Acoustic Monitoring of the Bowhead Spring Migration off Pt. Barrow, Alaska: Results from 2009 and Status of 2010 Field Effort

Christopher W. Clark[1]; Robert Suydam[2], Craig George[2]

[1] *Bioacoustics Research Program, Cornell University, 159 Sapsucker Woods Road, Ithaca, New York 148504, USA (contact cwc2@cornell.edu)*
[2] *Department of Wildlife Management, North Slope Borough, Box 69, Barrow, Alaska, USA*

Abstract
In early April 2009, four marine autonomous seafloor recorders were deployed off Pt. Barrow Alaska during the bowhead spring migration (see George and Suydam 2009). The primary objective of this effort was to demonstrate that this equipment could effectively replace the previous mechanism that relied on an array of hydrophones deployed from the ice edge for recording calling and singing bowheads. Three of the four recorders were recovered in early August 2009. Preliminary analyses based on one hour of data/day detected singing or calling bowheads on 36 of the 40 days for the 10 April - 18 May 2009 period. Singing was the more common acoustic activity. Preliminary analysis further indicates that the multi-channel data collected with this type of autonomous seafloor array can be used to reliably locate and track acoustically active bowheads as they migrate past Barrow. Results from this 2009 acoustic effort demonstrate the efficacy of this new seafloor array procedure and indicate that it can be used in the future as the method for obtaining acoustic data for the bowhead census and population estimation process. In early April 2010 an array of five recorders were deployed along the ice edge, and their recovery is scheduled for sometime in early Agust 2010.

Introduction
Beginning in 1984 and continuing through 2001 arrays of hydrophones have been used to obtain multi-channel acoustic recordings during the spring migration of bowhead whales (*Balaena mysticetus*) past Point Barrow, Alaska (e.g., Clark and Ellison 1988; Clark et al. 1996). These array recording are analyzed for bowhead sounds which are then analyzed to calculate the locations of the calling and singing whales. Locations are subsequenctly merged with visual sightings to calculate a population estimate (Raftery and Zeh 1998; Zeh et al. 1993). The time series of these population estimates is used to calculate a population trend which is used as part of the process for setting the bowhead quota (George et al. 2004).

The effort required to deploy and maintain ice-based hydrophone arrays and record the necessary multi-channel recordings is intense and, despite the thrills, often risky. The array consists of at least three hydrophones deployed from the ice edge or through the ice near the edge. Each hydrophone is cabled to a modified Navy sonobuoy RF transmitter system mounted in the ice, and the data from each of these stations are received in a portable hut a safe distance away from the ice edge, where the data are recorded directly into synchronized, multi-channel acoustic files. This data collection approach requires a coordinated team of ice-savy, and sometimes a bit crazy, people working 24-h per day throughout the migration season.

Using this procedure, the largest hydrophone arrays have consisted of up to five hydrophones, and the largest array apertures (the distance between the hydrophones at the ends of the array) have been approximately 4 km. The number of hydrophones in the array and the array aperture size are important factors in that they determine, to a great extent, the likelihood of locating a calling/singing bowhead and the accurracy/precision of the resultant location.

Spring ice conditions are critically important for the success of the spring census. In general, these conditions have not been improving, and there have been growing concerns that our ability to safely maintain ice camps throughout a April-June census period will be compromised. In anticipation of these changing conditions and the potential impact on our ability to successfully conduct the acoustic component of the spring census, in the spring of 2009 we evaluated the efficacy of using an array of marine autonomous recording units for the spring census. This paper reports on the preliminary results of the 2009 study.

Field Effort

The field effort was designed around the deployment of marine autonomous recording units (MARUs, aka “pop-ups”; Figure 1) A MARU is a digital audio recorder that can be programmed to record on a desired daily schedule and operate for periods from weeks to months in a remote environment. A MARU is packaged in positively buoyant glass sphere and deployed by being dropped to the seafloor with an anchor such that it floats a few meters above the bottom. Underwater sounds are recorded through a hydrophone mounted outside the sphere. The incoming sound data are conditioned, digitized, and stored in a binary digital audio format on electronic storage media within the sphere. At the conclusion of the deployment, the MARU is sent an acoustic command to release itself from its anchor, and it floats to the surface for recovery. After the device is recovered, its recorded audio data are extracted, merged with data from the other units into multi-channel files that are stored on a server for analysis. At the start and end of the deployment all units are synchronized.

