Revised 12/30/2015

BOWHEAD WHALE (*Balaena mysticetus*): Western Arctic Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Western Arctic bowhead whales are distributed in seasonally ice-covered waters of the Arctic and near-Arctic, generally north of 60°N and south of 75°N in the western Arctic Basin (Braham 1984, Moore and Reeves 1993). For management purposes, four stocks of bowhead whales have been recognized worldwide by the International Whaling Commission (IWC 2010). Small stocks, comprised of only a few tens to a few hundreds of individuals, occur in the Sea of Okhotsk and the offshore waters of Spitsbergen (Zeh et al. 1993, Shelden and Rugh 1995, Wiig et al. 2009). Bowheads occur in western Greenland (Hudson Bay and Foxe Basin) and eastern Canada (Baffin Bay and Davis Strait), and recent evidence suggests that these should be considered one stock based on genetics (Postma et al. 2006, Bachmann et al. 2010, Heide-Jørgensen et al. 2010, Wiig et al. 2010), aerial surveys (Cosens et al. 2006), and tagging data (Dueck et al. 2006; Heide-Jørgensen et al. 2006; IWC 2010, 2011). This stock, previously thought to include only a few hundred animals, may number over a thousand (Heide-Jørgensen et al. 2006, Wiig et al. 2011), and perhaps over 6,000 (IWC 2008). The only stock found within U.S. waters is the Western Arctic stock (Figs. 1 and 2), also known as the Bering-Chukchi-Beaufort stock (Rugh et al. 2003) or Bering Sea stock (Burns et al. 1993). Although Jorde et al. (2007) suggested there might be multiple stocks of bowhead whales in U.S. waters, several studies (George et al. 2007, Taylor et al. 2007, Rugh et al. 2009) and the IWC Scientific Committee concluded that data are most consistent with one stock that migrates throughout waters of northern and western Alaska (IWC 2008).

The majority of the Western Arctic stock migrates annually from wintering areas (December to March) in the northern Bering Sea, through the Chukchi Sea in the spring (April through May), to the eastern Beaufort Sea (Fig. 1) where they spend much of the summer (June through early to mid-October) before returning again to the Bering Sea (Fig. 2) in the fall (September through December) to overwinter (Braham et al. 1980, Moore and Reeves 1993, Quakenbush et al. 2010a). Some bowheads are found in the western Beaufort,

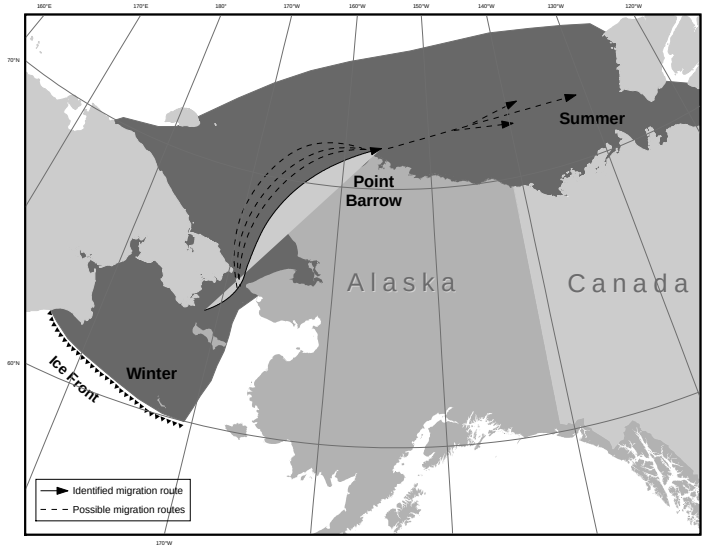

Figure 1. Dark areas depict the approximate distribution of the Western Arctic stock of bowhead whales. The spring migration represented here by lines and arrows follows a route from the Bering Sea wintering area to the Beaufort Sea summering area, mostly along a coastal tangent that constricts somewhat as it goes east past Point Barrow.

