Revised 11/30/2010

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 2010a). Single small stocks occur in the Sea of Okhotsk and the offshore waters of Spitsbergen, comprised of only a few tens to a few hundreds of individuals (Shelden and Rugh 1995, Wiig et al. 2009, Zeh et al. 1993). Until recently, available evidence indicated that only a few hundred bowheads were in the Western Greenland (Hudson Bay and Foxe Basin) and Eastern Canada (Baffin Bay and Davis Strait) stocks, but recent evidence suggests that these should be considered one instead of two stocks based on genetics (Postma et al. 2006; Heide-Jørgensen et al. 2010; Wiig et al. 2010; Bachmann et al. 2010), aerial surveys (Cosens et al. 2006), and tagging data (Dueck et al. 2006; Heide-Jørgensen et al. 2006), and the abundance may be over a thousand (Heide-Jørgensen et al. 2007), perhaps over 6,000 (IWC 2008a). The International Whaling Commission's Scientific Committee has agreed "to consider a single stock of bowhead whales in this [Eastern Canada and Western Greenland] region as the 'working hypothesis' while acknowledging that there is still some uncertainty about the population structure" (IWC 2010a). The only stock found within U. S. waters is the Western Arctic stock (Figs. 43 and 44), also known as the Bering-Chukchi-Beaufort stock (Rugh et al. 2003) or Bering Sea stock (Burns et al. 1993). Although Jorde et al. (2004) suggested there might be multiple stocks of bowhead whales in US waters, several studies (George et al. 2007, Rugh et al. 2009, Taylor et al. 2007) concluded that data are most consistent with one bowhead stock that migrates around northern and western Alaska waters (IWC 2008b).

The majority of the Western Arctic stock migrates annually from wintering areas (December to March) in the northern Bering

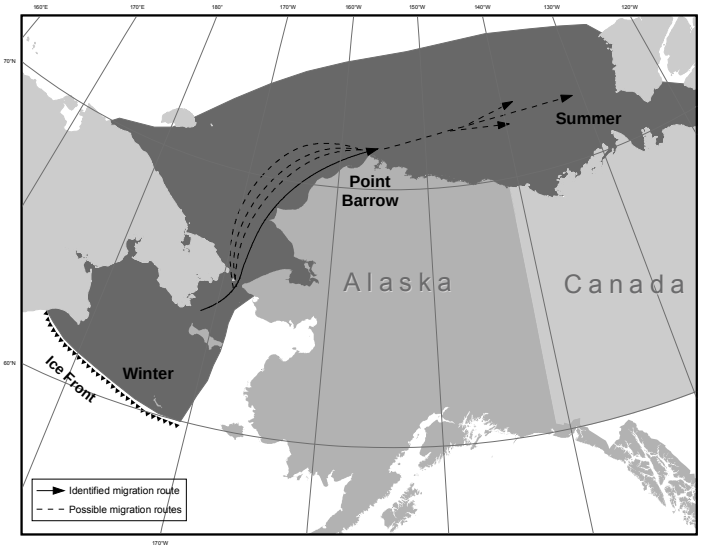


Figure 43. Dark areas depict the approximate distribution of the western Arctic stock of bowhead whales. The spring migration represented here by lines and arrows follows a route from the Bering Sea wintering area to the Beaufort Sea summering area, mostly along a coastal tangent that constricts somewhat as it goes east past Point Barrow.

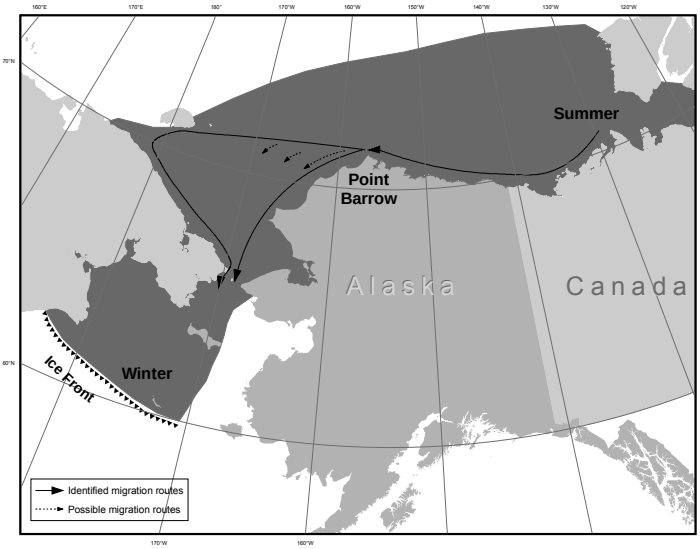


Figure 44. Dark areas depict the approximate distribution of the western Arctic stock of bowhead whales. The fall migration is represented here by lines and arrows showing generalized routes used to travel from the Beaufort Sea (summering area) to the Bering Sea (wintering area).