In early April 2009 a set of four MARUs were deployed in an array along the ice edge (Figure 2). Three of the four units were successfully recovered in early August 2009

(Figure 3). Each of these three units recorded throughout the 9 April – 5 August 2009 period.

In April 2010 an array of 5 MARUs was deployed off the ice edge in anticipation of a successful census. Unfortunately conditions did not materialize for a successful census. The 5-MARU array has been under ice for sometime and and their recovery is scheduled for sometime in early August 2010.

Figure 1. Marine Autonomous Recording Units (MARUs). A) MARUs on deck waiting for deployment. B) Deploying the individual MARU. C) Retrieving the MARU. D) MARUs being refurbished before redeployment

Preliminary Analysis

Bowhead sound detections: A sub-sample of the 3-channel array data was analyzed for detections of bowhead sounds and to determine our ability to locate vocalizing bowheads. The sub-sample data consisted of a randomly selected hour per day for each of the three channels over the 40-day recording period from 10 April through 19 May, where a channel represents the acoustic data from one of the MARUs. Each of the 120 hours was processed by an experienced analyst using XBAT (eXtensible BioAcoustic Tool, **http://xbat.org**) to detect and annotate the first occurrence of a bowhead sound. At that time the analyst also noted whether the sound was a call or part of a song (see Figures 4 and 5).

Table 1 lists the results of the preliminiary detection analysis and shows that for 69 of the 120 MARU-hours sampled, song was the first bowhead sound detected, while a call was the first bowhead sound detected for 27 hours, and no bowhead sounds were detected on 29 of the 120 hours. Furthermore, on 14 of the 40 hours the first bowhead sound detected was not detected on three MARUs and could therefore could not be located.

Bowhead sound locations: A random subset of calls and song notes was analyzed to evaluated whether or not the MARU array data were acceptable for location analysis. Two primary factors were of greatest concern for this evaluation: synchronization and bowhead sound received levels. The concern regarding synchronization refers to the fact that unlike previous array recording efforts, each of the MARUs in a MARU array is operating with its own crystal controlled clock and each clock has a slightly different drift rate, which is partly dependent on temperature. Although the MARUs were synchronized at the start and end of deployment, and the water temperature was essentially the same at each recorder, they will each drift differently throughout their deployment. Without calibrating each MARU's crystal-temperature response function and correcting for this drift throughout a deployment, differences in MARU drifts lead to a certain amount of asynchrony in the multi-channel data, which, in turn, translates into uncertainty in a location. The concern regarding bowhead sound levels refers to the fact that in order to locate the vocalizing whale its sound must be recorded at a reasonable level on at least three recorders. In past ice-based arrays, hydrophones were deployed 600-1100m apart, whereas in this 2009 MARU array the units were deployed about 2,500m apart. The smaller inter-unit separation for the earlier, ice-edge-deployed arrays meant that there was a good chance of detecting the same call on at least three hydrophones, but the smaller aperture size reduced the area within which sounds could be reliably located. In contrast the wider inter-unit separation and larger array aperture with the MARU array has benefits in that this reduces the negative effect of synchronization error and allows for a larger area in which to reliably locate vocalizing animals.

The preliminary location analysis of the data from the asymmetric, 3-element MARU array with an aperture of over 4km yielded reliable locations. Based on previous experiences in this environment we expect that further analysis of these data will show that reliable locations can be obtained out to ranges of at least 12 km. Given that the population estimate relies on differentiating between acoustic locations that are closer or further than 4km from the ice edge, we feel quite confident that the application of an array of MARUs will perform effectively in a future visual-acoustic census effort. This approach will be especially effective if the array is calibrated and can include 5-8 MARUs with an apperture of 5-8 km.

Figure 3. Locations of the three MARUs deployed and recovered off Point Barrow, Alaska, 9 April – 5 August 2009. The fourth unit (MARU-4) was never recovered.

