STATUS REVIEW FOR THE BRISTOL BAY BELUGA WHALE STOCK
for the NAMMCO Global Review of Monodontids
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1. Distribution and stock identity

Belugas of the Bristol Bay stock are typically found in Nushagak and Kvichak bays and tributaries during the summer and range widely in the northern and eastern region of Bristol Bay in the winter (Fig. 1). The Bristol Bay stock of beluga whales is probably the most studied beluga stock in Alaskan waters. This is largely because Bristol Bay contains the largest commercial sockeye salmon (*Oncorhynchus nerka*) fishery in the world (Jones *et al.* 2013). Studies of belugas in Bristol Bay began in the 1950s because there was concern that they were consuming too many smolt and limiting salmon populations (e.g., Brooks 1955, Lensink 1961, Fish and Vania 1972). Since then, researchers have studied the diet (e.g., Brooks 1955, Lowry *et al.* 1988, Quakenbush *et al.* 2015), distribution (e.g., Frost *et al.* 1984, 1985; Frost and Lowry 1990, Lowry *et al*. 2008, Citta *et al.* 2016, 2017), abundance (e.g., Frost and Lowry 1990, Lowry *et al.* 2008), behavior (e.g., Frost *et al.* 1985), health (e.g., Norman *et al.* 2012, Cornick *et al.* 2016), and subsistence harvest (Frost and Suydam 2010) of belugas in Bristol Bay.

Satellite telemetry studies indicate that Bristol Bay belugas remain in the greater Bristol Bay region throughout the year (e.g., Citta *et al.* 2016, 2017). In spring and summer (Fig. 2a and 2b), their distribution is largely restricted to Nushagak and Kvichak bays (Frost *et al.* 1984, 1985, Lowry *et al.* 2008, Citta *et al.* 2016), which are in northeastern Bristol Bay. Here, belugas are known to feed on a variety of fish, including salmonids, and invertebrates (e.g., Brooks 1955, Lowry *et al.* 1986). After the salmon runs end in late summer, their distribution widens, but is still contained mostly within Nushagak and Kvichak bays (Fig. 2c; Citta *et al.* 2016). In winter, Bristol Bay belugas range into outer Bristol Bay, frequenting the inner bays less often, perhaps because they are covered in ice and pose a risk of entrapment or because there are few prey available there. However, even in winter, Bristol Bay belugas tagged with satellite depth recorders (SDRs) have not passed west of Cape Newenham (Fig. 2d; Citta *et al.* 2016). The nearest stock of belugas is the Eastern Bering Sea stock; the ranges of these two stocks overlap in winter, at least in space if not time (Fig. 3). Belugas from both the Bristol Bay and Eastern Bering Sea stocks were tagged with SDRs in 2013. Although a beluga from the Eastern Bering Sea stock moved into the range of Bristol Bay belugas in January 2013, this occurred when Bristol Bay belugas were within the inner bays and there was no evidence that the two populations were in the same place at the same time (Citta *et al.* 2017).

Studies examining patterns in mitochondrial DNA (mtDNA) support the idea that Bristol Bay belugas are distinct from other stocks that summer and winter in the Bering Sea (O'Corry-Crowe *et al*. 1997, 2002; Muto *et al*. 2016). More recent analyses of nuclear DNA (microsatellite) variation have found a lower but still discernable level of differentiation compared to mtDNA, indicating that there is only limited exchange among beluga stocks in the Bering Sea (O'Corry-Crowe *et. al*. in prep).

Furthermore, the Bristol Bay stock is a single stock and is not composed of distinct sub-populations within Bristol Bay. Satellite tagging studies show that belugas commonly move between their summer concentration areas in Nushagak and Kvichak bays (Citta *et al.* 2016) and a comparison of mtDNA from whales in Nushagak and Kvichak bays found no genetic differentiation (O'Corry-Crowe, unpublished data).

