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2016 Health Report for the Bering-Chukchi-Beaufort Seas

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INTERNATIONAL WHALING COMMISSION

2016 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 summarizing various health-related statistics would be helpful for management and tracking the status of the BCBS population. This report is the first of the series and summarizes basic information on: calf production (aerial surveys), body condition, presence of domoic acid/saxitoxins associated with harmful algal blooms (HABS), cyamid prevalence, hunter observations, proportion of whales injured from line entanglement, killer whale attacks, and/or ship strikes, gross pathological findings from postmortem examinations of landed whales, number of dead floating and beach-cast bowheads, radionuclide levels in landed whales, proportion of landed whales showing evidence of feeding, ship traffic, and population size and trend. Important health metrics such as population size and trend, calf production and crude pregnancy rates show positive or stable trends. No serious health issues were identified but there appears to be increase in the number of immature bowhead carcasses at sea recorded during aerial marine mammal surveys.

KEYWORDS: BOWHEAD WHALE, HEALTH, PATHOLOGY, ENTANGLEMENT

INTRODUCTION
At the 2016 IWC Scientific Committee (SC) meeting, George et al. (2016) proposed and the SC agreed that an annual or bi-annual report on the Bering-Chukchi-Beaufort Seas (BCB) stock of bowhead whales (*Balaena mysticetus*) that summarized health-related information would be helpful for making management recommendations and monitoring the status of that stock.

This report is the first of the series and summarizes basic information on: calf production, body condition, cyamid prevalence, hunter observations, proportion of whales injured from line entanglement, killer whale attacks, and/or ship strikes, and gross pathological findings from postmortem examinations of landed whales, exposure to harmful algal blooms (HABS), radionuclide levels in landed whales, number of dead floating and beach-cast bowheads, proportion of landed whales showing evidence of feeding, ship transits, and population size and trend. Our goal is to provide the SC with more comprehensive information about status and health of BCB bowheads.

HEALTH METRICES

Calf Production

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

ASAMM surveys are 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 provide data on the calf ratio (number of calves/number of total whales seen) during summer and fall in the northeastern Chukchi and western Beaufort seas. The ASAMM project (and its precursors) have spanned over 30 years and provide a good long-term indicator of bowhead whale calf production, distribution, relative abundance, frequency of feeding, and other metrics. The entire database (1979-2015) 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) has 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 Beaufort Sea in summer. In the eastern Chukchi Sea (157°-169°W), surveys were conducted in 1982-1991 and 2008-2016; 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, 2017).

From 1982 to 2016, 624 bowhead whale calves were sighted out of a total of 15,386 bowhead whales in the ASAMM study area (Ljungblad et al. 1987, Moore and Clarke 1992, Clarke et al. 2011, 2012, 2013, 2014, 2015a, 2015b, 2017, MML unpublished data) (Figure 1). Most bowhead whale calves (76%) 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. The majority of the calves were broadly distributed on the continental shelf and slope, out to approximately the 200-m isobath. In fall, most of the bowhead whale calves were sighted on the continental shelf in the Beaufort and Chukchi seas and in Barrow Canyon (Figure 1). 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 were highest in the early to mid-2010s and early 1980s. For all seasons combined, the highest calf ratio occurred in 2013 (0.089), followed by 1983 (0.077). The summer calf ratio was highest in 2012 (0.087), followed by 1985 (0.083), and 2013 and 1982 (0.074) (Figure 2). The fall calf ratio was highest in 2013 (0.106), followed by 2016 (0.093) and 1983 (0.088) (Figure 2).

Circling effort over cetacean sightings serves to verify species, group size, and presence or absence of calves. Most calves (76%) sighted from 2009-2016 were observed after circling was initiated and likely would not have been seen if circling had not commenced. Prior to 2009, circling occurred but was not specifically designated in the data, so it is difficult to determine the impact of circling on historical calf ratios. Calf detection probabilities may have been lower due to lack of circling, resulting in an underestimate of the number of calves present. 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 a short amount of time.

Although the calf observations were not standardized for effort, sightings during the 2016 ASAMM surveys suggest that calf production was high during the year.

Pregnancy Rates of Landed Adult Females

A crude pregnancy rate of adult females is presented annually in harvest reports (e.g., Suydam et al. 2016). This metric is computed as the number of pregnant females/number of presumed mature females (>13.4m; George et al., 2004). 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, the long-term dataset does provide a useful index of reproduction.

In 2016, Suydam et al., 2017 reported the following:

> "Based on a length >13.4 m (George et al., 2004) and the pregnancy of one whale that was 12.6 m long (16B9), nine of the females were sexually mature. Eight of those were examined for pregnancy. Five were pregnant, three with term fetuses (3.8 to 4.3 m long) and two with small fetuses (0.1 to 0.3 m long). Discounting the two females with small fetuses because they would have given birth in the following year (i.e., 2018), three (37.5% of examined mature females) were about to give birth. This pregnancy rate is about the same or slightly higher than the long-term average of 33% (George et al., 2004; George et al., 2011). Interestingly, a pregnant female was harvested at Point Hope on 10 April and one was also harvested at Wainwright on 26 April. More typically, pregnant females or newly born calves are not seen by hunters or during surveys at Barrow until mid- to late May (e.g., Koski et al. 2006). The timing of migration in 2016 appeared to be early, at least for pregnant females."

Sightings from ASAMM surveys (see above) and the crude pregnancy rate of landed whales suggest that calf production was high in 2016. The fall calf ratio was highest in 2013 (0.106), followed by 2016 (0.093) and 1983 (0.088) for ASAMM surveys and 37.5% of mature females that were landed during the hunt were pregnant with term fetuses.

Body Condition of Landed Whales

A simple body condition index (BCI) can be computed for harvested whales by examining axillary girth as a function of body length. The BCI can be compared with the long-term database of measurements dating to the 1970s. However it is important to compare specific cohorts to each other in making such comparisons because different growth stages have quite different physiological characteristics which can affect body condition (George et al., 2015). For example, freshly weaned yearlings are quite rotund but largely reflect the condition of their mother rather than conditions in a specific feeding season. The long-term mean BCI for 1990-2016 and the BCI for 2016 alone was calculated. The calculations were made using only the highest data quality morphometric scores (DQ=1-3; i.e., where girth measurements are collected in a consistent manner as possible by trained biologists). A subadult body condition was computed for Barrow fall whales following methods in George et al., 2015 (Table 1).

Table 1. Basic statistics on bowhead body condition for 2016 and historical values (1990-2016).

Index	All years	2016
Body Condition index	$\bar{X}$= 0.686; SD = 0.077, N = 560	$\bar{X}$= 0.665, SD=0.064; n = 23
"Subadult" Index	$\bar{X}$= 0.671; SD = 0.042; N = 150	$\bar{X}$=0.657, SD= 0.035; n = 6;

Body condition indices of all whales and subadult whales (excludes yearlings) in 2016 were similar to all years. Some caution is needed because of small sample sizes from 2016 but this result suggests that feeding opportunities in the eastern Beaufort Sea were good for bowheads in summer 2016.

