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Evaluation of Beluga Whales in Kotzebue Sound, Alaska, as a Demographically Independent Population

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N. A. Friday

February 2026

U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric
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National Marine Fisheries Service
Alaska Fisheries Science Center

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ABSTRACT

Recent revisions to the U.S. Guidelines for Preparing Stock Assessment Reports Pursuant to the Marine Mammal Protection Act (MMPA) included the need to incorporate Indigenous Knowledge into the demographically independent population (DIP) delineation and stock assessment processes when these marine mammal populations are co-managed by the National Marine Fisheries Service (NMFS) and Alaska Native organizations. The MMPA directs NMFS to use the “best scientific information available” to assess stocks, and by extension, to delineate DIPs. Guidance exists for the incorporation of lines of evidence for DIP designation based on morphology, genetics, movements, distributional hiatuses or low-density areas, contaminants, stable isotopes and fatty acids, life history, trends in abundance, physiographic or oceanographic differences in habitat, association data, and acoustics, but not for Indigenous Knowledge. This evaluation is the first to incorporate Indigenous Knowledge within the framework of the DIP delineation process. Multiple information sources, including Indigenous Knowledge, subsistence harvest, sightings data, genetic data, passive acoustic monitoring, and satellite telemetry data, were used to evaluate whether there has been, or is, a DIP of beluga whales in Kotzebue Sound. Indigenous Knowledge and mtDNA analyses support the existence of a DIP for belugas that occupied Kotzebue Sound prior to the mid-1980s. Acoustic monitoring and satellite telemetry data were not collected during this time period. By the mid-1990s, beluga numbers were significantly reduced, and hunting occurred opportunistically within Kotzebue Sound. After the mid-1980s, genetic data are ambiguous about the existence of a DIP given small sample sizes and the presence of Beaufort Sea belugas in some years. Acoustic monitoring between September 2014 and July 2015 recorded beluga presence one day in May. June was poorly sampled due to weather delays and recorders failing, but acoustic detections also occurred in July and August. However, the majority of acoustic detections were recorded during the fall and winter months. Satellite telemetry data from the Beaufort Sea and Eastern Chukchi Sea beluga stocks did not identify whales with functioning transmitters within Kotzebue Sound. Indigenous Knowledge indicates that belugas arriving in late May and in June since the mid-1980s are part of the historic population based on behavior and seasonal ranging patterns. We conclude that 1) during the historical time period a Kotzebue Sound DIP existed based on Indigenous Knowledge, harvest/sightings, and genetic lines of evidence, and 2) Indigenous Knowledge supports the existence of a contemporary DIP, but other lines of evidence do not support or refute the existence of a contemporary DIP.

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INTRODUCTION

Marine mammals within U.S. waters are protected under the Marine Mammal Protection Act of 1972 (MMPA as amended, 16 U.S.C. §§ 1361 et seq). The MMPA identifies a marine mammal “population stock” or “stock” as the fundamental unit of conservation. The statute uses the term “population stock” and “stock” interchangeably, defining them as “a group of marine mammals of the same species or smaller taxa in a common spatial arrangement that interbreed when mature.” Whenever possible, a demographically independent population (DIP) of marine mammals is designated and managed as a stock (NMFS 2019, 2023).

NMFS’ Guidelines for Preparing Stock Assessment Reports Pursuant to the Marine Mammal Protection Act (often referred to as the Guidelines for Assessing Marine Mammal Stocks, or GAMMS; NMFS 2023) define a DIP as “a group of animals for which the population dynamics are more a consequence of births and deaths within the group (internal dynamics) than immigration or emigration (external dynamics)”. Given this definition, it follows that the primary quantitative criterion for determining whether a group of individuals constitutes a DIP is dispersal rate: if the rate of immigration into a population is less than the rate of internal recruitment, then the population constitutes a DIP (Martien et al. 2019). Martien et al. (2019) highlight that separate populations do not need to be reproductively isolated to be considered demographically independent because “gene flow (the transfer of genetic material from one group to another through interbreeding) does not necessarily equate to dispersal (and vice versa).” For example, there could be gene flow between two populations because they co-occur during the breeding season, but the two populations could still be demographically independent of each other due to minimal dispersal (i.e., immigration or emigration).

NMFS defines the process of DIP delineation for marine mammals as “interpreting the scientific lines of evidence supporting whether or not groups of animals meet the definition of a DIP as laid out in the GAMMS, including determining the geographic range of the groups (which may shift through time, especially for migratory species)” (NMFS 2019). The MMPA directs NMFS to use the “best scientific information available” to assess stocks, and by extension, to delineate DIPs (Martien et al. 2019). There are no limitations on the age of information that may be used for these tasks. Recent revisions to the GAMMS specify that NMFS will consult with appropriate Alaska Native co-management partners regarding scientific and other information relevant to preparing assessments for stocks that are co-managed by NMFS and Alaska Native organizations (NMFS 2023).

Because it is not always possible to obtain direct measurements of dispersal rates to ascertain demographic independence, NMFS’ guidance addresses the use of various other lines of evidence for DIP designation including morphology, genetics, movements, distributional hiatuses or low-density areas, contaminants, stable isotopes and fatty acids, life history, trends in abundance, physiographic or oceanographic differences in habitat,

association data, and acoustics (Martien et al. 2019). However, there is no specific guidance on incorporating Indigenous Knowledge into the DIP evaluation. Herein, we describe the lines of evidence (data and analyses), as well as the strengths and weaknesses of each line of evidence that we used to evaluate the demographic independence of beluga whales (*Delphinapterus leucas*) in the Kotzebue Sound area, Alaska, USA (Fig. 1). This evaluation is the first to incorporate Indigenous Knowledge within the framework of the DIP delineation process.

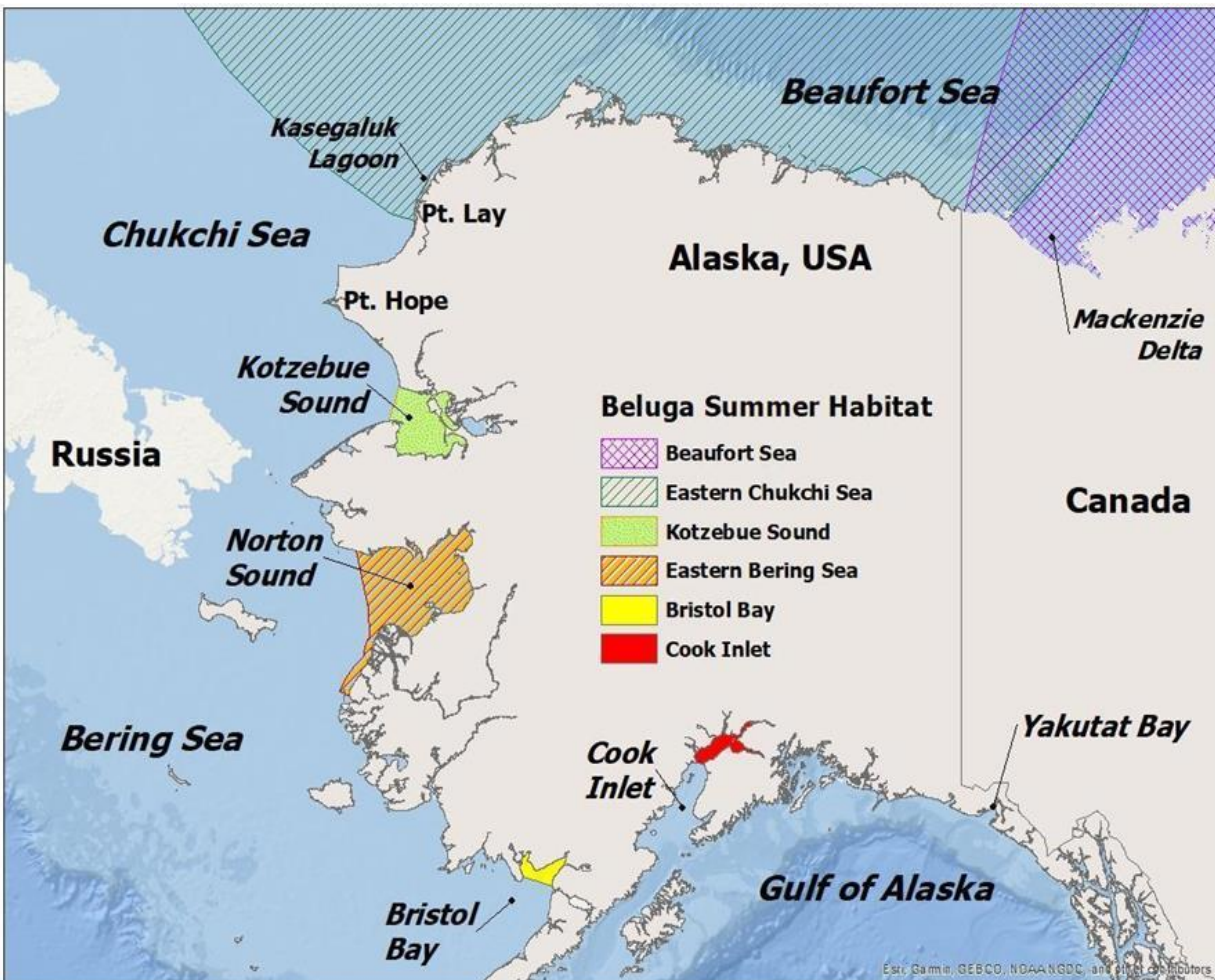


Figure 1. -- Beluga whale summer habitat in Alaska waters.

Request for Stock Recognition

NMFS began this investigation at the request and recommendation of its co-management partner, the Alaska Beluga Whale Committee (ABWC). The ABWC based this recommendation on both Indigenous Knowledge and genetic data presented in O’Corry-Crowe et al. (2021), which suggested that belugas harvested historically in Kotzebue Sound comprised a unique stock, and that this stock continues to be harvested. The ABWC acknowledged that belugas from other populations may also occur in Kotzebue Sound, given evidence of occasional incursions of belugas into the area, specifically from the Beaufort Sea population (O’Corry-Crowe et al. 2021; ABWC 2023a,b,c). Throughout this document, we use the term “Kotzebue Sound belugas” to mean belugas that were observed or harvested, or that occur(red) in Kotzebue Sound, regardless of genetic provenance; thus, “Kotzebue Sound belugas” may refer to animals from one or more populations.

Both the ABWC and O’Corry-Crowe et al. (2021) considered the overarching guidance in the MMPA for whether a population meets the definition of a stock, but they did not specifically consider NMFS’ guidance for delineating DIPs or NMFS’ procedures for designating stocks under the MMPA. NMFS treats DIP delineation and stock designation as separate processes, where stock designation is “the official naming of a stock as a management unit that will then be assessed in SARs” (NMFS 2019). As noted above, in most cases, a DIP of marine mammals should generally be designated and managed as a stock (NMFS 2019, 2023). However, there may be cases where it would be impractical, or there are insufficient data or analytical tools, to assess and manage at the DIP level; in these cases, it may be appropriate to combine multiple DIPs into a single stock (NMFS 2019, 2023).

This report summarizes our evaluation of the available lines of evidence for determining whether a DIP of beluga whales occurs in Kotzebue Sound. We expect that the NMFS Alaska Region, Alaska Fisheries Science Center, Office of Science and Technology, and Office of Protected Resources will collectively consider the findings presented here as part of an evaluation of whether any changes to the current beluga whale stock designations are necessary.

EXISTING LINES OF EVIDENCE

The available lines of evidence to review for belugas in Kotzebue Sound include harvest and sighting histories, which are often provided by hunters and hunting communities as Indigenous Knowledge and documented in the scientific literature; recent Indigenous Knowledge documented by the ABWC; genetics; passive acoustics; and satellite telemetry data. In accordance with Martien et al. (2019), for each line of evidence we provide the following information: 1) the extent to which the evidence indicates demographic independence, 2) limitations of the data and analyses used (e.g., sample size, seasonality or spatial distribution of samples, violated assumptions or biases in the analyses), and 3) how those limitations might impact results of the DIP delineation.

We refer to two time periods, historical and contemporary. The historical period refers to the years prior to 1985, at which point the harvest declined substantially. The contemporary period begins with 1985; however, the start and end years included in the contemporary period are case-specific and depend on the information used by the original source cited. Therefore, the contemporary period may extend from 1985 or 1994 through 2007, 2019, or 2022, depending on the source. The years included in the contemporary period are stated explicitly throughout the text below.

Indigenous Knowledge, Subsistence Harvests, and Sightings

Belugas have long been important to Indigenous societies in the Kotzebue Sound area. Knowledge of beluga behavior and movement patterns was provided through discussions, interviews, and surveys with members of these hunting communities (e.g., Morseth 1997, Burch 1998, Huntington et al. 1999). Ethnographic studies in the early 1950s drew directly on Iñupiat knowledge of the annual return of belugas to Kotzebue Sound going back to the 1860s and 1870s (Lucier and Vanstone 1995). Archaeological studies recorded beluga remains in settlement sites around Kotzebue Sound dating 2,800 years before the present (Giddings and Anderson 1986). From 1977 to 1986, harvest data for Kotzebue Sound were collected by Alaska Department of Fish and Game (ADFG) biologists (e.g., Seaman and Burns 1981, Burns and Seaman 1986). Since 1987, harvest data have been provided by ABWC hunter delegates from the villages of Buckland, Deering, Kivalina (spring and summer hunt), Kotzebue, and Noatak (e.g., Frost and Suydam 2010, Frost et al. 2021; Fig. 2).



Figure 2. -- Kotzebue Sound, including the primary hunting locations of Sisualik and Eschscholtz Bay. Red arrows and solid lines indicate the historical and contemporary movements of belugas based on Indigenous Knowledge and are adapted from several sources mentioned in the text. The dotted line shows pre-1970s movements of belugas into areas where they were hunted historically; this hunt has largely ceased (based on fig. 2 in O'Corry-Crowe et al. 2021).

Seasonal distribution and movements

Historically, subsistence hunters observed that belugas entered Kotzebue Sound in the spring as leads formed in the sea ice and the ice began to break up, typically late May or early June (e.g., Burch 1998, Seaman et al. 1986, Huntington et al. 1999, Seaman et al. 2015, Seaman et al. 2018). Off Kivalina, the first beluga whales appeared in late April-early May, together with bowhead whales, in open leads and polynyas within the ice. Hunters established ice camps to harvest these belugas off Kivalina in the spring, which were initially thought by ADFG biologists to be part of the Eastern Chukchi Sea stock (Burns and Seaman 1986, p. 282). However, based on genetic analysis of samples from whales harvested near Kivalina during these months (in 1994 and 2000), they are likely from the Beaufort Sea stock (O'Corry-Crowe et al. 2021) on their northward migration to their

summering grounds in the eastern Beaufort Sea. Belugas are also seen and sometimes hunted near Kivalina during the summer open water season. According to Indigenous Knowledge, the belugas hunted during this period may be from the historical Kotzebue Sound beluga group. In early June, beluga whales entered Kotzebue Sound along the northern coast, passing Sisualik by mid-June, where, prior to the 1970s, hunters would 'drive' or herd the belugas into shallow waters to harvest (ABWC 2017, Fig. 2). Belugas typically moved into southern Kotzebue Sound and entered Eschscholtz Bay around this same time. Belugas would enter the shallow bay with the incoming tides and exit with the outgoing tides (Morseth 1997, Burch 1998, Huntington et al. 1999; Fig. 2).

