2008 MYSTICETE PASSIVE ACOUSTIC MONITORING REPORT

PREPARED FOR MAINE DEPARTMENT OF MARINE RESOURCES

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ALLIED WHALE

BAR HARBOR, MAINE

JULY 4 – OCTOBER 1, 2008

Project No.			**Allied Whale**
Report No.			**105 Eden Street**
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1. EXECUTIVE SUMMARY

The coastline of Maine is utilized by a large number of traditional stakeholders including commercial and recreational fishing, commercial and recreational boating, ecotourism and commercial aquaculture in addition to being an important foraging and migration habitat for multiple species of baleen whales. The Maine Department of Marine Resources (MDMR) is tasked with balancing the needs of stakeholders and complying with the Atlantic Large Whale Take Reduction Plan (ALWTRP). Accordingly, MDMR contracted Allied Whale to deploy seven marine autonomous recording units (MARUs) in a network off the coast of Bar Harbor, Maine from July 4 – October 1, 2008 as a pilot study to determine whether or not passive acoustic monitoring (PAM) is a viable method for long-term monitoring of baleen whale habitat use off the coast of Maine.

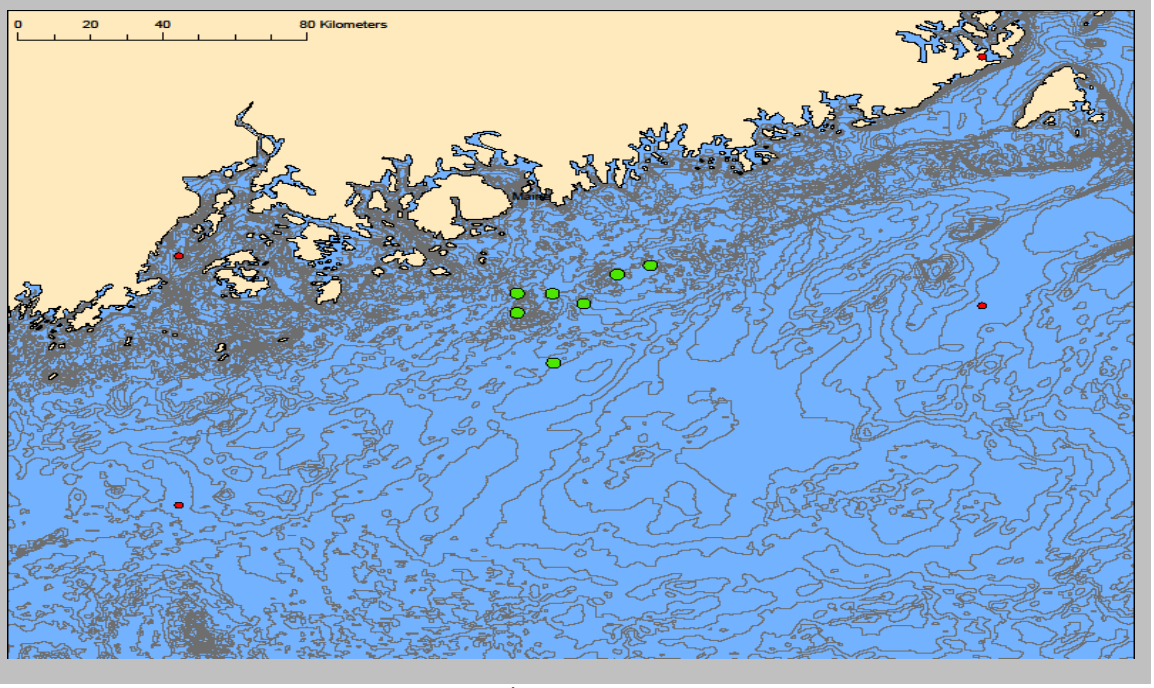
1.1. PROJECT SUMMARY

In order to assess the effectiveness of PAM as a method for monitoring and analyzing baleen whale habitat use off of Bar Harbor, Maine, Allied Whale deployed a network of seven MARUs obtained from Cornell University (CU) during July 4 – October 1, 2008 (see Figure 1 below). MARUs were mounted a few meters above the ocean floor and set to continuously record frequencies from 1-1000 Hz. In addition, these MARUs were deployed in a network traversed often by the Bar Harbor Whale Watch Company, LLC (BHWW). Allied Whale partnered with BHWW to obtain opportunistic visual observation data collected by dedicated research assistants aboard BHWW vessels traversing the study area concurrent with MARU deployment to compare the efficiency of visual and acoustic observation results.