Sea, through the Chukchi Sea in the spring (April through May), to the Beaufort Sea (Fig. 43) where they spend much of the summer (June through August) before returning again to the Bering Sea (Fig. 44) in the fall (August through December) to overwinter (Braham et al. 1980, Moore and Reeves 1993, Quakenbush et al. 2010a). Some bowheads are found in the Chukchi and Bering Seas in summer, and these are thought to be a part of the expanding Western Arctic stock (Rugh et al. 2003).

Most of the year, 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 the summer, most of the population is in relatively ice-free waters in the southern Beaufort Sea, an area often exposed to industrial activity related to petroleum exploration and extraction (e.g., Richardson et al. 1987, Davies 1997). During the autumn migration, bowheads select shelf waters in all but "heavy ice" conditions, when they select slope habitat (Moore 2000). Bowheads on wintering grounds in the Bering Sea 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; Barrow; Wrangel Island; the coast of Chukotka, between Wrangel Island and the Bering Strait; the western Bering Sea; and the Alaskan Beaufort Sea (Quakenbush et al. 2010a, Quakenbush et al. 2010b, Lowry et al. 2004, Clarke and Ferguson 2010a, Ashjian et al. 2010). 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 approximate how many bowheads there were 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 (2004) used Bayesian model averaging to estimate that the Western Arctic stock consisted of 10,960 (9,190-13,950; 5th and 9th 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 north of Point Barrow during the whales' spring migration (Krogman et al. 1989). These counts have been corrected for whales missed due to distance offshore (through 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 42 and Figure 45. However, these estimates of abundance have not been corrected for a small portion of the population that may not migrate past Point Barrow during the period when counts are made. Attempts to count migrating whales near Point Barrow in 2009 and 2010 were unsuccessful due

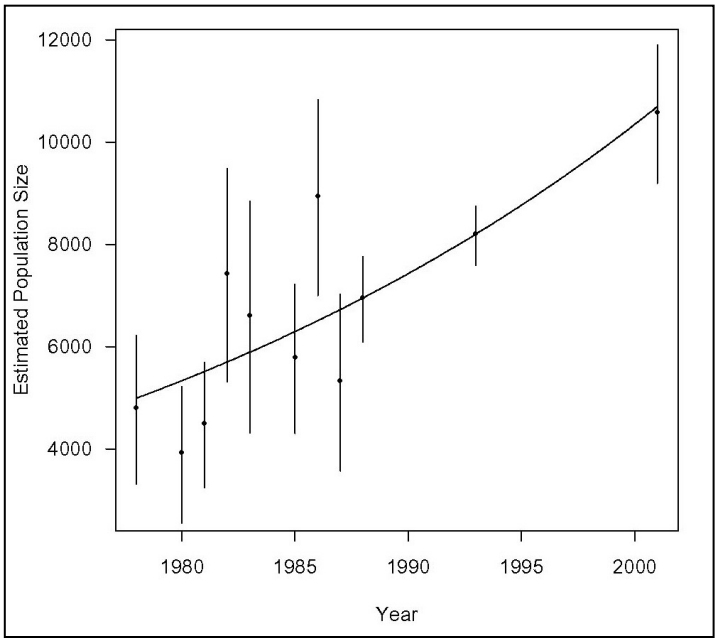
Table 42. Summary of population abundance estimates for the western Arctic stock of bowhead whales. The historical estimates were made by back-projecting using a simple recruitment model. All other estimates were developed by corrected ice-based census counts. Historical estimates are from Woodby and Botkin (1993); 1978-2001 estimates are from George et al. (2004) and Zeh and Punt (2004).

Year	Abundance estimate (CV)	Year	Abundance estimate (CV)
Historical estimate	10,400-23,000	1985	5,762 (0.253)
End of commercial whaling	1000-3000	1986	8,917 (0215)
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)		

to sea ice conditions, resulting in no new estimates of abundance (IWC 2010b). The most recent abundance estimate, based on surveys conducted in 2001, is 10,545 (CV = 0.128) (updated from George et al. 2004 by Zeh and Punt 2004).

