Conducted in support of the U.S. Navy's Hawaii-Southern California Training and Testing 2014 Annual Monitoring Report

Passive Acoustic Monitoring for Marine Mammals in the SOCAL Naval Training Area Dec 2012 – Jan 2014

Amanda J. Debich, Simone Baumann-Pickering, Ana Širović, John A. Hildebrand,
Alexa L. Alldredge, Rachel S. Gottlieb, Sean T. Herbert, Sarah C. Johnson, Ally C. Rice,
Lauren K. Roche, Bruce J. Thayre, Jenny S. Trickey, Leah M. Varga, Sean M. Wiggins

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

Pacific White-sided Dolphin, photo by Amanda J. Debich

MPL TECHNICAL MEMORANDUM # 552
January 2015

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
01-2015

2. REPORT TYPE
Monitoring report

3. DATES COVERED *(From - To)*
Dec 2012 - Jan 2014

4. TITLE AND SUBTITLE
Passive Acoustic Monitoring for Marine Mammals in the SOCAL Naval Training Area Dec 2012 – Jan 2014

5a. CONTRACT NUMBER

5b. GRANT NUMBER
W9126G-14-2-0040

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Amanda J. Debich, Simone Baumann-Pickering, Ana Širović, John A. Hildebrand, Alexa L. Alldredge, Rachel S. Gottlieb, Sean T. Herbert, Sarah C. Johnson, Ally C. Rice, Lauren K. Roche, Bruce J. Thayre Jenny S. Trickey, Leah M. Varga, Sean M. Wiggins

5d. PROJECT NUMBER
MPL TECHNICAL MEMORANDUM # 552

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Whale Acoustics Laboratory, Marine Physical Laboratory, Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA 92037

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Commander, U.S.Pacific Fleet, 250 Makalapa Dr., Pearl Harbor, HI 96860-3131

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSORING/MONITORING AGENCY REPORT NUMBER

12. DISTRIBUTION AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Passive acoustic monitoring was conducted in the Navy's Southern California Range Complex from December 2012 to January 2014 to detect marine mammal and anthropogenic sounds. High-frequency Acoustic Recording Packages (HARPs) recorded sounds between 10 Hz and 100 kHz at three locations: near Santa Barbara Island (880 m), west of San Clemente Island (1000 m), and southwest of San Clemente Island (1300 m). Six baleen whale species were recorded: blue whales, Bryde's whales, fin whales, gray whales, humpback whales, and minke whales. Signals from seven odontocete species were detected: Risso's dolphins, Pacific white-sided dolphins, killer whales, sperm whales, Baird's beaked whales, Cuvier's beaked whales, and an unknown beaked whale species identified as BW43. Neither Blainville's beaked whales nor Stejneger's beaked whales were detected. The following anthropogenic sounds were detected: broadband ship noise, echosounders, explosions, underwater communications, Low Frequency Active (LFA) sonar, Mid-Frequency Active (MFA) sonar, and a previously undescribed sound near 180 Hz.

15. SUBJECT TERMS
Monitoring, marine mammal, passive acoustic, Southern California Range Complex, Hawaii-Southern California Training and Testing

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES
Unclassified	Unclassified	Unclassified	UU	96

19a. NAME OF RESPONSIBLE PERSON
Department of the Navy

19b. TELEPONE NUMBER (*Include area code*)
(619) 767-1567

Table of Contents

Executive Summary

Passive acoustic monitoring was conducted in the Navy's Southern California Range Complex from December 2012 to January 2014 to detect marine mammal and anthropogenic sounds. High-frequency Acoustic Recording Packages (HARPs) recorded sounds between 10 Hz and 100 kHz at three locations: near Santa Barbara Island (880 m depth, site M), west of San Clemente Island (1000 m depth, site H), and southwest of San Clemente Island (1300 m depth, site N).

Data analysis consisted of analyst scans of long-term spectral averages (LTSAs) and spectrograms, and automated computer algorithm detection when possible. Three frequency bands were analyzed for marine mammal vocalizations and anthropogenic sounds.

Six baleen whale species were recorded: blue whales, Bryde's whales, fin whales, gray whales, humpback whales, and minke whales. Across all sites, fin whales and humpback whales were the most commonly detected baleen whales. Blue whale B calls and Bryde's whale calls peaked in fall months, while blue whale D calls peaked in summer months. Fin whale 20 Hz calls peaked in winter and spring months while fin whale 40 Hz calls peaked later in summer. Humpback whale calling peaked in late-December through January. Gray whale M3 calls were detected in small numbers at each site, primarily in the winter and spring. Minke boings were detected at all sites in small numbers except for site M.

Signals from seven odontocete species were detected: Risso's dolphins, Pacific white-sided dolphins, killer whales, sperm whales, Baird's beaked whales, Cuvier's beaked whales, and an unknown beaked whale species identified as BW43. Neither Blainville's beaked whales nor Stejneger's beaked whales were detected. Risso's dolphin echolocation clicks peaked in February at sites H and N while detections peaked in summer months at site M. Pacific white-sided dolphins were detected in low numbers at sites M and N. Killer whale clicks peaked in late-October 2013 at site H and were detected in low numbers at site M and N. Sperm whales were detected in low numbers at sites H and M while detections peaked at site N in June 2013. Cuvier's beaked whale frequency modulated pulses were common at every site and were the most commonly detected beaked whale. Baird's beaked whales were detected in low numbers during summer months at sites M and N. Site N was the only site at which BW43 pulses were detected, albeit in low numbers.

The following anthropogenic sounds were detected: broadband ship noise, echosounders, explosions, underwater communications, Low Frequency Active (LFA) sonar, Mid-Frequency Active (MFA) sonar, and a previously undescribed sound near 180 Hz. Broadband ships were common at all sites, with fewer detections at site H. Echosounders were detected in low numbers at sites H and M, and at higher numbers with a peak in detections at site N in February 2013. Explosions were detected at all sites, but were most prevalent at site M and their characteristics suggest association with fishing. Underwater communication signals were detected in low numbers at sites H and N. LFA sonar with frequency between 500 Hz and 1000 Hz was detected at all sites. MFA sonar was also detected at all sites. Site M had the fewest MFA sonar pings and lowest received levels, site N had the highest received levels, and site H had the greatest number of MFA pings recorded. A previously un-described anthropogenic signal at 180 Hz was detected at site N, with peaks in detections occurring in January 2013.

Project Background

The Navy's Southern California Offshore Range (SCORE) is located in the Southern California Bight and adjacent deep waters to the west (Figure 1). This region has a highly productive marine ecosystem owing 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 cetaceans and pinnipeds.

In January 2009, an acoustic monitoring effort was initiated near SCORE with support from the Pacific Fleet under contract to the Naval Postgraduate School. The goal of this effort was to characterize the vocalizations of marine mammal species present in the area, to determine their seasonal presence patterns, and to evaluate the potential for impact from naval operations. This report documents the analysis of data recorded by three High-frequency Acoustic Recording Packages (HARPs) that were deployed within SCORE in December 2012 and collected data through January 2014. The three recording sites include one to the northwest (site M), one to the west (site H), and one to the southwest (site N) of San Clemente Island (Figure 1). Initial acoustic monitoring efforts for the SCORE area focused primarily on sites M and N, and later on site H. In this report site H was analyzed for the December 2012 – April 2013 and November 2013 through January 2014 time periods; site M was analyzed for the April 2013 – January 2014 time period; and site N was analyzed for the December 2012 – September 2013 time period (Table 1).

