Seasonal occurrence of sei whales (*Balaenoptera borealis*) in the Gulf of Maine: An examination using passive acoustic monitoring of the Outer Fall region

Sara Golaski: College of the Atlantic

Methods:

Acoustic Data Collection

Recordings were collected using Marine Autonomous Recording Units (MARUs) developed by the Cornell University Bioacoustics Research Program (Cornell BRP). These MARUs are pop-up buoys which are moored to the sea-floor until they receive an acoustic signal to detach and float to the surface for retrieval. They include a durable, easily-visible yellow case around a vacuum-sealed 43.18 cm glass sphere containing a microprocessor, hard drive, batteries, and electrical equipment. They use an externally mounted hydrophone (High tech, Inc. 94-SSQ) sensitive up to -165 dB re 1 V / µPa and a preamplifier system with a frequency response of 10 Hz to 32 kHz. The entire system has a flat frequency response (± 1 dB) from 20 to 800 Hz and records to a 120 GB hard drive in binary format. With this setup, these units have the ability to record continuously for approximately 120 days.

Four of these units were deployed in approximately the same location at Outer Fall in the Gulf of Maine (Figure 1). Only three of these units were successfully retrieved. The first unit deployed was most likely displaced during Hurricane Bill in 2009. Another of the units has not yet been fully analyzed. The two units recording between October 2009 and October 2010 were used for this analysis. Of the two analyzed, the first MARU was deployed at 43˚ 18.90N, 068˚ 37.338W and the second MARU was deployed at 43˚ 18.23N, 068˚ 37.336W. Each MARU recorded continuously at a sampling rate of 2 kHz, one from October 30, 2009 to May 28, 2010 and the other from June 29, 2010 to October 13, 2010. Because of a delay between retrieval of one unit and deployment of the next, there was only one day available for analysis in June.