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 to 15,450) in 2001 (Schweder et al. 2009) and 11,836 whales (95% CI: 6,795 to 20,618) in 2003-4 (Koski et al. 2008), estimates that are consistent with trends in abundance estimates made from ice-based counts.

Figure 45. Population abundance estimates for the western Arctic stock of bowhead whales, 1977-2001 (George et al. 2004), as computed from ice-based counts, acoustic locations, and aerial transect data collected during bowhead whale spring migrations past Barrow, AK. Vertical bars show +/- 1 standard error.



Minimum Population Estimate

The minimum population estimate (N_{MIN}) for this stock is calculated from Equation 1 from the PBR Guidelines (Wade and Angliss 1997): $N_{MIN} = N/\exp(0.842\times[\ln(1+[CV(N)]^2)]^{½})$. Using the 2001 population estimate (N) of 10,545 and its associated CV(N) of 0.128, N_{MIN} for the Western Arctic stock of bowhead whales is 9,472.

Current Population Trend

Based on concurrent passive acoustic and ice-based visual surveys, George et al. (2004) reported that the Western Arctic stock of bowhead whales has increased at a rate of 3.4% (95% CI = 1.7-5%) from 1978 to 2001, during which time abundance doubled from approximately 5,000 to approximately 10,000 whales. Similarly, Schweder et al. (2009) estimated the yearly growth rate to be 3.2% between 1984 and 2003 using a sight-resight analysis of aerial photographs. The count of 121 calves during the 2001 census was the highest yet recorded and was likely caused by a combination of variable recruitment and the large population size (George et al. 2004). The calf count provides corroborating evidence for a healthy and increasing population.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

The current estimate for the rate of increase for this stock of bowhead whales (3.2-3.4%) should not be used as an estimate of (R_{MAX}) because the population is currently being harvested and because the population has recovered to population levels where the growth is expected to be significantly less than R_{MAX}. It is recommended that the cetacean maximum theoretical net productivity rate (R_{MAX}) of 4% be used for the Western Arctic stock of bowhead whale (Wade and Angliss 1997).

POTENTIAL BIOLOGICAL REMOVAL

Under the 1994 reauthorized Marine Mammal Protection Act (MMPA), the potential biological removal (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 guidelines Wade and Angliss 1997). Thus, PBR = 95 animals (9,472 × 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 managed under the authority of the International Whaling Commission (IWC). Accordingly, 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 2008-2012, a block quota of 280 bowhead strikes has been allowed, of which 67 (plus up to 15 unharvested in the previous year) could be taken each year. This quota includes an allowance of 5 animals to be taken by Chukotka Natives in Russia.

ANNUAL HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Fisheries Information

Several cases of rope or net entanglement have been reported from whales taken in the subsistence hunt (Philo et al. 1993). Further, preliminary counts of similar observations based on reexamination of bowhead harvest records indicate entanglements or scarring attributed to ropes may include over 20 cases (Craig George, Department of Wildlife Management, North Slope Borough, pers. comm.).

There are no observer program records of bowhead whale mortality incidental to commercial fisheries in Alaska. However, some bowhead whales have historically had interactions with crab pot gear. There are several documented cases of bowheads having ropes or rope scars on them. Alaska Region stranding reports document three bowhead whale entanglements between 2001 and 2005. In 2003 a bowhead whale was found dead in Bristol Bay entangled in line around the peduncle and both flippers; the origin of the line is unknown. In 2004 a bowhead whale near Point Barrow was observed with fishing net and line around the head. The average annual entanglement rate in U.S. commercial fisheries is currently unknown.

Subsistence/Native 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 take approximately 0.1-0.5% of the population per annum, primarily from ten Alaska communities (Philo et al. 1993). Under this quota, the number of kills has ranged between 14 and 72 per year, the number depending in part on changes in management strategy and in part on higher abundance estimates in recent years (Stoker and Krupnik 1993). Suydam and George (2004) summarize Alaskan subsistence harvests of bowheads from 1974 to 2003 reporting a total of 832 whales landed by hunters from 11 villages with Barrow landing the most whales (n = 418) while Little Diomede and Shaktoolik each landed only one. Alaska Natives landed 55 bowheads in 2005 (Suydam et al. 2006), 31 in 2006 (Suydam et al. 2007), 41 in 2007 (Suydam et al. 2008), 38 in 2008 (Suydam et al. 2009), and 31 in 2009 (Suydam et al. 2010). 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%, the mean for 1999-2008 was 78% (SD=8%), and in 2009 it was 82% (Suydam et al. 2010).

