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2018-2019 Health report for the Bering-Chuckchi-Beaufort Seas bowhead whales preliminary findings

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INTERNATIONAL WHALING COMMISSION

2018-2019 HEALTH REPORT FOR THE BERING-CHUKCHI-BEAUFORT SEAS BOWHEAD WHALES – PRELIMINARY FINDINGS

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ABSTRACT

At the 2016 IWC Scientific Committee meeting, it was agreed that an annual or bi-annual report on the Bering-Chukchi-Beaufort Seas (BCB) bowhead whale stock would be submitted that summarizes various health-related data. This summary is intended to be helpful for providing ancillary but pertinent information for informing management recommendations and tracking the status of the BCB stock. This report is the 3rd of the series and summarizes general information on population indices, whale health and hunter observations of bowhead whales for 2018 and 2019. We provide new information on *(1) population size and trends, (2) adult survival rate, (3) acoustic index of relative abundance of migrating whales, (4) distribution and migration, (5) calf production (aerial surveys), (6) pregnancy rates of landed adult females, (6) body condition and whale lice burden of landed whales, (7) proportion of landed whales showing evidence of feeding, (8) proportion of landed whales with injuries consistent with line entanglement, killer whale attacks and/or ship strikes, (9) non-harvest related mortality of bowhead whales, (10) pathological findings from postmortem examinations of landed whales, and (11) hunter observations.* The various indices suggest that the bowhead population remains robust and the subsistence harvest sustainable. We will continue to monitor these indices in the coming years.

INTRODUCTION

At the 2016 IWC Scientific Committee meeting, it was agreed that an annual or bi-annual report on the BCB bowhead whale (*Balaena mysticetus*) stock would be submitted by the North Slope Borough and collaborators that summarizes various health-related data (George et al. 2016). This summary is intended to be helpful for providing ancillary but pertinent information for informing management recommendations and tracking the status of the BCB stock (IWC 2018). This report is the 3rd of the series (George et al. 2017a; Stimmelmayr et al. 2018) and summarizes general information on population indices, distribution and migration, whale health and hunter observations of bowhead whales. Taken together these different metrics provide timely information on bowhead whale resilience in an era of rapid ecosystem alteration (Moore and Reeves 2018).

Population Size and Trend, Adult Survival Rate

Bowhead whales migrate during spring along Alaska's northeastern Chukchi coast where a long time series exists of ice-based abundance estimates dating from 1978. Until 2019, the best and most recent estimate had been that of Givens et al. (2016), who estimated the 2011 abundance estimate for BCB bowhead whales at 16,820 (95% CI: 15,176 to 18,643), and a long-term (1978-2011) estimated annual rate of population increase of 3.7% (2.9% to 4.6%). This 2011 survey used an ice-based visual and acoustic design. Analysis of a fully independent aerial photoID- based survey conducted in 2011 produced an estimate for 2011 of 18,797 (95% CI: 12,403 to 28,486) (Givens et al. 2018).

In 2019, two independent abundance surveys were undertaken. The first was an ice-based visual survey during spring using the same approach used in many past years. A Horvitz-Thompson-type estimator was used to estimate population abundance from the resulting data, correcting for detection probabilities, whale availability within visual range, and whale passage during periods of missed effort (see Givens et al. 2020). Analytical methods mirrored those used by Givens et al. (2016) for the 2011 survey as much as possible; however, unlike 2011, no simultaneous acoustic monitoring was conducted in 2019. Instead, an availability correction factor was estimated from past years. The estimated abundance was 12,505 with 95% confidence interval of (7,994, 19,560) and a CV of 0.228 (Givens et al. 2020). This estimated abundance is markedly lower than the 2011 estimate of 16,820, but the 2019 confidence interval wholly encompasses the 2011 interval. Givens et al. (2020) do not interpret this finding as evidence of a decline for many reasons including: highly unusual ice conditions, an unusual migration route that was sometimes too distant from observers to detect whales, failure to conduct watch because of closed leads during the early weeks of the migration when numerous whales likely passed, an unusually short perch, and hunters' frequent use of powered skiffs near the observation perch which likely deflected the whales during the survey.

The second survey was conducted by the Aerial Survey for Arctic Marine Mammals (ASAMM) Bowhead Abundance (ABA) line-transect surveys conducted in August 2019. The study area extended from 117°W-158°W. The study area focused on the Beaufort Sea shelf and Amundsen Gulf, with secondary priorities west of Banks Island and in Viscount Melville Sound. The spatial and temporal scope were chosen to coincide with the time period when the majority of the

BCB bowhead whale stock is believed to be in a region that could be effectively surveyed using aerial line-transect methods. Based on those surveys Ferguson (2020) estimated the abundance of the BCB bowhead whales in 2019 to be 14,531whales (CV = 0.540; bootstrap 95% CI [7,968, 29,376]). The two 2019 estimates provide an update of the abundance of BCB bowhead whales as required by the IWC's Aboriginal Whaling Scheme (IWC 2018). It would be valuable to conduct another ice-based survey when practicable as the ice-based survey appeared to be biased low.

Adult Survival Rate

We previously reported on an estimate of adult survival rate based on the 2011 photoID analysis that uses photo matches of re-identified whales as far back as 1985 (2018). The estimated survival rate was 0.996 (with an approximate lower confidence bound of 0.976). This estimate is consistent with previous ones and with other research showing that bowhead lifespans can be very long (George et al. 1999; Rosa et al. 2013; Borchman et al. 2017).

Acoustic Index

Spring short-term moorings

In 2018 we deployed a mooring that was likely behind grounded ice and therefore the sound quality was poor. Analysis of these data is on-going. In 2019 we deployed two acoustic moorings in late March to record the bowhead whale migration. Unfortunately, one was flattened by a pack-ice shove event (or *Ivu*; Inupiat) and despite numerous dragging attempts it was not recovered. The other mooring did not respond when the acoustic release was queried.

Short-term hydrophone data

From 21 March to 7 May 2019 ~104 h of acoustic data were collected. 102 hours were collected by deploying a "soundtrap" from the ice edge and 2 hours from dipping hydrophone recordings. The first acoustic data were collected on 22 March but no bowheads were recorded. Faint and distant bowhead whales were recorded on the 7th and 8th of April. The first loud singing was recorded on 15 April 2019. By 6 and 7 May (the last dates that the ice was sufficiently safe to make recordings), only faint bowhead whale calls were heard, no songs. Throughout the month of April and the first week of May, bearded seals and beluga whales were commonly heard.

2019 Distribution and Migration

Summary of Bowhead Whale Distribution and Migration from the Aerial Surveys of Arctic Marine Mammals Project (ASAMM)

Bowhead whale distribution in the eastern Beaufort Sea and Amundsen Gulf (118°W-140°W) in August 2019 occurred largely where expected based on previously collected data (Figure 1). Relative abundance (number of whales per kilometer surveyed) was highest in the eastern Beaufort Sea (0.0236 whales/km) and lower in Amundsen Gulf (0.0129 whales/km). Bowhead whale distribution in the western Beaufort Sea (140°–157°W) in August 2019 was similar to that observed annually since 2012, although fewer bowhead whales were seen compared to previous years. Relative abundance in the western Beaufort Sea was much lower (0.0044 whales/km) compared to relative abundance in the eastern Beaufort Sea and Amundsen Gulf.

Even though distribution in August 2019 was near normal, the bowhead whale distribution and migration across the western Beaufort Sea during September and October 2019 was unlike any on record. The 2019 Arctic sea ice seasonal minimum extent was second lowest, tied with 2007, since satellite data were first recorded in 1979 (National Snow and Ice Data Center 2019). However, the 2019 bowhead whale September and October distribution was similar to that observed in 1983, 1988, 1991, and 1992, which were all years characterized by heavy sea ice (Moore et al. 2000). During years with less sea ice, bowheads were typically nearer to shore (Moore et al. 2000). In 2019, bowhead whales were farther from shore and in deeper water in September than in any previous year since 1982 (Figure 2), which is particularly interesting because the sea ice retreated at least 500 km in the Beaufort Sea. Median depth (46 m) of bowhead whale sightings in the western Beaufort Sea in autumn 2019 was deeper than in any previous autumn except 1991 (139 m) and 1992 (55 m). Similarly, the median distance from shore (46.2 km) of bowhead whale sightings in the region in autumn 2019 was farther than in any previous year except 1991 (61 km). Overall sighting rates in September and October for the area 140°W to 154°W , irrespective of latitude, were similar to 2009-2018, but sighting rates for the area 154°W to 157°W were lower than any previous year since 2009 (Figure 3).