The area around Eschscholtz Bay was a critical area for subsistence hunting of belugas for years after the drive hunts at Sisualik ceased, and organized drive hunts continued through the early 1980s (ABWC 2017). If not disturbed, belugas came into the shallow eastern end near the mouth of the Buckland River on every high tide for about 4 weeks. Belugas sometimes returned later in smaller numbers to Eschscholtz Bay, likely following salmon (Lowry et al. 1985, Frost and Lowry 1990). Buckland residents observed belugas calving in Eschscholtz Bay (Burns and Seaman 1986, ABWC 2023d). Belugas are highly sensitive to tidal fluctuations (Kleinenberg et al. 1964), and hunters noted belugas departed when the tide ebbed and left the shallow eastern end of the bay. The harvest at Eschscholtz Bay co-occurred with that at Sisualik, and both typically were completed by mid-July (Burch 1998). For example, in 1982, beluga sightings were reported from June 7 to 23 in Kotzebue Sound and June 29 near Kivalina (Burns and Seaman 1986, p. 284); hunting occurred in the southeast, including Eschscholtz Bay, from June 17 to 26; and in the northeast, including Sisualik, from June 22 to 26, where most whales were taken in nets (Burns and Seaman 1986, p. 242).

Harvest timing and numbers

Harvest records in Kotzebue Sound prior to ~1960 are scarce but suggest that harvests were once substantial (Fig. 3, Appendix Table 1). An account from 1960, quoted in Seaman and Burns (1981), documented a June hunt by Noatak and Kotzebue residents. Hunters noted that the belugas appeared in two waves, the latter in early July consisting of larger whales. About 50 whales were harvested prior to early July that year at Sisualik. The average annual harvest from 1961 to 1973 was ~244 belugas/year (Patterson 1974, Uhl and Uhl 1977, Fig. 3). Beluga hunters attributed the decline in beluga numbers near Sisualik and Kotzebue in the 1970s to commercial chum salmon fishing, increased use and size of outboard motors, and commercial aircraft traffic. Until the 1970s, Sisualik and Eschscholtz Bay were the primary hunting areas, although some belugas were taken at the mouth of the Kobuk River (Kobuk Lake) and Selawik River (Fig. 2) by hunters from Selawik, Noorvik, and Kiana (Fig. 3), and along southern Kotzebue Sound. After the mid-1970s, belugas were no longer common near Kotzebue and Sisualik, and most were harvested in Eschscholtz Bay; although harvest numbers declined precipitously between 1982 and 1985 and continued to be greatly reduced thereafter (Fig. 3). Anomalous high harvest events occurred in 1996 and 2007 (Fig. 3). These two events were attributed to an

influx of large beluga groups during anomalously low sea ice coverage. These conditions appear to have had a population-wide effect on migrations patterns of multiple beluga populations (O’Corry-Crowe et al. 2016). In addition, the observed presence of killer whales, *Orcinus orca*, and instances of predation in Kotzebue Sound in 2007 were considered contributing factors for belugas entering the sound and remaining in shallow waters despite hunting pressure (ABWC 2017; O’Corry-Crowe et al. 2016, 2021). Unlike historical harvests, hunters did not observe calves, with very few young or immature belugas sighted in 2007 (ABWC 2017). That year, hunters from Kivalina first harvested whales, then Kotzebue and Noatak, and later Buckland and Deering (Fig. 3).

Observations and surveys

Observations (not systematic surveys) of belugas in Kotzebue Sound include 900-1,200 belugas in 1962 in southeastern Kotzebue Sound, and 900-1,000 belugas in Eschscholtz Bay in 1978 (Frost and Lowry 1990). In those two years, belugas were present in Kotzebue Sound from mid to late June in 1962 and from June 11 to July 9 in 1978, with belugas also present near Kivalina from June 21 to 24 in 1978 (Burns and Seaman 1986, p. 284). From 1979 to 1982, all beluga observations occurred in June (Burns and Seaman 1986, p. 284): 1979 (June 8-25), 1980 (June 13-23), 1981 (June 12-19), and 1982 (June 7-23). Belugas were harvested in large numbers in most years prior to the mid-1980s (Fig. 3). The average annual harvest from 1977 to 1984 was 89 belugas (range: 12-158).

Beluga abundance in Kotzebue Sound and harvest numbers declined dramatically between 1982-1985. After 1984, beluga sightings were much less frequent. ADFG flew aerial surveys in the eastern Chukchi Sea and Kotzebue Sound in 1986 (June 17-18) and 1987 (June 13-15, 20-22, 24-26, and July 7-10). June survey sighting conditions were compromised by ice-covered waters during those years. The highest survey count of belugas ($n = 51$) occurred on June 22, 1987 in Eschscholtz Bay, though sightings of 100+ belugas were reported at multiple locations along the northern coast: near Sadie Creek (~3 miles south of Kotzebue) on June 10, between Kotzebue and Sisualik on June 18, and off Kotzebue on July 6, days the aerial survey was not underway (Frost and Lowry 1990). These sighting numbers are not beluga abundance estimates. But even if these numbers were increased by a factor of two to roughly account for belugas underwater and not available for counting (e.g., Lowry et al. 2019), or available but missed by observers, it is clear that the population was severely reduced relative to estimates of historic abundance in this area.

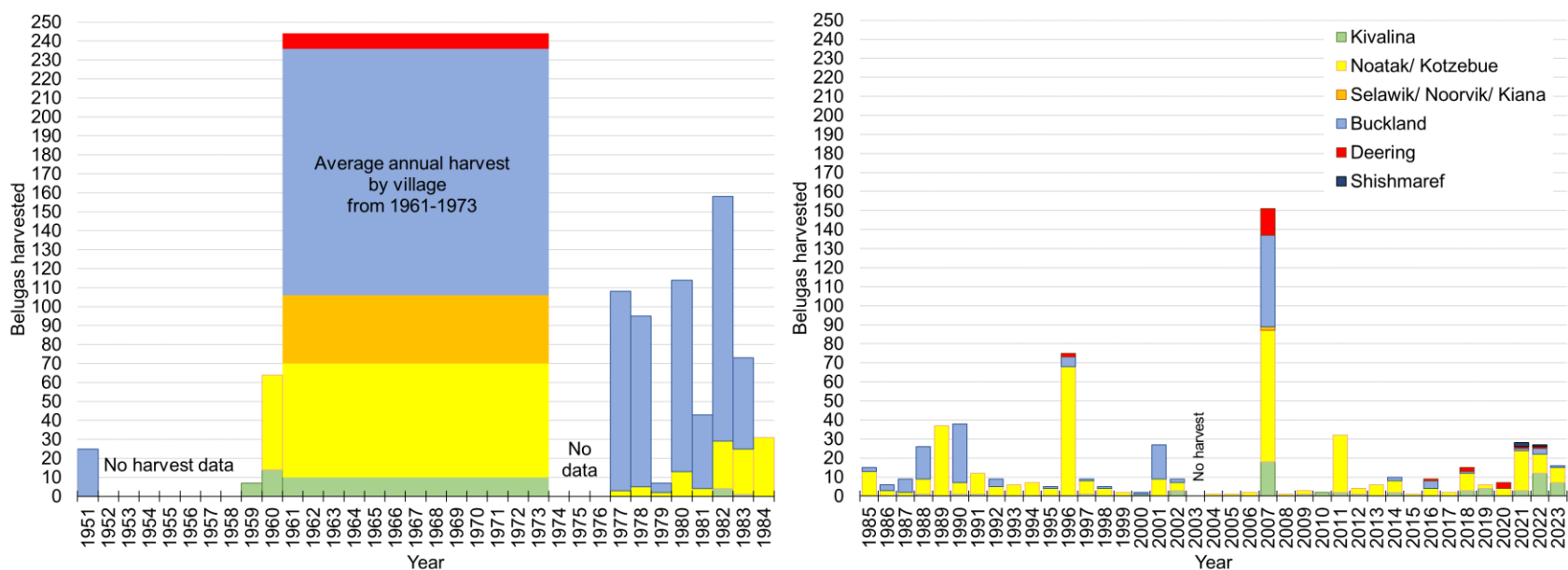


Figure 3. -- Beluga whales landed by Alaska Native subsistence hunters in each village in the Kotzebue Sound area (see Fig. 2 for village locations). Years prior to and including 1984 are considered “historical” (left panel); years after 1984 are considered “contemporary” (right panel). Note the contemporary period for genetic sampling begins in 1994 (Fig. 4). See Appendix Table 1.

Observations from some local hunters as to why this decline occurred (see Morseth 1997, Huntington et al. 1999, O’Corry-Crowe et al. 2021), and other supporting evidence, include the following:

- Overharvest. If there was a local population of beluga whales numbering approximately 900-1,200 whales, the maximum sustainable removals would be roughly 15-20 animals annually, based on similar calculations of Potential Biological Removal for other stocks of beluga whales (Young et al. 2023).
- Ice entrapments and changes to sea ice. Belugas of an unknown stock were entrapped in ice at Little Diomedé in April 1984, and thousands of belugas (stock unknown) were entrapped in ice near the Russian Chukotka Peninsula (Yttygran Island) in December 1984, with about 2,000 belugas released by Soviet icebreakers in February 1985. However, even if these entrapments involved belugas that frequent Kotzebue Sound, they could not have been responsible for the observed decline in abundance as the large entrapments occurred after the decline. Also, hunters reported that ice leads had shifted and no longer directed belugas into Kotzebue Sound.
- Noise. Hunters first noted changes in beluga distribution with increasing aircraft traffic and size of the aircraft, in particular commercial jets. The use and size of motorized outboards and vessels for the spring (April) hunt for bearded seals (oogruk) have increased, and the range of hunting areas expanded. Early open leads allowed for earlier bearded seal and walrus hunting seasons, using motorized boats.
- Increased killer whale predation. Incidents of killer whales chasing belugas into the shallows and predation on belugas were reported by hunters to Burns and Seaman (1986). In the mid-1950s, in early July, an incident of chasing and predation occurred near Sisualik. Similar incidents in this area occurred in early July in the late 1970s and in mid-June in 1984. The lack of hunting success in Eschscholtz Bay in June 1979 was attributed to killer whales preventing belugas from accessing the bay. In 2007, killer whales were observed by pilots flying outside the entrance to Kotzebue Sound in late July and have been attributed as the main reason for hundreds of belugas entering the Sound and remaining in the shallows despite being hunted. Killer whale occurrence in the Pacific Arctic may have increased over the past decades (Stafford 2019), but the extent to which killer whale predation could have driven a decline or currently be contributing to ongoing low densities of belugas in Kotzebue Sound is unknown.
- Beluga prey. Beluga prey abundance, availability, and distribution may have changed in response to changes in climate. While it is unknown if prey changed in the 1980s, current warming in the Arctic could affect beluga prey, and

therefore belugas, and could be a reason why Kotzebue Sound belugas have not increased in number.

The decline in beluga abundance in the mid-1980s resulted in a near collapse of the Indigenous subsistence beluga hunt in Alaska Native communities around Kotzebue Sound, almost ending an age-old relationship between the Iñupiat and the belugas (Frost and Lowry 1990, Huntington et al. 1999, Seaman et al. 2015, Seaman et al. 2018). Since 1985, the average annual harvest of belugas in Kotzebue Sound has been approximately 11 whales (range: 0-40+), except for the anomalous events in 1996 (75 whales) and 2007 (149 whales) (Fig. 3). After the decline of belugas in Kotzebue Sound, hunters from Kotzebue Sound traveled to other areas, such as Cook Inlet, to hunt belugas, particularly during years when environmental conditions in Kotzebue Sound made hunting impossible (Shelden et al. 2019). Hunting in Kotzebue Sound transitioned from a focused, seasonally planned event, with camping, family gatherings, and large-scale drive hunts (Seaman and Burns 1981, Lucier and VanStone 1995, Morseth 1997), to opportunistic hunting with the hunters acting individually, using anchored nets, or incidentally seeing and shooting a beluga when hunting for seals or traveling by boat (Morseth 1997). Although the whales were greatly reduced in number, hunters have continued to observe belugas entering Kotzebue Sound in late May-early June (ABWC 2023c). These belugas were accompanied by calves and immature whales, which hunters noted were not present in late July (ABWC 2008, 2017, 2023d). Hunters have commented that the belugas that entered Kotzebue Sound in 1996 and 2007 behaved differently than the belugas they normally hunted and thought they belonged to a different group (ABWC 2023c).

In 1996, the ABWC flew its first aerial surveys of the eastern Chukchi Sea, including Kotzebue Sound, with additional surveys in 1997 and 1998 (Lowry et al. 1999). Surveys in 1996 occurred in Kotzebue Sound on June 26-29 and July 3, with only 13 belugas observed on June 29 within the Sound. Lowry et al. (1999) reported that surveys in 1996 occurred too late in the season, after one of the largest harvests in northern Kotzebue Sound since the early 1980s. Poor sighting conditions occurred during the one day in 1997 (July 8) that surveys occurred within Kotzebue Sound. In 1998, the northern coastline from Kotzebue to Kivalina was surveyed on June 25-26, 28, 30 (including Kobuk Lake), July 2-3, and 5. The only day the entire Sound, including Eschscholtz Bay, was surveyed was on July 3. Belugas were not observed within Kotzebue Sound, with only a lone whale observed 10 nautical miles (nmi) east of Cape Espenberg (Fig. 2). Due to the low number of beluga sightings and acoustic detections (see Passive Acoustic Monitoring section) in recent decades, dedicated research efforts (e.g., aerial and boat-based surveys, biopsy, and satellite telemetry (see Satellite Telemetry section)) have not occurred in Kotzebue Sound. Based on harvest records, spikes in beluga presence (harvests > 20 whales) appear to occur about every 5 to 10 years and the locations of these pulses vary from north to south (Fig. 3), further confounding attempts to design or implement an effective survey of belugas in Kotzebue Sound.

In summary, Indigenous Knowledge and the observations by hunters during historical and contemporary times suggest that belugas in Kotzebue Sound are unique and continue to exist based on distribution, timing, presence of calves, behavior, and movements within the Sound (Morseth 1997; Huntington et al. 1999; ABWC 2008, 2017, 2023a,c,d).