Canadian and Russian Natives are also known to take whales from this stock. Hunters from the western Canadian Arctic community of Aklavik harvested one whale in 1991 and one in 1996. Eight whales were harvested by Russian subsistence hunters between 1999-2005 (Borodin 2004, 2005; IWC 2007). No catches were reported by either Canadian or Russian hunters for 2006-2007 (IWC 2008b) or by Russia in 2009 (IWC 2010b), but two bowheads were taken in Russia in 2008 (IWC 2009). The annual average subsistence take (by Natives of Alaska, Russia, and Canada) during the 5-year period from 2005 to 2009 was 39.6 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). Within the first two decades of the fishery (1850-1870), over 60% of the estimated pre-whaling abundance was harvested, although 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 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.

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 (9.5), and therefore can be considered to be insignificant. The annual level of human-caused mortality and serious injury (40) is not known to exceed the PBR (95) nor the IWC annual maximum quota (67). The Western Arctic bowhead whale stock has been increasing in recent years; the estimate of 10,545 is between 19% and 105% 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 Endangered Species Act and therefore also designated as "depleted" under the MMPA. NMFS intends to use recovery criteria developed for large whales in general (Angliss et al. 2002) and bowhead whales in particular (Shelden et al. 2001) in the next formal review of stock status.

Habitat Issues

Increasing oil and gas development in the Arctic has led to an increased risk of various forms of pollution to bowhead whale habitat, including oil spills, other pollutants, and nontoxic waste. Noise produced by increased vessel traffic resulting from exploration and drilling operations and shipping are also of concern. 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 vicinity. Figure 2b in Schick and Urban (2000) demonstrates, however, that the area of disturbance was localized in this instance. Studies conducted as part of a monitoring program for the Northstar project (a drilling facility located on an artificial island in the Beaufort Sea) indicate that in one of the three years of monitoring efforts, the southern edge of the bowhead whale fall migration path may have been slightly (2-3 mi) further offshore during periods when higher sound levels were recorded; there was no significant effect of noise detected on the migration path during the other two monitored years (Richardson et al. 2004). Evidence indicated that deflection of the southern portion of the migration in 2001 occurred during periods when there were certain vessels in the area and did not occur as a result of noise emanating from the Northstar facility itself. Because the bowhead whale population is approaching its pre-exploitation population size and has been documented to be increasing at a roughly constant rate for over 20 years, the impacts of oil and gas industry on individual survival and reproduction in the past have likely been minor. However, since 2006 there has been elevated interest in exploiting petroleum reserves in the seas around Alaska, including most areas where bowheads feed or migrate. The accumulation of impacts from vessels, seismic exploration, and drilling are of concern across the North Slope of Alaska and Canada.

Another concern is climate change in the Arctic, which is affecting high northern latitudes more than elsewhere. There is evidence of a shift in regional weather patterns in the Arctic region (Tynan and DeMaster 1997). Ice-associated animals, such as the bowhead whale, may be sensitive to changes in Arctic weather, sea-surface temperatures, or ice extent, and the concomitant effect on prey availability. Currently, there are insufficient data to make reliable predictions of the effects of Arctic climate change on bowhead whales. A study reported in 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 tolerating the recent ice-retreat at least at present.

On 22 February 2000, NMFS received a petition from the Center for Biological Diversity and Marine Biodiversity Protection Center to designate critical habitat for the Western Arctic bowhead stock. Petitioners asserted that the nearshore areas from the U. S.-Canada border to Barrow, Alaska, should be considered critical habitat. On 22 May 2001, NMFS found the petition to have merit (66 FR 28141). On 30 August 2002 (67 FR 55767), NMFS announced the decision to not designate critical habitat for this population. NMFS found that designation of critical habitat was not necessary because the population is known to be increasing and approaching its pre-commercial whaling population size, there are no known habitat issues that are slowing the growth of the population, and activities that occur in the petitioned area are already managed to minimize impacts to the population.

CITATIONS

Angliss, R. P., G. K. Silber, and R. Merrick. 2002. Report of a workshop on developing recovery criteria for large whale species. U. S. Dep. Commer., NOAA Tech. Memo. NMFS-OPR-21. 32 pp.

Ashjian, C.J., S. R. Braund, R. G. Campbell, J. C. George, J. Kruse, W. Maslowski, S. E. Moore, C. R. Nicolson, S. R. Okkonen, B. F. Sherr, E. B. Sherr, and Y. H. Spitz. 2010. Climate Variability, Oceanography, Bowhead Whale Distribution, and Iñupiat Subsistence Whaling near Barrow, Alaska. Arctic 63(2): 179-194.