1.2. SURVEY METHODOLOGY

All seven MARUs deployed from July 4-October 1, 2008 were successfully retrieved,

Figure 1. General location of survey.



however B4 stopped recording data on August 26, 2008 (see figure 1 for B4 location).

The remaining buoys recorded successfully throughout the deployment period.

Once the buoys were retrieved, CU retrieved the hard drives from each buoy, and synchronized the buoy recordings based on initial and ending manual bang sequences recorded immediately before and after deployment to minimize MARU time drift. From there, a set of comprehensive files were created including all synchronized MARU data separated into 15 minute audio files.

Both XBAT and RAVEN Pro v 1.4 were utilized for post-processing analysis. Several different data management methods were attempted and discarded before reaching a final post-processing methodology that was both reasonably thorough and reasonably efficient.

The initial goal of this project was to develop auto-detection presets in XBAT that would pick up 90% of all baleen whale vocalizations and return less than a 10% false positive rate. This methodology was pursued from January 2009 through April 15, 2009 with little success. Although a dedicated team of student workers was involved in both hand-browsing and evaluating the effectiveness of auto-detection presets created during this time, several problems were encountered. First, the sheer quantity and variety of baleen whale vocalizations encountered during this period was unanticipated. Student workers and acoustic staff identified at least 17 distinct vocalization types attributed to 5 different species of baleen whales. In total, during one 24-hour period of recordings, there were approximately 1500 individual vocalizations identified across the seven MARUs. As a result, running auto-detection presets in XBAT took up too much random access memory (RAM) to be an efficient process. In addition, XBAT only allows for spectrogram cross-correlation auto-detection presets; a preset which enables the human operator to select a specific “pattern” vocalization spectrogram to be the standard for which all vocalization spectrograms are selected for. This is a sound theoretical concept, but two distinct issues arose. First, because ambient noise varied from buoy to buoy, a high rate of both false positives and false negatives was generated utilizing this methodology. False positives were generated when the auto-detection preset identified ambient noise as a vocalization spectrogram, and false negatives were generated when vocalization frequencies were altered slightly, vocalization timing patterns were altered slightly, or background noise varied from that of the original vocalization spectrogram. In addition, humpback whales were observed varying the base frequency of several different vocalization types as the dominant frequency of the ambient noise changed. This resulted in either a large number of false negatives or a need to run as many as 10 auto-detection presets in order to achieve a 60% positive detection return, reducing auto-detection efficiency.

Instead, on April 16, 2009 the acoustic staff switched our focus to developing presets for band-limited energy auto-detection (BLEAD) tool in RAVEN Pro. BLEADs do not utilize a spectrogram cross-correlation, but instead allow the operator to develop a frequency range, duration range, and signal to noise ratio to define specific vocalizations to be detected. Although this method is relatively crude, because of the relatively low levels of ambient noise recorded by all seven MARUs during deployment, the acoustics staff were able to create BLEAD presets for two humpback vocalizations that had a 80% or greater

true positive return combined with a 50% or less false positive return (MnMegap1 and MnFM). As with XBAT post-processing, all humpback vocalizations identified by autodetectors were verified by human operators to verify preset auto-detection accuracy.

Although this was a significant improvement in auto-detection accuracy, the sheer volume of mysticete vocalizations combined with the amount of human operator hours required to go behind the BLEAD presets still posed a significant data management issue. The acoustics staff experimented with running the BLEAD presets as built, then exporting the results into a spreadsheet, creating appropriate Hidden Markov Models (HMM) to determine the likelihood of true positive detections, and utilizing those HMMs to filter future exported spreadsheets from the same BLEAD presets run on additional 15-minute audio files. This reduced false positive auto-detection preset rate to approximately 35% for both BLEAD presets, but required too much RAM to be considered a sustainable post-processing method.

After attending the post-processing workshop at CU during September 2009, the acoustics staff again switched our focus. CU unveiled additional BLEAD preset criteria in the updated version of Raven Pro (v. 1.4) that included the ability to require the preset to ignore specific frequency bands when selecting vocalizations. This allowed for the creation of one additional humpback vocalization auto-detection preset (MnLongCall), and improved the efficiency of the presets as follows: 80% true positive combined with 10% false positive return for MnLongCall and MnFM, and 65% true positive combined with 25% false positive return for MnMegap1. The return for MnLongCall and MnFm at this rate was better than the results achieved by CU for any humpback call; again, likely as a result of the extremely low levels of ambient noise recorded in these frequency ranges off the coast of Maine.