Gross Pathological findings from postmortem examinations of landed whales

Veterinarians, hunters and biologists examine landed bowhead whales on an annual basis. Extensive tissue samples are collected and gross examinations are conducted annually. These are periodically summarized (Philo et al. 1993; Stimmelmayr 2015). Often it is the hunters that first identify abnormal findings. An example is the bowhead whale landed in Kaktovik in fall 2015 that had many “encapsulated abscesses of variable sizes” probably associated with a hunter strike decades earlier (see Suydam et al. 2016).

Similar to previous years (Suydam et al. 2015; Stimmelmayr, 2015), a number of unusual findings (abnormal and/or pathological) were observed in several subsistence harvested bowhead whales in 2016. Briefly, abnormal findings included: (1) a single small fatty tumor (lipomatosis) in the liver of an immature whale; (2) single to multiple gastric parasitic nodules and adult whale worms (*Anasakis* spp.) in the stomach of two immature whales; and (3) kidney worm (*Crassicauda* spp.) infection with renal abscesses in two immature bowhead whales.

Lipomatosis: Neoplastic lesions in bowhead whales are rare with a single case of a lipoma in the liver of an immature male bowhead whale reported by Migaki and Albert (1982). From 1980-2011, only one hepatic lipoma was noted in a whale landed in 2003. Since 2012, fatty tumors have been detected regularly in at least one to two landed whales per year at Utqiaġvik, Alaska (Stimmelmayr and Rotstein unpubl.data). Based on this data series, lipomatosis of the liver is not uncommon in bowhead whales. A realistic estimate of prevalence for this type of hepatic lesion in bowhead whales is difficult to assess as completeness of viscera examination is challenging (Migaki and Albert 1982) and varies between landed whales because of variable seasonal photoperiod length during harvest (spring versus fall), the enormous size and weight of viscera, and examiners experience. A conservative estimate ranges between 5-10 %, based on a yearly maximum subsistence harvest quota of 25 whales for Utqiaġvik[i], Alaska. The biological behavior of these lipomateous lesions is not known, but histologic features and absence of metastases suggests that these are benign proliferative lesions. Additionally, these lesions are not associated with extensive atrophy and/or destruction of hepatic parenchyma. Future monitoring for hepatic lipomateous lesions in landed bowhead whales will help to better understand the prevalence and explore possible etiological risk factors for bowhead whales under the ongoing climate-change driven Arctic maritime regime shift.

Anisakis “Whale or Herring worm”: We recently analyzed stomach contents and determined that 17% of harvested BCB bowhead whale stomachs had anisakis (Sheffield et al. 2016*a*). We also reported on a few cases of gastric anisakiosis characterized by gastric nodules. The latter are caused by the penetration of anisakis worms/larvae of the stomach lining. Migaki et al. (1982) reported first on gastric anisakiosis in two immature bowhead whales. Our total case material from 1980 to 2016 consists of six cases of gastric anisakiosis in landed bowhead whales at Utqiaġvik which suggests it to be a rare condition. However, since “systematic screening for gastric lesions was not an identified objective during past stomach post-mortem examinations,” this conclusion needs to be revisited with future examinations (Sheffield et al. 2016). Field and stomach content screening for anisakis is ongoing for landed bowhead whales in Utqiaġvik, Kaktovik, Gambell, and Savoonga, Alaska.

*Crassicauda**:*** Kidney worms (*Crassicauda* spp.) have been documented in various baleen whales, including an Atlantic bowhead whale (Delyamure 1955). In 2016, kidneys from two bowhead whales harvested for subsistence-purposes in the fall were submitted by whaling captain’s wives for further examinations as both kidneys had abscesses and were unsuitable for food. On gross post mortem examination several large kidney worms associated with multiple renal abscesses were identified. To our knowledge, kidney abscesses have previously not been observed in subsistence-harvested BCB bowhead whales (hunter’s wives, pers. comm.; Stimmelmayr 2015). The kidney abscesses were associated with the renal vessels. Host response was mild in comparison to the description of kidney worm infection in other baleen whales (Lambertsen 1986, 1992) and was unlikely to have impacted the health of these individual whales**.** These are the first confirmed cases of kidney worm infection in BCB bowhead whales. Climate related sea ice and ocean temperature changes, opening of the Northwest Passage, and temporally extended range overlap with seasonal southern migrants known to carry kidney worms (i.e. humpback whales, gray whales) may be setting the stage for shifts in prevalence rates of kidney worms in BCB bowhead whale stock. Future monitoring and molecular characterization of kidney worms detected in bowhead whales is warranted.

In summary, the liver tumors, presence of Anasakis, and presence of Crassidauda in some whales are interesting scientific results but do not suggest that the health of bowhead whales is compromised. These infections are not posing a health risk to the whales we examined or to humans. Continued monitoring is warranted.

Proportion of Landed Whales carrying Cyamids

Von Duyke et al. (2016) describe a methodology for examining the prevalence of cyamid lice on bowhead whales. A robust baseline was established based on examinations of 673 whales. In 2016, only two of 24 (8.3%) bowheads examined had cyamids present on the skin. The baseline percentage of whales that carry cyamids is ~20%. Nevertheless, the low percentage of bowheads carrying cyamids in 2016 is not unusual given the observed variation among years, and the relationships between cyamid presence and whale age and length (Table 2, Figure 3). Continued monitoring of subsistence-harvested whales for cyamids, along with further investigations into the roles of environmental and anthropogenic variables in cyamid prevalence can serve as a useful indicator of change for BCB bowheads and the Arctic ecosystem generally.

Table 2. Harvested bowhead whales examined for cyamids, 2006-2016 for Gambell, Savoonga, Kaktovik and Utqiagvik.

Year	Whales examined	Whales with cyamids present	Percentage of Whales examined with Cyamids
2016	24	2	8.3%
2015	27	7	25.9%
2014	19	2	10.5%
2013	23	2	8.7%
2012	27	6	22.2%
2011	21	3	14.3%
2010	24	6	25.0%
2009	23	3	13.0%
2008	28	3	10.7%
2007	23	4	17.4%
2006	24	2	8.3%

Proportion of landed whales testing positive for Harmful Algal Blooms (HABS)

Climate related sea ice and ocean temperature changes may be setting the stage for the emergence of harmful algae bloom events in the Arctic. Marine biotoxins can have significant health impact on marine species including marine mammals ranging from morbidity to mortality. Recent findings from a comprehensive biotoxin screening effort among Arctic marine mammals (see Lefebvre et al. 2016; Stimmelmayr 2015) confirmed that several species of baleen whales (i.e. bowhead and humpback whale) in Arctic waters are exposed to marine biotoxins. Our recent long-term retrospective screening study (2002-ongoing) updates and expands the previous marine biotoxin study for BCB bowhead whales under a changing Arctic. Preliminary findings (Lefebvre and Stimmelmayr unpubl.data) confirm marine biotoxins (domoic acid and saxitoxins) are present in bowhead whales over the entire study period. There is great inter-annual variation in toxin levels detected as well as percentages of animals positive per collection year suggesting complex interactions of multiple oceanic and climatic drivers**.** Levels of algal toxins measured in bowhead whales were well below the seafood safety regulatory limits for domoic acid and saxitoxins. Fecal marine biotoxin screening is ongoing for landed bowhead whales in Utqiaġvik, Alaska.

