



Five Years of Whale Presence in the SOCAL Range Complex 2013-2017

Simone Baumann-Pickering, Ally C. Rice, Jennifer S. Trickey,
John A. Hildebrand, Sean M. Wiggins, Ana Širović

Marine Physical Laboratory
Scripps Institution of Oceanography
University of California San Diego
La Jolla, CA 92037



Cuvier's beaked whales, Photo by Jennifer Trickey

Suggested Citation:

Baumann-Pickering, S., Rice, A.C., Trickey, J.S., Hildebrand, J.A., Wiggins, S.M., and Širović, A. (2018) "Five Years of Whale Presence in the SOCAL Range Complex 2013-2017," Marine Physical Laboratory, Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA, MPL Technical Memorandum #626 under Cooperative Ecosystems Study Unit Cooperative Agreement N62473-17-2-0014 for U.S. Navy, U.S. Pacific Fleet, Pearl Harbor, HI.

Table of Contents

Executive Summary	1
Project Background	2
Methods	5
Passive Acoustic Monitoring Recorders	5
Data Collected	5
Data Analysis	6
Blue Whales	6
Fin Whales	8
Beaked Whales	10
Results	13
Mysticetes	13
Blue Whales	13
Fin Whales	13
Beaked Whales	15
Cuvier’s Beaked Whales	15
BW43	15
Conclusions.....	18
References.....	20

List of Tables

Table 1. SOCAL Range Complex acoustic monitoring since January 2013.....	4
Table 2. Site P acoustic monitoring since January 2014.....	4
Table 3: Summary of Cuvier’s beaked whale and BW43 FM pulse detections since 2013.	15

List of Figures

Figure 1. SOCAL Range Complex with acoustic recorder site locations and bathymetric map.....	3
Figure 2. Blue whale B calls in Long-term Spectral Average (LTSA) and an individual call recorded at site N.....	7
Figure 3. Blue whale D calls from site H in the analyst verification stage of the detector.	8
Figure 4. Fin whale 20 Hz calls in an LTSA and spectrogram recorded at site P.	9
Figure 5. Echolocation sequence of Cuvier’s beaked whale in an LTSA, example FM pulse in a spectrogram, and corresponding time series recorded at site N.	11
Figure 6. Echolocation sequence of BW43 in an LTSA, example FM pulse in a spectrogram and corresponding time series recorded at site N.....	12
Figure 7. Weekly presence of NE Pacific blue whale B calls, NE Pacific blue whale D calls, and fin whale 20 Hz acoustic index between January 2013 and June 2017 at sites H, M, N and P.....	14
Figure 8. Weekly average daily detections in minutes of Cuvier’s beaked whale and BW43 FM pulses between January 2013 and June 2017 at sites H, M, and N.....	16
Figure 9. Cuvier’s beaked whale FM pulses in one-minute bins at sites H, M, and N.....	17
Figure 10. BW43 FM pulses in five-minute bins at sites H and N.....	18

Executive Summary

Passive acoustic monitoring was conducted in the Navy's Southern California Range Complex from January 2013 to June 2017 to detect marine mammal sounds. High-frequency Acoustic Recording Packages (HARPs) recorded sounds between 10 Hz and 100 kHz at four locations: west of San Clemente Island (1,000 m depth, site H), south of San Clemente Island (1200 m depth, site N), northwest of San Clemente Island (900 m depth, site M) and west of La Jolla, California (500 m depth, site P).

While a typical southern California marine mammal assemblage is consistently detected in these recordings (Hildebrand *et al.*, 2012), only occurrence of acoustic signals from a select sub-set of species including blue whales, fin whales, and beaked whales were analyzed for this report.

Data analysis was performed using automated computer algorithms. Calls of two baleen whale species were detected: blue whale B calls and D calls, and fin whale 20 Hz calls. Both species were present at all sites but call detections and the fin whale acoustic index representative of 20 Hz calls were highest at sites H and N, sites that also had the largest detection range. Blue whale B call detections peaked from September to December and very few B calls were detected after January. Blue whale D calls peaked in May and June. The fin whale acoustic index was highest from October to April.

Frequency-modulated (FM) echolocation pulses from Cuvier's beaked whales were regularly detected at sites H, M, and N but were most common at site H. Detections were highest in spring and fall with a low in summer. Site H had particularly high numbers of detections in spring of 2016. There was an additional beaked whale-like FM pulse type, BW43, possibly produced by Perrin's beaked whale (Baumann-Pickering *et al.*, 2014), that was detected infrequently during winter at site N and rarely at site H. No other beaked whale signal types were detected, and there were no beaked whale detections at site P.

Project Background

The Navy's Southern California (SOCAL) Range Complex is located in the Southern California Bight and the adjacent deep waters to the west. This region has a highly productive marine ecosystem due to the southward flowing California Current, and associated coastal current system. A diverse array of marine mammals is found here, including baleen whales, beaked whales and other toothed whales and pinnipeds.

In January 2009, an acoustic monitoring effort was initiated within the SOCAL Range Complex with support from the U.S. Pacific Fleet. The goal of this effort was to characterize the vocalizations of marine mammal species present in the area, determine their seasonal presence, and evaluate the potential for impact from naval training. In this current effort, the goal was to explore the seasonal presence of a subset of species of particular interest, including blue and fin whales, as well as beaked whales, over the last five years of monitoring effort.

This report documents the analysis of data recorded by High-frequency Acoustic Recording Packages (HARPs) that were deployed at four sites within the SOCAL Range Complex and collected data between January 2013 and June 2017. Three of the four recording sites surround San Clemente Island, site H to the west, site M to the northwest and site N to the south and one is west of La Jolla, California (site P; Figure 1). Analysis of data included recordings from sites H and N collected from January 2013 through June 2017 (Table 1), recordings at site M from January 2013 through February 2015, and site P recordings from January 2014 through May 2017 (Table 2).

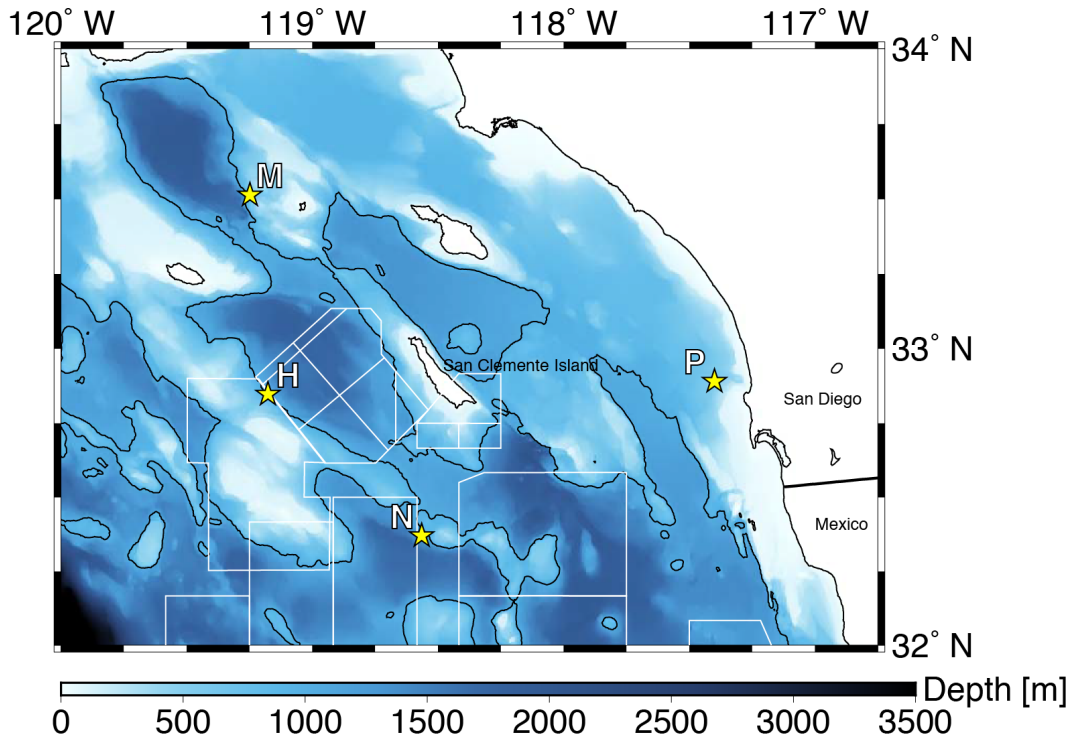


Figure 1. SOCAL Range Complex with acoustic recorder site locations and bathymetric map. Acoustic recorder locations are shown as yellow stars at sites H, M, N and P. White polygons are Navy operational areas. Black contours are coastlines and 1000 m depth. Darker colors are deeper.

