Distribution, Abundance, Harvest, and Status of Western Alaska Beluga Whale, *Delphinapterus leucas*, Stocks

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Introduction

Beluga whales, *Delphinapterus leucas* (also called white whales), are a conspicuous and important component of the marine mammal fauna of western Alaska. Early reports indicated regular spring, summer, and fall occurrences of belugas in the Bering Sea in Bristol Bay (Brooks et al.[1]; Lensink[2]), Norton Sound and the Yukon Delta (Nelson, 1887; Zagoskin, 1967), and in the Chukchi Sea in Kotzebue Sound and along lagoons near Point Lay (Nelson, 1887; Foote and Williamson, 1966; Childs[3]). Traditional knowledge of Alaska Natives indicated that these occurrences represented long established migration routes and summer concentration areas, and that belugas were an important subsistence resource harvested at many coastal villages (Huntington et al., 1999; Neakok et al.[4]; Chythlook and Coiley[5]).

Research on belugas in Alaska initially focused on competition with commercial fisheries but later included potential impacts of proposed oil and gas leasing. Belugas in Bristol Bay were the subject of early scientific attention mostly because the largest commercial sockeye salmon, *Oncorhynchus nerka*, fishery in the world occurs there (Jones et al.[6]) and

[1]Brooks, J. W., A. S. Mossman, and H. Z. Hansen. 1955. Predator control and investigation: beluga investigation. *In* 1955 annual report, p. 98–106. Alaska Fish. Board, Alaska Dep. Fish., Rep. 7, Juneau (avail. at http://www.arlis.org/docs/vol1/A/31110164etc/31110164etc-1955.pdf#page=97).

[2]Lensink, C. J. 1961. Status report: beluga studies. Alaska Dep. Fish Game, Div. Biol. Res., Unpubl. Rep., Juneau (avail. at http://www.adfg.alaska.gov/static/home/library/pdfs/wildlife/research_pdfs/status_report_beluga_studies_1961.pdf).

[3]Childs, H. E., Jr. 1969. Birds and mammals of the Pitmegea River Region, Cape Sabine, northwestern Alaska. Biol. Pap. No. 10, Univ. Alaska, Fairbanks, 76 p. (avail. at https://scholarworks.alaska.edu/handle/11122/1432).

[4]Neakok, W., D. Neakok, W. Bodfish, D. Libbey, E. S. Hall, Jr., and the Point Lay elders. 1985. To keep the past alive: the Point Lay cultural resource site survey. North Slope Borough, Barrow, AK, 111 p.

[5]Chythlook, M., and P. Coiley 1994. The subsistence use of beluga whale in Bristol Bay by Alaska Natives, 1993. Tech. Paper No. 231. Alaska Dep. Fish Game, Div. Subsistence, Juneau, AK, 29 p.

[6]Jones, M., T. Sands, S. Morstad, P. Salomone, G. Buck, F. West, C. Brazil, and T. Krieg. 2013. 2012 Bristol Bay area annual management report. Alaska Dep. Fish Game, Fish. Manage.

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ABSTRACT—The Alaska Beluga Whale Committee co-manages three western Alaska beluga whale Delphinapterus leucas, *stocks with the National Marine Fisheries Service, NOAA, and has conducted studies on stock identity, distribution, abundance, and subsistence harvests. Studies of mitochondrial DNA revealed substantial differentiation among belugas that use summering areas in Bristol Bay, the eastern Bering Sea, and the eastern Chukchi Sea, and there is little overlap in their seasonal distributions. The Bristol Bay stock summers in bays in inner Bristol Bay and winters in outer Bristol Bay. Abundance estimates from aerial surveys increased by more than 4% per year during 1994–2005. Survey counts in 2016 were similar to 2004–2005 indicating that the population may now be stable. Survey results and a genetics mark-recapture study indicate a population of approximately 2,000 whales. The average annual Alaska Native subsistence harvest over the past decade (23) is below the calculated potential biological removal (PBR; 39-43). The eastern Bering Sea beluga stock concentrates in summer off the Yukon River Delta and in Norton Sound and in winter moves offshore in the eastern Bering Sea. Abundance has been estimated at approximately 9,242 based on aerial survey data collected in 2017. The average annual subsistence harvest, plus the estimated number of struck and lost belugas, is 215 and exceeds the PBR calculated from this abundance estimate (201), but the abundance estimate is thought to be biased low and local and traditional knowledge does not indicate any decrease in abundance or availability. The eastern Chukchi Sea stock is migratory, wintering in the northern Bering Sea, moving north through the eastern Chukchi Sea in spring, and summering in the Beaufort Sea and Arctic Ocean. It is large, estimated at approximately 20,000 animals based on 2012 aerial surveys. The average annual subsistence harvest (57) is well below PBR (293). Few significant threats to persistence of western Alaska beluga stocks have been identified, although climate warming and declines in sea ice and industrial activities related to resource development and increases in commercial shipping are of concern and could pose challenges in the future. Continued monitoring of population size and trend, subsistence harvest, and health of western Alaska belugas is warranted.*

salmon stocks were depleted. Studies began in Bristol Bay in the 1950's because of concern that belugas were consuming enough salmon smolt to limit salmon populations (Brooks et al.[1]; Lensink[2]) and there was pressure by commercial fisheries to reduce beluga predation on salmon (Fish and Vania, 1971).

Research throughout western Alaska began in 1977 to assess potential impacts of oil and gas exploration and development in the Bering, Chukchi, and Beaufort seas (Burns and Seaman[7]). Compilations of observational data confirmed the widespread distribution and common occurrence of belugas in western Alaska (Seaman et al.[8]). When all available sightings were plotted, a non-uniform distribution of belugas in coastal waters during the summer was evident and suggestive of population subdivisions (Frost and Lowry, 1990). This summer distribution pattern formed the basis for provisional stock designations recognizing that genetic studies would be required to confirm underlying patterns of relatedness among the seasonal groupings (O'Corry-Crowe and Lowry, 1997).

The Alaska Beluga Whale Committee (ABWC) was formed in 1988 to conserve beluga whales and manage beluga subsistence hunting in western Alaska in cooperation with NOAA's National Marine Fisheries Service (NMFS) (Adams et al., 1993; Fernandez-Gimenez et al., 2006; ABWC[9]). When the ABWC was formed, there was no consistently funded research or management program for belugas in Alaska. With its formation, the ABWC brought together representatives from beluga hunting communities in Alaska; federal, state, tribal, and local governments; and beluga researchers to develop and implement a program to provide the data needed for sound beluga management. Goals of the ABWC were to identify management stocks in western Alaska, estimate abundance and trends of those stocks, and monitor the number of belugas harvested from those stocks for subsistence by Alaska Natives. In furtherance of these goals and with funding from NMFS and other cooperators, the ABWC has conducted a total of 23 multi-day aerial surveys of belugas in three areas, Bristol Bay (*N* = 7), Norton Sound/Yukon Delta (*N* = 7), and the eastern Chucki Sea (*N* = 9) since 1990. The ABWC began satellite tracking studies of beluga movements and habitat use in 1996, and has facilitated and collaborated in beluga tracking studies, including the training of hunters to attach transmitters, in Bristol Bay (*N* = 69), Norton Sound (*N* = 7), and the eastern Chukchi Sea (*N* = 30). In 1989, the ABWC initiated a pioneering genetics study of beluga stock identity and by 2017 had facilitated the collection of more than 2,000 beluga skin samples. It supported a genetics-based mark-recapture study to estimate beluga abundance in Bristol Bay and to validate aerial survey estimates. The ABWC has collected subsistence harvest data during 1987–2017 from more than fifty Alaska communities where beluga hunting occurs. The ABWC stands as a model of what can be achieved when scientists, Alaska Native hunters, and managing agencies work together.

The goal of this manuscript is to update what is known about the stock identity, distribution, abundance, subsistence harvest, and fisheries bycatch of the three stocks of beluga whales that are co-managed by the ABWC in western Alaska (i.e., Bristol Bay, eastern Bering Sea, and eastern Chukchi Sea stocks). Using recent abundance and harvest information, we calculate the Potential Biological Removal (PBR) (Wade and Angliss, 1997) and comment on sustainability of current anthropogenic removals. To facilitate the use of this information for NOAA Stock Assessment Reports (SAR's), we follow the format found in those reports.

Identity of Management Stocks

To understand the relationship of belugas summering in different regions of western Alaska, the ABWC sponsored genetic studies. A total of 1,212 beluga skin samples were collected from this region, many by Alaska Native beluga hunters. Differences in mitochondrial DNA (mtDNA; Fig. 1) from different regions led to the identification of four genetically distinct stocks (Fig. 2) in the eastern Bering, Chukchi, and Beaufort seas: 1) Bristol Bay (BB), 2) eastern Bering Sea (EBS), 3) eastern Chukchi Sea (ECS), and 4) Beaufort Sea (Muto et al., 2018). All of these stocks are genetically distinct from the stock in Cook Inlet. These genetic differences likely reflected long-established patterns of female-mediated philopatry and group isolation (O'Corry-Crowe et al., 1997, 2002, 2018; Brown-Gladden et al., 1997, 1999; Meschersky et al., 2008, 2013). Data from aerial surveys and satellite-linked depth recorders (SDR's) attached to whales have shown that each stock has distinct seasonal distribution patterns (see Distribution and Movements below and Fig. 2). The three stocks, BB, EBS, and ECS, that have summer concentration areas in western Alaska are the subject of this review. We do not consider Gulf of Anadyr belugas, because they summer in eastern Russia and are not known to range into Alaska waters (Citta et al., 2016; Litovka et al.[10]; Fig.

Rep. 13-20, Div. Commer. Fish., Anchorage, AK (avail. at www.adfg.alaska.gov/FedAidPDFs/FMR13-20.pdf).

[7]Burns, J. J., and G. A. Seaman. 1988. Investigations of belukha whales in coastal waters of western and northern Alaska. II. Biology and ecology. U.S. Dep. Commer., Outer Continental Shelf Environ. Assess. Prog. Fin. Rep. 56: 221-357 (avail. at https://www.boem.gov/ESPIS/0/81.pdf).

[8]Seaman, G. A., K. J. Frost, and L. F. Lowry. 1988. Investigations of belukha whales in coastal waters of western and northern Alaska. Part I. Distribution and abundance. U.S. Dep. Commer., Outer Continental Shelf Environ. Assess. Prog. Fin. Rep. 56:153-220 (avail. at https://www.boem.gov/ESPIS/0/82.pdf).

[9]Alaska Beluga Whale Committee (ABWC). 1999. Agreement between the National Marine Fisheries Service and the Alaska Beluga Whale Committee for co-management of the western Alaska beluga whale population. Avail. from North Slope Borough, Dep. Wildl. Manage., Box 69, Barrow, AK 99723, 8 p.

[10]Litovka, D. I., R. C. Hobbs, K. L. Laidre, G. M. O'Corry-Crowe, J. R. Orr, P. R. Richard, R. S. Suydam, and A. A. Kochnev. 2002. Research of belugas *Delphinapterus leucas* in Anadyr

2, 3). Beaufort Sea belugas winter in the Bering Sea (Citta et al., 2016; Fig. 3), are harvested at some locations in Alaska during spring migration (see Point Hope in Fig. 1), and spend summers near and offshore of the Mackenzie estuary, Canada (Hauser et al., 2014; Fig. 2). We do not review the Beaufort Sea stock in this paper because research has been conducted primarily by Canadian researchers and the majority of removals occur in Canada.

