Bowhead Whales: Recent Insights into Their Biology, Status, and Resilience

DOI: 10.25923/cppm-n265

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Highlights

- Bowhead whales can live over 200 years and have unique anatomical and physiological attributes. Their sequenced genome holds promise for the advance of medical knowledge related to cell senescence, bone biology, and fat metabolism in mammals including humans.
- Commercial fishing and associated gear entanglement, industrial shipping, oil and gas activities including seismic exploration, and orca predation are affecting all four bowhead populations to varying degrees. Resilience of the species to these human-induced and natural ecological shifts vary by region.
- Bowhead whales are a useful indicator species that reflect variability in arctic marine ecosystems. Population size of bowheads in the Pacific Arctic has increased in the past 30 years in part due to increases in primary production as well as transport of the zooplankton north from the Bering Strait. The East Canada-West Greenland population has also increased. Conversely, the smaller bowhead populations in the Atlantic and Okhotsk Sea have remained at low numbers and are considered vulnerable or at risk.

Introduction

Bowhead whales, the only "true" arctic baleen species, are large rotund whales with a range confined to icy arctic and sub-arctic seas. The four bowhead populations, or "stocks" in management terms, are named for the seas they inhabit: Okhotsk Sea (OKH; ~218 individuals); the East Greenland, Svalbard, Barents Sea (EGSB; ~318 individuals); the East Canada-West Greenland Sea (ECWG; ~6,400 individuals); and the Bering-Chukchi-Beaufort Seas (BCB; ~16,800 individuals) (Fig. 1; Givens and Heide-Jørgensen 2021; Baird and Bickham 2021). All populations were hunted to near-extinction by commercial whaling, which ceased by the early 1900s, but the two last mentioned have nearly fully recovered. Their conservation success story was made possible by the productive collaboration of international organizations, Indigenous hunters, non-governmental organizations, and national governments (Suydam and George 2021). The two smaller populations have not recovered and are considered at high risk by the International Union for Conservation of Nature (IUCN; Givens and Heide-Jørgensen 2021).