Table 1. SOCAL Range Complex acoustic monitoring since January 2013.
Dates in italics were only used for high frequency analysis.

Deployment Name	Site H Monitoring Period	# Hours	Site M Monitoring Period	# Hours	Site N Monitoring Period	# Hours
SOCAL 48	12/21/12 – 4/30/13	3140	12/20/12 – 4/25/2013	3041	12/20/12 – 5/1/13	3155
SOCAL 49	-	-	4/30/13 – 9/5/13	3057	5/2/13 – 9/11/13	3156
SOCAL 50	9/10/13 – 1/6/14	2843	9/9/13 – 1/6/14	2852	-	-
SOCAL 51	1/7/14 – 4/3/14	2082	1/6/14 – 4/4/14	2110	1/7/14 – 2/16/14	956
SOCAL 52	4/4/14 – 7/30/14	2814	4/4/14 – 5/29/14	1324	4/4/14 – 7/30/14	2817
SOCAL 53	7/30/14 – 11/5/14	2340	7/30/14 – 11/3/14	2319	7/30/14 – 11/5/14	2342
SOCAL 54	11/5/14 – 2/4/15	2198	11/4/14 – 2/5/15	2233	11/4/14 -2/5/15	2196
SOCAL 55	2/5/15 – 6/1/15	2800	-	-	2/5/15 – 2/23/15	433
SOCAL 56	6/2/15 – 10/3/15	2952	-	-	6/2/15 – 10/3/15	2966
SOCAL 57	-	-	-	-	10/3/15 – 11/21/15	1168
SOCAL 58	11/21/15 – 4/25/16	3734	-	-	11/21/15 – 4/18/16	3578
SOCAL 59	7/6/16 – 11/9/16	3011	-	-	7/7/16 – 11/8/16	2999
SOCAL 60	-	-	-	-	11/9/16 – 2/21/17	2457
SOCAL 61	2/22/17 – 6/6/17	2518	-	-	2/21/17 – 6/7/17	2528
Totals		30432 (1268.0 days)		16936 (705.7 days)		30751 (1281.3 days)

Table 2. Site P acoustic monitoring since January 2014.

Deployment Name	Site P Monitoring Period	# Hours
LJ 23	1/25/2014 – 3/4/2014	936
LJ 26	3/6/2014 – 6/27/2014	2711
LJ 31	6/2/15 – 9/18/15	2593
LJ 32	9/25/15 – 10/19/15	574
LJ 33	10/20/15 – 11/20/15	747
LJ 34	11/20/15 – 3/1/16	2448
LJ 35	4/9/16 – 8/10/16	2971
LJ 36	8/12/16 – 10/26/16	1803
LJ 37	-	-
LJ 38	-	-
LJ 39	2/14/17 – 5/24/17	2377
Total		71160 (715.0 days)

Methods

Passive Acoustic Monitoring Recorders

High-frequency Acoustic Recording Packages (HARPs; Wiggins and Hildebrand, 2007) have been used to record marine mammal, ambient, and anthropogenic sounds in the SOCAL Range Complex. HARPs are autonomous, battery-operated instruments capable of recording underwater sounds from 10 Hz to 100 kHz continuously over long periods (up to ~1 year) to provide a comprehensive time series of the marine soundscape. HARPs are configurable into standard large oceanographic-style moorings, medium or small moorings, and seafloor mounted instrument frames, all of which use a releasable ballast-weight anchor to secure the instrument to the sea floor until planned recovery. A combination of these configurations was used in the SOCAL Range Complex, and was chosen depending on deployment and site requirements.

To capture underwater sounds, HARPs use hydrophones tethered and buoyed approximately 10 – 30 m above the seafloor. The hydrophones typically used were constructed with two channels, one for low-frequency sounds (<2 kHz) and the other for mid- and high-frequency signals (>2 kHz) with different lead-zirconium-titanate (PZT) ceramic elements and different preamplifier, filter, and signal conditioning electronics for each channel. Each hydrophone's electronic circuit board was calibrated in the laboratory at Scripps Institution of Oceanography and representative data loggers with complete hydrophones were full-system calibrated at the U.S. Navy's Transducer Evaluation Center in San Diego, CA to provide the full-band frequency response of the system so that accurate sound pressure levels can be measured from the recordings.

Acoustic data were recorded to an array of standard laptop computer style 2.5" hard disk drives in a compressed format. Upon instrument recovery, used batteries and disk drives were removed and replaced with new batteries and empty disk drives along with a new ballast-weight anchor to ready the HARP for the next deployment.

Data Collected

Acoustic recordings have been collected at three offshore sites within the SOCAL Range Complex since January 2013 (Table 1) and one off La Jolla, CA since January 2014 (Table 2) using HARPs sampling at 200 kHz. The sites are designated site H (32° 56.76N, 119° 10.57W, depth 1,000 m), site M (33° 30.58N, 119° 15.28W, depth 900 m), site N (32° 22.21N, 118° 33.85W, depth 1,200 m), and site P (32° 53.40N, 117° 24.006W, depth 500 m). Site H yielded data from January 1, 2013 to June 6, 2017. Site M yielded data from January 1, 2013 to February 5, 2015. Site N yielded data from January 1, 2013 to June 7, 2017. Data recording occurred at site P from January 25, 2014 to May 24, 2017. The recordings at these four sites varied in data quality over the monitoring period described here. Specifics about data quality have been described in previous annual reports (Debich *et al.*, 2015a; Debich *et al.*, 2015b; Širović *et al.*, 2016; Rice *et al.*, 2017; Rice *et al.*, 2018). For all four sites, a total of 95,279 hours, covering 3,970 days of acoustic data were recorded in the deployments analyzed in this report.

Data Analysis

Recording over a broad frequency range of 10 Hz to 100 kHz allows detection of baleen whales (mysticetes) and toothed whales (odontocetes). All analyses were conducted using appropriate automated detectors for whale sound sources. Analysis was focused on the following species: blue whales (*Balaenoptera musculus*), fin whales (*B. physalus*), and Cuvier's beaked whales (*Ziphius cavirostris*). In addition, the data were screened for signals from Blainville's (*Mesoplodon densirostris*) and Stejneger's (*M. stejnegeri*) beaked whales, as well as for FM pulse types known as BW40, BW43, and BW70, which may belong to Hubbs' (*M. carlhubbsi*), Perrin's (*M. perrini*), and pygmy beaked whales (*M. peruvianus*), respectively (Baumann-Pickering *et al.*, 2014). Individual blue whale B calls, D calls, and beaked whale echolocation clicks were detected automatically using computer algorithms. Presence of fin whale 20 Hz calls was detected using an energy detection method and is reported as a daily average, termed the 'fin whale acoustic index' (Širović *et al.*, 2015). Details of all automatic detection methods are described below.

In this report we summarize results of the acoustic analysis on data collected between January 2013 and June 2017 at sites H, M, N, and P. We also discuss seasonal occurrence, interannual variability, and relative abundance of calls for different species that were consistently identified in the data.

Blue Whales

Blue whales produce a variety of calls worldwide (McDonald *et al.*, 2006). Calls recorded in the eastern North Pacific include the Northeast Pacific blue whale B call (Figure 2) and the D call (Figure 3). Northeast Pacific blue whale B calls are geographically distinct and potentially associated with mating functions (McDonald *et al.*, 2006; Oleson *et al.*, 2007). They are low-frequency (fundamental frequency <20 Hz), long duration (> 10 s) calls that are often regularly repeated. D calls are downswept in frequency (approximately 100-40 Hz) with a duration of several seconds. These calls are similar worldwide and are associated with feeding animals; they may be produced as call-counter call between multiple animals (Oleson *et al.*, 2007).

Northeast Pacific blue whale B calls

Blue whale B calls (Figure 4) were detected automatically using spectrogram correlation (Mellinger and Clark, 1997). The detection kernel was based on frequency and temporal characteristics measured from 30 calls recorded in the data set, each call separated by at least 24 hours. The kernel was comprised of four segments, three 1.5 s and one 5.5 s long, for a total duration of 10 s. Since blue whale calls change over time (McDonald *et al.*, 2009; Širović, 2016), separate kernels were measured for summer and fall periods (see details in previous reports by Debich *et al.*, 2015a; Debich *et al.*, 2015b; Širović *et al.*, 2016; Rice *et al.*, 2017; Rice *et al.*, 2018). As example of this change, the fall 2012 kernel was defined as sweeping from 46.8 to 45.8 Hz; 45.8 to 45.1 Hz, 45.1 to 44.9 Hz, and 44.9 to 44.3 Hz, whereas the fall 2016 kernel was defined as 46.0 to 45.4 Hz; 45.4 to 44.7 Hz, 44.7 to 44.1 Hz, and 44.1 to 43 Hz. The kernel bandwidth was 2 Hz. Total numbers of detections are reported for this call type.