Belugas found in Kotzebue Sound deserve special mention. Studies conducted in the 1970's and early 1980's reported belugas entering Kotzebue Sound in mid- to late-June every year, during or shortly following ice breakup (Frost and Lowry, 1990; Seaman et al.[8]). Traditional knowledge confirmed this was a long-established summer concentration area (Huntington et al., 1999). The number of whales returning to Kotzebue Sound declined substantially after 1983 and has not recovered; however, belugas have entered the Sound intermittently in summer in some subsequent years (Frost and Lowry, 1990; Seaman et al.[11]). MtDNA characteristics of belugas harvested before the decline showed that those taken by Kotzebue Sound hunters in the early 1980's differed from the other western Alaska stocks (O'Corry-Crowe et al., 2016, 2018). O'Corry-Crowe et al. (2018) also determined that belugas recently harvested in Kotzebue Sound, at least in years with adequate sample sizes, were either from the Beaufort Sea stock or from a group closely related to that stock. Why the group of belugas using Kotzebue Sound declined after 1983, the status of that group of belugas prior to 1983, and the relationships of belugas harvested since 1983 to other stocks remain unclear. These are current topics of research, and because of the uncertainty described above we do not consider Kotzebue Sound belugas further in this paper.

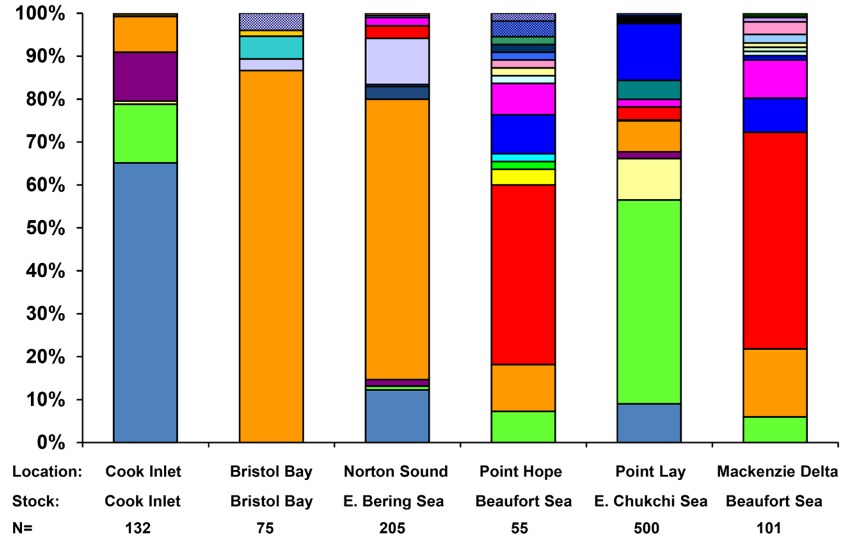

Figure 1.—Frequency distribution of the distinct mtDNA lineages found in the five major geographic regions used by summering beluga whales in Alaskan and northwestern Canadian waters: Cook Inlet, Bristol Bay, eastern Bering Sea, eastern Chukchi Sea, and the Beaufort Sea, as well as one spring migration location, Point Hope, Alaska (adapted from O'Corry-Crowe et al., 1997, 2002, 2018). Each mtDNA lineage, or haplotype, is denoted by a different color. The location of the summer aggregation, stock identity, and sample size are given at the bottom of the figure.

Distribution and Movements

Bristol Bay

Telemetry studies using SDR's indicate that BB belugas are typically found in Nushagak and Kvichak bays and associated river mouths and tributaries during the summer and range more widely in the northeast region of Bristol Bay in the winter (Citta et al., 2016, 2017). In spring and summer (Fig. 4a, b), their distribution is largely restricted to Nushagak and Kvichak bays (Frost et al., 1985; Lowry et al., 2008; Citta et al., 2016; Frost et al.[12]), where belugas are known to feed on a variety of prey, including salmonids, other fishes, and invertebrates (Quakenbush et al., 2015; Brooks et al.[1]; Lowry et al.[13]). After the salmon runs end in late summer, belugas widen their distribution, but remain mostly within Nushagak and Kvichak bays (Fig. 4c; Citta et al., 2016). In winter, BB belugas range into outer Bristol Bay as far as Cape Newenham (Fig. 4d; Citta et al., 2016) and frequent the inner bays less often, perhaps because the bays are covered in ice and pose a risk of entrapment or because few prey are available there. In winter, BB belugas are known to spatially overlap with belugas from the EBS stock but they have not overlapped in time, although sample size is small (Fig. 3). Belugas in both stocks were tracked in 2013,

Gulf (Chukotka) using satellite telemetry. Marine Mammals of the Holarctic. Abstracts of the conference presentations. Moscow, p. 161–163 (avail. at http://marmam.ru/upload/conf-documents/mmc2002_full.pdf).

[11]Seaman G., E. Barger, and R. Lee. 2015. Buckland Beluga Whale Traditional Knowledge Project. Final Rep. Avail. from North Slope Borough, Dep. Wildl. Manage., Box 69, Barrow, AK 99723.

[12]Frost, K. J., L. F. Lowry, and R. R. Nelson. 1984. Belukha whale studies in Bristol Bay, Alaska. *In* B. R. Melteff (Editor), Proceedings of the workshop on biological interactions among marine mammals and commercial fisheries in the southeastern Bering Sea, p. 187–200. Alaska Sea Grant Report 84-1, Univ. Alaska, Fairbanks. Alaska Sea Grant. P.O. Box 755040, 201 Elvey Building, Fairbanks, AK 99775-5040.

[13]Lowry, L. F., K. J. Frost, and G. A. Seaman. 1988. Investigations of belukha whales in coastal waters of western and northern Alaska. Part III. Food habits. U.S. Dep. Commer., Outer Continental Shelf Enviromental Assessment Program Fin. Rep. 56:359–391 (avail. at https://www.boem.gov/ESPIS/0/80.pdf).

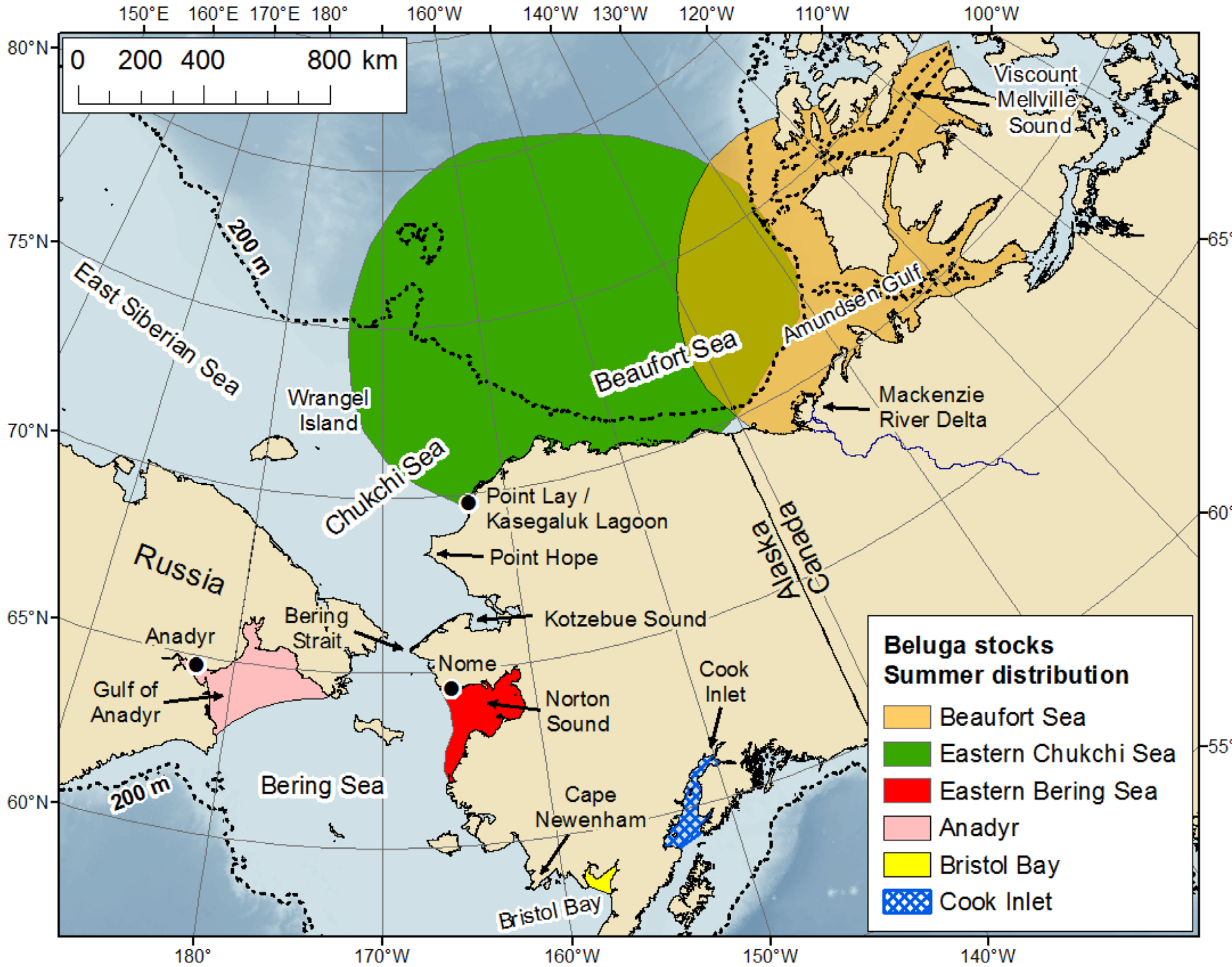

Figure 2.—The summer distribution of known beluga whale stocks in the Bering, Chukchi, and Beaufort seas. Figure modified from Citta et al. (2017).

and although one EBS beluga moved southeastward into the winter range of BB belugas in January, BB belugas had moved into the inner bay, therefore there is no evidence that the two stocks were in the same place at the same time (Citta et al., 2017).

Eastern Bering Sea

Although there were few winter sightings, Frost and Lowry (1990) reported belugas in the Norton Sound region in all seasons. ECS and Beaufort Sea belugas may migrate through the western part of this region in spring and autumn when moving between summering grounds in the Chukchi and Beaufort seas and wintering grounds in the Bering Sea, but only the EBS stock occupies nearshore waters in the northeastern Bering Sea in summer (Fig. 2).

Aerial surveys for belugas in the Yukon Delta/Norton Sound region were begun by the ABWC in 1992. Most surveys were flown in June when belugas were concentrated off the mouths of the Yukon River and in southern Norton Sound (Lowry et al., 2017a; Lowry et al.[14]). High densities were observed along the 5 m isobath in silt-laden Yukon River water (Fig. 5) where belugas were most likely feeding on Pacific salmon, *Onchorhynchus* spp. Belugas are known to occur hundreds of kilometers up the Yukon River on occasion, presumably following salmon. In spring and fall, belugas are seen along the coast at many locations in the Yukon Delta/Norton Sound region (Nelson, 1887; Frost and Lowry, 1990).