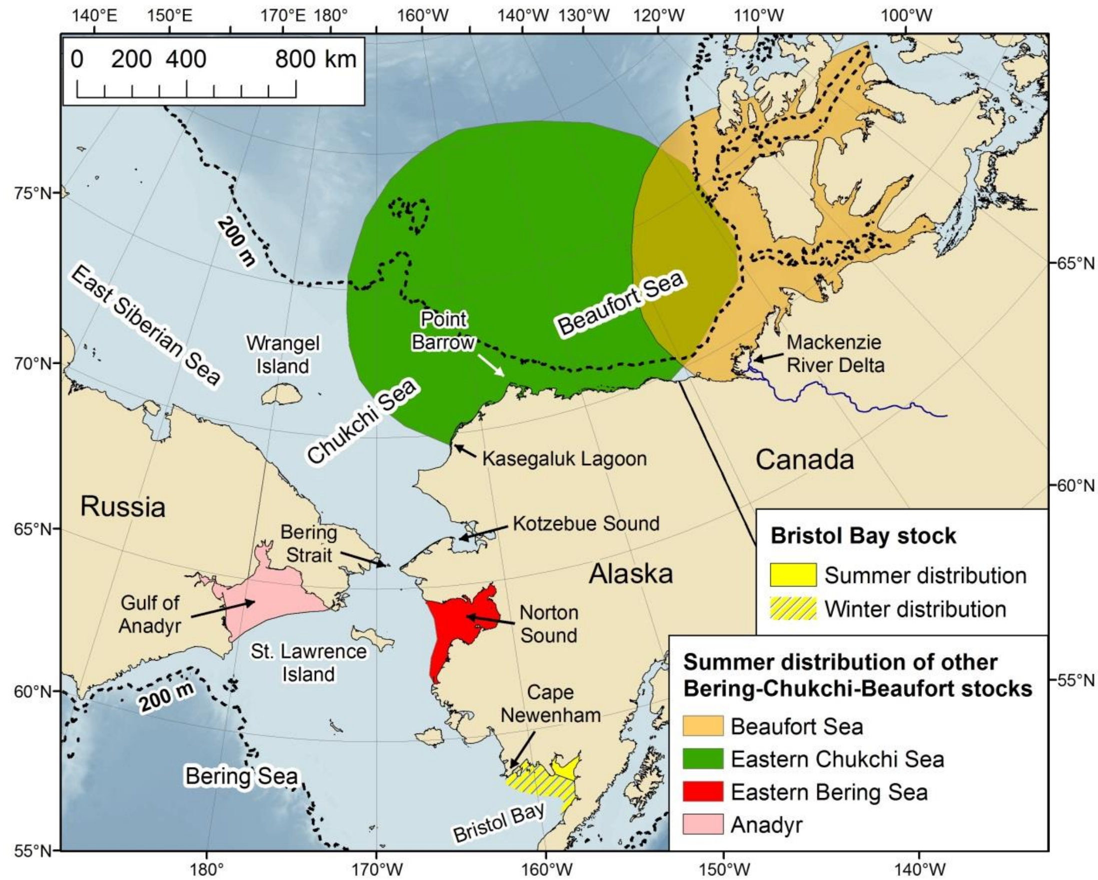

Figure 1. The annual range of belugas in the Bristol Bay stock and the summer distribution of other known beluga stocks in the Bering, Chukchi, and Beaufort seas.

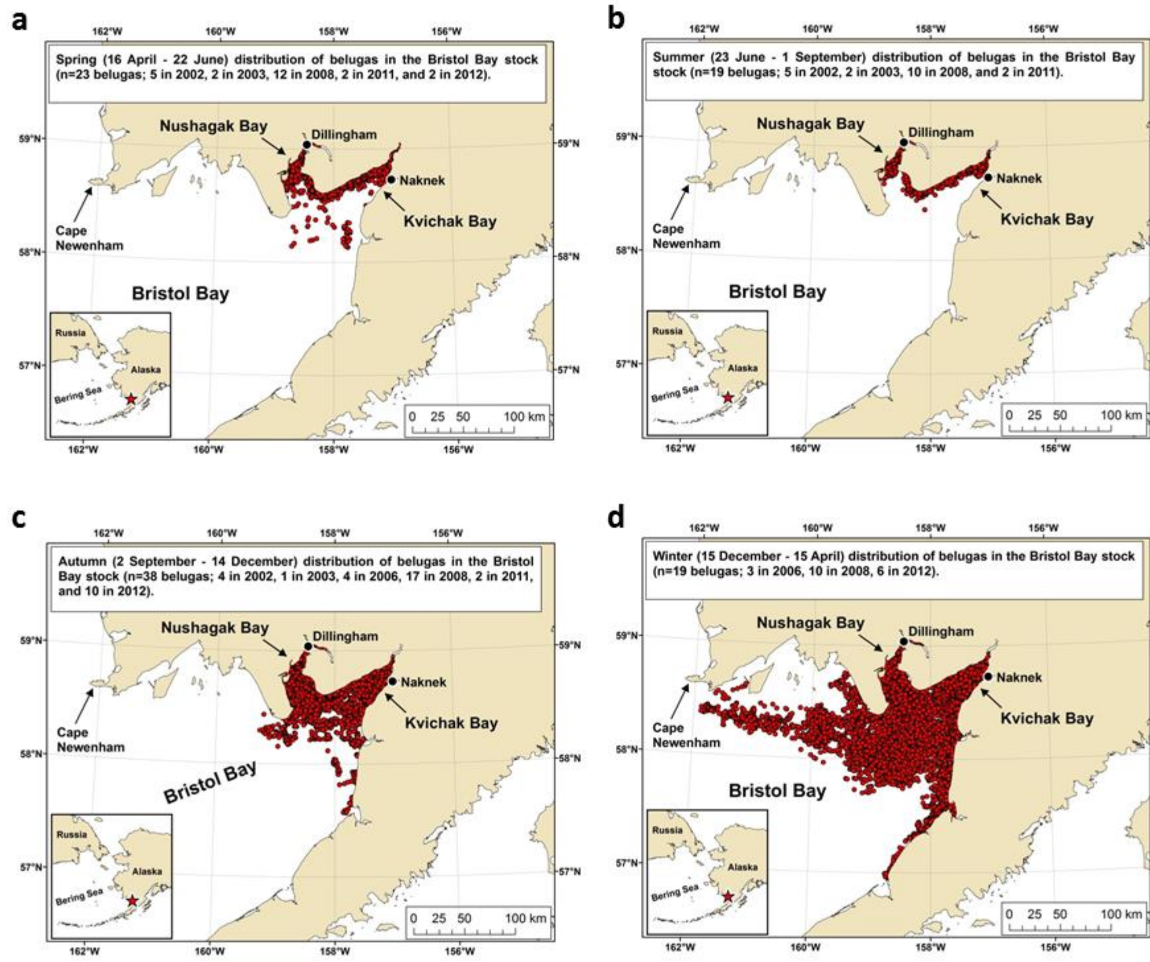

Figure 2. Locations for satellite tagged beluga whales in the Bristol Bay stock for (a) the spring (16 April – 22 June), when salmon smolt (*Oncorhynchus* spp.) and rainbow smelt (*Osmerus mordax*) are migrating; (b) the summer (23 June – 1 September), when adult salmon are migrating; (c) the autumn, 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).

