

A Review of Science and Conservation Management for the Cumberland Sound Beluga Population

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ABSTRACT. For many centuries, belugas, or white whales (*Delphinapterus leucas*), have been a major source of subsistence and cultural identity for the Inuit living along the shores of Cumberland Sound, southeastern Baffin Island. During the late 1800s and first half of the twentieth century, the whales were also heavily exploited commercially for their oil and skins. By the late 1960s and early 1970s it had become clear that the beluga population was greatly reduced from its historical abundance, and efforts began to limit the harvest and monitor the population. The purposes of this paper are to (i) provide a synthesis of developments in Cumberland Sound beluga science and harvest management since 1980 and (ii) describe and discuss efforts to improve the conservation status of the beluga population. Despite large investments in research since the transition to co-management under the Nunavut Agreement, much uncertainty and disagreement remains. Best scientific estimates of current beluga numbers are in the range of 1000–1500, with no clear evidence of an increasing or decreasing trend. Officially reported annual landings of harvested whales for the Baffin Island community of Pangnirtung in recent years have ranged between 15 (1993) and 52 (2006), with an average of around 40 whales. Ongoing known or potential threats identified by hunters and scientists include overharvest, ecosystem (including climate-driven) change, interactions with commercial fisheries, predation by killer whales, and stress due to vessel noise. Addressing these issues will require continued research and improved relations between Inuit and the government. Fresh approaches are needed. Newly available analytical and procedural tools may help to overcome longstanding issues that are deeply embedded in cultural and philosophical differences.

Keywords: Inuit; belugas; white whales; *Delphinapterus leucas*; Cumberland Sound; Baffin Island; Pangnirtung; harvest; subsistence; conservation management

RÉSUMÉ. Depuis bien des siècles, le béluga, ou baleine blanche (*Delphinapterus leucas*), est une source de subsistance et d'identité culturelle majeure pour les Inuits des côtes du détroit de Cumberland, au sud-est de l'île de Baffin. Vers la fin des années 1800 et la première moitié du XX^e siècle, ces baleines ont également été fortement exploitées à l'échelle commerciale pour leur huile et leur peau. Vers la fin des années 1960 et le début des années 1970, il était évident que la population de bélugas avait diminué considérablement comparativement aux années d'abondance historique. Des efforts ont donc été déployés à partir de ce moment-là pour restreindre l'exploitation de ces baleines et surveiller leur population. Les objectifs de cet article consistent i) à présenter la synthèse des développements scientifiques et de la gestion des récoltes de bélugas dans le détroit de Cumberland depuis 1980 et ii) à décrire et à exposer les efforts d'amélioration de l'état de conservation de la population de bélugas. Malgré les importants investissements faits en recherche depuis la transition à la cogestion en vertu de l'Accord du Nunavut, il existe encore beaucoup d'incertitudes et de désaccords. Selon les meilleures évaluations scientifiques du nombre actuel de bélugas, il existe entre 1 000 et 1 500 de ces baleines, sans preuve manifeste de tendance à l'augmentation ou à la diminution de ce nombre. Ces dernières années, les débarquements annuels officiellement déclarés de baleines récoltées dans la communauté de Pangnirtung, sur l'île de Baffin, se sont échelonnés entre 15 (1993) et 52 (2006), avec une moyenne d'environ 40 baleines. Selon les chasseurs et les scientifiques, les menaces connues ou potentielles qui existent en ce moment sont la surexploitation, le changement de l'écosystème (y compris le changement lié au climat), les interactions avec les pêcheries commerciales, la prédation par les épaulards et le stress attribuable au bruit des navires. Pour gérer ces enjeux, il faudra que les recherches se poursuivent et que les relations entre les Inuits et les gouvernements s'améliorent. De nouvelles approches doivent être adoptées. L'existence de nouveaux outils d'analyse et de procédure pourrait aider à surmonter les enjeux anciens et profondément enracinés dans les différences culturelles et philosophiques.

Mots-clés : Inuit; bélugas; baleines blanches; *Delphinapterus leucas*; détroit de Cumberland; île de Baffin; Pangnirtung; récolte; subsistance; gestion de la conservation

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INTRODUCTION

The belugas (or white whales; *Delphinapterus leucas*) that occur in Cumberland Sound, a large water body (250 km long and 80 km wide at its mouth) on the southeastern coast of Baffin Island, Qikiqtaaluk Region, Nunavut, Canada (65°20' N, 66°01' W; Fig. 1), have been, for many centuries and probably millennia, a source of food for Inuit living in the area. The arrival of ship-borne whalers from Great Britain (mainly Scotland), the United States, and Newfoundland from the mid 19th century onward and into the early 20th century had profound impacts on the demography, settlement patterns, health, and ways of life of the Indigenous human population, as well as on the region's natural living resources, including whales and other marine mammals (Reeves and Mitchell, 1981; Ross, 1985; Eber, 1989; Stevenson, 1997). An exhaustive search of records in libraries, museums, and archives revealed that the foreign whalers killed at least 4400 belugas in Cumberland Sound between 1868 and 1887, and drive hunts organized by the Hudson's Bay Company (after whaling ships had stopped visiting Cumberland Sound regularly in search of bowhead whales, *Balaena mysticetus*) removed at least another 5500 belugas from 1925 to 1943 (Stewart, 2018; Fig. 2). This commercial hunting was driven by the market demand for beluga leather and oil. Beluga harvesting for domestic use (as food for both humans and sled dogs), often with oil and hides traded to the Hudson's Bay Company, continued without any government-imposed strictures through the 1970s (Freeman et al., 1998). Figure 3a–f includes photographs from Cumberland Sound during the first half of the 20th century depicting the processing of belugas for trade. Once the belugas were landed on shore, men and women removed hides and blubber from the carcasses and separated the blubber for the hides. They then rendered the blubber into oil. According to Brodie (1970), during the 1960s (when he was there), Pangnirtung hunters preferred taking young belugas or females with calves because they were easier to catch and their maktaaq (beluga skin) was more desirable than that of older individuals.

Concerns about (i) a sudden rise in the landed catch (number of belugas killed, secured, and butchered) by Pangnirtung hunters during the mid-1970s, apparently related to the sale of maktaaq by the Pangnirtung co-operative to other northern communities (Kemper, 1980; Brodie et al., 1981), and (ii) rifle-first hunting practices (shooting the whales before striking them with a harpoon to secure the carcass) led the Canadian Department of Indian and Northern Affairs to conclude that the Cumberland Sound beluga population required “immediate protection from further exploitation” and that without such protection the population would be “all but exterminated within 5 years” (Kemper, 1980:491). The officially reported landed catches at Pangnirtung in 1977 and 1978 were 178 and 85, respectively. Those numbers can be converted to account for hunting loss (whales killed or mortally injured but not landed) in two ways. Using what has become a standard

correction factor of 1.18 (Richard, 2008) based on an average from community reports in 1999–2003 in Iqaluit, Kimmirut, and Pangnirtung, the numbers from 1977 and 1978 convert to 210 and 100 respectively. Alternatively, using a population dynamics model (Watt et al., 2021), the conversion for those years is to 242 and 116, respectively. In response to the conservation concerns, the Department of Fisheries and Oceans Canada (DFO) discouraged inter-settlement trade in maktaaq, hunters agreed to exercise restraint, and the reported Pangnirtung landings were reduced in 1979 (Brodie et al., 1981) to 70 belugas (83 or 95 estimated killed according to the above-mentioned adjustments to account for hunting loss).

DFO announced that a quota of 40 belugas would come into effect at Pangnirtung in 1980 (Brodie et al., 1981). From that time and through at least 1990, Pangnirtung hunters reportedly limited their annual harvest to 40 landed whales (Ikkidluak et al., 1991). The Pangnirtung Hunters and Trappers Association (HTA, now known as the Hunters and Trappers Organization, or HTO) co-managed the hunt with the Nunavut Wildlife Management Board (NWMB, known at the time as the Nunavut Wildlife Management Advisory Board) and DFO from 1991 to 1999. Indications suggesting that the population had increased led NWMB and DFO to increase the total allowable harvest from 35 to 41 beginning in 2002 (DFO, 2002). Between 1980 and 2020 (inclusive), Pangnirtung's officially reported annual catch ranged between 15 (in 1993) and 52 (in 2006) belugas (mean 39.4, SD = 7.2) (Watt, 2021).

With signing of the Nunavut Agreement in 1993, the right to harvest wildlife and to participate in the process of deciding how such harvesting is managed became a constitutionally protected right of Inuit living in Nunavut (Richard and Pike, 1993). Motivated at least partly in recent years by the listing of Cumberland Sound belugas as threatened under Canada's Species at Risk Act in 2017, and since then listed as endangered (COSEWIC, 2020), DFO has made substantial investments to improve scientific understanding of numbers, biology, and behaviour of the belugas in Cumberland Sound (Hobbs et al., 2019; Watt et al., 2021).

The main aims of this paper are twofold: (i) to provide a synthesis of developments in beluga science and harvest management in Cumberland Sound since 1980, with an emphasis on the 30 years since 1993, and (ii) to describe and discuss efforts to improve the conservation status of Cumberland Sound belugas.