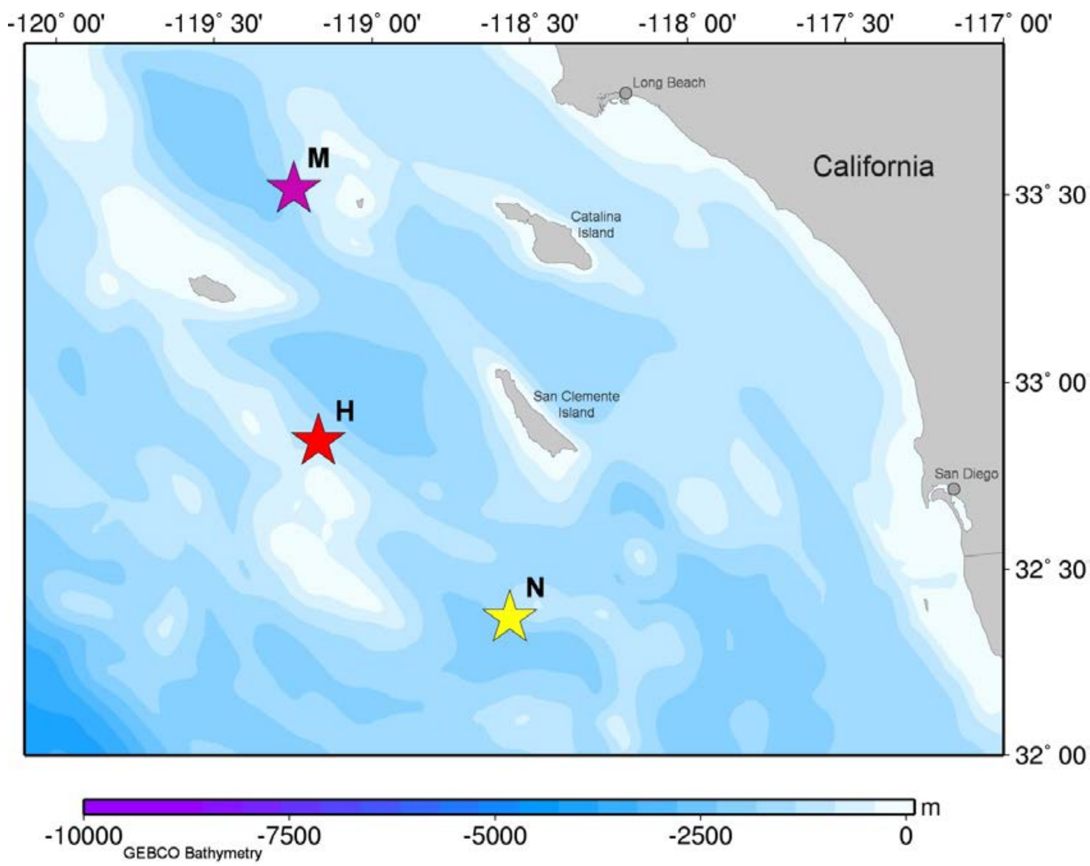

Figure 1. Locations of High-frequency Acoustic Recording Packages (HARPs) at sites H, M, and N deployed in the SOCAL study area December 2012 through January 2014. Color is bathymetric depth.

Table 1. SCORE acoustic monitoring since January 2009. Periods of instrument deployment analyzed in this report are shown in bold.

Deployment Name	Site H Monitoring Period	# Hours	Site M Monitoring Period	# Hours	Site N Monitoring Period	# Hours
SOCAL 31	1/13/09 – 3/08/09	1320	1/13/09 – 3/08/09	1320	1/14/09 – 3/09/09	1296
SOCAL 32	3/14/09 – 5/07/09	1320	3/11/09 – 5/04/09	1296	3/14/09 – 5/07/09	1320
SOCAL 33	5/19/09 – 6/13/09	600	5/17/09 – 7/08/09	1248	5/19/09 – 7/12/09	1296
SOCAL 34	7/23/09 – 9/15/09	1296	7/27/09 – 9/16/09	1224	7/22/09 – 9/15/09	1320
SOCAL 35	9/25/09 – 11/18/09	1320	9/25/09 – 11/17/09	1272	9/26/09 – 11/19/09	1296
SOCAL 36	12/6/09 – 1/29/10	1296	12/5/09 – 1/24/10	1200	12/6/09 – 1/26/10	1224
SOCAL 37	1/30/10 – 3/22/10	1248	1/30/10 – 3/25/10	1296	1/31/10 – 3/26/10	1296
SOCAL 38	4/10/10 – 7/22/10	2472	4/10/10 – 7/12/10	2232	4/11/10 – 7/18/10	2352
SOCAL 40	7/23/10 – 11/8/10	2592	7/22/10 – 11/7/10	2592	7/23/10 – 11/8/10	2592
SOCAL 41	12/6/10 – 4/17/11	3192	12/5/10 – 4/24/11	3360	12/7/10 – 4/09/11	2952
SOCAL 44	5/11/11 – 10/12/11	2952	5/11/11 – 10/2/11	2712	5/12/10 – 9/23/11	3216
SOCAL 45	10/16/11 – 3/5/12	3024	10/27/11 – 3/18/12	3432	10/16/11 – 2/13/12	2904
SOCAL 46	3/25/12 – 7/21/12	2856	3/24/12 – 7/22/12	2904	3/25/12 – 8/5/12	3216
SOCAL 47	8/10/12 – 12/20/12	3192	8/10/12 – 12/19/12	3168	8/10/12 – 12/6/12	2856
SOCAL 48	**12/21/2012 – 4/30/2013**	**3140**	**-**	**-**	**12/20/2012 – 5/1/2013**	**3155**
SOCAL 49	**-**	**-**	**4/30/2013 – 9/5/2013**	**3057**	**5/2/2013 – 9/11/2013**	**3156**
SOCAL 50	**9/10/2013 – 1/6/2014**	**2843**	**9/9/2013 – 1/6/2014**	**2852**	**-**	**-**

Methods

High-frequency Acoustic Recording Package (HARP)

HARPs were used to detect marine mammal sounds and characterize anthropogenic sounds and ambient noise in the SOCAL Naval Training area. HARPs can record underwater sounds from 10 Hz up to 160 kHz and are capable of approximately 300 days of continuous data storage. The HARPs were in a seafloor configuration with the hydrophones suspended 10 m above the seafloor. Each HARP is calibrated in the laboratory to provide a quantitative analysis of the received sound field. Representative data loggers and hydrophones were also calibrated at the Navy's TRANSDEC facility to verify the laboratory calibrations (Wiggins & Hildebrand 2007).

Data Collected

Acoustic data have been collected at three sites within SCORE using autonomous HARPs sampling at 200 kHz since January 2009 (Table 1). The sites are designated site M (33° 30.92N, 119° 14.96W, depth 920 m), site H (32° 56.54, 119° 10.217 W, depth 1000 m) and site N (32° 22.18N, 118° 33.77W, depth 1250 m). Each HARP sampled continuously at 200 kHz, except for the December 2012 – April 2013 recording period at site H, which was sampled at 320 kHz. A total of 18,203 hours, covering 759 days of acoustic data were recorded in the deployments analyzed in this report. Earlier data collection in the SOCAL region is documented in annual reports (Hildebrand *et al.* 2009a, Hildebrand *et al.* 2009b, Hildebrand *et al.* 2010a, Hildebrand *et al.* 2010b, Hildebrand *et al.* 2011, Hildebrand *et al.* 2012, Kerosky *et al.* 2014).

Data Analysis

To visualize the acoustic data, frequency spectra were calculated for all data using a time average of 5 seconds and variable size frequency bins (1, 10, and 100 Hz). These data, called Long-Term Spectral Averages (LTSAs) were then examined as a means to detect marine mammal and anthropogenic sounds. Data were analyzed by visually scanning LTSAs in source-specific frequency bands and, when appropriate, using automatic detection algorithms (described below). During visual analysis, when a sound of interest was identified in the LTSA but its origin was unclear, the waveform or spectrogram was examined to further classify the sounds to species or source. Signal classification was carried out by comparison to known species-specific spectral and temporal characteristics.

Recording over a broad frequency range of 10 Hz – 100 kHz allows detection of baleen whales (mysticetes), toothed whales (odontocetes), and anthropogenic sounds. The presence of acoustic signals from multiple marine mammal species and anthropogenic noise was evaluated in the data. To document the data analysis process, we describe the major classes of marine mammal calls and anthropogenic sound in the SOCAL region, and the procedures used to detect them. For effective analysis, the data were divided into three frequency bands: (1) Low-frequency, between 10-300 Hz, (2) Mid-frequency, between 10-5,000 Hz, and (3) High-frequency, between 1-100 kHz.