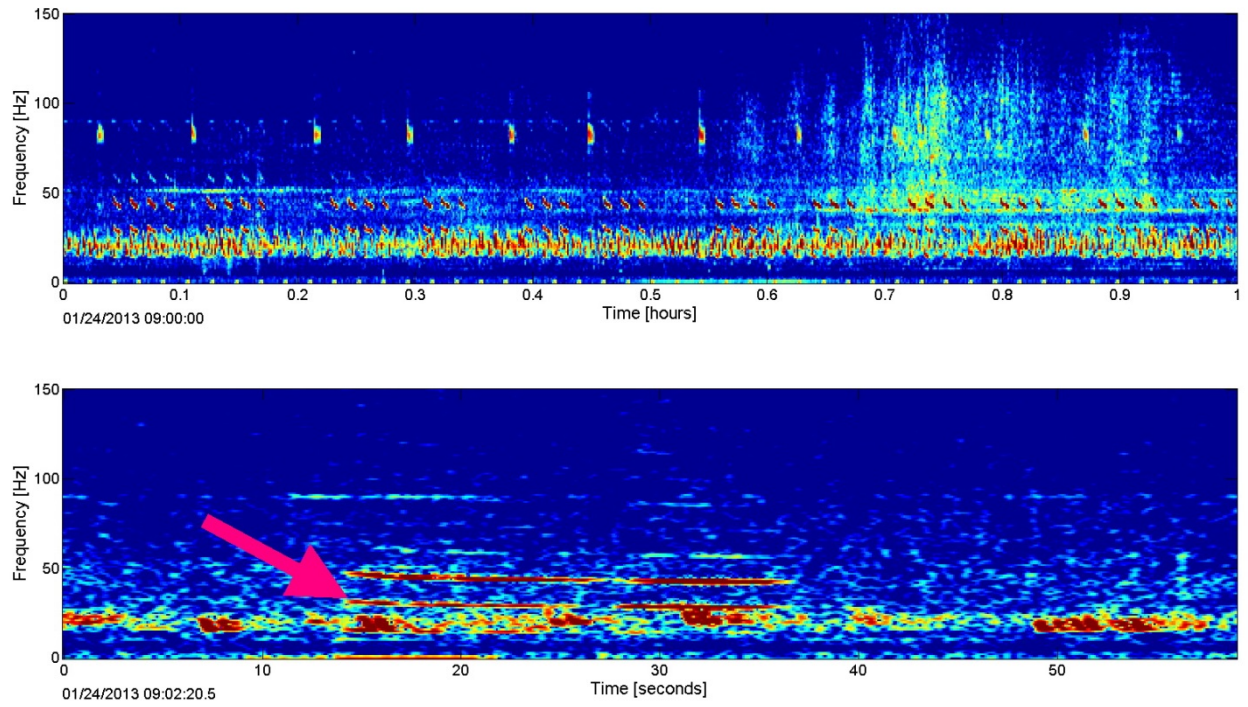


Figure 2. Blue whale B calls in Long-term Spectral Average (LTSA; top) and an individual call shown in a spectrogram (bottom) recorded at site N.

Blue whale D calls

Blue whale D calls (Figure 3) were detected using an automatic algorithm based on the generalized power law (Helble *et al.*, 2012). This algorithm was adapted for the detection of D calls by modifying detection parameters that included the frequency space over which the detector operates. A trained analyst subsequently verified the detections (Figure 3).

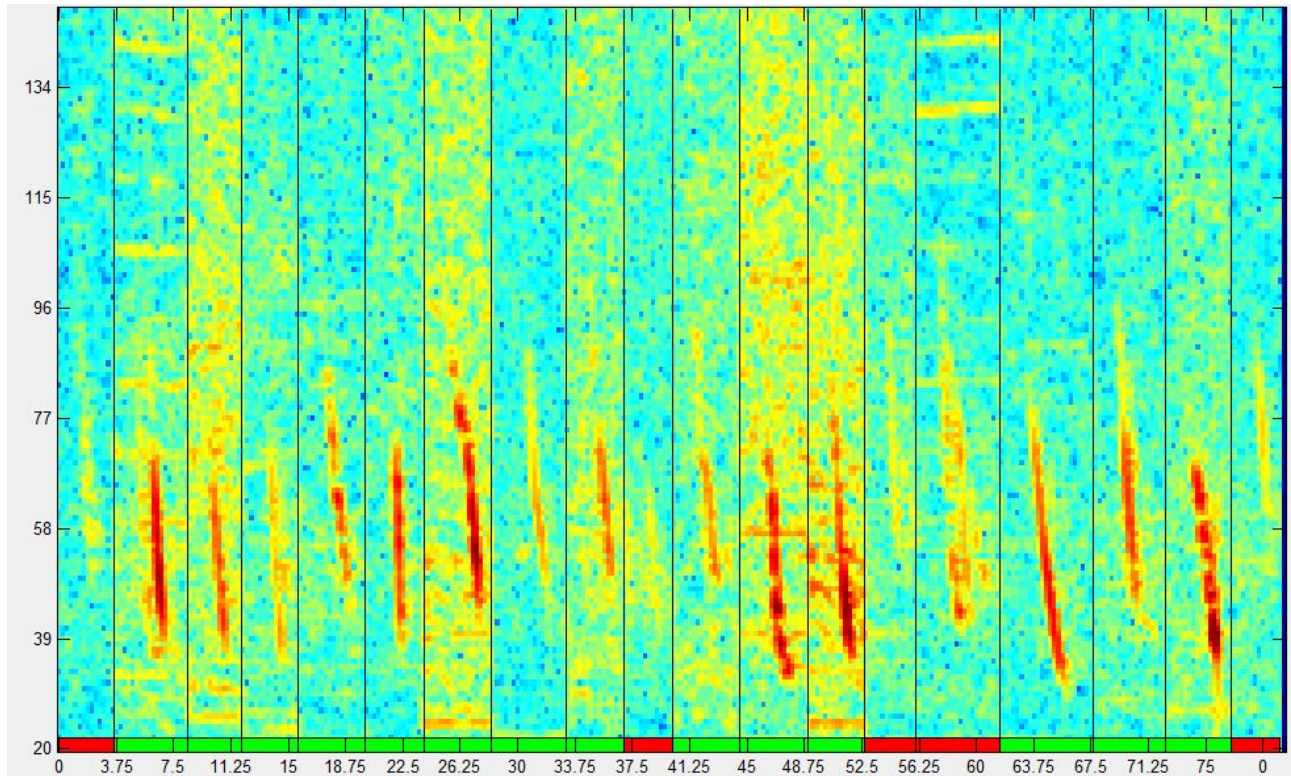


Figure 3. Blue whale D calls from site H in the analyst verification stage of the detector. Green along the bottom evaluation line indicates true detections and red indicates false detections.

Fin Whales

Fin whales produce short (~ 1 s duration), low-frequency calls. The most common is a frequency downsweep from 30-15 Hz called the 20 Hz call, although they also produced a higher frequency version called 40 Hz calls (Watkins, 1981). 20 Hz calls can occur at regular intervals as song (Thompson *et al.*, 1992), or irregularly as call counter-calls among multiple, traveling animals (McDonald *et al.*, 1995).

Fin whale 20 Hz calls

Fin whale 20 Hz calls (Figure 4) were detected automatically using an energy detection method (Širović *et al.*, 2015). The method uses a difference in acoustic energy between signal and noise, calculated from a long-term spectral average (LTSA) calculated over 5 s with 1 Hz frequency resolution. The frequency at 22 Hz was used as the signal frequency, while noise was calculated as the average energy between 10 and 34 Hz. The resulting ratio is termed ‘fin whale acoustic index’ and is reported as a daily average score. All calculations were performed on a logarithmic scale.