SCIENCE

Government-sponsored scientific research on the belugas of Cumberland Sound began in the 1960s. Paul Brodie, a graduate student at Dalhousie University in Halifax, Nova Scotia, carried out his doctoral research based in Pangnirtung between 1966 and 1969 (Brodie, 1970, 1971). From analyses of tooth layering and reproductive organs of

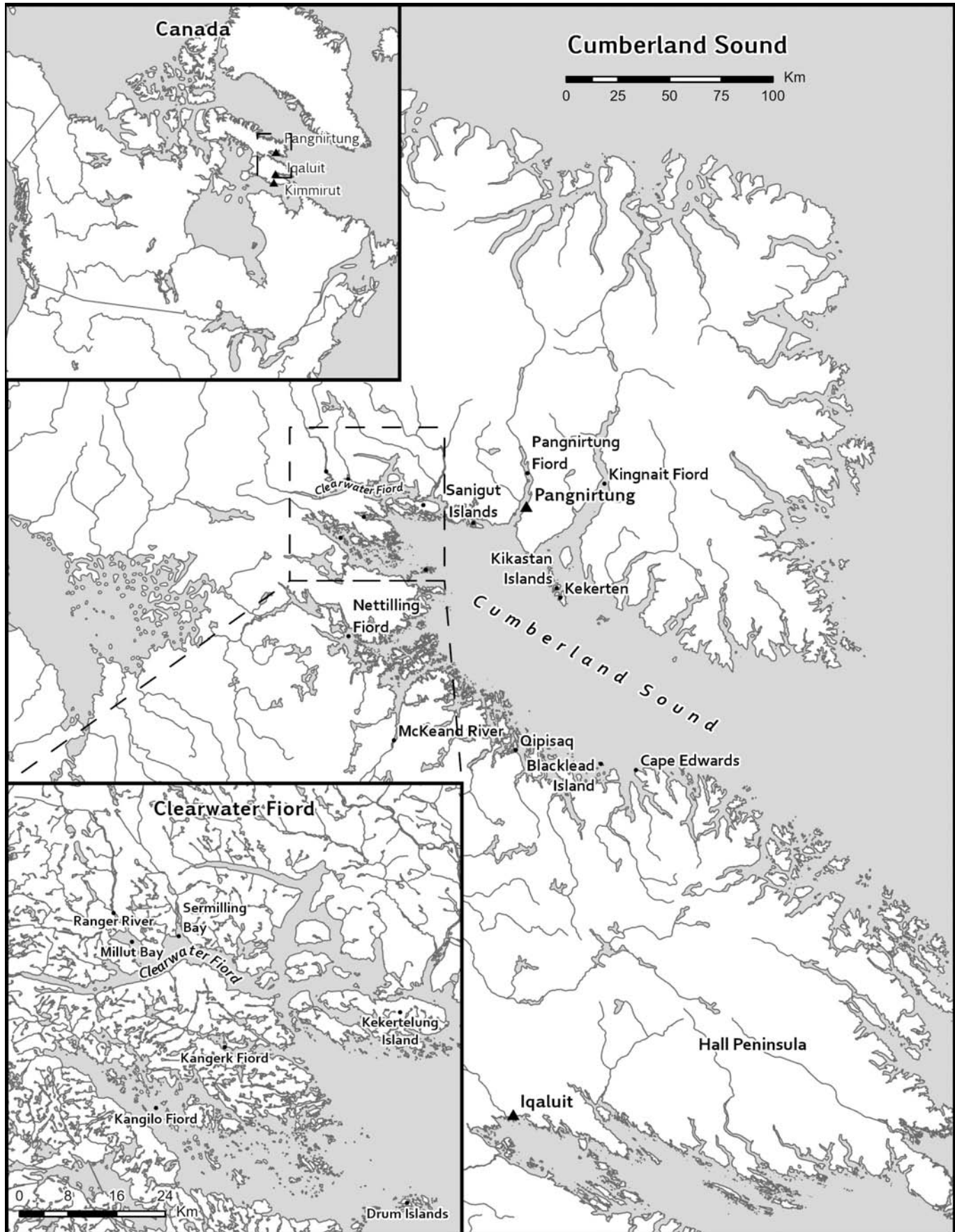
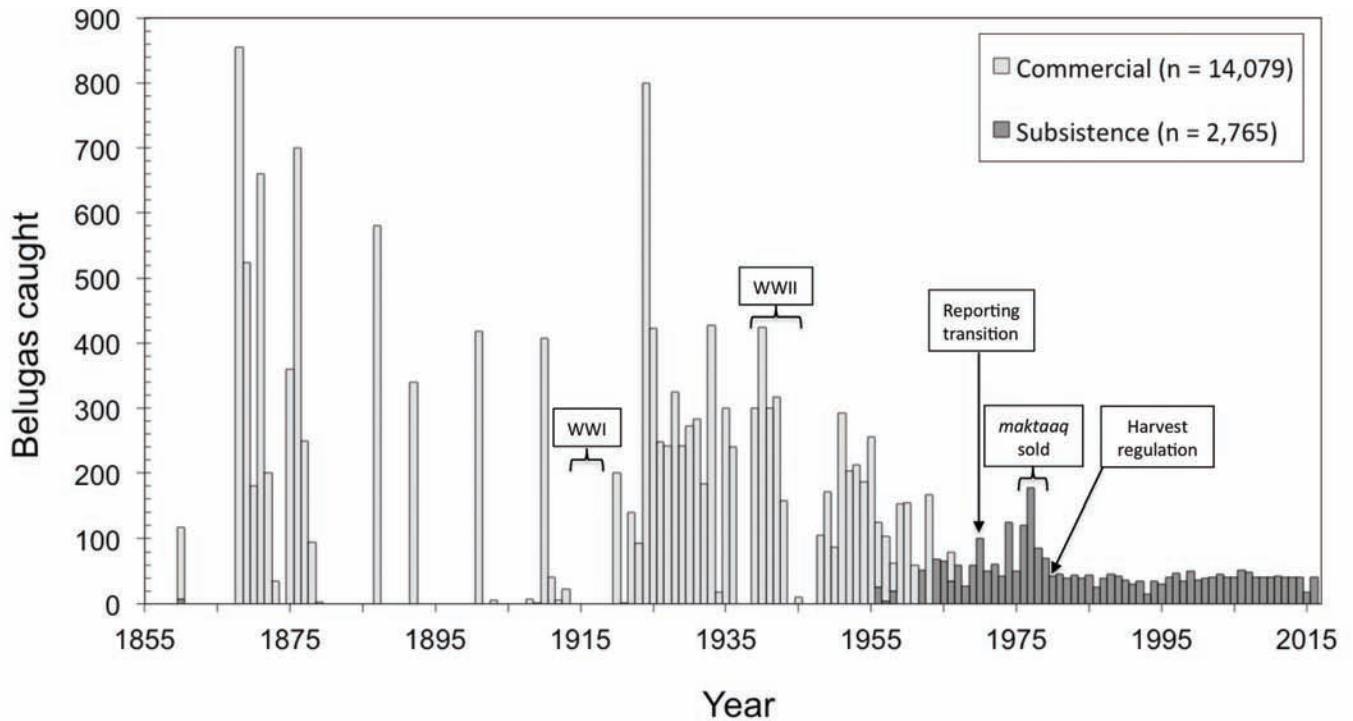


FIG. 1. Map of Cumberland Sound and environs, showing places mentioned in the text. Prepared by Ezra Greene.



| COMMERCIAL | Ship-based whaling | Transition from ship-based to land-based whaling | Drives organized by the HBC | Drives organized by Inuit | Small quantities of meat and oil were sold to the HBC until ca. 1970, and <i>maktaaq</i> was sold to the Co-op in the late 1970s. |
|-------------|--|--|--|---------------------------|---|
| SUBSISTENCE | Inuit involvement in commercial and subsistence hunts by whalers, traders, and others. Few data on Inuit subsistence catches or needs. | | | Drives organized by Inuit | Primarily Inuit subsistence hunts except in the late 1970s, when there was a market for <i>maktaaq</i> . Formal catch regulation began in 1980. |
| REPORTING | Vessel logbooks | | Archived newspapers and commercial catch summaries | | HBC Journals and Records |
| | | | | | RCMP |
| | | | | | DFO |

FIG. 2. Summary of documented beluga catches, 1855–2015. Credit: with permission from D.B. Stewart (2018).

belugas netted or shot in Clearwater Fiord at the head of the sound, he inferred that the reproductive cycle encompassed around three years, with gestation lasting 14.5 months and lactation at least two years. These parameter estimates were generally supported by subsequent research on a number of beluga populations (see Hobbs et al., 2015, for a review; also see Matthews and Ferguson, 2015).

Until about 2006–07, both the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2004) and DFO (2005b) were assessing beluga population status and recovery potential with an assumed generation time of 14 years, following Brodie’s (1971, 2013) assumption of two dentinal growth layer groups deposited per year. However, beginning around 2007–08, the evidence led to a shift in scientific opinion toward the view that tooth layering in belugas is no different from other toothed cetaceans, and they deposit one growth layer group annually (Stewart et al., 2006; Lockyer et al., 2007; NAMMCO, 2013). This change in opinion has had a major effect on estimates of some key life-history parameters. It is now generally accepted that generation time is around 28 years (Lowry et al., 2019) or somewhere in the range of 20–30 years (COSEWIC, 2020) rather than 13–15 years (average 14 years), as previously proposed (COSEWIC, 2004); age at sexual maturity (evidence of ovarian activity in

females, mature testes in males) is 6–14 years in females and 14–22 years in males (COSEWIC, 2014, 2016, 2020), rather than 4–7 and 8–9 years, respectively (Braham, 1984); life expectancy may be 30–60 years (COSEWIC, 2014, 2020), and maximum longevity is now estimated as at least 70 years (Luque and Ferguson, 2010; Lesage et al., 2014), rather than 25–30 years (Braham, 1984).