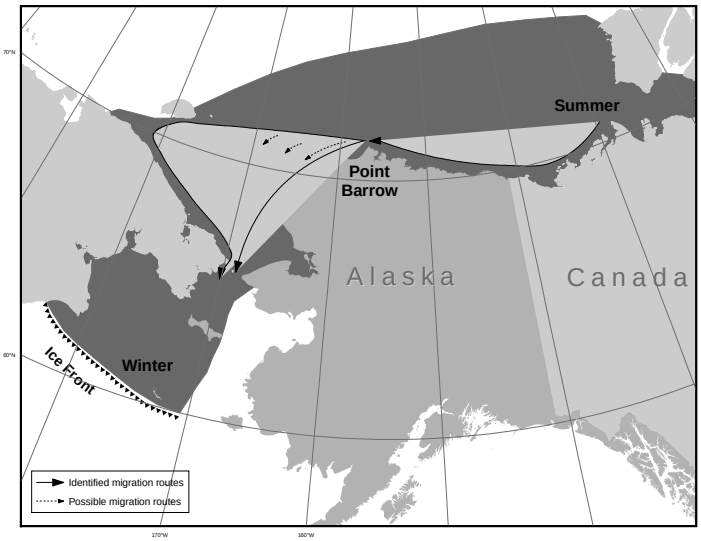

Figure 2. Dark areas depict the approximate distribution of the Western Arctic stock of bowhead whales. The fall migration is represented here by lines and arrows showing generalized routes used to travel from the Beaufort Sea (summering area) to the Bering Sea (wintering area).

Chukchi, and Bering seas in summer, and these are thought to be a part of the expanding Western Arctic stock (Rugh et al. 2003; Clarke et al. 2013, 2014).

During winter and spring, bowhead whales are closely associated with sea ice (Moore and Reeves 1993, Quakenbush et al. 2010a). The bowhead spring migration follows fractures in the sea ice around the coast of Alaska, generally in the shear zone between the shorefast ice and the mobile pack ice. During summer, most of the population is in relatively ice-free waters in the southeastern Beaufort Sea, an area often exposed to industrial activity related to petroleum exploration (e.g., Richardson et al. 1987, Davies 1997). Summer aerial surveys conducted in the western Beaufort Sea during July and August of 2012-2014 have had relatively high sighting rates of bowhead whales, including cows with calves and feeding animals (Clarke et al. 2013, 2014; NMML, unpubl. data, available online: http://www.afsc.noaa.gov/nmml/cetacean/bwasp/flights_2014.php, accessed December 2015). During the autumn migration through the Beaufort Sea, bowheads select shelf waters in all but "heavy ice" conditions, when they select slope habitat (Moore 2000). Heavy ice years in the autumn in the Beaufort Sea are becoming less common because of the retreat of Arctic sea ice. In winter in the Bering Sea, bowheads often use areas with ~100% sea-ice cover, even when polynas are available (Quakenbush et al. 2010a).

Evidence suggests that bowhead whales feed on concentrations of zooplankton throughout their range. Likely or confirmed feeding areas include Amundsen Gulf and eastern Canadian Beaufort Sea; central and western U.S. Beaufort Sea; Wrangel Island; and the coast of Chukotka, between Wrangel Island and the Bering Strait (Lowry et al. 2004; Ashjian et al. 2010; Clarke and Ferguson 2010a; Quakenbush et al. 2010a, 2010b; Okkonen et al. 2011; Clarke et al. 2012, 2013, 2014; NMML, unpubl. data, available online: http://www.afsc.noaa.gov/nmml/cetacean/bwasp/flights_2014.php, accessed December 2015). Bowheads have also been observed feeding during the summer in the northeastern Chukchi Sea (Clarke and Ferguson 2010b).

POPULATION SIZE

All stocks of bowhead whales were severely depleted during intense commercial whaling, starting in the early 16th century near Labrador (Ross 1993) and spreading to the Bering Sea in the mid-19th century (Braham 1984, Bockstoce and Burns 1993, Bockstoce et al. 2007). Woodby and Botkin (1993) summarized previous efforts to estimate bowhead population size prior to the onset of commercial whaling. They reported a minimum worldwide population estimate of 50,000, with 10,400-23,000 in the Western Arctic stock (dropping to less than 3,000 at the end of commercial whaling). Brandon and Wade (2006) used Bayesian model averaging to estimate that the Western Arctic stock consisted of 10,960 (9,190-13,950; 5th and 95th percentiles, respectively) bowheads in 1848 at the start of commercial whaling.