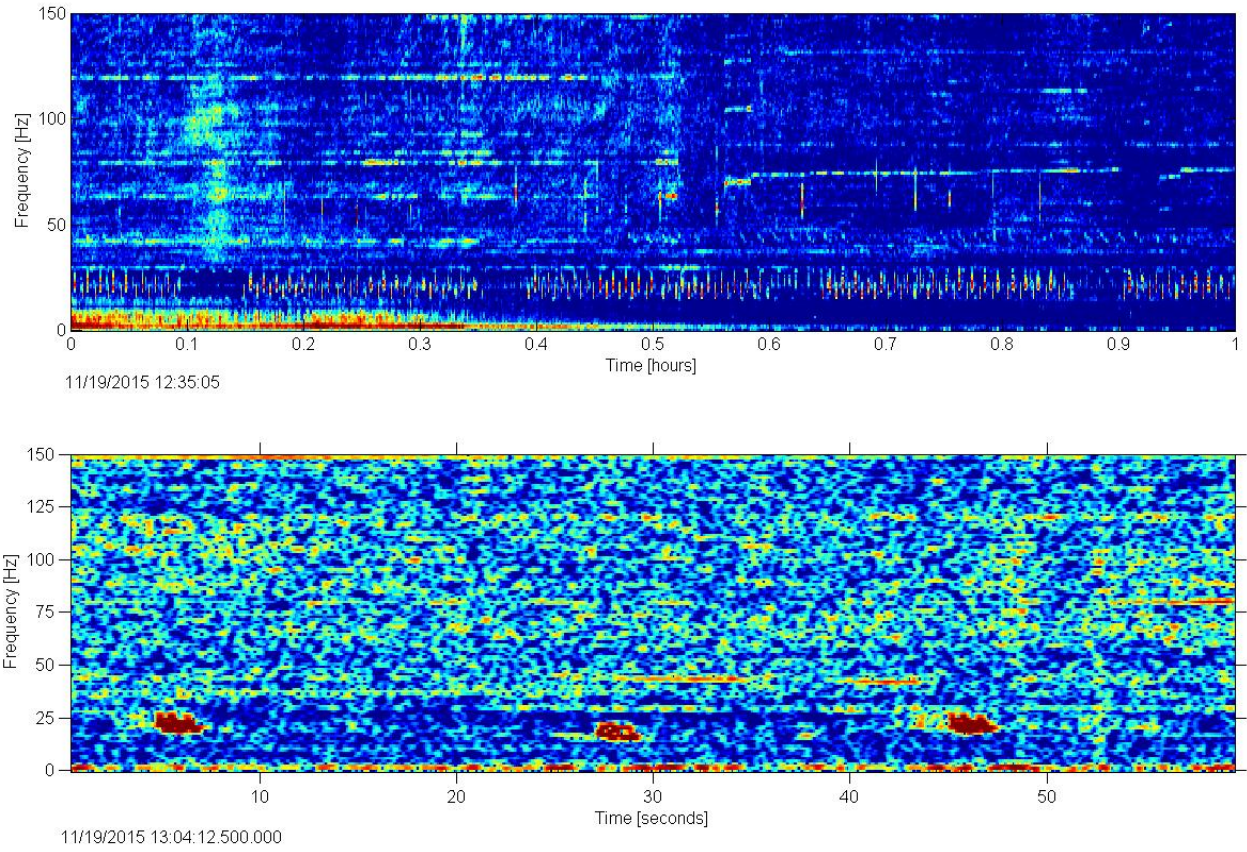


Figure 4. Fin whale 20 Hz calls in an LTSA (top) and spectrogram (bottom) recorded at site P.

Beaked Whales

Beaked whales found in the Southern California Bight include Baird's (*Berardius bairdii*), Cuvier's, Blainville's, Stejneger's, Hubbs', Perrin's, and pygmy beaked whales (Jefferson *et al.*, 2008; Jefferson *et al.*, 2015).

Beaked whales can be identified acoustically by their echolocation signals (Baumann-Pickering *et al.*, 2014). These signals are frequency-modulated (FM) upswept pulses, which appear to be species specific and are distinguishable by their spectral and temporal features. Identifiable signals are known for Baird's, Blainville's, Cuvier's, and likely Stejneger's beaked whales (Baumann-Pickering *et al.*, 2013b).

Other beaked whale signals detected in the Southern California Bight include FM pulses known as BW40, BW43, and BW70, which may belong to Hubbs', Perrin's, and pygmy beaked whales, respectively (Baumann-Pickering *et al.*, 2013a; Baumann-Pickering *et al.*, 2014). Only Cuvier's and BW43 signals were detected during this recording period at the respective sites and their signals are described below in more detail.

Beaked whale FM pulses were detected with an automated method. This automated effort was for all identifiable signals found in Southern California except for those produced by Baird's beaked whales because they produce a signal with a lower frequency content than is typical of other beaked whales and therefore are not reliably identified by the detector used. After all echolocation signals were identified with a Teager Kaiser energy detector (Soldevilla *et al.*, 2008; Roch *et al.*, 2011b), an expert system discriminated between delphinid clicks and beaked whale FM pulses.

A decision about presence or absence of beaked whale signals was based on detections within a 75 second segment. Only segments with more than seven detections were used in further analysis. All echolocation signals with a peak and center frequency below 32 and 25 kHz, respectively, a duration less than 355 μ s, and a sweep rate of less than 23 kHz/ms were deleted. If more than 13% of all initially detected echolocation signals remained after applying these criteria, the segment was classified to have beaked whale FM pulses. This threshold was chosen to obtain the best balance between missed and false detections. A third classification step, based on computer assisted manual decisions by a trained analyst, labeled the automatically detected segments to pulse type and rejected false detections (Baumann-Pickering *et al.*, 2013a). The rate of missed segments was approximately 5%, varying slightly between deployments. The start and end of each segment containing beaked whale signals was logged and their durations were added to estimate cumulative weekly presence.

Cuvier's Beaked Whales

Cuvier's beaked whale echolocation signals are well differentiated from other species' acoustic signals as polycyclic, with a characteristic FM pulse upsweep, peak frequency around 40 kHz, and uniform inter-pulse interval of about 0.4 – 0.5 s (Johnson *et al.*, 2004; Zimmer *et al.*, 2005). An additional feature that helps with the identification of Cuvier's FM pulses is that they have characteristic spectral peaks around 17 and 23 kHz (Figure 5).

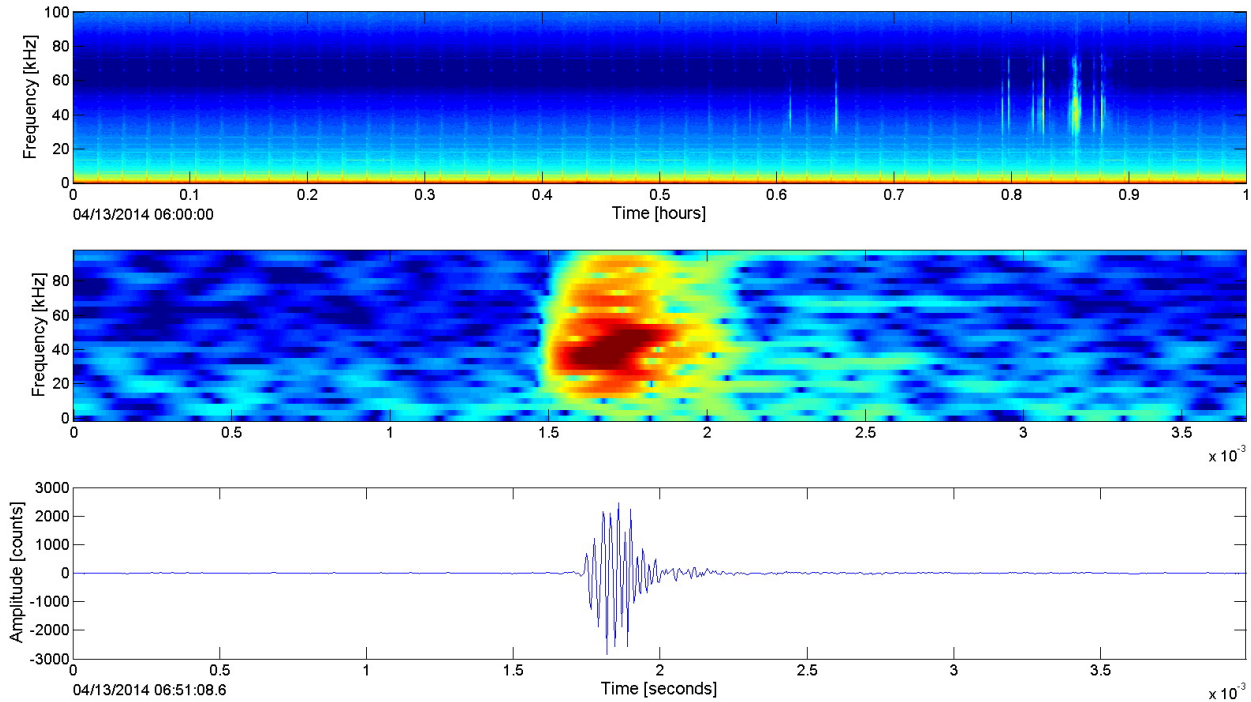


Figure 5. Echolocation sequence of Cuvier's beaked whale in an LTSA (top) and example FM pulse in a spectrogram (middle) and corresponding time series (bottom) recorded at site N.