Genetic Structure of Belugas

For many years, biologists presumed belugas in Kotzebue Sound belonged to the Eastern Chukchi Sea stock that migrates along the Chukchi Sea coast and are hunted at Point Lay and Wainwright. Belugas appeared in Kotzebue Sound annually in late May and June, and would appear off Point Lay in late June and early July. In the 1980s, when beluga numbers declined steeply in Kotzebue Sound but remained in high numbers off Point Lay, biologists and hunters began to question whether belugas in the two areas were actually the same stock.

In 1993, with funding from ABWC and NMFS, the ABWC began working with a geneticist (Dr. Greg O’Corry-Crowe) to understand Alaska beluga population genetic structure. ABWC hunters and representatives and biologists began collecting beluga skin samples throughout Alaska for molecular genetic analyses. However, because the annual harvests in the Kotzebue Sound areas were low and samples were collected from only a small portion of the harvested belugas (Fig. 4), obtaining an adequate sample size for population identification in this area took decades.

Recently, new methods for extracting DNA from bone and teeth allowed for analyses of mitochondrial (mtDNA) lineages from belugas harvested in Kotzebue Sound during the historical years (1978-1982, samples were not collected 1983-1985) to compare with contemporary Kotzebue Sound beluga samples (1994-2019, samples were not collected 1986-1993) (O’Corry-Crowe et al. 2021). Sample location and month (when provided) are shown in Figure 5. For the historical years, all samples came from the harvest in Eschscholtz Bay, which occurred in June (Burns and Seaman 1986). Samples collected during the contemporary years included Eschscholtz Bay and four other locations, with harvests occurring from April to October (Fig. 5).

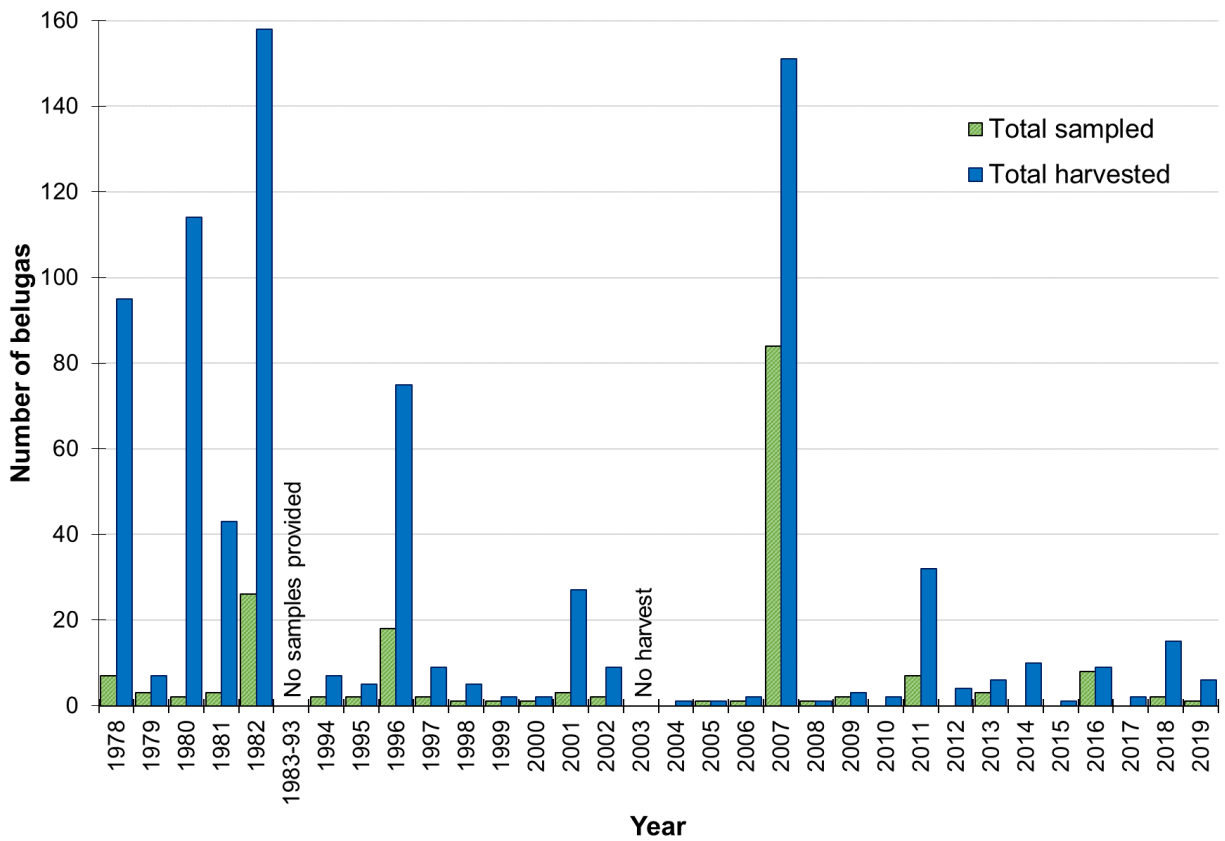


Figure 4. -- Harvest samples provided for genetic analysis presented in O’Corry-Crowe et al. (2021) compared to total harvest. Samples from harvested belugas were not provided between 1982 and 1994, and a harvest did not occur in 2003. See Appendix Tables 1 and 2.

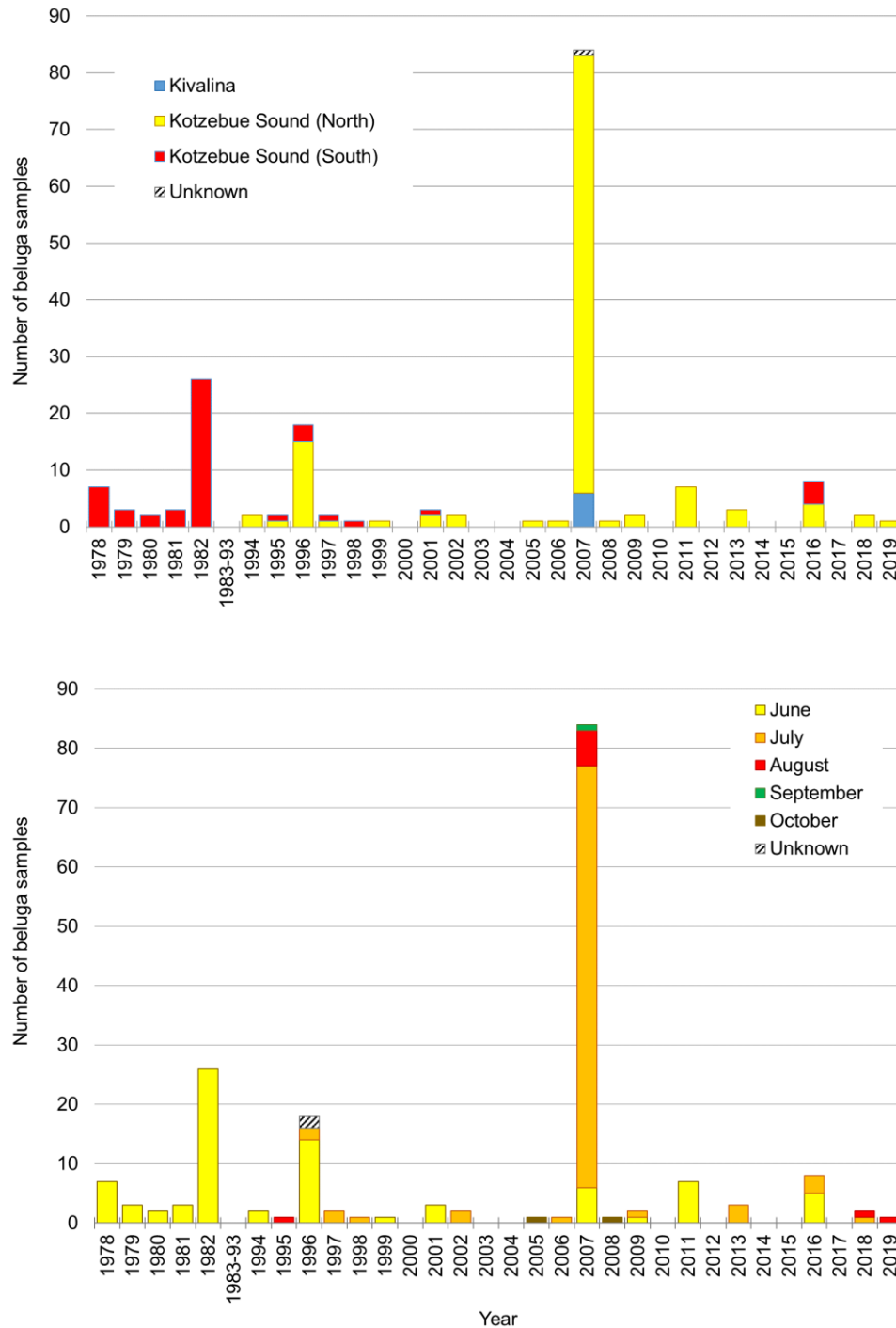


Figure 5. -- Harvest samples provided for genetic analyses by location (top panel) and month (bottom panel) for historical (1978-1982) and contemporary (1994-2019) years presented in O’Corry-Crowe et al. (2021). Kotzebue Sound (North) includes Sisualik, Noatak, Kotzebue, and Cape Blossom; Kotzebue Sound (South) includes Eschscholtz Bay and Deering. Only summer samples are shown for Kivalina. See Appendix Table 2.

Mitochondrial DNA

Molecular genetic studies examining the population genetic structure and connectivity of beluga whale populations throughout the Arctic and sub-Arctic revealed significant geographic partitioning of mitochondrial (mtDNA) lineages in beluga whales (O’Corry-Crowe et al. 1997, de March et al. 2003, Turgeon et al. 2012, Meschersky et al. 2013), reflecting persistent patterns of maternal philopatry and demographic isolation (Brown-Gladden et al. 1997; O’Corry-Crowe et al. 1997, 2002, 2010). Findings indicating that closely related beluga whales may travel in close temporal or spatial proximity to one another, and evidence that related individuals return to the same summering location highlight both geographic structuring of beluga populations and the potential for kinship and cultural transmission among migrating individuals within larger complex herds (Colbeck et al. 2013; O’Corry-Crowe et al. 2018, 2020). Genetic studies performed to examine population structure, dispersal patterns, and stock identity of belugas rely on the collection of tissue samples from individual whales, which can be limiting for some populations and time periods (see below).

While belugas once returned annually to Kotzebue Sound each summer in numbers likely exceeding 1,000 individuals, numbers declined dramatically in the mid-1980s (see Indigenous Knowledge section). Population genetic studies that included samples from Kotzebue Sound were limited to bones and teeth representing the historical period (1978-1982) and tissue samples collected from a fraction of harvested whales during the contemporary period (1994-2019) (O’Corry-Crowe et al. 2021). The majority of samples from the contemporary period were collected during two discrete sampling events (in 1996 and 2007) when large numbers of belugas entered Kotzebue Sound and were harvested. These two events corresponded with low ice years (O’Corry-Crowe et al. 2016), and in 2007, also with killer whale presence (ABWC 2008). Analysis of data generated from samples during the contemporary period were performed both with and without these two years to reflect the suspected anomalous events of 1996 and 2007.

Some early genetic studies, which were based on mtDNA haplotypes alone, included samples collected from 1977 to 1997 from locations in Alaska and western Canada (i.e., Cook Inlet, Bristol Bay, Kuskokwim River, Yukon River, Norton Sound, Kotzebue Sound, Point Hope, Kasegaluk Lagoon, Beaufort Sea, Mackenzie River Delta, and Amundsen Gulf) (O’Corry-Crowe et al. 2002). Samples from beluga whales harvested in Kotzebue Sound, primarily in the mid-1990s, provided evidence that those whales were genetically differentiated from belugas harvested near Kasegaluk Lagoon in the eastern Chukchi Sea ($F_{ST} = 0.244$, $P < 0.001$; $\Phi_{IST} = 0.167$, $P < 0.001$; O’Corry-Crowe et al. 2002). The majority (15/20) of the samples from Kotzebue Sound were collected during the anomalous harvest in June 1996 (Fig. 5), raising the concern that these differences may be an artifact of sampling bias. However, the June 1996 Kotzebue Sound samples were also significantly differentiated from Kasegaluk Lagoon belugas sampled that same year in early July ($n = 37$, $F_{ST} = 0.182$, $P < 0.001$; $\Phi_{IST} = 0.174$, $P < 0.01$), supporting genetic divergence of belugas sampled in 1996 in these two adjacent areas (O’Corry-Crowe et al. 2002).

To understand whether Kotzebue Sound beluga whales harvested prior to 1985 were from a recognized beluga population, ancient DNA techniques were used to generate mitochondrial DNA sequence data (410 bp) from archived teeth and bone samples. Control region sequences from these tooth and bone samples indicate that historical Kotzebue Sound samples (1978-1982) are significantly different from all known North Pacific beluga populations, including belugas sampled in Kotzebue Sound in contemporary years (1994-2007), except Bristol Bay ($n = 39$, from 1982; O’Corry-Crowe et al. 2016, 2018) and Eastern Bering Sea belugas. Importantly, these studies increased the sample size ($n = 80$), temporal span (to 2007), and number of genetic markers (nuclear microsatellites (nDNA) and mtDNA sequences) for the contemporary period.

In the most recently published genetic analyses, 22 additional samples were added from the contemporary period for the years 2008-2019 and an additional 24 samples from the historic period (1978-1982; O’Corry-Crowe et al. 2021). This improved the power to resolve patterns of genetic differentiation among populations of beluga whales (i.e., Cook Inlet, Bristol Bay, Eastern Bering Sea, Kotzebue Sound, Eastern Chukchi Sea, Beaufort Sea, Anadyr Bay, and Okhotsk Sea). With this expanded dataset, the number of historical (1978-1982) samples from Kotzebue Sound increased to 63 whales, and the number of contemporary (1994-2019) samples increased to 102 whales. Samples representing the contemporary period included the two anomalous event years ($n = 18$ in 1996; $n = 48$ in 2007) and 36 additional samples for mtDNA analyses outside the anomalous years (Table 1). Patterns of mtDNA variation reinforced earlier studies (O’Corry-Crowe et al. 2002, 2016, 2018) indicating statistically significant differences between the Kotzebue Sound historical samples and contemporary samples, and between the Kotzebue Sound historical samples and all other sampled regions except Bristol Bay (Table 1). The genetic similarity to Bristol Bay appeared to be driven by the high frequency of one widespread haplotype common to Bristol Bay, Eastern Bering Sea, and Kotzebue Sound (historical and contemporary) belugas; none of the other six mtDNA haplotypes found among the historical Kotzebue Sound beluga samples were shared between Kotzebue Sound and Bristol Bay belugas. Moreover, satellite telemetry data provide no indication that Bristol Bay belugas move into the northern Bering Sea or the Chukchi Sea (see Satellite Telemetry section).