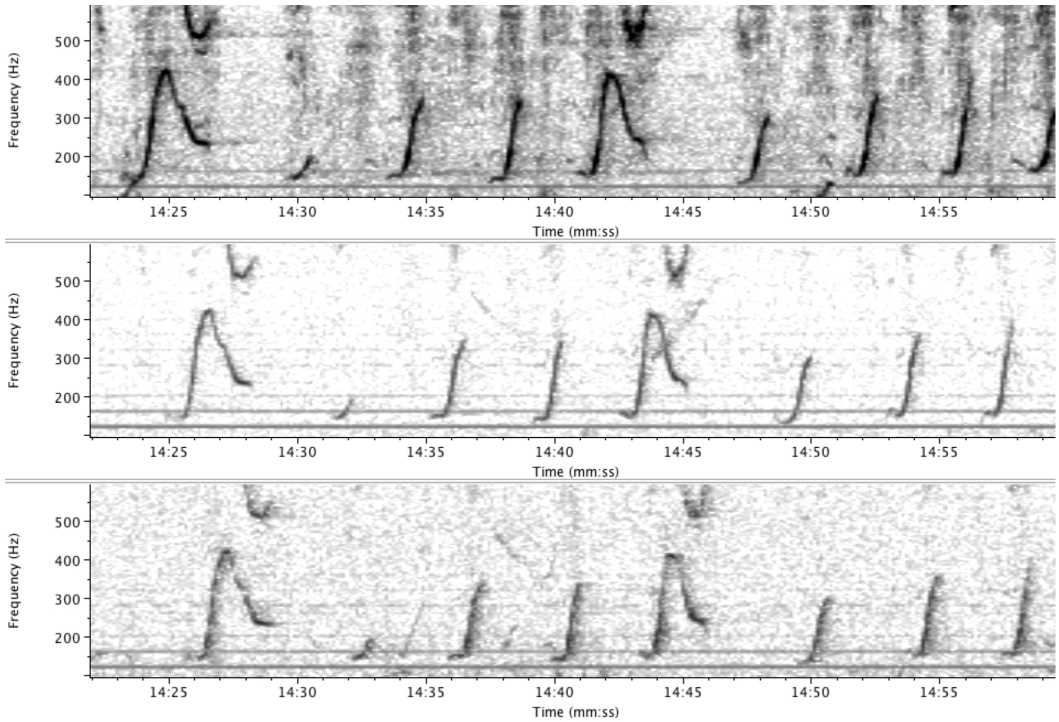

Figure 4. Example of 3-channel spectrogram of bowhead song starting at 01:44:25 on 10 April 2010. [Top is MARU-1, middle is MARU-2, bottom is MARU-3.]

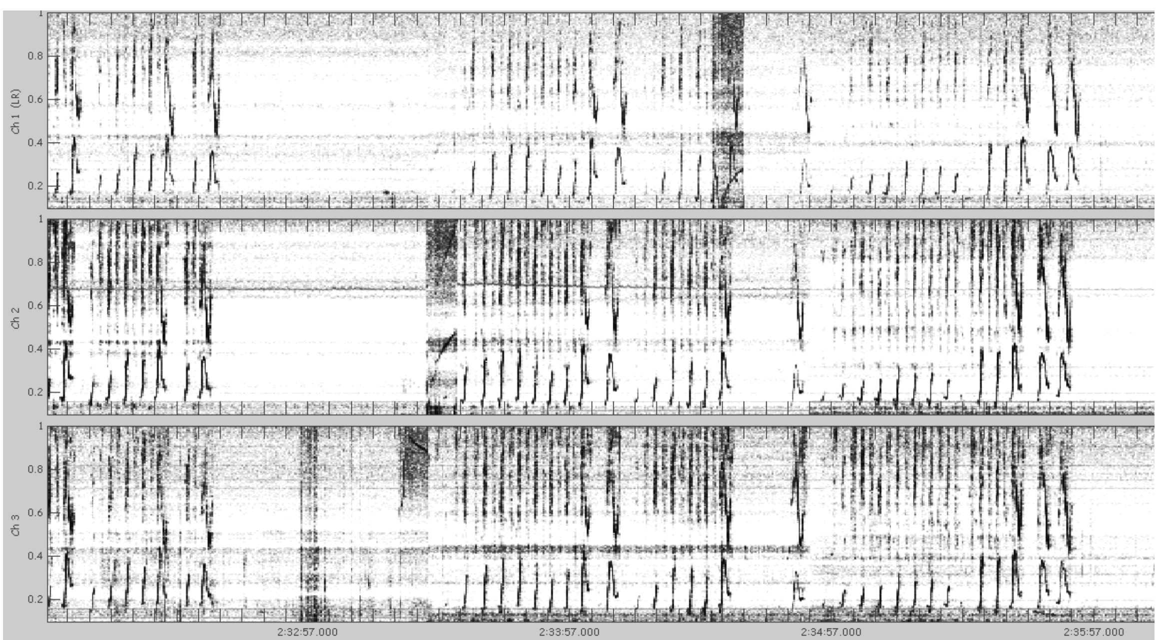

Figure 5. Example of 3-channel spectrogram showing a series of bowhead songs from approx 02:32 – 02:36 at 10 April 2010.