Population Structure and Stock Identity

Belugas occur in geographically discrete portions of the Arctic, sub-Arctic, and several cold temperate regions. Prior to 1990, researchers in Canada generally followed Sergeant and Brodie (1969, 1975), Brodie (1971), and Mitchell and Reeves (1981) in assuming that the belugas in Cumberland Sound (or at least those found in summer in river mouths, bays, and fiords deep inside the sound) constituted a geographically separate population, or stock. This practice has also been followed by the scientific committees of the International Whaling Commission (IWC, 1993, 2000) and the North Atlantic Marine Mammal Commission (NAMMCO, 1999, 2018). However, for a period beginning around 1990, DFO defined the relevant management unit as the Southeast Baffin stock, basing this primarily on

inferred migratory movements and on the seasonal timing of occurrence and hunting by people from the communities of Pangnirtung, Iqaluit, and Kimmirut (Richard, 1991).

Despite the difficulties of clearly and definitively delineating stocks (e.g., de March et al., 2002), the concept of a Southeast Baffin stock persisted until around 2004, when the balance of evidence from hunter knowledge, morphometrics, radio tagging, organochlorine contaminant profiles, and both mitochondrial and nuclear deoxyribonucleic acid (DNA) led de March et al. (2004:241) to conclude that at least some of the belugas taken by Pangnirtung hunters were “very distinct” and, therefore, that “a separate stock occurs in Cumberland Sound.” This conclusion was accepted by COSEWIC (2004) and reinforced by the findings of Richard and Stewart (2009) from aerial surveys, satellite tracking, and local knowledge; by Luque and Ferguson (2010), from satellite tracking and morphometrics; and by Rioux et al. (2012) from analyses of stable isotopes and trace elements in beluga tissues. De March et al. (2004) noted the possibility that some of the whales hunted at Kimmirut and Iqaluit were also hunted at Pangnirtung (a suggestion also supported by other genetic analyses; Turgeon et al., 2011), but also that, regardless, one stock hunted at Pangnirtung was not hunted at the other two communities. De March et al. (2004:248) concluded that their results were consistent with the long-held belief of hunters, as reported by Kilabuk (1998), that “more than one group of whales [belugas] comes into Cumberland Sound.” The Kilabuk study included a map showing an area on the west side of the sound, roughly corresponding to what Richard and Stewart (2009, Figure 9) and Watt et al. (2021) referred to as the west or western survey stratum in DFO’s standard aerial survey design. This area between Nettilling Fiord and Cape Edwards is where Pangnirtung elders and hunters said a different (i.e., non-Clearwater Fiord) population of belugas occurred. Kilabuk’s report (1998:53) also noted that these west-side whales (i) were smaller and less fat and had thicker skin than the Clearwater whales, (ii) tended to sink when killed, and (iii) had stronger tasting meat and maktaaq and more flexible maktaaq.

A recent study by Watt et al. (2023:11) found evidence to support the view of Pangnirtung elders and hunters that belugas from two different populations (or stocks; also see IWC, 2002) were present (and harvested) in Cumberland Sound during the summer (July–August, possibly into September). The genetic evidence led them to suspect that most of the individuals from outside Cumberland Sound were males from western Hudson Bay. Watt et al. (2023) were unable to identify or evaluate any of the differences in behaviour or morphology previously described by Kilabuk (1998). They did conclude, however, that whales assignable to the two different populations (Cumberland Sound and WHB) overlapped in space and time within Cumberland Sound, making it difficult to distinguish the populations in the field (Watt et al., 2023). Also, they acknowledged that it was not yet possible to determine whether western Hudson Bay whales were seasonal or permanent migrants or

whether their visitation of Cumberland Sound was sporadic or recurrent. Those authors’ advice was to provisionally consider all belugas in Cumberland Sound in summer as a single stock comprised of two genetic populations and to manage any harvest accordingly.

Distribution and Movements

Cumberland Sound has long provided, and presumably still provides, high-quality habitat for belugas. Sergeant and Brodie (1969) made a series of body-size comparisons in samples from 12 locations in Canada, Russia, Greenland, and Alaska, including 115 specimens netted in Clearwater Fiord. They ranked Cumberland Sound whales as intermediate in size using three metrics: body length, girth, and body weight. They also found that belugas from Hudson Bay were smaller and had thinner blubber than those from Cumberland Sound. Broadly similar results concerning differences in asymptotic length were found by Doidge (1990a) and Luque and Ferguson (2010) based on larger and more diverse datasets.

In the 1920s, Soper (1928:75) stated that, in early July, belugas entered the fiords of upper Cumberland Sound, but that Clearwater Fiord was the principal major congregation site at the time. Having killed “about 600” belugas in the fiord in 1923, hunters operating on behalf of the Hudson’s Bay Company secured “about 800” in Millut Bay in early July 1924 in the following manner:

Large numbers of white whales having been observed swimming up the bay, they were held in the bay by racing motor-boats across the narrow entrance and by firing rifles and beating pans. When the tide dropped, the whales were left stranded, were then shot and skinned, and the carcasses permitted to drift out to sea on succeeding tides.

Toward the end of July, large numbers of belugas were seen at high and low tide in Millut and Sermilling bays (both in Clearwater Fiord; Fig. 1). Later that summer, belugas were seen in Pangnirtung Fiord on 12 August, and they were described as “abundant” in Nettilling Fiord on 24 September. The next summer, large numbers were again taken in Millut Bay by the Hudson’s Bay Company (see Fig. 3) and, during September, “numerous white whales were observed ... along the upper coasts of Cumberland Sound” (Soper, 1928:75).

Some 40 years later, Brodie (1971:1316) reported that, according to his own observations and those of Inuit hunters, “all or almost all Cumberland Sound belugas inhabit Clearwater Fiord during late July to mid-September.” Pangnirtung hunters in the 1990s described beluga use of Cumberland Sound as follows (Ikkidluak et al., 1991:5):

During the period of ice cover, beluga can always be found at the floe edge. As the floe edge breaks up, beluga move steadily toward the head of the Sound. During the



FIG. 3. Series of images depicting Inuit hunters harvesting belugas for domestic and commercial use. A: hunters from Pangnirtung preparing to depart for the annual beluga hunt in 1926 or 1927 (Library and Archives Canada, Geoffrey Milling fond/e004665219); B: a portion of the large beluga harvest at Clearwater Fiord in 1924 (Archives of Manitoba [AOM], 2000/19/33); C: initial hide and blubber removal from carcasses (AOM, H4-199-4-6); D: separating the hides from blubber (AOM, H4-199-4-6); E: women mince blubber for grinding (H4-199-4-6); F: blubber is moved toward the whaling shed where it is rendered into oil (AOM, H4-199-4-6).

ice-free period the beluga can be found at or near the head of Cumberland Sound. Residents of the Qipisq Outpost camp say that beluga can be found there throughout the ice-free season. At that time beluga are not found along the north shore of Cumberland Sound east of Pangnirtung Fiord nor along the northeast shore of Hall Peninsula, southeast of Cumberland Sound.

The same report (Ikkidluaq et al., 1991:5) added, “This local knowledge has been confirmed in limited aerial surveys of these areas by DFO,” presumably referring to Brodie’s August 1967 aerial count (Brodie, 1971), as well as a series of photographic and visual aerial surveys and

cliff-top and boat counts during the 1970s and 1980s by consulting companies and DFO. Those surveys, along with reports by hunters, confirmed that, in summer during the 1960s through the 1980s, Cumberland Sound belugas tended to congregate in, or at least visit, Clearwater Fiord, primarily the Ranger River mouth and Millut Bay (as is true today; Booy et al., 2021), but they also circulated and occurred in small groups elsewhere in the head of the sound (e.g., Kangilo, Kangerk, and Nettilling fiords, the McKeand River mouth, and around the Drum Islands; Fig. 1) (Brodie et al., 1981; Richard and Orr, 1986; Richard, 1991).

The movements and distribution of belugas are likely influenced to some degree by hunting and disturbance.

Sergeant and Brodie (1975:1050) reasoned that a river mouth near Pangnirtung was unoccupied by belugas in summer 1971 because of “excessive hunting or boat traffic.” According to Richard (1991:211), “Continued harassment will cause belugas to temporarily vacate Clearwater Fiord but they stubbornly return to the Ranger River estuary, usually within a few hours, sometimes after a few days of absence.” The eight hunters and elders from Pangnirtung interviewed by Kilabuk (1998:49) were convinced that noise from “numerous motorized boats” was “the biggest factor ... causing a decline in the number of whales” in Cumberland Sound as a whole, and specifically in the number of belugas reaching Clearwater Fiord each year.

Belugas have been described as philopatric, meaning that they return to the same area (often a particular estuary, embayment, or estuarine complex) year after year (Caron and Smith, 1990; O’Corry-Crowe et al., 2020). They also exhibit strong site tenacity, meaning that individuals tend to visit and, in fact, occupy, for significant lengths of time, a particular site or sites. Based on research in the Nastapoka River (eastern Hudson Bay), Smith et al. (1990:3) noted that not only did identifiable individuals return to the estuary in successive years, but also, that if they were displaced by repeated disturbance from motor vessel traffic and hunting, they usually returned to the site after only hours or days. Those authors concluded, “This remarkable tenacity, undeterred by hunting pressure, makes belugas vulnerable to human-induced changes to their habitat and to over-exploitation.”

This vulnerability has been plainly evident in some other Canadian estuaries. The belugas that once occupied Great Whale River (Grande rivière de la baleine) and several other estuaries in eastern Hudson Bay and southern Ungava Bay kept coming back, year after year and decade after decade, despite being hunted both commercially and for subsistence, until they were extremely depleted or, in some cases, essentially extirpated (Smith and Hammill, 1986; Reeves and Mitchell, 1987a, 1987b, 1989; Kingsley, 2000; Doniol-Valcroze and Hammill, 2012).

