Bowhead whale calls recorded on an autonomous instrument in the Beaufort Sea, 2003-2004

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ABSTRACT

Here we augment our provisional report on recordings of bowhead whale calls from an autonomous instrument deployed in the western Beaufort Sea (SC57BRG3) and provide a synoptic comparison of sound profiles from known and unknown sources. We focused our analyses on data from the recorder containing the longest data record. Bowhead calls were recorded only during the first few weeks after deployment on 3 October 2003 and then not again until 12 April 2004 after which calls were recorded until the instrument failed on 12 May 2004. Ambient noise levels in the vicinity of the hydrophone, based on spectra derived from 30-minute samples of whale calls, ship's passage and a range of wind and ice conditions, varied by as much as 20 dB. Notably, as reported last year, gray whale calls dominated the spectra, especially in late autumn 2004.

INTRODUCTION

Although there were occasional summertime sightings of bowhead whales near Barrow in the late 1970s and 1980s (Moore 1992), the bulk of the herd was thought to occupy Canadian Beaufort waters (Moore & Reeves 1993) during the summer. Since 1999, there have been increasing reports of bowhead whales summering near Barrow, with whales seen northeast and southwest of Barrow during opportunistic surveys in July 1999 and July 2003, respectively (Moore unpublished data). The increase in sightings could be due to expanding populations (George et al. 2004), climate-induced changes in habitat (e.g., Moore et al. 2003), or both. To document this possible summertime occurrence of bowheads, three hydrophones were deployed in October 2003 for one year to record the sounds of migrating bowhead whales.

Oceanographic research related to climate variability is expanding in the Arctic, which provides opportunities for collaborative investigations of cetacean habitats. One such collaboration with the US National Science Foundation/Shelf Basin Interaction (NSF/SBI) project resulted in the year-long deployment of three autonomous recorders in the western Beaufort Sea. The SBI project is an interdisciplinary component of the US National Science Foundation (NSF) Arctic System Science (ARCSS) Program (http://sbi.utk.edu), which seeks to investigate the impact of global climate on the physical and biogeochemical processes on the shelf and basin of the western Arctic. Although habitat investigation for Arctic cetaceans was included in the Final SBI Science Plan, available funding was insufficient to support cetacean-focused field research. Nonetheless, with support from NOAA/National Marine Mammal Laboratory (NMML) and in-kind contributions from SBI Principal Investigators from Woods Hole Oceanographic Institution (R. Pickart) and the University of Washington (R. Woodgate), three autonomous Acoustic Recording Packages (ARPs, Wiggins 2003) were deployed in the western Beaufort Sea in early October 2003 to provide continuous year-round sampling for cetacean calls. The recorders were placed near a mooring line focused on fine-scale sampling of physical oceanographic parameters along the Beaufort Sea slope and in the vicinity of recent bowhead whale sightings (Fig. 1).

METHODS

Two of three acoustic recording packages (ARPs) deployed in the Beaufort Sea in October 2003 were recovered in September 2004 (A & B in Figure 1). The third ARP was not retrieved after repeated attempts, either due to instrument malfunction, or drift from the deployment site. Instrument A was deployed at 71° 28.3 N latitude, 151° 56 W longitude in water 316 m deep and instrument B was deployed at 71° 39.3 N latitude, 151° 48 W longitude in water depth of 1258 m. ARPs sit on the seafloor with a hydrophone suspended roughly 10 m above the instrument by flotation (Figure 2). The ARPs sampled data continuously at 1000 Hz and were low-passed with a 6-pole filter at the Nyquist frequency for an effective bandwidth of 10-500 Hz (see Wiggins 2003). Data were archived on-board the instrument in ~1 GB binary files which represented just over 6 days of data per file.

Upon recovery, the internal hard drives were removed and the data downloaded for processing. Due to a battery malfunction, instrument A only recorded data from 4 October 2003 to 29 December 2003 while instrument B recorded from 3 October 2003 until 12 May 2004. Because our interest is in the seasonal occurrence of bowhead whale calls, only data from instrument B were analysed for this report. The available data files were split into 2-

hour segments to facilitate processing and 20 s spectrogram equalization was applied to remove long-term noise such as that produce by ships. Data files were scanned visually for the presence of bowhead whale calls.

Examples of ambient noise levels were chosen from throughout the dataset to illustrate the variability in sound levels in the vicinity of the instrument. This was done by first examining spectrograms and then spectra of data containing different noise sources to briefly survey variations in ambient noise at site B. Uncorrected wind speed and direction recorded at the Point Barrow Observatory (http://www.cmdl.noaa.gov/obop/met/brw/) were obtained to determine if there was any obvious correlation between noise levels and wind speeds.

