Allied Whale Research Report, Field Seasons 2010/2011

For work performed as funded by the Maine Department of Marine Resources, Large Whale Take Reduction Office

by

Sean Todd, Jackie Bort, Dan Dendanto, Tanya Lubansky, Brandyn Schult, Toby Stephenson and Chris Tremblay (2011)

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Summary of expenditure:	Research Expenses	$53,874
	Overhead	$10,775
	Total	$64,649

Executive Summary

In April 2010 Allied Whale solicited funds from Maine Department of Marine Resources' (DMR) Large Whale Take Reduction Program to continue out research activities in the northern Gulf of Maine that would inform current research programs and proposed management strategies at the state level designed to minimize take of large whales in Maine-governed waters. Proposed activities included: sighting transects, oceanographic data acquisition, acoustic census, and fishing gear distribution analysis. Work was successfully completed in the 2010 field season as detailed below, although in some cases we have expanded our results here to include 2011 as those data show the final conclusion of research investments in 2010. Also, certain subprojects are not reported here as they were analyzed through subcontracts with other third parties, specifically oceanographic data acquisition (Gulf of Maine Research Institute, GMRI), and fishing gear distribution analysis (Walk). Thus, this report focuses on results from sighting transects and acoustic census only.

Description of Work

In our initial proposal of work Allied Whale proposed to continue support of the current investigation led by Maine DMR concerning the presence, spatial and temporal distribution of large whales in inshore (< 30nm) waters of the State of Maine by completing the following work:

a) Sighting transects: Within the operational field season (June–September, inclusive) and weather dependent, Allied Whale operated randomized transects that range between the GoMOOS "I" buoy to a region known as the "Right Whale Hole" (RWH), 5 miles southeast of Mount Desert Rock, around Mount Desert Rock (MDR) and the Inner Schoodic Ridges (ISR). Transects were of two types, including census and more detailed focal group work. During census transects, counts of all marine mammals, large fish species (tuna, basking shark, others), and where possible birds, were noted (only marine mammals sightings are reported here). Focal group transects searched for clusters of animals previously unsurveyed; once found, teams performed full photo-identification and biopsy protocols on those animals under the Whale Center for New England's research permit **NMFS 605-1904**, under which Allied Whale's Principal Investigator (Todd) is a listed collaborator. Note that photo-identification protocols were modified to include capture of images usable for scarification analysis.

b) Oceanographic and plankton surveys: Allied Whale continued to contract lobsterman Chris Candage, of the F/V *Georgia Madison*, to conduct oblique tows from as close to the seafloor as possible to the surface using a 270μ, 0.5 m hoop, 5:1 aspect ratio plankton net (as provided by DMR). Samples were fixed in denaturized ethanol and sent to a third party (GMRI) for analysis. Methodologies were standardized to allow comparison of these data to concurrent *Calanus* surveys in other regions of the GoM. For each tow, a CTD profile was also obtained that included fluorometer readings. As data in this sub-project were entirely managed by GMRI, no further report of results is included here. Note that this subcontract was terminated at DMR's request so funds were not fully expended for this part of the proposed work.

c) Acoustic census. Funds requested this year supported an analyst/technician to analyze data collected by the Marine Autonomous Recording Units (MARUs) deployed on ISR, MDR in previous years and Outer Falls in this research season, with priority going to the latter of these buoys. The majority of this latter analysis constituted a Masters thesis by Ms. Jacqueline Bort at College of the Atlantic. We also request funds to continue to support MDR-based visual observations of whale behavior, to be correlated to acoustic sightings post-season.

d) Gear Distribution. Allied Whale continued to contract Dominique Walk as a ½-time technician collecting data for gear distribution. As Ms. Walk reported directly to DMR in this regard, no further results from this project are presented here.

Available resources used for this project

All transect work was conducted principally by the R/V *Borealis*, a 26' f/g downeast cruiser. As a small vessel, *Borealis* has safe operations capacity up to ~30 nm offshore, in no more than Beaufort Force 3. Flexibility in scheduling was maintained so that transects could be conducted on days of good (> 10nm) to unlimited (25 nm+) visibility, with conditions less than Beaufort Force 2, to maximize sightings of individuals. *Borealis* is equipped with multiple navigational systems, is capable of night-running, and can simultaneously download bathymetry/time/position/SST data to ASCII for later processing as part of transect analysis. Focal groups transect work was supplemented by M/V *Myrus*, an 18' rigid-hulled inflatable vessel operating from Mount Desert Rock to maximize sampling opportunities of those animals in that vicinity.

All biological/oceanographic survey work was conducted aboard F/V *Georgia Madison* (Chris Candage, operator) using a fluorometer-equipped SB19 CTD and sampling equipment for a 270μ oblique tow, on loan from DMR, to collect plankton data.

Work on water was conducted by boat working either out of the port of Bar Harbor, or from Mount Desert Rock Marine Research Station (MDR). Therefore, some of the funds requested in this proposal were used to support logistics at MDR, including staff salaries, and food.

Additional support for research program

Work proposed to DMR in 2010 by Allied Whale was part of a larger research project that was funded, in addition to DMR, by a variety of in-kind and third party resources. Allied Whale/COA contributed approximately ~$58,000 of institutional match to the project, in addition to a further ~$20,000 in private grants.

Results I – Transects

In 2010, systemized surveys on the R/V *Borealis* allowed for the expansion of effort beyond the typical movement range of the local whale watch vessels and examination of the density of whales in alternative locations. In 2010, transect lines were designed with the intention of balancing coverage of a wide area and encounters with whales in areas previously known to exhibit high densities. A series of six random points were placed near Mount Desert Island representing start points for each of the transects. Surveys ran from that point offshore and cut toward shore to the end in the area known locally as the Ballpark. This design is illustrated in Figure 1.

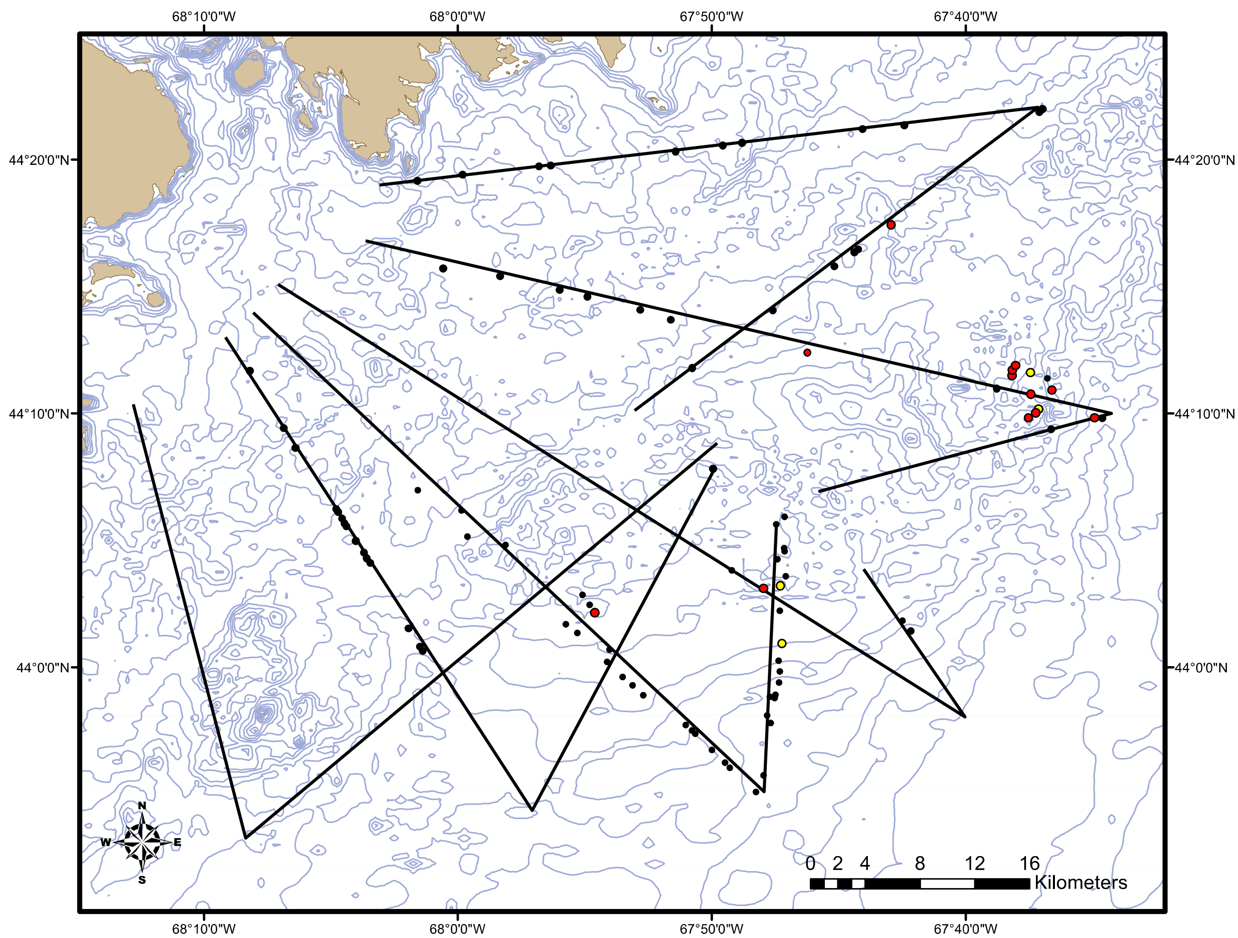

Figure 1. Transect Design and Sightings 2010. This figure shows transect lines followed in the 2010 field season as well as whale sightings. Humpback whales are shown in red, fin whales in yellow. Harbor porpoises were also included in black.

Line transects were run using distance sampling techniques. The vessel traveled on the predetermined lines at a speed of 15 knots. On each survey, two observers located on either side of the boat called out all sightings of marine mammals, including data on species, group size, estimated distance from ship, and radial angles. A third person served as a recorder and gave a GPS time stamp for each sighting using *Logger* software. To eliminate visual bias dependent on sighting conditions, transects were only run on days with high visibility and wave height under 3 feet.