SDR's were attached to two belugas in northern Norton Sound near Nome in the autumn of 2012 (Citta et al., 2017). Those whales remained in Norton Sound in October and early November, then as sea ice cover advanced they moved out of the Sound and southward, but remained in the eastern Bering Sea

[14]Lowry, L. F., D. P. DeMaster, and K. J. Frost. 1999. Alaska Beluga Whale Committee surveys of beluga whales in the eastern Bering Sea, 1992–1995. Paper SC/51/SM 34 presented to the IWC Scientific Committee, May 1999.

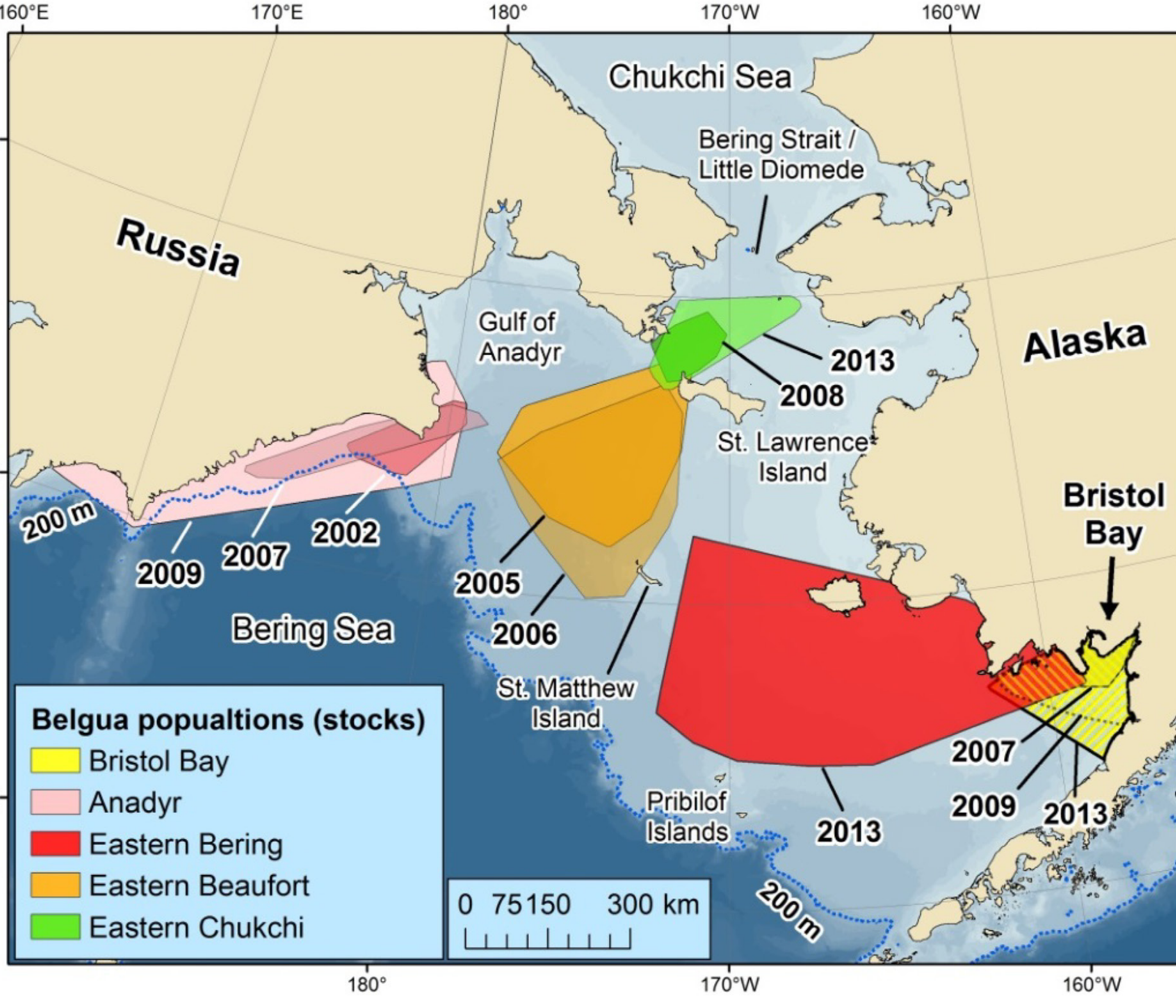

Figure 3.—Winter ranges (minimum convex polygons of beluga whale satellite tag locations) of beluga stocks that winter in the Bering Sea. Polygons are drawn using January–March locations and years are denoted by the degree of shading. Figure reproduced from Citta et al. (2017).

(Fig. 3). Both returned to Norton Sound by mid-June 2013. Another beluga was tagged near Nome in November 2016. That animal spent November–December 2016 and January–April 2017 in western Norton Sound and adjacent waters of the eastern Bering Sea. In May–June it moved into Norton Sound and to the mouth of the Yukon River where it remained through October then moved again to western Norton Sound (ABWC[15]).

[15]Satellite tagging maps 2016-17 (avail. at http://www.north-slope.org/departments/wildlife-management/co-management-organizations/alaska-beluga-whale-committee/abwc-research-projects/satellite-maps-of-tagged-alaskan-beluga-stocks/satellite-tagging-maps-nov-2016).

Eastern Chukchi Sea

Studies conducted in the 1970's and early 1980's reported belugas congregating in nearshore waters and passes near Kasegaluk Lagoon typically in late June (Frost and Lowry, 1990; Seaman et al.[8]). Traditional knowledge confirmed this was a long-established summer concentration area (Huntington et al., 1999). Other than the annual return to the Kasegaluk Lagoon area, little was known about the distribution of the ECS stock until belugas were tagged with SDR's. During 1998–2012, 29 belugas were captured in conjunction with the annual subsistence hunt at Point Lay and equipped with SDR's that each provided location data for 5–522 days (Suydam, 2009; Hauser et al., 2014). Results showed that after leaving Kasegaluk Lagoon in July, whales moved into the northern Chukchi and Beaufort seas and some went far into the Arctic Ocean, penetrating heavy ice cover north of lat. 80° N (Suydam et al., 2001). Although belugas ranged widely in summer, both adults and subadults and both sexes were most often found in water deeper than 200 m, along and beyond the continental shelf break, including into very deep basin waters (Citta et al., 2013). They rarely

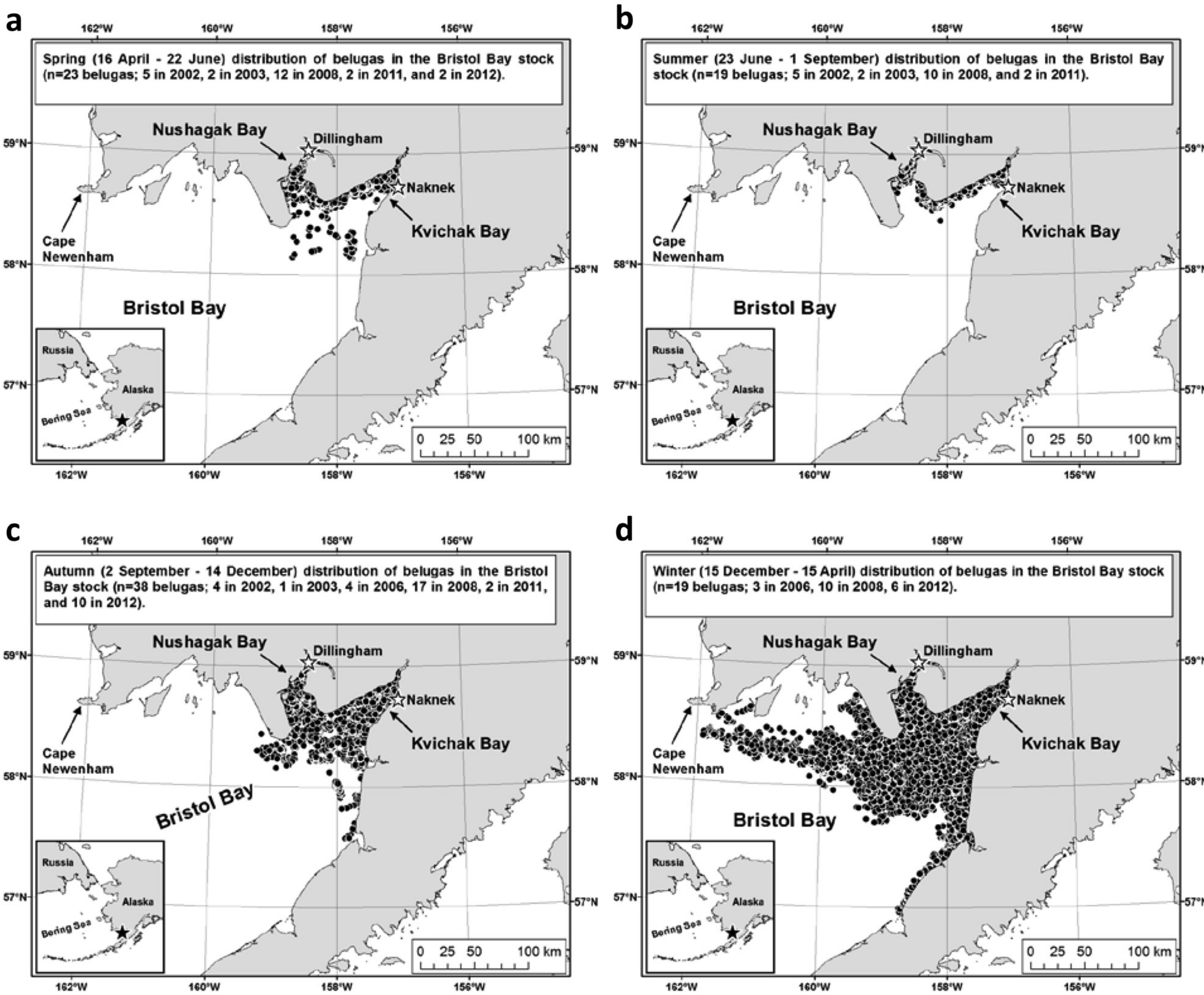

Figure 4.—Locations for satellite tagged beluga whales in the Bristol Bay stock for (a) the spring (16 April–22 June), when salmon smolt, *Oncorhynchus* spp., and rainbow smelt, *Osmerus mordax*, are migrating; (b) the summer (23 June–1 September), when adult salmon are migrating; (c) the autumn, after the salmon migrations are complete (2 September–14 December); and (d) the winter (15 December–15 April), when sea ice is typically present. Data include those presented in Citta et al. (2016).

used shelf waters of the Beaufort Sea (Suydam, 2009; Clarke and Ferguson, 2018; Stafford et al., 2018). Hauser et al. (2014) used these data to describe beluga distributions and home ranges for July through November by which time the whales had moved southward through the Chukchi Sea to the Bering Strait region (Fig. 6). The six whales whose tags continued to transmit into late fall passed through Bering Strait in November–December then remained in the northern Bering Sea, between Bering Strait and St. Lawrence Island, into May (Fig. 3). One tag lasted long enough to re-enter the Chukchi Sea in late May and another stopped transmitting in early May, just south of Bering Strait (Citta et al., 2017).