The anomalous autumn bowhead whale distribution was not an artefact of spatial variability in aerial survey effort. Clarke et al. (2019) used spatial models of bowhead whale relative abundance based on ASAMM data from 2000 to 2018 to illustrate the offshore extent of the bowhead whale distribution in the western Beaufort Sea. The results were summarized as relative abundance percentiles, where the model predicts that 30% of the bowhead whales in the region will be inshore of the 30th relative abundance percentile, with similar predictions for 40% to 70%. Therefore, the 50th percentile corresponds to the median: 50% of bowhead whales in the region are predicted to be inshore of the 50th relative abundance percentile. Nearly all bowhead whale sightings during September 2019 were offshore of the 70th relative abundance percentile for 2000-2018 (Figure 4). The picture is not as striking for October 2019; however, most (54%) of the October sightings overlapping the 30th to 70th relative abundance percentiles were due to a single flight, conducted on 29 October 2019, during which 21 bowhead whale sightings totaling 30 whales (including 8 calves) were detected. To put this into perspective, ASAMM conducted 15 other flights in October 2019, covering 8,200 km in the western Beaufort Sea during October, and only 19 additional bowhead whales were detected.

The 50th relative abundance percentiles for autumn 2012 to autumn 2019, all years of extremely light sea ice, are plotted in Figure 5. In some years and in some places (e.g., 2013, 2016, and 2018 near Barrow Canyon; 2012 and 2016 northeast of Deadhorse, Alaska), the 50th percentile is farther offshore than in 2019. However, the 50th percentile for 2019 (heavy black line) is consistently farther offshore across the western Beaufort Sea compared to most previous years.

The difference in bowhead whale 2019 autumn distribution was also noted by subsistence hunters from Kaktovik, Nuiqsut, and Utqiaġvik, Alaska. Whalers from Kaktovik had a successful autumn hunt, landing all three of their 2019 strikes, but traveled much farther than normal to land two of their whales. The village of Nuiqsut, with whaling operations based on Cross Island, had four strikes allocated for autumn 2019 and used three of them. Nuiqsut whalers also travelled further than usual to find whales, particularly west of Cross Island, where whalers reported that whales were swimming north instead of west. The impact of the abnormal bowhead whale distribution was especially strong in Utqiaġvik. Utqiaġvik had 16 strikes for autumn 2019, and autumn whaling commenced on 21 September. Whalers ventured up to 80 km offshore for over 6 weeks in search of bowhead whales but saw only gray whales and a few bowheads at a distance. A flight contracted by the Alaska Eskimo Whaling Commission on 15 November, after ASAMM surveys had ended, extended approximately 65 km east and west of Point Barrow and 32 km offshore, and no bowhead whales were seen. Finally, on 16 November, one bowhead was taken approximately 13 km east of Point Barrow. This is the latest known date for a bowhead whale harvest in Utqiaġvik; the previous date was in late October.

The anomalous bowhead whale distribution in autumn 2019 was ecologically perplexing, with real-world implications to the subsistence communities of northern Alaska. Impacts to these communities included increased financial burden due to the higher fuel costs associated with scouting farther from the villages, and greater dedication of time, which limited the opportunity to pursue other subsistence hunting activities. The greater distances traveled increased risks to each whaling crew, particularly later in autumn when weather conditions become more unpredictable. Finally, the limited subsistence hunt for bowheads in Utqiaġvik means the very real potential for food shortages, as the community will have to increase reliance either on other subsistence foods or on non-subsistence foods, which are expensive and difficult to obtain.

The underlying causes for the anomalous bowhead whale distribution in autumn 2019 are unknown. In addition to the record low summer and winter sea ice extents, other extreme environmental variables were recorded, including warmer surface air temperatures, warmer sea surface temperatures, lower snow cover, thawing permafrost, and decreased sea ice thickness (Richter-Menge et al. 2019), which undoubtedly affected primary and secondary productivity, transport from the Bering Sea, and freshwater runoff. Very few bowhead whale aggregations, an indication of potential feeding, were observed in the western Beaufort Sea, and feeding behavior was conspicuously absent, suggesting that krill and other bowhead whale prey were not significantly present in the western Beaufort Sea, although the whale landed on 16 November had krill in its stomach. The presence of killer whales in the western Beaufort Sea may also have influenced the distribution of bowheads. It is unknown whether autumn 2019 is a “one-off” and unlikely to happen again, or if this represents a new normal (Huntington et al. 2020). Continuation of broad-scale aerial surveys in the western Beaufort Sea and eastern Chukchi Sea, combined with oceanographic sampling and local indigenous knowledge, are well suited to answer these questions.

No bowhead whales were seen in autumn in the eastern Chukchi Sea, also unprecedented compared to all previous years during which aerial surveys were conducted (1982-1991; 2008-2019). The most likely explanations for the lack of sightings in the Chukchi Sea are a migration that occurred much farther north than normal, outside the normal ASAMM study area and therefore was not detectable during aerial surveys, migration was delayed and whales remained in the eastern Beaufort Sea longer and later in the year.

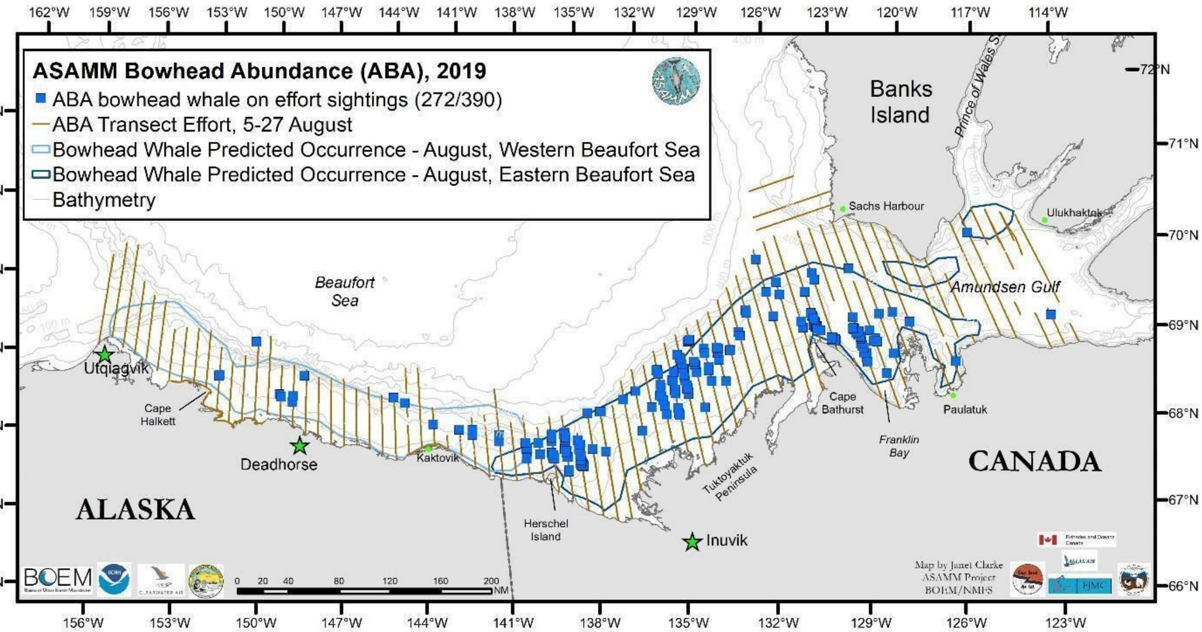


Figure 1. ASAMM August 2019 on-effort bowhead whale sightings and survey effort. Polygons in the eastern Beaufort Sea encompass the predicted distribution of bowhead whales during August, based on commercial whaling, 1980s research, 2007-09 aerial surveys, and satellite tag results. Polygons in the western Beaufort Sea encompass the predicted distribution of bowhead whales during August, based on ASAMM data from 2012-18.