During the 2010 field season, the lines were only covered once due to weather and logistics. Because of the wide spread of the designed lines, the sample size of sightings was low (see Figure 1, Table 1). A majority of sightings was seen in the area known locally as the East Bumps, which was also recorded as the seasonal hotspot by the local whale watch.

Table 1. Sightings 2010

Transect Line	Humpback Whales	Fin Whales	Unidentified Whales
1	1	0	0
2	9	2	0
3	1	1	2
4	1	1	1
5	0	0	0
6	0	0	0
Total	12	4	3

Surveys were redesigned before the 2011 field season to increase the sample size of sightings. The feeding ground was split into three study areas, each containing a previously observed hotspot as well as a large buffer. Equal-space zig-zag lines were placed using Distance software to achieve maximum coverage of the study areas. Study areas and transect lines can be seen in Figure 2.

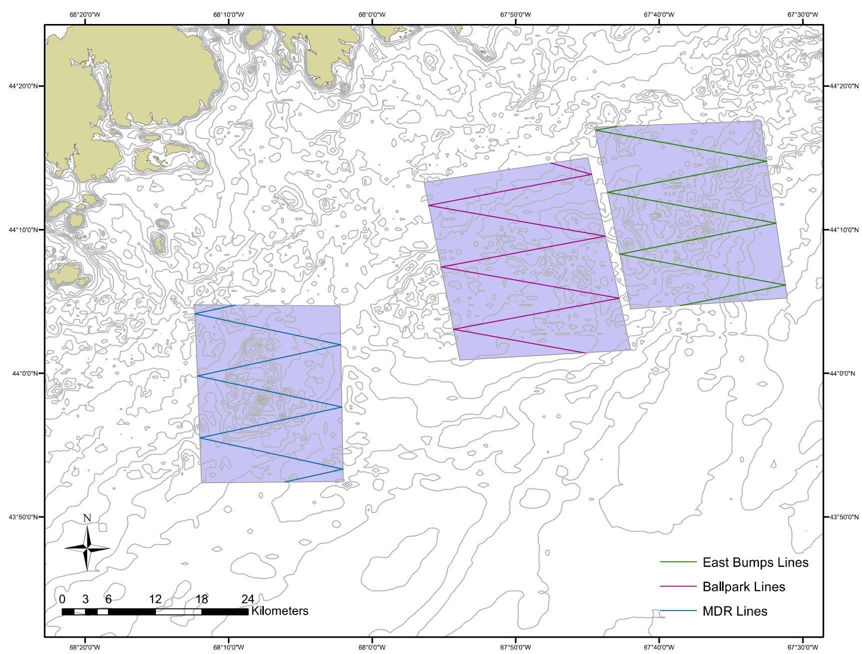

Figure 2. Transect Design 2011. The feeding grounds were split into three concentrated study areas. Line 1 contains the Eastern Bumps, Line 2 contains the Ballpark, and Line 3 contains Mount Desert Rock.

Sampling protocol was similar to that of 2010. Transects were run along the predetermined lines. Vessel speed was decreased this season to 12 knots to maximize probability of sightings. Survey teams again consisted of two observers on each side of the vessel and one recorder. Participating observers were trained with a laser rangefinder to estimate accurate distances. Surveys followed procedures of a passing transect, meaning that the transect lines were not left to collect species or individual identification. If possible, attempts were made at the completion of the transect to obtain that information.

Transects were completed from June through September. Each line was covered four times, allowing for good seasonal as well as spatial coverage. Sighting rates were greatly increased and possible trends were observed. Unlike the previous year, highest number of sightings was in the Ballpark study area. Combined sightings per unit effort of humpback and fin whales can be seen in Figure 3. Total sighting numbers can be seen in Table 2.

Table 2. Sightings 2011

Transect Line	Humpback Whales	Fin Whales	Unidentified Whales
1	5	11	3
2	17	11	18
3	15	5	9
Total	37	27	30

Future Directions for Research

Further analyses are still in their preliminary stages. Work is being developed to build habitat selection models and explore temporal and spatial use of the area, although the data has now been effort-corrected and built into a GIS model (Figure 3). Our next steps are to use the distance and angle data to estimate regional abundances and to explore predictive power of oceanographic covariates such as sea surface temperature and bathymetry. The data will also be split to look at shifts in abundances in each study area throughout the whole season. These systematic survey data will also be used in conjunction with historic whale photo-ID data to examine how general abundance and densities may affect individual movement decisions.

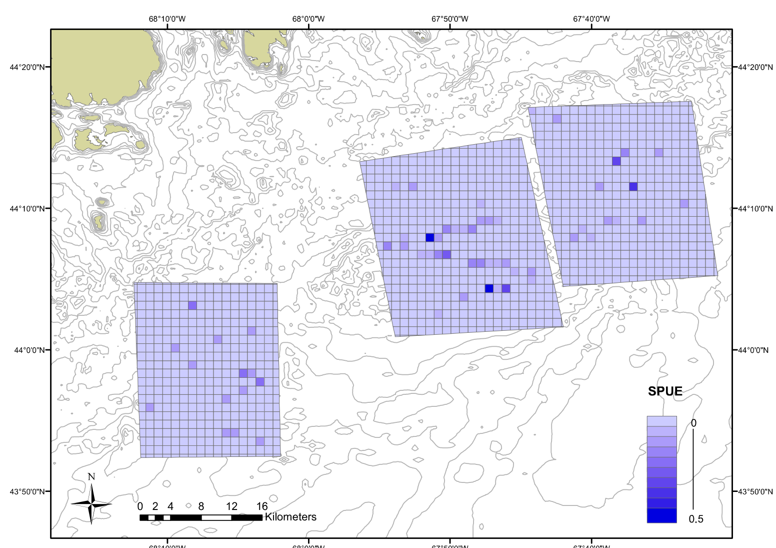

Figure 3. Sightings Per Unit Effort of Humpback and Fin Whales 2011. Each study area was split into equal sized cells. In each cell, the sightings per unit effort was calculated. High ratios are depicted by darker blue shades.

Our effort-corrected sighting data, combined with data received from whale-watch deployed research assistants, continues to build a powerful longitudinal sightings database for this region that can be used to ask long-term questions of spatio-temporal distribution. Below we list two abstracts presented at the recent Society for Marine Mammalogy meetings that utilized these data.

Interannual variation in fin whale (*Balaenoptera physalus*) relative abundance correlates with environmental conditions in the Northeastern Gulf of Maine

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Fin whales (*Balaenoptera physalus*) are one of the most abundant and commonly found whale species during summer along the northeastern coast of the USA. However, the environmental conditions that influence their patterns of occurrence are not well understood. In the Gulf of Maine (GOM) an important regional driver of oceanographic variation and biological response is the North Atlantic Oscillation (NAO). To determine patterns of fin whale temporal and spatial habitat use and its relationship with oceanographic-atmospheric variables in the northeast GOM, we used data gathered from dedicated and opportunistic photo-identification/biopsy research cruises conducted from 2000 to 2006. The study focused on areas of known concentrations, including waters surrounding Mount Desert Rock (44°00' N, 68°01' W) and the Inner Schoodic Ridges (44°08' N, 67°50' W). Data were used to compile values of relative abundance (number of individuals/effort hours) and to generate an index of photo-identified whales. Whale relative abundance differed between years, but these differences were not statistically significant (Kruskal-Wallis; $H_{(6)} = 6.81$; $p = 0.33$); however, abundance was highest in 2001 (1.28 ind/h) and lowest in 2005 (0.60 ind/h). The occurrence of oceanic fronts generates appropriate conditions for the whales' presence during the summer ($r_{s(6)} = 0.886$; p = 0.048). Fin whale abundance correlated to the NAO winter index when a two-year lagged relationship was applied ($r_{s(7)} = 0.893$; $p = 0.029$). A similar lag was demonstrated between whales and summer primary productivity ($r_{s(7)} = 0.857$, $p = 0.036$). Our data suggests that linkages between atmospheric variations and oceanographic conditions may influence whale presence in the northeastern GOM both directly and with a time-lagged effect that cascades trophically. Further research should explore how the NAO affects fin whale spatio-temporal distribution in the GOM.

A decadal geographic shift in humpback whale (*Megaptera novaeangliae*) distribution in the Northern Gulf of Maine

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Many North Atlantic humpback whales (*Megaptera novaeangliae*) migrate annually to feed in the nutrient rich waters of the Gulf of Maine. In 2000, we instituted a research program in the northern Gulf that uses whale watch vessels as opportunistic observation platforms. Here, on the basis of data collected from that program, we document a clear distributional shift in humpback whale sightings in the northern Gulf of Maine over the past decade. Sightings from 2000–2010 (n = 2,941) were mapped in ArcMap and entered in a

multivariate analysis of variance delineated by year (MANOVA; $\lambda = 0.68$; $F = 62.3$; $df = 20, 5858$; $p < 0.0001$). Statistical analysis demonstrated that average longitude ($p < 0.0001$) and latitude ($p < 0.0001$) varied significantly across years. Scheffé *post hoc* analyses on pairwise yearly average latitude and longitude positions revealed a shift in humpback whale distribution in a generally consistent direction. Early in the decade humpback whales were regularly sighted in the most southwestern area of coverage, within the waters surrounding Mount Desert Rock. Since then, they have moved northeast paralleling the coastline and can now be found more than ~16.7 miles away from habitat typical at the beginning of the decade, although in similar depths. These opportunistic data are supported by periodic standardized effort-corrected transects. On the basis of our findings we propose that humpback whales have undergone a small-scale distribution shift in the past decade, most likely related to changes in prey distribution.

Results II – Acoustic census

Here we focus our findings on a) the Outer Falls MARUs that were deployed year-round in order to examine the suggestion that this offshore area may serve as an important breeding ground for Northern right whales, as well as an area for wintering humpback, minke, fin and sei whales, as well as b) four MARUs deployed in the MDR/Inner Schoodic Ridge region.