Bachmann, L., Ø. Wiig, M. P. Heide-Jørgensen, K. L. Laidre, L. D. Postma, L. Dueck, and P. J. Palsbøl. 2010. Genetic diversity in Eastern Canadian and Western Greenland bowhead whales (*Balaena mysticetus*). Unpub. doc. Submitted to Int. Whal. Comm. (SC/62/BRG26). 6 pp.

Braham, H. W. 1984. The bowhead whale, *Balaena mysticetus*. Mar. Fish. Rev. 46(4):45-53.

Braham, H. W., M. A. Fraker, and B. D. Krogman. 1980. Spring migration of the western Arctic population of bowhead whales. Mar. Fish. Rev. 42(9-10):36-46.

Bockstoce, J. J., and J. J. Burns. 1993. Commercial whaling in the North Pacific sector. Pp. 563-577 *In* J. J. Burns, J.J Montague, and C.J. Cowles (eds.). The Bowhead Whale. Soc. Mar. Mammal., Spec. Publ. No. 2.

Bockstoce, J. R., D. B. Botkin, A. Philp, B. W. Collins, and J. C. George. 2007. The geographic distribution of bowhead whales (*Balaena mysticetus*) in the Bering, Chukchi, and Beaufort Seas: Evidence from whaleship records, 1849-1914. Mar. Fish. Rev. 67(3): 1-43.

Borodin, R. 2004. Subsistence whale harvest of the Russian Federation in 2003. Unpubl. report submitted to Int. Whal. Comm. (SC/56/BRG49). 7 pp.

Borodin, R. G. 2005. Subsistence gray and bowhead whaling by native people of Chukotka in 2004. Unpubl. doc. submitted to Int. Whal. Comm. (SC/57/BRG24). 6 pp.

Brandon, J., and P. R. Wade. 2004. Assessment of the Bering-Chukchi-Beaufort Seas stock of bowhead whales. Unpubl. report submitted to Int. Whal. Comm. (SC/56/BRG20). 32 pp.

Burns, J. J., J. J Montague, and C. J. Cowles (eds.). 1993. The Bowhead Whale. Soc. Mar. Mammal., Spec. Publ. No. 2. 787 pp.

Clark, C. W., S. Mitchell, and R. Charif. 1994. Distribution and behavior of the bowhead whale, *Balaena mysticetus*, based on preliminary analysis of acoustic data collected during the 1993 spring migration off Point Barrow, Alaska. Unpubl. doc. submitted to Int. Whal. Comm. (SC/46/AS19). 24 pp.

Clarke, J. T. and M. C. Ferguson. 2010a. Aerial Surveys for Bowhead Whales in the Alaskan Beaufort Sea: BWASP Update 2000-2009 with Comparisons to Historical Data. Unpubl. doc. Submitted to Int. Whal. Comm. (SC/62/BRG14).

Clarke, J. T. and M. C. Ferguson. 2010b. Aerial Surveys of Large Whales in the Northeastern Chukchi Sea, 2008-2009, with Review of 1982-1991 Data. Unpubl. doc. Submitted to Int. Whal. Comm. (SC/62/BRG13).

Cosens, S. E., H. Cleator, and P. Richard. 2006. Numbers of bowhead whales (*Balaena mysticetus*) in the Eastern Canadian Arctic, based on aerial surveys in August 2002, 2003 and 2004. Unpubl. paper submitted to the Scientific Committee of the Int. Whal. Comm. June 2006 (SC/58/BRG7). 19 pp.

daSilva, C. Q., J. Zeh, D. Madigan, J. Laake, D. Rugh, L. Baraff, W. Koski, G. Miller. 2000. Capture-recapture estimation of bowhead whale population size using photo-identification data. J. Cetacean Res. Manage. 2(1):45-61.

Davies, J. R. 1997. The impact of an offshore drilling platform on the fall migration path of bowhead whales: a GIS-based assessment. Unpubl. MS Thesis, Western Washington Univ., Bellingham, WA. 51 pp.

Dueck, L. P., M. P. Hiede-Jorgensen, M. V. Jensen, and L. D. Postma. 2006. Update on investigations of bowhead whale (*Balaena mysticetus*) movements in the eastern Arctic, 2003-2005, based on satellite-linked telemetry. Unpubl. paper submitted to the Scientific Committee of the Int. Whal. Comm. June 2006 (SC/58/BRG5). 17 pp.