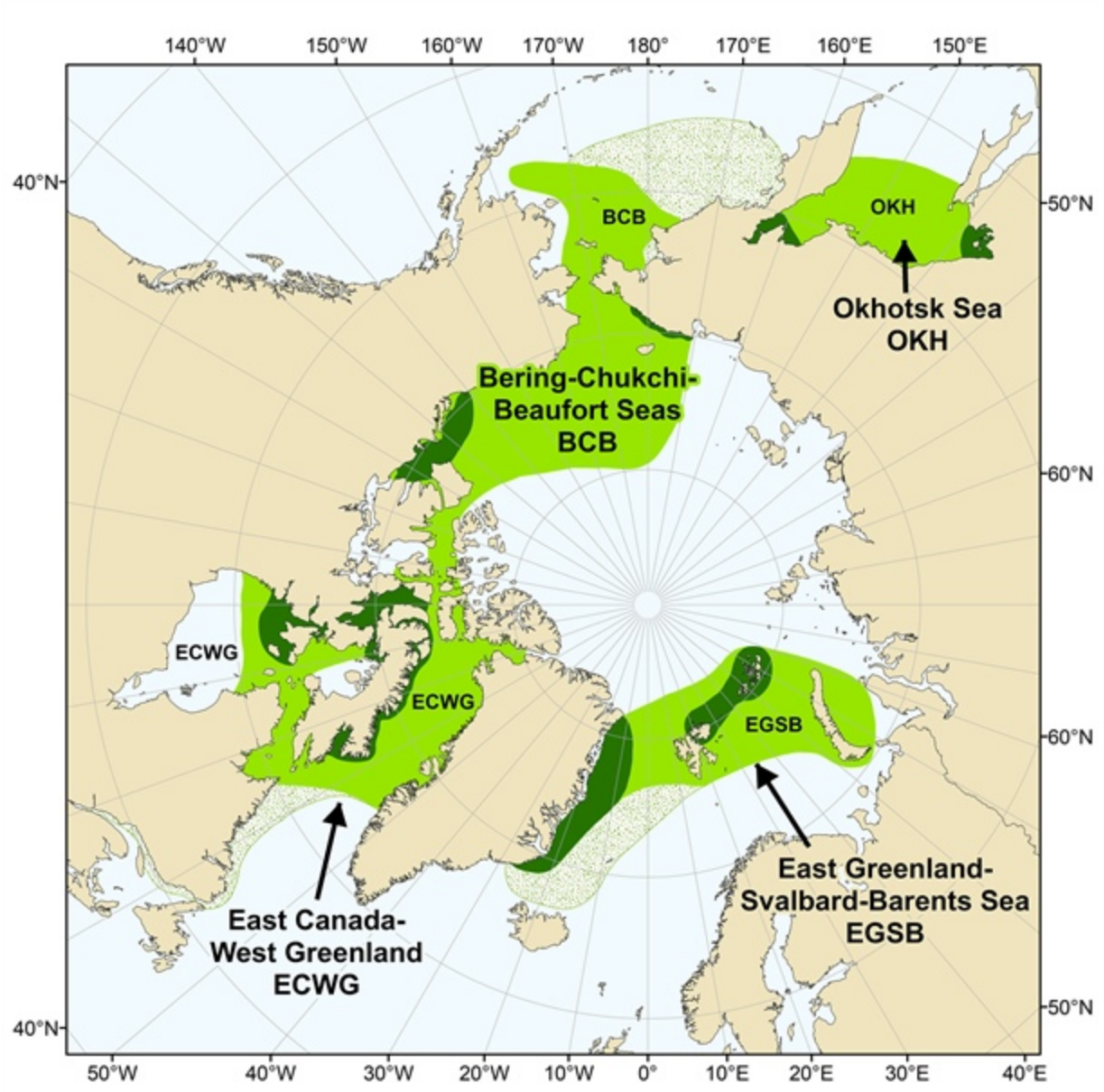

Fig. 1. Range of the four recognized bowhead whale regional populations: Bering-Chukchi-Beaufort (BCB) seas; Sea of Okhotsk (OKH); East Greenland, Svalbard, Barents Sea (EGSB); and East Canada-West Greenland Sea (ECWG). The range of the BCB and ECWG populations overlap slightly in the western Canadian Arctic archipelago. Green - current range; Dark green - areas of high summer density; Dotted - historical distribution. Source: Map by John Citta (modified from: Baird and Bickham 2021).

Compared to other whales, bowheads have greater blubber reserves, longer baleen, proportionally larger heads, and are highly adapted to live in ice-covered waters. They can break through ice up to 2 m in thickness, and feed on the small but seasonally rich zooplankton in arctic waters. They reach sexual maturity in their mid-20s, have a body temperature lower than that of most mammals, and can reach ages over 200 years (George et al. 2021a). Sea ice provides a refuge from orcas, their only natural predator, and may have allowed the evolution of many of their unusual traits.

Anatomy, physiology, and genetics

Collaborations with Indigenous whale hunters have allowed researchers to study samples from freshly harvested whales from the BCB population, providing the foundation for detailed anatomical and health assessments (Fig. 2), as well as quantification of population biology statistics, such as age composition and calf production rates (George et al. 2021a; Stimmelmayr et al. 2021). In turn, these findings have also informed oceanographic studies whereby stomach contents can be used to identify whether prey was derived from local production or transported from the Bering Sea by currents (Ashjian et al. 2021).