Description of equipment, deployment and analysis methods

This study utilized Marine Autonomous Recording Units (MARUs) developed by Cornell University Bioacoustics Research Program. These units, which are positively buoyant, are anchored to the seafloor and can be released by sending an acoustic signal, which triggers a release system. The recording system utilizes an externally mounted hydrophone (High Tech, Inc. 94-SSQ) with sensitivity up to -165 dB re 1 V/μPa and a preamplifier system providing a frequency response of 10 Hz to 32 kHz. The pop up buoy system has a flat frequency response (±1 dB) from 20 to 800 Hz. These units initially record onto a 120 GB hard drive in binary format at a sample rate of 2 kHz. With these specifications, the recording system will capture signals up to 1 kHz. This setup is ideal for capturing the vocalizations of large cetaceans.

We deployed four MARUs around the Mount Desert Rock area during the summer months of 2010 for approximately four months. Three of these MARUs were deployed north of Mount Desert Rock, and one (MARU #66) deployed to the northeast, closer to Inner Schoodic Ridge. A further two MARUs were deployed in the Outer Fall region sequentially, allowing for a total of 11 months of data in this region (see Tables 3 and 4 for deployment schedules and Figures 4 and 5 for MARU locations. All MARUs were successfully retrieved with the exception of a seventh deployed in 2009 at Outer Falls).

A hardware malfunction on MARU #66 (see Table 3) prevented retrieval of data for that buoy. However, all other units returned to Cornell yielded data as expected.

Table 3. MDR MARU Deployment Schedule

Popup ID	134	223	182	66
Site ID	2010PUA1	2010PUA2	2010PUA5	2010PUA6
Deployment Date	20-Jul-2010	20-Jul-2010	20-Jul-2010	20-Jul-2010
Actual Latitude	44 02.5 N	44 02.499 N	44 00.6 N	44 05.023 N
Actual Longitude	68 09.5 W	68 04.07 W	67 59.3 W	67 49.959 W
Recovery Date	15-Oct-10	15-Oct-10	15-Oct-10	15-Oct-10

Table 4. Central Gulf of Maine MARU Deployment Schedule (taken from Bort, 2011)

Deployment	Vessels	Area	Location	Deployment Dates	Amount of Data
1	R/V *Stellwagen* M/V *Indigo*	Outer Fall	43° 18N 068°37W	July 30 2009 (not retrieved)	n/a
2	M/V *Bay King III* M/V *Indigo*	Outer Fall	43° 18.190N 068°37.338W	October 30 2009 May 28 2010	67.7 GB
3	M/V *Lady Anne*	Outer Fall	43° 18.234N 068° 37.336W	June 29 2010 October 13 2010	34.1 GB

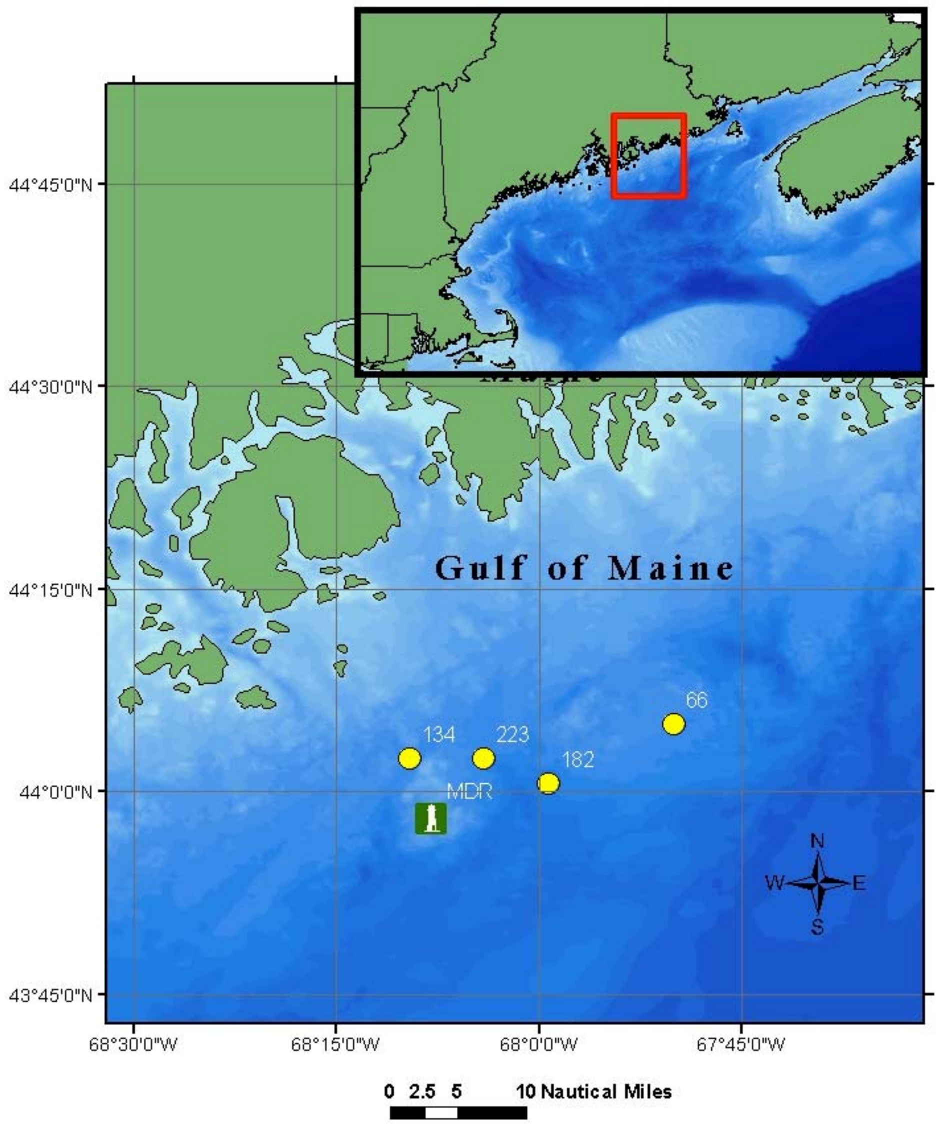

Figure 4. MARU locations around Mount Desert Rock, Maine.

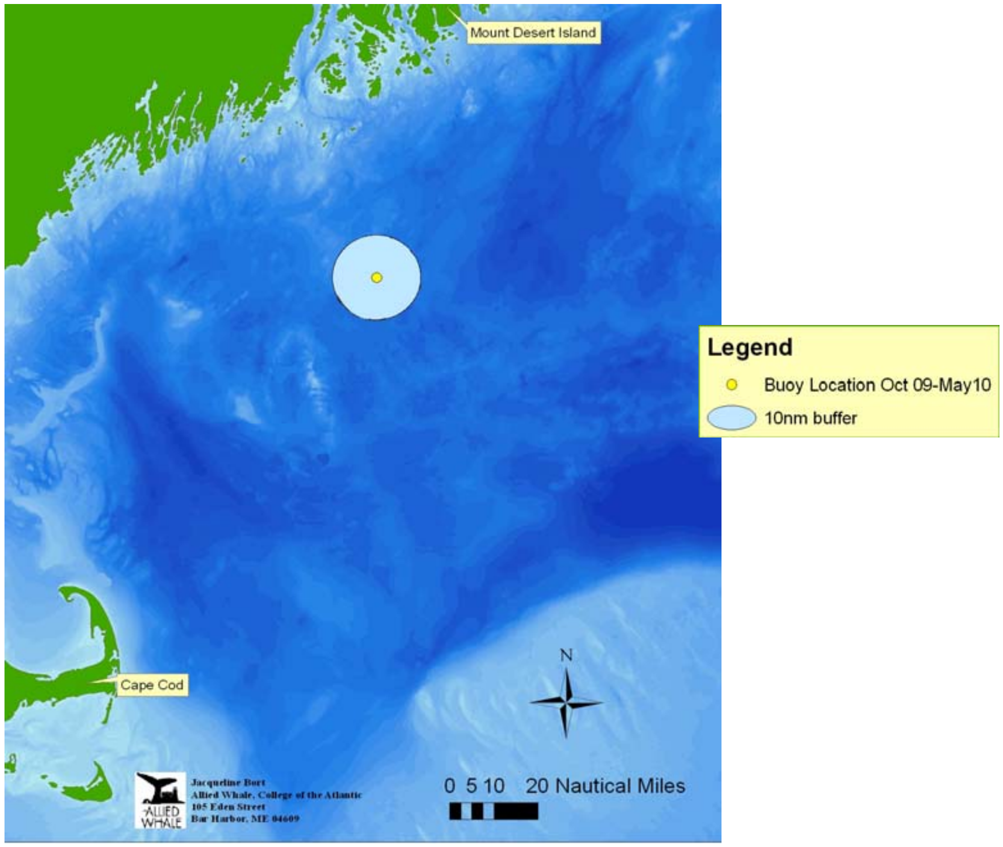

Figure 5. MARU location at Outer Fall, Gulf of Maine. The 10 nm buffer is the estimated recording range of the MARU based on other studies.

Data were analyzed through eXtensible BioAcoustic Tool (XBAT), a MATLAB (Mathworks 2006) supported open source analysis software for sound analysis and management of large-scale acoustic data sets developed by Cornell BRP (Figueroa 2008). To look for right whales specifically, we first ran an automatic detector for right whale upcalls, ISRAT (Urazghildiiev and Clark 2006), on all days. This detector functions as a generalized likelihood ratio test by examining a sound file second by second to determine how similar each is to a right whale upcall template. We ran ISRAT with a 0.35 minimum detection correlation threshold (the minimum percentage of similarity of the detected calls to the template) since this is the threshold used in other areas and studies. This was done for all days of data, and data was later hand-browed to correct for false negatives and positives.

Due to the sheer enormity of data, we subsampled the Outer Fall dataset (also known as the Central Gulf of Maine) at a rate of every third day (excluding October 2009 and 2010 for which we did not have full recordings—these were analyzed in full). In total, we analyzed 108 days of data from this data set. In addition to ISRAT, the data were hand-browsed in full for other right whale calls including the gunshot call, and social sounds such as moans. Other whales were detected in this dataset but were not analyzed fully.

