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Bowhead Whales: Modern and Future Threats to Recovery

Abstract:

Bowhead whales (*Balaena mysticetus*) are the only baleen whale that maintains a permanent residence in the Arctic Ocean. The International Union for Conservation of Nature (IUCN) characterizes the species by four subpopulations: 1) Bering-Chukchi-Beaufort, 2) East Canada-West Greenland, 3) East Greenland-Svalbard-Barents Sea, and 4) Okhotsk Sea. Bowhead whales across the Arctic were the target of massive, pre-20th-century commercial whaling efforts that severely depleted their population. Bowhead whales are currently listed as a species of “Least Concern” by the IUCN; however, current and future threats have the potential to jeopardize full population recovery if left unchecked. Present-day threats to the recovering bowhead whale population include, but are not limited to, entanglement in fishing gear, vessel strikes, killer whale (*Orcinus orca*) predation, noise pollution, and polychlorinated biphenyls (PCBs). Future threats to bowhead populations mainly arise as consequences of global, anthropogenic climate change. Warming ocean temperatures threaten to alter their habitat along the ice edge, vary their prey distribution, and allow for killer whale populations to expand northward. Decreased sea ice extent in the Arctic Ocean will likely result in a higher probability of human-bowhead interaction as military operations, oil exploration expedition, industrial shipping vessels, and tourist excursions are allowed into this previously inaccessible area. International cooperation and mitigation of these threats are necessary to reduce the risk to recovering bowhead whales and the indigenous Inuit communities that still rely on them for subsistence hunting.

Introduction:

Bowhead whales (*Balaena mysticetus*) are unique in that they are the only baleen whale species that live in the Arctic year-round (Rugh et al., 2003). They are found only in the circumpolar area surrounding the North pole and are uniquely adapted to ice-filled environments; they possess the thickest blubber layer of any mammal, and their skulls can break through 30-60 cm of sea ice (Würsig & Clark 1993). Bowheads could live up to 200 years old and females reach reproductive maturity around 25 years of age, after which they birth calves every 3 to 4 years. The gestation period is 12 to 14 months and calves are weaned at an age of 9 to 12 months (Koski et al. 1993). Little is known about the seasonal movements of bowhead whales, but it is thought they survive at the ice edge in the winter and follow its retreat in the spring to productive feeding grounds (Ivashchenko and Clapham, 2010). The International Whaling Commission, the organization that manages legal whaling and whale conservation, distinguished five subpopulations of bowhead whales based on locations where they are found: 1) Bering-Chukchi-Beaufort, 2) Hudson Bay-Foxe Basin, 3) Baffin Bay-Davis Strait, 4) Svalbard-Barents Sea, and 5) Okhotsk Sea (Rugh et. al. 2003). Recent surveys revealing overlapping distributions coupled with a lack of genetic differences between populations led the International Union for Conservation of Nature (IUCN) to narrow its official distinction to four subpopulations: 1) Bering-Chukchi-Beaufort, 2) East Canada-West Greenland, 3) East Greenland-Svalbard-Barents Sea, and 4) Okhotsk Sea (Cooke and Reeves, 2018). The wide geographical distribution, and occasional overlapping, of the separate subpopulations results in certain bowheads being under the jurisdiction of different countries, each with potentially different conservation and management strategies. The IUCN lists the global bowhead population as of “Least Concern”, but has separate listings for specific subpopulations. All bowhead whales are protected from

modern commercial whaling due to the International Convention for the Regulation of Whaling (Cooke and Reeves, 2018); however, the same organization identified remaining threats included fishing gear entrapment, vessel strikes, killer whale predation, and pollution in the form of noise and of chemicals like polychlorinated biphenyls (PCBs). This paper examines the status of the four recognized subpopulations of bowhead whales, threats to their post-industrial whaling recovery as they relate to human activity and climate change, and the impacts of changing bowhead whale population dynamics as they relate to Arctic indigenous peoples.