George, J. C., C. Nicolson, S. Drobot, J. Maslanik, and R. Suydam. 2006. Sea ice density and bowhead whale body condition preliminary findings. Poster presented to the Society for Marine Mammalogy, San Diego, CA.

George, J. C., S. E. Moore, and R. Suydam. 2007. Summary of stock structure research on the Bering-Chukchi-Beaufort Seas stock of bowhead whales 2003-2007. Unpubl. report submitted to Int. Whal. Comm. (SC/59/BRG3). 15 pp.

George, J. C., J. Zeh, R. Suydam, and C. Clark. 2004. Abundance and population trend (1978-2001) of western arctic bowhead whales surveyed near Barrow, Alaska. Mar. Mammal Sci. 20:755-773.

Heide-Jørgensen, M. P., K. L. Laidre, M. V. Jensen, L. Dueck, L. D. Postma. 2006. Dissolving stock discreteness with satellite tracking: bowhead whales in Baffin Bay. Mar. Mamm. Sci. 22:34-45.

Heide-Jørgensen, M. P., K. Laidre, D. Borchers, F. Samarra, and H. Stern. 2007. Increasing abundance of bowhead whales in West Greenland. Biol. Lett. 3:577-580.

Heide-Jørgensen, M. P., K. L. Laidre, Ø. Wiig, and L. Dueck. 2010. Large scale sexual segregation of bowhead whales. Unpub. doc. Submitted to Int. Whal. Comm. (SC/62/BRG23). 13 pp.

International Whaling Commission. 2007. Report of the Scientific Committee. Annex F. Report of the sub-Committee on bowhead, right and gray whales. J.Cetacean Res. Manage. (Suppl.) 9:142-155.

International Whaling Commission. 2008a. Report of the Scientific Committee. J. Cetacean Res. Manage. (Suppl.) 10:1-74.

International Whaling Commission. 2008b. Report of the Scientific Committee. Annex F. Report of the sub-committee on bowhead, right and gray whales. 25 pp.

International Whaling Commission. 2009. Report of the Scientific Committee. (IWC/61/Rep 1) 108 pp.

International Whaling Commission, 2010a. Report of the Scientific Committee. (IWC/62/Rep 1) 91 pp.

International Whaling Commission, 2010b. Report of the Scientific Committee. Annex F. Report of the sub-committee on bowhead, right and gray whales. 16 pp.

Jorde, P.E., T. Schweder, and N.C. Stenseth. 2004. The Bering-Chukchi-Beaufort stock of bowhead whales: one homogeneous population? Unpubl. report submitted to Int. Whal. Comm. (SC/56/BRG36) 21 pp.

Koski, W., J. Mocklin, A. Davis, J. Zeh, D. Rugh, J.C. George, and R. Suydam. 2008. Preliminary estimates of 2003-2004 Bering-Chukchi-Beaufort bowhead whale (*/Balaena mysticetus/*) abundance from photo-identification data. Unpubl. report submitted to Int. Whal. Commn. (SC/60/BRG18). 7pp.

Krogman, B., D. Rugh, R. Sonntag, J. Zeh, and D. Ko. 1989. Ice-based census of bowhead whales migrating past Point Barrow, Alaska, 1978-1983. Mar. Mammal Sci. 5:116-138.

Lowry, L. F., Sheffield, G., and George, J. C. 2004. Bowhead whale feeding in the Alaskan Beaufort Sea, based on stomach contents analyses. J. Cetacean Res. Manage. 6(3):215-223.

Marquette, W. M., and J. R. Bockstoce. 1980. Historical shore-based catch of bowhead whales in the Bering, Chukchi, and Beaufort Seas. Mar. Fish. Rev. 42(9-10):5-19.

Miller, G. W., R. E. Elliot, W. R. Koski, V. D. Moulton, and W. J. Richardson. 1999. Whales. *In* W. J. Richardson (ed.). Marine Mammal and Acoustical Monitoring of Western Geophysical's Open-Water Seismic Program in the Alaskan Beaufort Sea, 1998.

Moore, S. E. 2000. Variability in cetacean distribution and habitat section in the Alaskan Arctic, autumn 1982-91. Arctic. 53(4):448-460.

Moore, S. E. 1992. Summer records of bowhead whales in the northeastern Chukchi Sea. Arctic. 45(4):398-400.