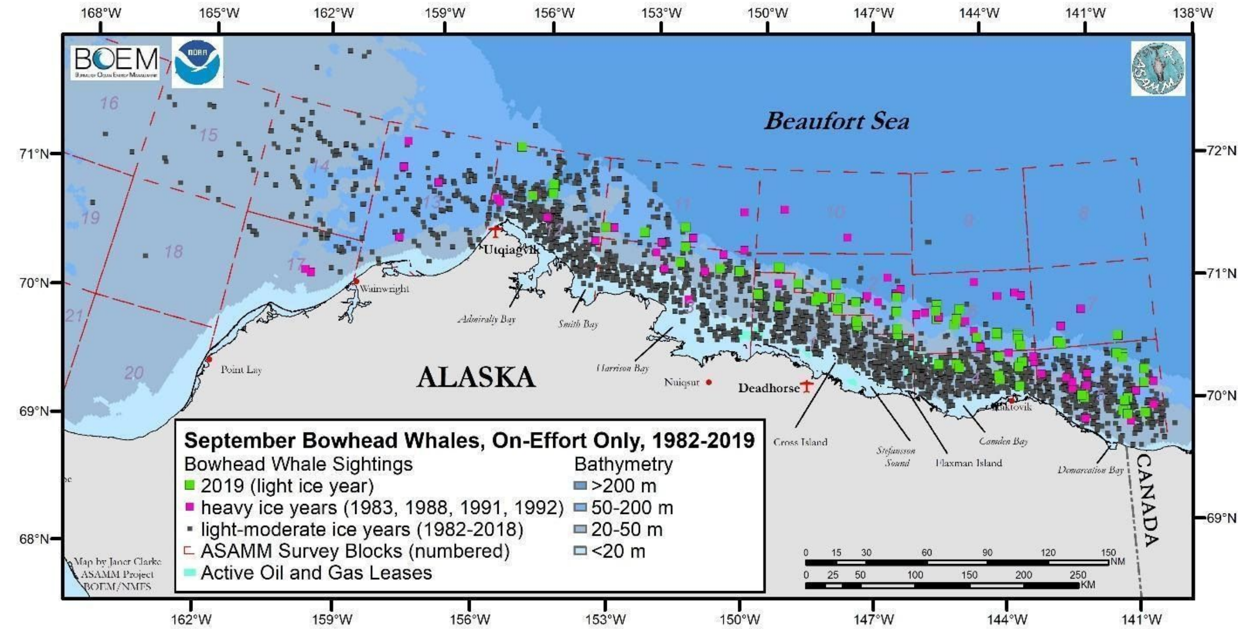


Figure 2. ASAMM bowhead whale sightings in September 2019 (light sea ice), 1983, 1988, 1991, and 1992 (heavy sea ice extent), and 1982, 1984-87, 1989-90, 1993-2018 (light-to-moderate sea ice extent).

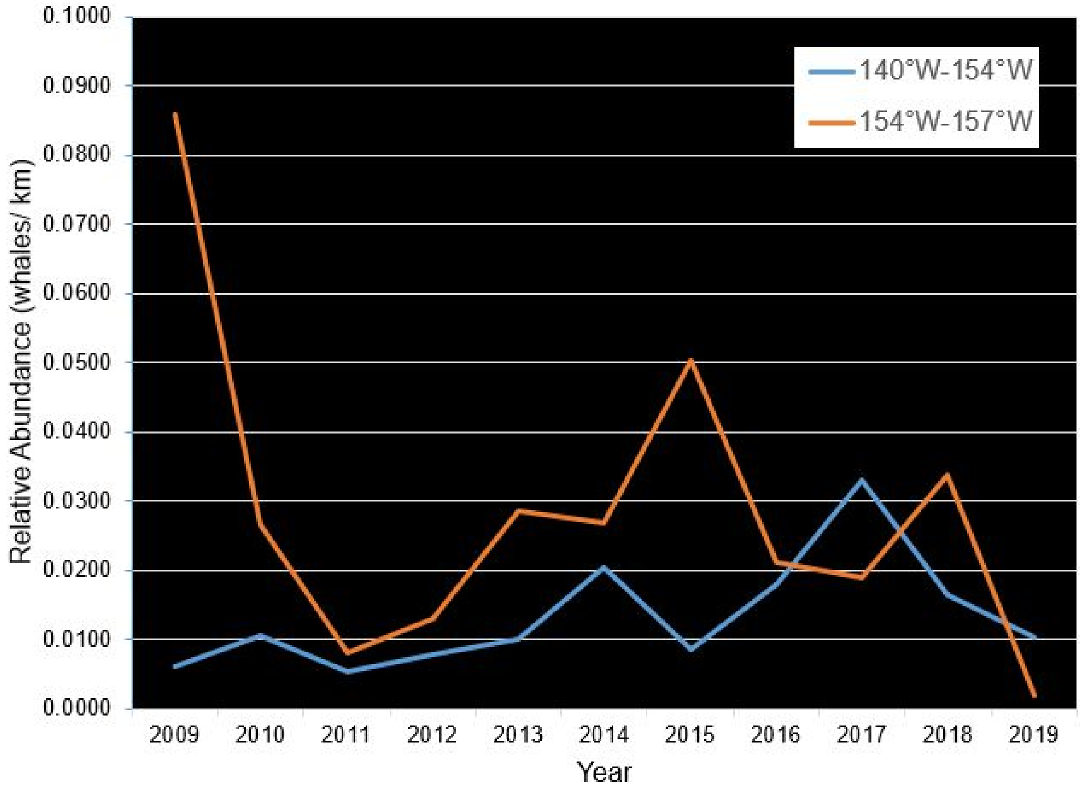
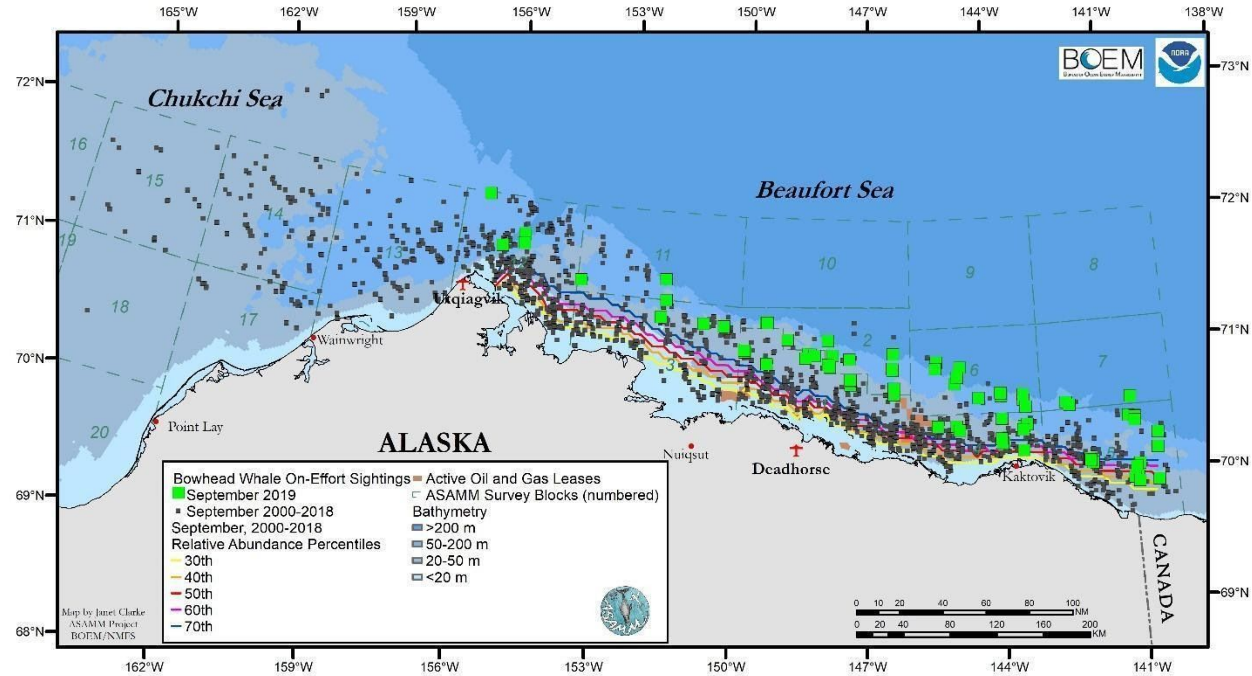


Figure 3. ASAMM relative abundance (number of whales per kilometer surveyed, on effort only) in two areas of the western Beaufort Sea, 140°W-154°W and 154°W-157°W, autumn, 2009-19.