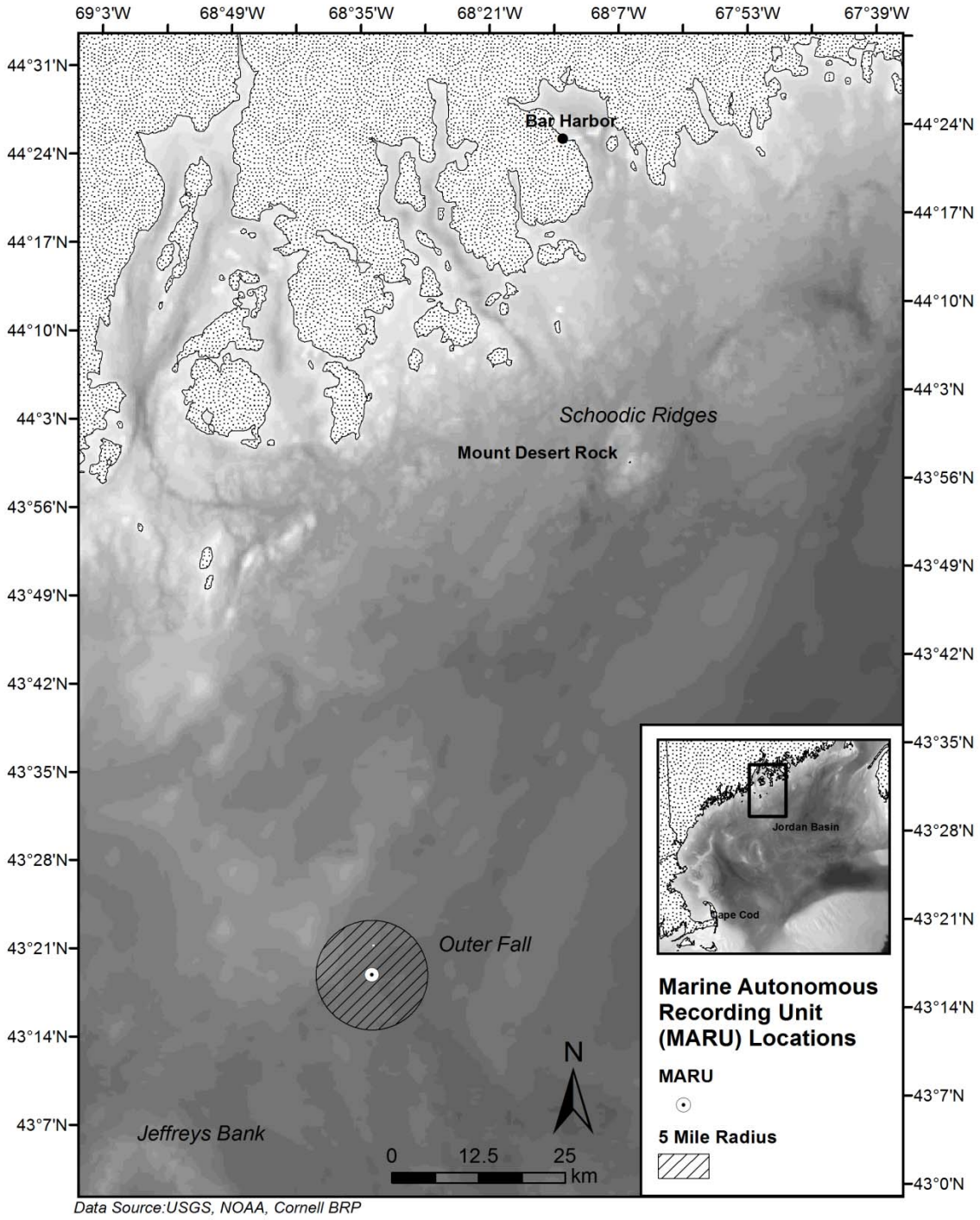

Figure 1: The first MARU was deployed at 43˚ 18.190N, 068˚ 37.338W. The second MARU was deployed at 43˚ 18.234N, 068˚ 37.336W. The 5 mile radius is an estimate of the buoys' listening range, though stronger signals could be heard from farther away.

Aerial Surveys

Aerial survey data was examined to potentially assist with visual confirmation of acoustic sei whale detections. The NOAA Northeast Fisheries Science Center conducted 68 aerial surveys in the Gulf of Maine during the duration of this study, but only 8 of these surveys covered the Outer Fall region. No surveys were conducted during July, August, or September of 2010. Figure 2 depicts all aerial survey sightings of both sei and right whales north of 42˚N during the times that the MARUs were recording. These results are not directly comparable to the acoustic data because so few surveys were flown within the estimated listening range of the buoys. However, the data do give an indication of distribution during the months that sei whales were sighted, as well as an indication that sei whales and right whales are often associated in the Gulf of Maine.