BW43

The BW43 FM pulse type has yet to be positively linked to a specific species. These FM pulses are distinguishable from other species' signals by their peak frequency around 43 kHz and uniform inter-pulse interval around 0.2 s (Baumann-Pickering *et al.*, 2013a) (Figure 6). A candidate species for producing this FM pulse type may be Perrin's beaked whale (Baumann-Pickering *et al.*, 2014).

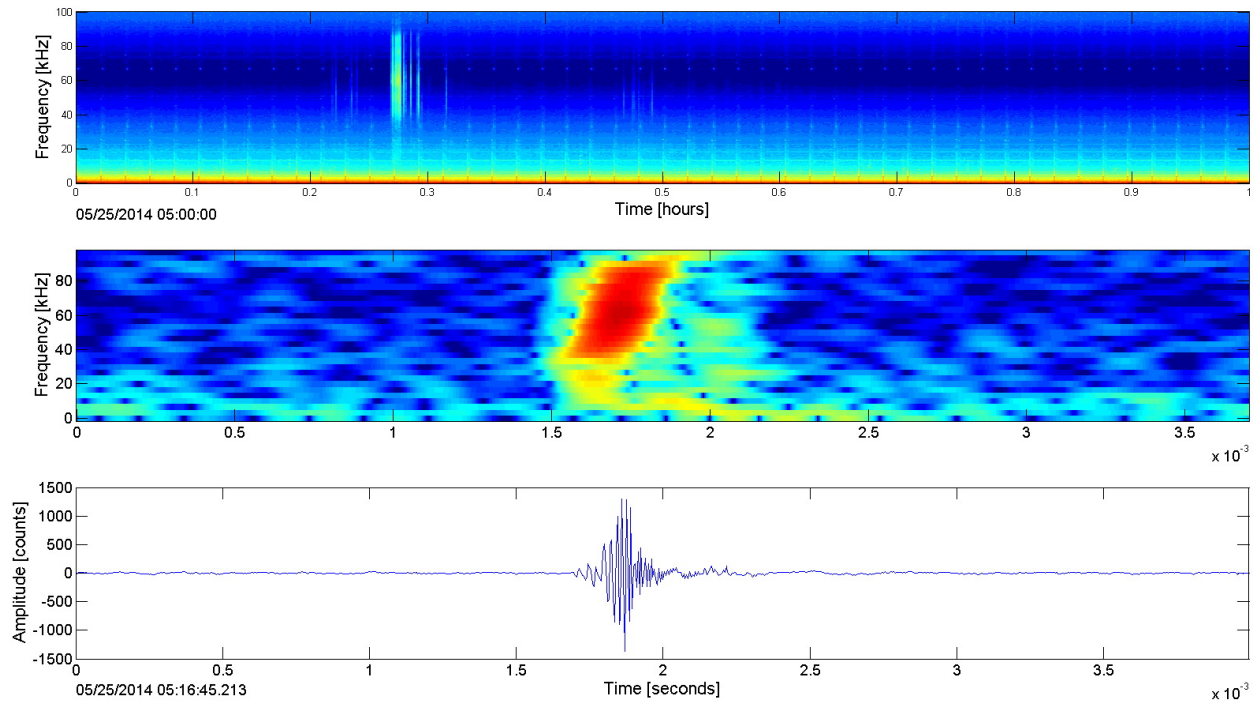


Figure 6. Echolocation sequence of BW43 in an LTSA (top) and example FM pulse in a spectrogram (middle) and corresponding time series (bottom) recorded at site N.

Results

The results of the seasonal occurrence and relative abundance of marine mammal acoustic signals at sites H, M, N, and P from January 2013 through June 2017 are summarized below.

Mysticetes

Blue and fin whale calls recorded between January 2013 and June 2017 were detected using automated methods. Details of each species' presence at multiple sites are given below.

Blue Whales

Blue whale calls were detected at all sites and were most prevalent during the summer and fall.

- Northeast (NE) Pacific blue whale B calls were typically detected from summer through late winter with a peak in November. (Figure 7).
- Site P had substantially higher numbers of NE Pacific blue whale B calls than sites H and N in summer and fall of 2014; however, in the years 2015-2017 these numbers decreased substantially (Figure 7). Interestingly, the detection range at site P was the lowest across sites (Širović *et al.*, 2015) meaning that site P had the highest density of blue whale B calls.
- Sites H and N had relatively stable numbers of NE Pacific blue whale B calls across all recording years; detections at site M were low in 2013.
- NE Pacific D call detections occurred between March and December but were highest from May through June at all sites (Figure 7).
- There was a strong increase in NE Pacific D call detections at sites H and N in 2017 while there was nearly a complete lack of detections at site P during that time. D call detections peaked at site P in 2015 (Figure 7).
- There was no clear diel pattern in any blue whale calls at any site (Debich *et al.*, 2015a; Debich *et al.*, 2015b; Širović *et al.*, 2016; Rice *et al.*, 2017; Rice *et al.*, 2018).

Fin Whales

Fin whales were detected through most of the recordings at all sites. Only 20 Hz calls were analyzed for this report.

- Fin whale acoustic index (representative of 20 Hz calls) peaked in late fall or early winter at all sites and it was typically low during the summer months.
- Across years, highest level of the acoustic index occurred in the winter of 2013/2014 and 2016/2017. It was generally low in the winter of 2015/2016 (Figure 7).
- Highest values of fin whale acoustic index were measured at site H, the site with intermediate size of the overall detection area (Širović *et al.*, 2015).

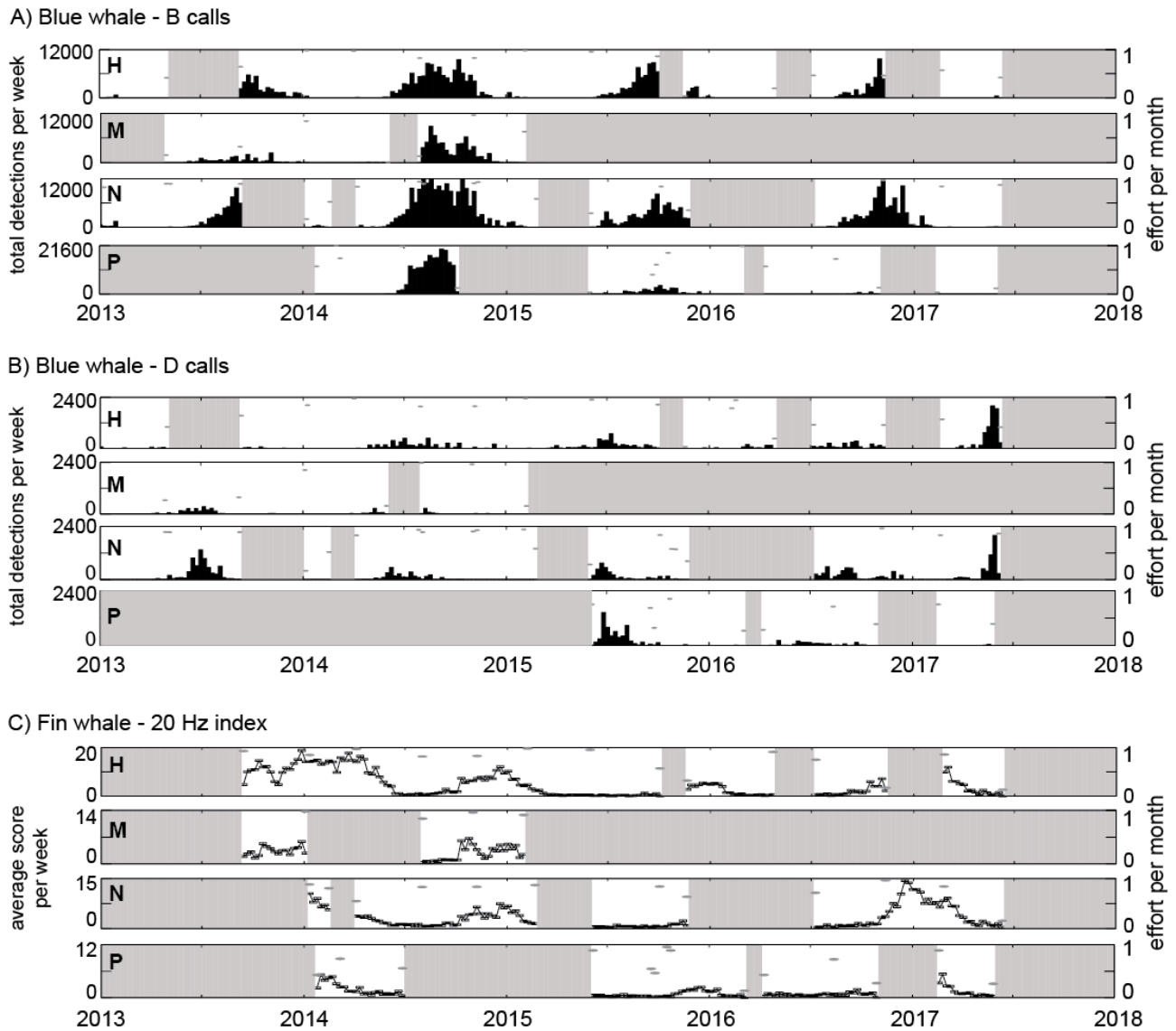


Figure 7. Weekly presence of A) NE Pacific blue whale B calls (note the different vertical axis scale for site P), B) NE Pacific blue whale D calls, and C) Fin whale 20 Hz acoustic index between January 2013 and June 2017 at sites H, M, N and P. Gray dots represent percent of effort per week in weeks with less than 100% recording effort, and gray shading represents periods with no effort. Where gray dots or shading are absent, full recording effort occurred for the entire week.