Each band was analyzed for the sounds of an appropriate subset of species or sources. Blue, fin, Bryde's, and gray whale sounds were classified as low-frequency. Humpback, minke, killer whale tonal and pulsed calls, nearby shipping, explosions, underwater communications, and mid-frequency active sonar sounds were classified as mid-frequency. The remaining odontocete and sonar sounds were considered high-frequency. Analysis of low-frequency recordings required decimation by a factor of 100. For the analysis of the mid-frequency recordings, data were decimated by a factor of 20. The LTSAs were created using a 5s time average with 1 Hz resolution for low-frequency analysis, 10 Hz resolution for mid-frequency analysis, and 100 Hz frequency resolution for high-frequency analysis.

We summarize acoustic data collected between December 2012 and January 2014 at sites M, H, and N. We discuss seasonal occurrence and relative abundance of calls for different species and anthropogenic sounds that were consistently identified in the acoustic data.

Low-Frequency Marine Mammals

The Southern California Bight is inhabited, at least for a portion of the year, by blue whales (*Balaenoptera musculus*), fin whales (*B. physalus)*, Bryde's whales (*B. edeni*), and gray whales (*Eubalaena japonica*). For the low-frequency data analysis, the 200 kHz sampled raw data were decimated by a factor of 100 for an effective bandwidth of 1 kHz. Long-term spectral averages (LTSAs) were created using a time average of 5 seconds and frequency bins of 1 Hz. The same LTSA and spectrogram parameters were used for manual detection of all call types using the custom software program *Triton*. During manual scrutiny of the data, the LTSA frequency was set to display between 1-300 Hz with a 1 hour plot length. To observe individual calls, the spectrogram window was typically set to display 1-250 Hz with a 60 second plot length. The FFT was generally set between 1500 and 2000 data points, yielding about 1 Hz frequency resolution, with an 85-95% overlap. When a call of interest was identified in the LTSA or spectrogram, its presence during that hour was logged.

The hourly presence of Northeast Pacific blue D calls, fin whale 40 Hz, Bryde's whale Be4 calls, calls, and gray whale M3 calls was determined by manual scrutiny of low-frequency LTSAs and spectrograms. Individual blue whale B calls were detected automatically using computer algorithms described below. Fin whale 20 Hz calls were detected automatically using an energy detection method and are reported as fin whale acoustic index, also described below.

Blue Whales

Blue whales produce a variety of calls worldwide (McDonald *et al.* 2006). Blue whale calls recorded in the eastern North Pacific include the Northeast Pacific blue whale B call (Figure 2), which is a geographically distinct call possibly associated with mating functions (McDonald et al. 2006, Oleson *et al.* 2007). B calls are low-frequency (fundamental frequency <20 Hz), have long duration (>10 s), and often are regularly repeated. Also detected were blue whale D calls, which are downswept in frequency (approximately 100-40 Hz) with duration of several seconds (Figure 3). 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 were detected automatically for all other deployments using the spectrogram correlation method (Mellinger & Clark 1997). The 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. Separate kernels were used for the periods December 2012 through April 2013, May through September 2013, and September 2013 through January 2014. The kernel for data recorded December 2012 through April 2013 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 43.9 Hz. The kernel for data recorded May through September 2013 was defined as sweeping from 47.1 to 46.3 Hz, 46.3 to 45.5 Hz, 45.5 to 44.6 Hz, and 44.6 to 43.9 Hz. The kernel for data recorded September 2013 through January 2014 was defined as sweeping from 46.4 to 45.7 Hz, 45.7 to 45.0 Hz, 45.0 to 44.6 Hz, and 44.6 to 43.7 Hz. The bandwidth for all kernels was 2 Hz.

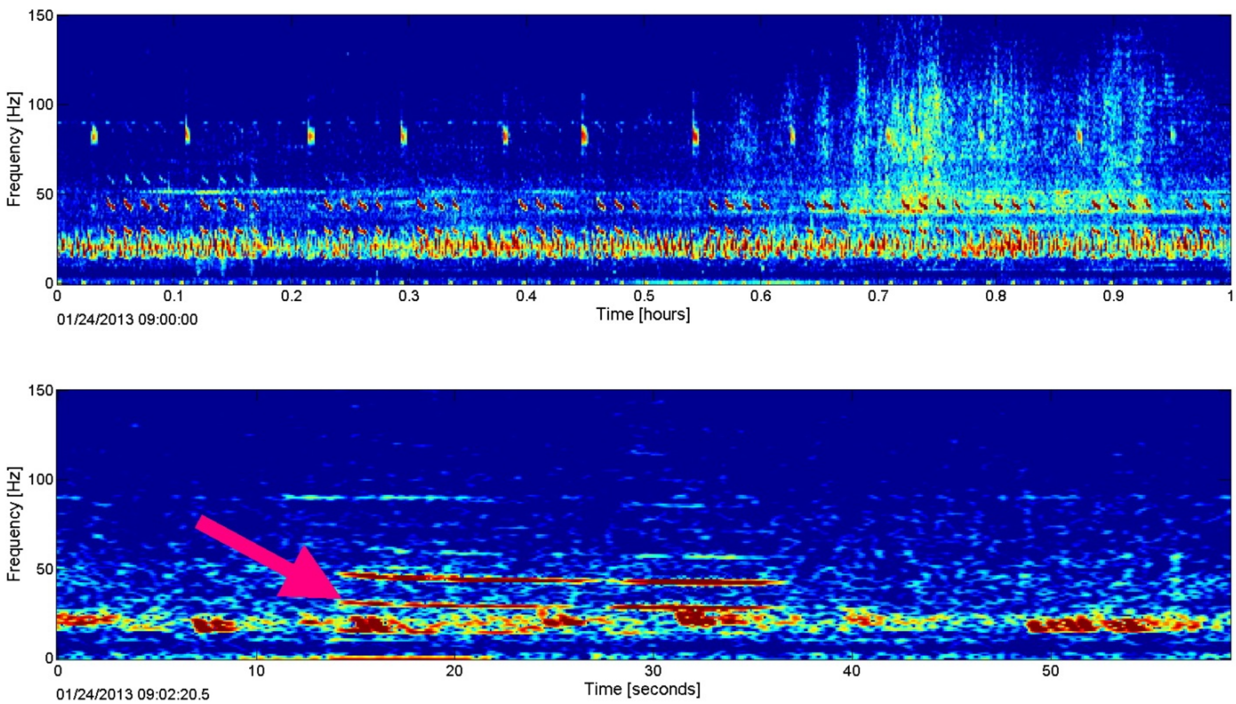

Figure 2. Blue whale B call in LTSA (top) and spectrogram (bottom) at site N.

Blue whale D calls

Blue whale D calls (Figure 3) were detected via manual scanning of the LTSA and subsequent verification from a spectrogram of the frequency and temporal characteristics of the calls at each site.