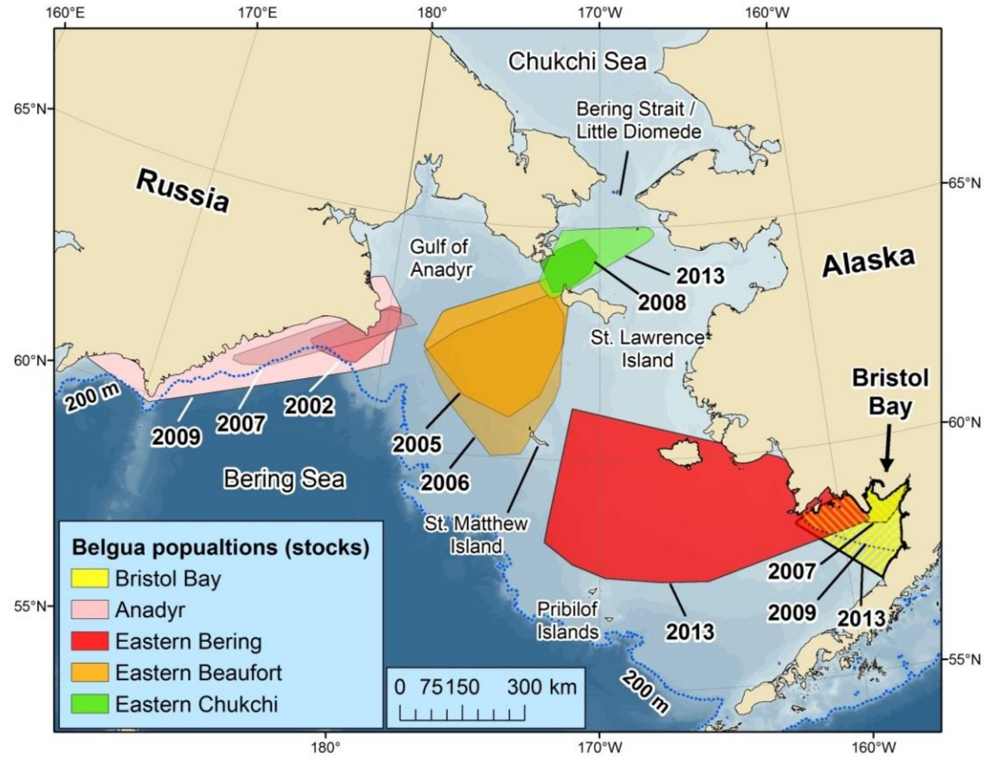

Figure 3. Winter ranges (minimum convex polygons of beluga satellite tag locations) of beluga stocks that winter in the Bering Sea. Polygons are drawn using January-March locations and years are denoted by the degree of shading. The orange striped area is where Bristol Bay and Eastern Bering Sea stock overlap. Figure reproduced from Citta *et al.* (2017).

2. Abundance

Aerial surveys were conducted in Bristol Bay periodically between 1993 and 2016 (Lowry *et al.* 2008, Alaska Beluga Whale Committee (ABWC), unpublished data). 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, one or two survey flights were flown each day; only data from flights with good viewing conditions were considered (see Lowry *et al.* 2008 for more information). The count of belugas varied greatly between individual flights and population inference was typically made using the maximum count within a year, as this was the minimum number of belugas in the population.

Counts from aerial surveys are typically corrected for the number of belugas that are diving and not available to be sampled and/or for the number that are available but missed by the observer. Because beluga calves are small and gray colored and are typically not spotted in the silty (i.e., gray-colored) water, a separate correction is sometimes used for calves (e.g., Brodie 1971). In Bristol Bay, however, correction factors have only been developed to correct for the number of adults at the surface (i.e., availability correction). Frost *et al.* (1985) used VHF transmitters to estimate an availability correction factor of 2.75. This estimate was later revised to 2.62 by Frost and Lowry (1995). Citta *et al.* (ABWC unpublished data) used satellite transmitters to estimate a correction factor of 3.3 (standard deviation = 4.52). The estimate of abundance for Bristol Bay belugas in the most current National Marine Fisheries Service Stock Assessment Reports is 2,877 (Muto *et al.* 2016) and was derived by multiplying the average of the maximum count from surveys in 2004 (794) and 2005 (1,067) by an availability correction factor (2.62) and by a correction for the number of calves (1.18) from a study of belugas in Cumberland Sound, Baffin Island, Canada (Brodie 1971). We used the same methods to calculate an updated abundance from the most recent aerial surveys completed in 2016 (maximum count = 1,024; ABWC unpublished data) which produced an abundance estimate of 3,166.