Since 1978, systematic counts of bowhead whales have been conducted from sites on sea ice near Point Barrow during the whales' spring migration (Krogman et al. 1989). These counts have been corrected for whales missed due to distance offshore (since the mid-1980s, using acoustical methods described in Clark et al. 1994), whales missed when no watch was in effect (through interpolations from sampled periods), and whales missed during a watch (estimated as a function of visibility, number of observers, and distance offshore; Zeh et al. 1993). A summary of the resulting abundance estimates is provided in Table 1 and Figure 3. These estimates of abundance have not been corrected for a small portion of the population that may not migrate past Point Barrow during

Table 1. Summary of abundance estimates for the Western Arctic stock of bowhead whales. The historical estimates were made by back-projecting using a simple recruitment model. All other estimates were developed by corrected ice-based census counts. Historical estimates are from Woodby and Botkin (1993); 1978-2001 estimates are from George et al. (2004) and Zeh and Punt (2004). The 2011 estimate is reported in Givens et al. (2013).

Year	Abundance estimate (CV)	Year	Abundance estimate (CV)
Historical estimate	10,400-23,000	1985	5,762 (0.253)
End of commercial whaling	1,000-3,000	1986	8,917 (0.215)
1978	4,765 (0.305)	1987	5,298 (0.327)
1980	3,885 (0.343)	1988	6,928 (0.120)
1981	4,467 (0.273)	1993	8,167 (0.017)
1982	7,395 (0.281)	2001	10,545 (0.128)
1983	6,573 (0.345)	2011	16,892 (0.058)

the period when counts are made. Attempts to count migrating whales near Point Barrow in 2009 and 2010 were unsuccessful due to sea ice conditions (IWC 2010, George et al. 2011) but were successful in 2011. The ice-based abundance estimate in 2001 was 10,545 (CV = 0.128) (updated from George et al. 2004 by Zeh and Punt 2004). The 2011 ice-based abundance estimate was 16,892 (95% CI: 15,074-18,928) (Givens et al. 2013).

Bowhead whales were identified from aerial photographs taken in 1985 and 1986, and the results were used in a sight-resight analysis. This approach provided estimates of 4,719 (95% CI: 2,382-9,343; SE 1,696) to 7,022 (95% CI: 4,701-12,561; SE 2,017), depending on the model used (daSilva et al. 2000). These population estimates and their associated error ranges are comparable to the estimates obtained from the combined ice-based visual and acoustic data for 1985 (6,039; SE 1,915) and 1986 (7,734; SE 1,450; Raftery and Zeh 1998). Aerial photographs provided another sampling of the bowhead population in 2003 and 2004. Sight-resight results provided estimates of 8,250 whales (95% CI: 3,150-15,450) in 2001 (Schweder et al. 2009) and 12,631 whales (95% CI: 7,900-19,700) in 2004 (Koski et al. 2010), which are consistent with trends in abundance estimates made from ice-based counts. An aerial photographic survey was conducted near Point Barrow concurrently with the ice-based spring census in 2011; these data are currently being analyzed to produce a revised abundance estimate based on sight-resight data (Mocklin et al. 2012).

Minimum Population Estimate

The minimum population estimate (N_{MIN}) for this stock is calculated from Equation 1 from the potential biological removal (PBR) guidelines (Wade and Angliss 1997): $N_{MIN} = N/\exp(0.842\times[\ln(1+[CV(N)]^2)]^{½})$. Using the 2011 population estimate (N) of 16,892 and its associated CV(N) of 0.058, N_{MIN} for the Western Arctic stock of bowhead whales is 16,091.