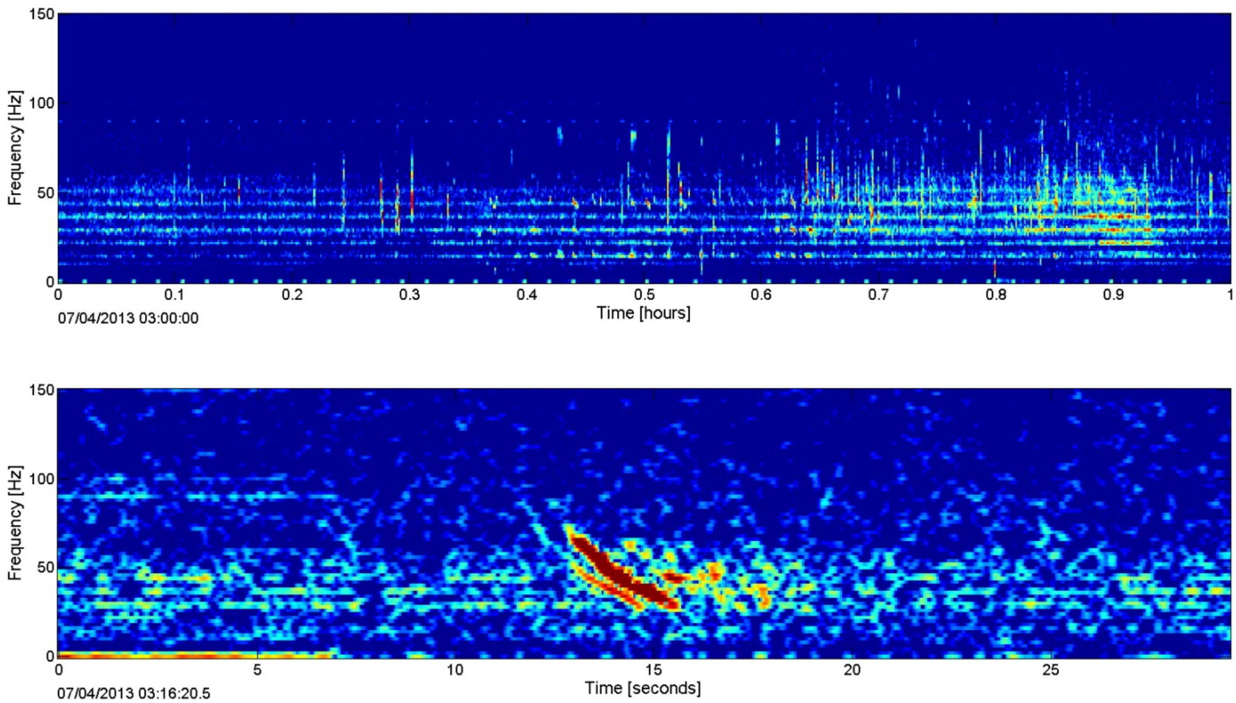

Figure 3. Blue whale D call in LTSA (top) and spectrogram (bottom) at site N.

Fin Whales

Fin whales produce two types of short (approximately 1 s duration), low-frequency calls: downsweeps in frequency from 30-15 Hz, called 20 Hz calls (Watkins 1981) (Figure 4), and downsweeps from 75-40 Hz, called 40 Hz calls (Figure 5). The 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). The 40 Hz calls most often occur in irregular patterns.

Fin whale 20 Hz calls

Fin whale 20 Hz calls (Figure 4) were detected automatically using an energy detection method. The method used a difference in acoustic energy between signal and noise, calculated from 5 s LTSA with 1 Hz 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. All calculations were performed on a logarithmic scale.

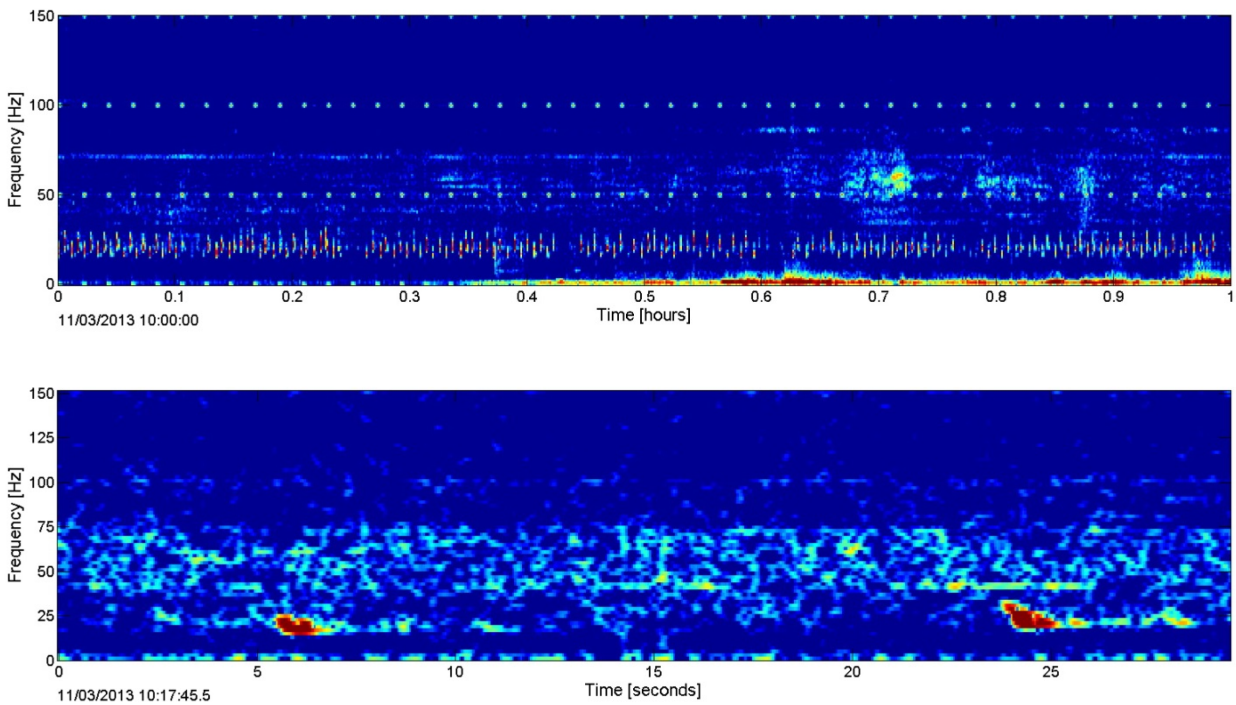

Figure 4. Fin whale 20 Hz calls in LTSA (top) and spectrogram (bottom) at site M.

Fin whale 40 Hz calls

Fin whale 40 Hz calls (Figure 5) were detected via manual scanning of the LTSA and subsequent verification from a spectrogram of the frequency and temporal characteristics of the calls.

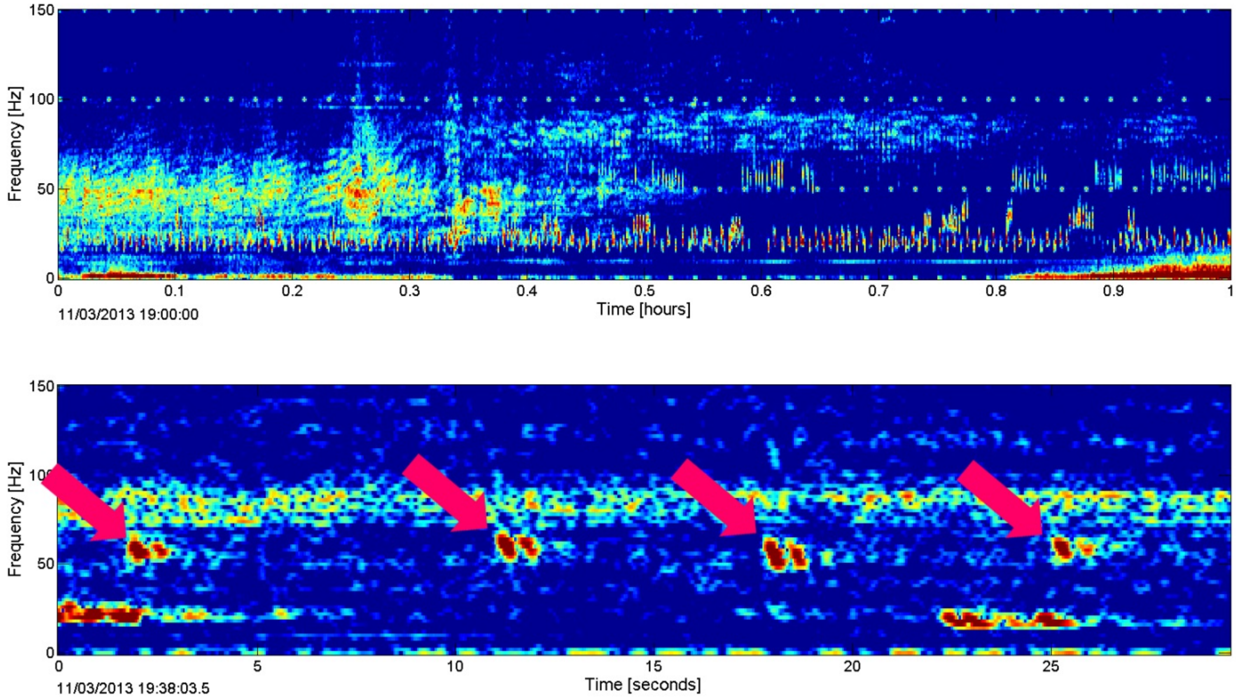

Figure 5. Fin whale 40 Hz calls in LTSA (top) and spectrogram (bottom) at site M.