RESULTS

The results reported here are based on a preliminary analysis of the 7.5 months of acoustic data available from one instrument. Bowhead whales were recorded on 10 of the 28 days available in October 2003 and not thereafter until April 2004 when they were recorded on 14 of 30 days beginning on 12 April 2004 and every available day in May 2004 (Figure 2). During the last 3 weeks of data recording, bowhead whale calls were recorded almost every hour. These included up- and down-swept signals as well as inflected calls (Figure 3) as described by previous authors (Cummings & Holliday 1987; Ljungblad et al. 1982; Clark & Johnson 1984). Most of the calls recorded were “non-sequential” (Ljungblad et al. 1982) and no instances of “song” were noted in the short time in which we recorded bowhead whales (Ljungblad et al. 1982).

Ambient noise recorded by the hydrophone varied over 20 dB over most of the 500 Hz frequency range and over relatively short time periods (Figure 4). No quantitative study of noise levels was undertaken for this report but examination of the data showed evidence of ship passages, ice noise, and gray and bowhead whale calls (Figure 5). Because the spectra from January 4 and January 8 2004 showed broadband differences from 10 dB to just over 20 dB during the same time of day, it was thought that, despite presumed ice cover, the sound levels might have been driven by wind speeds. On 4 January, however, the day with lower ambient noise levels, the daily average wind speed was 11 m/s (range5-15, uncorrected data) from roughly 240°. Wind speed on 8 January, the louder of the two days, was only 7 m/s (range 5-8 m/s) from 20°.

DISCUSSION

The successful integration of acoustic data with visual observations to census migrating bowhead whales off Barrow has been the exemplar for monitoring large whale populations with passive acoustics (cf Clark & Ellison 2000; Ko et al. 1986). This study generally occurred during the bowhead whale’s spring migration eastwards and is the basis for current population estimates. This long-term study, however, has recently become the victim of warming in the Arctic, as the shore fast pack has become less stable as a platform for monitoring the annual migration past Barrow. The seasonality of the bowhead whale data presented here is similar to previous work where animals migrate past Barrow from about mid-April to mid-June (George et al. 1989). Unfortunately, the instrument failed just as the number and occurrence of bowhead whale calls were increasing; therefore we were not able to determine if this pattern continued through the spring nor if bowheads remained in the area throughout the summer as has been suggested by visual surveys. The acoustic data did illustrate that bowhead whales have left the Barrow region by late October and apparently do not over winter there.

Although the variability in ambient noise shown here is intriguing, a quantitative, year-round study is necessary to describe the acoustic environment of the Arctic. For instance, we do not know if the differences in ambient noise highlighted from early January 2004 may have resulted from west winds forcing ice east, closing any leads and creating a quieter environment while the winds from the ENE 4 days later may have piled ice towards the shore, thereby increasing ambient noise levels. With the potential for increased variation in ambient noise due to climate-driven changes in wind speed (Stone 1997), reduced ice cover (Parkinson et al. 1999) increased anthropogenic inputs as the wintertime Arctic becomes more accessible (IPCC 2001) and greater contribution to ambient noise from extra-seasonal species such as gray whales (Stafford et al., submitted), we suggest that a long-term project to study the Arctic environment by use of passive acoustic methods be undertaken in order to document and monitor year-round changes in ambient noise.