Although such calculations are warranted because estimates of abundance are needed for management, we know that assuming the correction factor does not vary with circumstances is unrealistic. Counts of belugas often vary widely, even when surveys are conducted on the same day and cover the exact same area. In 2016, replicate counts ranged from 484 to 1,024 on days with good viewing conditions. In fact, these two counts were collected on the same day, within a few hours of each other. If the true number of adult belugas was 3,000, then the availability correction factor for those surveys would be 6.2 and 2.9. In 2002, the ABWC decided to fund a genetic mark-recapture project in Bristol Bay. Estimates of abundance based upon mark-recapture methods are not reliant on estimating correction factors and provide an independent estimate of abundance. During 2002–2011, the Alaska Department of Fish and Game (ADFG) worked with Alaska Native beluga hunters and collected skin samples with biopsy tips mounted on jab-sticks. Unique genotypes were determined by PCR amplification of mtDNA and eight microsatellite loci. Matching of genetic samples was accomplished using program CERVUS (Kalinowski *et al.* 2007). During the study, 668 unique belugas were sampled and 84 of these belugas were recaptured in different years. A preliminary estimate of abundance was estimated using the POPAN formulation of the Jolly-Seber model (Schwarz and Arnason 1996). The preliminary estimate of abundance is 3,009 belugas (95% confidence interval (CI) = 2,491–3,673). The preliminary estimate of abundance is very similar to the 2004 (2,455) and 2005 (3,299) estimates (Muto *et al.* 2016), suggesting that using aerial counts with fixed correction factors can yield results that are useful.

The genetic mark-recapture project is nearing completion. Matching of all genetic samples is not yet complete, so the preliminary estimate could be biased high. If more recaptures are detected in the samples, this will increase the probability of encounter and decrease the population estimate. We also need to determine if the estimate of abundance applies to the entire population in Bristol Bay. For the mark-recapture estimate to be unbiased, all segments of the population should be available to be sampled within each year; however, most samples were collected in Kvichak Bay at a time when belugas are present in both Kvichak and Nushagak bays. Although the movement of satellite tags during mark-recapture sampling and the movements of genetically marked belugas between years suggest that the mark-recapture estimate of abundance applies to the entire population, this assumption needs to be examined in greater detail.

In summary, aerial surveys and a genetic mark-recapture study both suggest the Bristol Bay stock contains approximately 3,000 belugas, a number that is close to what was estimated in 2005.

3. Anthropogenic removals

Subsistence harvest

The ABWC and the Bristol Bay Native Association have collected data on Alaska Native subsistence harvests within Bristol Bay since 1987. Harvest data during 1987–2006 are presented by Frost and Suydam (2010). Here, we show the harvest record through 2016 (Fig. 4a; ABWC, unpublished data).

Over the last ten years, the annual harvest has averaged 23 belugas (95% CL = 21–25).
Although there is a slight positive trend in the harvest (an increase of 0.15 belugas per year; (Fig. 4b), this trend is neither statistically significant (p = 0.64) nor biologically important. The current potential biological removal (PBR) is more than twice this value (see Section 5, below).

Reporting of struck and lost belugas in Bristol Bay is sporadic. A struck and lost beluga is reported once every few years (ABWC, unpublished data) and the true rate is likely higher. Frost and Suydam (2010) did not report struck and lost rates as they were inconsistently reported for most communities in Alaska, including those in Bristol Bay.

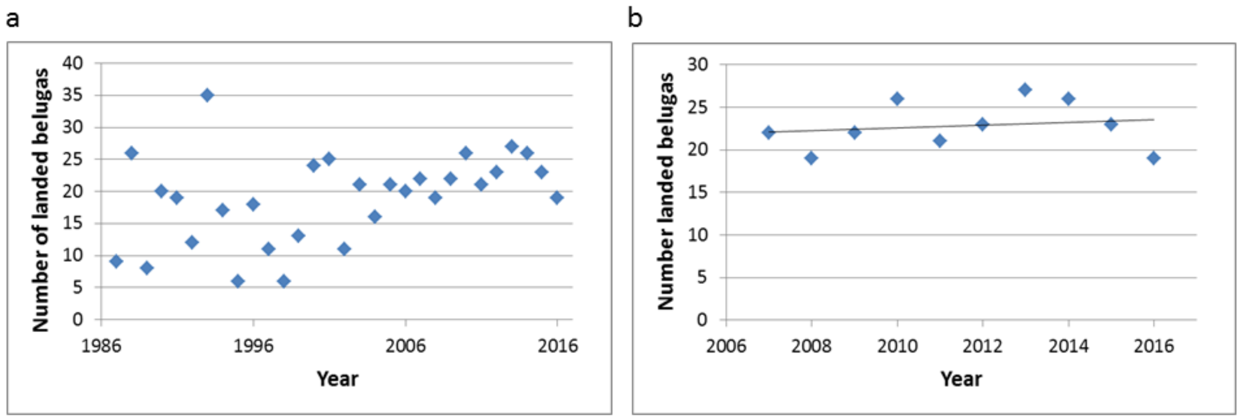

Figure 4. (a) Number of Bristol Bay belugas landed by subsistence hunters in Alaska, 1987–2016, and (b) the trend in the number of Bristol Bay belugas landed during the last ten years (2007–2016). For more information on how harvest is documented, see Frost and Suydam (2010).