Abundance and Trends

Bristol Bay

Aerial strip-transect surveys were conducted in Bristol Bay periodically during 1993–2005 (Lowry et al., 2008). Within each survey year, multiple flights covered the entire area where belugas have been observed during the survey period in late June and early July. Weather permitting, two surveys were conducted each day, both covering the entire summer range of this stock; only data from surveys with good viewing conditions were considered. Counts on individual flights during 1994–2005 ranged from 200–1,067, with annual averages of 362–623 (Fig. 7). Data from VHF transmitters attached to two BB belugas were used to estimate an availability correction factor of 2.75 (Frost et

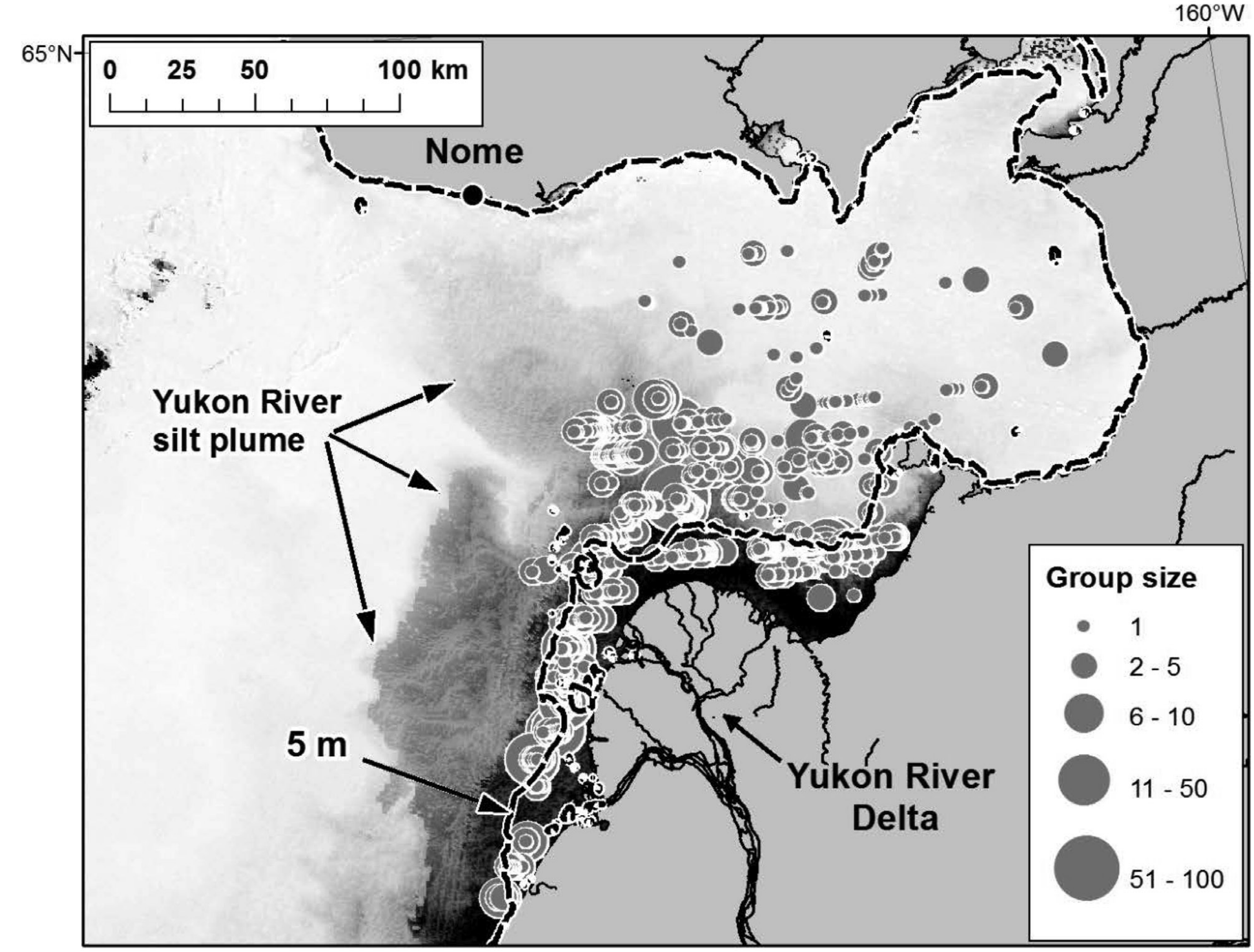

Figure 5.—MODIS image of Norton Sound and the Yukon River Delta taken from the Terra satellite on 17 June 2002. Dots are sightings of beluga whales made during aerial surveys 1995–2000. The dotted line indicates the 5 m isobath. The discharge plume of the Yukon River is darker where silt is more dense.

al., 1985), which was later revised to 2.62 (Frost and Lowry[16]). The estimate of abundance for the BB stock in the most current SAR is 1,926 (Muto et al., 2018) and was calculated by multiplying the average of counts from surveys in 2004 and 2005 (623) by the revised availability correction factor (2.62) and by a correction for the number of calves (1.18; Brodie, 1971), that are dark colored and difficult to see during surveys.

The ABWC conducted aerial surveys again in 2016 using the same methods as the 1993–2005 surveys (Citta et al., 2019). The average count from eight complete surveys of Bristol Bay in 2016 was 660 (coefficient of variation (CV) = 0.09; see Fig. 7). Using the corrections that have been applied in the past yields an estimated abundance of 2,040 (CV = 0.26) for 2016. The uncertainty in the correction factors has not been estimated; instead we have estimated the CV of the abundance estimate using the standard deviation of the counts divided by the average.

To further address the issues of abundance and correction factors, the ABWC and collaborators conducted a genetic mark-recapture study of the BB stock beginning in 2002. Estimates of abundance based upon mark-recapture methods are not reliant on estimating correction factors and provide an independent estimate of abundance. During 2002–11, the Alaska Department of Fish and Game (ADFG) worked with Alaska Native beluga hunters and collected skin samples using biopsy tips mounted on jab-sticks. Unique genotypes were determined by PCR amplification of mtDNA and eight microsatellite loci. Using a POPAN Jolly-

[16]Frost, K. J., and L. F. Lowry. 1995. Radio tag based correction factors for use in beluga whale population estimates. Working paper for Alaska, Beluga Whale Comm. Sci. Workshop, Anchorage, AK, 5–7 April 1995, 12 p. Avail. from North Slope Borough, Dep. of Wildlife Manage., Box 69, Barrow, AK 99723.

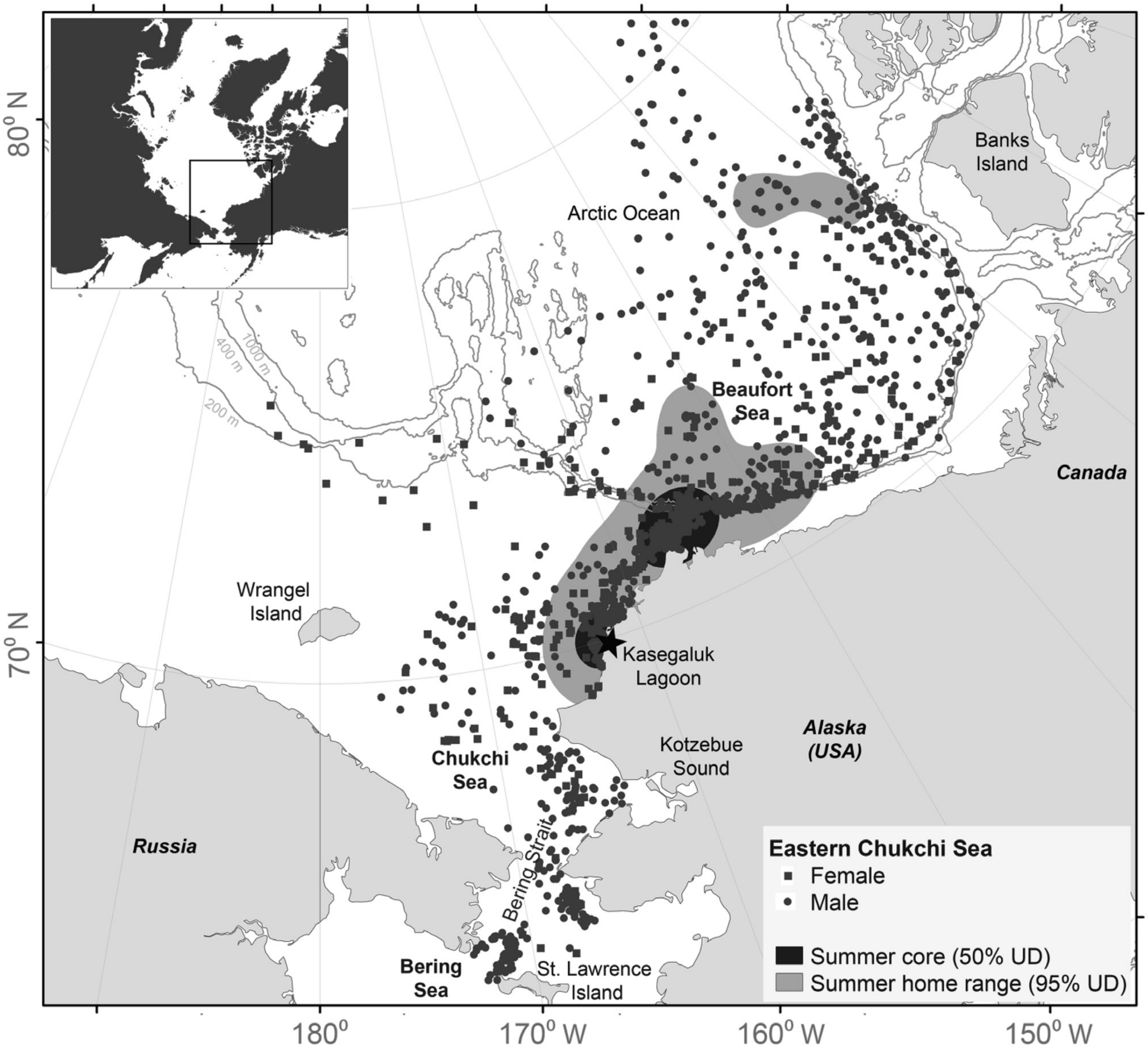

Figure 6.—Daily locations and home ranges of eastern Chukchi Sea belugas based on data collected during 1998–2012 from 29 whales equipped with satellite data recorders. Locations were collected during July–November; core and home ranges shown are for July and August, only. Modified from Hauser et al. (2014).