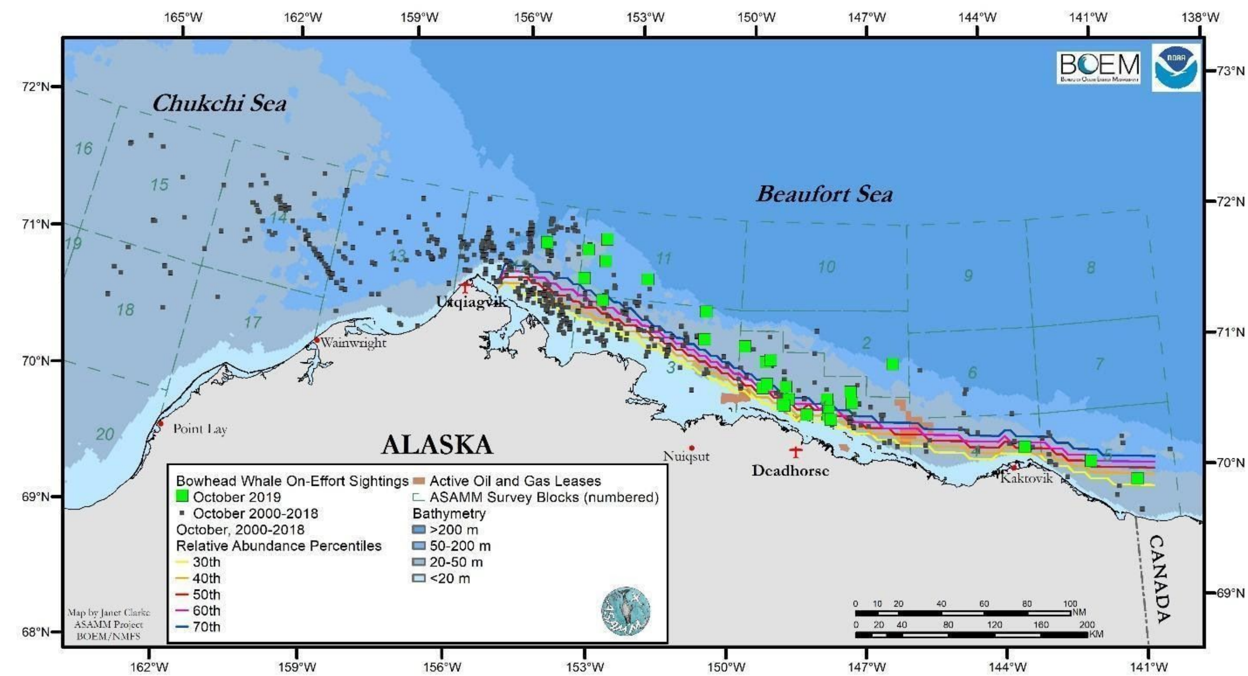


Figure 4. ASAMM September (top) and October (bottom) bowhead whale sightings, 2019 and 2000-18, and relative abundance percentiles.

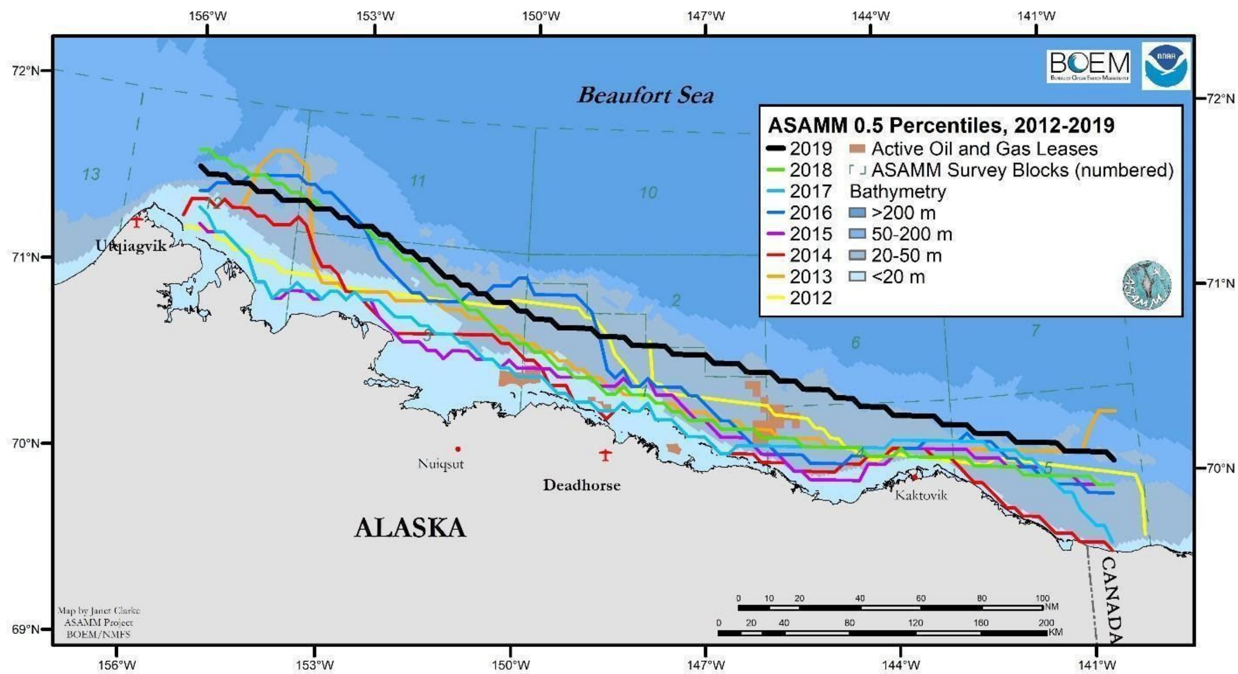


Figure 5. ASAMM autumn 50th relative abundance percentiles, 2012-19.

Calf Production

Summary of Bowhead Whale Calf Sightings from the Aerial Surveys of Arctic Marine Mammals Project (ASAMM)

ASAMM surveys were flown annually during summer and fall in the western Beaufort and eastern Chukchi seas by the U.S. National Marine Fisheries Service (NMFS), with funding from the U.S. Bureau of Ocean Energy Management (BOEM). These surveys provided data on the calf ratio (number of calves/number of total whales seen) and sighting rate (number of calves/km flown) during summer and fall. The ASAMM project and its precursors spanned over 40 years and provide a long-term indicator of bowhead whale calf production, distribution, relative abundance, frequency of feeding, and other metrics. The database (1979-2018) and annual reports dating back to 2006 are available at:
https://www.afsc.noaa.gov/nmml/cetacean/bwasp/index.php.

Survey effort in the ASAMM study area (67°-72°N and 140°-169°W) varied by year and month. In the western Beaufort Sea (140°-157°W), surveys were conducted during fall (September-October) every year since 1982, but summer (July-August) effort has varied. In many years there was no summer survey effort at all. Starting in 2012, surveys were consistently conducted in the western Beaufort Sea in summer. In the eastern Chukchi Sea (157°-169°W), surveys were conducted in 1982-1991 and 2008-2019; survey effort per month varied by year until 2009, when surveys were consistently conducted from July to October. Additional survey design, protocol, and analysis information can be found elsewhere (e.g., Monnett and Treacy 2005; USDOI, MMS 2008; Clarke *et al*. 2011, 2012, 2013, 2014, 2015a, 2017a,b, 2018, 2019).

Starting in 2009, all sightings of large whales were circled (if fuel and weather allowed) to verify species, group size, and presence or absence of calves. The aircraft broke from the transect and initiated circling effort as soon as observers recorded the declination angle from the horizon to the sighting when the aircraft was abeam of the sighting. Most calves (72%) sighted from 2009 to 2019 were observed after circling was initiated and likely would not have been seen if circling had not commenced. Prior to 2009, circling was not specifically designated in the data, so it is difficult to determine the degree to which circling occurred and, therefore, the impact of circling effort on historical calf ratios. Years in which less circling occurred would likely have lower calf detection probabilities. Calf detection probabilities may also be lower in areas where bowhead whales aggregate in large groups (e.g., feeding aggregations). For example, some calves were probably undetected in 2016 on one day in late August when several hundred bowhead whales were seen in <15 minutes.

During all survey effort from 1982 to 2019, 869 bowhead whale calves were sighted out of a total of 17,600 bowhead whales in the ASAMM study area (Clarke et al. 2011, 2012, 2013, 2014, 2015a, 2015b, 2017a,b, 2018, 2019; Ljungblad et al. 1987; Moore and Clarke 1992; MML unpublished data) (Figure 1). Most bowhead whale calves (74%) were seen in the Beaufort Sea in fall. In summer, bowhead whale calves were not sighted in the Chukchi Sea but were seen in the Beaufort Sea. Summer calves were broadly distributed on the continental shelf and slope, out to approximately the 200-m isobath. In fall, most bowhead whale calves were sighted on the continental shelf in the Beaufort and Chukchi seas and in Barrow Canyon (Figure 6). During both seasons, there were a few sightings in waters deeper than 1000 m in the western Beaufort Sea. Calf distribution was similar to the distribution of all bowhead whales sighted.

Calf ratios (number of calves/total whales) in the ASAMM study area were calculated using whales on effort only, which limits the analysis to only those sightings initially made during flat and level flight on predetermined, systematic transects while the observers were actively searching for whales. Annual calf ratios for the Beaufort and Chukchi seas combined were highest in 2019 (0.157), followed by 2017 (0.113), 1991 (0.105), 2013 (0.097), 2001 (0.087), and

2009 (0.083) (Figure 7). Highest summer calf ratio was recorded in 2017 (31 calves, 219 total bowheads, calf ratio=0.142); summer calf ratios were high in 2011 (0.200) and 1985 (0.100) when single calves were observed out of a total of five and ten whales, respectively (Figure 7). As noted above, calves were likely underreported in summer 2016 due to the very high density of whales observed on one day in August. Fall calf ratios were highest in 2019 (0.177), 2013 and 2016 (0.118), and 1991 (0.105) (Figure 7).