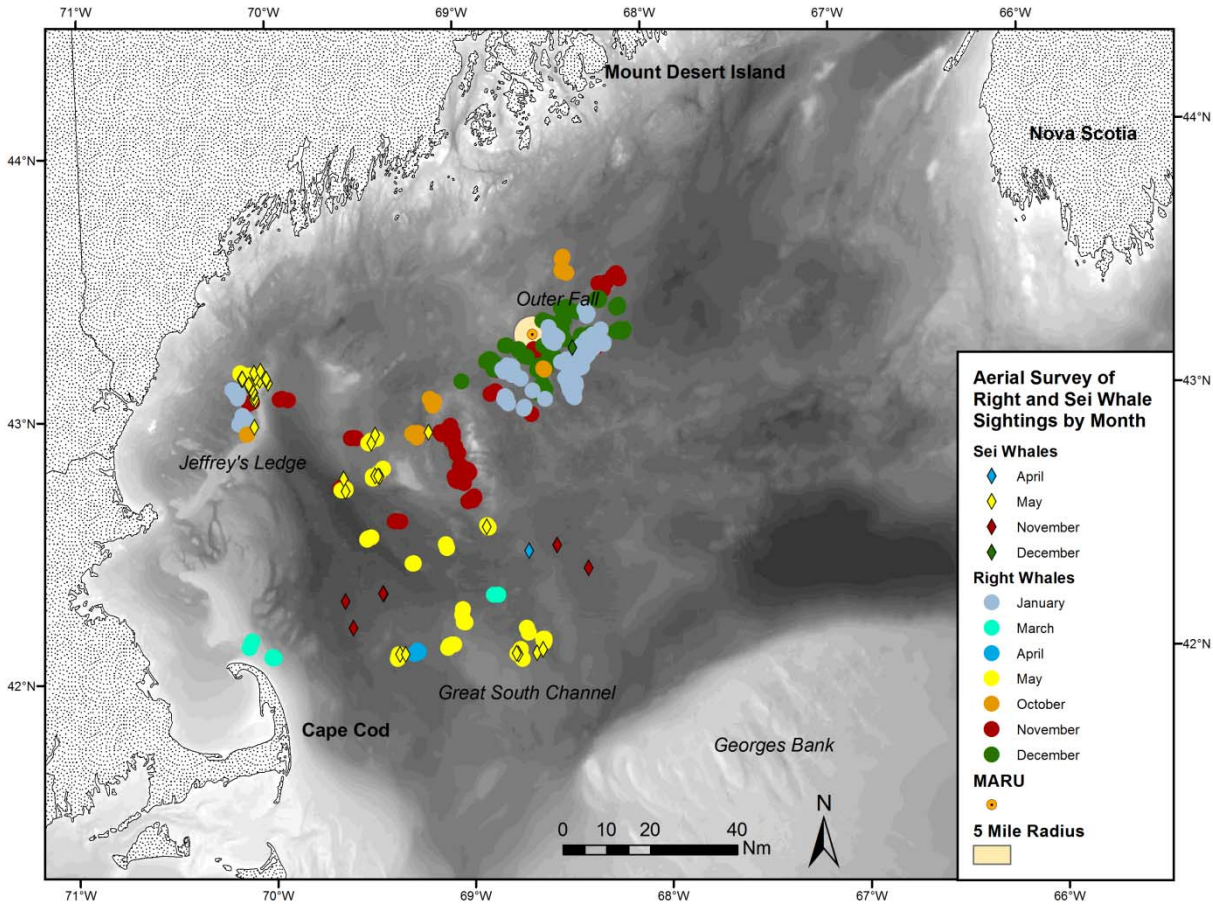

Figure 2: Aerial Survey sightings of both sei whales and right whales during the study period (October 30, 2009 to May 28, 2010 and June 29, 2010 to October 13, 2010).

Acoustic Analysis

XBAT (eXtensible BioAcoustic Tool) was used to analyze the recordings. XBAT is a MATLAB (Mathworks 2006) supported open source software for sound analysis and management of large-scale acoustic data sets developed by Cornell BRP. Hann spectrograms (1026 FFT, 60s window, 0-500Hz) were created for a subset of 39 days using XBAT. A detector for the downsweep call was created within XBAT using an example downsweep call taken directly from this dataset as a template. This detector was run on each day analyzed to scan for the presence of downsweep calls using spectrogram cross-correlation as described by Mellinger and Clark (2000). One benefit of using an automated detector is that any bias remains constant throughout a dataset rather than changing over time. Each of the 39 days was then reviewed by an analyst, who counted and deleted false detections. In addition, the analyst logged missed calls, creating a record of the time and frequency range of each call, though these measures were often affected by echoing and by attenuation of higher frequencies. All calls were also rated for quality so that questionable calls could be excluded from the analysis. All calls of a very short duration, consistent with fin whale downsweeps, or that appeared to be part of a pattern consistent with humpback song were excluded as well in order to avoid misidentification of species. From these records, an error rate was calculated and the detector was deemed unreliable for use on the rest of the dataset as it missed many calls and produced a high rate of false detections. These false detections occurred because the detector occasionally logged low-frequency pulsed vocalizations which were clearly not downsweep calls.

Logged calls were then sorted into one hour bins for each day, creating a record of the number of calls in each hour to test whether vocal activity followed a diel pattern as shown by Baumgartner and Fratantoni (2008). The number of total calls for each day was then averaged by month to test for seasonal variation in sei whale occurrence.