Current Population Trend

Based on concurrent passive acoustic and ice-based visual surveys, Givens et al. (2013) reported that the Western Arctic stock of bowhead whales increased at a rate of 3.7% (95% CI = 2.8-4.7%) from 1978 to 2011, during which time abundance tripled from approximately 5,000 to approximately 16,000 whales (Givens et al. 2013). Schweder et al. (2009) estimated the yearly growth rate to be 3.2% (95% CI = 0.5-4.8%) between 1984 and 2003 using a sight-resight analysis of aerial photographs.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

The current estimate for the rate of increase for this stock of bowhead whales (3.2-3.7%) should not be used as an estimate of (R_{MAX}) because the population is currently being harvested. It is recommended that the cetacean maximum theoretical net productivity rate (R_{MAX}) of 4% be used for the Western Arctic stock of bowhead whales (Wade and Angliss 1997).

POTENTIAL BIOLOGICAL REMOVAL

Under the 1994 reauthorized Marine Mammal Protection Act (MMPA), the PBR level is defined as the product of the minimum population estimate, one-half the maximum theoretical net productivity rate, and a recovery factor: $PBR = N_{MIN} \times 0.5R_{MAX} \times F_R$. The recovery factor ($F_R$) for this stock has been set at 0.5 rather than the default value of 0.1 for "endangered" species because population levels are increasing in the presence of a known take (see Wade and Angliss 1997, Pp. 27-28). Thus, PBR = 161 animals (16,091 × 0.02 × 0.5). The calculation of a PBR level for the Western Arctic bowhead stock is required by the MMPA even though the subsistence harvest quota is established under the authority of the IWC based on an extensively tested strike limit algorithm (IWC 2003). The quota is based on subsistence need or the ability of the bowhead population to sustain a harvest, whichever is smaller. The IWC bowhead whale quota takes precedence over the PBR estimate for the purpose of managing the Alaska Native subsistence harvest from this stock. For 2013-2018, the IWC established a block quota of 306 landed bowheads. Because some whales are struck and lost, a strike limit of 67 (plus up to 15 previously unused strikes) could be taken each year. This quota includes an allowance of five animals to be taken by Chukotka Natives in Russia. The 2013-2018 quota maintains the *status quo* of the previous 5-year block quota (2008-2012) but was extended for 6 years.

ANNUAL HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Fisheries Information

Detailed information (including observer programs, observer coverage, and observed incidental takes of marine mammals) for federally-managed and state-managed U.S. commercial fisheries in Alaska waters is presented in Appendices 3-6 of the Alaska Stock Assessment Reports.

Several cases of rope or net entanglement have been reported from whales taken in the subsistence hunt (Philo et al. 1993). Further, a thorough reexamination of bowhead harvest records is ongoing and there are preliminary indications that entanglements or scarring attributed to ropes may include over 20 cases (C. George, Department of Wildlife Management, North Slope Borough, pers. comm.).

There are no observer program records of bowhead whale mortality incidental to U.S. commercial fisheries in Alaska. However, some bowhead whales have historically had interactions with crab pot gear and fishing nets. One dead whale was found floating in Kotzebue Sound in early July 2010, entangled in crab pot gear similar to that used by commercial crabbers in the Bering Sea (Suydam et al. 2011; Table 2), and one entangled bowhead was photographed during the 2011 spring aerial photographic survey of bowhead whales near Point Barrow (Mocklin et al. 2012). More recently, Citta et al. (2014) found that the distribution of satellite-tagged bowhead whales in the Bering Sea spatially and temporally overlapped areas where commercial pot fisheries occurred and noted the potential risk of entanglement in lost gear. The minimum average annual mortality and serious injury rate in U.S. commercial fisheries in 2009-2013 is 0.2 whales; however, the actual rate is currently unknown.

Table 2. Summary of mortality and serious injury of the Western Arctic stock of bowhead whales, by year and type, reported to the NMFS Alaska Region, marine mammal stranding database, in 2009-2013 (Helker et al. 2015). Only cases of serious injury were recorded in this table; animals with non-serious injuries have been excluded.