In summary, bowheads have been exposed to HABS although there have been no documented associated bowhead mortalities. With regard to HABS, biotoxin levels in bowhead whales are low and do not pose a risk related to human consumption; however, we recommend continued monitoring of exposure to HABS.

Organic Contaminants

Despite low trophic position in the arctic food web, bowhead longevity leads to bioaccumulation and biomagnification of organic contaminants. Males are more prone to bio-accumulation because females can clear these lipophilic contaminants through lactation. Because bowhead whales are an important subsistence resource for Alaskan Eskimo whaling communities throughout northern and western Alaska, contaminant body burden of landed whales is an important food security and food safety issue. Various drivers including climate related sea ice and ocean temperature changes, increased maritime traffic, natural oil seeps, and oil resource development and extraction activities, could be influencing previously determined baselines for the BCB bowhead whale. Our recent long-term screening study (2006-2015) updates and expands previous contaminant studies for BCB bowhead whales under a changing Arctic. Preliminary findings (Ylitalo and Stimmelmayr unpubl.data) confirm that concentrations of summed PCBs and summed DDTs in blubber are at least 10 times lower than the U.S. Food and Drug Administration (FDA) tolerance levels for DDTs (5000 ng/g wet weight) and PCBs (2000 ng/g wet weight) in seafood. Concentrations of summed PCBs and summed DDTs in whale muscle are at least 100 times lower than the FDA tolerance levels for DDTs (5000 ng/g wet weight) and PCBs (2000 ng/g wet weight) in seafood. Summed PCB Levels measured in blubber in males in 1992-1993 were approximately 4-5 times higher than the levels determined in males in 2015. DDT mean levels measured in blubber in males in 1992-1993 were approximately three times higher than the mean levels determined in males in 2015. Hexachlorobenzene mean levels measured in blubber in males in 1992-1993 were approximately twice the levels determined in males during 2015. PBDE, a flame retardant was detected at very low levels across the years.

In summary, there appears to be a long-term downward trend in body burden of lipophilic contaminants in male BCB bowhead whales. Only males were analyzed as females “dump” contaminates during lactation. We are working on additional analysis of trends of contaminant levels, controlling for age, and possibly other environmental factors. That information will be presented in future health reports.

Generally, organic contaminants are low in bowheads and do not pose a risk for human consumption and/or the health of bowheads as measured levels are substantially below FDA regulatory limits for seafood. Because organic contaminants are carried to the Arctic, on-going oil and gas development continues in the Beaufort and Chukchi seas, industrial maritime ship traffic is increasing, there is a need to continue monitoring for exposure to organic contaminants – especially as the whale is food for coastal communities throughout Alaska.

Anthropogenic Radionuclide Levels in landed whales

During 2016, radionuclide levels were low in bowhead whales. Interest in Arctic radionuclide monitoring of marine mammal species utilized as food by coastal communities continued to be high among aboriginal whaling communities, in large part because of the 2011 release of radiation during the Fukushima Daiichi reactors accident. Our radioecology bowhead monitoring effort provided baseline data to the whaling communities. Our program is similar to other radioecology programs (i.e., Sweden, Norway, Germany, etc.) that monitor trends of anthropogenic radionuclides in marine biota to better understand Arctic food web transfers (Arctic radioecology). Briefly, muscle tissues from subsistence harvested bowhead whales (2011-2016) were screened as composite (n=10) or single animals (n=68) using an ORTEC FoodGuard-1 Sodium Iodide rapid Food Screening system. We report on preliminary findings on cesium 137 and 134 muscle tissue levels in single animal counts. Count time per sample was set at 160 minutes. Minimum detectable concentration (MDC) for the FoodGuard-1 is for a 60 minute count time at 6.0 (Bq/L) for cesium 137 and 8.8 (Bq/L) for cesium 134. By increasing the count time the MDC decreases in a time dependent manner. Overall cesium 137 activity (kg/bq wet weight),greater than the minimal detection limit, was detected in 34 % (23/68) bowhead whales. Cesium 137 tissue levels ranged between 3.60-5.31kg/Bq/kg wet weight. These values are below FDA (1200 Bq/kg) and current Japanese Food Safety levels (100 Bq/kg wet weight). Cesium 134 was not detected in any of the tissue samples from bowhead whales. A subset of samples have been archived (frozen and freeze dried) for future gamma spectrometry analysis.

Hunter Observations of Bowhead Whales

Over 150 whaling captains organize bowhead whale hunting crews annually along the northern and western coasts of Alaska. Inuit whale hunters are astute observers of many aspects of bowhead whale life history, as attested by the many examples of traditional and local knowledge being used in scientific assessments and research (Huntington et al. 2009; Noongwook et al. 2007; Wohlforth 2004). Obviously, summarizing numerous observations from 2016 is not within the scope of this report. However, Table 3 provides a few unusual or specific observations or statements relative to whale health, timing of bowhead migration, pregnancy and other aspects of bowhead biology.

Table 3. Selected hunter-based observations regarding bowhead whales in northern and western Alaska during 2016.

Date	**Location**	**Observation**	**Significance**
07-March-16	Point Hope	Three bowheads were seen off Point Hope from the beach. There was no shorefast ice at that time. Two more bowheads were seen on 8 March. They were migrating north.	These observations were earlier than is typical.
27-March-16	Savoonga	Savoonga harvested the first whale (16S1) of spring 2016 in March.	This is an early successful hunt.
10-April-16	Point Hope	Whale 16H1 was pregnant with a term fetus (3.8 m in length) (Suydam et al. 2017).	This is the earliest pregnant whale harvested at Point Hope in NSB records (1972-present) and a very unusual occurrence based on comments from Point Hope hunters.
20 April 2016	Wainwright	Whaling crews are hunting essentially from the village with only 100 yards of shorefast ice.. A local informant said this was the first time that Wainwright whalers have launched from the village in spring in anyone's living memory.	Normally the shorefast ice is several miles wide in April and May. Sea ice cover in the north eastern Chukchi Sea was greatly reduced in 2016.
24 April 2016	Wainwright	Whale 16WW5 was pregnant with a term fetus (3.8m in length) (Suydam et al. 2017).	As with the pregnant Point Hope mentioned above, this is very early for pregnant females

			to appear in the migration in the northeastern Chukchi Sea.
September 2016	Utqiaġvik (Barrow)	Two whales landed with kidney abscesses, noticed by whaling captain wives who were processing the kidneys for sharing with the community (see Pathological findings).	Unusual sightings of abscesses.