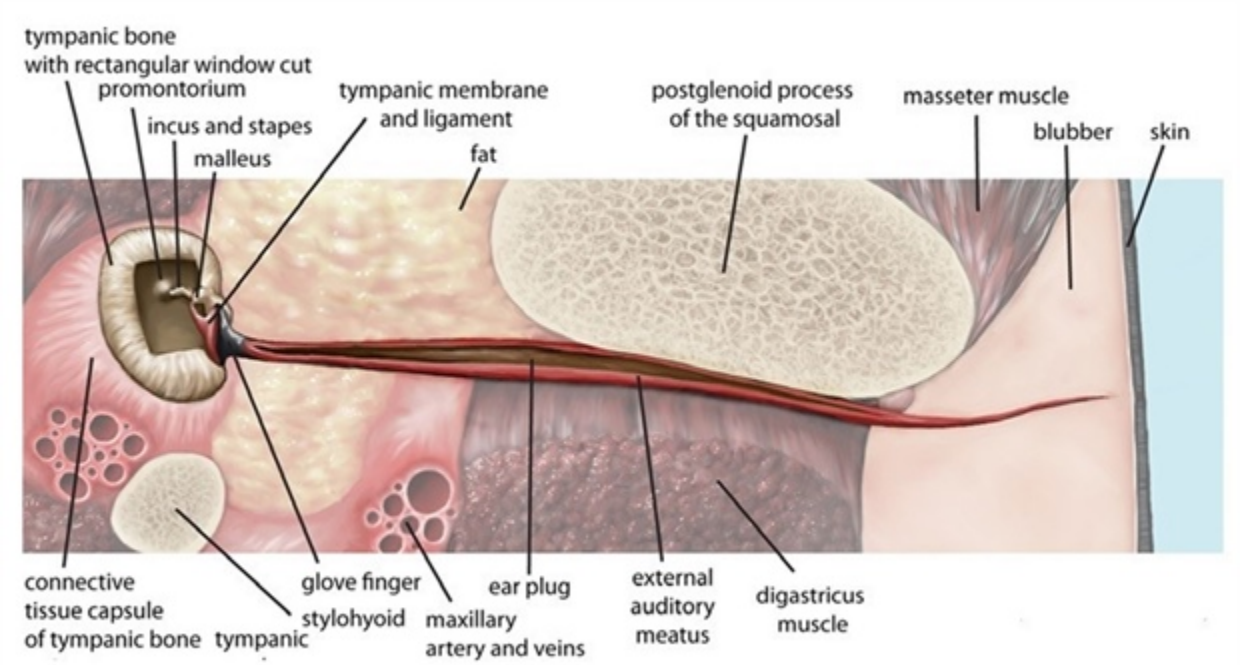

Fig. 2. Diagram of the ear of a bowhead whale (from Rehorek et al. 2020). Detailed anatomy work such as this would not be possible without collaborations with Indigenous hunters. Studies like these allow researchers to describe normal anatomy and identify disease and possible anthropogenically induced abnormalities and injuries from full-scale seismic surveys, industrial shipping, and oil and gas. Illustration by Jacqueline Dillard.

Bowhead blubber is the thickest of any cetacean (Fig. 3) and is important as an energy storage organ for times when food availability is limited (Burns 1993; George et al. 2021b). This allows bowheads to survive years of low oceanic productivity. It may also be a liability; observed avoidance of warmer waters in the Canadian Arctic (Chambault et al. 2018) and energetic models suggest bowheads are "over-insulated" and might overheat in a warming arctic. Other interpretations suggest bowheads may not be thermally stressed in part due to their relatively low metabolic rate and that the whales may simply be seeking higher prey densities in colder waters, and not directly avoiding warmer waters (George et al. 2021b; Citta et al. 2018).