It has long been known that, throughout their circumpolar range, belugas associate with estuaries and even move (or moved historically) considerable distances (hundreds of kilometers) upstream in some rivers (Kleinenberg et al., 1964). Kumlien (1879:67) surmised that belugas did not go into Clearwater Fiord to give birth because he knew (or believed) that females were already accompanied by calves upon arrival, and he further reasoned that since the stomachs of killed whales contained “little or nothing,” they must not be coming there for food. Another possibility mentioned by Kumlien (1879:66) was this:

One thing I noticed, when they go up the fjord they have a ragged appearance and dirty color, and, according to some whalers, are covered with parasites; but after they have been rolling and rubbing themselves on the sand-beaches for a few days they look much smoother and their color is a creamy white.

Pangnirtung elders and hunters contradicted Kumlien’s belief that belugas gave birth before arriving in Clearwater Fiord. In fact, they told Kilabuk (1998:49) that the fiord was the only place in the southeastern Baffin region where belugas were “known to give birth to their calves,” and that most births took place in July or early August. They added that females gave birth “only after spending some time in Clearwater.”

Sergeant (1973) investigated the estuarine habit of belugas in western Hudson Bay, where he observed newborn animals in the Seal River estuary from late June to early August, inferred to be the peak time of calving. This led him to posit that belugas “seek out estuarine areas primarily for calving” (Sergeant, 1973:10180). He suggested that the relatively warm water temperatures in the Seal estuary (10°C at low water) could “lessen the shock of birth and reduce heat loss in the first few days until the young animal has acquired some subcutaneous fat.”

The idea that estuaries serve primarily as calving (and early calf-rearing) habitat had become conventional wisdom among scientists by the late 1960s and early 1970s (Sergeant and Brodie, 1969, 1975), but research in the late 1980s (St. Aubin and Geraci, 1989; St. Aubin et al., 1990) showed that the combination of elevated water temperatures and low salinity of estuaries had the effect of enhancing or accelerating what has been described as a period of “epidermal proliferation, causing molt-like shedding which so far appears to be unique to belugas” (Smith et al., 1990:3). This explains Kumlien’s (1879) observations quoted above concerning the changed appearance and colour of belugas’ skin after spending some time rubbing on the sand in Clearwater Fiord. In some parts of the beluga’s range, neonates are regularly observed in cold meltwater estuaries, and young calves occur in pack ice and coastal areas devoid of freshwater input (Frost and Lowry, 1990; Smith et al., 2017). Among the hypotheses put forward to explain belugas’ estuarine habit are feeding, thermal advantage (specifically for calving and early stages of nursing), molting, and avoidance of killer whales and humans. The driving factors “likely vary geographically and across populations and may not be mutually exclusive” (Smith et al., 2017:2). Whatever the reason or reasons for belugas’ persistent use of Clearwater Fiord, Brodie et al.’s (1981:580) statement that they had not changed or “lost” their “traditional concentration site” in 50 years remains true today, 40-odd years later.

Population Size and Trends

Scientists, as well as some beluga hunters, have inferred from variation in catches and from direct observation that beluga abundance in Cumberland Sound, and specifically in Clearwater Fiord, has declined markedly. The Pangnirtung elders and hunters interviewed by Kilabuk (1998:49) told him that although drive hunting had ended by the 1940s or 1950s, whale numbers had declined “even after the commercial hunts were stopped.”

Brodie et al.'s (1981:580) basic analysis of numbers in the early twentieth century led them to conclude that if large numbers of belugas were still present in Clearwater Fiord after the reported kill of 800 there in July 1924 (Soper, 1928), the total population in the summer of 1924 "could not have been less than a thousand animals." In fact, Mitchell and Reeves (1981) estimated that the Cumberland Sound beluga population numbered more than 5000 in 1923. A population dynamics model suggested there were 8465 (SE=426) in the late 1800s and 2018 (SE=271) in 2002 (DFO, 2005a).

According to an ad hoc committee formed in 1990 to review the status of Cumberland Sound belugas (see Co-management), some hunters acknowledged that the number of belugas in Cumberland Sound had declined because of commercial whaling, but not to the extent claimed by DFO (Ikkidluak et al., 1991). The committee concluded, based on annual harvest levels and the results of aerial surveys and cliff counts, that the number of belugas in Cumberland Sound was stable between 1986 and 1990 and that the Southeast Baffin stock as a whole (i.e., belugas hunted in summer by hunters from Pangnirtung, Iqaluit, and Kimmirut) was larger than the number currently estimated by DFO, which was less than 500 and declining in 1990–91 based on the most recent uncorrected counts from visual and photographic aerial surveys in August 1985 and 1986 (Richard et al., 1990; Richard, 1991). DFO's aerial survey design was changed in 1990 to include a North Stratum outside Clearwater Fiord "at the suggestion of the Pangnirtung HTO" (Richard, 2013:5), and this stratum has since become a regular component of DFO survey programs.

DFO flew more aerial surveys (both visual and photographic) after 1990 and through 2009. The results of two surveys flown in 1999 (720–777 belugas counted) led DFO (2005a) to estimate, after correcting for submerged animals, a population of 1960 (SE=250) belugas in Cumberland Sound at the time. It was assumed that conditions had improved, and the population was on a trajectory toward recovery. However, a decade later, the best estimate from an aerial survey in August 2009 was 788 (2.5–97.5 bootstrap percentiles = 310–1679) belugas (Richard, 2013).

More aerial visual and photographic surveys, covering essentially the same three strata (Clearwater Fiord, North Stratum, and West Stratum) as were covered in 2009, were conducted in August 2014 (Marcoux et al., 2016). No whales were observed in the West Stratum, but counts in the North Stratum (visual only) and Clearwater Fiord (photographic only), adjusted to account for various biases, resulted in a total estimate of 1151 (CV=21.2%, 95% CI 760–1744).

Marcoux and Hammill (2016) fitted a discrete formulation of the Pella–Tomlinson model to the aerial survey data collected from 1980 through 2014, together with the reported catch data from 1960 through 2015 using Bayesian methods (Pella and Tomlinson, 1969; Innes and Stewart, 2002). The best-fitting model was the one that used 1990–2014 aerial survey data and an estimated

starting population in 1960 (after hunting that year) of 3100 belugas (rounded to the nearest 100). The model results indicated that the population had declined to about 1000 animals in 2015 (again, rounded to the nearest 100). The Global Review of Monodontids accepted those results and considered them to represent the best science available at the time (NAMMCO, 2018; Hobbs et al., 2019).

More aerial surveys were conducted in late July and early August 2017, with coverage similar to the 2009 and 2014 surveys, but with expanded coverage in response to a request from the Pangnirtung HTO (Watt et al., 2021). The resulting total estimate of abundance, adjusted for perception and availability bias, was fairly precise: 1381 belugas (CV=4.29%, 95% CI 1270–1502). However, the Pangnirtung HTO continued to suspect that even with the greater coverage, whales were being missed at the southern edge of their range in the sound. Watt et al. (2021) acknowledged that if their surveys had failed to capture the entire summer range, their estimate would be biased low. A Bayesian surplus-production model, fitted to a time series of abundance estimates (from surveys in 1990–2017) and reported subsistence harvests between 1960 and 2017, still indicated a serious decline over a nearly 60-year period, from around 3000 in 1960 to around 1000 in 2018. Importantly, Watt et al. (2021:561) appear to have incorporated due consideration for many of the uncertainties that surround our imperfect understanding of beluga life history and population dynamics. For example, they limited the upper bound of the modelled estimate of maximum population growth rate to 5% "to reflect potential stress-induced impacts on reproductive success." Watt et al. (2021) excluded from their analysis abundance surveys conducted between 1980 and 1990 on the reasonable assumption that the results of those surveys were negatively biased and could only provide minimum estimates of population size.

An analysis of very high resolution (VHR) satellite imagery collected over Cumberland Sound between 30 August and 7 September 2021 resulted in an estimate (corrected for availability bias) of 1690 (CV = 0.16; 95% CI: 1,241–2,301) (Sherbo et al., 2024). This somewhat higher estimate may be explained, at least in part, by the fact that the early August 2017 survey covered an area of 12,485 km² whereas the 2021 analysis covered a much larger area, 22,663 km².

THREATS

In 2005, DFO, apparently in line with the then-current status report on belugas by COSEWIC (2004), summarized threats to the Cumberland Sound beluga population (DFO, 2005a:7). These included:

- i. subsistence hunting, deemed a demonstrated threat "if not managed properly."

- ii. other “demonstrated” threats were killer whale predation, contaminants, disease, ice and tidal entrapment, net entanglement, and bycatch—but the immediacy and severity of these threats were “not fully understood”; and
- iii. “possible (speculative)” threats such as climate change, competition for prey (e.g., Greenland halibut [*Reinhardtius hippoglossoides*, also known as turbot] fishing), anthropogenic noise and disturbance, pollution, and loss of habitat.

There is some redundancy and ambiguity in that list, leaving room to question whether some of the threats should be classified differently. However, the Global Review of Monodontids (NAMMCO, 2018; Hobbs et al., 2019) largely endorsed the DFO list of threats, noting that the Cumberland Sound stock was declining due to overharvest by subsistence hunting, ecosystem changes (inferred from a shift in diet away from the consumption of Arctic cod [*Boreogadus saida*] to consumption of capelin [*Mallotus villosus*]), and stress (possibly due to anthropogenic noise and the cumulative impacts of multiple stressors) (NAMMCO, 2018).