Moore, S. E., and R. R. Reeves. 1993. Distribution and movement. Pp. 313-386 *In* J. J. Burns, J. J. Montague, and C. J. Cowles (eds.), The bowhead whale. Soc. Mar. Mammal., Spec. Publ. No. 2.

Philo, L. M., E. B. Shotts, and J. C. George. 1993. Morbidity and mortality. Pp. 275-312 *In* J. J. Burns, J. J. Montague, and C. J. Cowles (eds.), The bowhead whale. Soc. Mar. Mammal., Spec. Publ. No. 2.

Postma, L. D., L.P, Dueck, M.P. Heide-Jorgensen, and S.E. Cosens. 2006. Molecular genetic support of a single population of bowhead whales (*Balaena mysticetus*) in Eastern Canadian Arctic and Western Greenland waters. Unpubl. paper submitted to the Scientific Committee of the Int. Whal. Comm. June 2006 (SC/58/BRG4). 15 pp.

Quakenbush, L.T., R.J. Small, and J.J. Citta. 2010a. Satellite tracking of Western Arctic bowhead whales. Unpubl. report submitted to the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE 2010-033).

Quakenbush, L.T., J.J. Citta, J.C. George, R.J. Small, and M.P. Heide-Jørgensen. 2010b. Fall and Winter Movements of Bowhead Whales (*Balaena mysticetus*) in the Chukchi Sea and Within a Potential Petroleum Development Area. Arctic 63(3): 289-307.

Raftery, A. and J. Zeh. 1998. Estimating bowhead whale population size and rate of increase from the 1993 census. J. Am. Stat. Assoc. 93:451-463.

Richardson, W. J. 1995. Documented disturbance reactions. Pp. 241-324 *In* W. J. Richardson, C. R. Greene, C. I. Malme, and D. H. Thomson (eds.), Marine mammals and noise. Academic Press, San Diego, CA.

Richardson, W. J., and C. I. Malme. 1993. Man-made noise and behavioral responses. Pp. 631-700 *In* J.J. Burns, J.J. Montague, and C. J. Cowles (eds.). The Bowhead Whale. Soc. Mar. Mammal., Spec. Publ. No. 2.

Richardson, W. J., R. A. Davis, C. R. Evans, D. K. Ljungblad, and P. Norton. 1987. Summer distribution of bowhead whales, *Balaena mysticetus*, relative to oil industry activities in the Canadian Beaufort Sea, 1980-84. Arctic 40 (2):93-104.

Richardson, W. J., T. L. McDonald, C. R. Greene, and S. B. Blackwell. 2004. Acoustic localization of bowhead whales near Northstar, 2001-2003: Evidence of deflection at high-noise times? Chapter 8 *In* W. J. Richardson and M. T. Williams (eds.). 2004. Monitoring of industrial sounds, seals, and bowhead whales near BP's Northstar oil development, Alaskan Beaufort Sea, 1999-2003. Rep. from LGL Ltd (King City, Ont.), Greenridge Science Inc (Santa Barbara, CA), and WEST Inc. (Cheyenne, WY) for BP Explor. (Alaska) Inc., Anchorage, AK.

Ross, W. G. 1993. Commercial whaling the North Atlantic sector. Pp. 511-561 *In* J.J. Burns, J.J. Montague, and C.J. Cowles (eds.). The Bowhead Whale. Soc. Mar. Mammal., Spec. Publ. No. 2.

Rugh, D., D. DeMaster, A. Rooney, J. Breiwick, K. Shelden, and S. Moore. 2003. A review of bowhead whale (*Balaena mysticetus*) stock identity. J. Cetacean Res. Manage. 5(3): 267-279.

Rugh, D., W. Koski, J. George, and J. Zeh. 2009. Interyear re-identification of bowhead whales during their spring migration past Barrow, Alaska, 1984-1994. J. Cetacean Res. Manage. 10(3):195–200.

Schick, R. S., and D. L. Urban. 2000. Spatial components of bowhead whale (*Balaena mysticetus*) distribution in the Alaskan Beaufort Sea. Can. J. Fish. Aquat. Sci. 57:2193-2200.

Schweder, T., D. Sadykova, D. Rugh, and W. Koski. 2009. Population estimates from aerial photographic surveys of naturally and variably marked bowhead whales. J. Agric. Biol. Environ. Stat. 15(1):1-19.

Shelden, K. E. W., D. P. DeMaster, D. J. Rugh, and A. M. Olson. 2001. Developing classification criteria under the U.S. Endangered Species Act: Bowhead whales as a case study. Conserv. Biol. 15(5):1300-1307.