Results:

In total, 39 days from 13 months were analyzed and 2803 downsweep calls attributed to sei whales were identified (Table 1). This is a minimum estimate of sei whale downsweeps because many potential calls that were not of a high enough quality or had too-short a duration were excluded. This was to ensure that the study was as conservative as possible by attempting to safeguard that all calls logged were not produced by other species. Of all calls logged, approximately 29% were single calls, approximately 69% were part of a pair, and approximately 2% were in a triplet. There were also eight downsweeps that appeared to form two quartets.

Date	Total calls	Detected	False Detections	True Detections	Missed Calls	Analyst	Ambient Noise	20Hz pulse
MARU 1 (151)								
30-Oct-09	245	47	14	33	212	SBG	H	Y
31-Oct-09	429	95	7	88	341	LEN	M	Y
7-Nov-09	11	0	0	0	11	ES	H	Y
16-Nov-09	13	10	10	0	13	ES	H	Y
25-Nov-09	0	5	5	0	0	PJKO	M	Y
4-Dec-09	14	0	0	0	14	AJB	M	Y
13-Dec-09	52	2	2	0	52	SBG	H	Y
22-Dec-09	0	0	0	0	0	ASP	M	Y
31-Dec-09	0	0	0	0	0	AJB	M	Y
9-Jan-10	0	0	0	0	0	SBG & TO	L	Y
18-Jan-10	0	41	41	0	0	AJB	L	Y
27-Jan-10	0	4	4	0	0	ASP	M	Y
5-Feb-10	0	0	0	0	0	AJB	L	Y
14-Feb-10	0	5	5	0	0	SBG	M	Y
23-Feb-10	0	7	7	0	0	SBG	M	Y
4-Mar-10	0	1	1	0	0	LEN	M	Y
13-Mar-10	0	0	0	0	0	LEN	H	Y
22-Mar-10	0	0	0	0	0	SBG	H	Y
31-Mar-10	8	2	2	0	8	SBG	H	Y
9-Apr-10	10	0	0	0	10	AJB	M	Y
18-Apr-10	3	0	0	0	3	AJB	M	Y
27-Apr-10	10	0	0	0	10	LEN	H	Y
6-May-10	33	0	0	0	33	PJKO	H	N
15-May-10	10	0	0	0	10	SBG	H	N
24-May-10	26	0	0	0	26	SBG	M	N
MARU 2 (148)								
30-Jun-10	4	0	0	0	4	SBG	H	N
1-Jul-10	97	0	0	0	97	SBG	M	N
10-Jul-10	177	11	6	5	172	SBG & TO	H	N
19-Jul-10	0	0	0	0	0	SBG	H	Y
28-Jul-10	7	4	4	0	7	SBG	H	N
6-Aug-10	81	0	0	0	81	EI	H	N
15-Aug-10	1	0	0	0	1	SBG	H	N
24-Aug-10	120	21	1	20	100	SBG	L	Y
2-Sep-10	269	333	154	179	90	PJKO	H	Y
11-Sep-10	82	8	8	0	82	SBG	H	Y
20-Sep-10	4	4	4	0	4	EI	M	Y
29-Sep-10	632	166	22	144	488	EI	M	Y
2-Oct-10	465	124	27	97	368	SBG	H	Y
11-Oct-10	0	0	0	0	0	EI	H	Y

Table 1: Totals for each day analyzed. The blank line after May 24th indicates the gap in data between retrieval of the first MARU and deployment of the second MARU.

Time of Year

The number of calls decreased towards the winter, and from Dec 22, 2009 to March 22, 2010, no sei whale downsweep calls were detected (Figure 3). Calls then increased steadily until October 2010, when the study ended. A quadratic regression showed significant seasonal variation in call rates with all data included ($R^2 = 0.3551$, $p < 0.001$), and once data were averaged by month (Figure 4) ($R^2 = 0.6972$, $p < 0.001$).