Beaked Whales

Cuvier’s beaked whales were detected throughout the recording period. The FM pulse type, BW43, possibly produced by Perrin’s beaked whales (Baumann-Pickering *et al.*, 2014) was detected only occasionally. No other beaked whale species were detected during this recording period. More details of each species’ presence at the four sites are given below.

Cuvier’s Beaked Whales

Cuvier’s beaked whale was the most commonly detected beaked whale in the SOCAL Range Complex.

- Cuvier’s beaked whale FM pulses were detected most commonly at site H and less commonly at sites M and N (Figure 8, Table 3). There were no detections at site P.
- Detections were highest during fall through spring with a summer dip in presence (Figure 8).
- There was no discernable diel pattern for Cuvier’s beaked whale detections (Figure 9).

BW43

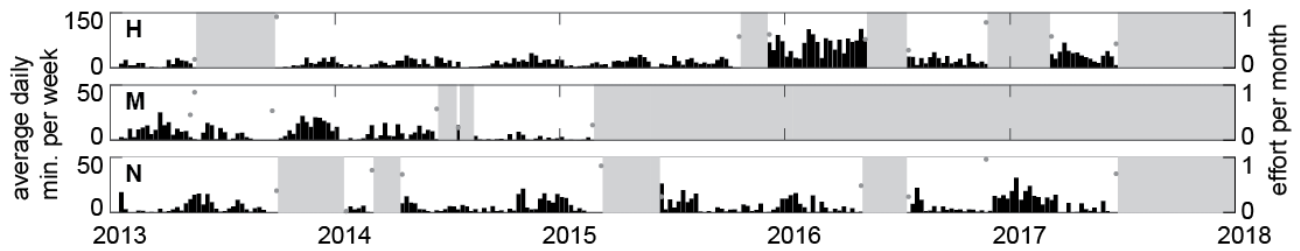
Overall, there were very few detections of BW43 FM pulses.

- BW43 FM pulses were most regularly detected at site N and to a lesser degree at site H. There were no detections at sites M and P (Figure 8, Table 3).
- BW43 FM pulses occurred during late fall through spring months, with a similar dip in presence during the summer as Cuvier’s beaked whales.
- There may be a weak diel pattern for BW43 detections, with more detections at night, but more acoustic encounters are needed to confirm if this is a persistent pattern (Figure 10).

Table 3: Summary of Cuvier’s beaked whale and BW43 FM pulse detections since 2013.

Site	Effort Days	Cuvier's beaked whale				BW43 - possible Perrin's beaked whale			
		Total detection times (min)	Days with detections	Days with detections (%)	Average daily detection times (min)	Total detection times (min)	Days with detections	Days with detections (%)	Average daily detection times (min)
H	1268	28,450	941	74	22.4	56	5	<1%	0.04
M	706	4,065	281	40	5.8	-	-	-	-
N	1281	7,512	506	39	5.9	185	32	2	0.14
P	715	-	-	-	-	-	-	-	-

A) Cuvier's beaked whale



B) BW43 signal type

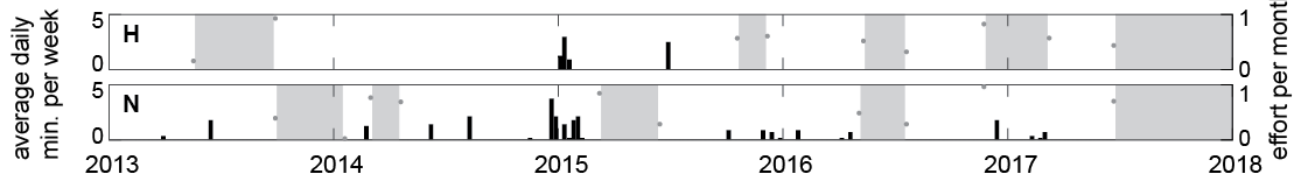


Figure 8. Weekly average daily detections in minutes of A) Cuvier's beaked whale and B) BW43 FM pulses between January 2013 and June 2017 at sites H, M, and N. There were no detections of either signal type at site P, and no detections of the BW43 signal type at site M. Gray dots represent percent of effort per week in weeks with less than 100% recording effort, and gray shading represents periods with no effort. Where gray dots or shading are absent, full recording effort occurred for the entire week.

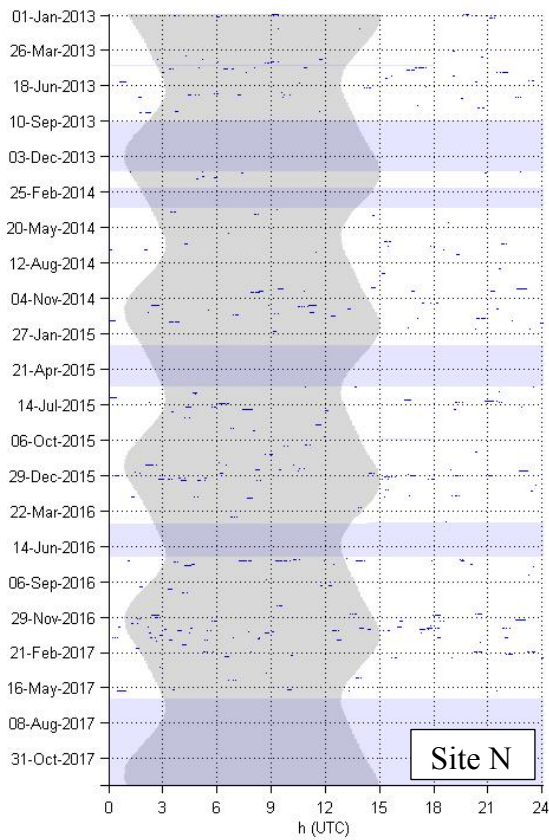
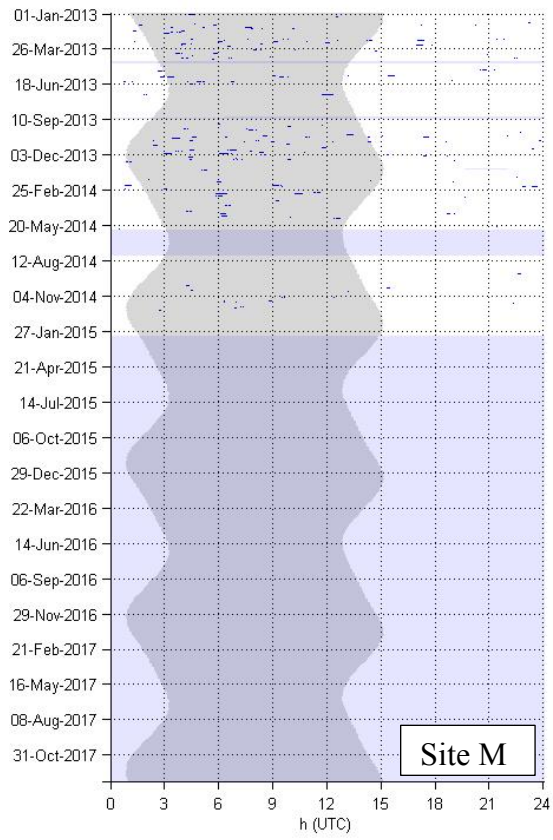
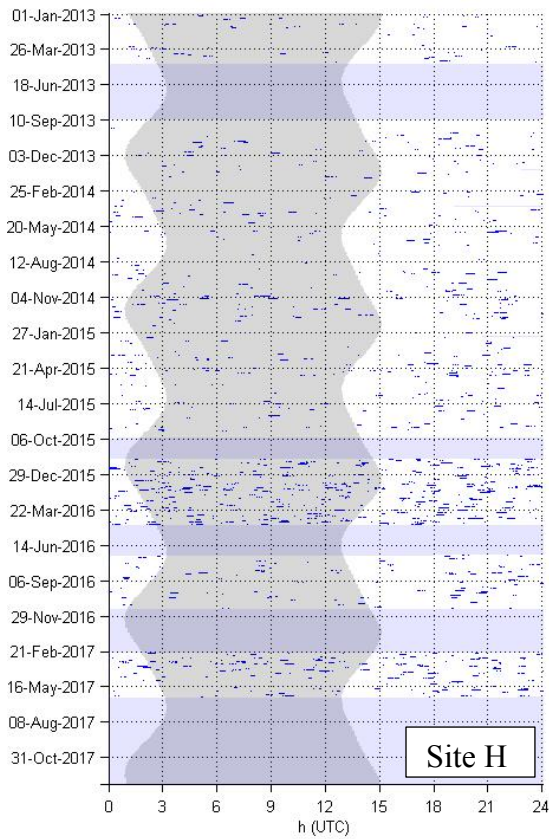