Bryde's Whales

Bryde's whales generally inhabit warm waters with a tropical and subtropical distribution worldwide (Omura 1959, Leatherwood *et al.* 1988). Acoustic detections and visual sightings over the last decade suggest they have become seasonal inhabitants of the SOCAL region (Kerosky *et al.* 2012, Smultea *et al.* 2012). The Be4 call is one of several call types (Oleson *et al.* 2003) in the Bryde's whale repertoire, and the most common Bryde's whale call observed in the SOCAL region. The Be4 call consists of a short, mostly flat tone around 60 Hz. The call occasionally has harmonics and overtones present, along with an undertone that follows the primary tone (Figure 6). The Be4 call is occasionally observed at regular intervals so that it becomes evident that multiple callers are present.

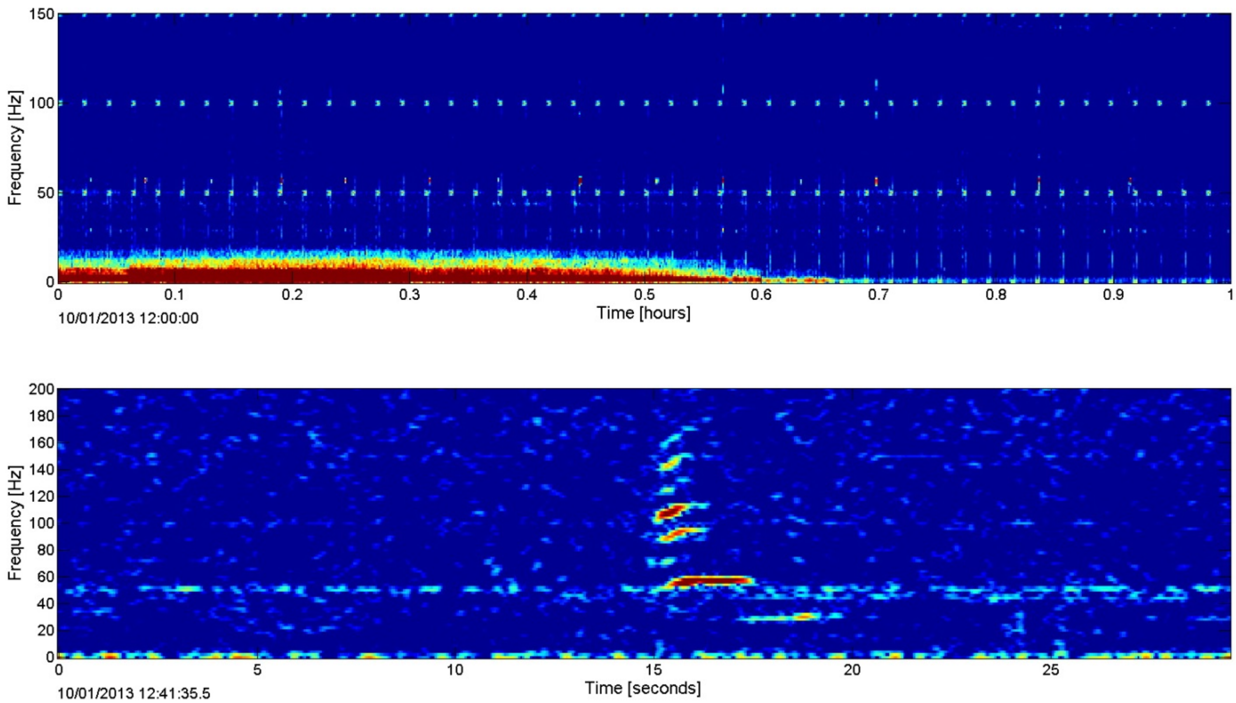

Figure 6. Bryde's whale Be4 call in LTSA (top) and spectrogram (bottom) at site M.

Gray Whales

Gray whales produce a variety of calls, which often have lower source levels than most other baleen whale calls and thus propagate over shorter distances. The only gray whale call type for which there was detection effort during our study was the M3 call, which is a low-frequency, short moan with most energy around 50 Hz (Figure 7), and the most common call produced by migrating gray whales (Crane & Lashkari 1996).

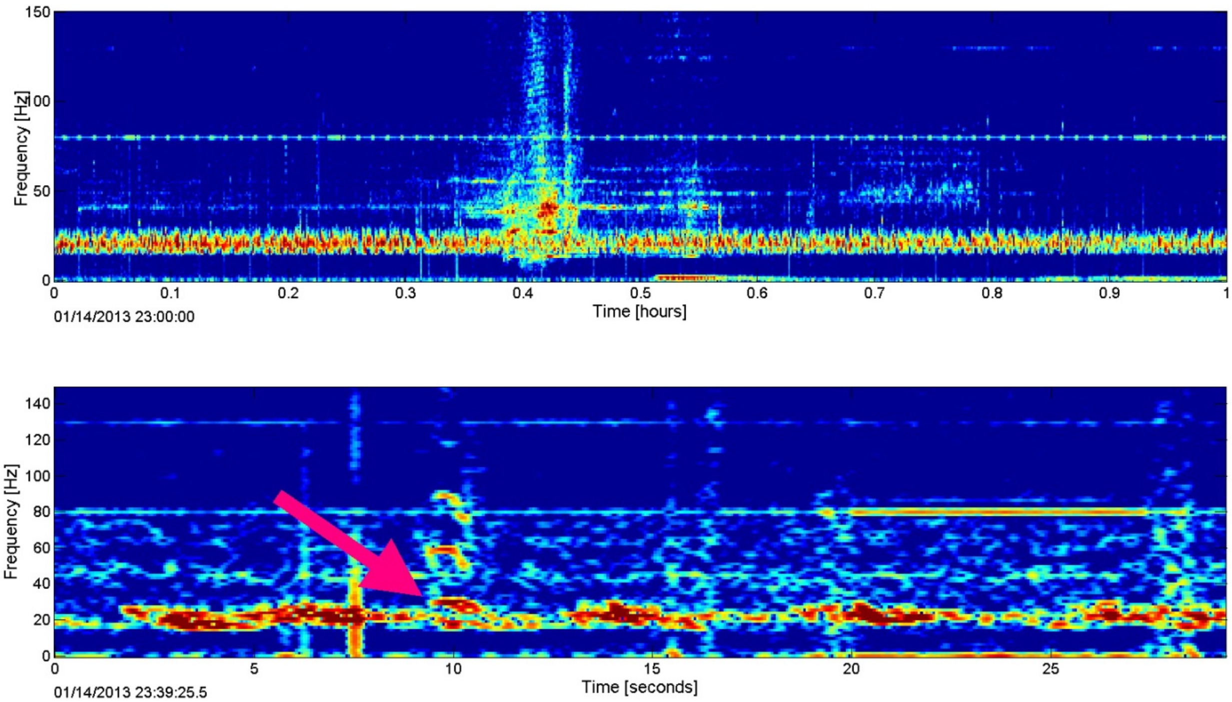

Figure 7. Gray whale M3 call in LTSA (top) and spectrogram (bottom) at site H.

Mid-Frequency Marine Mammals

Marine mammal species with sounds in the mid-frequency range expected in the Southern California Bight include humpback whales (*Megaptera novaeangliae*), minke whales (*Balaenoptera acutorostrata*), and killer whales (*Orcinus orca*). For mid-frequency data analysis, the 100 kHz data were decimated by a factor of 20 for an effective bandwidth of 5 kHz. The LTSAs for mid-frequency analysis were created using a time average of 5 seconds, and a frequency bin size of 10 Hz. The presence of each call type was determined using an “encounter” granularity, to one-minute precision, for each mid-frequency dataset. Humpback whales and minke whales were detected automatically as described in the sections below. The detections were subsequently verified for accuracy by a trained analyst. Whistles resembling those of killer whales were logged as unidentified odontocete whistles <5 kHz due to overlapping distributions with other large delphinids in the area.