Bowhead Subpopulation Assessment

Bering-Chukchi-Beaufort

This stock is one of two located in the Canadian Arctic and is the largest out of the four bowhead subpopulations. They feed on a large variety of pelagic organisms, mainly copepods and euphausiids, but also up to 60 other species (Lowry et al. 2004). Whales of this subpopulation migrate more than 3000 km between their summer grounds in the Beaufort Sea and their wintering grounds in the Bering Sea (Fig. 1). This subpopulation was nearly depleted by commercial whaling efforts lasting from 1848 to 1914, but is currently demonstrating a significant recovery (Rugh et al. 2003). Canada considers the Bering-Chukchi-Beaufort stock to be of “Special Concern” due to its elevated risk of reaching a “threatened” or “endangered” conservation designation in the near future.

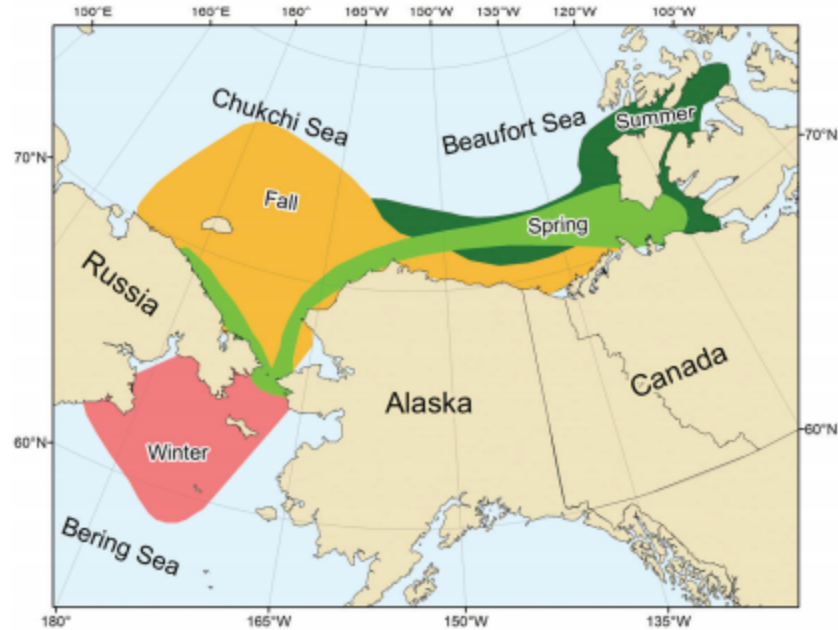


Fig 1. Seasonal range of the Bering-Chukchi-Beaufort bowhead whales. (George et al. 2017)

East Canada-West Greenland

Also located in the Canadian Arctic, this subpopulation was similarly subjected to extreme population declines as a result of commercial whaling. It is the second largest subpopulation, and there is speculation that it could be increasing slowly (Cooke and Reeves, 2018). Bowheads of this subpopulation feed on benthic organisms such as worms, as well as copepods, euphausiids, and mysids (Pomerleau et al. 2010). Norden Anderson et al. (2014) observed large numbers of individual whales in northern Disko Bay, Greenland, during the late winter and spring while they were documenting the vast abundance of benthopelagic and pelagic invertebrates in the area. This population is segregated mostly by age and sex; juveniles and females with calves often inhabit areas separate from males (Ferguson et al., 2010a). Females with calves are frequently sighted in Foxe Basin, indicating it may serve as a nursery. The ice cover in Foxe Basin is expansive enough to protect from predators such as the killer whale (*Orcinus orca*), but not so thick that it risks the entrapment of juvenile and newborn calves.

Similar to the Bering-Chukchi-Beaufort stock, this subpopulation is under Canadian jurisdiction and considered to be of “Special Concern”.

East Greenland-Svalbard-Barents Sea

This subpopulation is found from the east coast of Greenland across the Greenland, Barents, and the Kara Sea to Russia’s Severnaya Zemlya, with individuals usually venturing as south as northern Iceland (Cooke and Reeves, 2018). Thick, impassable sea ice in northern Greenland most likely keeps this subpopulation from intermingling with the East Canada-West Greenland subpopulation, but this is expected to change as sea ice extent continues its downward trend. This subpopulation was initially the largest, but was almost decimated by commercial whaling from 1611 to 1911 (Ross 1993). This subpopulation is listed as “Critically Endangered” in Norway (Henriksen and Hilmo 2015). The IUCN lists this stock as “Endangered” due to the number of mature individuals ranging only from 50 to 250 whales.