In addition, upon attending the post-processing workshop at CU during September 2009, the process of applying to utilize the ISRAT XBAT auto-detection preset created by CU was started. This process continues, but as CU had already developed an auto-detection preset for right whale upcalls that operated at 90% true positive return combined with 20% or less false positive return, the acoustics staff determined it would be more effective to collaborate with CU than to continue attempting to create our own. This process is ongoing.

Finally, during the post-processing workshop at CU, several data management protocols were brought to our attention. First, that for their current long-term monitoring of mysticete vocalizations CU does not attempt to log all mysticete vocalizations recorded by the MARUs. Instead, they focus on establishing daily presence/absence for each mysticete species observed at each MARU deployed. After the workshop, acoustics staff decided to match CUs daily presence/absence data management protocols in an effort to reduce total post-processing time. Prior to the workshop, two acoustic staff and seven student workers had processed approximately three days of the 2008 MARU data over a nine month period. After altering the data management goals to achieve a species daily vocalization presence/absence as opposed to a comprehensive collection of all vocalizations recorded, one acoustic staff and three student workers were able to process the entire study period for finback and humpback whales during an eight month period; a significant improvement in post-processing time.

The final methodology used for data post-processing to determine daily species vocalization presence/absence within the deployed MARU network included running the

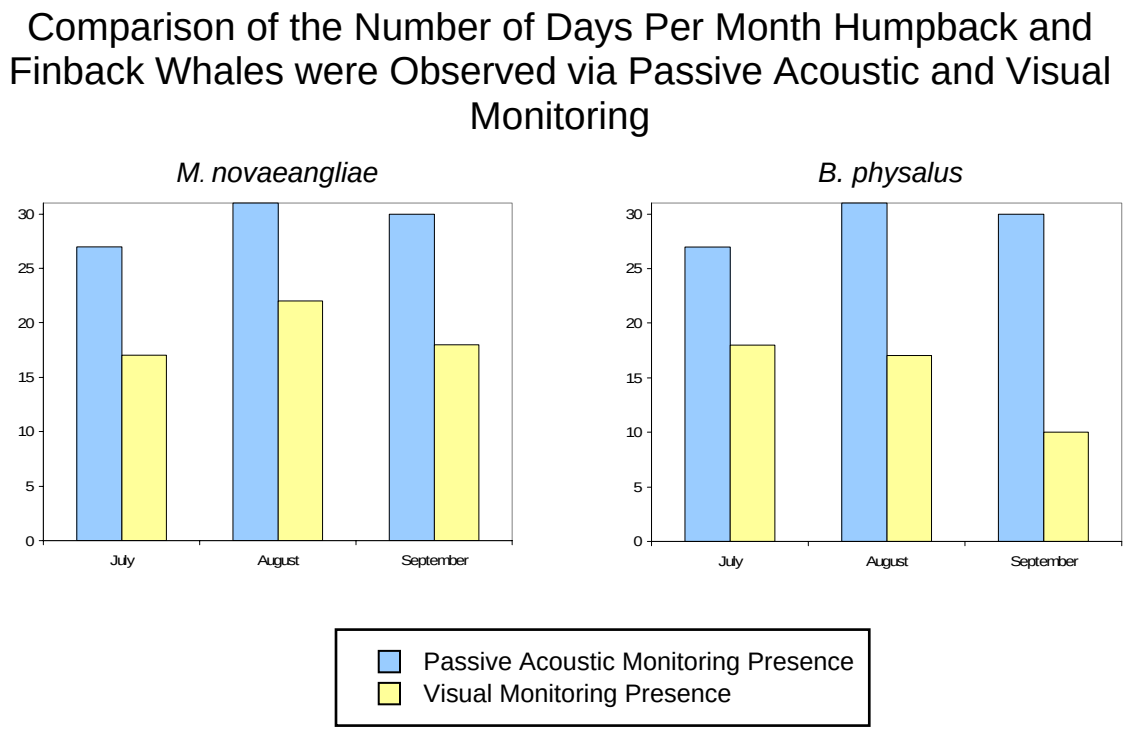
developed BLEAD presets for 3 humpback and 1 finback whale vocalization, then utilizing human operators to verify the results. These human operators were also free to glance at channels surrounding a BLEAD preset selection, but were not permitted hand-browsing, increasing our ability to detect many different mysticete vocalizations in an efficient manner. Once species presence was verified on a specific MARU during a specific date, further recordings from that MARU were disregarded, enabling human operators to reduce the total amount of time necessary to assess the acoustic data recorded.