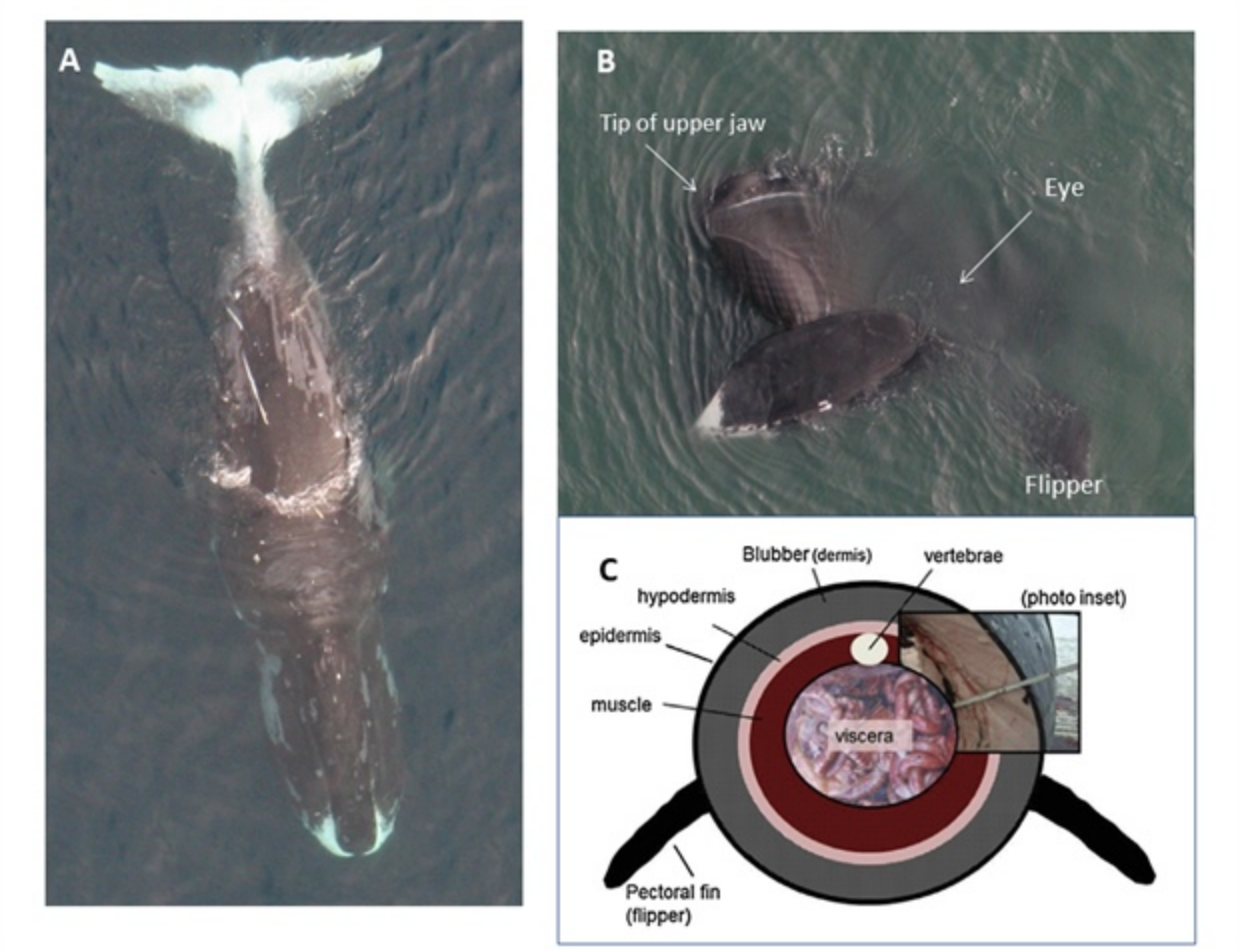

Fig. 3. (a) Large, heavily scared, and likely very old bowhead whale. The only baleen whale species endemic to the Arctic, bowheads grow to ~18 m (60 ft), weigh ~100 tons, and can live ~200 years. (b) A bowhead surfacing on its side with the mouth wide agape. These whales have the longest baleen rack of any mysticete allowing them to feed on remarkably small (1 mm) prey at relatively low densities (photo: C. George). (c) Diagram showing a cross-section of a harvested bowhead used in a body condition analysis. Increases in girth were associated with years with strong upwelling and reduced ice cover in their Beaufort Sea feeding grounds. The inset is an actual photograph of a yearling ''*ingutuq*'' bowhead showing the skin, blubber, a thick layer of fat underlying the blubber, and muscle (from: George et al. 2015).

The bowhead genome has been sequenced (Keane et al. 2015) and explored to understand the many remarkable aspects of their biology, such as their great longevity, ability to control fat deposits (Ball et al. 2013), low incidence of cancer, and bone metabolism (Cooper and Gorbunova 2021).