Okhotsk Sea

This southernmost stock of bowhead whales resides in eastern Russia, making it geographically and genetically separate from the others. Mainland Russia surrounds the Okhotsk Sea to the north and west, and the Kamchatka peninsula serves as an eastern border (Fig 2). Three major upwelling areas form in this region due to a cyclonic motion created by two main currents in the area: the northbound West Kamchatka Current and the southbound East Sakhalin current (Ivashchenko and Clapham, 2018). Upwelling regions are highly productive in planktonic and benthic organisms, and provide sustenance for this subpopulation. Much less is known about this group compared to the other subpopulations. In particular, the remote location and lack of large human settlements and facilities have made it challenging to conduct in-depth studies. Commercial whaling began in the Okhotsk Sea around 1846 and was dominated by

American, British, and French vessels (Ivashchenko and Clapham, 2010). It proceeded unchecked for twenty years, and by 1860 two hundred vessels were hunting in the Shantar area alone (Fig. 2). In 1967, USSR whalers hunted bowheads illegally in the Shantar region, and catch estimates during this time are unknown except for records indicating that 133 bowheads were killed by the Soviet fleet *Vladivostok* (Doroshenko 2000). This period of illegal hunting drained the already struggling subpopulation and further contributed to its decline. The lack of data on pre-whaling populations in this region, coupled with incomplete or altogether missing catch records, makes any population or catch estimate from this period fairly unreliable. The most popular population estimate is 6600 whales (Mitchell, 1977) which was calculated using average catch per vessel and extrapolating the total number of vessels operating in the Okhotsk Sea. This subpopulation has still not recovered and is listed as “Endangered” by the IUCN (Cooke and Reeves, 2018). The Red Data Book of the Russian Federation designates this subpopulation as Category 1, which is equivalent to an “endangered” listing (Shpak and Paramonov, 2018). Current abundance estimates place the population to be unknown (Ivashchenko and Clapham, 2018). Little is known about their winter distribution, and there is currently no evidence suggesting the whales leave the Okhotsk Sea at any time during the year. This subpopulation is particularly vulnerable to changing sea ice conditions due to their habitat being surrounded by land on three sides, which limits their potential for redistribution (Ivashchenko and Clapham, 2010). The IUCN estimates the number of mature whales to be 100-200 and that the population is experiencing a decreasing trend. Ivashchenko and Clapham (2010) urged that further status and conservation assessments are needed, but cannot be done without first discovering the exact preferred habitats of this stock within the Okhotsk Sea. This

subpopulation is the most understudied, and the most endangered, in the global bowhead whale distribution.