Bycatch

Fishery observers monitored the groundfish trawl, longline, and pot fisheries within greater Bristol Bay during 1990–1997 and no incidental mortalities or injuries were observed (Muto *et al*. 2016). Aerial surveys occur in late June and early July, during the sockeye fishery, and belugas are observed swimming around gillnet sets suggesting belugas could be caught in the commercial salmon set gillnet and drift gillnet fisheries that occur in the inner bays (i.e., Nushagak and Kvichak bays). During May-July 1983, Frost *et al*. (1984) conducted beach surveys in the inner bays from airplanes and boats and found 27 dead belugas, at least 12 of which were clearly attributed to fisheries. The commercial gillnet fisheries have never been monitored for bycatch and there are no current, reliable 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 2005–2012 (Allen and Angliss 2011, Muto *et al*. 2016). Some belugas caught in subsistence gillnet fisheries are reported as harvest because they are consumed by Alaska Natives, however, the proportion of bycatch that is reported as harvest is unknown. Bycatch would have to be at least 42 belugas per year, after accounting for an average annual harvest of 23 belugas, to exceed PBR (See Section 5). Documenting the current level of bycatch is warranted.

4. Population trajectory

As described above (See Section 2), aerial surveys have been conducted in Bristol Bay periodically between 1993 and 2016 and results from 1993 to 2005 are reported by Lowry *et al.* (2008). Using the trend in the number of belugas counted over time, they estimated the Bristol Bay stock increased 4.8% per year over the 12-year period. Although this value is higher than the maximum net productivity rate (4%) that has been used as a default for cetaceans (Wade 1998), the value estimated by Lowry *et al.* (2008) had a confidence interval (95% CI = 2.1–7.5%) that includes 4%. Lowry *et al.* (2008) speculated that the high net productivity rate indicated the population may have been recovering from research harvests in the 1950s and 1960s (e.g., Brooks 1955), a decline in subsistence harvest, or a delayed response to increases in salmon abundance in the 1980s.

The ABWC conducted aerial surveys again in 2016 (ABWC unpublished data) and found a minimum population size (i.e., maximum count) of 1,024 belugas and counted an average of 660 (coefficient of variation (CV) = 0.26) on individual surveys. This is similar to the minimum population size (1,067) and average count (640, CV = 0.25) found in 2005 and the average count (637, CV = 0.47) found in 2004, although the minimum population size in 2004 (794 belugas) was lower than what was observed in 2005 or 2016 (Fig. 5). Given the variability in the proportion of belugas that are available to be counted during any given survey, differences between 2004, 2005, and 2016 are minor and it appears that the population growth observed in during 1993–2005 has slowed or ceased. Although more surveys will be necessary to conclusively determine the current trend, the data show that there was approximately the same number of belugas in Bristol Bay in 2016 as there were in 2004 and 2005.

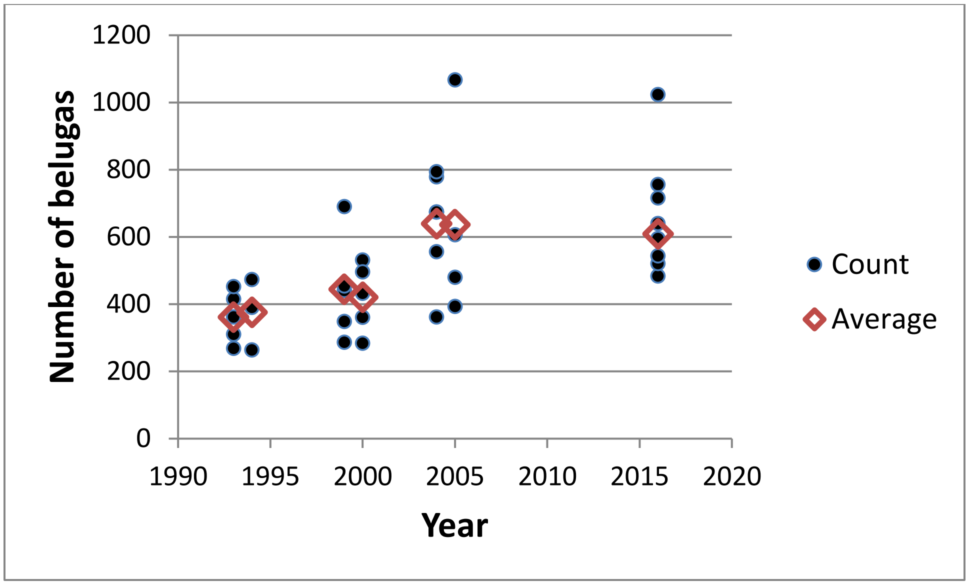

Figure 5. Number of beluga whales observed during aerial surveys in Bristol Bay, 1993–2016. Black dots are the number of belugas counted during replicate flights and red diamonds are the annual averages. For more information on aerial survey methods, see Lowry *et al.* (2008). The fit of linear versus other trends is statistically equivocal so we do not present a trend line here.

5. Potential biological removals or other information on safe (sustainable) limits of anthropogenic removals

Under the 1994 reauthorized Marine Mammal Protection Act (MMPA), the PBR 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. Most counts of belugas do not include reliable estimates of variability. Because of this, Muto *et al.* (2016) used a default CV of 0.2, resulting in a minimum population size of 2,467 belugas. R_{MAX} is the maximum net productivity rate (4.8%; Lowry *et al.* 2008) and F_R is the "recovery factor" and this is equal to 1.0 when a population is stable or increasing. Muto *et al.* (2016) used the average of the maximum counts from aerial surveys in 2004 and 2005 to calculate a PBR of 59 belugas (2,467 × 0.024 × 1.0) in Bristol Bay. Applying the same methods to the maximum count from the 2016 aerial survey yields a PBR of 64 belugas (2,679 × 0.024 × 1.0).