Using data collected since 2012, calf sighting rates (calves/km) for the western Beaufort Sea (140°W-157°W) were calculated using kilometers and calf sightings on effort (Figure 8). Summer calf sighting rates were highest in 2013 (0.0019) and lowest in 2018 (0.0002). Fall calf sighting rates were highest in 2017 (0.0029) and lowest in 2012 (0.0005). Calf sighting rates for summer and fall combined were highest in 2017 (0.0023) and lowest in 2012 (0.0005).

Surveys were conducted in the eastern Beaufort Sea and Amundsen Gulf in August 2019 as part of the ASAMM Bowhead Abundance (ABA) project (Clarke *et al*., in prep, 2020). Sixty-five bowhead whale calves were sighted out of a total of 400 bowhead whales. Calves were distributed between Cape Bathurst and Herschel Island, primarily in two nursery areas; calves were not seen in Amundsen Gulf (Brower *et al*. 2020). Calf ratio (number of calves/total whales) in the eastern Beaufort Sea, calculated using on-effort sightings only, was 0.177. Calf sighting rate (calves/km) in the eastern Beaufort Sea was 0.0040.

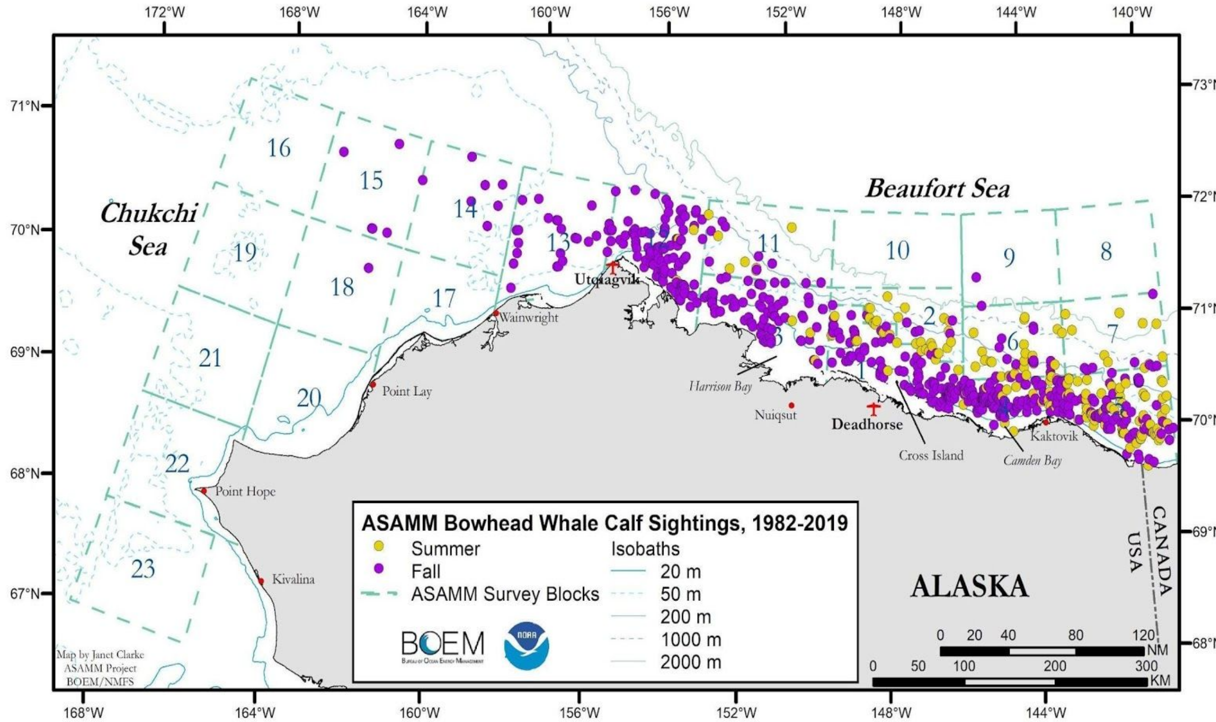


Figure 6. ASAMM bowhead whale calf sightings during summer (July-August) and fall (September-October) seasons, 1982-2019, in the western Beaufort (140°W-157°W) and eastern Chukchi (157°W-169°W) seas.

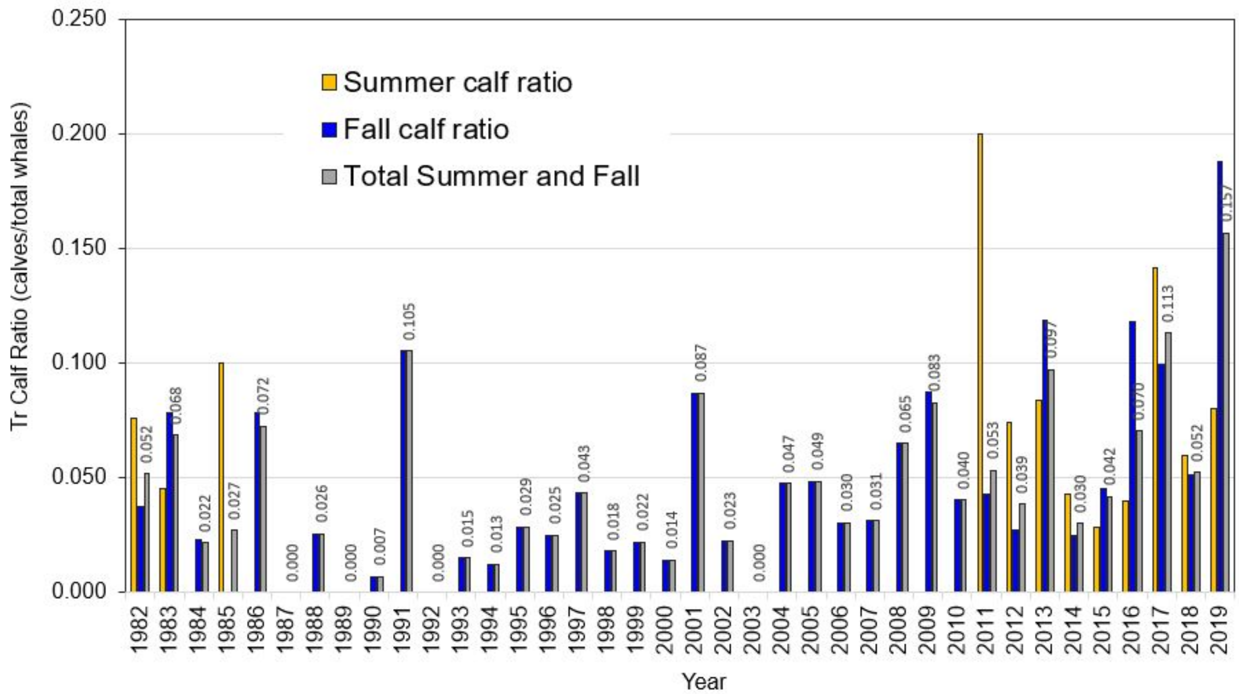


Figure 7. ASAMM bowhead whale calf ratios (number of calves on effort relative to total whales on effort) in summer (July-August pooled) and fall (September-October pooled) for each year from1982 to 2019 in the western Beaufort (140°W-157°W) and eastern Chukchi (157°W-169°W) seas.