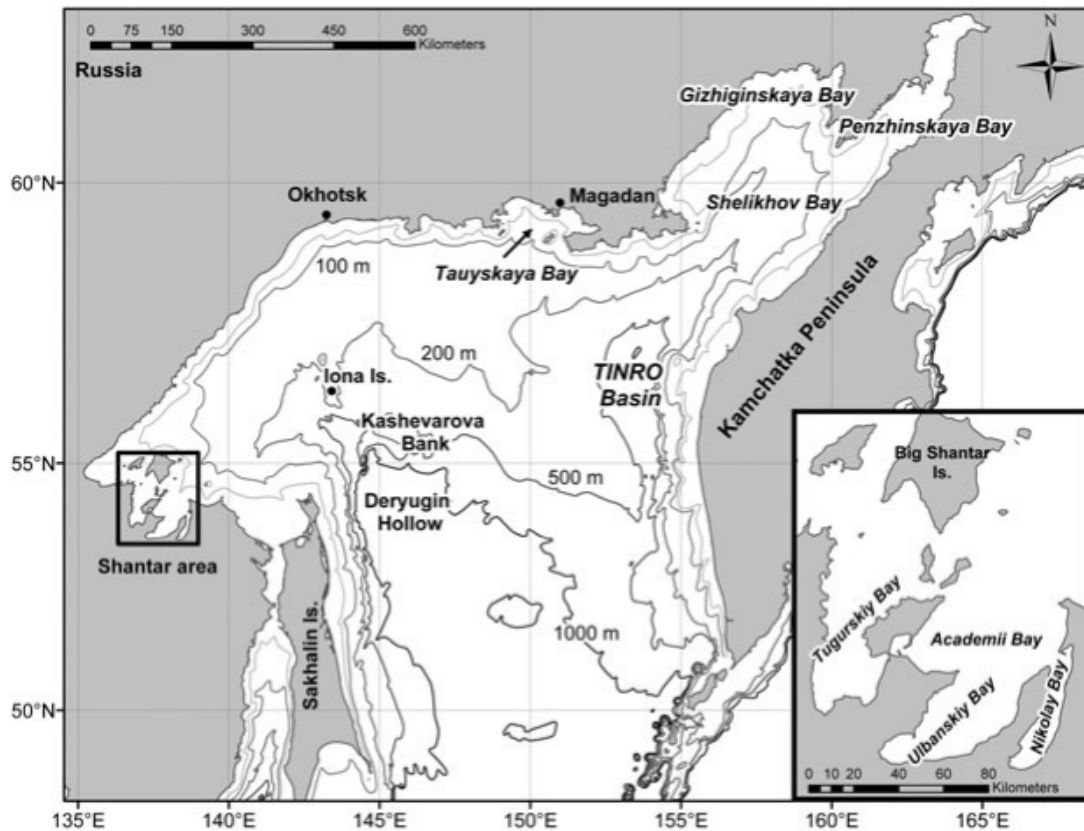


Figure 2. Geographical context of the Okhotsk Sea, with emphasis on the heavily-hunted Shantar area. (Ivashchenko and Clapham, 2018)

Cultural Significance

Arctic Inuit communities, particularly the Thule culture (about AD 1000-1600), relied on bowhead whales to survive for millennia (McCartney and Savelle, 1993). How the Thule and their ancestors moved from Alaska throughout the Eastern Arctic is often related to the bowhead hunt (McCartney and Savelle, 1993). Bowheads were essential to the Thule people for food and shelter; whale skulls and jaw bones were used as rafters for roof support, and the extremely strong lower mandible was cut to make durable sled runners. Studies of bones found at archaeological sites suggested the Thule targeted young whales for their smaller, more

manageable size (McCartney 1978). Bones were removed from Thule sites in Canada during the 1960s and 1970s due to a global interest in carved whalebone trinkets. McCartney (1978) estimated that 40 tons of whale bones per year were removed from archaeological sites between 1969 and 1973 for this purpose. Bowhead whales continue to be instrumental in the cultural and physical well-being of Arctic indigenous communities. The blubber, muscles, liver, heart, kidneys, diaphragm, tongue, and maktak (Greenlandic term for blubber attached to the skin) are utilized for consumption (Hoekstra et al. 2005). The whales provide essential nutrients such as omega-3 fatty acids and vitamins. Suk et al. (2004) observed increased health issues in indigenous populations that began to substitute traditional foods with imported ones such as diabetes, obesity, dental issues, and anemia, in addition to decreased physical activity and disease resistance. The acts of hunting, communal harvesting, and sharing the meat are a central component of the Arctic indigenous people's cultural and spiritual identity (Welfinger-Smith et al., 2011).

Threats

Climate Change

Since 1980, the average annual temperature increase over the Arctic Ocean has been twice as high as over the rest of the globe, and the amount of summer sea ice has hit record lows every year since 2001 (AMAP, 2011). Both factors are likely to impact bowhead whale habitat and distribution.

Warming ocean temperatures will likely lead to shifts in plankton concentration and distribution (Norden Anderson et al., 2014). Bowhead whale's dependence on zooplankton for nourishment could leave them vulnerable in warming Arctic waters. Their rapidly accumulated blubber reserves ensure warmth and energy throughout periods of food scarcity, but changes in

plankton communities could leave them unable to find sufficient amounts of food before their winter migration. Bowhead migrations tend to follow the oscillation of the sea ice edge, which will likely recede northward and impact the distribution of the species (Ferguson et al. 2010a.). In the winter bowhead whales reside in areas with decreased ice extent and thickness, possibly to avoid accidental entrapments in the winter months; conversely, in summer they seek out thicker ice margins to live by. Decreasing sea ice trends may also allow mixing between subpopulations, which would likely complicate conservation efforts due to management groups debating population designations.