Regional ecology and anthropogenic threats

Loss of arctic sea ice has become an iconic signal of climate change and all bowhead populations now regularly inhabit open-water regions from at least late summer through autumn (Moore et al. 2021). Recent occurrences of wintertime sea ice loss (e.g., in the Bering sea per Stabeno et al. 2019), elevated ocean temperatures, an overall 57% increase in primary production (Lewis et al. 2020), and now-routine extensive summer sea ice retreats (see essay *Sea Ice*) indicate that bowhead habitat is undergoing rapid biophysical alteration (e.g., Huntington et al. 2020; Moore et al. 2019).

Biophysical and anthropogenic drivers in regional marine ecosystems will influence how each bowhead population fares in the current era of rapid change. For example, in the Pacific Arctic, bowheads routinely feed both on local copepods and on euphausiids (krill), which are advected through the Bering Strait (Fig. 4; Ashjian et al. 2021). Increased primary productivity and advection through Bering Strait since ~2000 seemingly have resulted in more local (copepod) and advected (krill) prey (Fig. 4), respectively, leading to improved bowhead body condition and high calf production (George et al. 2015). There is interannual variability in these biophysical drivers, however. For example, during the nearly ice-free autumn of 2019 bowhead whales were not observed feeding over the continental shelf areas of the western Beaufort Sea where they are commonly seen (Moore et al. 2021). The reason for this shift remains unclear but could have been the result of a mismatch in timing of prey delivery and whale arrival in the western Beaufort Sea. In autumn 2020, bowheads were again in abundance in the western Beaufort Sea, coincident with unprecedented wash-ups of krill on local beaches (Fig. 4).

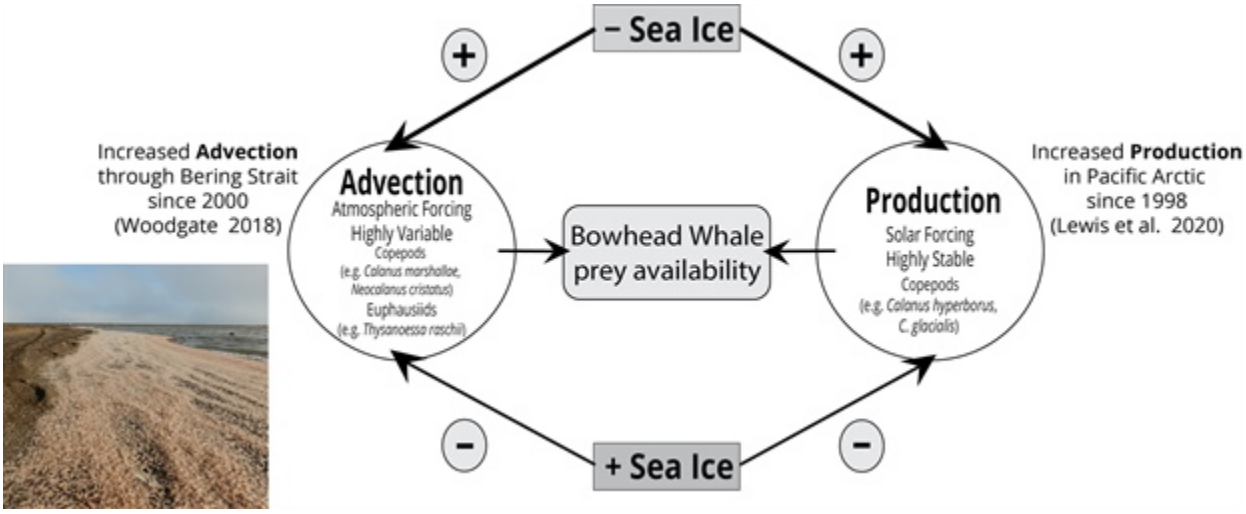

Fig. 4. Schematic summarizing biophysical drivers of bowhead prey reliant on local production (boreal copepods) and advection (e.g., euphausiids) and their relationship to sea ice (modified from Moore and Laidre 2006). In the past 20 years, with a decrease in sea ice, integrated primary production (see essay *Arctic Ocean Primary Productivity*) has increased by 96.1% in the Chukchi Sea and by 38.6% the Beaufort Sea (Lewis et al. 2020). Advection (transport) of nutrients and zooplankton has also increased (Woodgate 2018). Both of these biophysical changes have resulted in more prey and improved the body condition and health of bowheads. The inset photo is an unusual and tremendously large volume of beachcast euphausiids (or krill) near Point Barrow, Alaska in September 2020, where advection and local physical forcing trap krill to make it an important bowhead feeding area for the BCB population (Photo credit: Peter Detwiler 2020).