Humpback Whales

Humpback whales produce both song and non-song calls (Payne & McVay 1971, Dunlop et al. 2007, Stimpert et al., 2011). The song is categorized by the repetition of units, phrases, and themes of a variety of calls as defined by Payne & McVay (1971). Most humpback whale vocalizations are produced between 100 - 3,000 Hz. We detected humpback calls using an automatic detection algorithm based on the generalized power law (Helble *et al.* 2012). The detections were subsequently verified for accuracy by a trained analyst (Figure 8). There was no effort to separate song and non-song calls.

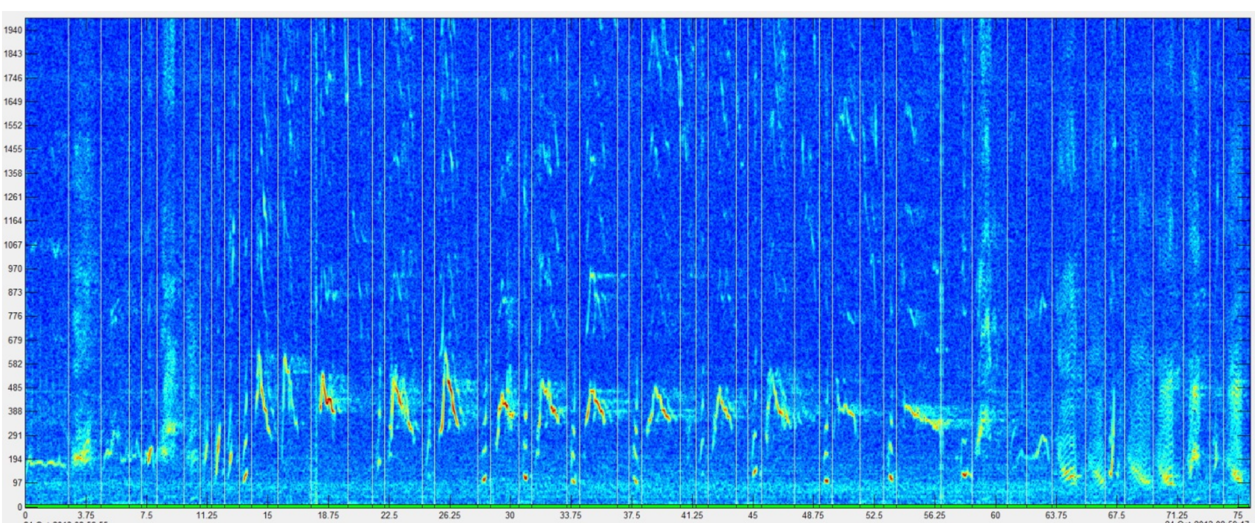

Figure 8. Humpback whale song from site M in the analyst verification stage of the detector. Green in the bottom evaluation line indicates true detections.

Minke Whales

Minke whale "boings" consist of 2 parts, beginning with a burst followed by a long buzz, with the dominant energy band just below 1,400 Hz (Figure 9). Boings are divided geographically into an eastern and a central Pacific variant, with a dividing line at about 135°W. Eastern boings have an average duration of 3.6 s and a pulse repetition rate of 92 s^{-1}(Rankin & Barlow 2005). For this report we detected minke boings using an automatic detection algorithm based on the generalized power law (Helble *et al*., 2012).

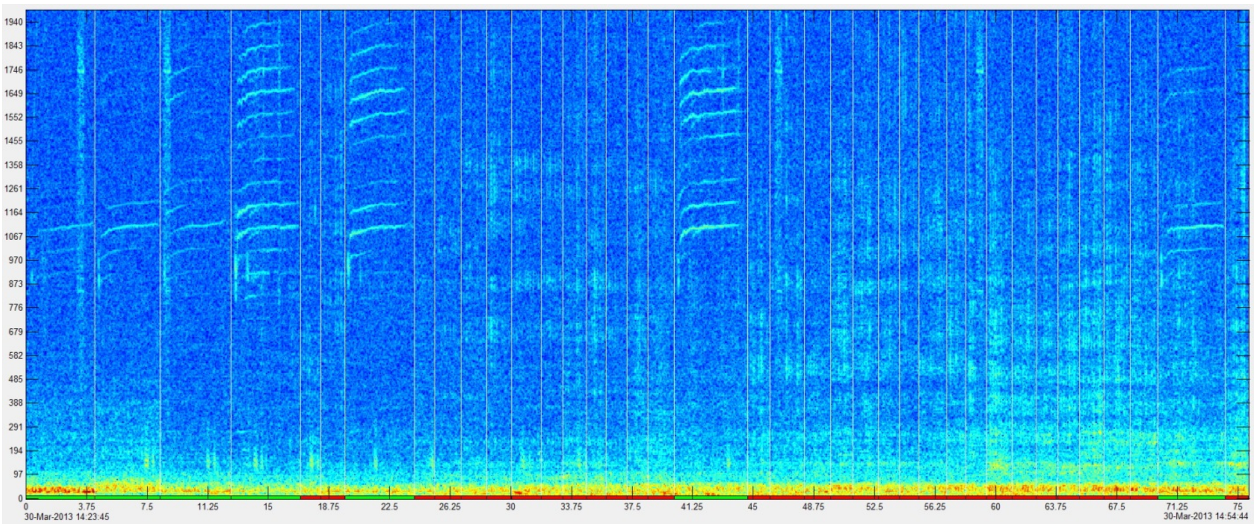

Figure 9. Minke whale boings from site N in the analyst verification stage of the detector. Green in the bottom evaluation line indicates true and red indicates false detections.

Killer Whales

Killer whale whistles are highly variable and not easily distinguished from other odontocete whistles (e.g. pilot whales and false killer whales). Therefore, whistles detected below 5 kHz were labeled as unidentified odontocete whistles <5 kHz. Manual effort was expended for killer whale pulsed calls, based on their abrupt and patterned shifts in repetition rate which are not present in click series (Ford & Fisher 1983). Killer whale pulsed calls are well documented and are the best described of all killer whale call types. Pulsed calls' primary energy is between 1 and 6 kHz, with high frequency components occasionally >30 kHz and duration primarily between 0.5 and 1.5 seconds (Ford 1989) (Figure 11). There were no killer whale pulsed calls detected in the data.