These observations indicate that the northwards spring migration from the Bering Sea to the Beaufort Sea was early in 2016, including the early migration of mature and pregnant females. Typically, pregnant females appear in the northeastern Chukchi Sea during mid-May. The reduced sea ice cover during 2016 may have greatly influenced the timing of migration. The observations on the kidney abscesses emphasizes the benefits of hunters, veterinarians and biologists working together to monitor the health status of bowhead whales (see: Gross Pathological Findings).

Proportion of whales with Line Entanglement, Killer Whale, and Ship Strike Injuries
Harvested bowhead whales in 2016 were examined by biologists and hunters for scars following methods in George et al. (2017a). We examined scars on bowhead whales harvested by Alaskan Native hunters to quantify the frequency of line entanglement, ship strike, and killer whale injuries. After data quality screening, we found records on scarring from 521 bowhead whales harvested between 1990 and 2012 within our database. Logistic regression was used to evaluate different combinations of explanatory variables (i.e., body length, year, sex) to develop a prediction model for each scar type.

All available whales were examined during 2016 for injuries in association with line entanglement, killer whale attacks, and ship strikes. Of these, 20.7%, 11.4% and 0.0% carried injuries, respectively (Table 4). Sample sizes for the different types of scars vary; reasons include: the flukes are removed before they can be examined for killer whale injuries, the peduncle was not examined for entanglement scars, darkness precluded a thorough examination. George et al. (2017a) provided evidence that killer whale scar rates had significantly increased on landed whales in the last decade of a study spanning from 1990 to 2012 but not for line entanglement or ship strikes.

Table 4. Proportions of whales with entanglement scars/injuries in 2016 with baseline information for 1990-2012. Historical scarring rates are given as approximations since scarring is highly correlated with whale length and presumably age (George et al. 2016a).

Year	Entanglement	Killer Whale	Ship Strike
Percentage of scarring on whales from 1990-2012	~12%	~8 %	~2%
Percentage of scarring on whales in 2016	20.7%	11.4%	0.0%
No. of whales examined in 2016	29	22	26

Aerial photography is another useful tool for assessing the frequency of anthropogenic injuries of bowheads. Analysis of aerial photographs from 2011 provided an independent entanglement frequency of 12.2% for BCB bowheads where the peduncle region was carefully examined (George et al. 2017b). Those aerial survey data will be presented in future health reports.

Number of Dead Floating and Beach-Cast Bowheads

Marine mammal aerial surveys have been flown in the eastern Chukchi and Alaskan Beaufort seas since 1982 (ASAMM and precursor projects). A brief summary of aerial survey methods is included in the **Calf Production** section, above. In addition to documenting live marine mammals, ASAMM also collects data on all bowhead whale carcasses seen.

From 1982 to 2016, a total of 49 carcasses that could be identified as bowhead whales were sighted (Figure 4, Table 5). Five carcasses were repeat sightings within the same season, bringing the total number of unique bowhead whale carcasses to 44. Bowhead whale carcasses were distributed across the Chukchi and Beaufort seas from 141.6°W to 168.7°W and 68.9°N to 72°N. Eight of the carcasses were sighted on the beach, and 41 were sighted floating in open water. Some of the carcasses were related to whale hunting activity; one carcass in 2013 and one carcass in 2015 were whales that had been struck and lost during the harvest. One whale (2015) had an orange buoy and line attached to it, and was more likely due to whaling than commercial crab-fishing gear (C. George, pers. comm. to J. Clarke on 28 October 2015) and one whale (2015) entanglement was due to commercial crab-fishing gear (Sheffield and SWCA, 2015).

From 2013 to 2016, 21 unique bowhead whale carcasses were sighted (Clarke et al. 2014, 2015, 2017, MML unpublished data, Sheffield and SWCA, 2015, Sheffield et al. 2016*b*); this is almost half of the total number of unique bowhead whale carcasses from all years. Some of this may be attributable to the increased amount of survey effort; however, annual survey effort in 2009-2012 was similar to annual survey effort in 2013-2016, and only two unique bowhead whale carcasses were seen. Of those 21 unique carcasses from 2013 to 2016, 10 occurred in 2015 which is twice the number observed in any other single year. An increase in bowhead abundance (see: Population size and trend) and sea ice reduction may also affect the number of carcasses (e.g., Savoonga whalers found the bowhead whale entangled in fishing gear during 2015, and a USCG helicopter survey was conducted in 2016). It is difficult to closely examine and the determine the cause of death of floating or beach-cast whales seen from aerial surveys in the Arctic; however, cause of death due to killer whale attacks, ship strikes, entanglement in fishing gear/ large line, or natural causes are all possibilities.

Since 1982, four of the bowhead whale carcasses were calves: one in 1991, one in 2013, and two in 2015. In 2015, two calf carcasses (one definite and one probable) had killer whale rake marks on their pectoral flipper or ventral "chin" suggesting death was due to killer whale predation. Prior to 2015, evidence of killer whale predation on bowhead whales had not been recorded in the ASAMM database. Again, the dramatic sea ice reduction during the fall season could allow killer whales to hunt in areas like the northeast Chukchi Sea that were previously ice covered. Hunters found a bowhead floating dead ~15-20 kilometers to the east of Point Barrow. The whale was still in good enough condition that it was towed back to Utqiaġvik and where the maktaq (i.e., the black skin and outer blubber) was utilized for human consumption and the baleen was salvaged for other purposes. The cause of death was somewhat unclear. There were clear killer whale rake marks on the flukes and flippers indicating killer whale predation; however, its lips and tongue were still intact. There was also a large "tear" along the ventrum (belly) consistent with a ship strike. We carefully looked for wounds or injuries associated with harvest activities but found none (Suydam et al. 2016).

Proportion of Landed Whales Showing Evidence of Feeding

Several publications (Lowry et al. 2004; Moore et al. 2010) on bowhead whale feeding provide a good framework for reporting the frequency of bowhead whales feeding and diet in several areas across the BCB range (Saint Lawrence Island to Kaktovik, Alaska). This dataset now spans 40 years of stomach contents collections. 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 *Anisakis* spp. infestation in the stomach (i.e., worms, gastric nodules, gastric ulcers, etc.) was tallied and reported here (see section Pathological findings).

In 2016, the stomachs of 21 whales harvested (in Utqiaġvik and Kaktovik) were examined for evidence of feeding (Sheffield 2017). Of these, a preliminary analysis suggests prey was found in 52% (11/22) of the whales. In spring, one whale of eight (12%) was listed as having a “possible trace of prey,” suggesting there was limited feeding during the spring season. In fall, 10 of 13 (77%) whales examined were feeding. This pattern is fairly consistent with what Lowry et al. (2004) reported for the years 1969-2000 where 77% of fall whales were feeding and 34% were feeding in spring. However, many of the spring whales analyzed in the Lowry et al. (2004) study had only trace amounts of prey in the stomach. Since 2000, a lower proportion (~14%) of whale stomachs was found with prey in spring; nevertheless, feeding does occasionally occur during spring migration.

Based on body condition of whales harvested at Utqiaġvik in fall 2016 (see Body Condition section, above) and stomach contents, there appeared to be ample food sources and foraging opportunities for bowheads in the Beaufort Sea in 2016.