1.3. SURVEY DATA SUMMARY

Daily Presence/Absence

Prior to this report, Allied Whale MARU data has been completely processed for humpback and finback whale vocalization presence/absence through the complete 2008 recording period (see Figure 2). During this time, finbacks were more consistently observed in all deployment months except August. During August, vocalizations from both species were recorded at least one time every day that each MARU was functioning properly with one exception; no finback whale vocalizations were recorded on MARU #6 on August 1, 2008. In addition, although our results are not significant, it appears that humpback vocalizations are absent more often than finback vocalizations during June and September.

These findings roughly correlate with BHWW sightings for this same time period, where visual surveys and PAM buoys overlap.



Number of Recorded Days that Each Species Had a Vocalization Presence at Specific Buoy Locations

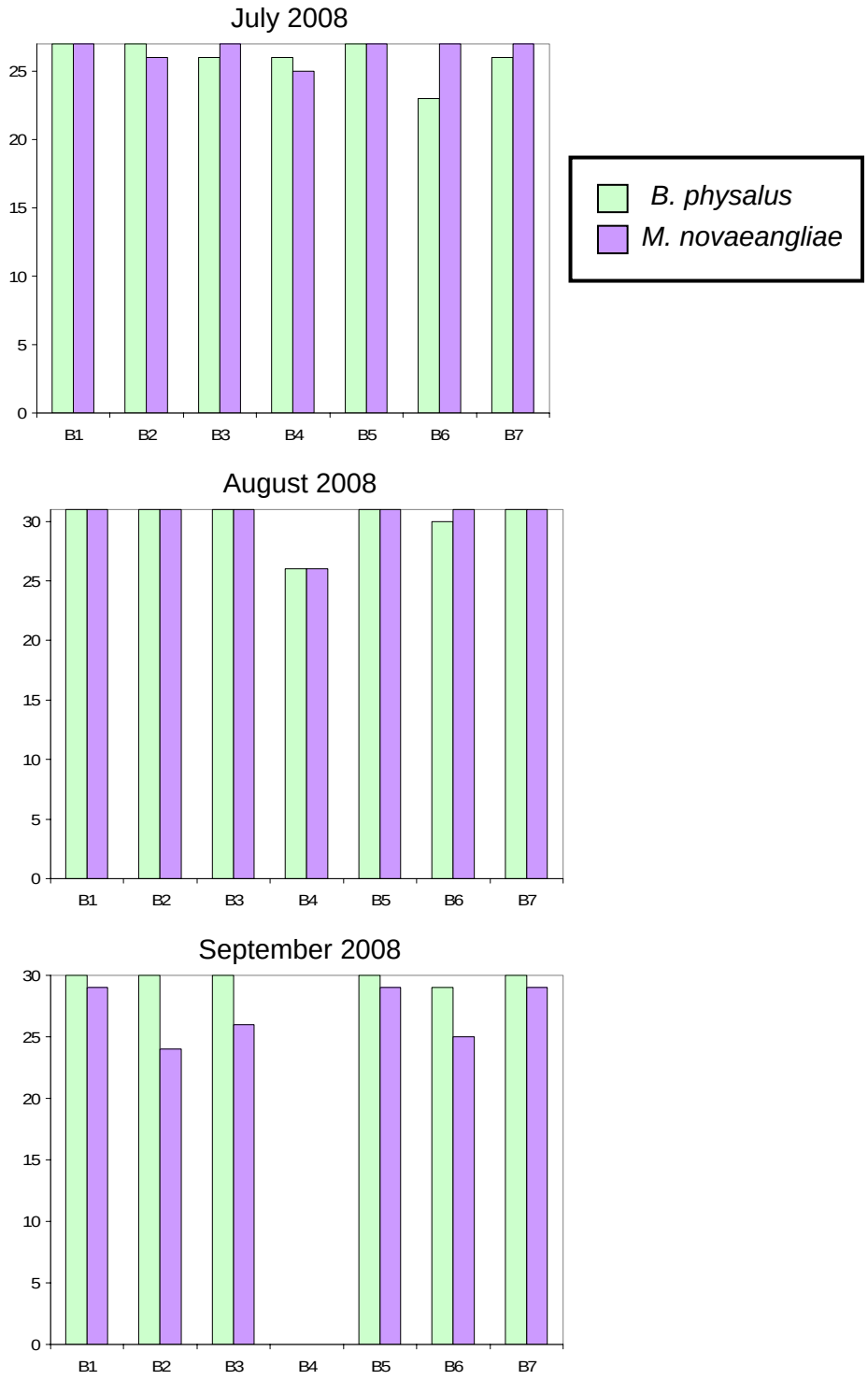
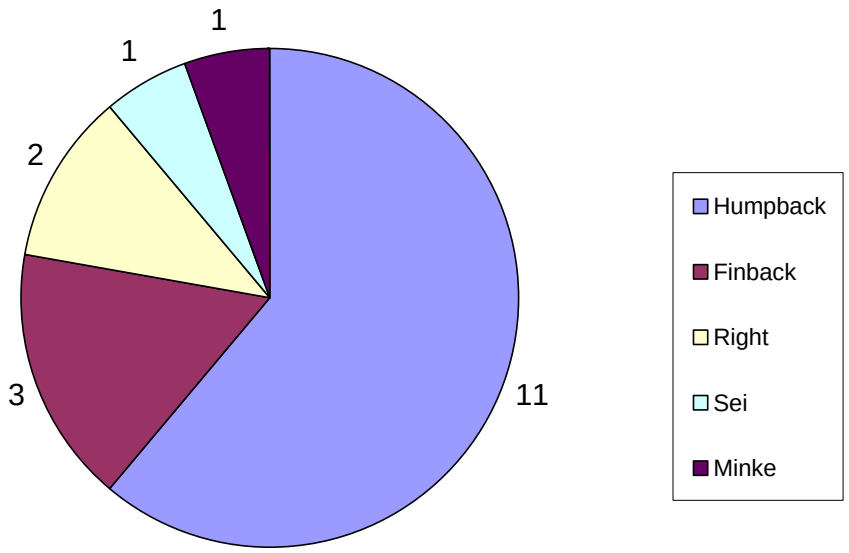