A study performed by Chambault et al. (2018) uncovered an interesting relationship between warming ocean temperatures and bowhead whale distribution, and concluded that increased Arctic Ocean temperatures could be a physical threat to bowheads. Chambault et al. (2018) observed 98 bowhead whales using satellite tags from 2001 to 2011 in the East Canada-West Greenland region. The seasonal distribution of bowhead whales has been hypothesized to follow the ice front, but this study found a significant correlation with sea surface temperature (SST) trends instead. The trackers showed bowheads leaving Disko Bay during a period of warm-water inflow from the West Greenland current, which matches behavior observed in the Bering-Chukchi-Beaufort stock, who were thought to be avoiding the warm Alaskan Coastal Current (Citta 2017). The relationship of SST to bowhead distribution is further evidenced by the fact that the East Canada-West Greenland whales in Disko Bay leave *before* the zooplankton biomass maximum in spring, which contradicts the idea that their movements were dependent on food availability. Chambault et al. (2018) further hypothesized that this behavior is in avoidance of heat stress or hyperthermia due to the thick blubber layer bowheads possess. The shrinking of annual Arctic sea ice extent is already resulting in increasing numbers of industrial,

commercial, and tourist vessels in the area, suggesting an increased probability of contact between bowhead whales and people. Changes in sea ice extent will provide opportunities for other whale species to enter bowhead habitats and possibly lead to interspecies competition for resources (Ferguson et al., 2010a). Bowhead whales' sea ice habitat is expected to diminish as SST increases and sea ice extent decreases, leaving them more vulnerable to predation.

Fishing Gear Entrapment

Information regarding the risks of increased Arctic industrialization to bowhead whales is often derived from their near relatives: right whales (*Eubalaena glacialis*). The two species are remarkably similar in evolutionary history, physiology, behavior, and feeding and migration strategies (Reeves et al., 2012). Southern populations of right whales have been increasing, not unlike the Bering-Chukchi-Beaufort subpopulation of bowhead whales, due to their habitat being located in less industrial regions (Reeves et al., 2012). Northern right whales, unfortunately, live in heavily industrialized areas near eastern North America and are one of the most endangered whale populations in the world. Entanglement in derelict fishing gear has a massive effect on cetacean populations worldwide. Read et al. (2006) estimated global cetacean bycatch to be 307,753 individuals *annually*. Bowhead distribution in the Bering-Chukchi-Beaufort subpopulation overlaps with several Bering Sea pot fisheries both seasonally and geographically. This subpopulation overwinters in the Bering Sea during the American Snow Crab, St. Matthew Island blue king crab, and Pacific cod fisheries (Fig. 3). Citta et al. (2013) investigated the specifics of the overlap and found that although there was spatial overlap, no temporal overlap existed; therefore, they declared current bowhead mortality rates due to entanglement in fishing gear to be “negligible”. However, it is important to note there is no available data on Russian pot fisheries, which share a more extensive overlap with the bowhead subpopulation than American

pot fisheries; therefore, the authors suggested that continued monitoring be conducted for entangled whales and carcasses. The authors also cautioned that changing climate conditions could influence the distribution of both bowhead whales and the pot fishery target species, and possibly lead to an increase of entanglements.