Table 1. -- Measures of genetic differentiation based on mitochondrial DNA control region sequences and eight nuclear microsatellite loci in beluga whales. Pairwise comparisons between Kotzebue Sound samples (columns) and all other sampled areas (rows) are shown below. Each cell indicates the metric of genetic differentiation (F_{ST}). Corresponding P values from homogeneity tests (based on 50,000 permutations; $P \leq 0.05$ indicates statistically significant genetic divergence between groups) are represented as follows: highlighted cells indicate $P \leq 0.05$ (light green) and $P \leq 0.01$ (dark green). Values that are unshaded indicate $P > 0.05$ (based on table 1 in O’Corry-Crowe et al. 2021). NA = microsatellite data not available for historical samples.

Mitochondrial DNA	Kotzebue Sound				
	Historical (n = 63)	Contemporary (n = 102)	1996 only (n = 18)	2007 only (n = 48)	All other years (n = 36)
Kotzebue Sound					
Contemporary	0.300				
1996 only	0.205	0.029			
2007 only	0.474	0.015	0.124		
All other years	0.274	-0.003	-0.007	0.062	
Cook Inlet (n = 133)	0.552	0.346	0.377	0.379	0.377
Bristol Bay (n = 140)	0.008	0.389	0.308	0.578	0.382
E. Bering Sea (n = 191)	0.077	0.182	0.055	0.305	0.121
Anadyr Bay (n = 83)	0.582	0.116	0.279	0.053	0.188
E. Chukchi Sea (n = 579)	0.394	0.223	0.238	0.230	0.244
Beaufort Sea (n = 156)	0.386	0.021	0.110	-0.001	0.057
Microsatellites					
	Historical	Contemporary (n = 85)	1996 only (n = 13)	2007 only (n = 43)	All other years (n = 29)
Kotzebue Sound					
Contemporary	NA				
1996 only	NA	0.000			
2007 only	NA	-0.006	0.009		
All other years	NA	-0.006	0.005	-0.001	
Cook Inlet (n = 78)	NA	0.055	0.070	0.054	0.052
Bristol Bay (n = 129)	NA	0.022	0.028	0.023	0.022
E. Bering Sea (n = 73)	NA	0.006	0.011	0.008	0.002
Anadyr Bay (n = 44)	NA	0.007	0.025	0.002	0.010
E. Chukchi Sea (n = 533)	NA	0.007	0.012	0.007	0.006
Beaufort Sea (n = 118)	NA	0.003	0.010	0.006	-0.004

The lesser but statistically significant degree of genetic differentiation between contemporary belugas in Kotzebue Sound and the Beaufort Sea stock ($F_{ST} = 0.021$, $P < 0.01$) appears to be driven by samples from 2007 ($F_{ST} = -0.001$, $P > 0.05$; Table 1). Increasing the sample sizes for both time periods (1978-1982 and 1994-2019) reinforced the significant genetic differentiation between the historical and all other subsets (1996 only, 2007 only, all other years) of samples collected from belugas in Kotzebue Sound during the

contemporary period ($F_{ST} = 0.3$, $P < 0.001$), but samples from late July 2007 may be driving much of this difference ($F_{ST} = 0.474$, $P < 0.0001$; Table 1).

Stratifying contemporary Kotzebue Sound beluga samples in subsets across several time periods (i.e., 1996 only, 2007 only, and all other years) revealed temporal genetic differentiation among Kotzebue Sound belugas represented in the contemporary dataset. The samples collected in July 2007 were genetically divergent from those collected in all other contemporary years and were also found to be more similar to Beaufort Sea belugas than any other stocks represented in the mtDNA analyses (Table 1). In addition, belugas sampled during the contemporary period in Kotzebue Sound exhibited high mtDNA haplotypic diversity ($H = 0.75$ contemporary; $H = 0.24$ historical), with a relatively high number of unique mtDNA haplotypes ($n = 7$). In contrast to the genetic divergence between the two Kotzebue Sound sampling time periods, such divergence was not evident in a temporal analysis among belugas sampled off Point Hope (Beaufort Sea stock) in the spring of 1977 ($n = 15$) and 1997 ($n = 13$), which revealed a lack of mtDNA genetic differentiation ($F_{ST} = 0.016$, $P = 0.248$; $a = -0.004$, $P = 0.441$) (O’Corry-Crowe et al. 2002) as well as belugas from Point Lay sampled in 2007 and all previous years (ABWC 2008).

All known beluga stocks included in the recent analyses were characterized by one or more unique mtDNA haplotypes (O’Corry-Crowe et al. 2021). Samples collected in Kotzebue Sound in the most recent period (2008-2019) contained several maternal lineages (mtDNA haplotypes) not previously detected in Kotzebue Sound, including two haplotypes previously detected only in the Eastern Bering Sea (O’Corry-Crowe et al. 2021). Seven mtDNA haplotypes unique to Kotzebue Sound were found primarily in whales sampled during the contemporary period (O’Corry-Crowe et al. 2021). One of these whales was harvested in early June (in 2007), the rest in late July (in 2007) and mid-August (in 1995). Only one mtDNA haplotype was also detected in belugas sampled in Kotzebue Sound during the historical period (in June 1981) (see Appendix Table 2). Excluding the samples from 1996 and 2007, which were considered to be anomalous years, belugas sampled in Kotzebue Sound during the contemporary period shared 4/9 haplotypes with Beaufort Sea belugas; the other five haplotypes were identified among belugas sampled in other areas including Bristol Bay, eastern Bering Sea, and the historical Kotzebue Sound dataset (O’Corry-Crowe et al. 2021).

Nuclear markers

While mtDNA data are particularly useful for examining population genetic structure for cetacean populations with strong matrilineal structure, the biparental inheritance of nuclear genetic markers, nDNA, can reveal patterns of gene flow undetected by mtDNA sequence data. Bayesian clustering approaches based on nuclear microsatellite data (8 loci) for 1,032 belugas representing eight regions (i.e., Cook Inlet, Bristol Bay, eastern Bering Sea (Norton Sound), Kotzebue Sound, eastern Chukchi Sea (Kasegaluk Lagoon), Beaufort Sea (Mackenzie-Amundsen), Anadyr Bay, and Okhotsk Sea) indicated

that the contemporary (1994-2007) Kotzebue Sound belugas consistently clustered with the Beaufort Sea (Mackenzie-Amundsen) belugas, with some individuals showing evidence of a small (< 50%) proportion of shared ancestry with eastern Chukchi Sea (Kasegaluk Lagoon) whales (O’Corry-Crowe et al. 2018). Genetic assignment tests for all whales with nDNA data indicated that the large number of belugas harvested in Kotzebue Sound in 1996 and 2007 were most likely whales from the Beaufort Sea stock (ABWC 2008; O’Corry-Crowe et al. 2016, 2018). The more recent expanded dataset for belugas also indicated that despite significant genetic differentiation (Table 1; nDNA F_{ST}) based on genotypic likelihoods, contemporary Kotzebue Sound samples (1994-2019) were assigned to the Beaufort Sea stock more often than any other population (O’Corry-Crowe et al. 2021).

High assignment probabilities to one reference population over all others, however, is not always definitive proof that the “assigned” population is where a whale originated; particularly if some reference stocks are missing, they are inadequately represented in the analysis due to limited sample sizes. As Kotzebue Sound whales from the historical period could not be profiled for microsatellites due to low sample DNA quality and quantity, they could not be included as a reference population. Therefore, an exclusion test was conducted to identify any whales from the contemporary era that were unlikely to come from any of the reference populations that were included in the assignment test. Depending on the exclusion criterion selected, a small number of Kotzebue Sound contemporary samples (3 out of 85 at $p < 0.05$; 6 out of 85 at $p < 0.10$) were excluded from all known, sampled reference populations (O’Corry-Crowe et al. 2021). Three of the six samples that had a very low probability of arising from the known contemporary stocks were sampled in July 2007. O’Corry-Crowe et al. (2021) suggested that the most parsimonious explanation is that the results indicate that some whales from the historical Kotzebue Sound beluga whale population still exist, rather than that the whales sampled in Kotzebue Sound in recent years represent an unknown, unsampled population, or a new stock resulting from interbreeding among populations.

While measures of genetic differentiation based on nuclear microsatellites indicate a very low level of divergence between whales sampled in Kotzebue Sound in 1996 and whales sampled in Kotzebue Sound in 2007 (Table 1), samples from both years showed no evidence of genetic divergence from the contemporary whales sampled in years other than these two years. Belugas sampled in Kotzebue Sound in years other than 1996 and 2007 (“All other years”, O’Corry-Crowe et al. 2021) are significantly differentiated from historical Kotzebue Sound whales and all other geographically defined beluga populations by mtDNA, but are not genetically differentiated from eastern Bering Sea and Beaufort Sea belugas based on nDNA (O’Corry-Crowe et al. 2021). The lack of significant genetic divergence (nDNA) between contemporary belugas in Kotzebue Sound, excluding samples from 1996 and 2007, and belugas from the eastern Bering Sea and Beaufort Sea (Table 1) suggests that at least some of these most recent whales have ancestry, or have come from other populations. Many years of dedicated, collaborative efforts were required to amass the genetic samples representing multiple beluga populations, yet uncertainties around genetic

differentiation among belugas representing some geographic areas still exist. Adequately characterizing the genetic diversity of very large populations such as the Beaufort Sea beluga population (population estimate 38,500 whales, DFO 2023) may be a limiting factor in the power of genetic exclusion and assignment tests.

Overall, belugas from the historical period in Kotzebue Sound are genetically different from contemporary belugas sampled in Kotzebue Sound, even when samples collected from the large harvests from putative anomalous years (1996 and 2007) are removed from the analysis. However, there are a number of limitations to interpreting the genetics data. Small sample sizes representing the very large Beaufort Sea beluga population likely impact the power of genetic assignment and exclusion tests. The sex bias in genetic samples (90% of samples are from males) could potentially limit the ability to detect maternally derived patterns of population genetic structure if sex-based differences in migration and dispersal exist.

Analysis of nDNA from contemporary samples from Kotzebue Sound revealed a small number of whales (6 of 85) with low likelihoods of originating from any of the other known contemporary stocks (Table 1). However, their mtDNA haplotypes were not unique to belugas sampled in Kotzebue Sound to date and are common to Beaufort Sea and Eastern Chukchi Sea belugas. The most common mtDNA haplotype in Kotzebue Sound historical samples is also the most common haplotype found among Bristol Bay and Eastern Bering Sea belugas; two additional haplotypes were detected among Eastern Bering Sea belugas. Despite the shared haplotypes, significant genetic differentiation among these areas has been found. Haplotypes unique to Kotzebue Sound were also found in a small number of belugas sampled in the contemporary period, though most occurred later in the season (late July-mid August) than historically observed, suggesting changes in harvest timing or seasonal use of this habitat (i.e., effect of ice regime shifts, increased predation, prey, etc.).

Passive Acoustic Monitoring in Kotzebue Sound

Martien et al. (2019) provides an overview of the different lines of evidence and considerations for their application to DIP delineation, including acoustics. Key acoustical elements to consider are vertical versus horizontal transmission of acoustic cues defining call types; sampling across multiple years within the same season; and considering social, environmental, and sexual factors potentially influencing vocal characteristics. Controls for these elements would ensure that differences in vocal repertoire are due to demographic differences, rather than environmental factors influencing vocal production. The only passive acoustics effort successfully completed thus far in Kotzebue Sound covered the period of July and August 2013 as a pilot study, followed by a year-round study from September 2014 to July 2016 (Castellote et al. 2015, 2022).

These studies used low-profile bottom mounted mooring packages containing a sound recorder and an echolocation logger. The areas covered included three moorings near Cape Krusenstern and one mooring near Chamisso Island (Fig. 6). A new study began in September 2022 and is currently ongoing with six mooring locations across Kotzebue Sound, but data analysis has not yet begun (Fig. 7). It should be noted that passive acoustic studies, like those reported by Castellote et al., are primarily designed to detect presence and absence of vocalizing animals in a given area, therefore silent animals cannot be detected (i.e., absence of detections does not confirm absence of animals present within detection range). Furthermore, detection and classification of social signals, not just echolocation, are required for DIP identification analyses.

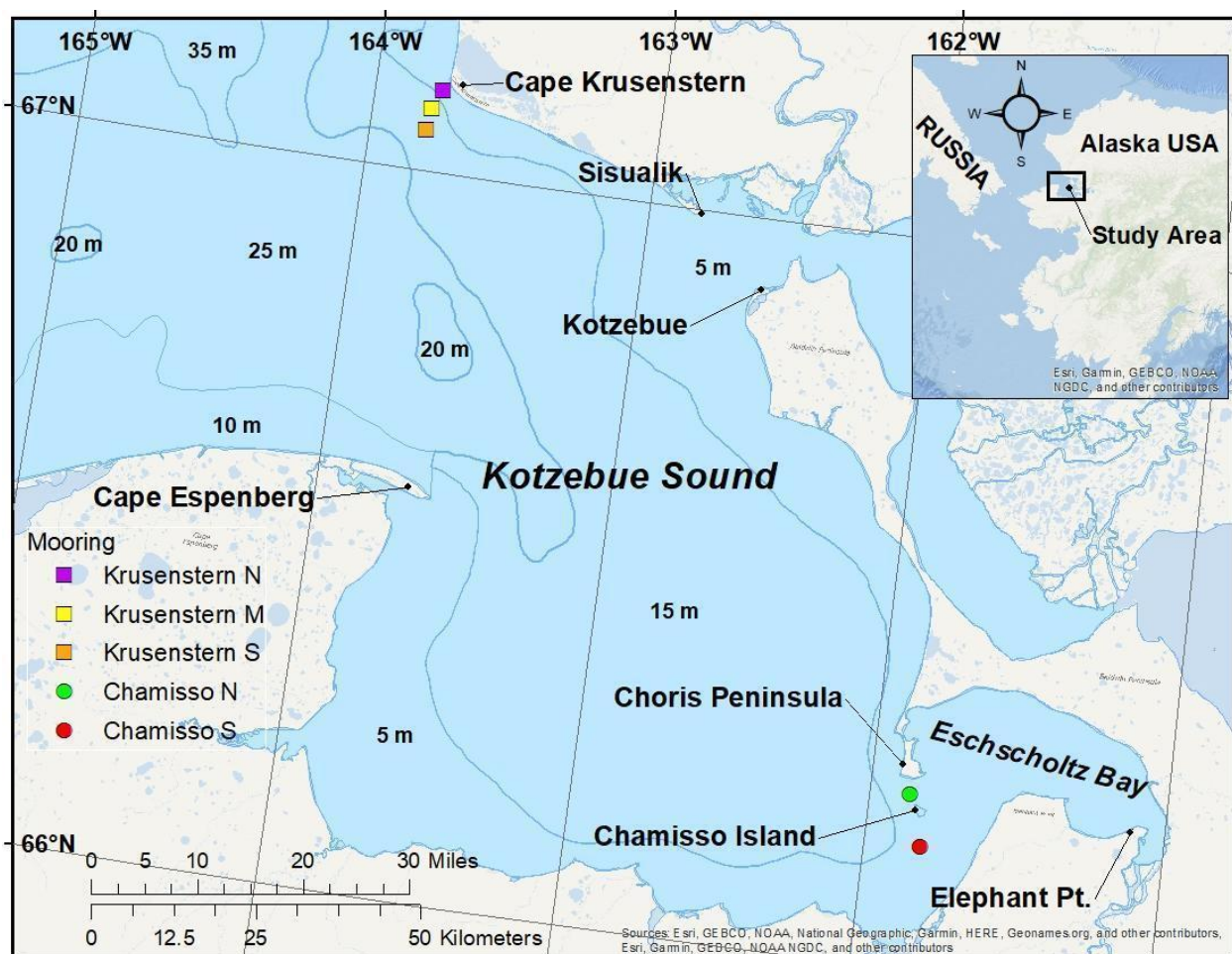


Figure 6. -- Passive acoustic monitoring study area in Kotzebue Sound, Alaska. Passive acoustic mooring locations are indicated as colored squares (Cape Krusenstern) or circles (Chamisso Island) for the summer 2013 pilot study, and the 2014–2016 study. The mooring deployed in 2014 north of Chamisso Island (green circle) was moved to the south of the island in 2015–2016 (red circle) to avoid high currents.