Seber model, abundance was estimated at 1,928 belugas (95% confidence interval (CI) = 1,611–2,337; Citta et al., 2018). Most belugas were sampled in Kvichak Bay at a time when belugas are also known to occur in Nushagak Bay. The pattern of genetic recaptures and data from belugas with SDR's indicated that belugas in the two bays regularly mix, suggesting the estimate of abundance likely applies to all Bristol Bay belugas. However, because it is likely that some belugas did not enter the sampling area during sampling, this estimate of abundance is best considered a minimum population size. Results from the genetic mark-recapture study are consistent with the estimate of 2,040 belugas from the 2016 aerial surveys.

A regression analysis of trend showed that the mean count of BB belugas increased 4.8% per year (95% confidence interval (CI) = 2.1–7.5%) over the 12-yr period, 1993–2005 (Lowry et al., 2008). The mean and range of counts made in 2016 is comparable to those in 2004–2005 (Fig. 7) suggesting that the population growth observed during 1993–2005 had slowed or ceased.

Eastern Bering Sea

To develop a population estimate for the EBS beluga stock, for which no directed efforts had ever been done,

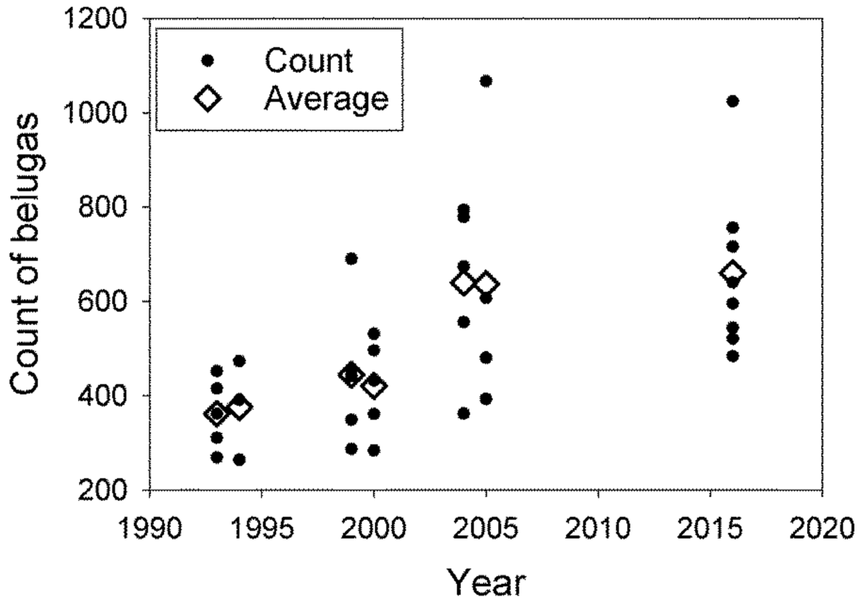

Figure 7.—Number of beluga whales observed during aerial surveys in Bristol Bay, 1993–2016. Black dots are the number of belugas counted during replicate flights and diamonds are the annual averages. For more information on aerial survey methods, see Lowry et al. (2008). The fit of linear versus other trends is statistically equivocal so we do not present a trend line here.

ABWC conducted aerial line-transect surveys in the Norton Sound/Yukon Delta region during 1993–95 (Lowry et al.[14]). These initial surveys provided distribution information and a preliminary abundance estimate that confirmed that the EBS stock was likely large (in the thousands) but the adequacy of survey coverage was questionable and confidence intervals of estimates were large. Additional line-transect surveys planned to cover all of Norton Sound and the Yukon Delta were flown in 1999 and 2000. Density and abundance were estimated from the 2000 survey, which had the most complete coverage of the area (Lowry et al., 2017a). In 2000, belugas were seldom seen in the northern portion of the Sound, thus the study area was restricted to the central and southern Sound and the northern and western Yukon Delta, and divided into four strata by latitude. The density estimated with the model that received most Akaike Information Criterion support was 0.121 belugas/km^2 and the number of belugas at the surface in the study area was estimated to be 3,497 (CV = 0.37). A generally accepted correction factor for availability of 2.0 (Reeves et al., 2011) was applied, resulting in an abundance estimate of 6,994 (95% CI = 3,162–15,472). In June 2017 NMFS conducted an aerial survey of this population following procedures similar to the 2000 survey (Fig. 8; Ferguson et al.[17]). Analysis of the survey data estimated a surface abundance of 4,621 belugas (CV=0.12, 95% CI =3,635–5,873); applying the multiplier of 2.0 to account for submerged whales yields an abundance estimate of 9,242 belugas (Ferguson et al.[17]). With only two population estimates 17 years apart, the current trend in abundance of the EBS stock is unknown; however, the two estimates are not significantly different, and we conclude that the population has not declined. These two estimates may be conservative because some belugas may have been outside the area surveyed (e.g., in the Yukon River) and the correction factor of 2.0 may be too low to account for the fraction of whales submerged in very turbid waters (Lowry et al., 2017a).

Eastern Chukchi Sea

An initial assessment of abundance of the ECS stock was made by using aerial photographs of belugas concentrated at Kasegaluk Lagoon passes to estimate that 2,282 belugas were present on 15 July 1979. The estimate included correction factors for whales outside the concentration area (+10%), whales too deep to be seen on the photographs (+20%), and dark colored yearlings that are difficult to see (+8%) (Seaman et al.[8]).

Subsequent aerial surveys were conducted in the 1980's and 1990's. On 8 July 1987, an aerial strip transect survey conducted over a large concentration of belugas near Point Lay counted 723 belugas; using correction factors of 2 or 3 to account for animals diving in relatively deep water it was estimated that there may have been 1,400–2,100 belugas in that group (Frost and Lowry, 1990). During 1989–91, aerial surveys of the concentration areas at Kasegaluk Lagoon resulted in single day counts ranging from 7 to 1,200 whales (Frost et al., 1993); offshore waters where belugas also occur were not surveyed. Correcting the 1,200 minimum count using VHF tag data from Bristol Bay for the proportion of belugas that were diving and thus not visible at the surface (2.62; Frost and Lowry[16]), and for the proportion of neonates and yearlings not seen due to small size and dark coloration (1.18; Brodie, 1971) produced a minimum abundance estimate of 3,710 belugas for the ECS stock. That estimate has been used in NOAA's SAR (Muto et al., 2016) and elsewhere (Laidre et al., 2015).

Surveys conducted during 1996–98 also found belugas farther offshore (Lowry et al.[18]), so subsequent efforts during 2001–03 included more off-

[17]Ferguson, M., K. Frost, A. Brower, A. Willoughby, C. Sims, and R. Suydam. 2018. Estimated abundance and distribution of eastern Bering Sea belugas from aerial surveys in 2017. 2018 Alaska Mar. Sci. Symp., Jan. 22–26, Anchorage, AK (Abstract only: avail. at https://www.alaskamarinescience.org/past-symposia/).

[18]Lowry, L. F., D. P. DeMaster, K. J. Frost, and W. Perryman. 1999. Alaska Beluga Whale Committee surveys of beluga whales in the eastern Chukchi Sea, 1996–1998. Rep. Int. Whal. Comm. SC/51/SM 33.

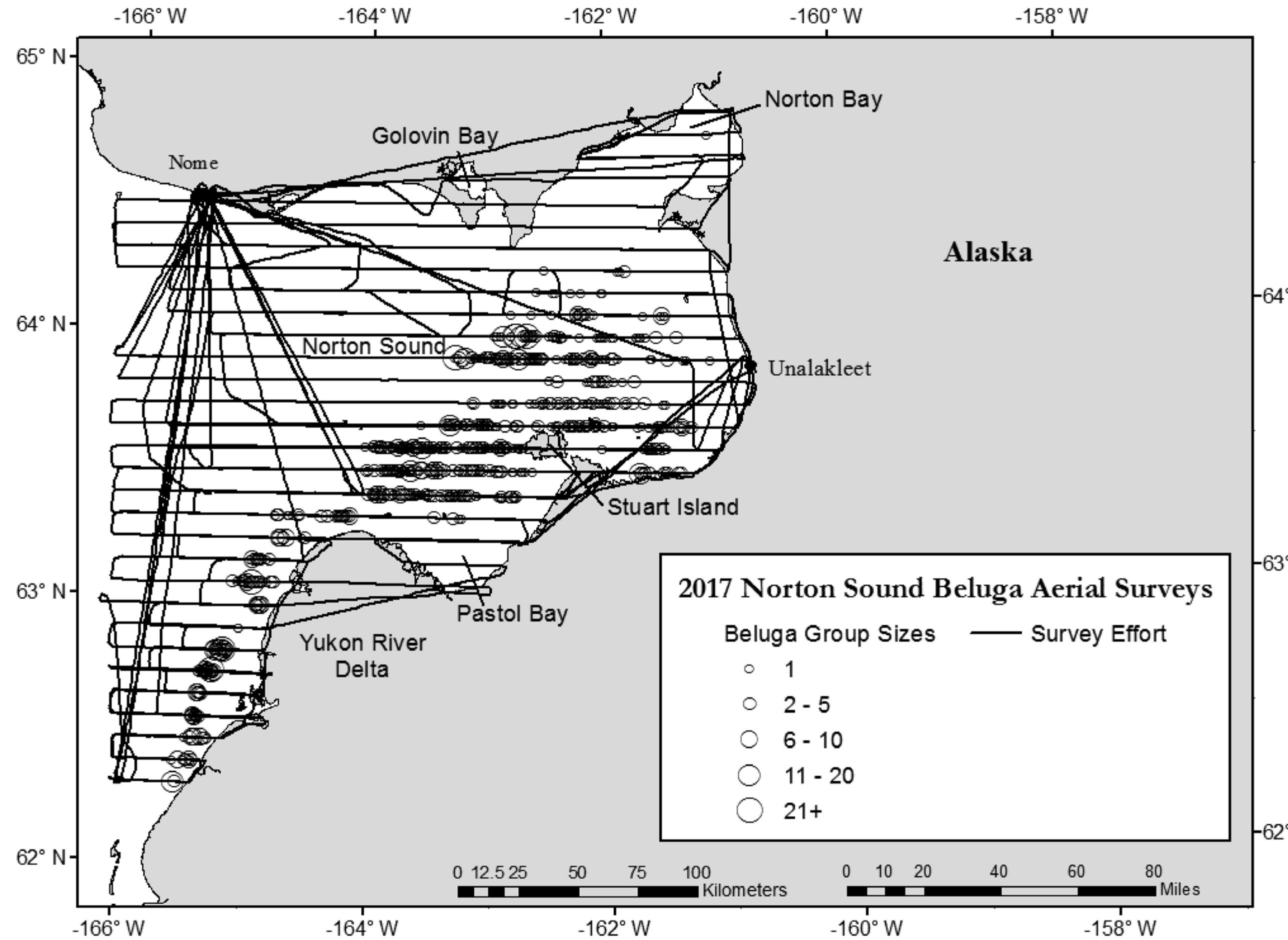

Figure 8.—Transects flown, strata used in the analysis, and beluga sightings made during NMFS beluga surveys in the eastern Bering Sea, June 2017.

shore flight lines. While belugas were occasionally sighted >50 km offshore, sightings were infrequent (Lowry and Frost[19,20]). Locations from whales tagged with SDR's at Kasegaluk Lagoon showed that many were beyond the limits of the area surveyed (Suydam et al., 2001). Aerial surveys for the ECS stock were suspended by the ABWC after 2003 due to the high cost relative to the low value of results for assessing abundance.