Cause of injury	2009	2010	2011	2012	2013	Mean annual mortality
Entangled in unspecified pot gear	0	1	0	0	0	0.2

Alaska Native Subsistence/Harvest Information

Eskimos have been taking bowhead whales for subsistence purposes for at least 2,000 years (Marquette and Bockstoce 1980, Stoker and Krupnik 1993). Subsistence takes have been regulated by a quota system under the authority of the IWC since 1977. Alaska Native subsistence hunters, primarily from 11 Alaska communities, take approximately 0.1-0.5% of the population per annum (Philo et al. 1993, Suydam et al. 2011). Under this quota, the number of kills in any one year has ranged between 14 and 72. The maximum number of takes per year is set by the quota, which is itself determined by the subsistence need and the abundance and trend estimates (Stoker and Krupnik 1993). Suydam and George (2012) summarized Alaskan subsistence harvests of bowheads from 1974 to 2011 and reported a total of 1,149 whales landed by hunters from 12 villages, with Barrow landing the most whales (n = 590) and Shaktoolik landing only one. Alaska Natives landed 31 whales in 2009 (Suydam et al. 2010), 45 in 2010 (Suydam et al. 2011), 38 in 2011 (Suydam et al. 2012), 55 in 2012 (Suydam et al. 2013), and 46 in 2013 (George and Suydam 2014, Suydam et al. 2014). The number of whales landed at each village varies greatly from year to year, as success is influenced by village size and ice and weather conditions. The efficiency of the hunt (the percent of whales struck that are retrieved) has increased since the implementation of the bowhead quota in 1978. In 1978, the efficiency was about 50% and Suydam et al. (2014) reported that the current mean efficiency, from 2004 to 2013, is 77%.

Canadian and Russian Natives also take whales from this stock. Hunters from the western Canadian Arctic community of Aklavik harvested one whale in 1991 and one in 1996. No catches for Western Arctic bowheads were reported by either Canadian or Russian hunters for 2006-2007 (IWC 2008, 2009) or by Russia in 2009, 2011, and 2012 (IWC 2011, Ilyashenko 2013), but two bowheads were taken in Russia in 2008 (IWC 2010), two in 2010 (IWC 2012), and one in 2013 (Ilyashenko and Zharikov 2014). The average annual subsistence take (by Natives of Alaska, Russia, and Canada) during the 5-year period from 2009 to 2013 was 44 bowhead whales.

Other Mortality

Pelagic commercial whaling for bowheads was conducted from 1849 to 1914 in the Bering, Chukchi, and Beaufort seas (Bockstoce et al. 2007). During the first two decades of the fishery (1850-1870), over 60% of the estimated pre-whaling population was killed, and effort remained high into the 20th century (Braham 1984). It is

estimated that the pelagic whaling industry harvested 18,684 whales from this stock (Woodby and Botkin 1993). During 1848-1919, shore-based whaling operations (including landings as well as struck and lost estimates from the U.S., Canada, and Russia) took an additional 1,527 animals (Woodby and Botkin 1993). An unknown percentage of the animals taken by the shore-based operations were harvested for subsistence and not commercial purposes. Estimates of mortality likely underestimate the actual harvest as a result of under-reporting of the Soviet catches (Yablokov 1994) and incomplete reporting of struck and lost animals.

Transient killer whales are the only known predators of bowhead whales. In a study of marks on bowheads taken in the subsistence harvest, 4.1% to 7.9% had scars indicating that they had survived attacks by killer whales (George et al. 1994).

With increasing ship traffic and oil and gas activities in the Chukchi and Beaufort seas, bowheads may become increasingly at risk from ship strikes.

STATUS OF STOCK

Based on currently available data, the estimated annual mortality rate incidental to U.S. commercial fisheries (0.2) is not known to exceed 10% of the PBR (16.1) and, therefore, can be considered to be insignificant. The average annual level of human-caused mortality and serious injury (44) is not known to exceed the PBR (161) nor the IWC annual maximum strike limit (67). The Western Arctic bowhead whale stock has been increasing in recent years; the estimate of 16,892 from 2011 is between 31% and 170% of the pre-exploitation abundance (estimates ranging roughly from 10,000 to 55,000), and this stock may now be approaching its carrying capacity (Brandon and Wade 2004, 2006). However, the stock is classified as a strategic stock because the bowhead whale is listed as "endangered" under the U.S. Endangered Species Act (ESA) and is therefore also designated as "depleted" under the MMPA.