Acoustic Index

Spring migration

Bowhead whale abundance surveys have been conducted since 1978. Since 1984, a combined visual-acoustic survey was conducted at various intervals. The acoustic aspect of the survey provided, among many other metrics, whale locations and call counts through most of the spring migration used for abundance estimation (e.g., Clark et al. 1996; Givens et al. 2016).

In order to assess whether a count of recorded bowhead calls might provide a useful index of relative abundance of migrating bowhead whales, a single hydrophone package was moored off the ice edge west of Barrow, Alaska, in 2015, 2016, and 2017. We wanted to compare counts of “calls,” “sequences” and “songs” with acoustic data from 1984 to 2011 to determine if the relative number of signals recorded has changed over time and can be correlated with increasing population abundance. These data are still being analyzed; however, based on an apparent change in acoustic behavior over this period whereby more "songs" have been recorded in recent years, we suspect that counts of the typical up-sweep calls (common in the 1980s and 1990s) may not be a reliable abundance metric.

Other methods to examine changes in bowhead relative abundance during the spring migration that use passive acoustic data include: a) documenting the beginning and end of the migration based on first and last dates of calls recorded, b) estimating the number of singers and distinct songs by year (following Johnson et al. 2015), and c) measuring the acoustic energy in the frequency band used by bowhead whales similar to the "fin index" described by Nieukirk et al. (2012).

In 2016, bowhead whale calls were detected from 9 April to 4 June with a brief conspicuous hiatus on 24 April (Figure 5). This call pattern is similar to past seasons; however, bowheads are arriving earlier than in the 1980s. Bowhead song (continuous series of complex calls) detection was near-constant from 9 April to 13 May with a few instances of song later in May. The trend towards increased singing during spring since the 1980s appears to be continuing; however the reasons remain unknown. We will provide additional results and analyses in future health reports describing the acoustic character of the migration and any implications to the health of this stock.

Population Size and Trend

Bowhead whales migrate along Alaska’s northeastern Chukchi coast where a long time series of abundance estimates dating from 1978 to 2011 exists. Givens et al. (2016) provide the most recent abundance estimate for BCB bowhead whales at 16,820 (95% CI: (15,176, 18,643) in 2011, and a long-term (1978-2011) estimated annual rate of population increase of 3.7% (2.9%, 4.6%) (Figure 6). Of all the "health parameters" presented here, arguably the current population size and rate of increase provides some of the best evidence that the BCB bowhead stock is "healthy." These statistics strongly suggest that anthropogenic mortality (including hunting) is having little effect on the current status and recovery of BCB bowhead whales from commercial Yankee whaling. Givens et al. 2016 points out: "*aside from the statistical techniques described here, our results are critical for the management of this population*."

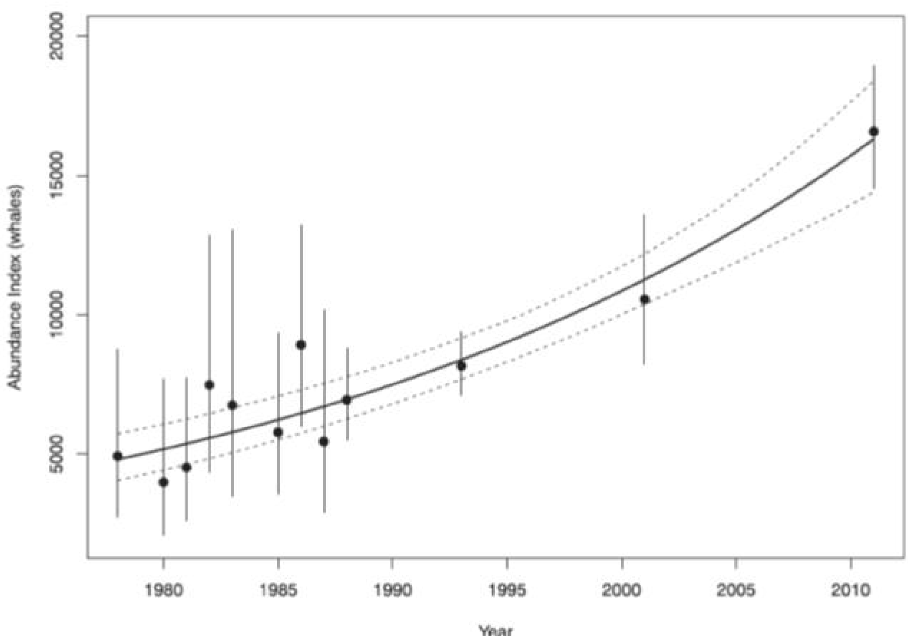

Figure 6. Estimated abundance indices, fitted curve, and pointwise 95% confidence band for the trend estimate using the time series from 1978 to 2011 (Givens et al. 2016).

CONCLUSIONS

In 2016, several analytical approaches were used to document the health status of the BCB population of bowhead whales. Important health metrics such as population size and trend, calf production and crude pregnancy rates show positive or stable trends. Calf production was relatively high in 2016, and feeding rates and body condition were consistent with past years. No serious health issues were identified; but there was a possible increase in the number of immature bowhead carcasses at sea recorded during arctic aerial marine mammal surveys. Bowhead parasite loads tend to be much lower than most other cetaceans for which data exist. Sea ice reduction from climate warming is a major concern; however, the various metrics mentioned here (in particular population size and trend) suggest that to date, bowheads are not being harmed by sea ice retreat.