[19]Lowry, L., and K. Frost. 2002. Beluga whale surveys in the Chukchi Sea, July 2002. Alaska Beluga Whale Comm., Rep. 02-2. Avail. from North Slope Borough, Dep. Wildl. Manage., Box 69, Barrow, AK 99723.

[20]Lowry, L. F., and K. J. Frost. 2003. Beluga whale surveys in the eastern Chukchi Sea, July 2003. AK Beluga Whale Comm. Rep. 03-1. Avail. from North Slope Borough, Dep. Wildl. Manage., Box 69, Barrow, AK 99723.

A different approach was clearly needed for estimating abundance of the ECS stock. An analysis of the SDR location data from belugas belonging to the ECS and Beaufort Sea stocks (Hauser et al., 2014) identified an area in the Beaufort Sea (long. 140° W to 157° W) and a period (19 July–20 August) when the two stocks did not overlap (Lowry et al., 2017b). In 2012, an aerial line-transect survey was conducted in that area during that period by the Aerial Surveys of Arctic Marine Mammals (ASAMM) project (Clarke et al.[21]) (Fig. 9). Analysis of those data estimated 5,547 (CV = 0.22) surface-visible belugas. SDR data were used to develop correction factors to account for animals that were missed because they were outside of the study area and those diving too deep to be seen, resulting in a total abundance estimate of 20,752 (CV = 0.70) (Lowry et al., 2017b). Additional surveys were conducted in 2013–16 and a full analysis of ECS beluga abundance using all available ASAMM data is underway.

[21]Clarke, J. T., C. L. Christman, A. A. Brower, and M. C. Ferguson. 2013. Distribution and relative abundance of marine mammals in the northeastern Chukchi and western Beaufort Seas, 2012. U.S. Bur. Ocean Energy Manage., Annu. Rep. OCS-BOEM-2013-00117.

Anthropogenic Removals

Subsistence Harvest

The ABWC, through its hunter delegates and collaborators, primarily the Bristol Bay Native Association and the North Slope Borough Department

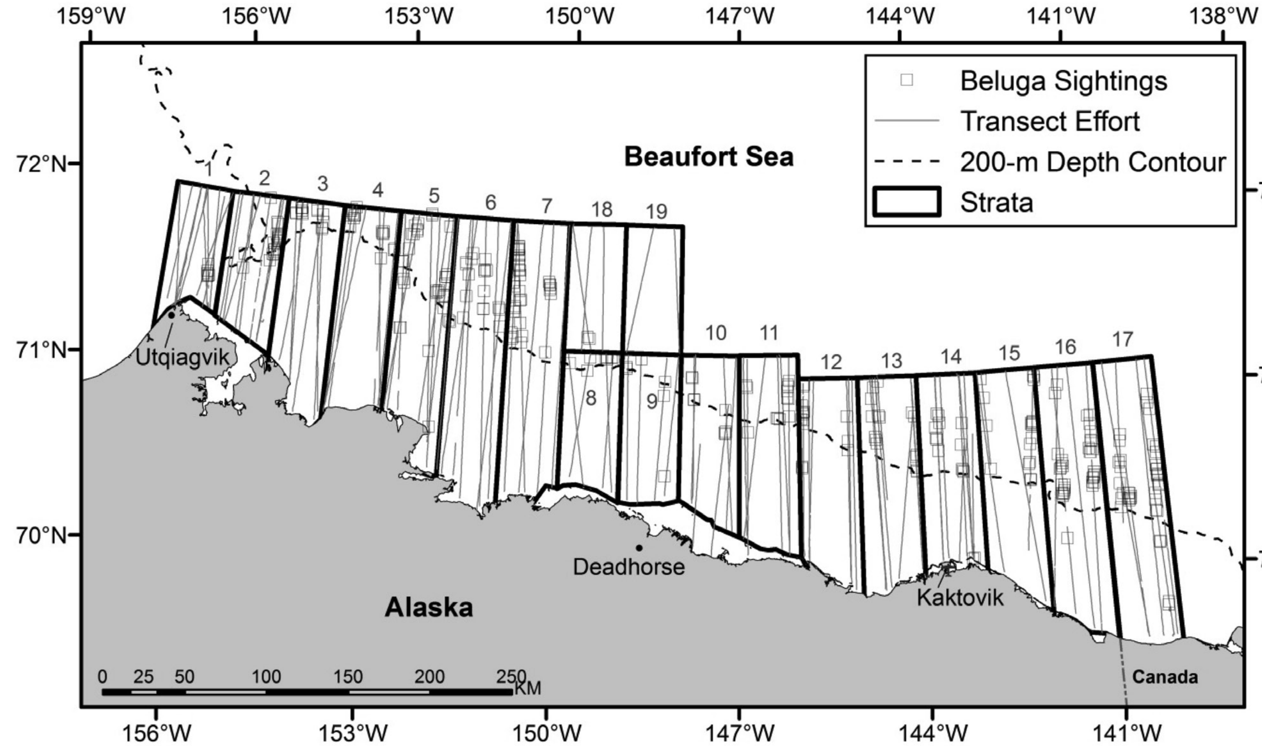

Figure 9.—Aerial surveys of Arctic marine mammals transect lines and sightings of eastern Chukchi Sea belugas in the Alaska Beaufort Sea during July–August 2012 (Lowry et al., 2017b).

of Wildlife Management, has collected data on Alaska Native subsistence harvests since 1987. Twelve villages harvested belugas in Bristol Bay in at least one year since 1987 (Table 1). During 1987–2006, the reported number of belugas landed each year by these villages combined averaged 17 (95% CI = 14–20, range 6–35; Fig. 10a). During 2007–16, the reported number of belugas landed each year by these villages combined averaged 23 (95% CI = 21–25, range 19–28; Fig. 10b). Reporting of belugas struck and lost in the Bristol Bay region is incomplete and total removals could be somewhat higher (Frost and Suydam, 2010; ABWC[22]). Although regression lines for both periods show a slight increasing trend, neither is statistically significant (p = 0.64 and 0.61).

Table 1.—Alaska communities that reported harvesting belugas from the Bristol Bay, eastern Bering Sea, or eastern Chukchi Sea beluga whale stocks in at least one year during 1987–2016.

Bristol Bay	Eastern Bering Sea		Eastern Chukchi Sea
	Norton Sound	Yukon River	
Aleknagek	Elim	Alakanuk	Point Lay
Clark's Point	Golovin	Chevak	Wainwright
Dillingham	Koyuk	Emmonak	
Egegik	Nome/Council	Hooper Bay	
Igiugig	Saint Michael	Kotlik	
Iliamna	Shaktoolik	Marshall	
Levelock	Stebbins	Mountain Village	
Manokotak	Unalakleet	Nunam Iqua	
Naknek	White Mountain	Pitka's Point	
Newhalen		Pilot Station	
New Stuyahok		Russian Mission	
Togiak		Saint Mary's	
		Scammon Bay	

Twenty-two villages report harvesting belugas from the EBS stock, 9 from Norton Sound and 13 from the Yukon Delta (Table 1). The average annual reported harvest for 1987–2006 was 152 belugas (95% CI = 123–181, range 31–281; Fig. 11a). During 2007–16, the average annual reported harvest was 191 belugas (95% CI = 171–211, range 126–236; Fig. 11b). The average annual reported harvest increased approximately 25% from 1987–2006 to 2007–16. Although this increase is statistically significant (p = 0.04), it is mostly due to better data being collected from more villages rather than more belugas being harvested (ABWC[22]). When the ABWC began meeting in 1988, there were two delegates representing Norton Sound

[22]Alaska Beluga Whale Committee (ABWC). Unpubl. data avail. from the North Slope Borough, Dep. Wildl. Manage., Box 69, Barrow, AK 99723.

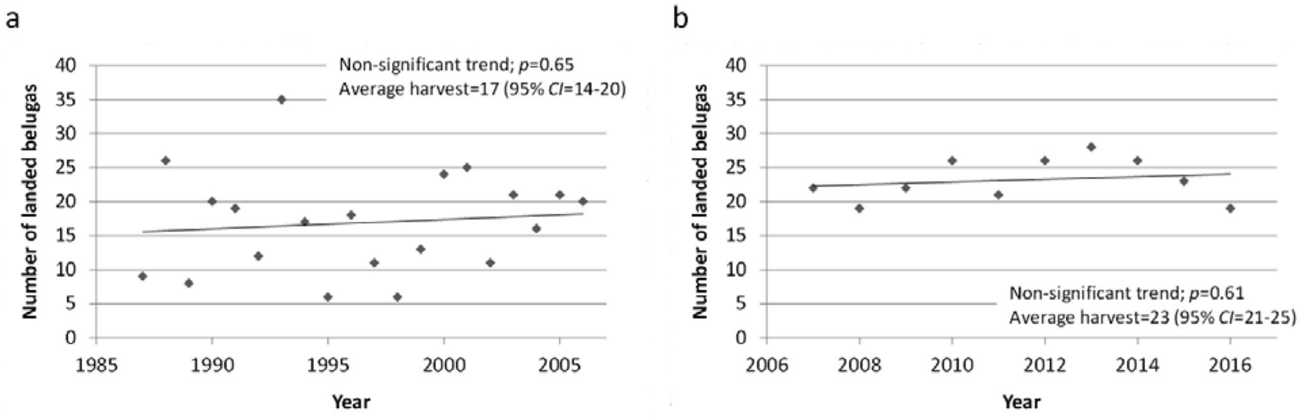

Figure 10.—(a) Number and trend of Bristol Bay belugas landed by subsistence hunters in Alaska during 1987–2006, and (b) during 2007–16). For more information on how harvest is documented see Frost and Suydam (2010).

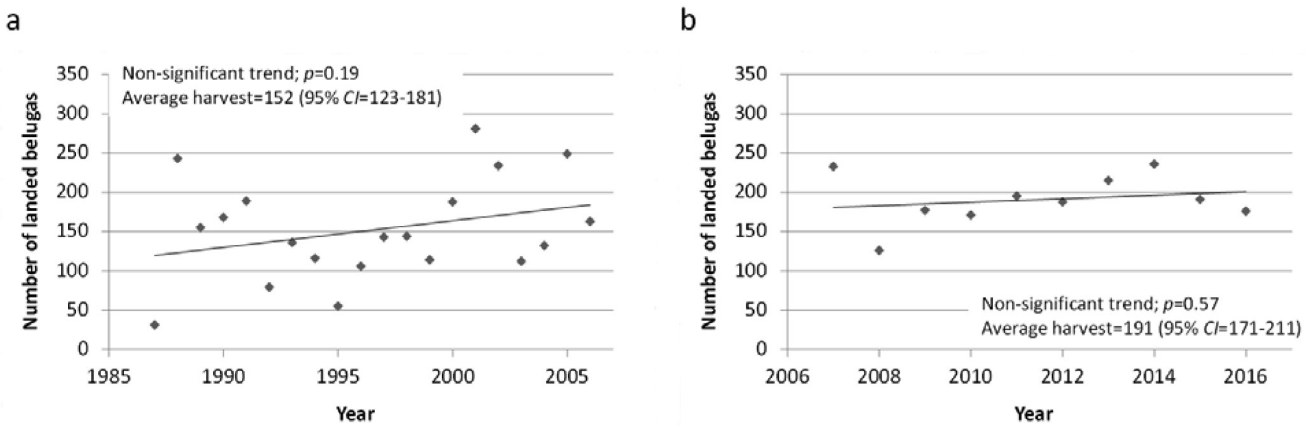

Figure 11.—(a) Number and trend of eastern Bering Sea belugas landed by subsistence hunters in Alaska during 1987–2006, and (b) during 2007–16. For more information on how harvest is documented see Frost and Suydam (2010).

and the Yukon Delta. Ten years later there were 10, and currently there are 15 communities represented by delegates who attend meetings and report harvest data for their own and nearby villages. Intermittent struck and lost data are available for the EBS stock for 17 villages during the last 5 years. During those years, the number of belugas reported to be struck and lost averaged 13% of the landed but this is based on incomplete data (ABWC[22]).