Shelden, K. E. W., and D. J. Rugh. 1995. The bowhead whale (*Balaena mysticetus*): status review. Mar. Fish. Rev. 57(3-4):1-20.

Stoker, S. W., and I. I. Krupnik. 1993. Subsistence whaling. Pp. 579-629 *In* J. J. Burns, J. J. Montague, and C. J. Cowles (eds.), The bowhead whale. Soc. Mar. Mammal., Spec. Publ. No. 2.

Suydam, R. S., and George, J.C. 2004. Subsistence harvest of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos, 1974 to 2003. Unpubl. report submitted to Int. Whal. Comm. (SC/56/BRG12). 12 pp.

Suydam, R. S., J. C. George, C. Hanns and G. Sheffield. 2005. Subsistence harvest of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos during 2004. Unpubl. report submitted to Int. Whal. Comm. (SC/57/BRG15). 5 pp.

Suydam, R. S., J. C. George, C. Hanns and G. Sheffield. 2006. Subsistence harvest of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos during 2005. Unpubl. report submitted to Int. Whal. Comm. (SC/58/BRG21). 6 pp.

Suydam, R., J. C. George, C. Rosa, B. Person, C. Hanns, G. Sheffield, and J. Bacon. 2007. Subsistence harvest of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos during 2006. Unpubl. report submitted to Int. Whal. Comm. (SC/59/BRG4). 7 pp.

Suydam, R., J. C. George, C. Rosa, B. Person, C. Hanns, G. Sheffield, and J. Bacon. 2008. Subsistence harvest of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos during 2007. Unpubl. report submitted to Int. Whal. Commn. (SC/60/BRG10). 7 pp.

Suydam, R., J. C. George, C. Rosa, B. Person, C. Hanns, G. Sheffield, and J. Bacon. 2009. Subsistence harvest of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos during 2008. Unpubl. report submitted to Int. Whal. Commn. (SC/61/BRG6). 6 pp.

Suydam, R., J. C. George, C. Rosa, B. Person, C. Hanns, and G. Sheffield. 2010. Subsistence harvest of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos during 2009. Unpubl. doc. submitted to Int. Whal. Commn. (SC/62/BRG18). 7 pp.

Taylor, B., R. LeDuc, J. C. George, R. Suydam, S. Moore, and D. Rugh. 2007 Synthesis of lines of evidence for population structure for bowhead whales in the Bering-Chukchi-Beaufort region. Unpubl. report submitted to Int. Whal. Comm (SC/59/BRG35). 12 pp.

Tynan, C. T., and D. P. DeMaster. 1997. Observations and predictions of Arctic climate change: potential effects on marine mammals. Arctic 50(4):308-322.

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

Wiig, Ø., L. Bachmann, N. Øien, K. M. Kovacs, and C. Lydersen. 2009. Observations of bowhead whales (*Balaena mysticetus*) in the Svalbard area 1940-2008. Unpubl. report submitted to Int. Whal. Comm. (SC/61/BRG2) 5pp.

Wiig, Ø., L. Bachmann, M.P. Heide-Jørgensen, K.L. Laidre, L.D. Postma, L. Dueck, and P.J. Palsbøl. 2010. Within and between stock re-identification of bowhead whales in Eastern Canada and West Greenland. Unpub. Doc. Submitted to Int. Whal. Comm. (SC/62/BRG25). 7 pp.

Woodby, D. A., and D. B. Botkin. 1993. Stock sizes prior to commercial whaling. Pp. 387-407 *In* J. J. Burns, J. J. Montague, and C. J. Cowles (eds.), The bowhead whale. Soc. Mar. Mammal., Spec. Publ. No. 2.

Yablokov, A. V. 1994. Validity of whaling data. Nature 367:108.

Zeh, J. E., and A. E. Punt. 2004. Updated 1978-2001 abundance estimates and their correlations for the Bering-Chukchi-Beaufort Seas stock of bowhead whales. Unpubl. report submitted to Int. Whal. Comm. (SC/56/BRG1). 10 pp.

Zeh, J. E., C. W. Clark, J. C. George, D. E. Withrow, G. M. Carroll, and W. R. Koski. 1993. Current population size and dynamics. Pp. 409-89 *In* J.J. Burns, J.J. Montague, and C.J. Cowles (eds.). The Bowhead Whale. Soc. Mar. Mammal., Spec. Publ. No. 2.