For the MDR data, a series of data template detectors were developed within XBAT. Data template detectors export sections of recording from a spectrogram for cross-correlation. This involved locating a particular signal of interest and developing a series of clips that would cross-correlate as accurately as possible. Here, ISRAT proved to be unreliable since it returned an extremely high a false positive rate. This was primarily due to the recordings themselves—the recordings contained the noise from the internal hard drive of the MARU spinning in order to back up data every three minutes. Therefore, a lot of time was spent developing a data-template detector that was accurate for right whales without picking up this extraneous noise. The files for October from MARU 134 became corrupt during analysis and are not included in the results here.

Results

Central Gulf of Maine Data: The data from the Central Gulf of Maine deployment series is presented in full in Bort (2011)—a master's thesis completed at College of the Atlantic. Analysis focused on the detections of two types of call associated with Northern right whale social and breeding behavior (Dawicki 2008; Mellinger et al. 2007; Parks and Tyack 2005). Below is the abstract from this thesis, an abstract from the talk that was presented at the 2011 North Atlantic Right Whale Consortium in New Bedford, MA, as well as data (Table 5) and several key illustrations (Figures 6 though 8) from Bort (2011). The final product of this project will be several scientific papers, which are currently in progress.

Acoustic Behavior of North Atlantic Right Whales in a Potential Winter Mating Ground: Implications for Management of Human Activity.

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The North Atlantic right whale (*Eubalaena glacialis*) is critically endangered, with a current population of approximately 473 individuals. Although this population has been protected internationally from whaling since 1935, it continues to decline because of negative human interactions. Protecting these animals from ship-strike and fishing gear entanglement requires additional legislation that is dependent on careful and continuous monitoring. One monitoring technique that leads to a better understanding of behavior and habitat preferences of the species is passive acoustic monitoring. This study utilized marine autonomous recording units in the Outer Fall region of the Gulf of Maine, an area recently identified as a wintering and possible mating ground for right whales. Recordings were made for 11 months from October 2009 to October 2010. We analyzed the recordings for two known right whale call types—the upcall, and the gunshot call (associated with mating/social behavior)—for seasonal and diel patterns. A variety of social sounds potentially produced by right whales were also identified and described. There was a strong seasonality in the frequency of call detections, with the majority of calls found in November, December and January. There was also a strong peak in diel calling patterns, with the majority of the calls occurring between 1400 and 2300. Determining how right whales use this area is essential to establishing protective legislation, especially when mitigating fishing activity or determining if Outer Fall/Central Gulf of Maine should be considered a Dynamic or Seasonal Management Area for ship traffic management.

North Atlantic right whale (*Eubalaena glacialis*) acoustic activity on a wintering ground in the Central Gulf of Maine

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The wintering and mating ground of the endangered North Atlantic right whale (*Eubalaena glacialis*) was, until very recently, unknown. The Outer Fall region of the Gulf of Maine was recently identified using aerial surveys as a wintering ground, and possibly a mating ground for the species. Assessing the vocal activity of the whales in this area can determine how long whales are utilizing this habitat, and provide insight into what kind of

behaviors they are engaged in—since many calls are associated with mating and social behavior. Marine acoustic autonomous recording units were deployed from October 2009 to October 2010 in the Outer Fall region in order to confirm seasonal presence, and to determine seasonal and diel patterns of two right whale call types: the upcall and gunshot. There were clear seasonal patterns in call frequency (ANOVA: upcalls $p \leq 0.001$; gunshots $p \leq 0.0001$). These patterns corresponded well with aerial survey sightings available for the region. Upcalls (n = 28,497) were frequently detected in November through January. Similarly, gunshots (n = 16,790)—a call sometimes associated with mating activity—were heard frequently in November, but decreased in occurrence through January. There was also a strong peak in diel calling patterns (ANOVA: upcalls $p = 0.0027$; gunshots $p = 0.0044$); with the majority of calls occurring between 1400 and 2300 hrs. These data suggest that this habitat is a seasonally important area for right whales. Given current knowledge of right whale gestation and calving times, our data also support the suggestion that the central Gulf of Maine may be a mating ground for this species. Based on our findings we recommend immediate further detailed assessment of this region, within the context of defining it as a seasonal management area, an action that could mitigate threatening anthropogenic activity conducted in the region.

Table 5. Monthly totals for detected upcalls and gunshots, average upcalls and gunshots, and associated standard deviations (taken from Bort 2011).

Month	Total Upcalls	Total Gunshots	Average Upcalls	Average Gunshots	St. Dev. Upcalls	St. Dev Gunshots
October	553	2929	276.5	1464.5	102.53	803.98
November	8719	5297	871.9	529.7	615.87	390.94
December	6324	5680	574.91	516.36	298.48	439.98
January	6027	432	602.7	43.2	438.55	33.43
February	209	6	23.22	0.66	37.8	2
March	59	0	5.36	0	8.33	0
April	47	0	4.7	0	11.78	0
May	0	0	0	0.11	0	0.33
July	164	13	14.91	1.18	32.69	2.18
August	403	504	40.3	50.6	112.11	159.31
September	4800	1092	480	109.2	843.07	143.4
October	1192	837	298	209.25	377.87	242.30

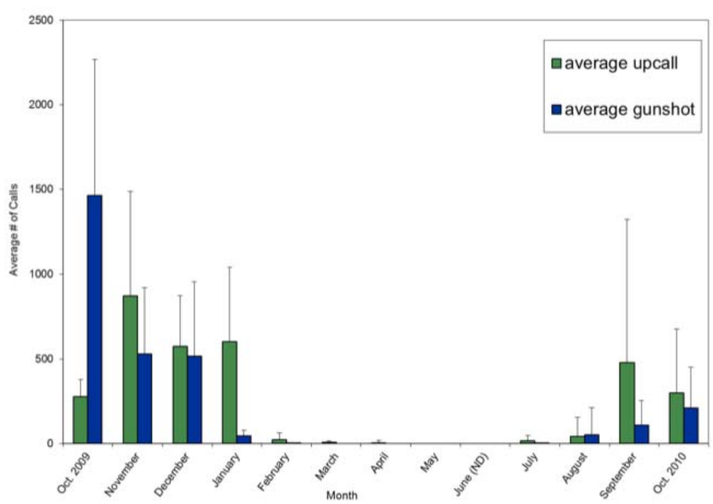

Figure 6. Average number of right whale upcalls and gunshots by month with standard deviations.

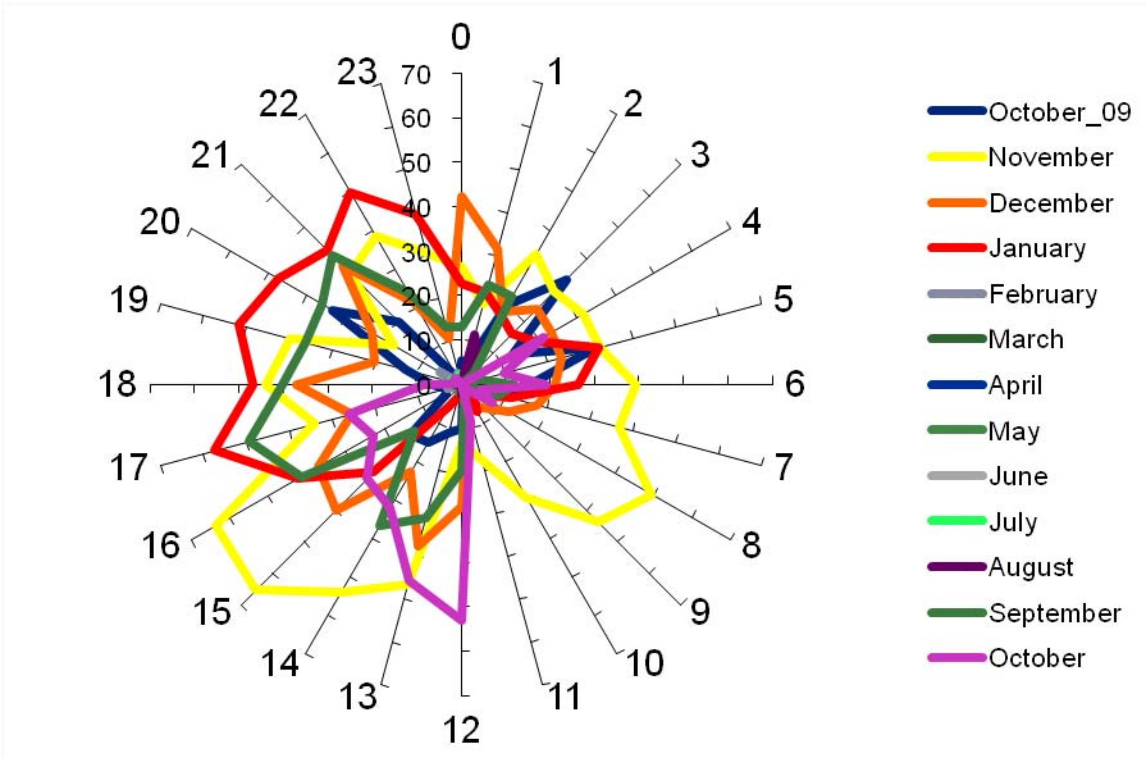

Figure 7. Hourly right whale upcall rate averaged by month. Each axis represents an hour of the day.