George et al. (2017) examined records of 904 bowhead whales of the Bering-Chukchi-Beaufort subpopulation for evidence of scars or injuries from derelict fishing gear (Fig. 4). Indigenous communities sustainably harvested the bowheads from 1990 to 2012. The authors were particularly interested in commercial crab pots, which weigh up to 400 kg, due to their potential to leave deep scars (George et al. 2017). Such scars appear as approximately 0.5 m, nearly linear, cuts or scars located on the mouth, flippers, fluke, and peduncle (where the fluke connects to the body). George and colleagues found the majority of confirmed entanglements occurred around the peduncle and were a function of age and sex. Longer (therefore older) whales had more scars than shorter ones, and males were scarred more than females (juveniles rarely had scars). The authors estimated a scarring rate of 12.2% to use when comparing to other bowhead subpopulations. It is important to note this study cannot estimate mortality rates since the dataset is composed of bowhead whales landed as the result of a hunt. There is no way to know how many individuals may have died as a result of gear entanglement. “Ghost gear”, or fishing gear that has detached from a vessel but is still dangerous to marine organisms, may contribute to why so many whales have been observed with scars far from commercial fishing grounds. Both Citta et al. (2013) and George et al. (2017) called for increased international communications, particularly with Russian fishery managers, to better understand the possibility for spatial and temporal overlap between pot fisheries and the bowhead whales inhabiting the same distribution.

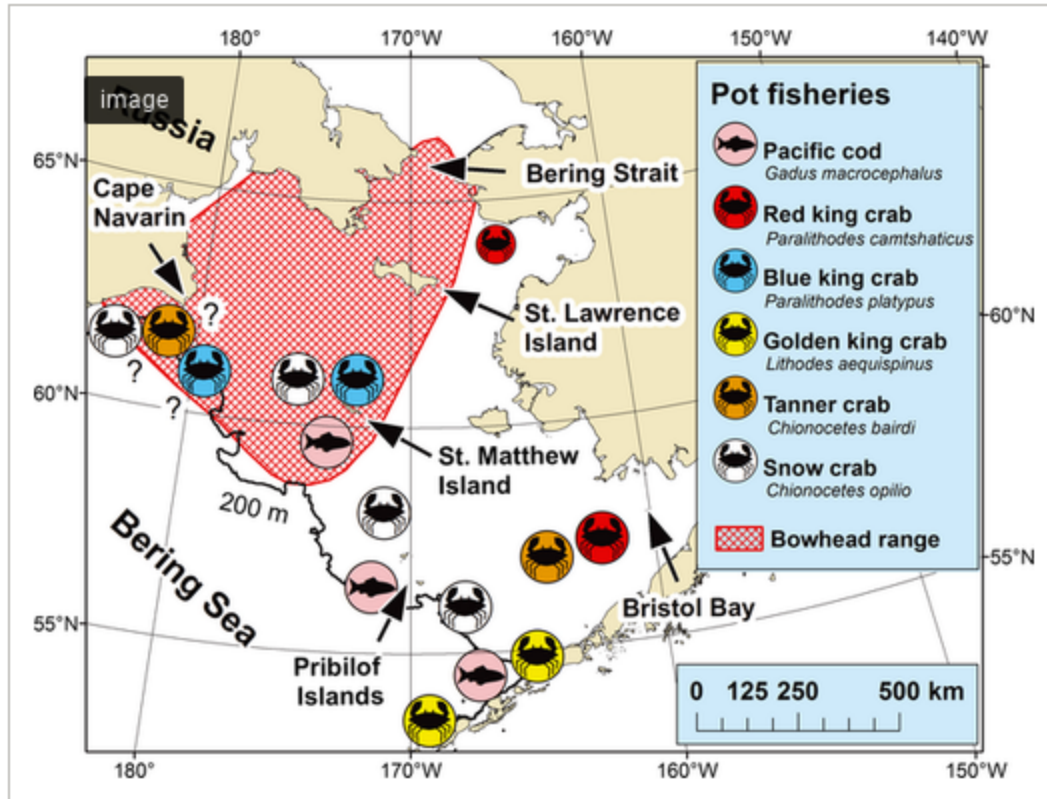


Figure 3. Locations of U.S. pot fisheries compared to the range of the Bering-Chukchi-Beaufort bowhead whales during winter months. (Citta et al. 2013)



Figure 4. Scarring from derelict fishing gear entanglement on adult female bowhead whale. Scars are located on the peduncle, just above the fluke. Photo is on a beach with people lingering in the background. Photo by G. Sheffield. (George et al. 2017)