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FIGURES

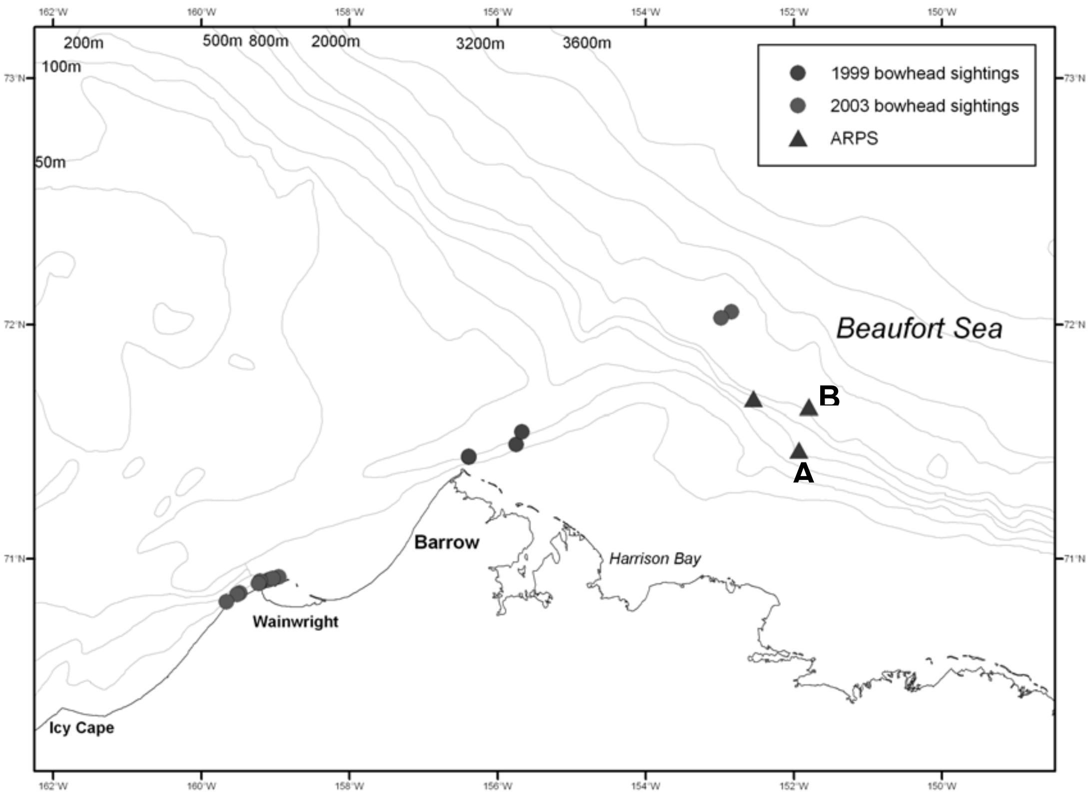

Figure 1. Locations of the ARPs (▲) in the Beaufort Sea. Instruments A and B were deployed in early October 2003 and recovered in September 2004. Locations of bowhead whale sightings from 1999 and 2003 are also shown (●).

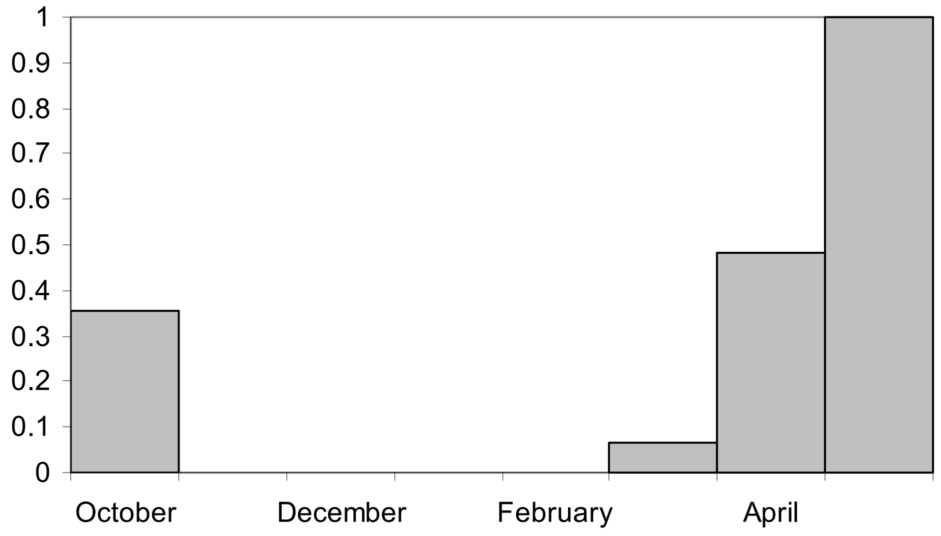

Figure 2. Bowhead whale call occurrence at site B: 3 October 2003 – 12 May 2004. Y-axis is the proportion of days in which bowhead whale calls were recorded out of total number of days of data available.