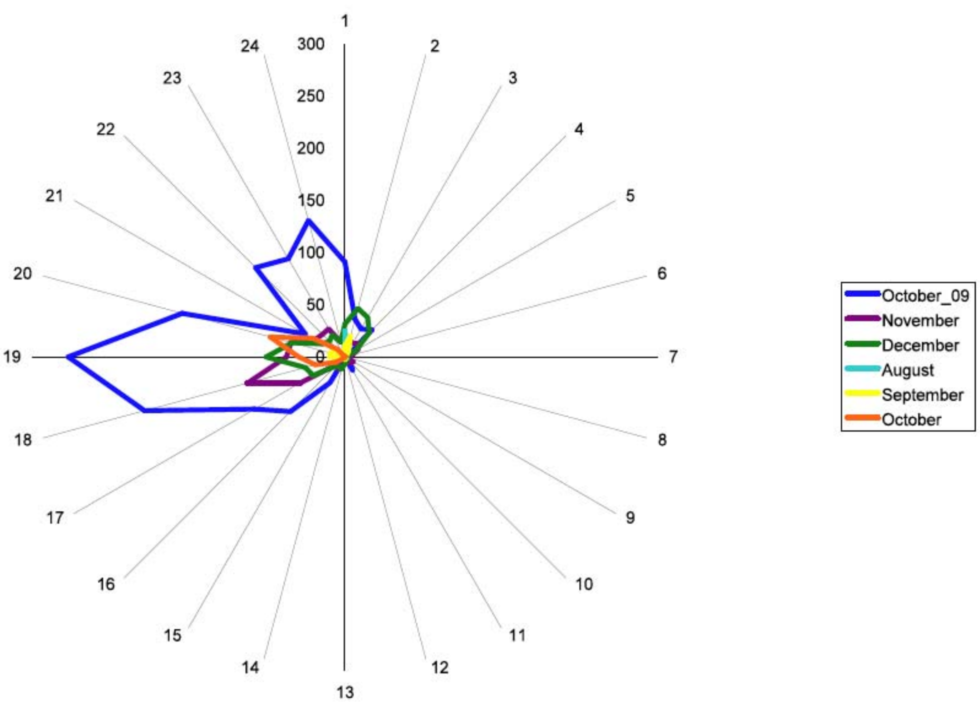

Figure 8. Hourly right whale gunshot rate averaged by month. Each axis represents an hour of the day.

MDR Data: The total number of all large whale calls detected increased in fall months (Table 6, 7). This is due to the increase in right whale vocalizations, which included gunshots. The increase in right whale calls in September and October is consistent with the finding in the Central Gulf of Maine dataset. Percentages of total calls per MARU location per month were calculated, shown in Figure 9. All calls detected in July were humpback whale. All calls detected on MARU 182 and 134 in August were humpback whale. Right whales were detected on MARU 223 in August. Right and humpback whales were detected on all MARUs in September and October.

There was a high level of variety in the calls detected in the MDR data. Even calls that were relatively stereotypic often had variations that were just slightly different in frequency, making them difficult to detect consistently. This issue has been previously reported for this region (Allen *et al.* 2008). Future analyses might use band-limited energy auto-detectors, available in the acoustic analysis software package *Raven*. Examples of the calls that could be detected through the use of data template auto-detectors are shown in Figures 10-22 (note that for this set of figures, data are presented as time in h:min:sec on the x-axis, frequency in kHz on the y-axis, and amplitude of signal is presented in grey-scale. Figures were generated in XBAT using a Hann window, 512-point FFT, and 25% overlap). The majority of the calls were consistent with calls noted in a senior project (Palmer 2007) completed using MARU data from 2006.

Another issue arose with humpback whale vocalizations in this area. It was noted that the majority of vocalizations were not distinct calls, but rather an almost constant chatter that often blended in with the ambient noise (especially during times of high boat traffic), making it difficult to determine the exact point at which these bouts of vocalizations began (Figure 19). These vocalizations were not usually picked up by auto-detectors. Therefore, it is likely that there are far more calls within this data than could be detected through the methods used during this project.

Fin whales were detected nearly every day, but an accurate detector to determine call rate could not be created due to the high level of low frequency noise that spanned the entire dataset..

A number of "click"-like calls were recorded in this study. Previous work in the MDR area (Allen *et al.* 2008) reported a humpback whale call commonly referred to as a "megapclick". Initial studies of megapclicks (Stimpert *et al.* 2007) used a bandpass filter to include only a specific frequency band—400 Hz to 3500 Hz—to reduce the impact of ambient noise in the recordings. The recording range of the units used in our study is from 0 Hz to 1 kHz. However, nany of the click trained observed within this study did not reach above 200 Hz. Therefore; we question the likelihood that these calls could be megapclicks.

Samples of signals identified as megapclicks from previous years, as well as examples of pulse trains observed in this study were sent to Alison Stimpert of the University of Hawaii. She did not believe any of our signals were megapclicks. Samples were then sent to Denise Risch of the NOAA NEFSC, who confirmed that these sounds were also probably too low to be from a Minke whale. The sounds were then sent to David Mann of the University of South Florida. He confirmed that these pulses were most likely fish sounds; however, he was not able to confirm what species. He suggested a type of gadoid was likely, possibly cod or haddock. His colleague James Locascio confirmed this. For final confirmation, the sound files were also sent to Tony Hawkins and Rodney Roundtree of the University of Massachusetts, Amherst. Both confirmed that it was likely produced by a fish, and also suggested a large gadoid. These clicks were therefore not included in the analysis for this study as our main focus was on marine mammals; however, it would be interesting to look into these clicks further especially if their source is cod. Atlantic cod stocks are considered overfished and still in decline (Mayo and O'Brien, 2006 NOAA). The stock is currently very low relative to SSB_{msy}.

Table 6. Total number of detected calls per month for all MDR MARUs.

	July	August	Sept	October
TOTAL	105	663	543	887

Table 7. Days where large whales were detected within study period.

July	August	September	October
20	1	1	1
22	2	2	3
23	3	5	4
25	4	6	5
26	5	7	7
27	6	8	8
28	7	9	9
29	8	10	10
	9	11	11
	10	12	12
	11	13	
	12	15	
	13	20	
	14	21	
	15	22	
	16	23	
	17	24	
	18	26	
	19	27	
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	31		

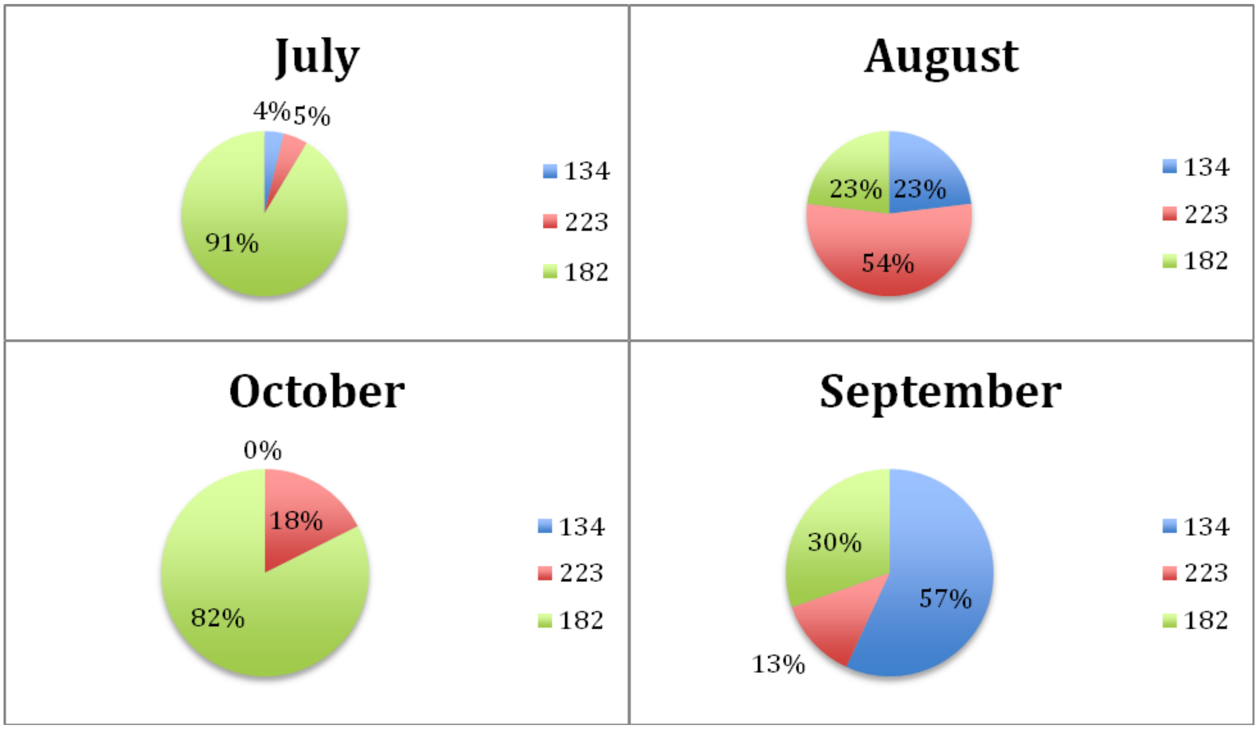

Figure 9. Percentages of total calls detected per month per MARU.

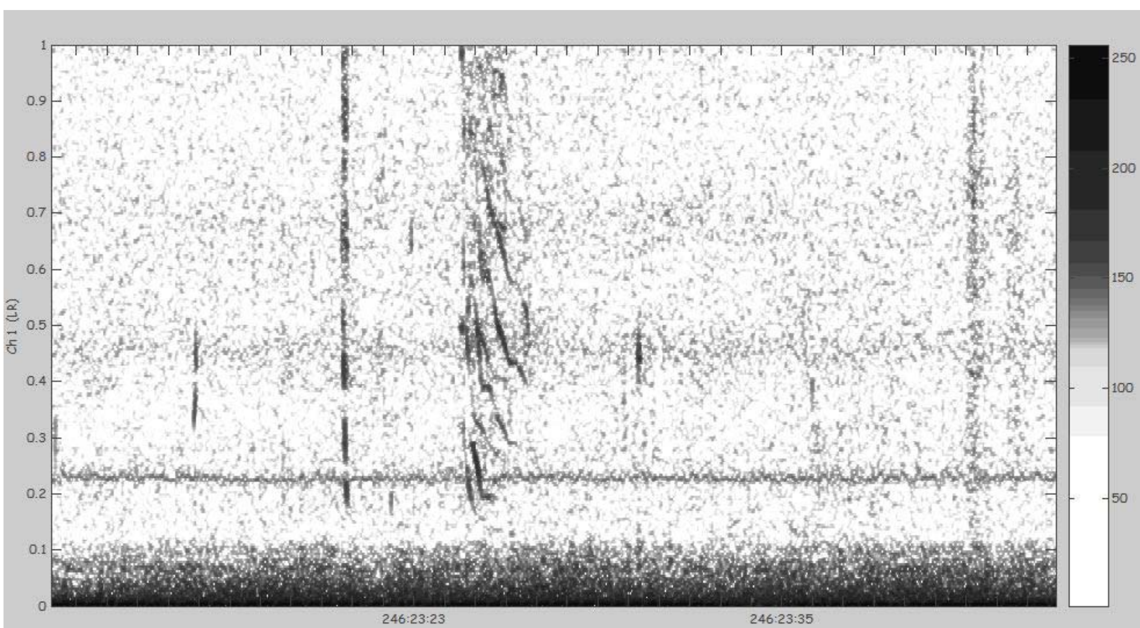

Figure 10. Humpback whale "T-call"- as described by Palmer (2007). There was only one instance of this call observed. This was in August on MARU 134.