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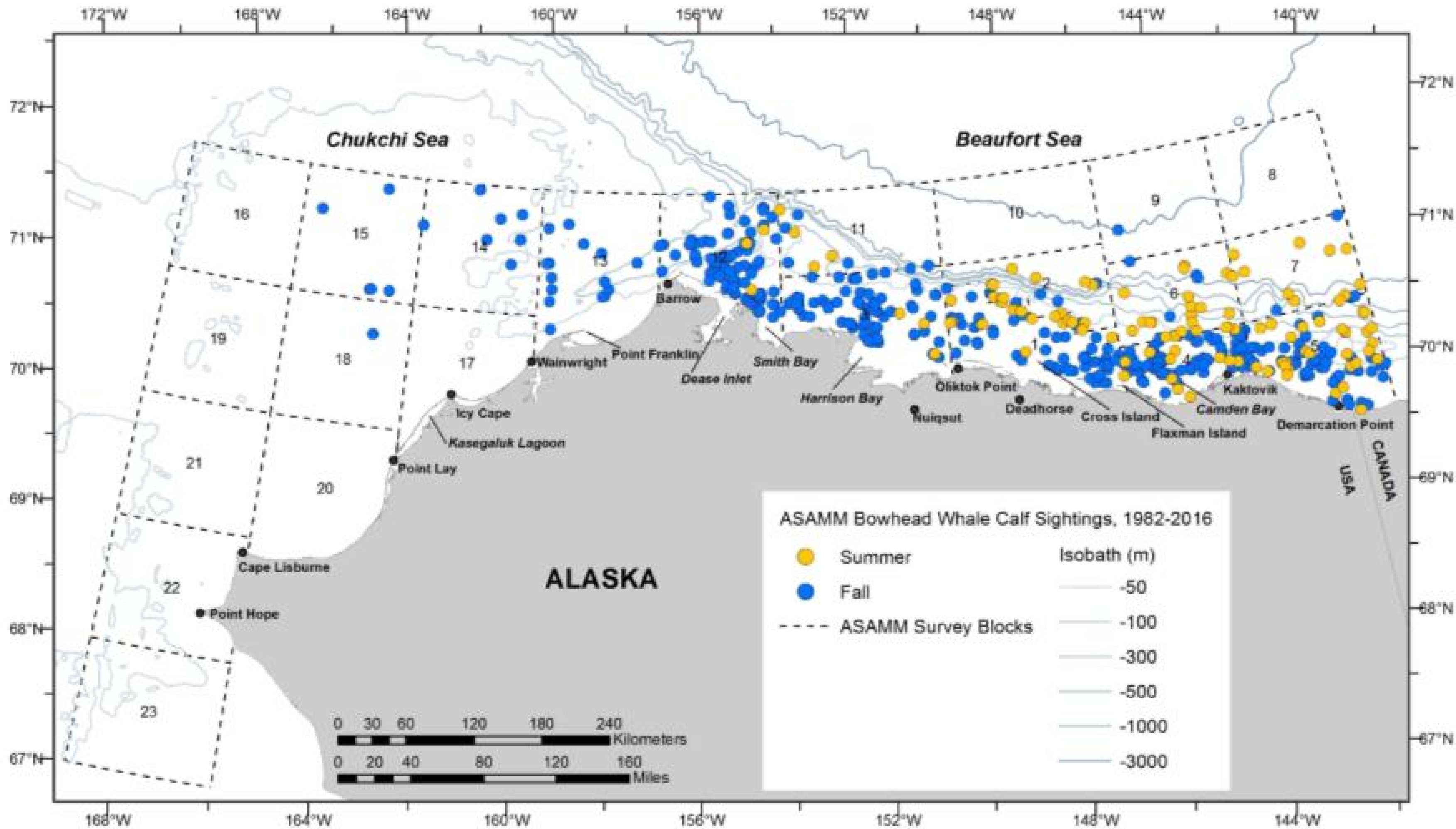

Figure 1. Bowhead whale calf sightings by summer (July-August) and fall (September-October) seasons, 1982-2016.

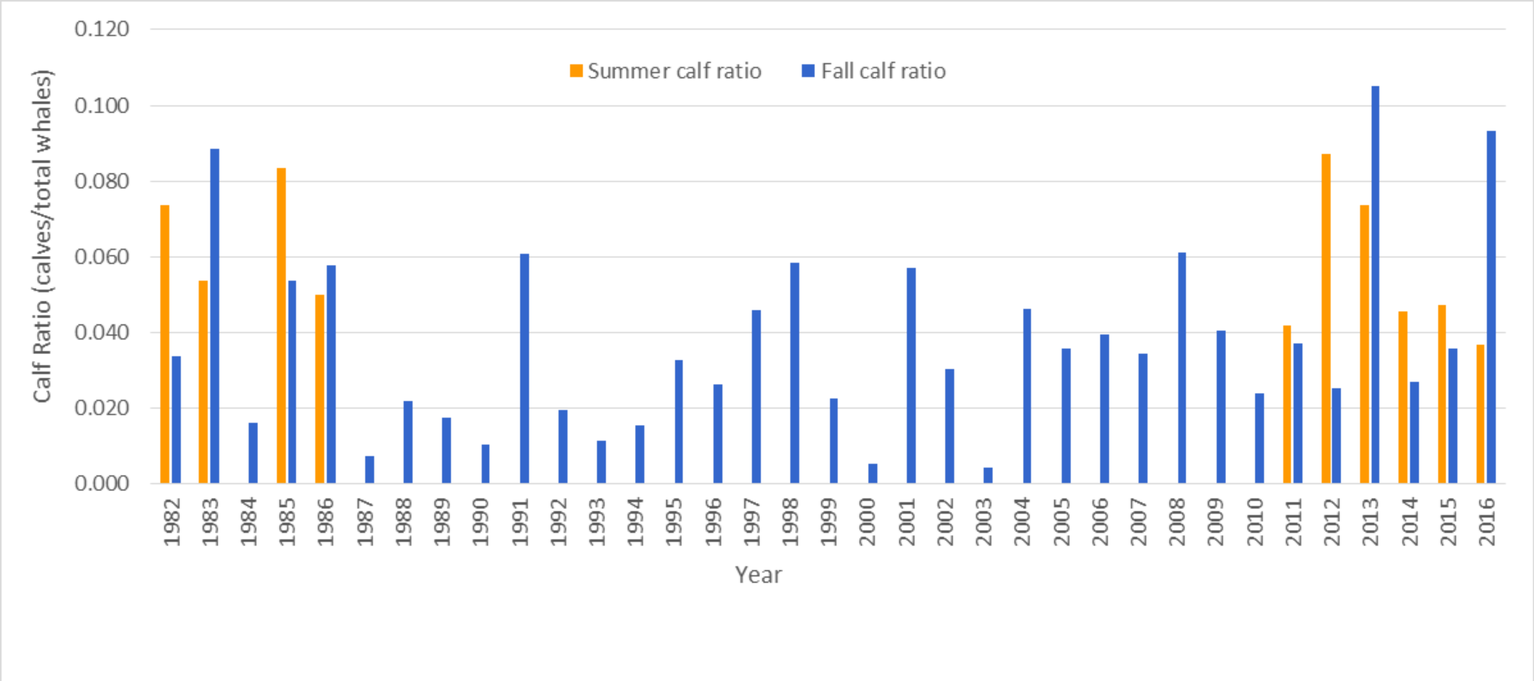

Figure 2. Bowhead whale calf ratios in summer (July-August pooled) and fall (September-October pooled), 1982-2016 in the Beaufort and Chukchi Seas.