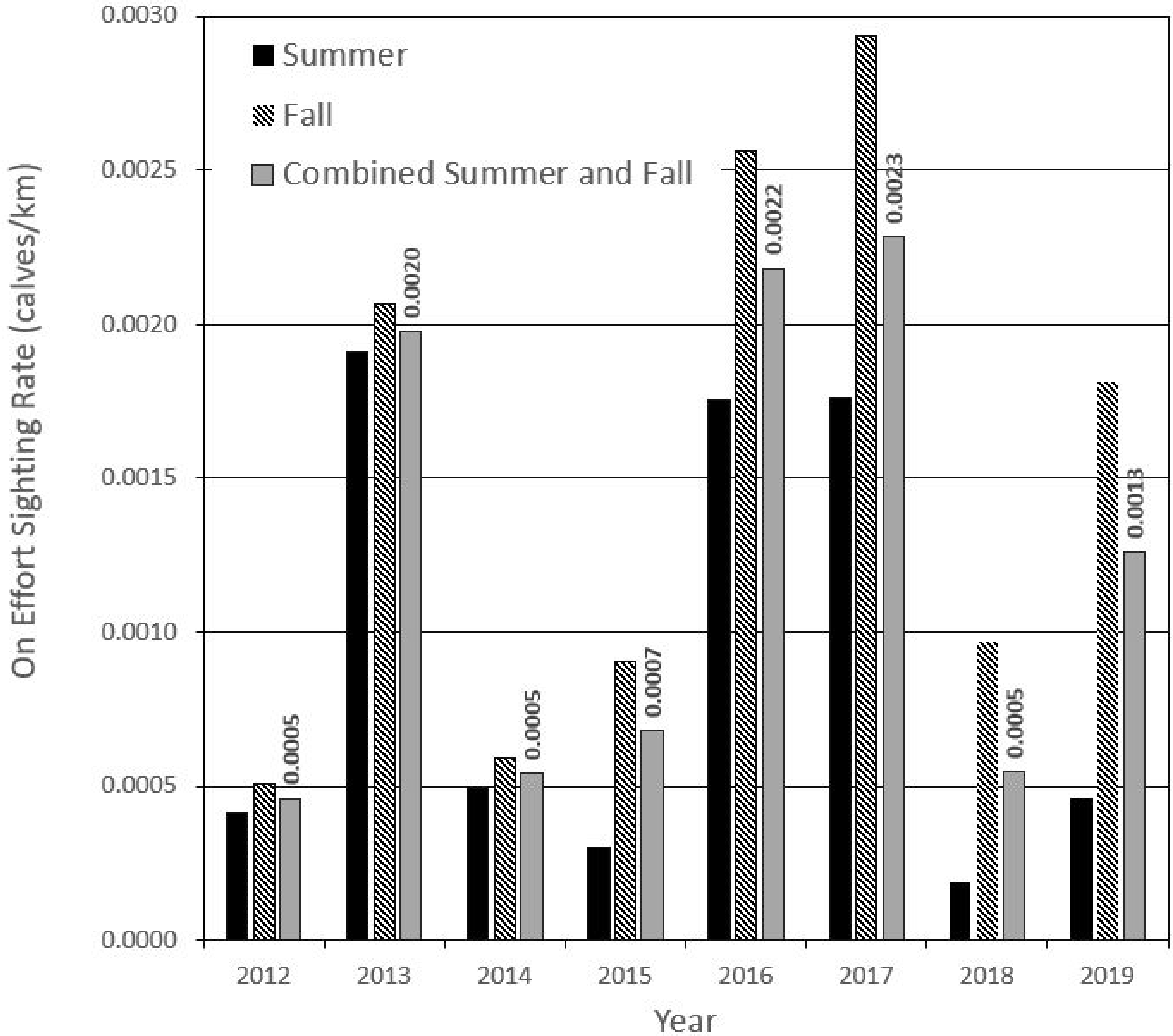


Figure 8. ASAMM bowhead whale calf sighting rates (number of calves on effort relative to on-effort kilometers (km) in summer (July-August pooled) and fall (September-October pooled), 2012-2019, in the western Beaufort Sea (140°W-157°W).

Pregnancy Rates of Landed Adult Females

A crude pregnancy rate of adult females is presented annually in harvest reports. This metric is computed as the number of pregnant females/number of presumed mature females (>13.7m; George et al. 2018). While the crude pregnancy rate of landed whales is not necessarily representative of the entire population for a specific year because of low sample sizes and the possibility that pregnant whales may be more vulnerable than other whales to hunters, the long-term dataset does provide a useful index of reproduction and is consistent with a reproductively healthy population. The estimated pregnancy rate for 1976-2016 was 0.317 (95% CI 0.251 to 0.385). with the possibility that it had increased slightly over this period (George et al. 2018). Suydam et al. (2020), reported the following: "*We do not have an updated estimate of pregnancy rate for the entire population since 2017 but based on data from harvested whales and aerial surveys, the BCB bowheads had a very strong period of reproduction from 2015 to 2019".*

Body Condition of Landed Whales

A bowhead body condition index (BCI) was developed for harvested whales using axillary girth and body length, where BCI = axillary girth/body length. George et al. (2015) maintained that it is important to compare the BCI of specific cohorts in a time series because the different bowhead age and growth stages have different physiological characteristics. For example, freshly weaned yearlings or *ingutuqs* are rotund but mostly reflect their mother's contribution rather than that of a specific feeding season. However, a BCI index that includes all whales and age groups is useful for making general comparisons over long time spans. Both are presented in Table 1.

Table 1 lists the estimated BCI statistics for harvested whales in 2017 to 2019 compared with the long-term mean BCI for 1990-2016. Caution is advised in interpreting the BCI for a single year because sample sizes tend to be small. For instance, only one whale was landed in fall at Utqiaġvik in 2019 so the "sub-adult" BCI index was not computed for that year. Moreover, reliable axillary girth measurements were only available for 3 whales in 2019 due to logistical problems during spring whaling at Utqiaġvik, where most BCI data are collected. George et al. (2015) reported that bowhead BCI varied considerably over a 23-year time series from 1990-2012. Nevertheless, they found a statistically significant increase in BCI over that 23-year period. Following 2012, while not tested statistically, there may be a downward trend in sub-adult BCI, but in recent years BCI appears similar to the long-term average body condition (0.671). The BCI for "all whales" is slightly higher (0.712) in 2018 compared to the baseline (0.686) but falls within the range of past estimates.

As a general summary, the BCI in 2018-2019 appears similar to past years, and no large deviations are evident. However, we strongly recommend continued collection of measurements and a full statistical reanalysis of all available BCI data. The analysis should include environmental covariates (e.g. ice density, upwelling-favorable winds, duration of open water) using the methods of George et al. (2015) as well as new statistical approaches.

Table 1. Preliminary statistics (mean +/- (SD) of point estimates of bowhead body condition index for the years 2017-2019 and the baseline period 1990-2016.

Index	**N**	**Fall "Subadult" Body Condition Index**	**N**	**Body Condition index (all whales, all seasons)**
1990-2016	**150**	0.671 (0.042)	560	0.686 (0.077)
2017	**13**	0.656 (0.03)	22	0.633 (0.04)
2018	**7**	0.66 (0.029)	21	0.712 (0.066)
2019		*Insufficient data*	3	0.675 (0.13)

Proportion of Landed Whales carrying Cyamid spp. (Whale lice)

The prevalence of cyamid "whale lice" on bowheads has been analyzed previously (Von Duyke et al. 2016). Over a period spanning 1973 – 2015, the prevalence of landed bowheads (*n* = 673) carrying cyamids was about 20%. Table 10 documents the numbers of bowheads examined for and carrying cyamids over the past 14 years (2006 – 2019), during which time, the mean prevalence for cyamid presence on landed bowheads was 16.2% (SD = 7.6%). In 2018, there was the highest percentage since 2005 (37%). Interestingly, all of the bowheads with cyamids present in 2018 and 2019 were subadults (length range = 7.1 – 9.9 m), which is inconsistent with previous results showing age as an important predictor of cyamid presence (Von Duyke et al. 2016). Further, the 2-3 year periodicity in cyamid prevalence appears to be continuing (Fig. 9) (Von Duyke et al. 2016), although it is unclear what might be driving such a cycle. By monitoring cyamid presence among subsistence-harvested bowheads, signals for an evolving host-parasite relationship under a changing Arctic ecosystem may be identified via departures from established baseline trends. Additional research into the influence and importance of environmental and anthropogenic variables on cyamid prevalence is recommended.

Table 2. Landed bowhead whales (n=345) examined for cyamids (2006 – 2019) in Gambell, Savoonga, Kaktovik, Nuiqsut, and Utqiaġvik, Alaska.