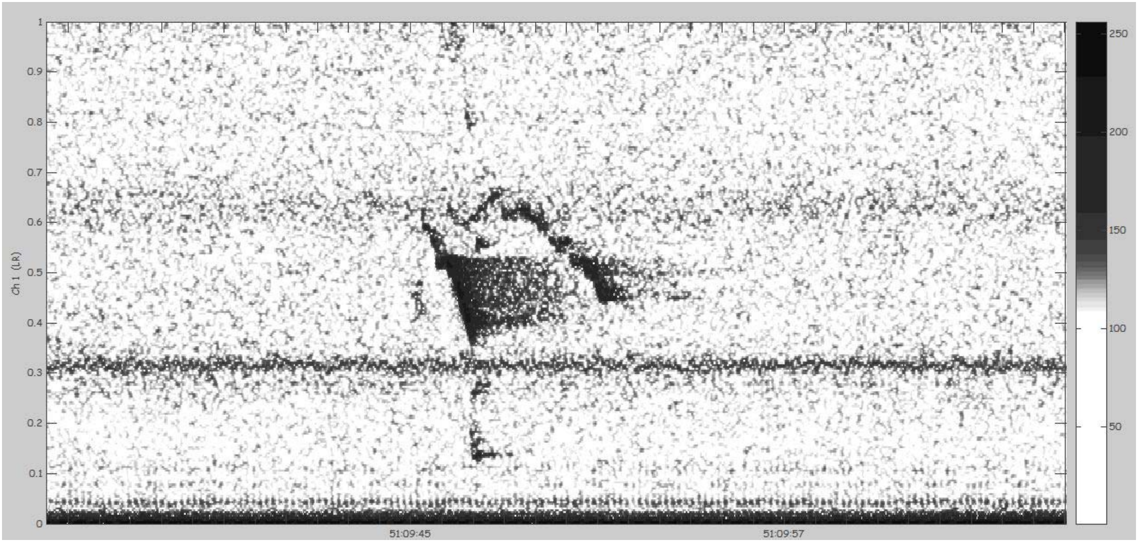

Figure 11. Humpback whale downsweep and long call (as described by Palmer 2007) together. The downsweep was observed regularly in intervals of 2-3 minutes, and is likely a contact call. The longcall was often associated with a downsweep every few calls when these series existed. On a few occasions the long call was at a lesser amplitude—there is a possibility that it was made by another individual.

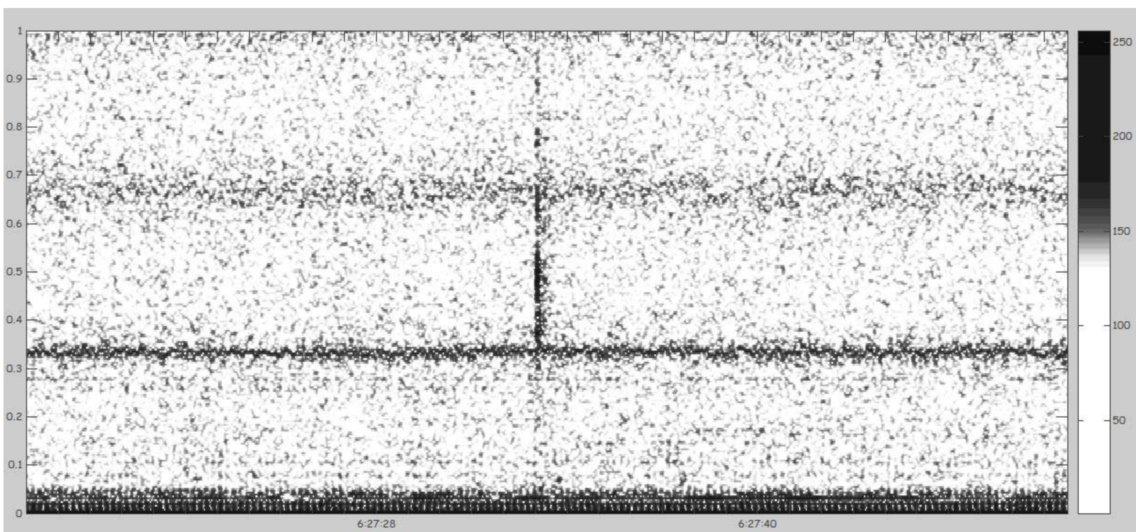

Figure 12. Humpback whale "droplet" call. These broadband calls sound similar to a water droplet falling onto a surface.

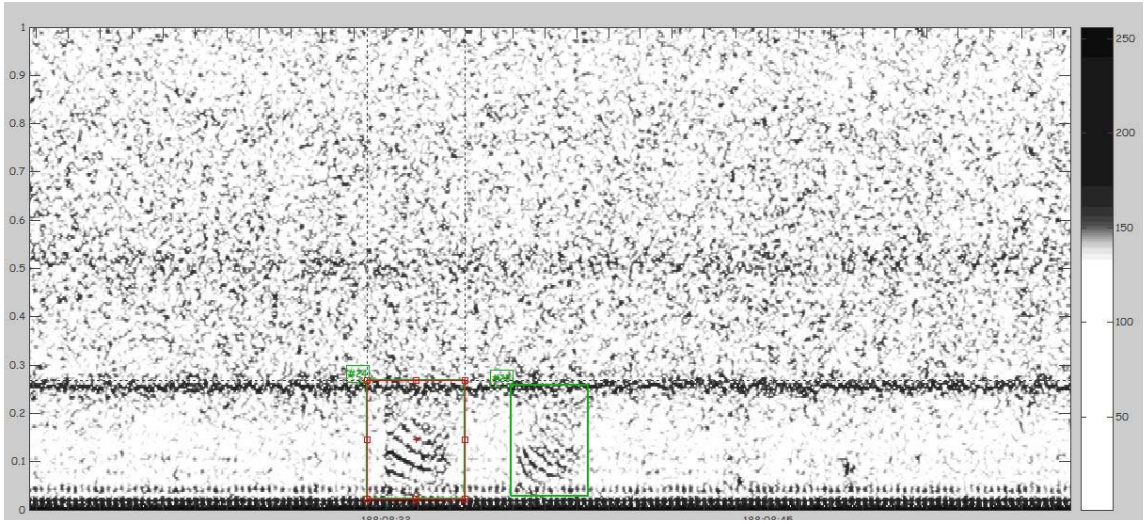

Figure 13. Humpback whale low frequency harmonic calls as described by Palmer (2007).

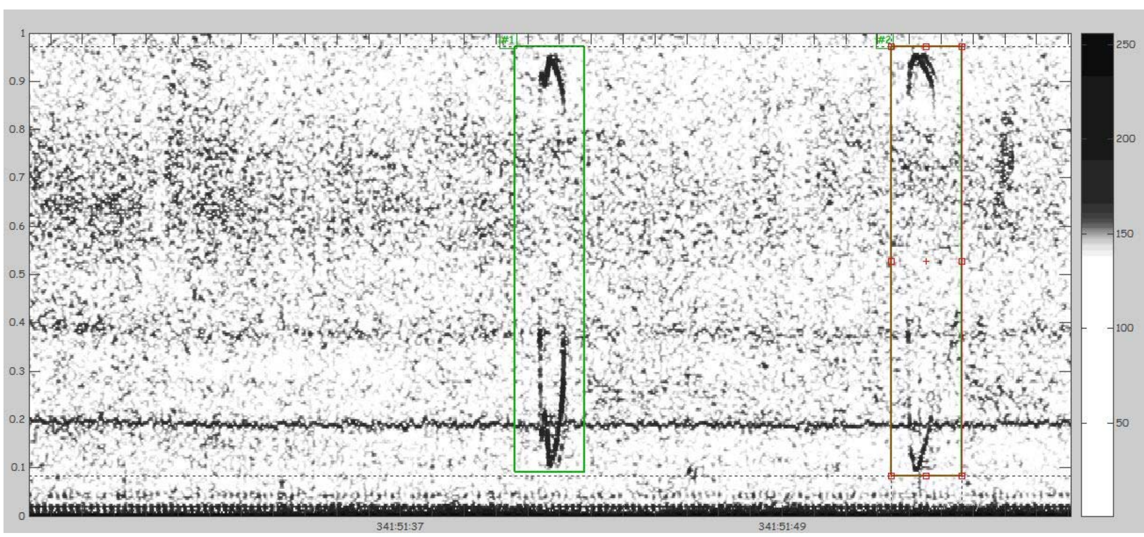

Figure 14. Humpback whale "loop" calls. These calls were often stereotyped. Whistles similar to the higher frequency portion of the spectrogram but not including the lower frequencies were also observed.