Figure 9. Cuvier’s beaked whale FM pulses, indicated by blue dots, in one-minute bins at sites H, M, and N. There were no detections at site P. Grey vertical shading represents nighttime and horizontal blue shading are periods without recording effort.

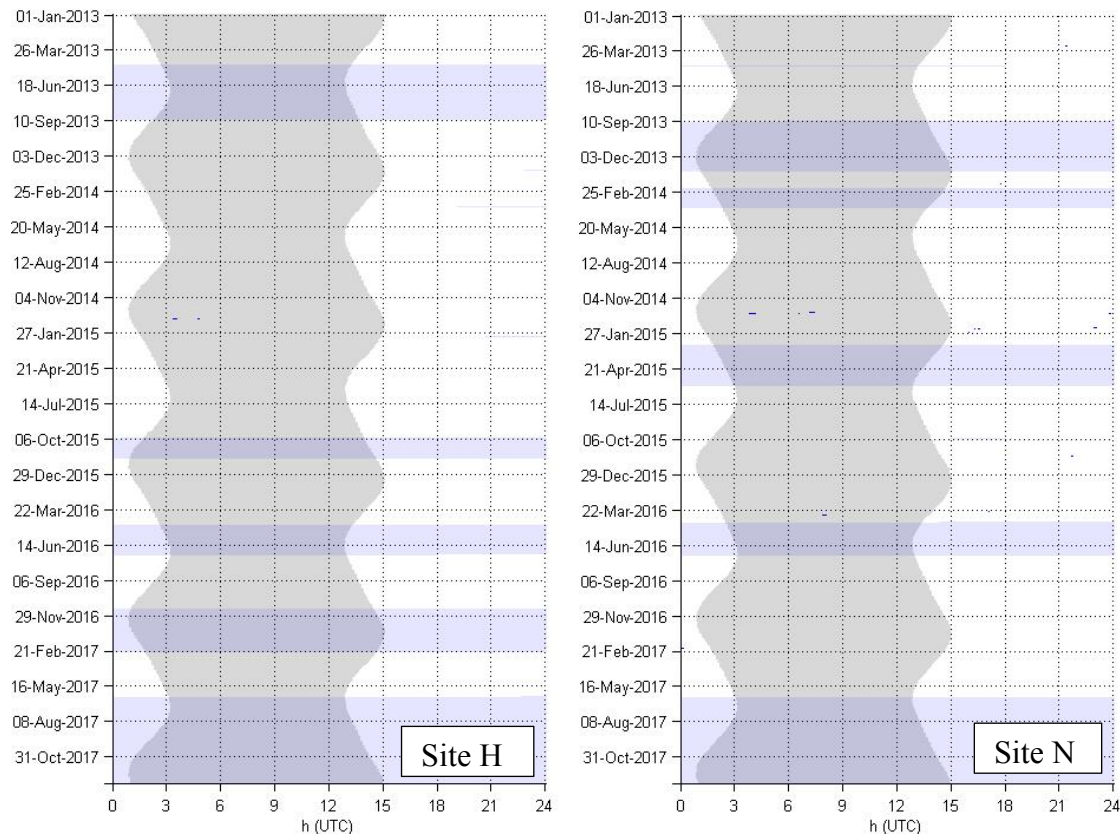


Figure 10. BW43 FM pulses, indicated by blue dots, in five-minute bins at sites H and N. There were no detections at sites M and P. Effort markings are described in Figure 9.

Conclusions

Blue whales, fin whales and Cuvier’s beaked whales were all commonly detected across the SOCAL Range Complex. The BW43 signal type, possibly originating from Perrin’s beaked whales, occurred infrequently. There was a clear seasonality in the occurrence of all detected calls, but a difference in their peak occurrence. Blue whales were generally present during the summer and fall. Fin whales were found in the area year-round, but their 20 Hz calls peaked during late fall and winter at all sites and were generally low during the summer months. Fin whale 40 Hz calls were not analyzed for this report but previous annual reporting from 2009-2014 (Hildebrand *et al.*, 2010a; 2010b; 2011; 2012; Kerosky *et al.*, 2013; Debich *et al.*, 2015b) has documented consistent fin whale 40 Hz call presence year-round, with peaks during May and June (in early reports they are referred to as 50 Hz calls). Combined call analysis shows fin whales appear across SOCAL year-round (Širović *et al.*, 2013). While both beaked whale signals were also detected year-round, highest acoustic activity occurred during fall through spring with a summer dip. Across the five years monitored here, there was some indication of lower baleen whale calling in 2015, which was the peak period of anomaly in the North Pacific Ocean known as “the blob,” but this was not true across all sites as high numbers of D calls were detected at site P. At the same time, highest detections of the BW43 signal type was noted at site N and to a lesser degree at site H. Blue whale calls had the highest density at site P, and fin whale 20 Hz

calls were most common at site H, where Cuvier's beaked whale signals were also detected most frequently.

References

- Baumann-Pickering, S., McDonald, M. A., Simonis, A. E., Solsona Berga, A., Merkens, K. P. B., Oleson, E. M., Roch, M. A., Wiggins, S. M., Rankin, S., Yack, T. M., and Hildebrand, J. A. (2013a). "Species-specific beaked whale echolocation signals," *Journal of the Acoustical Society of America* **134**, 2293-2301.
- Baumann-Pickering, S., Simonis, A. E., Roch, M. A., McDonald, M. A., Solsona Berga, A., Oleson, E. M., Wiggins, S. M., Brownell, J., Robert, L., and Hildebrand, J. A. (2014). "Spatio-temporal patterns of beaked whale echolocation signals in the North Pacific," *PLOS One*, e86072.
- Baumann-Pickering, S., Simonis, A. E., Wiggins, S. M., Brownell, R. L., and Hildebrand, J. A. (2013b). "Aleutian Islands beaked whale echolocation signals," *Mar. Mamm. Sci.* **29**, 221-227.
- Debich, A. J., Baumann-Pickering, A., Širović, A., Hildebrand, J. A., Herbert, S. T., Johnson, S. C., Rice, A. C., Trickey, J. S., and Wiggins, S. M. (2015a). "Passive Acoustic Monitoring for Marine Mammals in the SOCAL Range Complex January - July 2014," *Marine Physical Laboratory, Scripps Institution of Oceanography, (La Jolla, CA)*, p. 43.
- Debich, A. J., Baumann-Pickering, S., Širović, A., Hildebrand, J. A., Alldredge, A. L., Gottlieb, R. S., Herbert, S. T., Johnson, S. C., Rice, A. C., Roche, L. K., Theyre, B. J., Trickey, J. S., Varga, L. M., and Wiggins, S. M. (2015b). "Passive Acoustic Monitoring for Marine Mammals in the SOCAL Naval Training Area Dec 2012 - Jan 2014," *Marine Physical Laboratory, Scripps Institution of Oceanography, (La Jolla, CA)*, p. 96.
- Helble, T. A., Ierley, G. R., D'Spain, G. L., Roch, M. A., and Hildebrand, J. A. (2012). "A generalized power-law detection algorithm for humpback whale vocalizations," *Journal of the Acoustical Society of America* **131**, 2682-2699.
- Hildebrand, J. A. (2009). "Anthropogenic and natural sources of ambient noise in the ocean," *Marine Ecology Progress Series* **395**, 5-20.
- Hildebrand, J. A., Baumann-Pickering, S., Širović, A., Buccowich, J., Debich, A., Johnson, S., Kerosky, S., Roche, L., Berga, A. S., and Wiggins, S. M. (2012). "Passive Acoustic Monitoring for Marine Mammals in the SOCAL Naval Training Area 2011-2012," *Marine Physical Laboratory, Scripps Institution of Oceanography, (La Jolla, CA)*.
- Hildebrand, J. A., Baumann-Pickering, S., Širović, A., Bassett, H., Cummins, A., Kerosky, S., Roche, L., Simonis, A., Wiggins, S. M. (2011). "Passive Acoustic Monitoring for Marine Mammals in the SOCAL Naval Training Area 2010-2011," *Marine Physical Laboratory Technical Memo 531A, Scripps Institution of Oceanography, (La Jolla, CA)*.
- Hildebrand, J., Bassett, H., Baumann, S., Campbell, G., Cummins, A., Kerosky, S., Melcon, M., Merkens, K., Munger, L., Roch, M., Roche, L., Simonis, A., Wiggins, S. (2010a). "High Frequency Acoustic Recording Package Annual Data Summary Report March 11, 2009 – March 25, 2010 SOCAL Site M." *Marine Physical Laboratory, Scripps Institution of Oceanography, (La Jolla, CA)*.
- Hildebrand, J., Bassett, H., Baumann, S., Campbell, G., Cummins, A., Kerosky, S., Melcon, M., Merkens, K., Munger, L., Roch, M., Roche, L., Simonis, A., Wiggins, S. (2010b). "High Frequency Acoustic Recording Package Annual Data Summary Report March 14, 2009 – March 26, 2010 SOCAL Site N." *Marine Physical Laboratory, Scripps Institution of Oceanography, (La Jolla, CA)*.