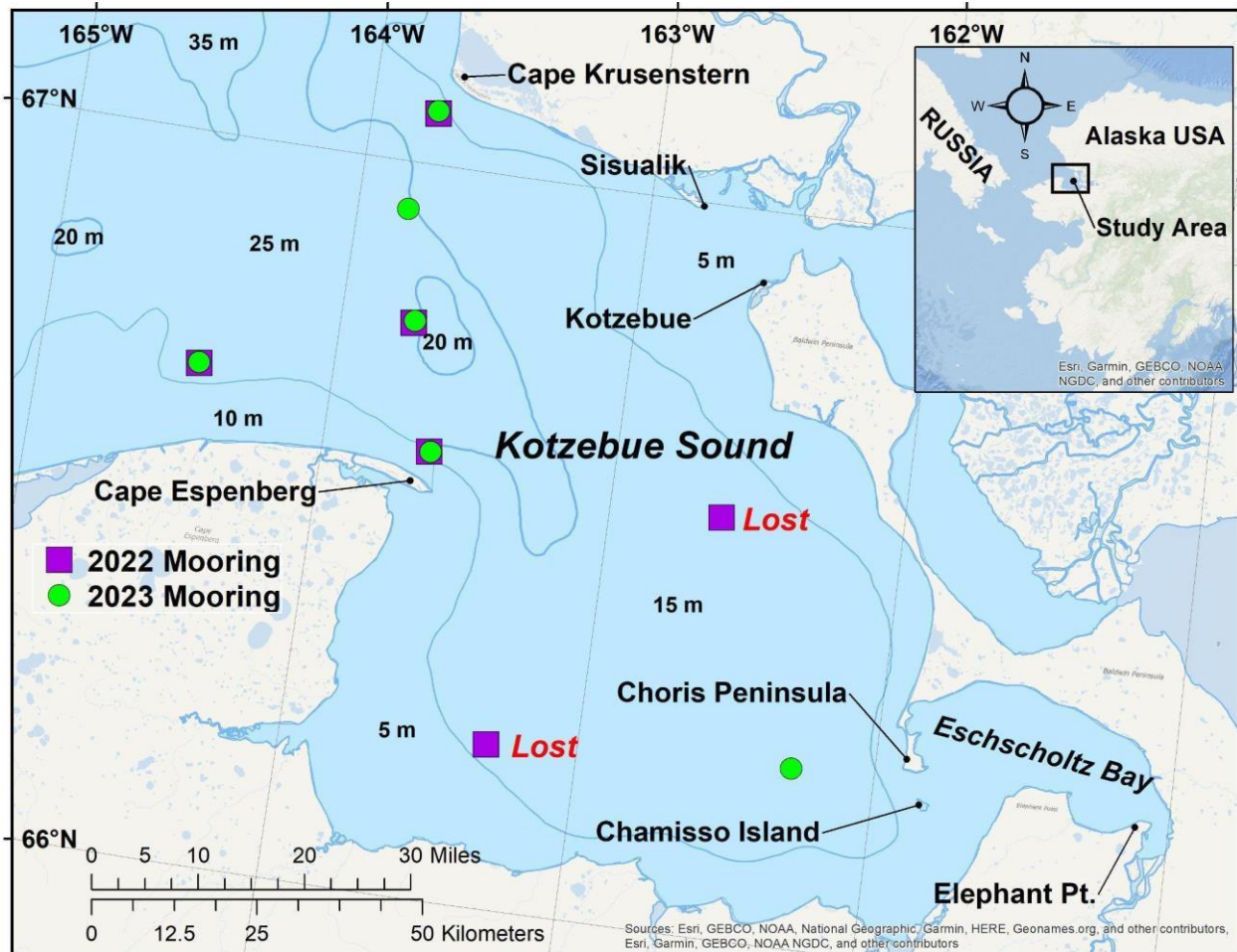


Figure 7. -- Passive acoustic mooring locations of the ongoing study, September 2022 to present time, in Kotzebue Sound, Alaska.

Results from the 2014-2016 study showed beluga presence near the Krusenstern moorings one day in May, and from July to January, while detections near Chamisso Island occurred from July to October (Fig. 8). Unfortunately, weather delays and recorder failure limited sampling during June. Detections were infrequent, about 20 separate occasions, and exclusively composed of echolocation click trains. It is unusual for belugas to not have social call signals and only use echolocation clicks. The absence of acoustic social call signals likely reflects an antipredator response to the presence of transient killer whales and possibly subsistence hunters (Fig. 8). It should be noted that the detection range of beluga echolocation signals (20-160 kHz) is shorter than vocalizations (0.3-20 kHz) due to the stronger propagation loss incurred for higher frequencies. For belugas in estuarine habitats, it is estimated that echolocation signals can be detected up to 900 m and social calls up to 3,300 m (Castellote et al. 2022). Therefore, in areas where belugas have a perceived risk of predation and tend to be acoustically cryptic, like Kotzebue Sound, the acoustic detectability of belugas is reduced in both range and opportunities.

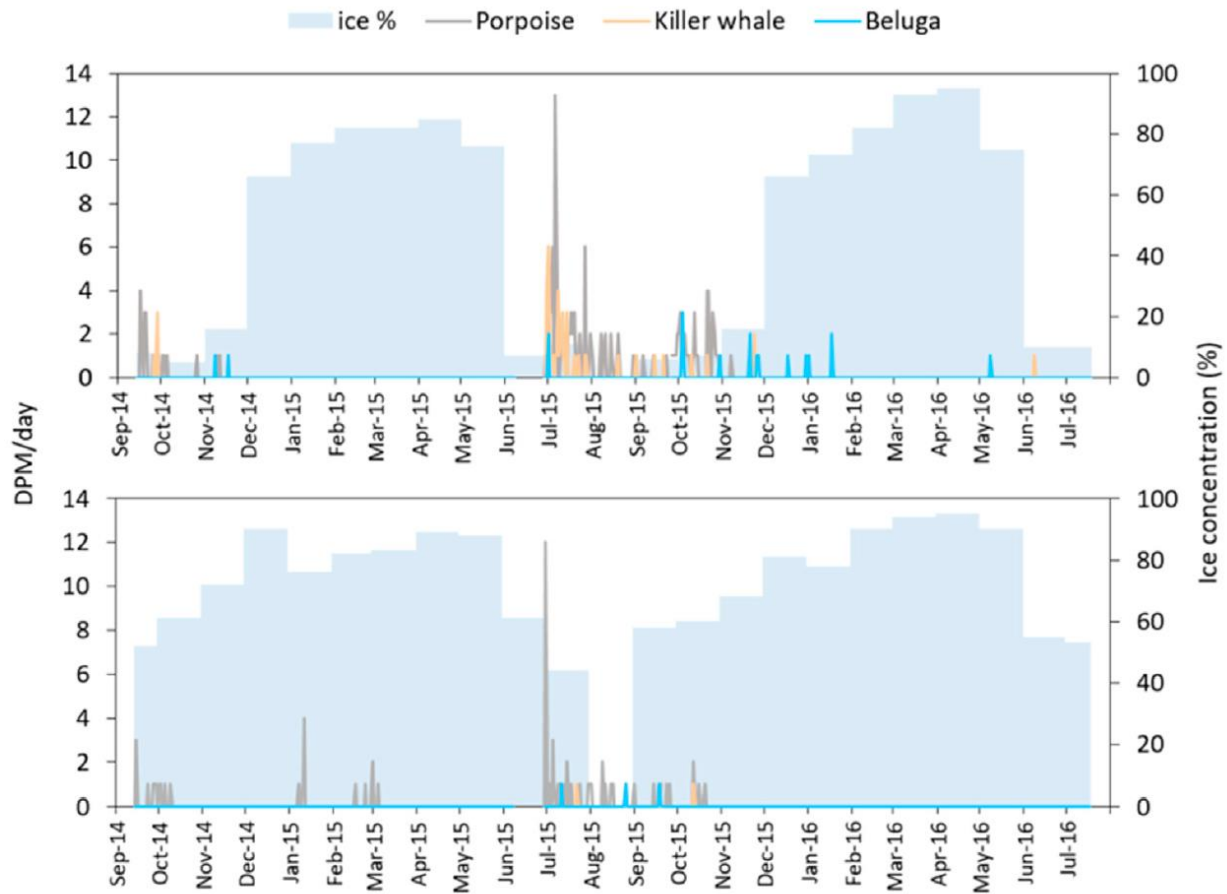


Figure 8. -- Acoustic detections as detection positive minutes per day (DPM/day) and 25×25 km monthly average ice concentration (0-100%) for the mooring sites at Krusenstern Point (upper panel) and Chamisso Island (lower panel), Kotzebue Sound, Alaska, for the 2014-2016 study (originally fig. 4 in Castellote et al. 2022).

The vocal repertoire of most beluga populations is not well known, but geographical differences have been proposed (Karlsen et al. 2002, Garland et al. 2015a). To date for Alaska stocks, only the Beaufort Sea, Bristol Bay, and Cook Inlet beluga populations have vocal repertoire descriptions (Angiel 1997, Garland et al. 2015b, Brewer et al. 2023). The passive acoustics study completed in Kotzebue Sound in 2014-2016 shows beluga vocal behavior was shaped by the presence of predators (transient killer whales and possibly boat-based hunters), or the risk of these predators' presence in beluga habitat (Castellote et al. 2022). These results highlight how the use of vocal repertoires or differences in call types to inform population demographics needs to be closely tied to understanding the environment where vocalizations are sampled. More importantly, differences in the

temporal or spatial use of habitat, could well be driven by factors that are independent of population demographics.

Satellite Telemetry from Known Beluga Stocks

Two recognized MMPA stocks of belugas, Beaufort Sea and Eastern Chukchi Sea, migrate from the northern Bering Sea to the Beaufort Sea in the spring and return in the fall. Belugas from these populations were captured for satellite tag placement between 1993 and 2019, and the resulting telemetry data are relevant to the question of whether belugas seen and harvested in Kotzebue Sound might be from the Beaufort Sea or Eastern Chukchi Sea stock.

Satellite telemetry data have supported several investigations into the spatiotemporal distributions and dive characteristics of the Beaufort Sea and Eastern Chukchi Sea beluga stocks. Hauser et al. (2014) estimated home ranges and core areas using kernel density estimators based on the locations of belugas from the Beaufort Sea and Eastern Chukchi Sea stocks that were tagged in 1993-2007. Hauser et al. (2016) examined changes in autumn migration based on these same stocks tagged in 1993-2012 using distribution concentration areas. Storrie et al. (2022) analyzed year-round dive characteristics of male Beaufort Sea belugas tagged in 2018-2019 and found seasonal shifts in foraging strategies.

We reviewed available information on satellite tagged beluga whales to investigate whether beluga movements would be helpful in delineating beluga whales in Kotzebue Sound as a DIP. To interpret the relevance and strength of evidence provided by the satellite telemetry data to the DIP question, it is important to consider the number of tagged whales in each population with respect to population abundance and the sex, age, reproductive status, capture location, and activity state of the tagged individuals (Martien et al. 2019).

In 2017, the abundance of the Eastern Chukchi Sea beluga stock was estimated at 13,305 belugas (Givens et al. 2020), however, it is biased low because the survey did not include the entire range. During the northbound spring migration (1998 to 2012), 27 Eastern Chukchi Sea belugas were tagged near Kasegaluk Lagoon in late June to early July. Spatial analyses were conducted using data from these 27 tagged belugas: 1998 (n = 5), 1999 (n = 4), 2001 (n = 8), 2002 (n = 4), 2007 (n = 3), 2010 (n = 2), and 2012 (n = 1). For all years combined, 19 male and 8 female belugas were tagged (Hauser et al. 2014, 2016).

The abundance of the Beaufort Sea beluga stock in 1992 was estimated at 39,258 belugas (Hobbs et al. 2019). A recent estimate of 38,500 belugas (95% CI = 20,700–71,300), from a survey conducted in 2019, was considered to be low because of inadequate coverage of all known habitats due to poor weather (DFO 2023). Beaufort Sea belugas were tagged during 1993-2005 and 2018-2019 in the Mackenzie River Delta during late June to

mid-July. Belugas in this area are known to feed and molt and then move west and south towards winter habitat. Spatial analyses were conducted using data from 53 tagged belugas (Hauser et al. 2014, 2016; Storrie et al. 2022): 1993 (n = 4), 1995 (n = 15), 1997 (n = 9), 2004 (n = 9), 2005 (n = 3), 2018 (n = 6), and 2019 (n = 7). For all years combined (including all belugas tagged in 2018-2019), 39 males and 14 females were tagged (Hauser et al. 2014, 2016; Storrie et al. 2022). For both stocks, body length and coloration patterns suggest that mostly adults were captured and tagged.

It is suspected that Beaufort Sea and Eastern Chukchi Sea belugas use the warm and fresh waters from the nearshore areas of the northeastern Chukchi Sea and Mackenzie River Delta, respectively, for their annual molt (Finley 1982, Finley et al. 1987, St. Aubin et al. 1990, Frost et al. 1992). Eastern Chukchi Sea belugas are found in the nearshore area, offshore of Kasegaluk Lagoon, during June-July, when migrating to the Beaufort Sea. Beaufort Sea belugas concentrate in the Mackenzie River Delta in July-August.