Year	**Whales examined**	**Whales with cyamids present**	**Percentage of whales examined with cyamids**
2006	24	2	8.3%
2007	23	4	17.4%
2008	28	3	10.7%
2009	23	3	13.0%
2010	24	6	25.0%
2011	21	3	14.3%
2012	27	6	22.2%
2013	23	2	8.7%
2014	19	2	10.5%
2015	27	7	25.9%
2016	24	2	8.3%
2017	29	2	6.9%
2018	34	10	29.4%
2019	19	4	21.1%
TOTAL	**345**	**56**	$\bar{x}$ **= 16.2%** (*SD* = 7.6%)

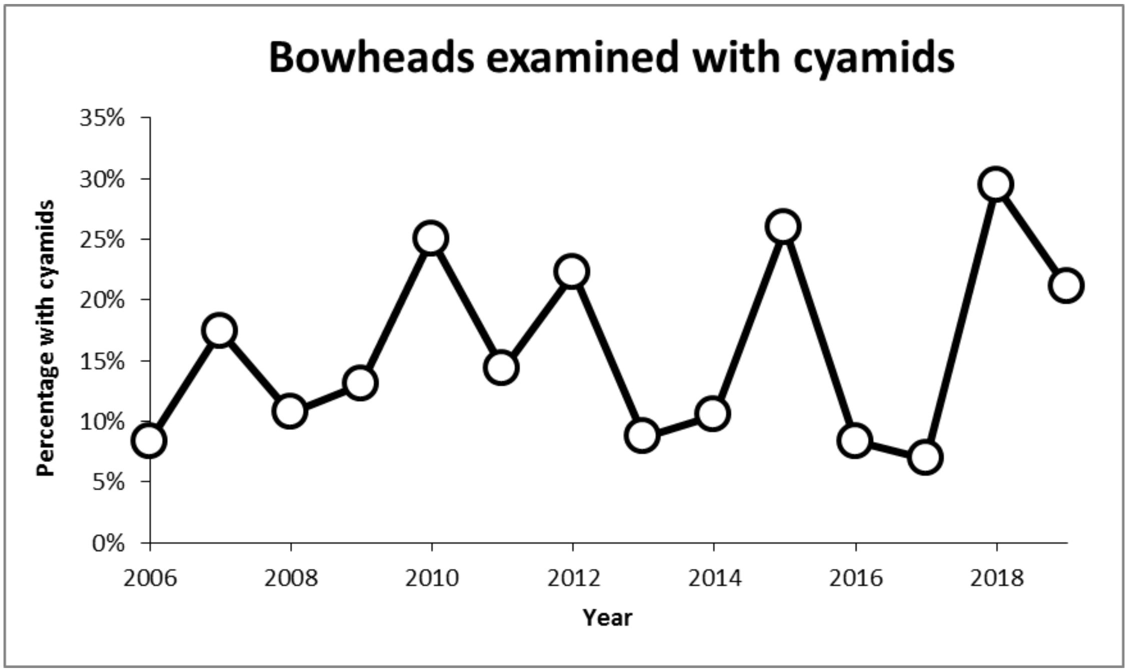


Figure 9 . Long-term trend in cyamid prevalence of landed bowhead whales (n=345; 2006-2019), Utqiaġvik, Alaska.

Proportion of Landed Whales Showing Evidence of Feeding

Evidence of Feeding

Several studies (Lowry et al. 2004; Moore et al. 2010; Sheffield and George 2013) on bowhead whale feeding provide a good framework for reporting the frequency of bowhead whales feeding and the diet in several areas across the BCB range (Saint Lawrence Island to Kaktovik, Alaska). One metric is simply the proportion of examined whales that were found to be feeding during the spring and fall seasons. The prevalence of examined whales with signs of gastric helminth infestation (i.e., worms, gastric nodules, gastric ulcers, etc.) was tallied and reported here (see section pathological findings).

During 2017-2019, the stomachs of 54 harvested whales (from Saint Lawrence Island to Kaktovik) were examined for evidence of feeding and samples of the contents were collected, when possible. Preliminary information presented here is from gross field examination of the stomach at the butchering location. Laboratory examinations of the stomach content samples are pending. The field notes for ten whales lacked enough information to determine feeding status and are not included until archived samples are analyzed.

Bering Sea (winter): During early January 2017, the first direct documentation based on stomach contents of winter feeding in the northern Bering Sea was from an adult bowhead harvested at St. Lawrence Island. The animal had been feeding heavily on krill prior to death (Sheffield 2017).

Chukchi Sea (spring): Neither of two subadult whales harvested near Wainwright nor seven subadult whales examined near Utqiaġvik had been feeding.

Beaufort Sea (fall): All of the 30 subadult whales harvested and examined near Utqiaġvik between 2017 and 2019 had been feeding. The one whale harvested during 2019 fall had been feeding on krill.

Farther to the east, of the four subadult and two adult whales harvested and examined during the fall near Kaktovik during 2017 and 2018, 83% had been feeding and one subadult (17%) had not been feeding.

Results presented here for the Chukchi and Beaufort seas are consistent with past studies (Lowry et al. 2004, Sheffield and George 2013) which demonstrated whales traveling during the northbound spring migration typically are not been feeding; though feeding does occasionally occur (Carroll et al. 1987). Additionally, the entire Alaskan Beaufort Sea during fall migration is an important feeding area for bowheads. The period 2017-2019 was marked by unprecedented sea ice retreat and a greatly expanded open water season and coincided with the first documentation of winter (January) feeding in the northern Bering Sea as well as the latest documented fall feeding (November) in the Beaufort Sea.

Proportion of Whales with Line Entanglement, Killer Whale, and Ship Strike Injuries

Fishing Gear Entanglement. In 2018 and 2019, a total of six of 56 examined landed whales carried injuries from line entanglement or 12% and 10%, respectively. These percentages are consistent with the 1990-2012 baseline of 12.2% (George et al. 2017b). In spring 2017, two whales were harvested at Utqiaġvik that were entangled in line/pot gear, presumably from the Bering Sea. Both animals had severe entanglement injuries to the tongue, pectoral fins, and peduncle. Body condition index for both of these animals were in the low range for landed whales. Rolland et al. (2019) analyzed a baleen plate from whale 17B6 for cortisol levels. Analysis showed a sharp spike in cortisol levels starting roughly a year prior to harvest, suggesting the animal picked up gear at that time. The glucocorticoid profile remained elevated indicating chronic stress from gear entanglement until time of death.

Killer whale injuries. In 2018, four of 33 (12%) examined whales carried scars consistent with injuries inflicted by killer whales (Table 3). In 2019, no killer whale injuries were reported on 20 examined-harvested whales. The latter is somewhat unusual as several large whales (>14 m) were taken in 2019 (Suydam et al 2020). Large whales tend to have a higher incident of killer whale associated scars. However, the average of 2018 and 2019 (6%) is similar to the long-term average of 7.9% (George et al. 2017b).

Vessel-Inflicted Injuries. Ship strike injuries on harvested bowheads have been relatively rare since monitoring began in the late 1970s. Consistent with this trend, no whales were scored with vessel injuries during the years 2016 to 2019. The long-term average for vessel-inflicted injuries is about 2% based on 23 years of data (1990-2012) and shows no trends over this period.

Table 3. Proportions of harvested whales with entanglement scars/injuries, killer whale injuries, and vessel strike injuries for 2016-2019. Also shown is baseline information* for the period 1990-2012 from George et al. (2017b).

Year	Entanglement	Killer Whale	Ship Strike
1990-2012 baseline*	~12%	~8 %	~2%
2016	20.7%	11.4%	0.0%
2017	13.8%	6.7%	0.0%
2018	12.0%	12.0%	0.0%
2019	10.0%	0.0%	0.0%

Number of Dead Floating and Beachcast Bowheads

Bowhead whale carcass data and imagery provide insight into the health of the species (Willoughby et al. 2018; Stimmelmayr et al. 2018). The Aerial Surveys of Arctic Marine Mammals (ASAMM) project surveys large areas of bowhead whale habitat annually from July to October. ASAMM offers a long time series of consistent information on floating and beach-cast bowhead whale carcasses detected during standardized line-transect surveys. A total of 44 bowhead whale carcasses were documented July–October, from 2009 to 2019. Thirty-one carcasses (70%) were found floating and 13 were beach-cast (30%). Carcasses were distributed across the eastern Chukchi (EC) and western Beaufort (WB) sea study areas from 141°W to 169°W and 69°N to 72°N. The highest percentage of carcasses was observed in 2019 (25%), followed by 2015 (23%) and 2016 and 2013 (14% each year). September had the most survey effort, the highest number and the highest sighting rate of bowhead whale carcass in both the EC and WB study areas. Bowhead whale carcasses having injuries consistent with killer whale predation were photo-documented in one carcass each in 2010 and 2017, two carcasses in 2012, three carcasses each in 2013 and 2015, four carcasses each in 2016 and 2018, and six carcasses in 2019. Four observed carcasses were presumed to be struck and lost whales from the subsistence hunt, one each in 2013 and 2018 and two in 2015 based on timing, proximity to known struck and lost whales, and image review of those carcasses. One carcass in 2019 had blubber sections with straight wound edges and was likely stuck by a vessel. Cause of death could not be determined for 15 carcasses. Methodology and results of the aerial effort are included in Willoughby et al. (2020b).