HABITAT CONCERNS

Vessel traffic in Arctic waters is increasing, largely due to an increase in oil and gas activities and commercial shipping. This increase in vessel traffic could result in an increased number of vessel collisions with bowhead whales (Huntington et al. 2015).

Increasing oil and gas development in the Arctic has led to an increased risk of various forms of pollution in bowhead whale habitat, including oil spills and other pollutants. Also of concern is noise produced by the increased number of seismic surveys and increased vessel traffic resulting from shipping and offshore energy exploration, development, and production operations. Evidence indicates that bowhead whales are sensitive to noise from offshore drilling platforms and seismic survey operations (Richardson and Malme 1993, Richardson 1995, Davies 1997) and that the presence of an active drill rig (Schick and Urban 2000) or seismic operations (Miller et al. 1999) may cause bowhead whales to avoid the activity. Studies in the 1980s indicated that bowheads reacting to seismic activity appeared to recover from behavioral changes within 30-60 minutes following the end of the activity (Richardson et al. 1986, Ljungblad et al. 1988). However, more recent monitoring studies of 3-D seismic exploration in the nearshore Beaufort Sea during 1996-1998 demonstrated that nearly all fall-migrating bowhead whales avoided an area within 20 km of an active seismic source (Richardson et al. 1999). Furthermore, the studies also suggested that the bowhead whales' offshore displacement may have begun roughly 35 km (19 nautical miles or 22 statute miles) east of the activity and may have persisted more than 30 km to the west (Richardson et al. 1999). Richardson et al. (1986) observed that feeding bowheads started to turn away from a 30-airgun array with a source level of 248 dB re 1 µPa at a distance of 7.5 km (4.7 mi) and swam away when the vessel was within about 2 km (1.2 mi); other whales in the area continued feeding until the seismic vessel was within 3 km (1.9 mi). More recent studies have similarly shown that feeding bowhead whales had a greater tolerance of higher sound levels than did migrating whales (Miller et al. 2005, Harris et al. 2007). Data from an aerial monitoring program in the Alaskan Beaufort Sea during 2006-2008 also indicated that bowheads feeding during late summer and autumn did not exhibit large-scale distribution changes in relation to seismic operations (Funk et al. 2010). This apparent tolerance, however, should not be interpreted to mean that bowheads are unaffected by the noise. Feeding bowheads may be so highly motivated to stay in a productive feeding area that they remain in an area with noise levels that could cause adverse physiological effects. They could be experiencing increased stress by staying in a location with very loud noise (MMS 2008). A recent study by Blackwell et al. (2015) found that bowheads react differently to different thresholds of seismic noise. At relatively low cumulative exposure levels (as soon as airguns were just detectable), bowhead whales almost doubled their call rates. Once cumulative exposure levels exceeded 127 dB re 1 μPa^2-s, call rates decreased. Bowheads went completely silent at received levels over 160 dB re 1 μPa^2-s. These authors note that the existence of two behavioral thresholds for calling by bowhead whales can explain results of previous studies that found variability in bowhead call rates in the presence or absence of airgun pulses (i.e., Greene et al. 1996).

Another concern for bowhead whales and other Arctic species is climate change, which is affecting high northern latitudes more than elsewhere. Climate projections for the next 50-100 years, produced by global climate models, consistently show a pronounced warming over the Arctic, accelerated sea-ice loss, and continued permafrost degradation (IPCC 2007, USGS 2011, Jeffries et al. 2014). Within the Arctic, some of the largest changes are expected to occur in the Bering, Beaufort, and Chukchi seas (Chapman and Walsh 2007, Walsh 2008). Ice-associated animals, such as the bowhead whale, may be sensitive to changes in Arctic weather, sea-surface temperatures, or sea-ice extent, and the concomitant effect on prey availability. Laidre et al. (2008) concluded that on a worldwide basis, bowhead whales were likely to be moderately sensitive to climate change based on an analysis of various life-history features that could be affected by climate. Currently, there are insufficient data to make reliable predictions of the effects of Arctic climate change on bowhead whales. George et al. (2006) showed that landed bowheads had better body condition during years of light ice cover. This, together with high calf production in recent years, suggests that the stock is presently tolerating recent trends in declining seasonal sea-ice coverage, volume, and duration.

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