If we calculate PBR with the preliminary genetic mark-recapture estimate, we get a similar value. The CV is the standard error divided by the estimate of abundance; for the mark-recapture estimate this equals 299.9/3009.2 = 0.1. N_{MIN} equals 2,767 and the PBR equals 66 belugas (i.e., 2,767 × 0.024 × 1.0).

Hence, the current estimate of PBR is between 64 and 66 belugas per year, which is more than twice the current annual subsistence harvest ($\bar{x}$ = 23/yr).

6. Habitat and other concerns

Sea ice and climate warming

Sea ice is declining in most of the Arctic, however, Bering Sea ice is largely disconnected from trends in most other Arctic regions (e.g., Douglas 2010, Laidre *et al.* 2015). Bristol Bay is at the southern boundary of seasonal sea ice extent and multiyear ice has never been present (Neibauer and Schell 1993). Rather, sea ice is highly fragmented within Bristol Bay and winds from the north may create open water within the inner bays at any time in winter. Citta *et al.* (2016) documented how belugas with SDRs will move into the inner bays when north winds create open water. Although belugas never traveled south of the ice edge, they were also never located in the inner bays when there was no open water, perhaps due to risk of entrapment. Sea ice in Bristol Bay will likely form later and melt earlier as the climate warms and this may allow belugas more access to the inner bays in winter. Unfortunately, virtually nothing is known about the winter diet of belugas or what habitats they prefer in winter. If climate warming has an effect on Bristol Bay belugas, it will likely be through the expansion of new prey species into their range (Watt *et al.* 2016), the introduction of new pathogens or parasites that could affect belugas or their prey, or the loss of feeding habitat if sea ice no longer provides a refuge from killer whales.

Fisheries bycatch

No incidental mortalities or injuries to beluga whales were reported by fishery observers that monitored the groundfish trawl, longline, and pot fisheries during 1990–1997 (Muto *et al.* 2016; see Section 3). Other observations show that belugas have been caught in the commercial and subsistence salmon fisheries that occur in the inner bays but overall there are no reliable data on incidental take. Although beluga mortalities due to fisheries occur, they did not prevent the population from growing between 1993 and 2005 (Lowry *et al.* 2008). We suspect that unless there is a change in how or where commercial gillnet fisheries occur, these fisheries will not be a threat to the long-term sustainability of belugas in Bristol Bay. However, assessing current levels of bycatch is warranted.

Oil and gas development

In 2014, then U.S. President Obama used his authority under the Outer Continental Shelf Lands Act to permanently withdraw Bristol Bay from petroleum development. The withdrawal area contains all of Bristol Bay outside of State of Alaska territorial seas and contains most of the winter range of Bristol Bay belugas. The remaining range of Bristol Bay belugas is contained within state waters in Nushagak and Kvichak bays. Although oil and gas leases are periodically offered for sale by the State of Alaska, there are currently no oil or gas wells and no active leases in state waters within Bristol Bay (Alaska Department of Natural Resources 2014; http://dog.dnr.alaska.gov/Publications/OGInventory.htm).

Mining

A large copper, gold, and molybdenum mine is proposed for an area that includes the headwaters of both the Nushagak and Kvichak rivers. This mine, named the Pebble Mine, would process ore using a cyanide solution and mine effluents would be toxic to fish if leaked into the river systems. All mine shares are currently owned by the Northern Dynasty Partnership and, at the moment, plans to develop the mine are on hold. There is political opposition to developing the mine and most of Northern Dynasty's funding partners backed out of the project between 2011 and 2014. In 2014, the U.S. Environmental Protection Agency also issued rules unfavorable for the development of this mine. At this time, it is unclear when or if the mine will be developed.

7. Status of the stock

The Bristol Bay stock of beluga whales is one of three stocks in western Alaska that is co-managed by NMFS and the ABWC (Adams *et al*. 1993, Fernandez-Gimenez *et al*. 2006). Two of the agreed upon objectives of the management plan are to "conserve the Western Alaska beluga whale population" and to "protect Alaska Native beluga whale subsistence hunting traditions and culture" (ABWC 1999). Bristol Bay beluga whales are not designated as "depleted" or "strategic" under the MMPA nor are they listed as "threatened" or "endangered" under the Endangered Species Act. In an assessment done in 2008, the IUCN listed belugas as a species as "Near Threatened" and also noted that the various subpopulations should be assessed separately (Jefferson *et al*. 2012).

The Bristol Bay population is relatively small (~3,000); however, the abundance and trend of this stock are periodically monitored and the stock appears to be stable. The PBR for this population is at least 64 belugas/year. Annual subsistence harvest over the last decade has been less than half this number ($\bar{x}$=23/yr). Although there is little information regarding incidental take or struck and lost rates, the fact that the population has increased in recent decades suggests that these sources of mortality are not problematic (Lowry *et al*. 2008). There are currently few threats to population persistence, although changes in resource development, the invasion of novel species or pathogens due to climate warming, and increased exposure to killer whales due to declines in sea ice could pose challenges in the future.

8. Citations

Adams, M., Frost, K.J., and Harwood, L. 1993. Alaska and Inuvialuit Beluga Whale Committee (AIBWC) - an initiative in "at home management". *Arctic* 46:134-137.