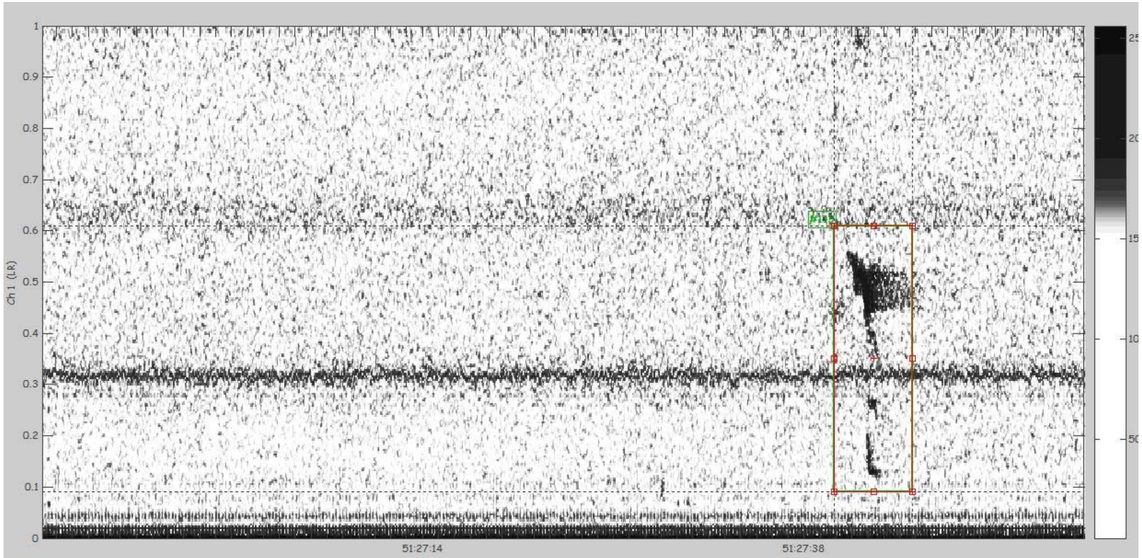

Figure 15. Humpback whale downsweep alone.

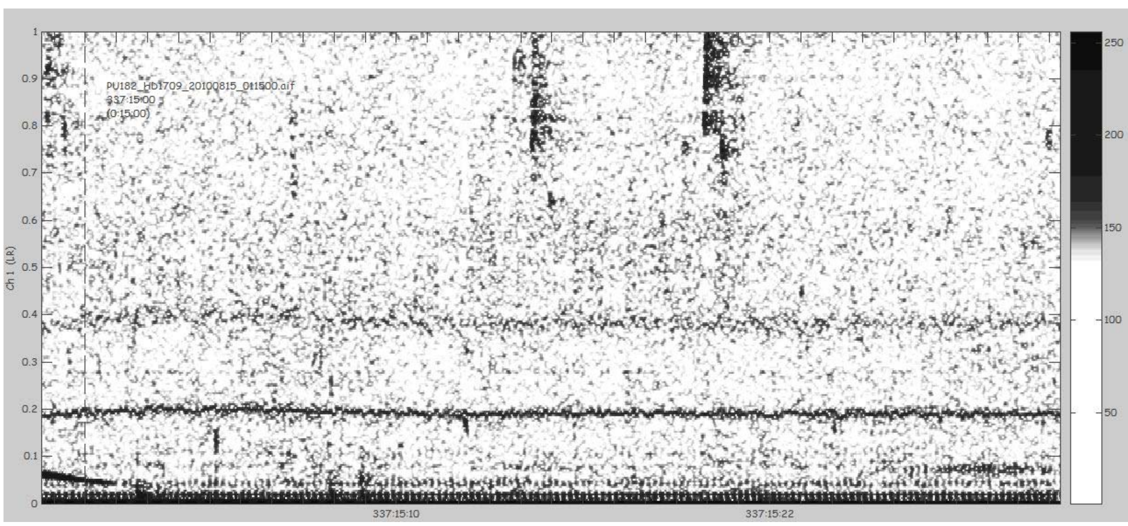

Figure 16. Humpback whale high screams.

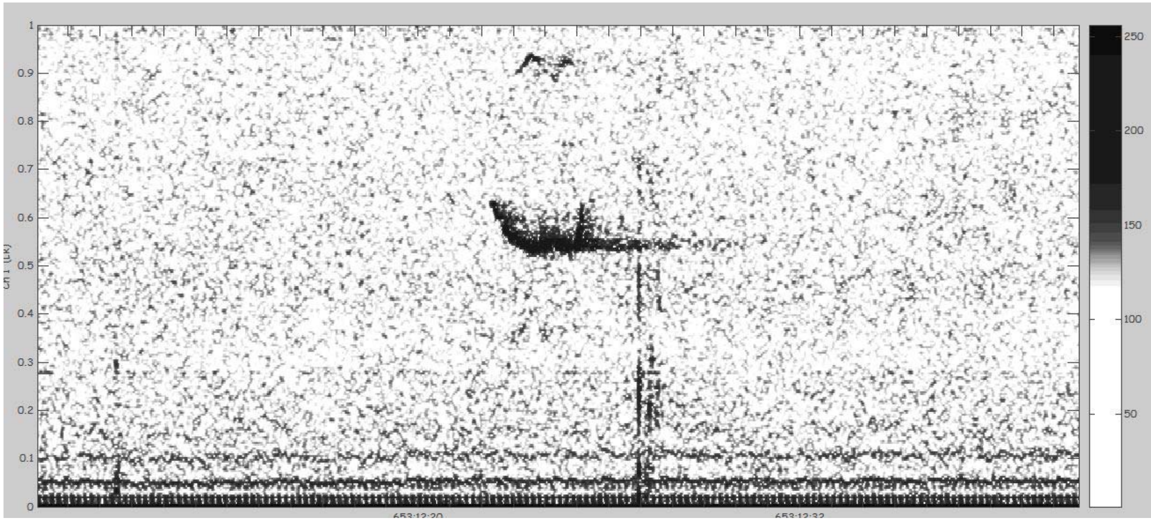

Figure 17. Humpback whale "W" call (similar to a description by Palmer 2007).

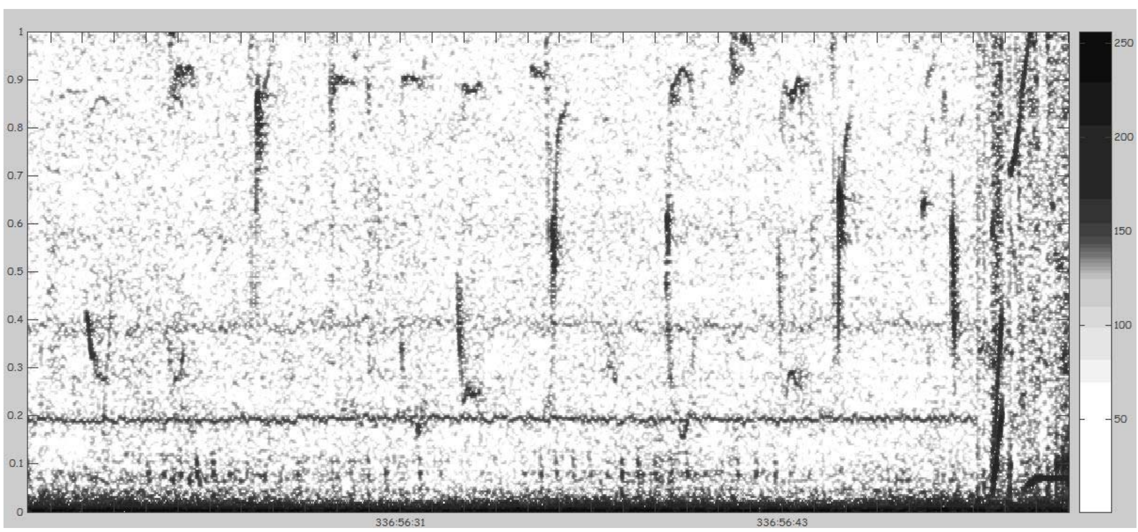

Figure 18. A series of humpback whale loops and whistles.

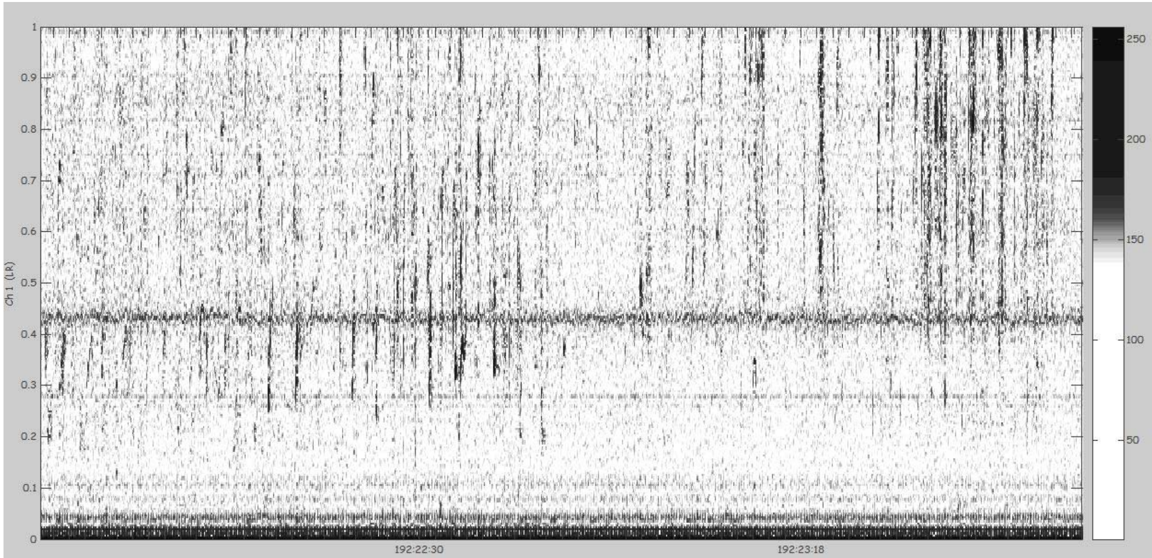

Figure 19. Humpback whale “chatter”; potentially feeding vocalizations.