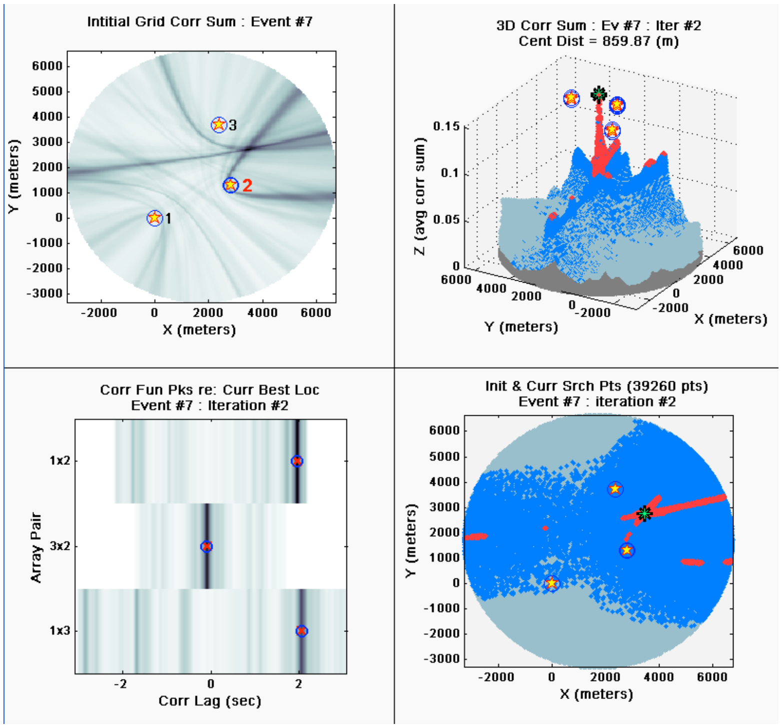

Figure 6. Location analysis display for bowhead song at 02:38:48 on 10 April 2010.

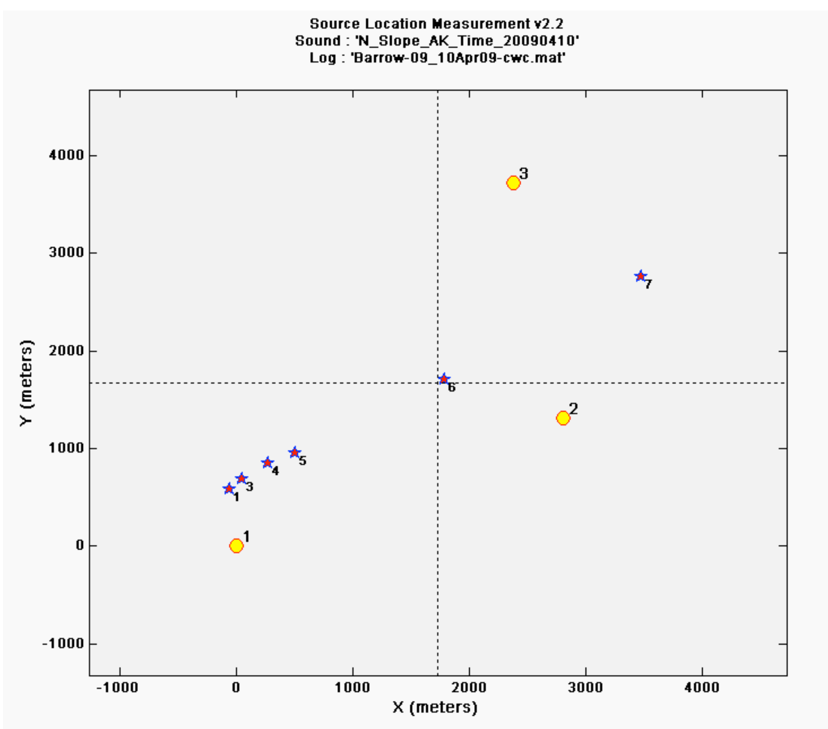

Figure 7. Plot showing a series of locations for the bowhead singer between 01:44 – 02:49 on 10 April 2009. This series defines this singer’s track as it moved through the array area.