Vessel Strikes

Reduced annual sea ice extent, and therefore more open water, has resulted in increased global shipping commerce in the Arctic Ocean, which is expected to develop further in the future (Ellis and Brigham, 2009). The Port of Nome, located in Alaska, saw dockings increase from 34 in 1990 to 301 in 2009 (Reeves et al., 2012). Vessels carrying materials such as oil, gas, coal, lead, and zinc from Arctic sources to southern refineries are increasing in number. To further complicate things, the increasingly accessible Arctic is of great interest to the tourism industry, international militaries, and various research operations. The industrialization of the Arctic is of great concern for those familiar with the plight of the previously mentioned Northern right whales, whose main habitat coincides with highly trafficked shipping lanes. Knowlton and Kraus (2001) found that vessel strikes are the most significant cause of fatalities among the endangered Northern right whale population, and they experience the highest rate of collisions of any whale species globally. Vessel strikes are typically fatal.

Two shipping routes are of great interest to participants in global maritime trade: the Northern Sea Route of Russia, and the Northwest Passage through the Canadian Arctic. The increased occurrence of industrial vessels in Arctic waters will likely pose a risk to bowhead whales. George et al. (2017) examined the 904 bowhead whales discussed in the previous section for evidence of vessel strikes (Fig. 5). They found only 10 whales (2% of the sample size) with such scars, and concluded ship strikes are rare in Alaska; however, it is important to note there is no way of estimating how many whales have died due to vessel strikes using the methods of this study. Maritime ship traffic is expected to increase as sea ice coverage decreases, so it could be expected that more vessel strike scars and fatalities will occur in bowhead whales. Reeves et al. (2012) recommended incentivizing completion of an Automatic Identification System (AIS)

receiver network. AIS transponders record the exact location and speed of vessels and would allow for comparisons with migration patterns of satellite-tagged bowhead whales. Installation of such a system could prompt the discovery of areas with high risk of vessel strikes, and allow for mitigation and revision of current strategies before bowhead injuries increase. The Bering Strait is an area of particular concern as the only waterway that provides a link between the Pacific and Arctic Oceans. It is likely to become a highly trafficked maritime corridor. The entirety of the Bering-Chukchi-Beaufort subpopulation of bowhead whales migrates through the Bering Strait twice a year, providing many chances for deadly encounters with vessels (Reeves et al., 2012). While it may not be possible to mitigate ship traffic through the Bering Strait since it is a necessary route for travel through the northern Pacific to the Arctic Ocean, ship speeds could be reduced to lower the risk of collisions with bowhead whales. Overall, the attempts to mitigate the dwindling Northern right whale population provides a clear example to those concerned about the industrialization of the Arctic; we should not make the same mistakes with Bowhead whales.



Figure 5. Vessel strike propeller scar on a legally harvested bowhead whale. Photo: Samarys Seguinot-Medina. (George et al. 2017)

Killer Whale Predation

Predation by killer whales could delay or jeopardize bowheads as they attempt to recover from commercial whaling. George et al. (2017) also looked for evidence of injuries from killer whale attacks in their study and found that 29 whales (7.9% of the sample size) exhibited “rake marks”, parallel and linear scars from killer whale teeth, on their flukes (Fig. 6). The probability of a killer whale attack during the years 2002-2012 was significantly higher than from 1990-2001, which corroborates accounts of a recent increase in predation on bowhead whales. These findings also agree with an earlier study done on the Eastern Canada-West Greenland subpopulation by Reinhart et al. (2013), which found a significant increase in scarring from killer whale predation attempts from 1986 to 2012. They identified rake marks on 61 of 598 whales, or 10.2% of the sample size. Recall that this only represents the portion of bowheads that survived such attacks. Reinhart et al. (2013) speculated that killer whale attacks on young Eastern Canada-West Greenland bowheads are more likely to be fatal, whereas larger (therefore older) whales have a greater occurrence of scars due to greater exposure to attacks over their lifetime. Increases in killer whale predation could be a result of their growing population size in the Arctic region or simply a greater occurrence of killer whales at high latitudes. It is also possible that longer periods of open water, such as those available in summer, provide increased hunting opportunities. More research is needed regarding killer whale’s foraging preferences, population size, and whether distinct stocks exist in the Arctic to fully understand the impacts killer whale predation has on the distribution and abundance of bowhead whales (Reinhart et al., 2013). Killer whales tend to avoid sea ice, possibly because it poses a risk of entrapment, so increased open water as ice extent decreases could lead to increased predation opportunities (Ferguson et

al., 2010a). Killer whale predation on bowhead whales could be inhibiting their recovery from industrial whaling.