Alaska Beluga Whale Committee. 1999. Cooperative agreement between the National Marine Fisheries Service and the Alaska Beluga Whale Committee for co-management of the western Alaska beluga whale population. *Available from North Slope Borough, Department of Wildlife Management, Box 69, Barrow, Alaska 99723, USA*.

Alaska Department of Natural Resources. 2014. Alaska Peninsula areawide oil and gas lease sales (corrected 12/01/14). Written finding of the director November 26, 2014. Available at: http://dog.dnr.alaska.gov/Leasing/Documents/BIF/Alaska_Peninsula/AP_BIF_FINAL_2014/2014_Alaska_Peninsula_Areawide_(Corrected)_complete_FBIF_12_01_14.pdf

Allen, B.M., and Angliss, R.P. 2011. Beluga whale (*Delphinapterus leucas*): Bristol Bay Stock. *U.S. Dep. Commer., NOAA Tech. Memo*. AFSC-234.

Brodie, P.F. 1971. A reconsideration of aspects of growth, reproduction, and behavior of the white whale with reference to the Cumberland Sound, Baffin Island, population*. J. Fish. Res. Bd. Can*. 28:1309-1318.

Brooks, J.W. 1955. Beluga. 1955 Annual Report, Alaska Department of Fish Game, Juneau, AK. pp. 98–106.

Citta, J.J., Quakenbush, L.T., Frost, K.J., Lowry, L., Hobbs, R.C. and Aderman, H. 2016. Movements of beluga whales (*Delphinaptrus leucas*) in Bristol Bay, Alaska. *Mar. Mamm. Sci*. 32:1272-1298. DOI: 10.1111/mms.12337

Citta, J.J., Richard, P., Lowry, L.F., O'Corry-Crowe, G., Marcoux, M., Suydam, R., Quakenbush, L.T., Hobbs, R.C., Litovka, D.I., Frost, K.J. and Gray, T., 2017. Satellite telemetry reveals population specific winter ranges of beluga whales in the Bering Sea. *Mar. Mamm. Sci. 33*(1):236-250.

Cornick, L.A., Quakenbush, L.T., Norman, S.A., Pasi, C., Maslyk, P., Burek, K.A., Goertz, C.E.C. and Hobbs R.C. 2016. Seasonal and developmental differences in blubber stores of beluga whales in Bristol Bay, Alaska using high-resolution ultrasound. *J. Mammal*. 97:1238-1248. DOI:10.1093/jmammal/gyw074

Douglas, D.C. 2010. Arctic sea ice decline: Projected changes in timing and extent of sea ice in the Bering and Chukchi seas. U.S. Geological Survey Open-File Report 2010-1176. 32 p.

Fernandez-Gimenez, M.E., Huntington, H.P., and Frost, K.J. 2006. Integration or co-optation? Traditional knowledge and science in the Alaska Beluga Whale Committee. *Environ. Conserv.* 33:1-10.

Fish, J.F., and Vania, J.S. 1971. Killer whale, Orcinus orca, sounds repel white whales, *Delphinapterus leucas*. *Fish. Bull.* 69:531–535.

Frost, K.J., Lowry, L.F. and Nelson, R.R. 1984. Belukha whale studies in Bristol Bay, Alaska. Pages 187–200 in B. R. Melteff, ed. Proceedings of the workshop on biological interactions among marine mammals and commercial fisheries in the southeastern Bering Sea. *Alaska Sea Grant Report 84-1*, University of Alaska, Fairbanks, AK.

Frost, K.J., Lowry L.F. and Nelson, R.R. 1985. Radiotagging studies of belukha whales (*Delphinapterus leucas*) in Bristol Bay, Alaska. *Mar. Mamm. Sci*. 1:191–202.

Frost, K.J., and Lowry, L.F. 1990. Distribution, abundance, and movements of beluga whales, *Dephinapterus leucas*, in coastal waters of western Alaska. Pages 39-57 in T.G. Smith, D.J. St. Aubin and J.R. Geraci, eds. Advances in research on the beluga whale, *Delphinapterus leucas*. *Can. Bull. Fish. Aquatic Sci*. No. 224.

Frost, K.J., and Lowry, L.F. 1995. Radio tag based correction factors for use in beluga whale population estimates. Working paper for Alaska Beluga Whale Committee Scientific Workshop, Anchorage, AK, 5-7 April 1995. 12 p.

Frost, K.J., and Suydam, R.S. 2010. Subsistence harvest of beluga or white whales (*Delphinapterus leucas*) in northern and western Alaska, 1987-2006. *J. Cet. Res. Manage*. 11(3):293-299

Jefferson, T.A., Karkzmarski, L., Laidre, K., O'Corry-Crowe, G., Reeves, R., Rojas-Bracho, L., Secchi, E., Slooten, E., Smith, B.D., Wang, J.Y., and Zhou, K. 2012. *Delphinapterus leucas*. The IUCN Red List of Threatened Species 2012: e.T6335A17690692. http://dx.doi.org/10.2305/IUCN.UK.2012.RLTS.T6335A17690692.en. Downloaded on 03 February 2017.