Health Assessment of Landed Whales

Over the last 40 years the basic knowledge of diseases and parasites in bowhead whales has continued to expand (Stimmelmayr 2015; Stimmelmayr et al. 2017; Sheffield et al. 2016; Shpak and Stimmelmayr 2017; Duyke et al. 2017). The available data on natural diseases and parasites of BCB bowhead whales have recently been analyzed and summarized in a comprehensive review (Stimmelmayr et al. 2020a). In general, very few infectious disease agents are present in bowhead whales (Smith et al 1987). Non-infectious disease conditions across organ systems (i.e. cardiovascular, reproductive) have been observed in few animals. Certain conditions including hepatic lipomas (Stimmelmayr et al. 2017), encapsulated fat necrosis (unpubl. data), and parasitic stomach nodules (Sheffield et al. 2016) are more frequent but still rare with prevalence ranging from 1 to 6%. Tumors remain rare but two single case reports of localized malignant types (alimentary; renal system) have been diagnosed. In the face of the dramatic ecosystem changes that the subarctic and Arctic are undergoing, there is a need for continued health assessment, as BCB bowhead whales are integral to Inuit communities meeting their nutritional, cultural and spiritual needs. Additionally, health data help inform the Alaska Eskimo whaling commission (AEWC) and federal agencies for the effective management and conservation of bowhead whales.

2018-2019 Bowhead Whale Health Assessment

Similar to previous years (for review see Stimmelmayr et al. 2018), we summarize unusual findings (abnormal; pathological) observed in landed bowhead whales in 2018 and 2019. In 2018, kidney worm infections (*Crassicauda spp.*) with acute and chronic renal lesions were observed in nine of 27 immature whales, ranging in body length from 8.7 to 10.9 (m). In 2019, kidney worm infections with acute and chronic renal lesions were observed in three of 10 whales. Two of the animals were large mature females (one being pregnant) during spring 2019 and a sub adult male harvested during fall. Kidney worms were absent in the full-term fetus. Transplacental infection (in-utero) has been proposed for fin whales (Lambertsen 1992). Since 2013 renal lesions associated with mild to severe *Crassicauda* infection have been diagnosed in bowhead whales landed in Utqiaġvik (2013-2019) (Stimmelmayr et al. 2018; Stimmelmayr et al. 2020a). The majority of infections were detected in immature whales. It is unclear whether the age distribution reflects sampling bias (~70% immature) or indicates age related host parasite effect.

Hepatic lipomas (Stimmelmayr et al. 2017) were present in three whales in 2018. A vaginal prolapse was observed in a mature female in 2018. With the exception of an unusual ocular lesion (bilateral nodular granulomatous episcleritis), in an immature female bowhead whale landed in Kaktovik, that also had bilateral cataracts, no other abnormal findings (gastric nodules, hepatic lipomas, encapsulated fat necrosis etc.) were observed during post-mortem examination of 2019 landed whales. Ocular disorders are rare in baleen whales but rare cases of cataracts have been reported in bowhead whales (Rolland et al. 2019; Stimmelmayr et al. 2020a).

Hematology, Serum Chemistry, Urine Composition

Available data on hematology, serum chemistry and urine of BCB bowhead whales have recently been analyzed and summarized in a comprehensive review (Stimmelmayr et al. 2020b). Reference ranges for blood, serum, and urine composition have been calculated and will provide a useful diagnostic tool for ad hoc post-mortem health assessment of bowhead whales.

Contaminants

Contaminant exposure occurs primarily through ingestion of contaminated prey or particulate matter although direct contact and inhalation may also be important. Petroleum-related contaminants commonly originate from unintentional releases during marine industrial activities. Long-term data on major classes of contaminants which are characterized as petroleum-related, metals (non-essential elements), and persistent organics, that are monitored in BCB bowhead whales, have recently been analyzed and summarized in two publications (Bolton et al. 2020; Schultz et al. 2020). Both efforts provide valuable baseline data to assess future trends. Polycyclic aromatic hydrocarbons (PAHs) are considered the most toxic of petroleum-related contaminants. Concentrations of summed PAH (∑PAHs) in muscle and blubber were below the lower limit of quantitation (<LOQ), or when detected, were low (<140 ng/g, wet weight) (Schultz et al 2020). With regard to metals, concentrations are generally comparable to those measured in other marine mammal species. Elemental content of bowhead liver and kidney tissue samples collected from over 50 individuals of varying age showed increasing tissue concentrations of the toxic metals cadmium and mercury with age (Schultz et al 2020). Cadmium levels were similar to those reported in prior studies, indicating levels are not increasing since monitoring began approximately 35 years ago. Recent data indicate legacy persistent organic pollutant such as hexachlorobenzene (HCB), hexachlorocyclohexanes (HCHs), dichlorodiphenyltrichloroethane-related pesticides (DDTs), chlordanes (CHLs) and polychlorinated bi-phenyls (PCBs) concentrations in blubber are ordered ΣHCHs > ΣCHLs ~ HCB > ΣPCBs > ΣDDTs ~ dieldrin. Levels appear to have peaked in bowhead blubber

(1992/1993) and have since been declining by approximately 1-8% per year (Bolton et al 2020). On the other hand, the growing human activity in the Arctic coupled with climate change effects on pollutant dynamics and biota exposure (Noyes & Lema 2015) emphasizes the need for continued surveillance of established contaminants but should also be expanded to include more emerging contaminants.

Marine Biotoxins

With increasing sea surface temperatures (SST) of the Bering-Chukchi-Beaufort seas, risks for harmful algae blooms (HABs) in the western and northern Arctic remain a concern (Anderson et al. 2018). Annual harmful algae toxin monitoring (domoic acid; saxitoxin) using feces from landed whales is ongoing (Lefebvre et al. 2016). Based on multi-year unpubl. data, domoic acid and saxitoxin levels are present in bowhead feces and remain consistently below Food and Drug Administration's (FDA) regulatory safety levels for these marine biotoxins.

Hunter Observations of Bowhead Whales

Over 150 whaling captains from 11 whaling communities annually organize bowhead whale hunting crews along the northern and western coasts of Alaska. Astute observers of bowhead whale life history and the ocean, Inuit whale hunters have been instrumental in guiding and advancing scientific knowledge of bowhead whales. For over 40 years, whaling communities have shared in the successful conservation and management of bowhead whales through their collaborative efforts to integrate vast indigenous, traditional and local knowledge with scientific information (e.g., Albert 2000; Noongwook et al. 2007).

Spring Whaling Conditions

Hunting conditions during much of spring 2019 were especially problematic in the northern Bering Sea because of another year with an early retreat of sea ice, considerable open water conditions, and prolonged windy conditions. At Saint Lawrence Island in the northern Bering Sea, whalers from Gambell landed two whales during April. Both whales were harvested in open water conditions as sea ice retreat in the northern Bering Sea / Bering Strait region had begun unseasonably early - during late February. Conditions at Point Hope, Point Lay, Wainwright, and Utqiaġvik allowed for some successful harvests during the spring. At Utqiaġvik, whales were observed farther offshore than typical. The shorefast ice was not sufficiently thick to support the large whales taken at Utqiaġvik and special measures were taken to remove sections of the whale prior to hauling. Similar breakage has occurred in the past spring seasons but hunters suggest it is more frequent in the last decade.

Fall Whaling Conditions

The start of the autumn harvest period in the Beaufort Sea was marked by the excessive northern withdrawal of the sea ice that persisted into late fall (December). At Kaktovik, three whales were landed between late August and mid-September during unusually warm and rainy conditions. Of note, whaling crews experienced an atypical four-day period (7-10 September) where no whales were observed by the ten crews actively hunting. Concurrent with the lack of whales were excellent environmental marine conditions for detectability of whales (i.e., calm winds, flat seas). Similar experiences were made by whaling crews on Cross Island with several days of excellent whaling conditions but no sightings of whales. On 12-September, the first whales detected from Cross Island were observed over 20 miles offshore. At Utqiaġvik, few whales were seen during 21 September to 16 November - when the first and only whale was harvested and landed. This lack of whale sightings and/or successful harvest was highly unusual as many whales are commonly landed in Utqiaġvik during the fall. With the late return of the sea ice during late fall/early winter 2019, few whales were observed in the northern Bering Sea / Bering Strait region.

These observations indicate that environmental change is proceeding fast and that bowhead whales, similar to other Arctic species, are responding to those changes by altering the timing and distribution of their seasonal migrations.

CONCLUSIONS

We utilized the same analytical approaches to document the health status of the BCB population of bowhead whales as outlined in previous health reports (George et al. 2017; Stimmelmayr et al. 2018). The overall health of the population and individual bowhead whales remains good. The continued detection of *Crassicauda spp.* needs to be monitored as detections suggest that this parasite-host relationship has potentially become established and further studies on kidney worm infection, life cycle and intermediate hosts are warranted. The IWC SC has considered fishing-gear entanglement to be the most serious threat to cetaceans globally; and it continues to be a chronic but low-level concern for BCB bowheads. Monitoring of other health and reproductive indices should continue as those data may provide insights of how bowheads respond to the on-going and future climatic changes.

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