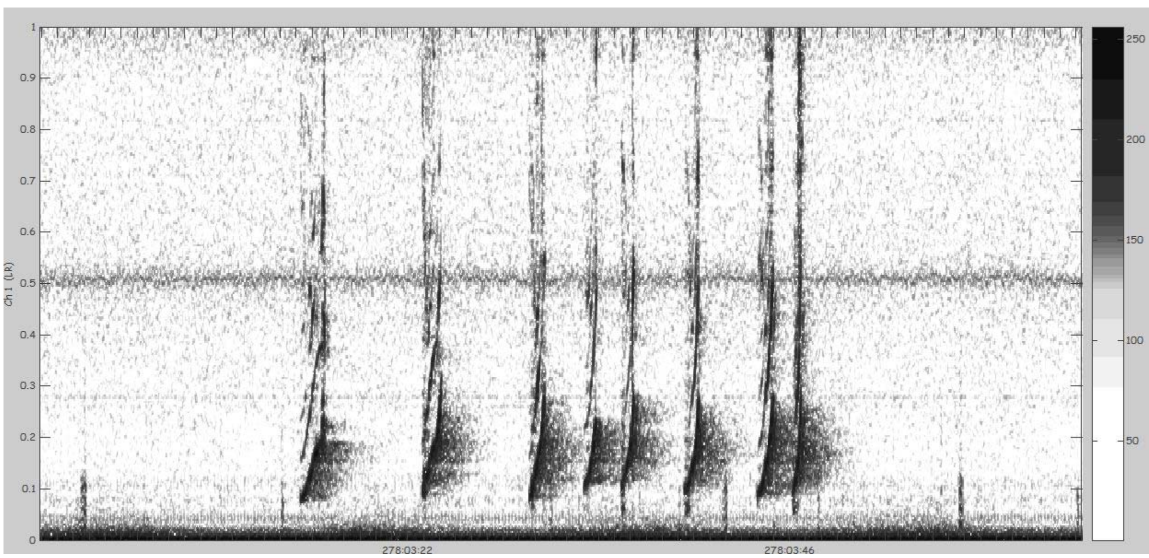

Figure 20. Right whale upcalls.

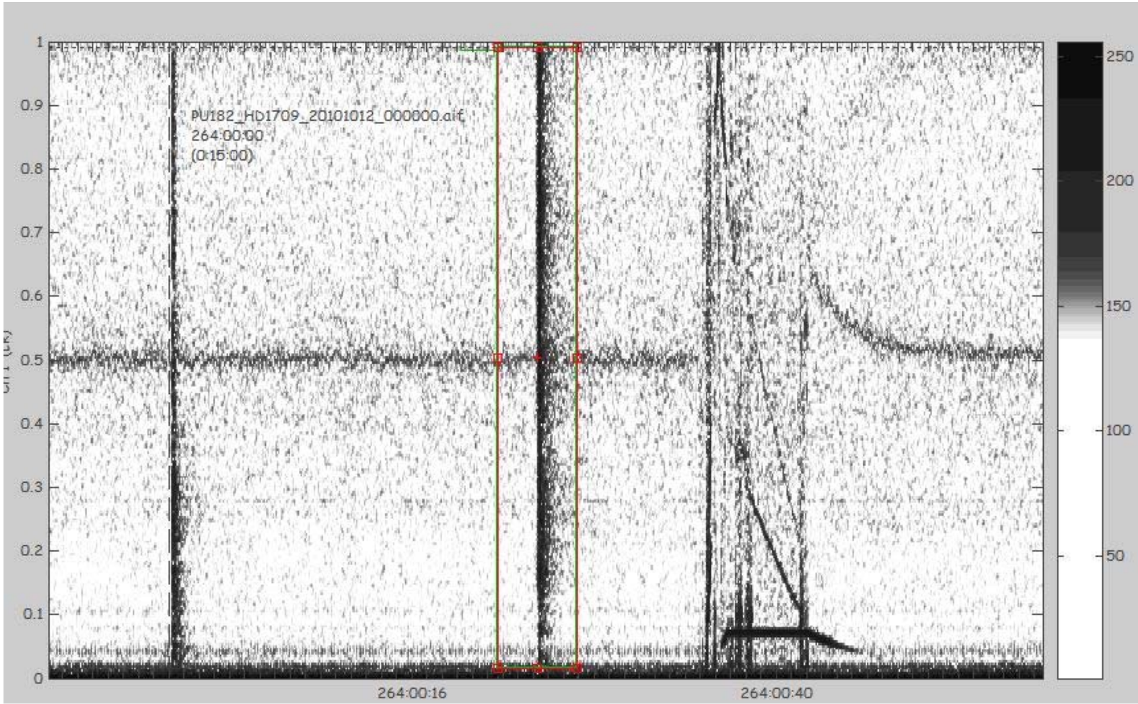

Figure 21. Right whale gunshots.

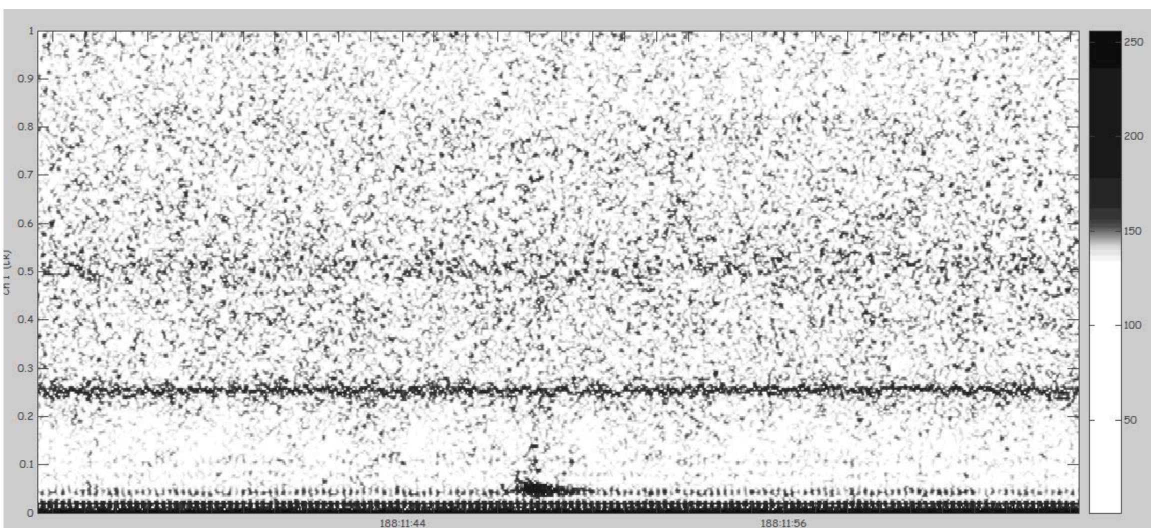

Figure 22. Fin whale vocalization.

Future Directions for Research

Our work to characterize the Gulf of Maine as a critical right whale wintering ground is extremely important for the protection of this endangered species. This area is an area of high use for shipping and fishing industries with many of the fishing types being fixed gear. These pose serious threats to right whales which are particularly vulnerable to negative anthropogenic interactions. The work represented in this report is constitutes only one year's worth of monitoring. It is important to continue to monitor this habitat to verify that the seasonal use described in this study does not fluctuate. It would be useful in subsequent studies to deploy several MARUs in the area over a greater distance to determine spatial distribution within the habitat. Having MARUs within an array in order to localize particular calls would also aid in comparing acoustic and aerial survey data. A study set up in this way may be able to directly attribute the observed social activity found in visual surveys with acoustic data; such a study will further our understanding of how these calls are used as well as support the idea that Outer Fall and the greater central Gulf of Maine is a winter mating ground. The prevalence of other species calls during the winter—especially humpback whales—heightens the need to better understand the use of this area by baleen whale species. A College of the Atlantic undergraduate student is currently investigating the seasonality of sei whale calls recorded at the Outer Falls buoy.

Many studies, particularly on humpback whales, have been done using hydrophones deployed in some fashion at the surface from a boat, or in areas where bottom-mounted hydrophones can be hardwired to a land-based listening station. In both of these cases, visual observation of the whales is often possible. This method of study allows for the observers to keep track of when a whale is calling in real time and possibly associate behaviors with a recorded signal. It is very difficult in our study to reliably associate signals with surface behavior such as breaching or flipper slapping in our study, though it is more than likely that we have recorded those signals. Our hope for future studies is to be able to associate visual data taken from Mount Desert Rock lighthouse station. The use of a dedicated theodolite tracking station at Mount Desert Rock, installed in 2011, will allow us to begin this work.

Humpback whale summer feeding ground vocalizations, as suggested by this study, are far less distinctly pronounced as humpback whale song. While there are some very stereotyped calls observed in this region, there is also a tendency for "chatter" which is a lot less distinguished. These bouts of less distinguished calling requires a much more detailed analysis. This analysis is currently ongoing as a senior thesis for a College of the Atlantic undergraduate student.

Budget/Expenditures

A complete budget is detailed in Appendix A. In brief, Allied Whale requested $75,515 from DMR, but expended only $64,649, mostly because the approved oceanographic/biological subsampling project was terminated early at the request of DMR.

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Appendix A - Budget

	Total cost[1]	DMR request	Total claimed
Salaries			
Boat Skipper (half time, 31 days total @ $200/day)	6,200	3,100	$3,100.00
Steward (fulltime May/June/July/August/September), @ $2,000/month	10,000	5,000	$5,000.00
Internship Coordinator/Research Asst. 1 (1/4-time Apr and May, 1/2 time June-September)	5,720	2,860	$2,834.00
Research Asst. 2 (crew, 31 days @ $100/day)	3,100	1,550	$1,550.00
Post-season photo/GIS analysis (half-time Oct/Nov/Dec)	3,432	1,716	$1,794.00
Post-season acoustics analysis (half-time, 12 months)[2]	13,728	13,728	$10,509.50
Fringe for Steward position @ 14.5%	1,450	725	$725.00
Operating costs			
Vessel operating costs (fuel, supplies, maintenance)	15,000	7,500	$8,110.00
Food at MDR field station (6 weeks @ $250/wk)	1,500	750	$750.00
MDR logistical support (R/V *Borealis* or M/V *Indigo* 8 days @ $500)	4,000	2,000	$2,000.00
Biopsy support	3,000	1,500	$1,500.00
Subcontracts			
Dominique Walk, gear density analysis	7500	7500	$7,751.62
Habitat monitoring (Candage, CTD-plankton), inc. contract oversight	20,000	15,000	$8,250.00
sub-total	$94,630	$62,929	$53,874.12
Institutional overhead @20%		$12,586	$10,774.82
Total Request, DMR		**$75,515**	$64,648.94

[1] As part of a larger project not all the cost for any one budget line was necessarily sought entirely from DMR
[2] Support for J. Bort, Masters student