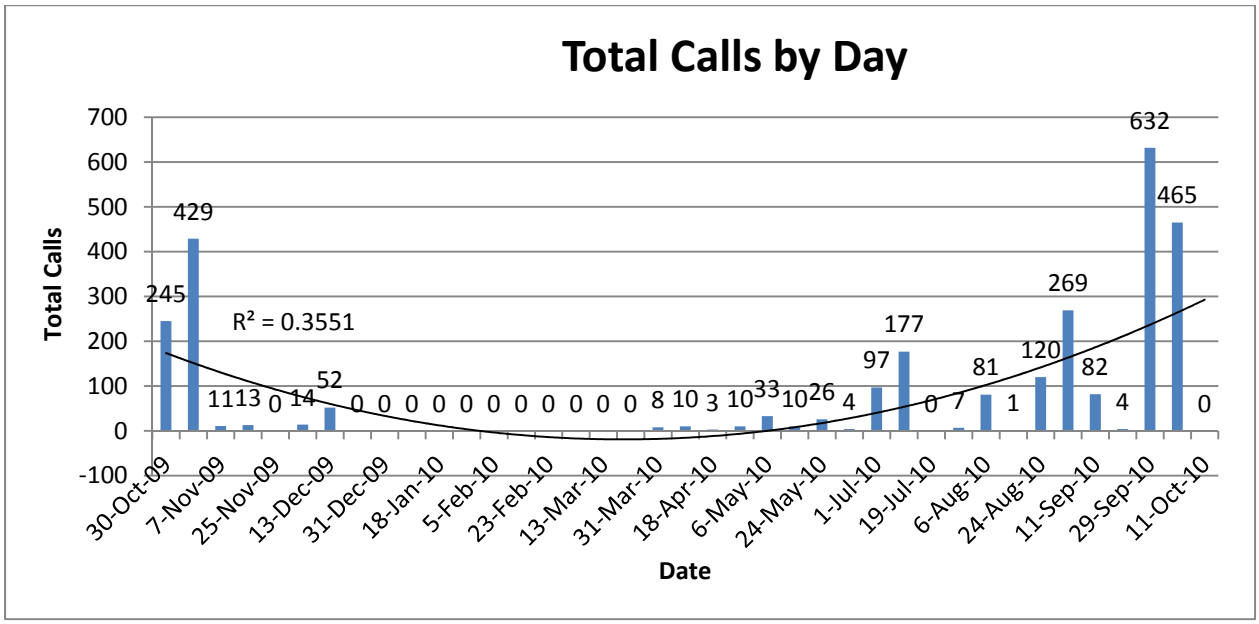

Figure 3: Totals of all calls detected by analyzed day

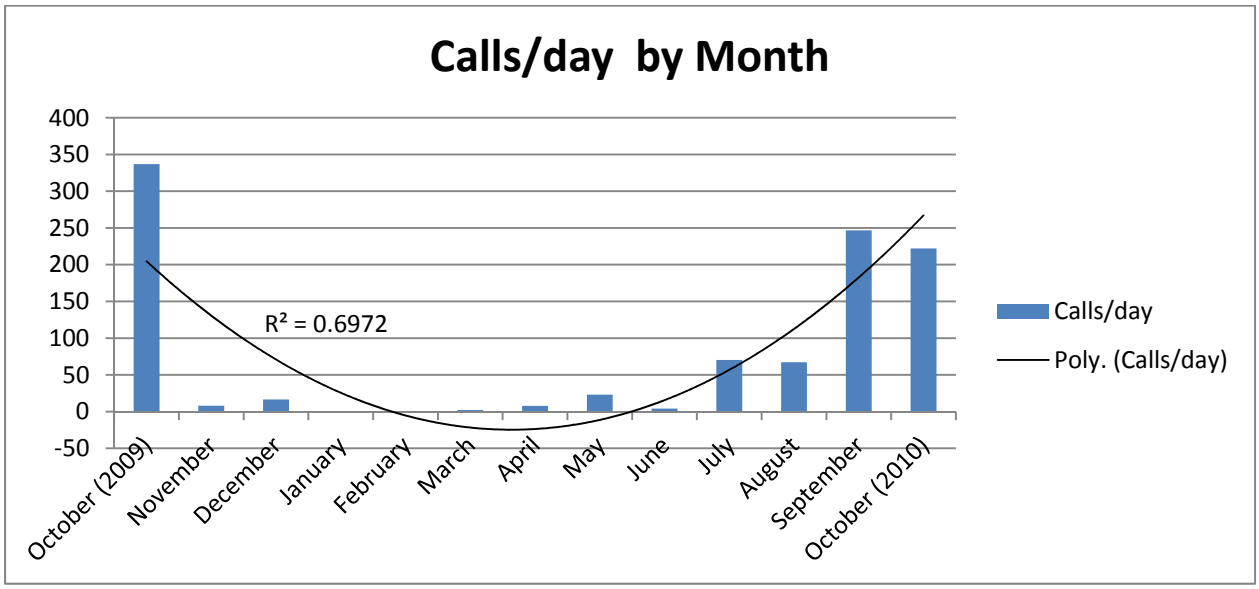

Figure 4: Average calls per day by month

Time of Day

Overall call rate increased around 2:00 – 3:00 and decreased drastically after 13:00 – 14:00 in a significant quadratic trend (Figure 5) ($R^2 = 0.4621$, $p<0.001$). There was some variation between months, but this was not testable because of the low number of total days analyzed (Figure 6).

