes were missing, there were large rake marks across their backs, and death seemed to have been caused by extensive internal hemorrhaging. The lack of any other remains led to the speculation that their calves were consumed. One other sighting in early September 1999 in Chinitna

¹⁰ Personal communication from Jim Diehl, Girdwood, AK 99587, 20 October 2000.

Bay, also involved a killer whale attacking an adult beluga with a beluga calf present. The killer whale was seen towing the adult beluga by its flipper into deeper water (Table 1). The final outcome was not observed.

Given the current knowledge, the overall contribution of killer whale predation to beluga mortality (at least one per year) appears small. Of the 47 beluga carcasses found in Cook Inlet since 1988, only six showed probable signs of killer whale predation (Moore *et al.* 2000). However, it is also likely that killer whale predation rates were underestimated because beluga carcasses sank, were carried out of the Inlet, were consumed entirely, or were too decomposed to determine cause of death.

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