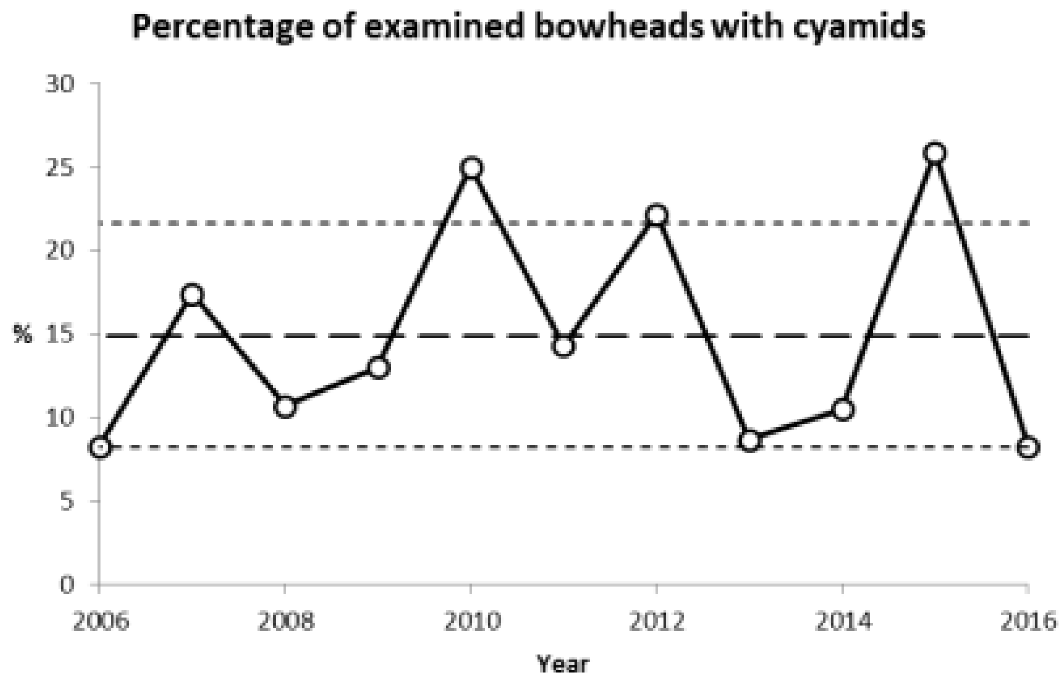

Figure 3: The percentage of examined bowhead whales with cyamids present. Heavy dashed line is the mean for this period (14.9%) and the dotted lines are one standard deviation (6.7). No significant trend exists in this time series.

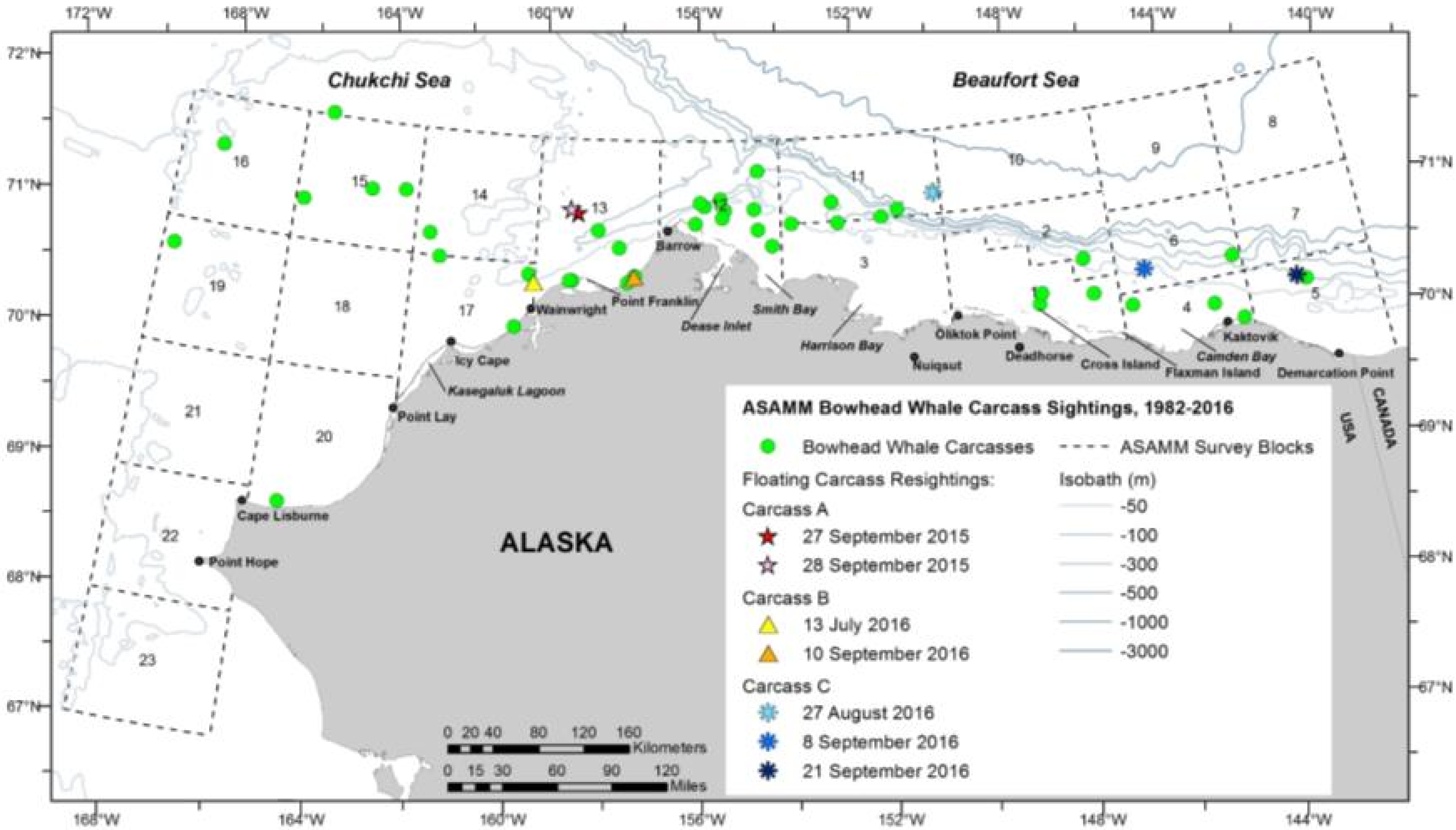

Figure 4. Bowhead whale carcass sightings, July-October, 1982-2016. Carcasses that were sighted floating and subsequently re-sighted are displayed individually by date.