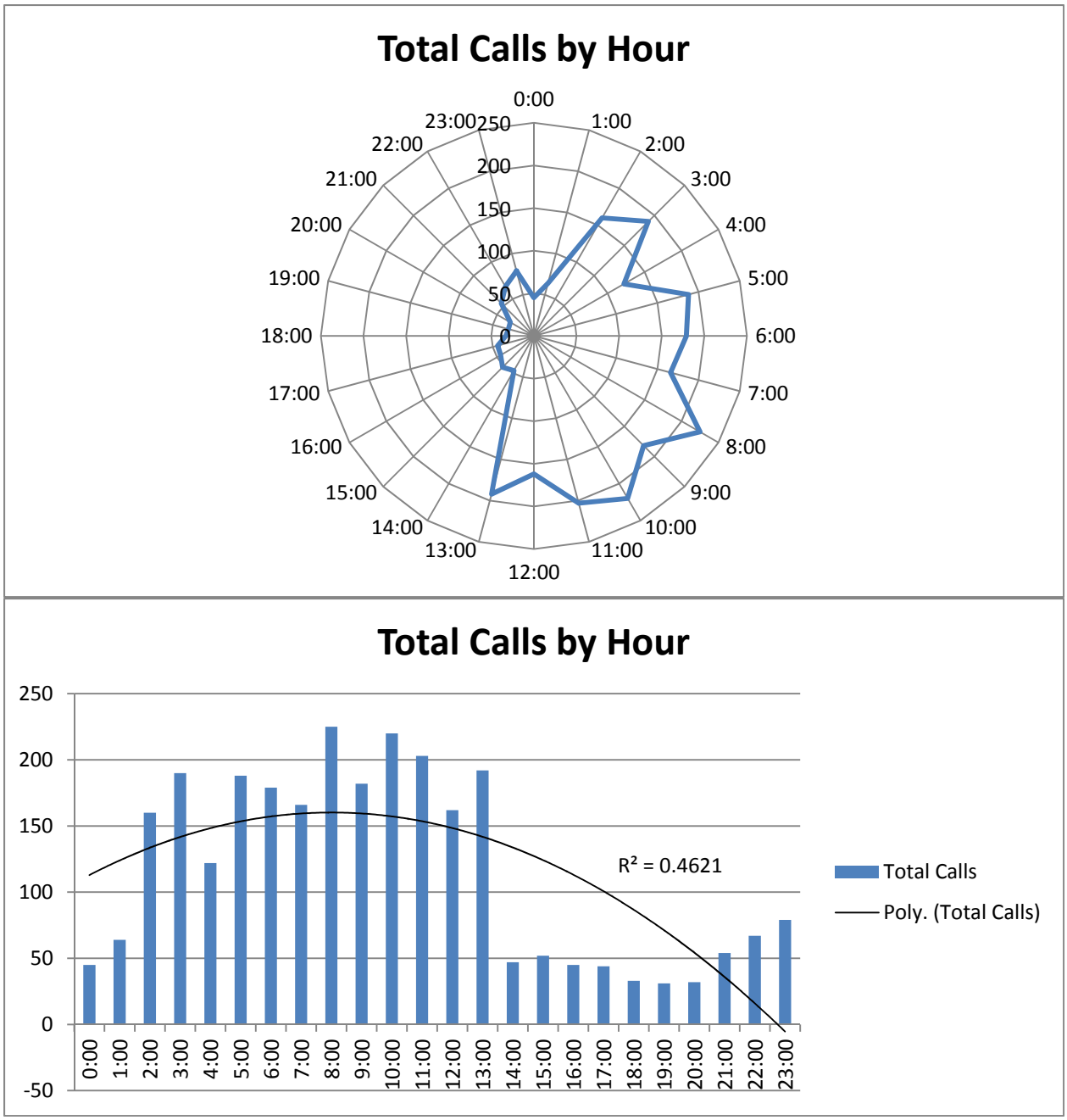

Figure 5: Totals of all calls detected by hour

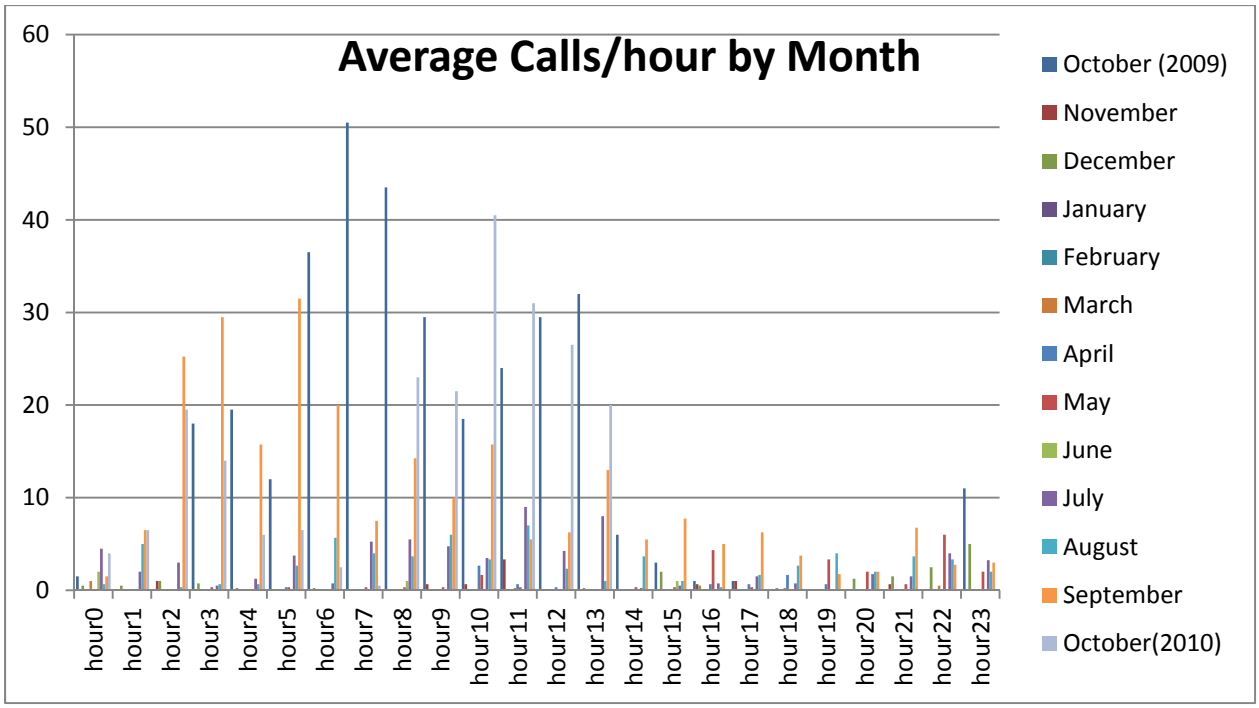

Figure 6: Average calls per hour by month

Sources:

Baumgartner, M. F., & Fratantoni, D. M. (2008). Diel periodicity in both sei whale vocalization rates and the vertical migration of their copepod prey observed from ocean gliders. Limnology and Oceanography, 2197-2209.

Mellinger, D. K., & Clark, C. W. (2000). Recognizing transient low-frequency whale sounds by spectrogram correlation. The Journal of the Acoustical Society of America, 107, 3518.