Tagged belugas from either stock were not near Kotzebue Sound during July through September. Rather, the tagged belugas were north in the northern Chukchi Sea and Beaufort Sea during the months when historical and contemporary beluga harvests occurred in Kotzebue Sound (Figs. 9 and 10). Tagged Eastern Chukchi Sea belugas never entered Kotzebue Sound, but a few tagged belugas, mostly males, were sufficiently close during October and November (Figs. 9 and 11) to create an estimated home range and concentration area that include waters immediately outside Kotzebue Sound. Although the estimated home range and concentration area of tagged Eastern Chukchi Sea male belugas included most of Kotzebue Sound in November (Fig. 9), average daily locations show that tagged whales remained outside the entrance to Kotzebue Sound (Fig. 12). Beaufort Sea belugas occurred in the western Chukchi Sea during fall (Hauser et al. 2014, 2016; Storrie et al. 2022) and similar to the Eastern Chukchi Sea whales, had locations outside Kotzebue Sound in the spring and fall (Fig. 12, O'Corry-Crowe et al. 2021).

Caution should be taken when assessing the satellite tag data and determining whether it supports or refutes the existence of a DIP of belugas in Kotzebue Sound. Belugas have not been captured to be tagged in Kotzebue Sound. Therefore, migratory patterns of a potential Kotzebue Sound DIP, and migratory patterns or potential overlap with Beaufort Sea or Eastern Chukchi Sea belugas, are unknown. Beaufort Sea and Eastern Chukchi Sea belugas were captured and tagged after they migrated past Kotzebue Sound and the southern Chukchi Sea. Tags rarely transmit longer than one year due to battery life. Of the 13 whales tagged in the Beaufort Sea in 2018-2019 (Storrie et al. 2022, Fig. 10), three tagged belugas documented the spring northbound migration and those belugas did not enter Kotzebue Sound. If there are Beaufort Sea and Eastern Chukchi Sea belugas that migrate north later in the season or stay in the Bering Sea or southern Chukchi Sea to enter Kotzebue Sound during summer, the satellite telemetry studies did not capture them or document these movements.

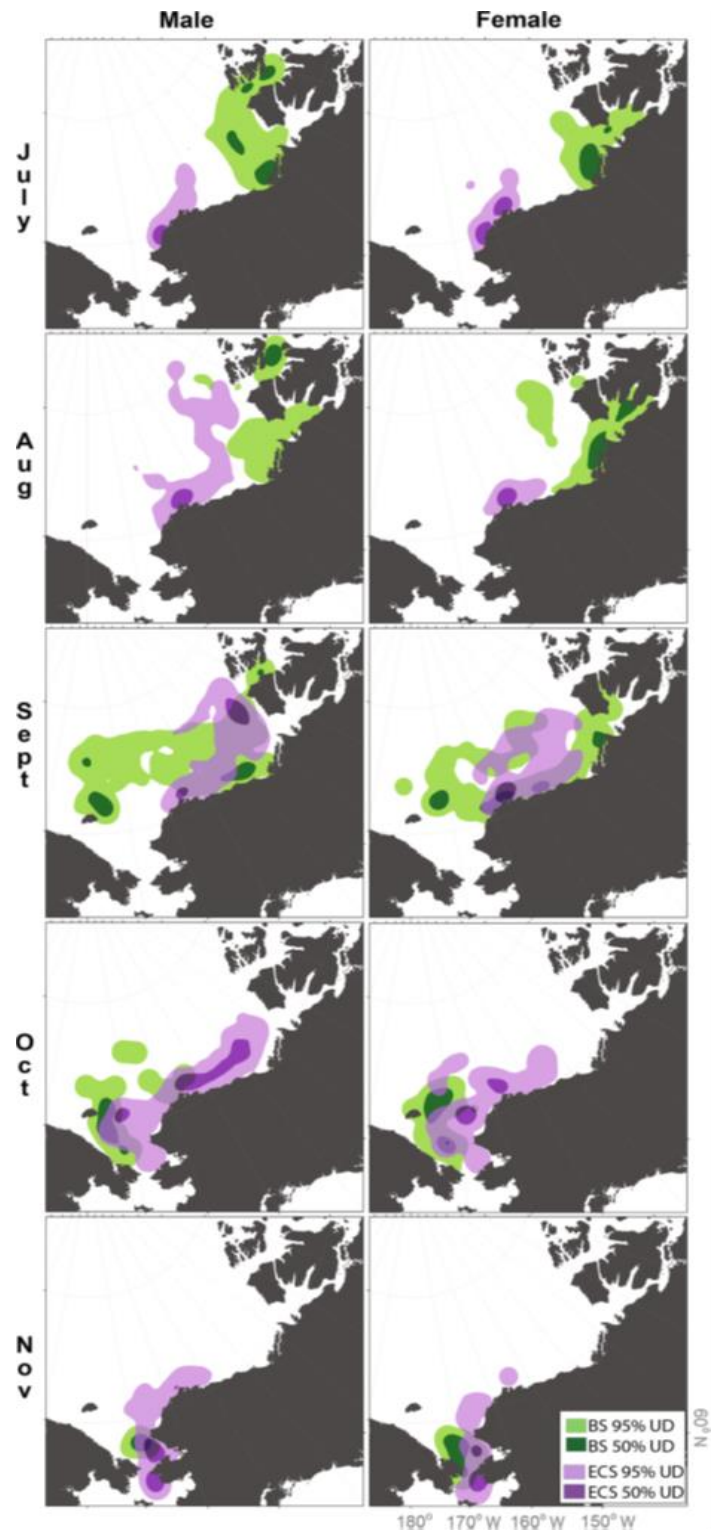


Figure 9. -- Hauser et al. (2014) provided the July–November home ranges (95% probability contour of the utilization distribution) and core areas (50% probability) for male and female Beaufort Sea and Eastern Chukchi Sea beluga whales, which were estimated using fixed kernel density.

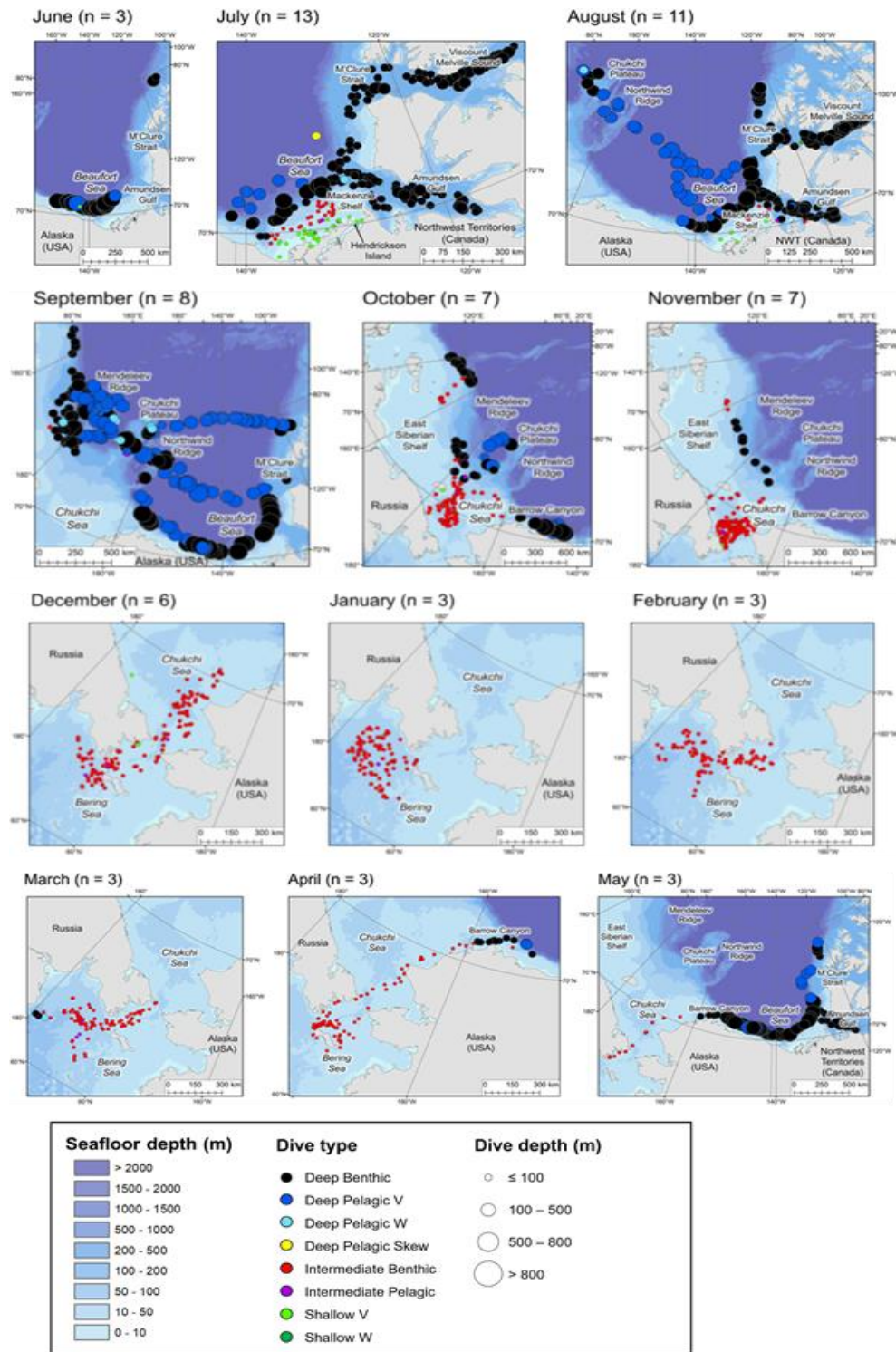


Figure 10. -- Storrie et al. (2022) provided the locations of the deepest dive made each day by each Beaufort Sea beluga. Symbol color represents dive type and symbol size represents the maximum depth reached. The “n” in parentheses gives the number of belugas which transmitted data in the given month. Note that the panel for June denotes locations of dives recorded in 2019 (made by belugas which were tagged in July 2018); and July and August are for 2018 and 2019.

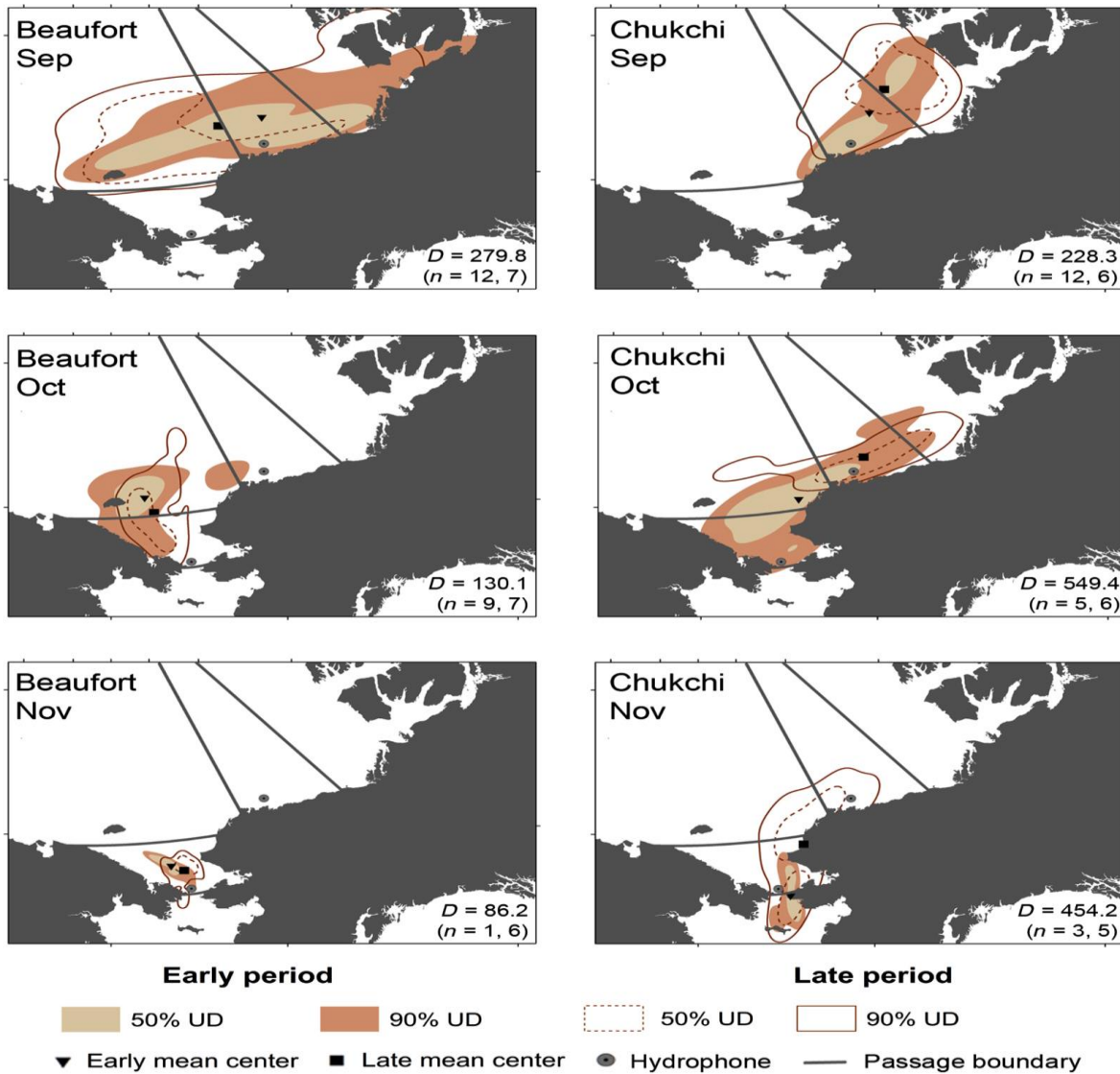


Figure 11. -- Hauser et al. (2016) provided the spatial distribution of autumn (September–November) monthly ranges (90% probability contour of the utilization distribution, UD), concentration areas (50% probability), and mean centers for the tagged Beaufort Sea and Eastern Chukchi Sea beluga whales.