Subsistence Harvest

The most recent DFO (2005a:12) assessment of this beluga population’s recovery potential concluded that harvest levels at the time were “low enough to allow recovery.” More recent work by DFO scientists, however, as summarized above (Watt et al., 2021), concluded that the current total allowable harvest for Pangnirtung (41 whales landed per year, with no consideration of hunting loss) is not sustainable (Watt et al., 2021). Local hunters challenged this conclusion, pointing out that earlier predictions by government scientists may have been alarmist. For example, as long ago as the late 1970s, one government scientist said the Cumberland Sound beluga population would be “all but exterminated within 5 years” unless given “immediate protection” (Kemper, 1980:491). Richard (1991:213) described the so-called Southeast Baffin beluga stock as the third Canadian stock—following the St. Lawrence estuary (SLE) and Ungava Bay stocks—to be “reduced to the point where its survival is endangered. It requires immediate and total protection.” Yet whales have continued to be present and harvested.

Fisheries

The incursion of capelin and the apparent shift of belugas away from a heavy reliance on Arctic cod to a more capelin-centred diet may signal (along with other more direct evidence) a shift in the Cumberland Sound ecosystem (Marcoux et al., 2012; Watt et al., 2016; Yurkowski et al., 2017). However, capelin is a major component of the diet of belugas in other areas (e.g., western Hudson Bay; Kelley et al., 2010), and it is uncertain whether a shift to greater

consumption of capelin in Cumberland Sound would have a significant negative impact on the beluga population. Pangnirtung hunters reported in the 1990s that belugas preyed on both Arctic cod and turbot along the floe edge in spring (Kilabuk, 1998). The report of the NAMMCO Global Review of Monodontids (NAMMCO, 2018) cited competition with commercial fisheries for turbot and shrimp in Baffin Bay, Davis Strait, and Hudson Strait as a significant concern for narwhals. Watt et al. (2016) expressed similar concern with regards to belugas in Cumberland Sound. The commercial open-water turbot fishery in Cumberland Sound operates between late July and early September, with an annual total allowable harvest of 500 t (DFO, 2021).

The best-known conflict between cetaceans and fisheries is the incidental mortality that results from entanglement or entrapment in fishing gear (i.e., bycatch). Belugas are believed to be less prone to bycatch than most cetaceans, possibly, at least in part, because of their exceptional echolocation capabilities, their body plan (e.g., no prominent beak or dorsal fin), and their ability to swim backward and wriggle free of large-mesh netting (NAMMCO, 2018). In any event, there is no evidence to suggest that entanglement or entrapment in fishing gear is an immediate threat to Cumberland Sound belugas.

Noise

The issue of noise disturbance is widely recognized as a problem for cetacean populations globally (Southall et al., 2021; Guan and Brookens, 2023), and it may be especially serious for populations like many of those in the Arctic where, until recently, the ambient acoustic environment was largely quiet for much of the year. In the early 1980s, when ship traffic and icebreaking activity in the Lancaster Sound region was ramping up, Finley et al. (1990) conducted an important study of how belugas and narwhals responded to the associated noise, leading Smith et al. (1990:3) to state, “The whales, which presumably had not been exposed to motor traffic, reacted to the ships even at remarkably long distances.” Specifically, belugas were “aware of an approaching ship over 80 km away and they showed strong avoidance reactions to ships approaching at distances of 35–50 km” (Finley et al., 1990:97).

In the 1990s Pangnirtung hunters and elders reported observing a slight decrease in the blubber thickness of belugas in Cumberland Sound, and they suspected this was “due to the whales needing to travel farther and faster to avoid the motorized boats” (Kilabuk, 1998:49). They also noted, “Overall the behaviour of the whales is very different than in the past. The noise and activities of the boats are suspected to be a major factor as to why fewer whales are reaching the Clearwater area than before.”

Belugas are among the most acoustically sophisticated cetaceans. Their vocal repertoire includes echolocation clicks, as well as whistles and trains of pulses that sound to the human ear like creaks, squawks, and screams (Vergara

and Mikus, 2019). Much of their vocalization is clearly used for navigation and foraging, but it is also used to support social integration and interaction. Belugas are believed to have individually distinctive signature calls, as well as contact calls that mothers and calves depend on for keeping in touch in turbid conditions that preclude visual contact (Van Parijs et al., 2003; Vergara et al., 2021).

Besides the problem of displacement by noise disturbance, whether brief or long-lasting, a critical effect of noise is that it can mask communication signals and disrupt social contact and interaction between or among individuals. This problem has been studied in detail with both captive and wild belugas (Vergara and Mikus, 2019; Vergara et al., 2021). Contact calls produced by newborn or very young belugas have much lower source levels (i.e., communication range) than those of adults and sub-adults (Vergara et al., 2021). There is no doubt that the range at which belugas can establish and maintain communication is reduced by vessel noise, and this must be especially critical to the survival of young animals in areas such as Clearwater Fiord.

Killer Whales

Another demonstrated threat, predation by killer whales (*Orcinus orca*), is difficult to evaluate, although there is certainly a long history of killer whales visiting Cumberland Sound regularly and preying on belugas there. The logbook of a whaleship (bark *Andrews* of New Bedford, Massachusetts) reported that killer whales were “frequently seen” on the bowhead whaling grounds around Blacklead Island and the Kikastan Islands, as well as near Pangnirtung during August–September in the 1860s (Reeves and Mitchell, 1988:141). According to Kumlien (1879:66), killer whales were very common in the sound in the 1870s, and he described them as arriving with the belugas, “which they follow up the fjords.” He indicated that he had seen belugas come close alongside the ship he was on while they were being attacked by killer whales. Soper (1944) reported hearing from Inuit in Clearwater Fiord that killer whales had followed large schools of belugas into Sermilling Bay in 1924.

Royal Canadian Mounted Police (RCMP) Game Reports from Pangnirtung during the 1950s and 1960s indicated that small groups of killer whales (from a few up to more than 20 individuals) were present in the sound (especially in Clearwater Fiord) every summer (June–September) (Reeves and Mitchell, 1988). In autumn 1956 the killer whales reportedly killed a bowhead, as well as more than 50 belugas, “in a single attack,” and in the early 1960s killer whales reportedly drove narwhals into Pangnirtung Fiord on several occasions, allowing the Inuit to harvest more narwhals than usual (Reeves and Mitchell, 1988:142). In 1966 the RCMP Game Report noted that according to Inuit in Pangnirtung, the number of killer whales coming into the area was “steadily increasing” and this was having a “marked effect” on the numbers of seals, walrus, belugas, and narwhals (Reeves and Mitchell, 1988:505).

The regular occurrence of killer whales in Cumberland Sound during summer in the 1970s was noted by Sergeant and Brodie (1969), and a 1973 report by the Government of the Northwest Territories stated that killer whales were seen annually between Pangnirtung Fiord and the Sanigut Islands (Murphy, 1973). In August 1977 a group of 11 killer whales was seen in Kingnait Fiord, and late the following month, 14 killer whales became trapped in a saltwater lake on Kekertelung Island at the head of the sound, apparently while chasing belugas (Reeves and Mitchell, 1988). All 14 were killed by Inuit in early October (Mitchell, 1979). The hunters took a calf and parts of some of the other whales to Pangnirtung, but the elders advised them not to consume the meat or maktaaq; the hunters prevented the local game officer from collecting biological samples from the whales (Davis et al., 1980). To our knowledge, no further deaths of killer whales have been reported in Cumberland Sound. A comprehensive analysis of killer whale records in the Canadian Arctic identified Cumberland Sound as one of several hot spots (areas of “relatively regular and predictable occurrence”) in the eastern Arctic, with peak presence in August and early September (Higdon 2007:24).

In the late 1990s Inuit hunters and elders at Pangnirtung speculated that one reason for belugas leaving Clearwater Fiord in late August rather than late October, as they had done in the 1960s, was that “a killer whale population is no longer in the area” (Kilabuk, 1998:50). The written proceedings document from the 2005 DFO meeting on recovery potential of the Southeast Baffin stock of belugas was equivocal, on the one hand stating that, “based on the information available,” predation by killer whales was not a threat (DFO, 2005b:60), but, on the other hand, stating that such predation was a “demonstrated” threat, the immediacy and severity of which was “still not fully understood” (DFO, 2005b:68).

Watt et al. (2021:563) reviewed evidence of killer whale occurrence in Cumberland Sound during the 2000s, including observations by hunters of predation on both belugas and bowhead whales in Clearwater Fiord. Their conclusion, however, was that the “magnitude of predatory pressure” on belugas in Cumberland Sound “remains unknown.” The role of killer whale predation as a contributing factor in the failure of the Cook Inlet (CI) beluga population in Alaska to recover since being fully protected from hunting pressure has been studied closely, but without conclusive results (Shelden et al., 2003; Burek-Huntington et al., 2015).

In 2021 the community of Pangnirtung and the Qikiqtaaluk Wildlife Board notified DFO that killer whales were increasingly present in Cumberland Sound, and the Pangnirtung HTO indicated its wish to “explore licensing options for local management of this killer whale population through harvesting” (DFO, 2021:3). Discussions of such culling to lessen the predation pressure on belugas and other marine mammals took place at an October 2021 meeting of the Cumberland Sound Beluga Working Group, comprised of representatives of the Pangnirtung

HTO, Pangnirtung elders, the Qikiqtaaluk Wildlife Board, Nunavut Tunngavik Inc., and DFO. That group has been formed to support development of a Cumberland Sound beluga management plan. At the very least, any decision to initiate a killer whale culling program intended to assist in recovery of the beluga population in Cumberland Sound will need to be carefully evaluated in terms of biology, ecology, feasibility, legality, and cultural norms.