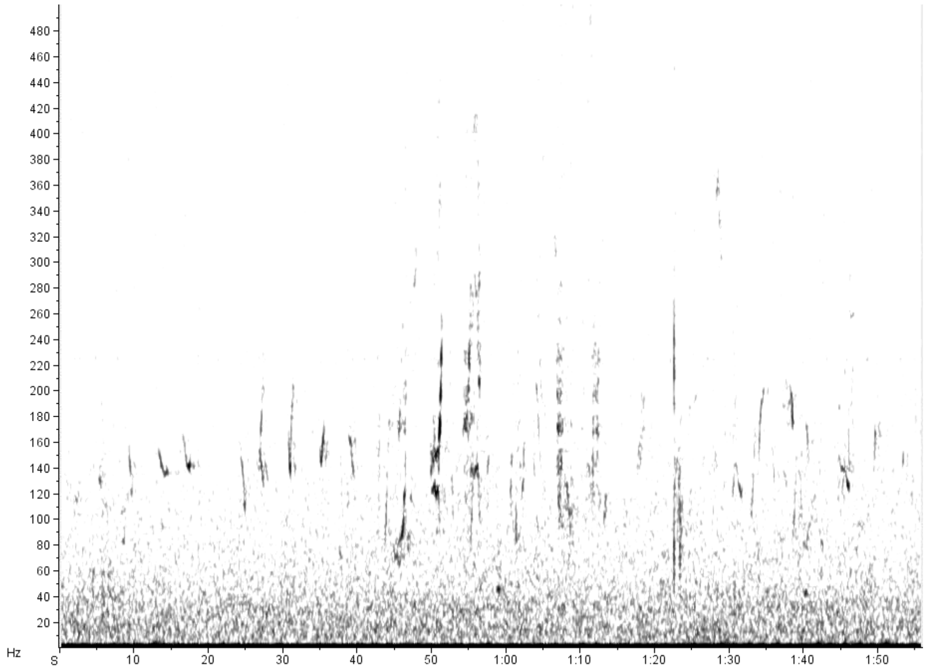

Figure 3. Bowhead whale call series recorded at site B on 1 May 2004. (256 pt FFT, 25% overlap, Hanning window).

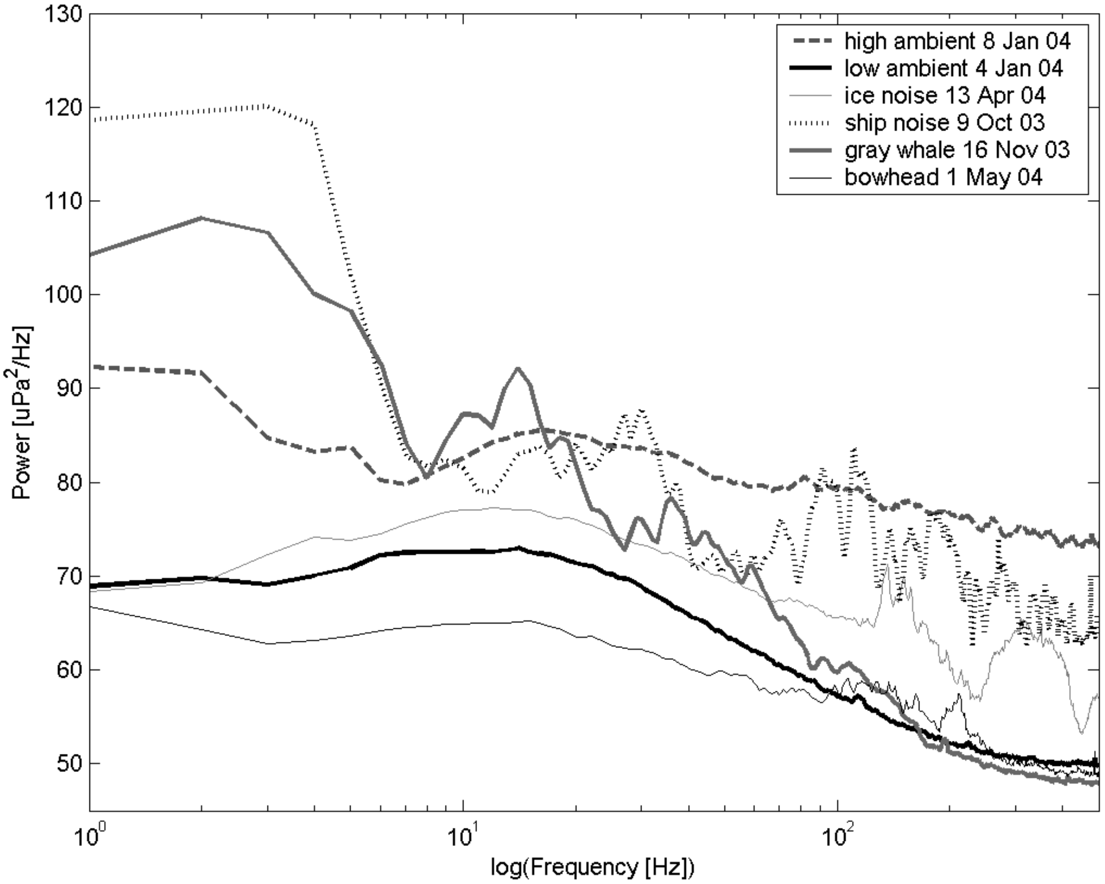

Figure 4. Spectra from 30 minute periods illustrating the variability in ambient noise received at the hydrophone.