Figure 2. Number of Days MARUs were deployed July 4-September 30, 2008 that each buoy recorded a qualifying species present vocalization for finback and humpback whales. Note that July had 27 total recording days, and MARU #4 stopped recording on August 26, 2008.

Vocalization Variety

In addition to daily presences/absence data, the Allied Whale acoustic staff and student workers were able to hand-browse through three complete days; July 4-July 6, 2008. As a result, a much larger variety of mysticete vocalizations were recognized and logged during this time (see figure 4).

Number of Different Species Specific Vocalizations Observed



Humpback whales exhibited the largest vocalization repertoire, with 61% of all vocalizations recorded attributed to this species (see table 1). Of these eleven recorded vocalizations, megapclick sequences were the most common. Relatively successful BLEAD presents were created in RAVEN Pro 1.4 during this post-processing period for humpback frequency modulated, long, and megapclick vocalizations.

Vocalization	Frequency Range	Duration	Broadband/Tonal	Auto-detection preset developed	Auto-detection success percentages
Breaker	137-502 Hz	1.4647 s	Broadband	No	n/a
Downsweep	151-213 Hz	1.1207 s	n/a	No	n/a
Frequency-modulated	223-418 Hz	1.9681 s	n/a	Yes	80:10
Grunt	80-208 Hz	1.1475 s	Broadband	No	n/a
Long Call	502-749 Hz	6.4879 s	n/a	Yes	80:10
Megapclick	47-126 Hz	2.2386 s	Broadband	Yes	65:25
Repetition	147-310 Hz	0.5814 s	Broadband	No	n/a
W call	450-650 Hz	2.3643 s	n/a	No	n/a
T' call	75-483 Hz	1.6925 s	Tonal	No	n/a
Tonal	89-531 Hz	0.8734 s	Tonal	No	n/a
Yup	79-815 Hz	0.2688 s	Tonal	No	n/a

Finback whales showed a surprising amount of vocalization diversity as well, with three distinct species specific vocalizations observed during this deployment (see table 2). Of these, 20 Hertz pulses were by far the most common, followed by rumbles and moans.

Vocalization	Frequency Range	Duration	Broadband/Tonal	Auto-detection preset developed	Auto-detection success percentages
20 Hz Pulse	17-102 Hz	0.6989 s	Broadband	Yes	50:50
Rumble	19-102 Hz	1.5346 s	Broadband	No	n/a
Moan	10-40 Hz	3.6671 s	Tonal	No	n/a

In addition, North Atlantic right whale gunshots and upsweeps, sei downsweeps, and minke pulse chains were observed during this deployment (table 3). The BHWW sighted North Atlantic right whales and minke whales concurrent with these results, but did not

record any sei whale visual sightings during the 2008 season, indicating the potential for greater species coverage through PAM monitoring.