Small Population Size

This threat was not mentioned by DFO (2005a), but Watt et al. (2021) raised the possibility that depensation could occur at some point if abundance of Cumberland Sound belugas continues to decline. Depensation, or the Allee effect (see Møller and Legendre, 2001), refers to situations where a population has been depleted to such an extent that demographic, environmental, or genetic factors (e.g., reduced probability of fertilization, predator saturation, inbreeding depression) are helping drive the population toward extinction or extirpation (Liermann and Hilborn, 2001; Kuparinen et al., 2014). However, Watt et al. (2021:562) concluded that if the beluga population in Cumberland Sound still numbers over 1000 individuals, it is likely “too large for inbreeding depression or reduced fertilization to be limiting recovery.”

Wade et al. (2012) developed the hypothesis that toothed cetaceans (which include belugas) are less resilient to intensive exploitation than baleen whales, and that the difference lies in aspects of their social structure and behaviour. Those authors defined resilience as the ability to recover from extreme depletion. Citing examples of both terrestrial and marine mammals, they suggested that the survival and reproductive success of many long-lived animals depends on such things as social cohesion and social organization; an ability and willingness to provide mutual aid in defence against predators; sometimes alloparental care (babysitting) and communal nursing; capability for intergenerational transfer of knowledge; and group leadership by older individuals who know where and when to find scarce prey resources and how to avoid high-risk circumstances, such as ice entrapment, stranding, and predation. Excessive removals from the population and disturbance by hunting can cause social disruption, fragmentation of social units, and the loss of key individuals. Non-linear and unpredictable consequences may ensue, making belugas slow to return and recolonize areas formerly occupied, vulnerable to localized threats (e.g., declining prey resources), and less able to adapt to ecosystem changes (O’Corry-Crowe et al., 2020). Outside of Cumberland Sound, several other beluga populations that were also greatly depleted by commercial hunting have shown little or no sign of sustained recovery. These include the populations in CI (Hobbs et al., 2019; but see Goetz et al., 2023), the SLE (Lesage, 2021; but see DFO, 2023), Southwest Greenland (Hobbs et al., 2019), Ungava Bay (Hobbs et al., 2019), and eastern Hudson Bay (Hobbs et al., 2019).

Climate Change

At their joint meeting in December 2021, the NAMMCO–Joint Commission on Conservation and Management of Narwhal and Beluga joint scientific working group (2021) considered an analysis of the impacts of climate change on Cumberland Sound belugas (Biddlecombe and Watt, 2022). That analysis modified the existing population dynamics model (from Marcoux and Hammill, 2016, mentioned above) by adding two environmental covariates, namely March sea ice concentration and August sea surface temperature in Cumberland Sound. Although the “mechanistic relationship” between these variables and beluga reproduction was unknown, they were incorporated into the model (NAMMCO-JCNB JWG, 2021:25). However, with no ability to define or quantify the mechanisms connecting climate changes and population dynamics, the group decided not to proceed with an attempt to improve the model. Instead, it suggested that data on the proportions of calves, juveniles, and adults be collected from aerial photographic and visual surveys and that information on the age structure be collected through harvest sampling, “as this could inform reproduction rates in modelling and be an indicator of changes in reproduction” (NAMMCO-JCNB JWG, 2021:25). The working group also recommended that sightings of belugas in new areas be recorded and used “to inform investigations into distribution changes” (NAMMCO-JCNB JWG, 2021:25).

Belugas in Cumberland Sound have higher blubber cortisol concentrations than other beluga stocks in Canada (Kucheravy et al., 2022), and this is generally regarded as an indication of elevated stress levels. Such stress could be the result of exposure to anthropogenic noise and disturbance, or a direct or indirect effect of climate change.

Beluga Health and Other Issues

Contaminants (= pollution), disease, ice and tidal entrapment, and loss of habitat were among the other threats mentioned by DFO (2005a) and classified as either “demonstrated” but “not fully understood” or as “possible (speculative).”

Contaminants: With respect to chemical pollution, belugas in southeastern Baffin Island are, like other northern populations, most likely to be exposed to contaminants through river discharge, ocean currents, and atmospheric transport, and also from a few local sources, such as sewage outfalls, municipal waste dumps, and mine effluent (COSEWIC, 2020). Some of the exposure may be direct (e.g., via inhalation), but most of it likely comes from consumption of contaminated prey, which could have been exposed locally or in distant locations in the case of migratory or otherwise highly mobile prey populations.

An assessment under the Northern Contaminants Program (NCP) using data from 1991–2011 found that levels of polychlorinated biphenyls and most other

persistent organic pollutants in beluga tissues from Cumberland Sound were stable or declining (NCP, 2013). However, significant increasing trends were found in levels of halogenated flame retardants (polybrominated diphenyl ethers and hexabromocyclododecane). All of these persistent organic pollutants can be transported by wind and water. They enter the food web at multiple levels, accumulating in fat stores, and become concentrated at each trophic step, a process known as biomagnification or bioaccumulation. Thus, levels of contaminants in beluga blubber can be quite high, even in otherwise pristine settings. Known effects of most such substances on mammals include endocrine disruption and neurotoxicity. The use of some flame retardants has been restricted over the past decade, but their replacement products are also of concern (de Wit et al., 2010; Simond et al., 2017).

Ongoing efforts to obtain and analyze samples for evaluation of the potential role of chemical pollutants in limiting the recovery of Cumberland Sound belugas remain a high priority.

Disease: Belugas are known to be exposed to a variety of infectious disease pathogens, including morbillivirus, *Toxoplasma*, and *Brucella* (COSEWIC, 2020). With climate warming, pathogens that are new to beluga populations are moving north. An example is the discovery of *Vibrio parahaemolyticus* in belugas in Bristol Bay, where it had not been observed in the past (Burek et al., 2008; Goertz et al., 2013). We are not aware of disease outbreaks in belugas in the southeast Baffin region, but this could change with further planetary warming.

Ice and Tidal Entrapment: Ice entrapment of belugas is apparently infrequent in Cumberland Sound, but it is a risk that must be considered. Pangnirtung elders and hunters cited areas along the west side of the sound where entrapments had occurred “repeatedly,” sometimes involving fairly large numbers of whales (e.g., from 35 to around 100 individuals) (Kilabuk, 1998:56). We are not aware of any reports of tidal entrapments. Watt et al. (2021) considered it unlikely that mortality from ice or tidal entrapments would have limited population recovery. This is probably true, but documentation and reporting of such events when they occur is important.

Habitat Loss: Evaluations of losses of suitable habitat for wildlife often fall under the influence of the shifting baseline syndrome, or generational amnesia, by which perceptions of normal environmental conditions are persistently downgraded with each successive human generation, leading to underestimation of the true magnitude of long-term changes in the environment (Jones et al., 2020). This would mean, for example, that elders in Pangnirtung (and other northern communities) are more aware of historical ecological conditions, and therefore more likely to perceive significant changes, than less experienced members of the community. As long as half a century ago, dam construction, offshore oil and gas activities, port development, tourism, and disturbance from hunting and motorized vessel traffic were cited as potential

causes of the loss of beluga habitat in various parts of Canada (Sergeant and Brodie, 1975), but not in Cumberland Sound, where none of those factors, other than hunting and vessel traffic, apply.

Cumulative Effects

While scientists and stakeholders regularly acknowledge the cumulative effects of multiple stress factors, they rarely manage to quantify or address these in detail. Probably the best examples of serious efforts to assess and address cumulative effects on a beluga population focus on the SLE and CI. As such, we summarize, in the following sections, some of the stressors thought to have contributed to cumulative impacts on these two populations. In both areas, belugas were heavily exploited historically for commercial, subsistence, and (in the case of the SLE) pest-control purposes. Both populations are now only remnants of what they were historically, and they are fully protected (legally) from deliberate hunting or harassment.

St. Lawrence Estuary: Living as they do in cool temperate latitudes year-round (47°N–49°N), SLE belugas comprise the southernmost beluga population in the world. Their year-round habitat is downstream of a highly industrialized and urbanized region. Because of its location, the population is exposed to a constantly replenished mixture of toxic chemical substances, as well as noise and physical disturbance from a large volume of traffic, which includes vessels involved in a multimillion-dollar whale-watching industry (Lesage, 2021). Some local or regional fish stocks have collapsed, and the St. Lawrence ecosystem has been significantly disturbed by commercial fishing for at least a century, with uncertain consequences for the whales’ prey base. The habitat has been modified in numerous ways, perhaps most notably by the network of dams constructed along the north shore of the estuary in the 1960s to produce hydroelectricity (Sergeant and Brodie, 1975; Kingsley, 2002).

The population histories of SLE belugas and Cumberland Sound belugas are an almost exact match, the former having numbered 5000–10,000 in the late 1800s and declining to perhaps only around 1800 now (Hammill et al., 2007; Lesage, 2021; DFO, 2023), and the latter declining from at least 5000, and possibly close to 8500, in the 1920s to about 1000 today. Although heavily exploited for commercial, recreational, and control purposes for many decades, in 1979 DFO conferred full legal protection on the SLE population (Reeves and Mitchell, 1984).

Decades after the ban on hunting and despite numerous management interventions intended to reduce anthropogenic pressures, the SLE beluga population has failed to recover. A simulation study concluded that the SLE population is unlikely to recover to pre-exploitation levels or meet interim recovery targets “even under [the] most optimistic scenarios” because “the reproductive capacity has been reduced both by sublethal threats and by climate changes observed in the decades since cessation of harvest” (Williams et al. 2021:6).