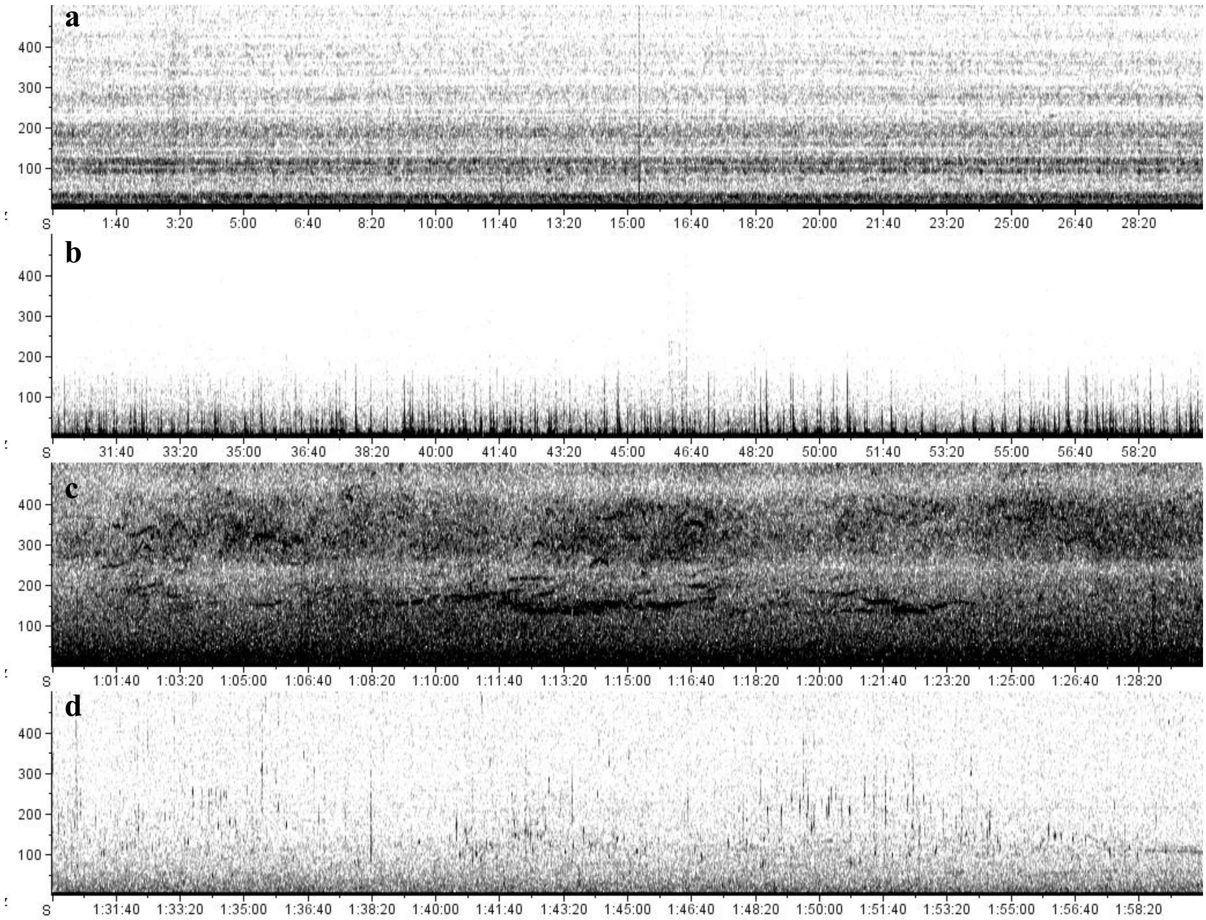

Figure 5. Spectrograms (256 pt FFT 75% overlap, Hanning window) illustrating the data shown in the spectra from Figure 4 above. a) ship noise; b) gray whale pulses; c) ice noise; d) bowhead whale calls.