- Jefferson, T. A., Webber, M. A., and Pitman, L. (2015). *Marine Mammals of the World: A Comprehensive Guide to their Identification* (2nd Ed). (Academic Press)."
- Jefferson, T. A., Webber, M. A., and Pitman, R. L. (2008). *Marine Mammals of the World: A Comprehensive Guide to their Identification* (Academic Press)."
- Johnson, M., Madsen, P. T., Zimmer, W. M. X., Aguilar de Soto, N., and Tyack, P. L. (2004). "Beaked whales echolocate on prey," *Proceedings of the Royal Society B: Biological Sciences* **271**, S383-S386.
- Kerosky, S. M., Baumann-Pickering, S., Širović, A., Buccowich, J. S., Debich, A. J., Gentes, Z., Gottlieb, R. S., Johnson, S. C., Roche, L. K., Thayre, B., Wakefield, L., Wiggins, S. M., and Hildebrand, J. A. (2013). "Passive Acoustic Monitoring for Marine Mammals in the SOCAL Range Complex during 2012," *Marine Physical Laboratory, Scripps Institution of Oceanography, (La Jolla, CA)*, p. 72.
- McDonald, M. A., Hildebrand, J. A., and Mesnick, S. (2009). "Worldwide decline in tonal frequencies of blue whale song," *Endangered Species Research* **9**, 13-21.
- McDonald, M. A., Hildebrand, J. A., and Webb, S. C. (1995). "Blue and fin whales observed on a seafloor array in the Northeast Pacific," *J. Acoust. Soc. Am.* **98**, 712-721.
- McDonald, M. A., Hildebrand, J. A., Wiggins, S. M., and Ross, D. (2008). "A 50 year comparison of ambient noises near San Clemente Island: A bathymetrically complex coastal region off Southern California," *Journal of the Acoustical Society of America* **124**, 1985-1992.
- McDonald, M. A., Mesnick, S. L., and Hildebrand, J. A. (2006). "Biogeographic characterisation of blue whale song worldwide: using song to identify populations," *Journal of Cetacean Research and Management* **8**, 55-65.
- Mellinger, D. K., and Clark, C. W. (1997). "Methods of automatic detection of mysticete sounds," *Marine and Freshwater Behaviour and Physiology* **29**, 163-181.
- Oleson, E. M., Calambokidis, J., Burgess, W. C., McDonald, M. A., LeDuc, C. A., and Hildebrand, J. A. (2007). "Behavioral context of call production by eastern North Pacific blue whales," *Mar. Ecol. Prog. Ser.* **330**, 269-284.
- Rice, A. C., Baumann-Pickering, S., Širović, A., Hildebrand, J. A., Debich, A. J., Meyer-Lobbecke, A., Thayre, B. J., Trickey, J. A., and Wiggins, S. M. (2017). "Passive Acoustic Monitoring for Marine Mammals in the SOCAL Range Complex June 2015 - April 2016," *Marine Physical Laboratory, Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA, MPL Technical Memorandum #610 under Cooperative Ecosystems Study Unit Cooperative Agreement N62473-16-2-0012 for U.S. Navy Pacific Fleet, Pearl Harbor, HI*, p. 36.
- Rice, A. C., Baumann-Pickering, S., Širović, A., Hildebrand, J. A., Rafter, M., Thayre, B. J., Trickey, J. S., and Wiggins, S. M. (2018). "Passive Acoustic Monitoring for Marine Mammals in the SOCAL Range Complex April 2016 - June 2017," *Marine Physical Laboratory, Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA, MPL Technical Memorandum #618 under Cooperative Ecosystems Study Unit Cooperative Agreement N62473-17-2-0014 for U.S. Navy Pacific Fleet, Pearl Harbor, HI*, p. 45.
- Roch, M. A., Brandes, T. S., Patel, B., Barkley, Y., Baumann-Pickering, S., and Soldevilla, M. S. (2011a). "Automated extraction of odontocete whistle contours," *Journal of the Acoustical Society of America* **130**, 2212-2223.

- Roch, M. A., Klinch, H., Baumann-Pickering, S., Mellinger, D. K., Qui, S., Soldevilla, M. S., and Hildebrand, J. A. (2011b). "Classification of echolocation clicks from odontocetes in the Southern California Bight," *Journal of the Acoustical Society of America* **129**, 467-475.
- Širović, A. (2016). "Variability in the performance of the spectrogram correlation detector for North-east Pacific blue whale calls," *Bioacoustics* **25**, 145-160.
- Širović, A., Baumann-Pickering, S., Hildebrand, J. A., Debich, A. J., Herbert, S. T., Meyer-Lobbecke, A., Rice, A., Thayre, B., Trickey, J. S., Wiggins, S. M., and Roch, M. A. (2016). "Passive acoustic monitoring for marine mammals in the SOCAL Range Complex July 2014 - May 2015," *Marine Physical Laboratory, Scripps Institution of Oceanography, (La Jolla, CA)*, p. 39.
- Širović, A., Rice, A., Chou, E., Hildebrand, J. A., Wiggins, S. M., and Roch, M. A. (2015). "Seven years of blue and fin whale call abundance in the Southern California Bight," *Endangered Species Research* **28**, 61-76.
- Širović, A., Williams, L. N., Kerosky, S. M., Wiggins, S. M., Hildebrand, J. A. (2013). "Temporal separation of two fin whale call types across the eastern North Pacific," *Marine Biology*, **160**, 47-57.
- Soldevilla, M. S., Henderson, E. E., Campbell, G. S., Wiggins, S. M., Hildebrand, J. A., and Roch, M. (2008). "Classification of Risso's and Pacific white-sided dolphins using spectral properties of echolocation clicks," *Journal of the Acoustical Society of America* **124**, 609-624.
- Thompson, P. O., Findley, L. T., and Vidal, O. (1992). "20-Hz pulses and other vocalizations of fin whales, *Balaenoptera physalus*, in the Gulf of California, Mexico," *Journal of the Acoustical Society of America* **92**, 3051-3057.
- Watkins, W. A. (1981). "Activities and underwater sounds of fin whales," *Scientific Reports of the Whale Research Institute* **33**, 83-117.
- Wiggins, S. M. (2015). "Methods for quantifying mid-frequency active sonar in the SOCAL Range Complex," *Marine Physical Laboratory Technical Memorandum 553, Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA.*
- Wiggins, S. M., and Hildebrand, J. A. (2007). "High-frequency acoustic recording package (HARP) for broadband, long-term marine mammal monitoring," in *International Symposium on Underwater Technology 2007 and International Workshop on Scientific Use of Submarine Cables and Related Technologies 2007* (Institute of Electrical and Electronics Engineers, Tokyo, Japan), pp. 551-557.
- Zimmer, W. M. X., Johnson, M. P., Madsen, P. T., and Tyack, P. L. (2005). "Echolocation clicks of free-ranging Cuvier's beaked whales (*Ziphius cavirostris*)," *Journal of the Acoustical Society of America* **117**, 3919-3927.