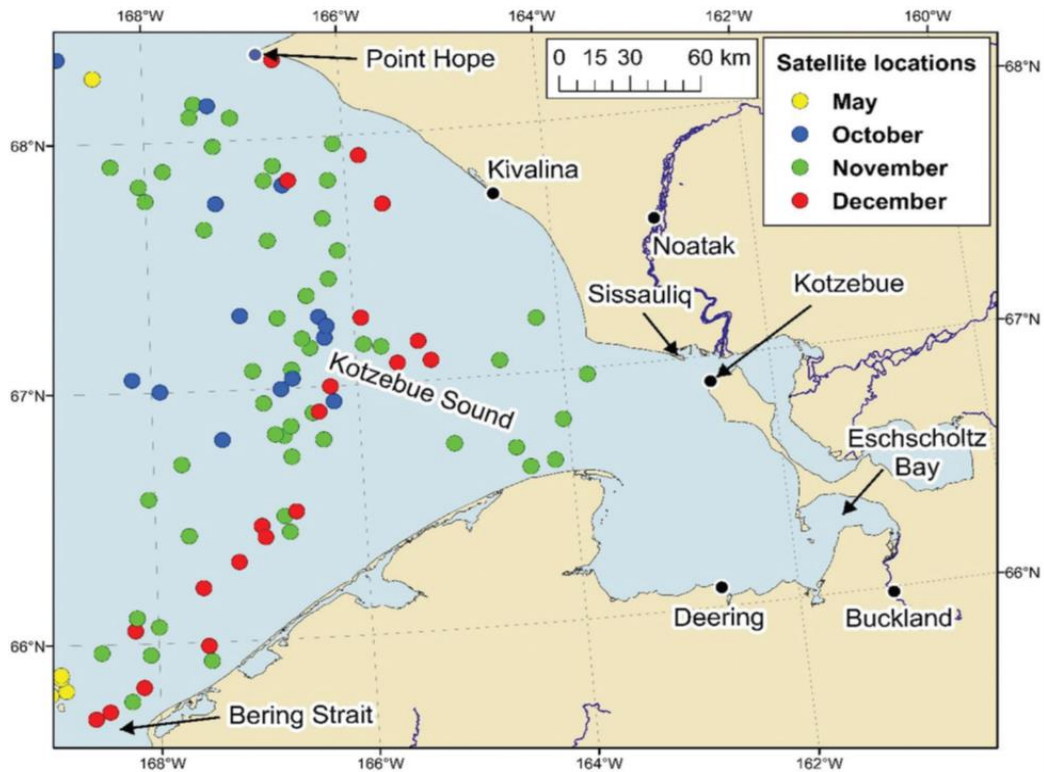


Figure 12. -- Average daily locations from satellite tagged belugas in the eastern Chukchi Sea stock, presented by month of occurrence. Satellite tagged belugas in the Beaufort Sea stock also had locations in this region during the spring and fall; none were within inner Kotzebue Sound (L. Loseto, pers comm.). (original figure from O’Corry-Crowe et al. 2021).

Although mtDNA samples showed a lack of statistical differentiation between the historical Kotzebue Sound and Bristol Bay samples (see Mitochondrial DNA section), this was not the case for the contemporary samples. Satellite-tag data from Bristol Bay showed whales from this stock remained in the southern Bering Sea and did not travel north into the Chukchi Sea (Citta et al. 2016). Similarly, Anadyr belugas tagged with satellite transmitters remained close to the Russian coastline (Citta et al. 2016).

Limited tagged beluga data are inconsistent with the O’Corry-Crowe et al. (2021) genetic findings that Beaufort Sea belugas were harvested in Kotzebue Sound, at least in recent years (e.g., 1996 and 2007). This apparent discrepancy is likely due to the fact that few belugas have been tagged ($n = 53$) relative to the Beaufort Sea beluga population ($n = 38,500$). Similarly, for the Eastern Chukchi Sea belugas, the number of tagged belugas ($n = 27$) is quite low compared to the overall population ($n = 13,305$). Variability in the presence of beluga predators and prey across seasons and years likely causes changes in beluga movements from year to year, which may not be captured by the small number of tagged belugas.

SYNTHESIS OF THE LINES OF EVIDENCE

Multiple information sources, including Indigenous Knowledge, subsistence harvest, sightings data, genetic data, passive acoustic monitoring, and satellite telemetry data, were used to evaluate whether to establish a DIP for beluga whales in Kotzebue Sound. The following sections summarize the available information.

Indigenous Knowledge, Subsistence Harvest, and Sightings

Martien et al. (2019) do not provide guidance for using Indigenous Knowledge, harvest data or declines in harvest followed by a lack of recovery, and sightings as lines of evidence on which a DIP delineation can be based. Alaska Native subsistence hunters have noted changes in the timing, behavior, and numbers of belugas returning to Kotzebue Sound each spring and summer. Hunters have described historical harvests in two “waves” of belugas, one wave arrived in late May/early June and the second wave, with larger whales, arrived by early July. Both groups included calves and immature whales, and arrived in large numbers prior to 1985. Harvests during the contemporary years have occurred opportunistically, during May-October, with two anomalous years (1996 and 2007) when large numbers of belugas entered Kotzebue Sound in late July. These whales were not accompanied by calves.

Historical observations of 900-1,200 belugas were followed by more contemporary counts of 50-100 belugas, and less. Dedicated aerial surveys in Kotzebue Sound were not attempted in decades. Many factors, or a combination of factors, may have caused the decrease in abundance and harvest, including overharvest, ice entrapment, killer whale predation, anthropogenic activity and/or noise, and prey availability. These factors could also influence the timing of beluga whale arrivals and persistence in Kotzebue Sound. For example, such abrupt declines in abundance have resulted in lack of recovery and recolonization for beluga stocks in Ungava Bay, Canada (~32 whales remain) and western Greenland, which were extirpated (Hobbs et al. 2019).

Based on behaviors, sightings, and harvest data, small numbers of belugas continue to routinely use Kotzebue Sound as spring and summer habitat. Hunters observe that belugas, including calves and immature whales, continue to enter Kotzebue Sound in late May-early July. The timing, age classes, and movement patterns for these belugas in Kotzebue Sound are similar to timing, age classes, and movements before the decline in the 1980s. This is consistent with the continued presence of the historical Kotzebue Sound population.

Genetics

At this time, molecular genetic analyses, including samples from belugas harvested in Kotzebue Sound, support the existence of a unique historical population of belugas that used Kotzebue Sound. In part, because of the influx of belugas from the Beaufort Sea in some years, the genetic results do not unequivocally support or refute the existence of a contemporary population of Kotzebue Sound belugas. Results from mtDNA genetic analyses of Kotzebue Sound beluga samples collected during the historical period (1978-1982, samples were not collected 1983-1985) indicate the historical presence of a unique population that was harvested in Kotzebue Sound. Contemporary genetic samples (1994-2019, samples were not collected 1986-1993) are a small percentage of the harvested belugas and are largely dominated by collections during the anomalous events in 1996 and 2007 and (1) are overall genetically distinct from all other stocks and (2) are most similar to the Beaufort Sea stock due primarily to the 2007 event, but (3) are significantly different from the historical Kotzebue Sound belugas. Excluding samples collected during the anomalous events of 1996 and 2007, belugas sampled in Kotzebue Sound in all other years are genetically differentiated from historical Kotzebue Sound whales and all other geographically defined beluga populations by mtDNA, but they are not genetically differentiated from eastern Bering Sea and Beaufort Sea belugas based on nDNA (O’Corry-Crowe et al. 2021). This may reflect the limited power of the existing samples representing very large populations, such as the Beaufort Sea beluga population.

Results from the nDNA analysis of contemporary samples ($n = 85$) revealed a small number of whales ($n = 6$; $p < 0.1$) that were assessed to have low likelihoods of originating from any of the known contemporary stocks, and may be evidence that some whales still exist from the historical Kotzebue Sound population. However, the Beaufort Sea stock consists of ~38,500 belugas and to date, genetic sampling in Alaska has included fewer than two hundred belugas ($n = 156$; O’Corry-Crowe et al. 2021), potentially limiting the ability to assign (or exclude) individual belugas to these populations. Assignment tests indicated a low likelihood that these six individuals sampled in Kotzebue Sound originated from other sampled contemporary populations, however, their mtDNA haplotypes were not unique to belugas sampled in Kotzebue Sound to date and are common among Beaufort Sea and Eastern Chukchi Sea belugas. The sex bias in genetic samples (90% from males) may also impact the ability to detect genetic differentiation in a species with matrilineal fidelity. It should be noted that while mtDNA data was collected for both historical and contemporary belugas, the lack of nDNA data from the historical period eliminates the possibility to compare the contemporary belugas to other stocks for nuclear markers at this time. This greatly limits the ability to use nDNA to determine whether belugas still exist from the Kotzebue Sound population harvested during the historical period.

Passive Acoustic Monitoring

Passive acoustics information about Kotzebue Sound belugas does not currently provide insights into whether belugas in this area constitute a DIP. The available and limited acoustic data cannot be used to evaluate potential differences in vocal repertoires or differences in call types that could inform an understanding of population structure. Acoustic recordings only occurred during the contemporary period. Acoustic results clearly identify beluga presence one day in late May near Sisualik, supporting the historical timing of arrival observed by hunters. However, sampling was limited in June due to weather delays and recorder failures. Although detections occurred in July and August, most occurred from September to January, a period when historically belugas had departed Kotzebue Sound.

Satellite Tracking

At this time, satellite tag data do not appear to be a useful line of evidence to support or refute whether there exists a DIP of belugas in Kotzebue Sound. The satellite tag data are limited to small numbers of belugas from the Beaufort Sea and Eastern Chukchi Sea stocks that were tagged north of Kotzebue Sound, and only during the contemporary period. All tagged belugas, with functioning satellite transmitters, were never located east of Cape Espenberg or within Kotzebue Sound near traditional hunting areas.

CONCLUSION

In summary, Indigenous Knowledge and mtDNA analyses show a DIP of belugas occupied Kotzebue Sound during June and July prior to the mid-1980s. By the mid-1990s, beluga numbers were significantly reduced, and hunting occurred opportunistically in Kotzebue Sound. Indigenous Knowledge indicates that belugas arriving in late May and in June during the contemporary years, and that travel in groups that include calves, are part of the historic population (Table 2). For the contemporary years, genetic data are ambiguous about the existence of a DIP because of the small sample size and the known presence of Beaufort Sea belugas in some years. Acoustic monitoring recorded beluga presence during months when belugas were historically present, but also in other seasons. Satellite-tagged belugas from the Beaufort Sea and Eastern Chukchi Sea stocks, with still functioning transmitters, were not present within Kotzebue Sound, near traditional hunting grounds. We conclude that 1) during the historical time period a Kotzebue Sound DIP existed based on Indigenous Knowledge, harvest/sightings, and genetic lines of evidence, and 2) Indigenous Knowledge supports the existence of a contemporary DIP, but other lines of evidence do not support or refute the existence of a contemporary DIP.

Table 2. -- Summary information on the status and identity of beluga whales harvested in Kotzebue Sound during "historical" (pre-1985) and "contemporary" (1985 and after) time periods. Lines of evidence are presented for the existence of a Kotzebue Sound DIP during the two time periods.

Time period	Indigenous Knowledge	Harvest/ Sightings	Genetics	Acoustics	Satellite Telemetry	Conclusions
Historical (pre-1985)	Clear evidence that a Kotzebue Sound DIP existed based on beluga arrival timing, movements, and presence of calves.	Clear evidence that a Kotzebue Sound DIP existed based on beluga arrival timing, locations, and harvest opportunities (annual drive hunts).	Clear evidence that a Kotzebue Sound DIP existed based on mtDNA data from available beluga samples. No samples for nDNA analysis.	Beluga acoustic recording data were not collected during this time period.	Beluga satellite telemetry data were not collected during this time period.	A Kotzebue Sound DIP existed based on Indigenous Knowledge, Harvest/ Sightings, and Genetics lines of evidence.
Contemporary (1985 and after)	Clear evidence that a Kotzebue Sound DIP exists based on beluga arrival timing, movements, and presence of calves.	Unclear evidence that a Kotzebue Sound DIP exists based on beluga arrival timing, locations, and harvest opportunities (no annual drive hunts).	Evidence is ambiguous that a Kotzebue Sound DIP exists based on mtDNA and nDNA data from available beluga samples and the presence of Beaufort Sea belugas in some years.	Beluga acoustic recording data are insufficient to evaluate differences in vocal repertoires that could indicate demographic independence. Acoustic presence in May supports beluga arrival timing from Indigenous Knowledge. Acoustic presence was also detected during months when belugas were not historically in Kotzebue Sound.	Satellite telemetry data show belugas from Anadyr, Bristol Bay, Eastern Bering Sea, Beaufort Sea, and Eastern Chukchi Sea stocks were not present within Kotzebue Sound.	Indigenous Knowledge supports the existence of a contemporary Kotzebue Sound DIP. Harvest/ Sightings, Genetics, Acoustics, and Satellite Telemetry data do not support or refute the existence of a contemporary DIP.

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APPENDIX: Kotzebue Sound Harvest Datasets

Appendix Table 1. -- Harvest records provided by the Alaska Beluga Whale Committee (ABWC) for belugas in Kotzebue Sound. Note: hunters traveled to where belugas were, therefore, village name does not always indicate where hunting occurred (see Appendix Table 2 for hunting location for genetic samples). Prior to the 1970s, drive hunts occurred near Sisualik, and by the 1980s these primarily occurred in Eschscholtz Bay near Elephant Point. Harvests also occurred in Selawik Lake and in the Kobuk River by hunters from Selawik, Noorvik, and Kiana (dashed line on Figure 2 in the main document). See Figures 3 and 4 in the main document. * = estimated average per sources shown. ND = no data.

Year(s)	Kivalina	Noatak/ Kotzebue	Selawik/ Noorvik/ Kiana	Buckland	Deering	Shishmaref	Total	Source
1951				25			25	1
1952-58								ND
1959	7						7	2
1960*	14	~50					64	2
1961*	10	60	36	130	8		244	3*,4*
1962*	10	60	36	130	8		244	3*,4*
1963*	10	60	36	130	8		244	3*,4*
1964	6	60	36	130	8		240	2,3*,4*
1965	4	60	36	130	8		238	2,3*,4*
1966*	10	60	36	130	8		244	3*,4*
1967*	10	60	36	130	8		244	3*,4*
1968*	10	60	36	130	8		244	3*,4*
1969*	10	60	36	130	8		244	3*,4*
1970*	10	60	36	130	8		244	3*,4*
1971*	10	60	36	130	8		244	3*,4*
1972*	10	60	36	130	8		244	3*,4*
1973*	10	60	36	130	8		244	3*,4*
1974-76								ND
1977	ND	3		105			108	5,6
1978	ND	5		90			95	5,6
1979	ND	2		5			7	5,6
1980	ND	13		101			114	6,7
1981	ND	4		39			43	6,7
1982	4	25		129			158	2,6,7
1983	1	19-24		48			68-73	2,6,7
1984		31		0			31	6,7
1985		13		2			15	6,7
1986		3		3			6	6,7
1987	0	2		7	0		9	6,8
1988	1	8		17	0		26	6,8
1989	0	37		0	0		37	8
1990	1	6		31	ND		38	8
1991	1	11		0	ND		12	8

Year(s)	Kivalina	Noatak/ Kotzebue	Selawik/ Noorvik/ Kiana	Buckland	Deering	Shishmaref	Total	Source
1992	0	5		4	ND		9	8
1993	0	6		0	0		6	8
1994	0	7		0	0		7	8
1995	0	4		1	0		5	8
1996	0	68		5	2		75	8
1997	1	7		1	0		9	8
1998	0	4		1	0		5	8
1999	0	2		0	0		2	8
2000	1	0		1	0		2	8
2001	0	9		18	0		27	8
2002	3	4		2	0		9	8
2003	0	0		0	0		0	8
2004	0	1		0	0		1	8
2005	0	1		0	0		1	8
2006	0	2		0	0		2	8
2007	18	69	<u>2</u>	48	14		151	9
2008	0	1		0	0		1	9
2009	1	2		0	0		3	9
2010	2	0		0	0		2	9
2011	2	30		0	0		32	9
2012	1	3		0	0		4	9
2013	0	6		0	0		6	9
2014	2	6		2	0		10	9
2015	0	1		0	0		1	9
2016	0	4		4	1		9	9
2017	0	2		0	0		2	9
2018	3	9		1	2		15	9
2019	4	2		0	0		6	9
2020	0	4		0	3		7	10
2021	3	21		1	1	2	28	10
2022	12	10		3	1	1	27	10
2023	7	8		1	0		16	

Sources: 1) Morseth 1997, 2) Burch 1998 (Kivalina only), 3) Uhl and Uhl 1977, 4) Patterson 1974, 5) Seaman and Burns 1981, 6) Frost and Lowry 1990, 7) Lowry et al. 1989, 8) Frost and Suydam 2010, 9) Frost et al. 2021, 10) ABWC 2023a.