Date	Hour	Vocalization Type MARU-1 (Song/Call)	Vocalization Type MARU-2 (Song/Call)	Vocalization Type MARU-3 (Song/Call)
10-Apr-2009	18:00	Call	Call	0
11-Apr-2009	3:00	Song	Song	Song
12-Apr-2009	9:00	Song	0	0
13-Apr-2009	21:00	0	0	0
14-Apr-2009	3:00	0	0	Call
15-Apr-2009	12:00	Song	Song	Song
16-Apr-2009	21:00	Song	Song	Song
17-Apr-2009	9:00	Song	Song	Song
18-Apr-2009	0:00	Song	Song	Song
19-Apr-2009	9:00	Song	Song	Song
20-Apr-2009	6:00	Song	Song	Song
21-Apr-2009	0:00	Song	Song	Song
22-Apr-2009	15:00	Song	Song	Song
23-Apr-2009	0:00	Song	Song	Song
24-Apr-2009	18:00	Song	Song	Song
25-Apr-2009	12:00	Song	0	Song
26-Apr-2009	15:00	Song	Call	0
27-Apr-2009	21:00	Song	Song	0
28-Apr-2009	12:00	0	0	Call
29-Apr-2009	21:00	Song	Song	0
30-Apr-2009	15:00	Song	Song	Song
1-May-2009	3:00	Song	Song	Song
2-May-2009	12:00	Song	Song	0
3-May-2009	18:00	Song	Song	Call
4-May-2009	0:00	Call	Call	Call
5-May-2009	0:00	Song	Call	Call
6-May-2009	9:00	Call	Call	Call
7-May-2009	6:00	Call	Call	Call
8-May-2009	15:00	Song	Call	Call
9-May-2009	12:00	Call	Call	Song
10-May-2009	12:00	Song	Song	Song
11-May-2009	3:00	0	0	0
12-May-2009	15:00	Song	Song	Song
13-May-2009	21:00	0	Song	Song
14-May-2009	6:00	Call	Call	Song
15-May-2009	3:00	Call	Call	Call
16-May-2009	3:00	Song	Call	Call
17-May-2009	21:00	0	0	0
18-May-2009	21:00	0	0	0
19-May-2009	12:00	Call	0	0

Total Number of Songs Found	64
Total Number of Calls Found	27
Total Number of Hours with neither Calls nor Songs	29
Total Hours Browsed	120

Table 1. Listing of dates and the hour analyzed on that date for the occurrence of bowhead whale sounds.

Acknowledgements
We acknowledge the cooperation of the Alaska Eskimo Whaling Commission (AEWC) and the whale hunters of Barrow who supported this study and allowed us to work near their camps on the sea ice. We greatly appreciate funding from the National Oceanic and Atmospheric Administration, the AEWC, the North Slope Borough (NSB) and BP Alaska. We could not have conducted this research without the able assistance of Jason Michalec, who assisted in the field deployment of the MARUs, and Ashik Rahaman, who conducted the preliminary analysis of the MARU data.

References
Clark, C.W. and Ellison, W.T. 1988. Numbers and distributions of bowhead whales, Balaena mysticetus, based on the 1985 acoustic study off Pt. Barrow, Alaska. Rep. int. Whal. Commn. 38:365-370.

Clark, C. W., Charif, R., Mitchell, S., and Colby, J. 1996. Distribution and Behavior of the Bowhead Whale, Balaena mysticetus, Based on Analysis of Acoustic Data Collected During the 1993 Spring Migration off Point Barrow, Alaska. Rep. int. Whal. Commn. 46: 541-552.

George, J. C. “Craig” and Suydam, R. 2009. Preliminary Report of the Spring 2009 Ice-Based Bowhead Whale Census Activities Near Barrow, Alaska. Paper SC/61/BRG23 submitted to the Int. Whal. Commn., Sci Comm. 2009.

George, J. C. “Craig”, Zeh, J., Suydam, R., and Clark, C. 2004. Abundance and population trend (1978-2001) of the western Arctic bowhead whales surveyed near Barrow, Alaska. Marine Mammal Science 20:755-773.

Raftery, A.E. and Zeh, J.E. 1998. Estimating bowhead whale population size and rate of increase from the 1993 census. *J. Am. Sta. Assoc*. 93:451-63.

Zeh, J., Clark, C.W., George, J.C., Withrow, D., Carroll, G.M. and Koski, W.R. 1993. Current Population Size and Dynamics. In: J. Burns, J. Montague, and C.J. Cowles (eds.), The Bowhead Whale. Society for Marine Mammalogy, Special Publication Number 2. Allen Press. Lawrence, Kansas. pp. 409-481.