Cook Inlet: The CI beluga population is demographically and geographically isolated, a relict of post-Pleistocene glacial retreat (O’Corry-Crowe and Lowry, 1997). The chronology and character of efforts by the U.S. National Ocean and Atmospheric Administration (NOAA) to monitor this population and manage beluga harvesting in the inlet have largely mirrored those by DFO in Cumberland Sound (see Hobbs et al., 2015). The history and recent trajectory of the CI population are also similar in some ways to that of Cumberland Sound belugas. The CI animals were hunted by Indigenous peoples for subsistence since prehistoric times and by commercial and sport hunters through much of the 20th century (Mahoney and Shelden, 2020). In the 1990s there was concern that inter-settlement trade in maktaaq was helping to drive a steep decline in the already depleted beluga population (Shelden et al., 2021). In 1999 Indigenous hunters agreed to cease beluga harvesting in CI, and the federal government required that any further subsistence hunting there be authorized only within the framework of a co-management agreement. Under an agreement between NOAA and the CI Marine Mammal Council, very small hunts (one or two belugas to be struck per year) were allowed from 2000 to 2006; no further harvesting has been authorized since then (Shelden et al., 2021).

Although there were signs of steady growth in the CI beluga population from around 2004 to 2010, this was followed by a fairly steady apparent decline (NOAA Fisheries, 2022). Intensified monitoring of the population has led to the conclusion that multiple factors other than harvest (e.g., ship traffic, competition with fisheries, anthropogenic noise, urban and industrial development, chemical and biological pollution, and the effects of climate change) have been preventing recovery (Hobbs et al., 2019).

The results of aerial surveys in 2021 and 2022 suggest that the CI population has at least stabilized and may finally be slowly increasing (Goetz et al., 2023). Nevertheless, the CI and SLE populations can be regarded as cautionary examples of how a beluga population, once disturbed over long periods by commercial exploitation, is at a high risk of remaining severely depleted because of factors other than hunting.

MANAGEMENT

Co-management

As mentioned earlier, in 1990 Inuit expressed strong displeasure with the decision by DFO to impose small beluga quotas on Pangnirtung, Iqaluit, and Kimmirut. As a result, DFO requested the Science Institute of the Northwest Territories to convene an ad hoc committee to review the status of Southeast Baffin belugas (see Richard and Pike, 1993; Freeman et al., 1998). The committee was chaired by J.D. Heyland of the Science Institute and included six

other members to represent the Baffin Region HTO, the Baffin Regional Council, the three communities, and DFO. The committee’s report, delivered in June 1991 (Ikkidluak et al., 1991:13), stated that hunters from the communities “already practice[d] several sound conservation measures,” including: (i) not disturbing adult females, adult females accompanied by a calf, or pregnant females; (ii) not hunting belugas in Clearwater Fiord; (iii) reducing wounding and loss of killed belugas; and (iv) salvaging the maktaaq (when suitable) from belugas found dead. Another local conservation practice arose from Pangnirtung hunters’ recognition and respect for certain large, badly scarred individual belugas which were “known for decades [to] lead whales into this area year after year” and therefore were not harvested (Kilabuk, 1998:50).

The transition from a government-controlled regulatory system that prevailed through the 1980s and early 1990s to a co-operative management system, as prescribed by the 1993 Nunavut Agreement, was prolonged and difficult (Richard and Pike, 1993; Freeman et al., 1998). The Nunavut Agreement assigns primary responsibility for wildlife management, including establishment of the total allowable harvest and the basic needs level (the level of harvesting by Inuit identified in the Nunavut Agreement), to the NWMB. The agreement also specifies that each regional wildlife organization is responsible for allocation of the basic needs level. The Government of Canada retains “ultimate responsibility for wildlife management” (NLCA, 1993:25).

The Canadian co-management arrangement differs in various ways from that in Alaska, where the Marine Mammal Protection Act is the main legal instrument for protecting and conserving marine mammals. This 1972 law was amended in 1994 to allow and encourage the creation of co-operative agreements between federal agencies and Indigenous communities to ensure that the knowledge and perspectives of those communities are incorporated into research and management of marine mammals harvested for subsistence.

One agreement stands out as a particularly effective model, and it has been likened to the system of co-management boards established under the Nunavut Agreement (Frost et al., 2021). The Alaska Beluga Whale Committee consists of “tribally appointed delegates” from hunting communities in western and northern Alaska, scientists and managers from federal, state, and regional governments, and “others as determined by the committee,” all of whom have voting privileges except that “only hunters may vote on hunting-related matters” (Frost et al., 2021:2). The committee’s work, which includes collecting, analyzing, and validating harvest data, prioritizing and coordinating research, and developing regional management plans, is funded primarily by NOAA.

We emphasize, however, that the Alaska Beluga Whale Committee does not have decision making authority and, in that sense, differs in a major way from the wildlife

management boards in Canada. Breton-Honeyman et al. (2021) described and compared similarities and differences among Indigenous stewardship practices and collaborative research with regards to belugas across the Arctic (i.e., in Canada, Greenland, USA, and Russia).

Management Goals and Vital Rates

Conservation management must start with establishing goals—never as easy and straightforward as is often assumed. In the case of Cumberland Sound belugas, DFO (2005a) set a recovery target at 70% of historical population size, corresponding to an estimate of around 6000 individuals. It was assumed that this target could be reached in 40, 55, and 90 years for scenarios with annual harvest quotas of 0, 20, and 41 (actual current quota), respectively. It was predicted that the population would decline under a harvest scenario of 60 or more whales per year. Although DFO apparently regarded attainment of 70% of historical population size to be an appropriate management goal, the question of how quickly that target should be reached was left unanswered (DFO, 2005a, b).

As recently as the 1970s, the conventional wisdom was that beluga populations could sustain annual removals by hunting of 5%–10% (Sergeant and Brodie, 1975). However, Sergeant (1981:587) inferred from data on catches and hunting effort at Churchill that the lower end of that range, 5%, was “probably sustainable” as long as most of the animals removed were non-calf males. He stressed that the commercial hunters at Churchill, who harpooned and shot their prey, selected large animals because of their higher yield of marketable products (meat, blubber, and hides) and that, as a result, only about a third of the whales taken there in the commercial hunt were females.

Kingsley’s (1989) analysis of vital rates for monodontids (narwhals and belugas) led him to conclude that a removal rate of 5%, as proposed by Sergeant (1981), was too high and that conservative annual harvest levels should be set at 3%–4%. Richard (1991) even concluded that, given their age structure, the population growth rate of Cumberland Sound beluga could be less than 2%–3%. The actual maximum potential rate of increase for beluga populations is unknown (Hobbs et al., 2019), but for population modelling, a rate of 3% has been assumed (Watt et al., 2021). The reasoning and approaches used to produce estimates have never explicitly incorporated consideration of the species’ sociality, behaviour, or culture, although such factors have been recognized and acknowledged (Watt et al., 2021). At times, assumptions underlying management measures can turn out to be unwarranted. For example, the restrictions placed on subsistence harvesting of bowhead whales in both Alaska and the eastern Canadian Arctic during the 1970s, 1980s, and 1990s proved to be more severe than was warranted in light of what has been learned from intensive population monitoring (Ban et al., 2018; Reeves and Lee, 2022)

Harvesting Strategy

In an analysis of beluga population dynamics in northern Quebec, Doidge (1990b:69) concluded that the survival of juveniles and young adults that have just begun producing calves (what he called “early breeders”) is critical for “sustained growth or maintenance of beluga whale populations.” He considered that, in terms of reproductive value to the population, young adults are twice as valuable to future production as young of the year, and that older animals contribute little to future population growth. Therefore, in his view, the ideal harvesting strategy would be to remove older animals and avoid young adults.

One practical problem with implementing such a strategy, however, is that hunters cannot consistently differentiate between young and old adults. Body length is a poor criterion for such differentiation because of the asymptotic nature of the growth curve (Doidge, 1990a). Doidge (1990b:69) maintained, however, that even though some grey belugas are reproductively mature and give birth, the colour change from gray to white is still probably “the best character with which to distinguish those animals having high reproductive value.” Therefore, in his view, “for a given harvest level, the protection of large gray [individuals] and their replacement in the harvest by white animals allows a greater potential for future population growth than a random harvest” (Doidge, 1990b:69). In other words, according to Doidge’s argument, a hunt that removes mainly white individuals and young of the year, but few gray individuals, is likely to be most sustainable, depending on the size and age structure of the population.

There is a long-held belief that selective removal of the oldest cohort, both males and females, is the best strategy for ensuring that exploitation of odontocetes (toothed cetaceans) is sustainable, but as discussed earlier, this belief has been called into question by an emerging new paradigm that recognizes the importance of socially inherited knowledge (culture). Much of the evidence for this new paradigm has come from detailed studies of elephants, apes, killer whales, and sperm whales. In elephants, one consequence of social learning is “the increased importance of key individuals as repositories of accumulated knowledge, making their targeted protection particularly important for the persistence of social units” (Brakes et al., 2019:1033). This echoes the local conservation practice mentioned earlier in which Pangnirtung hunters refrain from harvesting large, heavily scarred belugas that they believe lead the whales into upper Cumberland Sound year after year. Individuals that are no longer reproductively active may perform important roles that strengthen the group’s resilience to social disruption, whether caused by predation pressure (see Breed et al., 2017) or human activities (Caron and Smith, 1990; Finley et al., 1990), and enable the population to respond, even over relatively short timescales (e.g., a few years), to environmental variability, such as significant changes in the location

of prey aggregations due to the effects of climate change (Meyer-Gutbrod et al., 2021). In elephants, there is evidence suggesting that fertility rates of social groups are influenced positively by the transmission of information from the matriarch to younger females (McComb et al., 2001), and similar influences are suspected, though often less well documented, for many other species, including belugas (Wade et al., 2012; O’Corry-Crowe et al., 2020; Brakes et al., 2021). A recent study confirmed that post-reproductive (i.e., menopausal) females in at least one salmon-eating killer whale population confer survival advantages on their grand offspring, advantages that appear to be most important in difficult times, when salmon abundance is low to moderate (Natrass et al., 2019).