Jones, M., Sands, T., Morstad, S., Salomone, P., Buck, G., West, F., Brazil, C. and Krieg T. 2013. 2012 Bristol Bay area annual management report. *Alaska Department of Fish and Game, Fishery*

Management Report No. 13-20, Division of Commercial Fisheries, Anchorage, AK. Available at: www.adfg.alaska.gov/FedAidPDFs/FMR13-20.pdf.

Kalinowski, S.T., Taper, M.L. and Marshall, T.C. 2007. Revising how the computer program CERVUS accommodates genotyping error increases success in paternity assignment. *Mol. Ecol.* 16:1099-1006. DOI: 10.1111/j.1365-294x.2007.03089.x

Laidre, K.L., Stern, H., Kovacs, K.M., Lowry, L., Moore, S.E., Regehr, E.V., Ferguson, S.H., Wiig, Ø., Boveng, P., Angliss, R.P., Born, E.W., Litovka, D., Quakenbush, L., Lydersen, C., Vongraven, D., and Ugarte, F. 2015. Arctic marine mammal population status, sea ice habitat loss, and conservation recommendations for the 21st century. *Conserv. Biol*. 29:724-737.

Lensink, C.J. 1961. Status report: Beluga studies. Division of Biological Research, Alaska Department of Fish and Game, Juneau, AK.

Lowry, L.F., Frost, K.J. and Seaman, G.A. 1988. Investigations of belukha whales in coastal waters of western and northern Alaska. Part III. Food habits. *U.S. Dep. Commer., NOAA, OCSEAP Final Rep.* 56:359-391.

Lowry, L.F., Frost, K.J., Zerbini, A., DeMaster D., and Reeves R.R. 2008. Trend in aerial counts of beluga or white whales (*Delphinapterus leucas*) in Bristol Bay, Alaska, 1993– 2005. *J. Cet. Res. Manage*. 10:201–207.

Muto, M.M., Helker, V.T., Angliss, R.P., Allen, B.A., Boveng, P.L., Breiwick, J.M., Cameron, M.F., Clapham, P.J., Dahle, S.P., Dahlheim, M.E., Fadely, B.S., Ferguson, M.C., Fritz, L.W., Hobbs, R. C. Ivashchenko, Y. V.Kennedy, A. S. London, J. M. Mizroch, S. A. Ream, R. R. Richmond, E.L., Shelden, K.E.W., Towell, R.G., Wade, P.R., Waite, J.M. and Zerbini, A.N. 2016. Alaska marine mammal stock assessments, 2015. *U.S. Dep. Commer., NOAA Tech. Memo*. NMFSAFSC- 323, 300 p. doi:10.7289/V5/TM-AFSC-323.

Niebauer, H.J., and Schell, D.M. 1993. Physical environment of the Bering Sea population. Pages 23–43 in J.J. Burns, J.H. Montague and C.J. Cowles, eds. The bowhead whale. Special Publication Number 2, The Society for Marine Mammalogy.

Nelson, M.L. 1965. Abundance, size, and age of red salmon smolts from the Wood River system, 1964. Informational Leaflet 54, Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau, AK. Available at: http://ww.adfg.alaska.gov/FedAidPDFs/afrbil.054.pdf.

Norman, S.A., Goertz, C.E.C., Burek, K.A., Quakenbush, L.T., Cornick, L.A., Romano, T.A., Spoon, T., Miller, W., Beckett, L.A. and Hobbs, R.C. 2012. Seasonal hematology and serum chemistry of wild beluga whales (*Delphinapterus leucas*) in Bristol Bay, Alaska, USA. *J. Wildl. Dis*. 48:21-32.

O'Corry-Crowe, G.M., Suydam, R.S., Rosenberg, A., Frost, K.J., and Dizon, A.E. 1997. Phylogeography, population structure and dispersal patterns of the beluga whale *Delphinapterus leucas* in the western Nearctic revealed by mitochondrial DNA, *Mol. Ecol.* 6:955–970.

O'Corry-Crowe, G.M., Dizon, A.E., Suydam, R.S., and Lowry, L.F. 2002. Molecular genetic studies of population structure and movement patterns in a migratory species: the beluga whale, *Delphinapterus leucas*, in the Western Nearctic. Pages 53-63 *in* C. J. Pfeiffer, editor. Molecular and cell biology of marine mammals. Krieger Publishing Co. Malabar, Florida.

Quakenbush, L.T., Suydam, R.S., Bryan, A.L., Lowry, L.F., Frost K.J. and Mahoney, B.A. 2015. Diet of beluga whales (*Delphinapterus leucas*) in Alaska from stomach contents, March–November. *Mar. Fish. Rev*. 77:70–84.

Schwarz, C.J., and Arnason, A.N. 1996. A general methodology for the analysis of capture-recapture experiments in open populations. *Biometrics* 52:860-873.

Wade, P.R. 1998. Calculating limits to the allowable human-caused mortality of cetaceans and pinnipeds. *Mar. Mamm. Sci*. 14:1-37.

Wade, P.R., and Angliss, R. 1997. Guidelines for assessing marine mammal stocks: report of the GAMMS workshop April 3-5, 1996, Seattle, Washington. *U.S. Dep. Commer., NOAA Tech. Memo*. NMFS-OPR-12, 93 pp.

Watt, C.A., Orr, J., and Ferguson, S.H. 2016. A shift in foraging behaviour of beluga whales *Delphinapterus leucas* from the threatened Cumberland Sound population may reflect a changing Arctic food web. *End. Spec. Res.* 31:259-270.