Species	Vocalization	Frequency Range	Duration	Broadband/ Tonal	Number of Days Observed to Date
Right	Gunshot	28-670 Hz	1.9119 s	Broadband	1
Right	Upsweep	130-188 Hz	0.5524 s	n/a	5
Sei	Downsweep	39-118 Hz	2.0104 s	n/a	2
Minke	Pulse Chains	142-214 Hz	0.5577 s	Broadband	>20

Given the amount of mysticete vocalization variety discovered during the data processing, it is likely a larger variety of calls exists. Examining the data on a more thorough level may be scientifically interesting at a later date.

1.4. FUTURE PROJECT RECOMMENDATIONS

In the future, MDMR funding could be maximized by clearly defining the goal of the project as soon as possible, and by focusing research on autodetector presets that would select for many different mysticete species' vocalizations at the same time. For example, current acoustics staff recommend focusing further research on developing entropy autodetection presets that utilize the change in acoustic energy to define mysticete vocalizations instead of focusing on the development of species' specific BLEAD and spectrogram cross-correlation autodetector presets that are subject to individual variation.

2. BAND LIMITED ENERGY AUTODETECTOR PRESETS

The coastline of Maine is utilized by a large number of traditional stakeholders including commercial and recreational fishing, commercial and recreational boating, ecotourism and commercial aquaculture in addition to being an important foraging and migration habitat for multiple species of baleen whales. The Maine Department of Marine Resources (MDMR) is tasked with balancing the needs of stakeholders and complying with the Atlantic Large Whale Take Reduction Plan (ALWTRP). Accordingly, MDMR contracted Allied Whale to deploy seven marine autonomous recording units (MARUs) in a network off the coast of Bar Harbor, Maine from July 4 – October 1, 2008 as a pilot study to determine whether or not passive acoustic monitoring (PAM) is a viable method for long-term monitoring of baleen whale habitat use off the coast of Maine.

2.1. HUMPBACK WHALES

In order to assess the effectiveness of PAM as a method for monitoring and analyzing baleen whale habitat use off of Bar Harbor, Maine, Allied Whale deployed a network of seven MARUs obtained from Cornell University (CU) during July 4 – October 1, 2008 (see Figure 1 below). MARUs were mounted a few meters above the ocean floor and set to continuously record frequencies from 1-1000

Vocalization Type	**Long Call**	**Frequency Modulated Call**	**Megapclick (low base frequency)**
Frequency Minimum	450 Hz	150 Hz	60 Hz
Frequency Maximum	800 Hz	450 Hz	80 Hz
Duration Minimum	1.536 s	1.472 s	0.192 s
Duration Maximum	14.976 s	2.496 s	0.576 s
Minimum Separation	1.472 s	1.024 s	0.128 s
Minimum Occupancy	40 %	70 %	99 %
Minimum Signal:Noise Ratio	5.0 dB	8.0 dB	6.0 dB
Block Size	2.496 s	3.008 s	1.984 s
Hop Size	0.512 s	1.024 s	0.512 s
Percentile Occupancy	20.0 %	20.0 %	20.0 %
Exclusion Frequency Minimum	100 Hz	35 Hz	150 Hz
Exclusion Frequency Maximum	300 Hz	60 Hz	200 Hz
Exclusion Signal:Noise Ratio Minimum	6.0 dB	8.0 dB	6.0 dB

2.2. FINBACK WHALES

In order to assess the effectiveness of PAM as a method for monitoring and analyzing baleen whale habitat use off of Bar Harbor, Maine, Allied Whale deployed a network of seven MARUs obtained from Cornell University (CU) during July 4 – October 1, 2008 (see Figure 1 below). MARUs were mounted a few meters above the ocean floor and set to continuously record frequencies from 1-1000 Hz.

Vocalization Type	20 Hz pulse
Frequency Minimum	15 Hz
Frequency Maximum	25 Hz
Duration Minimum	0.192 s
Duration Maximum	0.576 s
Minimum Separation	0.192 s
Minimum Occupancy	85 %
Minimum Signal:Noise Ratio	5.5 dB
Block Size	1.024 s
Hop Size	0.512 s
Percentile Occupancy	20.0 %
Exclusion Frequency Minimum	50 Hz
Exclusion Frequency Maximum	150 Hz
Exclusion Signal:Noise Ratio Minimum	6.0 dB