Specifically in regard to belugas, a study of longevity, stability, and kin composition of groupings, which relied heavily on molecular genetic analyses and extensive field observations in Alaska, Canada, Russia, and Norway, showed that their social systems are extremely complex (O’Corry-Crowe et al., 2020). Individual-based studies of wild belugas are almost non-existent (but see Michaud, 2014; McGuire et al., 2020), and as a result, much less is known about their social dynamics than is known about those of killer whales and sperm whales, for example. While belugas, like killer whales and sperm whales, regularly interact and associate with close kin, they also “frequently associate and interact with more distantly related and unrelated individuals,” inhabit a wide variety of habitat types, and occur as both migratory and resident populations (O’Corry-Crowe et al., 2020:16). The nature of their social groupings appears to be influenced by the immediate social and ecological context, and this may include seasonal sexual segregation.

Management principles or approaches that have been recommended or applied to beluga harvesting in Cumberland Sound include the following:

Both netting and drive hunting should continue to be prohibited, as these removal methods are non-selective and, especially in the case of drive hunting, are highly disruptive and increase the risk of sub-lethal effects (e.g., mother–calf separation, physiological stress).

Any deliberate removals from the population should be selective, including avoidance of adult females and complete protection of calves. This recommendation is not new: it echoes the words of Ikkidluak et al. (1991) when they reported that hunters from Pangnirtung (as well as Iqaluit and Kimmirut) already avoided disturbing adult females, adult females accompanied by a calf, and pregnant females. However, it is unclear how the disturbance of adult females, whether unaccompanied by a calf, with a calf, or pregnant, can be avoided consistently and under all conditions experienced during a hunt (Breton-Honeyman et al., 2021).

Hunting belugas in Clearwater Fiord should not be allowed. Again, Ikkidluak et al. (1991) stated that this measure already in place and respected by southeast Baffin hunters.

As mentioned earlier, scientists consider recent harvest levels to be unsustainable (Hobbs et al., 2019; Watt et al., 2021). A modelling analysis based on harvest data (1960–2015) and the results of abundance surveys (1980–2014) suggested that a safe level of removals (in terms of sustainability and allowing for slow population recovery) would be between seven and 10 whales per year (Marcoux and Hammill, 2016). We note that the quota on harvest appears to be interpreted by both the hunters and the NWMB as a limit on the number of whales “struck and retrieved” (Priest and Usher, 2004:22), with no adjustment to account for animals injured or killed but lost.

HARVEST MONITORING AND BIOLOGICAL SAMPLING

Central though it is to effective management, obtaining complete and accurate data on hunting removals of belugas is always a challenge, particularly given the need to take account of the whales that are struck but lost (hit with a weapon but not landed). The Nunavut Wildlife Harvest Study, mandated by the Nunavut Agreement, was carried out under the auspices of the NWMB from 1996–2001 (Priest and Usher, 2004). This was an interview–recall study; that is, trained interviewers met with hunters, ideally monthly, either in person or by telephone, and filled out data forms based on information supplied by the hunters. The annual quota for Pangnirtung at the time was 35 belugas and the estimated harvests, according to Priest and Usher (2004), were 54 in 1996–97, 41 in 1997–98, 12 in 1998–99, 35 in 1999–00, and 35 in 2000–01. Those authors, apparently based on response rates as well as community feedback obtained during site visits, HTO workshops, and public meetings, considered the Pangnirtung estimates to be positively biased (i.e., overestimates) in 1996–97, negatively biased (i.e., underestimates) in 1998–99 and 1999–2000, and accurate in 1997–98 and 2000–01. Corresponding Pangnirtung harvests reported to DFO over the same period were 41, 47, 35, 50, and 37 belugas, respectively. Although the NWHS research team reportedly collected information on catch location and sex, this was not included in their final report. Nor did the report mention scientific sampling of harvested belugas, although a voluntary sampling program has existed since the early 1980s involving DFO Science, HTOs, HTAs, and hunters across Nunavut (Watt, 2021).

CONCLUSIONS

A number of recent articles provide examples of beluga co-management arrangements that appear to be functioning, at least to some degree (e.g., Frost et al., 2021; Lesage, 2021). Breton-Honeyman et al. (2021:12) observed that co-management and collaborative research “strive for cooperation and harmony through listening,

communication, building and maintaining relationships, and working together to identify and achieve common goals and create shared understandings.” Translating such fine words into needed actions is extremely difficult. Over the past half-century, since the 1960s and 1970s when Brodie was carrying out his research on Cumberland Sound belugas and authorities were imposing top-down management on beluga harvesting in Pangnirtung, little progress appears to have been made toward establishing something anywhere near that ideal. In fact, the “long-conflicted relationship between DFO and the community of Pangnirtung” to which Breton-Honeyman et al. (2021:6) alluded, citing Richard and Pike (1993), continues. There was a period during the 1990s when the prospects for shared understanding and pursuit of common goals looked favourable. With approval of a Southeast Baffin Beluga Management Plan developed collaboratively by Inuit and DFO, “the foundations were being laid” for a process in which Inuit would not be expected to “think like biologists” or “accept the state management model,” and biologists would not need to “adopt an Inuit cultural perspective” or follow “local management styles and philosophies” (Freeman et al., 1998:133; also see Ban et al., 2018). As recently as the late 1990s, it was believed that the mutually agreed plan “point[ed] the way for ... true resource co-management regimes in Nunavut” (Freeman et al., 1998:134). However, all scientific evidence, despite the many caveats associated with it, indicates that the Cumberland Sound beluga population continues to be overharvested and is still in decline (Watt et al., 2021). This means both that (i) DFO is failing in its mandate to ensure that fisheries (in this context, marine mammal harvesting) are “sustainable, stable, [and] prosperous” and that “lost protections” are “restored,” fish (= beluga) populations are “rebuilt,” and safeguards are in place to protect habitats “for future generations” (Trudeau, 2021:1), and (ii) it is unclear whether the common goal of managing and conserving “the traditional relationship ... between Inuit and beluga” in the region (Freeman et al., 1998:133) is achievable. Some Pangnirtung HTO members and elders remain unconvinced by DFO’s modelling results. They urge that more effort be made to examine the management implications of belugas from other stocks visiting Cumberland Sound (see Population Structure and Stock Identity). Clearly, a fresh approach is needed.

One possible option is what has come to be known as the Q method, a problem-oriented approach borrowed from the policy sciences (Watts and Stenner, 2013). The purpose of this analytical method is to identify both consensus and divergent perspectives on resource policy and governance within small groups of stakeholders (Zabala et al., 2018). In one application of the Q method, biologists and social scientists attempted to engage artisanal Caspian Sea sturgeon fishermen and seal hunters, as well as other regional stakeholders (boat owners, fishery managers, and traders of fish and seal products) in interviews and workshops intended to improve understanding and explore

ways to prevent regional species extinctions (Svolkinas et al., 2023:1199). After compiling and subjecting interview data to a rigorous sorting, classification, and ranking process, the project organizers proposed six “areas for targeting interventions” and solicited feedback on them from participants. These areas included enhanced law enforcement, increased regulation of fisheries, establishment of protected areas, provision of alternative livelihoods, reduction of demand for sturgeon and seal products, and research. Barriers to implementation, potential solutions, and necessary stakeholders were identified for each area. The process revealed “areas of divergence and disagreement, but also areas of alignment in viewpoints” (Svolkinas et al., 2023:1201).

In another study using a similar method that focused on controversies surrounding grizzly bear (*Ursus arctos*) conservation in Alberta, the challenges to success were said to be “more about decision-making processes and issues of legitimacy, power, trust, and respect rather than people’s attitudes toward bears” (Hughes et al., 2020:2). The authors encouraged participatory approaches that “decentralize decision functions and share power, build trust, and foster respect for different opinions and experiences in policy design” (Hughes et al., 2020:8; also see Chamberlain et al., 2012). We would expect any Q method or similar study in the present context to emphasize inclusive participation of beluga hunters, other community members, local, regional, and national government representatives, and other relevant stakeholders, and to be led by an impartial (i.e., disinterested) team of experts who organize and conduct interviews and then compile and analyze the results.

The challenges facing both Inuit hunters and resource managers in Nunavut are not unique or even exceptional. Marine mammal populations globally are in trouble not only because of historical over-exploitation, but also for a host of other reasons, most of which are rooted in the unintended consequences of humanity’s insatiable demand for living space, energy, modern conveniences, and recreational opportunities, to say nothing of food security. Humanity’s “massive ecological overshoot” (Bradshaw et al., 2021:4) seems bound to worsen. “Consumption and biodiversity challenges will [inevitably] be amplified by the enormous physical inertia of all large ‘stocks’ that shape current trends: built infrastructure, energy systems, and human populations” (Bradshaw et al., 2021:4). Meanwhile, both the Inuit of Nunavut and the various agencies charged with protecting and preserving Canada’s natural resources must continue to grapple with longstanding issues that are not only technical or scientific, but also historical and embedded in deep cultural and philosophical differences. Approaches to reconciling those differences have been limited and are largely out of date, although promising examples are increasingly available (e.g. Greene and Zawadzki, 2022; Little et al., 2023). We can only hope that the interested parties are willing to explore, adapt, and take advantage of newly available analytical and procedural tools in pursuit of shared understandings and common goals.

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