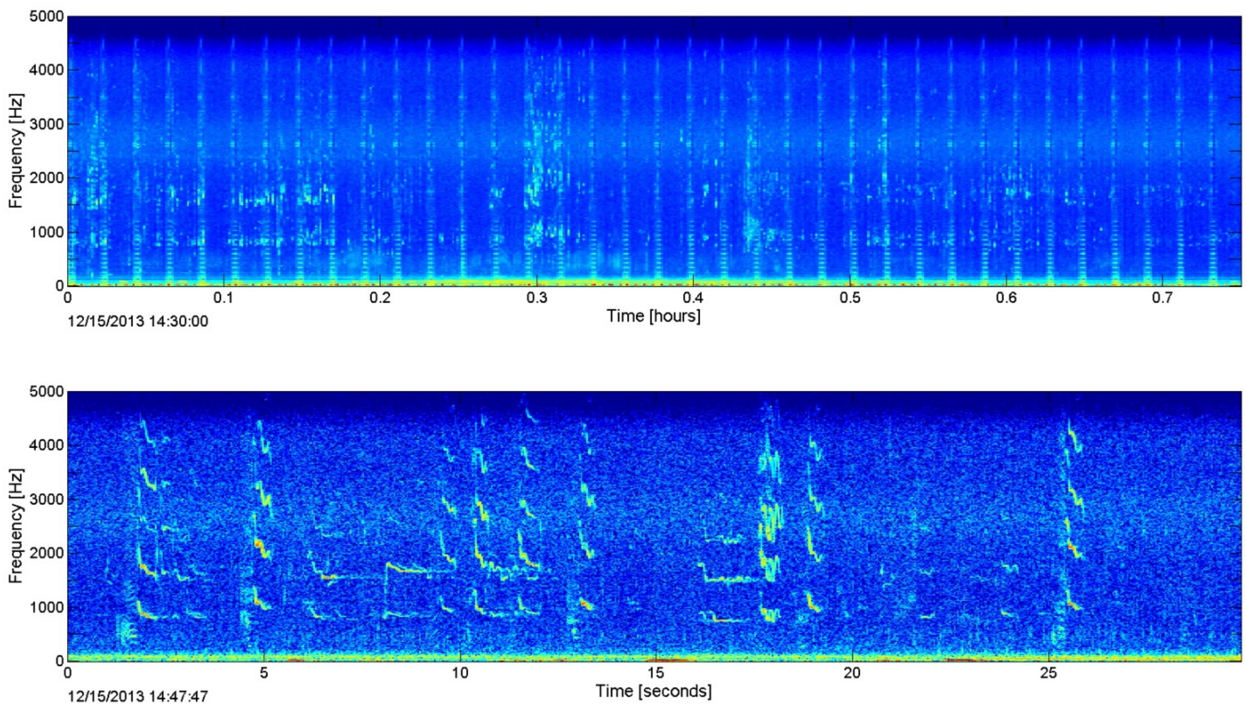

Figure 10. Unidentified odontocete whistles < 5 kHz in LTSA (top) and spectrogram at site H.

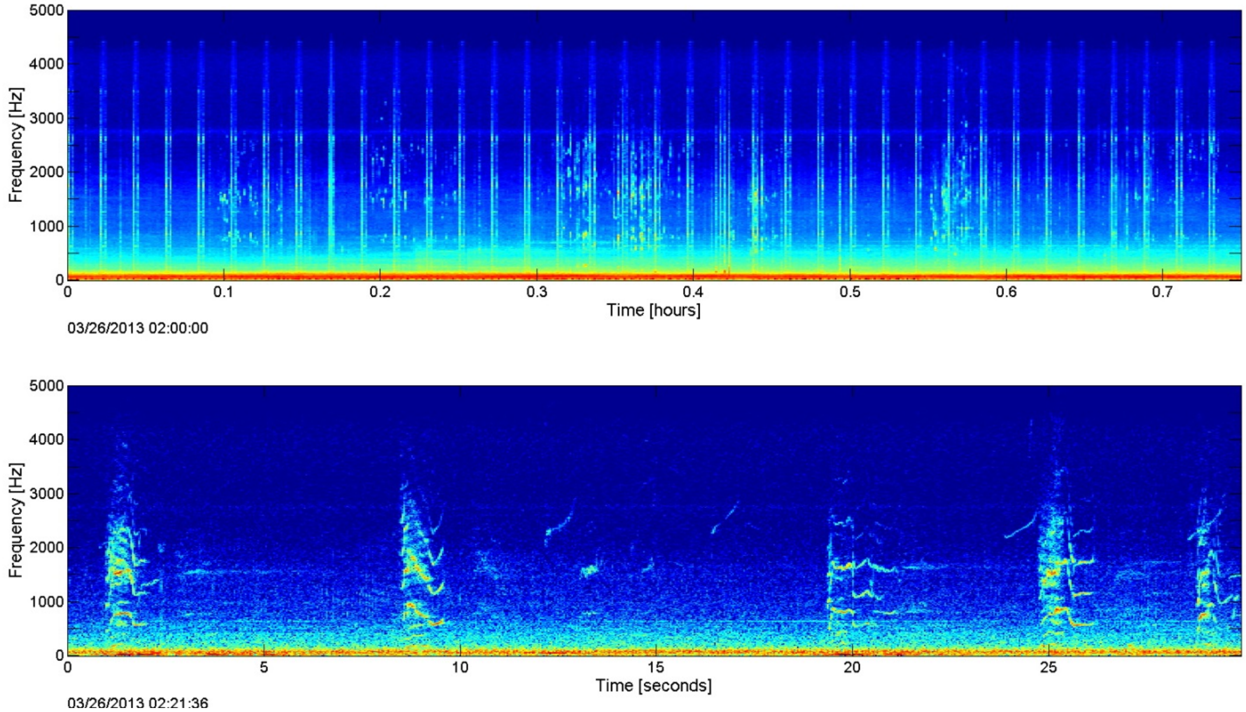

Figure 11. Killer whale pulsed calls in LTSA (top) and spectrogram (bottom) from a recording site off the coast Washington state.

High-Frequency Marine Mammals

Marine mammal species with sounds in the high-frequency range expected in the Southern California Bight include Risso's dolphins (*Grampus griseus*), Pacific white-sided dolphins (*Lagenorhynchus obliquidens*), long- and short-beaked common dolphins (*Delphinus capensis and D. delphis*, respectively), bottlenose dolphins (*Tursiops truncatus*), killer whales (*Orcinus orca*), sperm whales (*Physeter macrocephalus*), Baird's beaked whales (*Berardius bairdii*), Blainville's beaked whales (*Mesoplodon densirostris*), Cuvier's beaked whales (*Ziphius cavirostris*), Stejneger's beaked whales (*Mesoplodon stejnegeri*), Dall's porpoise (*Phocoenoides dalli*), and harbor porpoise (*Phocoena phocoena*).

High-Frequency Call Types

Odontocete sounds can be categorized as echolocation clicks, burst pulses, or whistles. Echolocation clicks are broadband impulses with peak energy between 5 and 150 kHz, dependent upon the species. Buzz or burst pulses are rapidly repeated clicks that have a creak or buzz-like sound quality; they are generally lower in frequency than echolocation clicks. Dolphin whistles are tonal calls predominantly between 1 and 20 kHz that vary in frequency content, their degree of frequency modulation, as well as duration. These signals are easily detectable in an LTSA as well as the spectrogram (Figure 12).

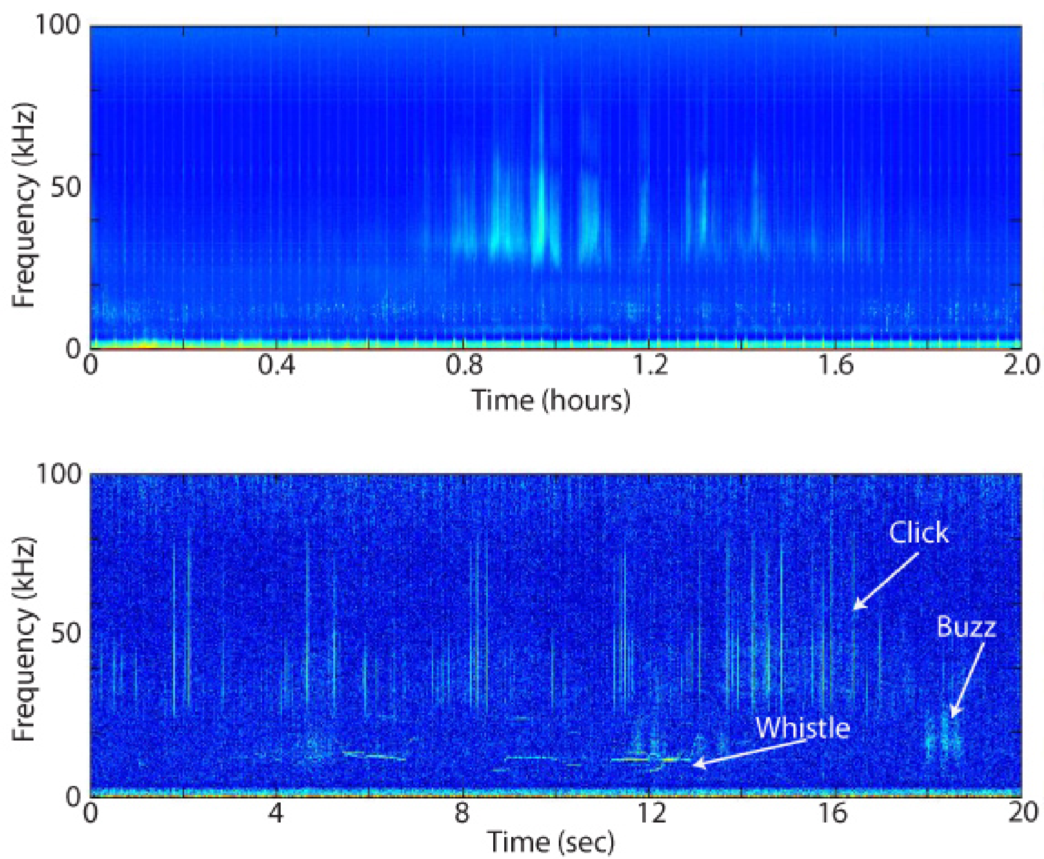

Figure 12. LTSA (top) and spectrogram (bottom) demonstrating odontocete signal types.