Appendix Table 2. -- Samples collected for genetic analyses (note not all samples were used in subsequent analyses if unable to extract DNA). See Figures 4 and 5 in the main document. * = has a haplotype unique to historical Kotzebue Sound samples.

Field ID	Year	Month	Day	Latitude	Longitude	Area
EPD-78-01	1978	6	13	66.500	-160.417	Elephant Pt
EPD-69-78	1978	6	14	66.250	-161.333	Elephant Pt
EPD-2-79	1979	6	16	66.250	-161.333	Elephant Pt
EPD-3-79	1979	6	23	66.250	-161.333	Elephant Pt
EPD-1-79	1979	6		66.250	-161.333	Elephant Pt
EPD-1-78	1978	6		66.250	-161.333	Elephant Pt
EPD-19-78	1978	6		66.250	-161.333	Elephant Pt
EPD-24-78	1978	6		66.250	-161.333	Elephant Pt
EPD-28-78	1978	6		66.250	-161.333	Elephant Pt
EPD-38-76	1976	6		66.250	-161.333	Elephant Pt
EPD-56-78	1978	6		66.250	-161.333	Elephant Pt
EPD-48-80	1980	6		66.250	-161.333	Elephant Pt
EPD-90-80	1980	6		66.250	-161.333	Elephant Pt
EPD-6-81	1981	6		66.250	-161.333	Elephant Pt
EPD-7-81	1981	6		66.250	-161.333	Elephant Pt
EPD-23-81	1981	6		66.250	-161.333	Elephant Pt
EPD-1-82	1982	6	17-26			Elephant Pt
EPD-7-82	1982	6	17-26			Elephant Pt
EPD-11-82	1982	6	17-26			Elephant Pt
EPD-16-82	1982	6	17-26			Elephant Pt
EPD-17-82	1982	6	17-26			Elephant Pt
EPD-19-82	1982	6	17-26			Elephant Pt
EPD-21-82	1982	6	17-26			Elephant Pt
EPD-27-82	1982	6	17-26			Elephant Pt
EPD-38-82	1982	6	17-26			Elephant Pt
EPD-39-82	1982	6	17-26			Elephant Pt
EPD-43-82	1982	6	17-26			Elephant Pt
EPD-48-82	1982	6	17-26			Elephant Pt
EPD-62-82	1982	6	17-26			Elephant Pt
EPD-65-82	1982	6	17-26			Elephant Pt
EPD-69-82	1982	6	17-26			Elephant Pt
EPD-71-82	1982	6	17-26			Elephant Pt
EPD-73-82	1982	6	17-26			Elephant Pt
EPD-80-82	1982	6	17-26			Elephant Pt
EPD-89-82	1982	6	17-26			Elephant Pt
EPD-94-82	1982	6	17-26			Elephant Pt
EPD-99-82	1982	6	17-26			Elephant Pt

Field ID	Year	Month	Day	Latitude	Longitude	Area
EPD-105-82	1982	6	17-26			Elephant Pt
EPD-107-82	1982	6	17-26			Elephant Pt
EPD-109-82	1982	6	17-26			Elephant Pt
EPD-120-82	1982	6	17-26			Elephant Pt
EPD-121-82	1982	6	17-26			Elephant Pt
KOTD-02-94	1994	6	23	66.750	-162.583	Cape Blossom
KOTD-01-94	1994	6	26			Sisualik
KOTZ-01-95	1995	8	3	66.883	-162.583	Sisualik
EPD-01-95*	1995	8	17			Elephant Pt
KOTZ-02-96	1996	6	10	66.883	-162.650	Sisualik
KOTZ-10-96	1996	6	10	66.883	-162.650	Sisualik
KOTZ-03-96	1996	6	14	66.883	-162.650	Sisualik
KOTZ-01-96	1996	6	15	66.883	-162.650	Sisualik
KOTZ-05-96	1996	6	15	66.883	-162.650	Sisualik
KOTZ-06-96	1996	6	15	66.883	-162.650	Sisualik
KOTZ-07-96	1996	6	15	66.883	-162.650	Sisualik
KOTZ-08-96	1996	6	21	66.883	-162.650	Sisualik
KOTZ-09-96	1996	6	21	66.883	-162.650	Sisualik
KOTZ-11-96	1996	6	25	66.883	-162.650	Sisualik
KOTZ-12-96	1996	6	25	66.883	-162.650	Sisualik
KOTZ-13-96	1996	6	25	66.883	-162.650	Sisualik
DEER-01-96	1996	6	26	66.000	-163.000	Deering
KOTZ-04-96	1996	6	28	67.750	-163.000	Sisualik
DEER-02-96	1996	7	2	66.000	-163.000	Deering
KOTZ-14-96	1996	7	16	66.883	-162.650	Sisualik
ELP-01-96	1996			55.683	-160.050	Elephant Pt
NOA-01-96	1996			67.567	-162.950	Sisualik
EPD-01-97	1997	7	15	55.683	-160.050	Elephant Pt
KOTZ-01-97	1997	7		66.883	-162.583	Sisualik
BKK-7-2-98	1998	7	2	66.300	-161.317	Elephant Pt
KOTZ-01-99	1999	6	25			Sisualik
DL-KOT02-01	2001	6		66.750	-163.000	Sisualik
DL-KOT-03-01	2001	6		66.750	-163.000	Sisualik
DL-KOT-01-01	2001	6		66.250	-161.333	Elephant Pt
DL-KZ-01-02	2002	7		66.750	-163.000	Sisualik
DL-KZ-02-02	2002	7		66.750	-163.000	Sisualik
KOTZ-DL-01-05	2005	10	14	66.750	-163.000	Sisualik
DL06NS001	2006	7		66.883	-162.650	Sisualik
DL07KZ051*	2007	6	5	66.883	-162.650	Sisualik
DL07KZ050	2007	6	11	66.883	-162.650	Sisualik
DL07KZ052	2007	6	11	66.883	-162.650	Sisualik
DL07KZ054	2007	6	11	66.883	-162.650	Sisualik

Field ID	Year	Month	Day	Latitude	Longitude	Area
DL07KZ007	2007	6	16	66.883	-162.650	Sisualik
DL07KZ014	2007	6	16	66.883	-162.650	Sisualik
DL07KZ053	2007	7	23	66.883	-162.650	Sisualik
DL07KZ055	2007	7	23	66.883	-162.650	Sisualik
DL07KZ056	2007	7	23	66.883	-162.650	Sisualik
DL07KZ057	2007	7	23	66.883	-162.650	Sisualik
DL07KZ058	2007	7	23	66.883	-162.650	Sisualik
DL07KZ059	2007	7	23	66.883	-162.650	Sisualik
DL07KZ060	2007	7	23	66.883	-162.650	Sisualik
DL07KZ061	2007	7	23	66.883	-162.650	Sisualik
DL07KZ062	2007	7	23	66.883	-162.650	Sisualik
DL07KZ063	2007	7	23	66.883	-162.650	Sisualik
DL07KZ064	2007	7	23	66.883	-162.650	Sisualik
DL07KZ065*	2007	7	23	66.883	-162.650	Sisualik
DL07KZ066	2007	7	23	66.883	-162.650	Sisualik
DL07KZ067	2007	7	23	66.883	-162.650	Sisualik
DL07KZ068	2007	7	23	66.883	-162.650	Sisualik
DL07KZ069	2007	7	23	66.883	-162.650	Sisualik
DL07KZ070	2007	7	23	66.883	-162.650	Sisualik
DL07KZ071	2007	7	23	66.883	-162.650	Sisualik
DL07KZ008	2007	7	23	66.883	-162.650	Sisualik
DL07KZ009	2007	7	23	66.883	-162.650	Sisualik
DL07KZ010	2007	7	23	66.883	-162.650	Sisualik
DL07KZ011	2007	7	23	66.883	-162.650	Sisualik
DL07KZ013	2007	7	23	66.883	-162.650	Sisualik
DL07KZ015	2007	7	26	66.883	-162.650	Sisualik
DL07KZ016	2007	7	26	66.883	-162.650	Sisualik
DL07KZ017	2007	7	26	66.883	-162.650	Sisualik
DL07KZ018	2007	7	26	66.883	-162.650	Sisualik
DL07KZ019	2007	7	26	66.883	-162.650	Sisualik
DL07KZ020	2007	7	26	66.883	-162.650	Sisualik
DL07KZ021	2007	7	26	66.883	-162.650	Sisualik
DL07KZ022	2007	7	26	66.883	-162.650	Sisualik
DL07KZ023	2007	7	26	66.883	-162.650	Sisualik
DL07KZ024	2007	7	26	66.883	-162.650	Sisualik
DL07KZ026	2007	7	26	66.883	-162.650	Sisualik
DL07KZ027	2007	7	26	66.883	-162.650	Sisualik
DL07KZ028	2007	7	26	66.883	-162.650	Sisualik
DL07KZ029	2007	7	26	66.883	-162.650	Sisualik
DL07KZ030*	2007	7	26	66.883	-162.650	Sisualik
DL07KZ031	2007	7	26	66.883	-162.650	Sisualik
DL07KZ032	2007	7	26	66.883	-162.650	Sisualik

Field ID	Year	Month	Day	Latitude	Longitude	Area
DL07KZ033	2007	7	26	66.883	-162.650	Sisualik
DL07KZ034	2007	7	26	66.883	-162.650	Sisualik
DL07KZ035	2007	7	26	66.883	-162.650	Sisualik
DL07KZ036	2007	7	26	66.883	-162.650	Sisualik
DL07KZ037	2007	7	26	66.883	-162.650	Sisualik
DL07KZ038	2007	7	26	66.883	-162.650	Sisualik
DL07KZ039	2007	7	26	66.883	-162.650	Sisualik
DL07KZ040	2007	7	26	66.883	-162.650	Sisualik
DL07KZ041	2007	7	26	66.883	-162.650	Sisualik
DL07KZ042	2007	7	26	66.883	-162.650	Sisualik
DL07KZ043	2007	7	26	66.883	-162.650	Sisualik
DL07KZ044	2007	7	26	66.883	-162.650	Sisualik
DL07KZ045	2007	7	26	66.883	-162.650	Sisualik
DL07KZ046	2007	7	26	66.883	-162.650	Sisualik
DL07KZ047	2007	7	26	66.883	-162.650	Sisualik
DL07KZ048	2007	7	26	66.883	-162.650	Sisualik
DL07KZ049	2007	7	26	66.883	-162.650	Sisualik
DL07KZ072	2007	7	27	66.883	-162.650	Sisualik
DL07KZ012	2007	7	27	66.883	-162.650	Sisualik
DL07KZ003	2007	7	27	66.883	-162.650	Sisualik
DL07KZ004*	2007	7	27	66.883	-162.650	Sisualik
DL07KZ005	2007	7	27	66.883	-162.650	Sisualik
DL07KZ006	2007	7	27	66.883	-162.650	Sisualik
07-28-01	2007	7	28	66.883	-162.650	Sisualik
07-28-02	2007	7	28	66.883	-162.650	Sisualik
07-28-03	2007	7	28	66.883	-162.650	Sisualik
07-28-04	2007	7	28	66.883	-162.650	Sisualik
07-28-05	2007	7	28	66.883	-162.650	Sisualik
07-28-06	2007	7	28	66.883	-162.650	Sisualik
DL07KZ001	2007	7	29	66.883	-162.650	Sisualik
DL07KZ002	2007	7	29	66.883	-162.650	Sisualik
DL07KVL001	2007	8		67.717	-164.533	Kivalina
DL07KVL002	2007	8		67.717	-164.533	Kivalina
DL07KVL003	2007	8		67.717	-164.533	Kivalina
DL07KVL004	2007	8		67.717	-164.533	Kivalina
DL07KVL005	2007	8		67.717	-164.533	Kivalina
DL07KVL006	2007	8		67.717	-164.533	Kivalina
DLEU0709	2007	9				Unknown
DL09KTZ002	2009	6				N. Kotzebue Sound
DL09KTZ001	2009	7				N. Kotzebue Sound
DL11KTZ001	2011	6	15-30	66.950	-162.617	Sisualik

Field ID	Year	Month	Day	Latitude	Longitude	Area
DL11KTZ002	2011	6	15-30	66.950	-162.617	Sisualik
DL11KTZ003	2011	6	15-30	66.950	-162.617	Sisualik
DL11KTZ004	2011	6	15-30	66.950	-162.617	Sisualik
DL11KTZ005	2011	6	15-30	66.950	-162.617	Sisualik
DL11KTZ006	2011	6	15-30	66.950	-162.617	Sisualik
DL11KTZ007	2011	6	15-30			Sisualik
KOTD1-08	2008	10				Sisualik
DL13KTZ001	2013	7				Sisualik
DL13KTZ002	2013	7				Sisualik
DL13KTZ003	2013	7				Sisualik
KotzB01	2016	6	27			Sisualik
KotzB02	2016	6	26			Sisualik
KotzB03	2016	6	16			Sisualik
KotzB04	2016	6	26			Sisualik
Deering01	2016	6	23			Deering
BB#1	2016	7				Elephant Pt
BB#2	2016	7				Elephant Pt
BB#3	2016	7				Elephant Pt
DL18OTZ001	2018	8				Kotzebue
DL18OTZ002	2018	7	14			Kotzebue
DL19OTZ001	2019	8	11			Sisualik



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