Harvest of belugas from the ECS stock occurs mainly at the villages of Point Lay and Wainwright. The average annual reported harvest for 1987–2006 was 48 belugas (95% CI = 37–59, range 0–86; Fig. 12a). During 2007–16, the average annual harvest was 57 belugas (95% CI = 38–76, range 14–121, Fig. 12b). The slight positive trend for 1987–2006 is not statistically significant (p = 0.93). The apparent strong negative trend for 2007–16 is not statistically significant either (p = 0.15) because of substantial annual variations in harvest. Both Point Lay and Wainwright usually conduct drive hunts, and typically only one or two whales at most are struck and lost during those hunts (ABWC[22]).

Fishery Bycatch

In the United States, commercial fisheries operating in federal waters (3–200 nmi. offshore) that may take marine mammals as bycatch are regularly monitored. Fishery observers have monitored the groundfish trawl, longline, and pot fisheries off western Alaska and during 2011–15 only one beluga mortality was reported (Muto et al., 2018).

During the Bristol Bay sockeye salmon fishery (managed by the State of Alaska) in late June and early July, belugas are observed swimming near fishing operations, suggesting they could be caught in the salmon set gillnet and drift gillnet fisheries that occur in the inner bays. During May–July 1983, Frost et al.[12] conducted beach surveys in the inner bays from airplanes and boats and found 27 dead belugas, at least 12 of which were attributed to bycatch in nets. The commercial gillnet fisheries have never been monitored for

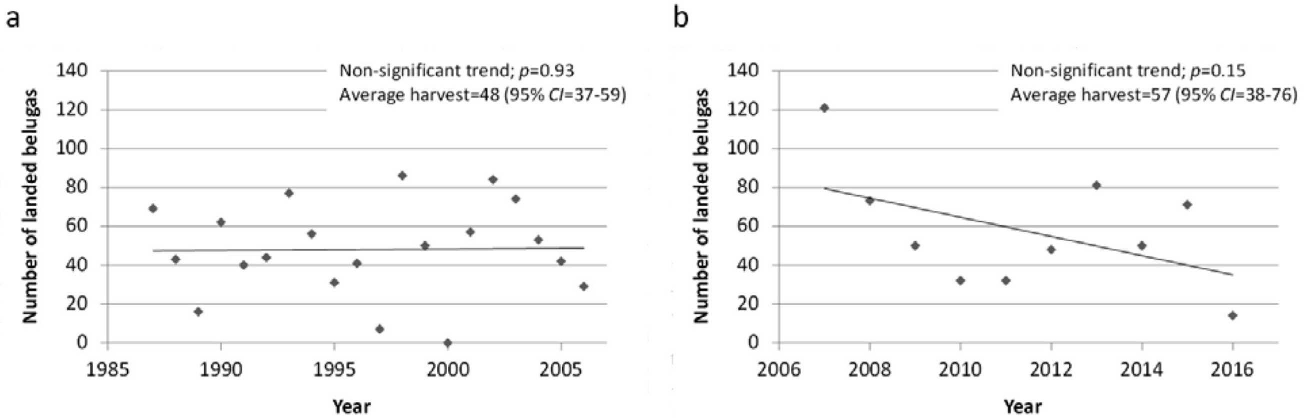

Figure 12.—(a) Number and trend of eastern Chukchi Sea belugas landed by subsistence hunters in Alaska during 1987–2006, and (b) during 2007–16. For more information on how harvest is documented see Frost and Suydam (2010).

bycatch and there are no current data on incidental take. There is also a large subsistence gillnet fishery for salmon in Bristol Bay in which four belugas were reported taken during 2013–14 (Muto et al., 2018). Three of those takes were reported as subsistence harvest as they were used for subsistence purposes by Alaska Natives.

State-managed commercial, personal use, and subsistence gillnet fisheries for salmon or whitefish, *Coregonus* spp., occur in nearshore waters in the range of the EBS and ECS stocks. Although these fisheries are a potential source of bycatch mortality and bycatch is not systematically monitored, it is likely that only a few whales are taken each year (ABWC and NSBDWM[22]).

Stock Status

None of the western Alaska beluga stocks are designated as “depleted” or “strategic” under the U.S. Marine Mammal Protection Act (MMPA), nor are they listed as “threatened” or “endangered” under the U.S. Endangered Species Act (Muto et al., 2018). In an assessment done in 2008, the International Union for the Conservation of Nature listed belugas as a species “Near Threatened” and also noted that the various subpopulations should be assessed separately (Jefferson et al.[23]). A revised assessment published on the IUCN Red List in 2017 listed the species as “Least Concern” (Lowry et al.[24]).

Under the 1994 reauthorization of the MMPA, the PBR for a stock is defined as the product of the minimum population estimate, one-half the maximum theoretical net productivity rate, and a recovery factor: PBR = $N_{MIN} \times 0.5R_{MAX} \times F_R$ (Wade and Angliss, 1997). N_{MIN} is the lower 20th percentile of a log-normal distribution that represents the minimum number of whales after accounting for uncertainty in the estimates. F_R is equal to 1.0 when a population is stable or increasing and can be adjusted lower for declining trends or high uncertainty. Although the system was designed only to evaluate fishery bycatch, PBR can be compared to all anthropogenic removals as a conservative measure of the sustainability of those removals.

The only data on maximum net productivity for belugas comes from the BB stock where the estimated rate of increase over the 12-yr period 1992–2005 was 4.8%/yr (Lowry et al., 2008), but that may not be the maximum rate because subsistence harvest was occurring during that period. The measured value for the BB stock is close to the 4%/yr that is used in the NOAA SAR as the default maximum net productivity rate for cetaceans (Wade, 1998), and we use the value of 4.8%/yr in the calculations below.

Bristol Bay

Based on 2004–05 average counts from aerial surveys, Muto et al. (2018) estimated the minimum population size for the BB stock as 1,565 belugas using a CV of 0.25. They did not estimate PBR because the abundance data were more than 8 years old. Using the rate of increase of 4.8%/yr (Lowry et al., 2008) as an estimate of R_{MAX}, we calculated PBR using both the 2016 aerial surveys and the mark-recapture estimate of Citta et al. (2018). For the 2016 aerial surveys, N_{BEST} = 2,040; CV = 0.26; N_{MIN} = 1,645, R_{MAX} = 0.048; F_R = 1.0; PBR = 39. For the mark-recapture estimate, which covers the period 2002–2011, N_{BEST} = 1,928; CV = 0.1; N_{MIN} = 1,773, R_{MAX} = 0.048; F_R = 1.0; PBR = 43. The current average annual subsistence harvest of 23 belugas is approximately 59% of PBR calculated from the 2016 survey data and 53% of PBR as calculated from the mark-recapture study. Some bycatch in fisheries is known to occur (Muto et al., 2018); howev-

[23]Jefferson, T. A., L. Karkzmarski, K. Laidre, G. O’Corry-Crowe, R. Reeves, L. Rojas-Bracho, E. Secchi, E. Slooten, B. D. Smith, J. Y. Wang, and K. Zhou. 2012. *Delphinapterus leucas*. The IUCN Red List of Threatened Species 2012: e.T6335A17690692 (avail. at https://doi.org/10.2305/IUCN.UK.2012.RLTS.T6335A17690692.en). Downloaded on 03 Feb. 2017.

[24]Lowry, L., R. Reeves, and K. Laidre. 2017. *Delphinapterus leucas.* The IUCN Red List of Threatened Species 2017: e.T6335A50352346 (doi: https://doi.org/10.2305/IUCN.UK.2017-3.RLTS.T6335A50352346.en).

er, bycatch has likely been too small for total removals to exceed PBR because this stock has been increasing or stable.

Eastern Bering Sea

In the 2017 SAR, the PBR for the EBS stock was considered to be “undetermined” because the most current abundance estimate was more than 8 years old (Muto et al., 2018). However with the 2017 abundance estimate of 9,242 (CV = 0.12) (Ferguson et al.[17]), PBR can be calculated as follows: N_{BEST} = 9,242; CV = 0.12; N_{MIN} = 8,357, R_{MAX} = 0.048; F_R = 1.0; PBR = 201. It should be noted that this estimate includes an arbitrary correction factor for missed animals of 2.0 that has no associated CV. The average annual subsistence removal for the past 10 years (191) is below this calculated PBR; if struck and lost is considered, total annual removals would be 215, or 7% above PBR. However, the abundance estimate is thought to be low because the survey did not include all potential beluga habitat (e.g., the Yukon River itself), dark gray animals (calves) were particularly hard to see in muddy water coming from the Yukon, and the analysis did not account for all aspects of perception bias. Regardless of the uncertainty in the estimate of abundance and PBR, that the harvest is approximately equal to PBR is of concern and the ABWC requested that NOAA conduct line-transect surveys on a regular basis. Although coastal fisheries are not regularly monitored for incidental take of belugas, all indications are that takes of belugas from this stock are very infrequent (Muto et al., 2018).

Eastern Chukchi Sea

In the 2017 SAR (Muto et al., 2018), data provided in Lowry et al. (2017b) were used to estimate PBR for the ECS stock as follows: N_{BEST} = 20,752; CV = 0.70; N_{MIN} = 12,194, R_{MAX} = 0.04; F_R = 1.0; PBR = 244. Using R_{MAX} = 0.048 we estimate PBR as 293. The average annual Alaska Native subsistence harvest from the ECS stock for the last 10 years (57 belugas) is about 19% of PBR. Although coastal fisheries are not regularly monitored for incidental take of belugas, all indications are that such takes are very infrequent and therefore anthropogenic removals from the ECS beluga stock are sustainable.

Threats

Sea Ice and Climate Warming

Because belugas are an ice-associated species, there is concern about possible impacts of climate warming and associated loss of sea ice habitat. Laidre et al. (2015) analyzed remotely sensed sea ice data and found little change in the duration of the reduced ice (summer) period in the Bering Sea from 1979 to 2013. In contrast, they found that the duration of the reduced ice period increased by 44 days in the Chukchi Sea and 52 days in the Beaufort Sea over the same period. These data suggest that ECS belugas are more susceptible to possible impacts of sea ice change, while EBS and BB belugas may be less at risk. However, we note that ABWC members who live and hunt in these regions report that Bering Sea ice has formed later, melted earlier, and not been as thick as in previous decades. They also report that, since 2013, some areas have remained ice free through the winter and in other areas there has been extremely rapid retreat of ice in the spring (ABWC[22]).