Figure 6. “Rake mark scars” from a killer whale (*Orcinus orca*) on bowhead fluke, Foxe Basin. Photo: David Yurkowski. (Reinhart et al. 2013)

Pollution

For millennia the Arctic was a place free of anthropogenic sound (Reeves et al. 2012). Noise from seismic surveys during oil exploration has been observed to cause bowheads to flee from hunting areas, making Inuit hunting attempts less successful (Richardson et al., 1995). Such noise pollution disrupts the whale’s normal behavior and hinders efforts by indigenous peoples to obtain traditional foods. Modern oil exploration surveys are not the sole industrial threat to bowhead whales and Inuit communities: contaminants accumulating in whale blubber could pose a risk to indigenous peoples that consume the animals (Hoekstra et al. 2005). One example is polychlorinated biphenyls (PCBs), which are known to condense out of the atmosphere and deposit in the Arctic (Gouin et al. 2004). PCBs are persistent and do not break down quickly. They are also fat-soluble, which results in bioaccumulation in lipid-containing tissues (particularly blubber). Welfinger et al. (2011) conducted a study on the PCB concentrations in food consumed by the indigenous Yupik people of St. Lawrence Island, Alaska. Yupik

subsistence food is 88% to 94% marine mammal in the form of walrus, seals, and bowhead whales. The authors found that elevated PCB concentrations in food could lead to significantly higher cancer risk in the Yupik people. Relatively high levels of contaminants were found in bowhead whale blubber, which was particularly surprising as animals feeding at lower trophic levels do not usually accumulate such large concentrations. Longer exposure time as a result of the extremely old age of many bowheads may be the cause of the elevated contaminant levels. The United States Environmental Protection Agency publishes fish consumption guidelines to protect citizens from increased cancer risk from pesticides and PCBs. PCB levels that exceed 100 ppb fall under a recommendation to cease consumption immediately due to high cancer risk. Welfinger et al. (2012) found levels that far surpassed this limit in bowhead whales: 317.6 ppb in the blubber and 354.1 ppb in the rendered oil. These values correspond with a separate study by Hoekstra et al. (2005), who measured levels of 345 ppb in bowhead blubber. This study, when expanded to include the entirety of the Arctic region, suggests that all indigenous Arctic peoples who subsist primarily on hunting have a significantly increased risk of cancer due to the consumption of food that has accumulated high levels of contaminants.

Conclusion:

The distribution of bowhead whales in all four subpopulations is likely dictated by prey availability, the location of the ice front (seasonality), and sea surface temperature. Global climate change is predicted to alter all three of these factors, resulting in adverse outcomes for bowhead whales. Shifting currents and nutrient regimes could result in the redistribution of planktonic organisms essential to bowhead diets. Decreasing sea ice extent and the possibility of ice-free summers could result in drastic habitat change as well as intermingling between different subpopulations. Already, they have been observed abandoning plentiful feeding grounds in favor

of cooler waters. The decline in sea ice extent has also plunged the Arctic region into a global spotlight as a region to develop tourism, industrial shipping, and military operations. These activities significantly increase the risk of vessel strikes, noise pollution, and contaminant discharge. The rapid decline of the critically endangered Northern right whale illustrates the difficulty in re-establishing a population inhabiting heavily industrialized waters. Conservation and preservation measures should be drafted by each country whose waters hold a portion of a bowhead whale subpopulation in an effort to prepare for the inevitable commercialization of the Arctic Ocean. Although they are far from the critically endangered status of their Northern right whale cousins, it is evident that changing oceanographic conditions coupled with increased human activity in their habitat has the potential to set back or eliminate any recovery from the commercial whaling industry. Bowhead whales are a unique, Arctic-specific species that is under threat from our actions both presently and in the fast-approaching future; therefore, the time to prepare is now.

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