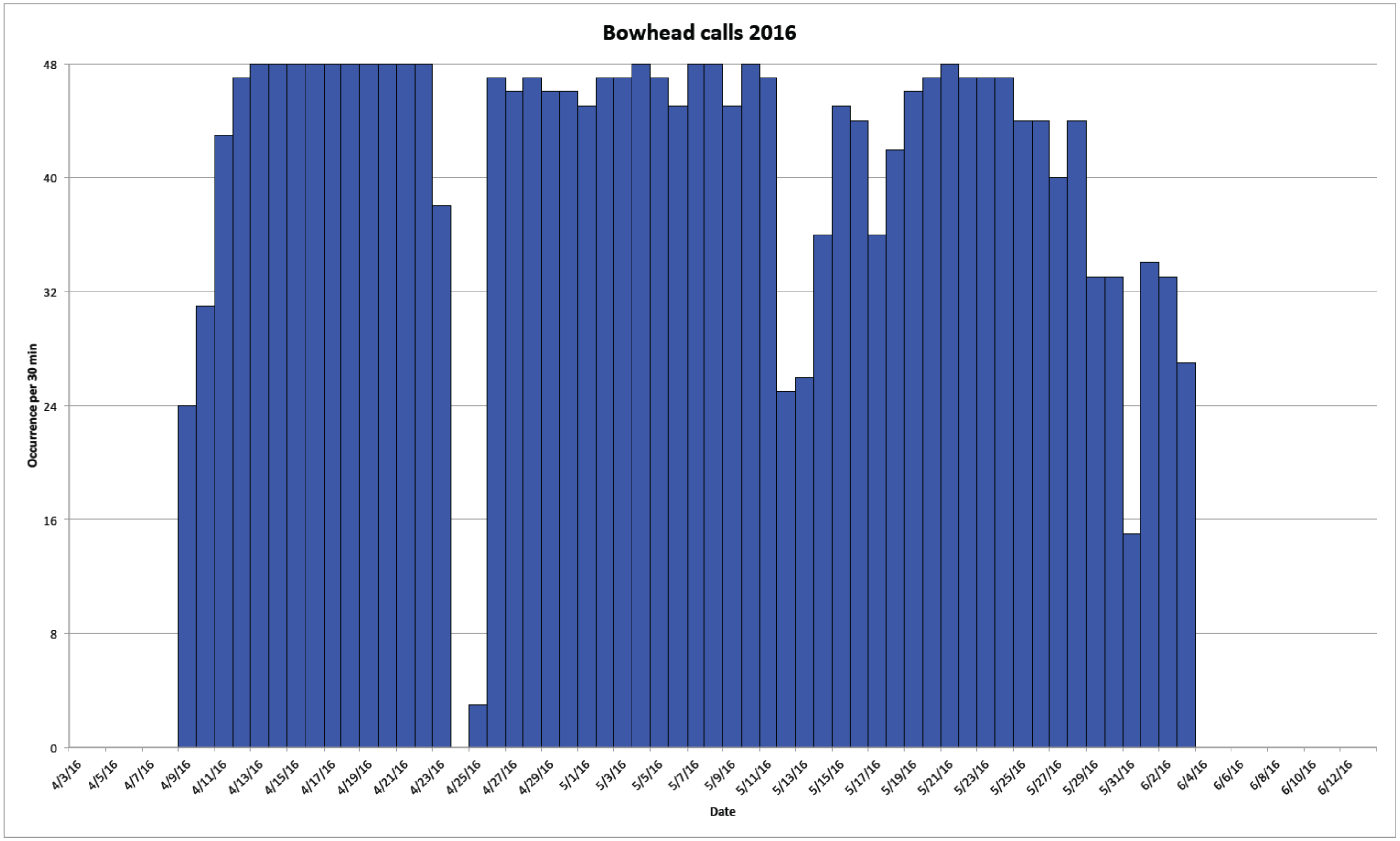

Figure 5. Occurrence of bowhead calls in 30 minute intervals for the 2016 spring season near Utqiaġvik, Alaska.

Table 5. Bowhead whale carcass sightings from aerial surveys, July-October, 1982-2016 and beach-cast whales in the Bering Sea region for 2016.

Date	Number of Carcasses	Age Class	Habitat	Latitude	Longitude	Notes
23-Sep-1982	1	Adult	open water	71.322	-152.600	
28-Sep-1982	1	Adult	open water	71.160	-154.232	
3-Oct-1982	1	Adult	open water	70.910	-160.162	
18-Jul-1984	1	Adult	beach	68.917	-165.367	
18-Sep-1984	1	Adult	open water	70.542	-146.605	
19-Oct-1984	1	Adult	open water	71.347	-151.517	
29-Sep-1991	1	Calf	open water	71.345	-156.115	
12-Sep-1992	1	Adult	open water	70.142	-143.230	
9-Sep-1993	1	Adult	open water	70.522	-147.910	
18-Oct-1997	1	Adult	open water	71.480	-155.890	
17-Sep-1998	1	Adult	open water	70.403	-145.750	
19-Sep-1998	1	Adult	open water	71.448	-155.383	
4-Oct-1998	1	Adult	open water	70.641	-143.205	
11-Oct-1998	1	Adult	open water	71.486	-152.732	
12-Sep-2000	1	Adult	open water	71.756	-154.556	
19-Sep-2003	1	Adult	open water	71.396	-151.102	
6-Sep-2004	1	Adult	open water	70.295	-143.847	
18-Sep-2004	1	Adult	open water	71.537	-155.501	
18-Sep-2004	1	Adult	open water	71.510	-155.997	
26-Sep-2004	1	Adult	open water	71.290	-154.574	
3-Oct-2007	1	Adult	open water	71.453	-154.664	
20-Aug-2009	1	Adult	beach	70.917	-157.607	Resighted 27 Aug 2009
27-Aug-2009	1	Adult	beach	70.925	-157.587	Resight of 20 Aug 2009
17-Sep-2010	1	Adult	open water	71.146	-157.986	
11-Sep-2013	1	Calf	open water	71.172	-162.642	
16-Sep-2013	1	Adult	open water	70.605	-147.825	Likely struck whale that was lost in this area
19-Sep-2013	1	Adult	beach	70.486	-160.431	

24-Sep-2013	1	Adult	beach	70.873	-157.765	
26-Sep-2013	1	Adult	beach	70.878	-159.103	
30-Sep-2013	1	Adult	open water	71.623	-167.994	Fresh dead with white scarring on flanks
7-Jul-2015	1	Adult	open water	63.32	-169.35	(Sheffield and SWCA 2015) Location approximate
18-Aug-2015	1	Adult	beach	70.875	-159.174	
21-Sep-2015	1	Adult	open water	70.789	-168.724	
23-Sep-2015	1	Adult	open water	70.828	-146.731	
27-Sep-2015	1	Calf	open water	71.415	-159.031	Resighted 28 Sep 2015
28-Sep-2015	1	Calf	open water	71.444	-159.198	Resighted 27 Sep 2015
4-Oct-2015	1	Adult	open water	71.281	-158.512	
4-Oct-2015	1	Adult	open water	71.388	-155.454	Confirmed via photos to be struck and lost whale from several days prior
4-Oct-2015	1	Calf	open water	71.331	-153.749	Rake marks on pec, possible killer whale predation
27-Oct-2015	1	Adult	open water	70.992	-162.354	
27-Oct-2015	1	Adult	open water	71.460	-164.172	Carcass had orange float attached
27-Oct-2015	1	Adult	open water	72.017	-165.377	Lower jaw partially missing
13-Jul-2016	1	Adult	open water	70.845	-160.018	Resighted on beach 10 Sep 2016
27-Aug-2016	1	Adult	open water	71.499	-150.158	Resighted 8 and 21 Sep 2016
5-Sep-2016	1	Adult	beach	63.12	-162.45	(Sheffield et al. 2016*b*)
8-Sep-2016	1	Adult	open water	70.669	-145.326	Resight of 27 Aug 2016; resighted 21 Sep 2016
10-Sep-2016	1	Adult	beach	70.919	-157.601	Resight of carcass floating on 13 Jul 2016
11-Sep-2016	1	Adult	open water	71.311	-165.809	
11-Sep-2016	1	Adult	open water	71.486	-163.339	
14-Sep-2016	1	Adult	open water	70.334	-141.614	
21-Sep-2016	1	Adult	open water	70.372	-141.813	Resight of 27 Aug and 21 Sep 2016

[i] Formerly Barrow, Alaska