Belugas do not occur in regions without at least seasonal sea ice suggesting a strong, if not obligate, connection. However, some subpopulations spend many months far from ice while others spend most of their time in or near ice of concentrations up to 90%, indicating substantial flexibility in the species as a whole (Hauser et al., 2017). Belugas that occupy ice covered areas may do so for feeding on abundant ice-associated species, such as arctic cod, *Boreogadus saida* (Loseto et al., 2009; Hauser et al., 2015). Changes in the distribution and characteristics of sea ice will result in changes in productivity and in the types and abundance of prey species (Laidre et al., 2008; Haug et al., 2017), but the potential costs or benefits to belugas of such changes are not known. Killer whales, *Orcinus orca*, prey on belugas (Frost et al., 1992) and concentrated sea ice may provide belugas some degree of refuge from predation. There is good evidence that killer whales are expanding into Arctic regions where sea ice has been declining (Higdon and Ferguson, 2009; Ferguson et al., 2010). Belugas are susceptible to entrapment in sea ice when conditions change rapidly and, if they cannot escape, they may die or be preyed upon by polar bears, *Ursus maritimus*, and humans (Lowry et al., 1987; Heide-Jørgensen et al., 2002, 2013; Laidre and Heide-Jørgensen, 2005).

There have been three studies that specifically address the potential influence of changes in ice conditions on western Alaska belugas. O’Corry-Crowe et al. (2016) analyzed long-term sighting and genetic data on belugas in the Bering, Chukchi, and Beaufort seas in conjunction with multi-decadal patterns of sea ice to investigate the influence of sea ice on spring migration and summer residency patterns. Although substantial variations in sea ice conditions were found across seasons, years, and sub-regions, the pattern of beluga migration and residency was quite consistent. Those results suggest that belugas can accommodate some changes to sea ice conditions and will return to traditionally used areas. However, they also observed anomalous movement patterns that coincided with years with anomalously low sea ice coverage, and in one case with an increase in killer whale sightings and predation on belugas, indicating that behavioral shifts may be driven by changing sea-ice and associated changes in resource dispersion and predation risk. Hauser et al. (2016) compared the timing of the autumn migration of ECS and Beaufort Sea belugas during the periods 1993–2002 and 2004–12. They found that, in the later period, ECS beluga migration during autumn from the Beaufort and Chukchi seas was delayed by 2 to > 4 weeks, but that Beaufort Sea belugas did not shift migration timing between periods. Hauser et al. (2018) applied resource selection models to movements of ECS and Beaufort Sea belugas during 1990–2014 and found that, although sea ice has declined, belugas are generally found in the same locations and speculated that bathymetric features were better predictors of summer habitat use than sea ice concentration. Hauser et al. (2018) also found that ECS belugas were making longer, deeper dives in recent years and speculated that this might be due to changes in sea ice concentration.

A long-term study of belugas off West Greenland found that belugas responded to changing sea ice by shifting their distribution and that abundance increased during a period of generally declining ice cover (Heide-Jørgensen et al., 2010). The authors concluded that "Global warming and sea-ice declines may pose less of a problem for belugas than to other Arctic marine mammals." Laidre et al. (2008) also concluded that, on a range-wide basis, the beluga would be the Arctic cetacean least sensitive to climate change because of their wide distribution, diverse diet, and flexible habits.

It is possible that climate warming may have effects on belugas beyond those linked to changes in sea ice. Specific annual summering areas likely have particularly suitable environmental conditions such as water temperature and substrate. Those areas may be important for feeding, molting, calving, and avoidance of killer whales (Frost and Lowry, 1990; Laidre et al., 2008). Little attention has been given to measuring the specific features of these areas or projecting how those features may change with climate warming. Warmer water may allow the expansion of new prey species into the belugas' range or cause traditionally used prey to move elsewhere. Although some beluga stocks may focus on certain prey, such as Arctic cod or Pacific salmon, belugas are capable of consuming a wide variety of prey and are best classified as generalist predators. In their examination of stomach contents from harvested belugas, Quakenbush et al. (2015) found a minimum of 14 species of fish and invertebrates from BB belugas, 22 species from EBS belugas, and 15 species from ECS belugas. Belugas clearly show flexibility and adaptive capacity making it particularly difficult to predict how they will be affected by climate change.

Fishery Interactions

No incidental mortalities or injuries to belugas were reported by fishery observers that monitored the groundfish trawl, longline, and pot fisheries off western Alaska during 1990–97 (Muto et al., 2016) and only one was reported during 2011–2015 (Muto et al., 2018). Other observations show that belugas have been caught in commercial and subsistence salmon fisheries that occur along the coast, but overall there are no reliable data on incidental take. Although beluga mortalities due to fisheries occur in Bristol Bay, they did not prevent population growth between 1993 and 2005 (Lowry et al., 2008). We suspect that unless there is a major change in how or where commercial gillnet fisheries occur, these fisheries will not be a threat to the long-term sustainability of belugas. Nevertheless, monitoring levels of bycatch in commercial and subsistence gillnet fisheries is warranted.

In Bristol Bay, belugas feed on salmon when they are available. They feed both on smolt migrating out of river systems and on adults returning to the rivers to spawn (Brooks et al.[1]). Because salmon runs were severely depressed in Bristol Bay in the 1950's, an effort was made to deter belugas from river mouths by playing underwater sounds recorded from killer whales (Fish and Vania, 1971). Efficacy of this effort was equivocal, and the "beluga spooker" program ended after 1978. In the early 1980's after salmon runs had largely recovered, Frost et al.[12] conducted additional studies in Bristol Bay and concluded that beluga predation was equal to less than 1% of the commercial catch of adult sockeye salmon and less than 5% of the smolt outmigration.

Belugas that summer in the Yukon Delta region also feed on Pacific salmon. This is a large stock of whales that may consume a substantial portion of some Yukon River salmon runs, thereby potentially impacting catches in commercial and subsistence fisheries and the trophic structure of the ecosystem (Lowry et al., 2017a).

Industrial Activities

An increase in the duration of the open water season and the decline in multi-year sea ice have generated concern that increases in oil and gas exploration and development, and shipping may have negative consequences for belugas (Reeves et al., 2014). Most oil and gas activity within the range of western Alaska belugas currently occurs over the continental shelf in the Beaufort Sea, although from 2006 to 2015 there was also considerable activity in the Chukchi Sea. In the Beaufort Sea, the distribution of ECS belugas is predominantly limited to offshore areas, near the continental shelf break and in the Arctic Basin. At present, oil and gas activity in the Alaska portion of the Beaufort Sea is far inshore of where belugas typically range (Suydam et al.[25]). In 2016, most of Bristol Bay and the U.S. portion of the Chukchi Sea were removed from future leasing by Presidential order, but that order was rescinded in 2018. Also, there are still active oil and gas lease areas in Alaska's Beaufort Sea and in the Russian portion of the Chukchi Sea, so impacts from oil spills and shipping activity are still possible in those areas.

Although shipping is increasing with declining sea ice (Eguíluz et al., 2016; Pizzolato et al., 2016), belugas are not known to be susceptible to ship strikes, even in congested areas such as the St. Lawrence River (King-

[25]Suydam, R. S., L. F. Lowry, and K. J. Frost. 2005. Distribution and movements of beluga whales from the eastern Chukchi Sea stock during summer and early autumn. Final report to Coastal Marine Institute, Univ. Alaska, Fairbanks, AK, 39 p.

sley, 2002). Furthermore, factors in addition to sea ice, such as where resources are being developed and commodity pricing, determine shipping trends (Brigham, 2011; Bensassi et al., 2016; Pizzolato et al., 2016). As such, predicting how patterns in shipping will change is difficult, as is how belugas will respond to those changes.

Impacts to belugas in the far north from noise associated with shipping, including icebreaking (e.g., Finley et al., 1990), or other industrial activities, may be more of a concern than ship strikes. Studies suggest that belugas may avoid sources of noise (e.g., Finley et al., 1990) or change their behavior in response to noise, by increasing swim speed, making longer dives, or foraging less (e.g., Blane and Jaakson, 1994; Kendall and Cornick, 2015). However, other studies suggest that belugas may habituate to anthropogenic noise or fishing boats (e.g., Fish and Vania, 1971). The population-level impacts of noise and shipping are poorly understood and what these studies, conducted in places such as Cook Inlet (Kendall and Cornick, 2015) or the St. Lawrence Estuary (Blane and Jaakson, 1994), may mean for belugas in Arctic shipping lanes is unclear. Dedicated studies are needed to investigate how belugas will respond to anthropogenic noise in Arctic shipping lanes.

There are currently two proposed mines in southwestern Alaska that have the potential to affect beluga habitat. A large copper, gold, and molybdenum mine, known as the Pebble Mine, is proposed for the headwaters of the Nushagak and Kvichak rivers, which flow into bays that are the primary summer habitat of the BB beluga stock. This mine would process ore using a cyanide solution and would produce effluents that would be toxic to fish and other organisms if leaked into the river systems. The Final Environmental Impact Statement is due to be released by the Army Corp of Engineers in summer 2020. The other notable mine, the Donlin Mine, is in the Kuskokwim River drainage and poses similar risks to fisheries. Although Kuskokwim Bay does not contain the primary summer range of any beluga stock, EBS belugas are known to frequent the area in winter. The Donlin Mine has been granted federal permits but is still acquiring state permits.

Conclusions

The BB beluga stock is relatively small (approximately 2,000 animals), but its abundance and trend are periodically monitored and the stock appears to have increased between 1993 and 2005, and may now be stable. The most conservative estimate of PBR for this stock (39) is more than the average annual Alaska Native subsistence harvest over the last decade (23). Although there is little information regarding incidental take or struck and lost rates, the population has increased in recent decades, suggesting that all sources of mortality have not been significant (Lowry et al., 2008).

The EBS beluga stock is quite large, and aggregates off the mouths of the Yukon River and in Norton Sound every June. The most recent abundance estimate of over 9,000 is based on data collected in 2017 and relies on an arbitrary correction factor to account for availability bias. Additional work (e.g., SDR tagging) is needed to develop better correction factors. The average annual reported subsistence harvest (191) does not exceed PBR calculated from this abundance estimate (201) however when struck and lost estimates are included it does. While available scientific data do not allow an estimation of population trend, local and traditional knowledge indicate that there has not been a noticeable decrease in abundance or availability of EBS belugas in recent years (ABWC[22]).

The ECS beluga stock is large, estimated as approximately 20,000 belugas (Lowry et al., 2017b). The average annual subsistence harvest (57) is well below PBR (293). ECS belugas are not at immediate risk from anthropogenic activities or climate change, however, additional monitoring of population size and trend, subsistence harvest, and health of belugas is warranted.

There are currently few identified threats to persistence of western Alaska beluga stocks, although climate warming, declines in sea ice, and industrial activities related to resource development are of concern and could pose challenges in the future.

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