Increased orca predation impacts all four populations of bowheads (Breed 2021). Orcas (killer whales) in arctic regions tend to avoid sea ice unlike those in the Antarctic. With the now-common extreme Arctic summer ice retreats, orca are regularly observed in Canadian high arctic waters, leading to a sharing of habitat with bowheads. Sightings of both live and dead bowheads with orca-inflicted scars are becoming more common. Bowhead behavior is also affected (Breed 2021). Where bowheads once fed undisturbed in places such as Peel Sound, Foxe Basin, Lancaster Sound, and the Canadian Beaufort, orcas now pose a predation threat, which has led to some displacement away from these traditional summer feeding areas. Evidence of increased predation on bowheads is now a conservation concern for bowheads in the Sea of Okhotsk and the Pacific Arctic regions (Breed 2021; Willoughby et al. 2020).

Entanglement in commercial fishing gear is now considered the greatest threat to baleen whales worldwide (George et al. 2021c). Commercial fishing and crabbing are shifting north, following targeted

species and taking advantage of ice-free waters, suggesting arctic bowhead populations will encounter fishing gear more often. Evidence from aerial surveys and Indigenous-harvested individuals indicate that about 12% of bowheads in the North Pacific have entanglement scars (George et al. 2017). In addition, the harvesting of bowheads that are still entangled in commercial fishing gear has occurred several times in recent decades (George et al. 2021c). Increased underwater noise (Blackwell and Thode 2021), ship strikes, oil and gas and mineral extraction, and tourism associated with the more ice-free Arctic also pose threats, as well as induce stress in bowheads (e.g., Reeves et al. 2014).

Bowhead resilience, Indigenous Peoples, and future research

Rapid changes in bowhead whale regional habitats call into question the future of the only arctic endemic baleen whale. Moore and Reeves (2018) provide a simplified framework to assess status and resilience of each of the four bowhead populations based on population size, geographic range, flexibility in behavior and diet, and health parameters. Overall, this framework suggests that the smaller populations are at higher risk (Moore et al. 2021).

Bowhead whales are a good indicator species of arctic change because they react to annual environmental perturbations, especially those influencing prey availability, and subsequently integrate these changes into long-term measurable trends in reproduction and health. So far, two of the populations (ECWG and BCB) appear stable or increasing with strong reproduction. The remarkable and steady recovery of the BCB population since the 1980s (Givens et al. 2016) confirms that the arctic ecosystem has fewer direct anthropogenic impacts (commercial fishing, shipping, etc.) relative to other marine regions and is actually more productive in the face of sea ice loss – at least to date. The recovery of the BCB population should be ranked among the great conservation successes of the last century, particularly considering the continued sustainable harvest by Inuit peoples.

Several arctic Indigenous societies, from Chukotka to Greenland, depend on bowhead whales for food and cultural identity. The changing Arctic has the potential to deeply affect these relationships. The scientific collaborations between Indigenous peoples and researchers are critically important to both high-quality science, conservation, and arguably the survival of these human societies in a changing Arctic. (*Please note that the ARC2020 was altered by the COVID-19 pandemic; a planned essay on impacts of the changing Arctic to subsistence hunting from the viewpoints of Indigenous experts from two northwest Alaska communities had to be postponed to a future report.*)

We strongly urge continued monitoring of subsistence bowhead harvests, regular population size estimates, oceanographic sampling across their range, periodic aerial surveys, as well as health assessments based on the two harvested populations and beachcast whales whenever possible (Stimmelmayr et al. 2021). There is reason for concern due to rapid changes within the bowhead's range, but given their persistence through 4 million years of dramatic ecosystem change and intensive commercial harvests, there is also room for optimism about the future of bowhead whales, given reasonable conservation measures.

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November 17, 2020