Unidentified Odontocetes

Some delphinid sounds are not yet distinguishable to species based on the character of their clicks, buzz or burst pulses, or whistles (Roch *et al.* 2011, Gillespie *et al.* 2013). Both common dolphin species (short-beaked and long-beaked) and bottlenose dolphins make clicks and whistles that are thus far indistinguishable from each other (Soldevilla *et al.* 2008). Since these signals are easily detectable in an LTSA as well as the spectrogram (Figure 13), they were monitored during this analysis effort and are characterized as unidentified odontocete signals.

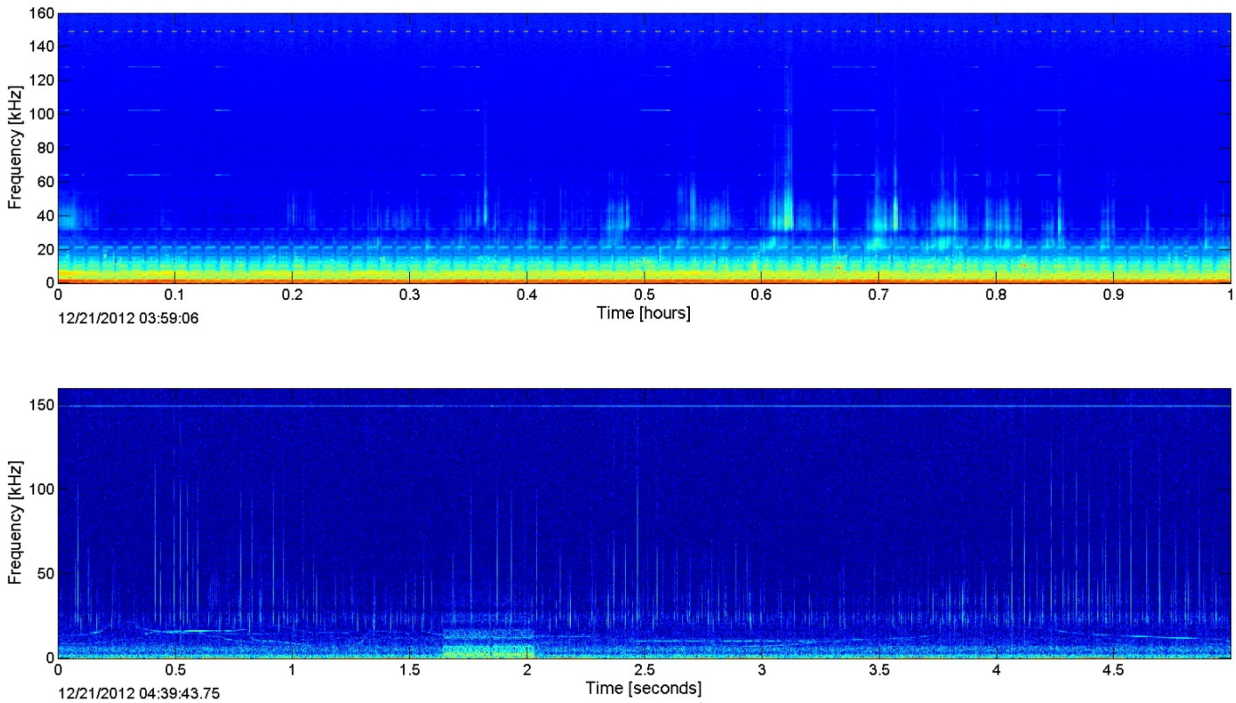

Figure 13. LTSA (top) and spectrogram (bottom) of unidentified odontocete signals at site H.

Risso's Dolphins

Risso's dolphin echolocation clicks can be identified to species by their distinctive banding patterns observable in the LTSA (Figure 14). Risso's dolphin echolocation clicks in the SOCAL area have energy peaks at 22, 26, 30, and 39 kHz (Soldevilla et al. 2008).

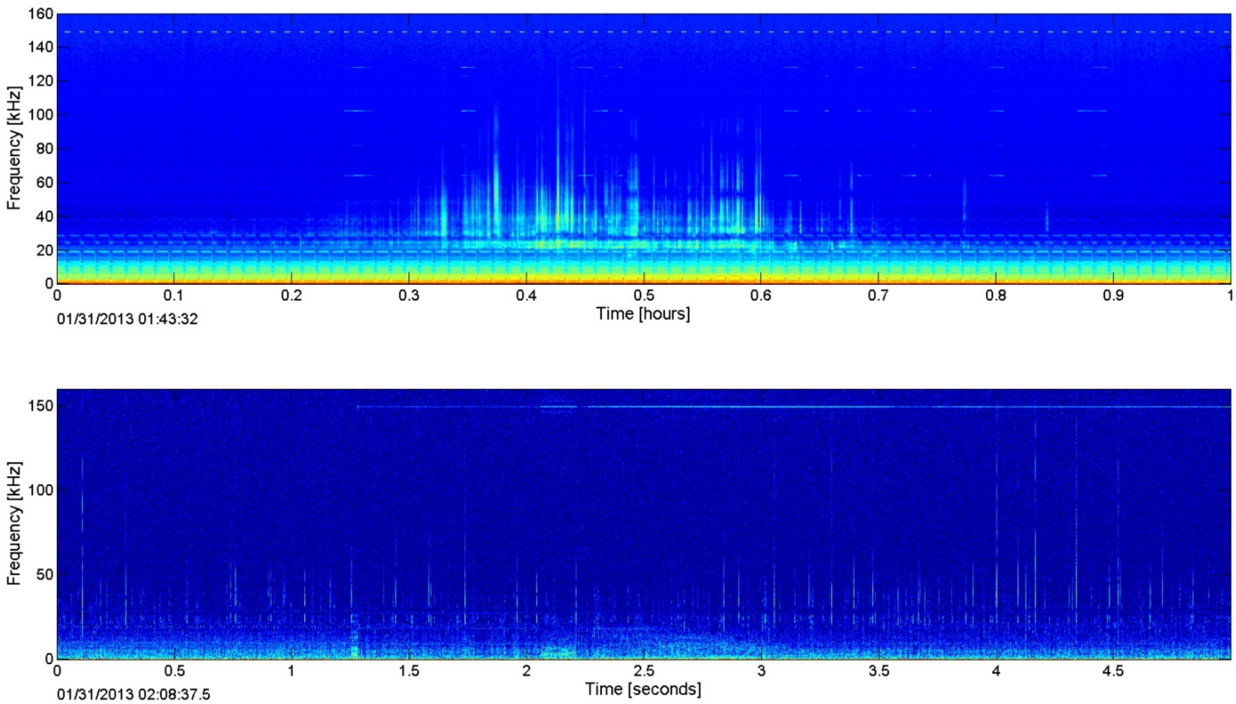

Figure 14. Risso's dolphin acoustic encounter in LTSA (top) and spectrogram (bottom) at site H.

Pacific White-Sided Dolphins

Pacific white-sided dolphin echolocation clicks also can be identified to species by their distinctive banding patterns (Figure 15 and Figure 16). Echolocation clicks recorded from Pacific white-sided dolphins offshore southern California have two distinctive patterns of energy peaks, designated type A (Figure 15) and type B (Figure 16) (Soldevilla *et al.* 2010b). Only type A group occupies the northern portion of the southern California Bight, whereas both groups are known from the southern portion of the Bight. Soldevilla *et al*. (2010) hypothesize that type A signals may be produced by the California/Oregon/ Washington population while type B signals may originate from a southern Baja California population.

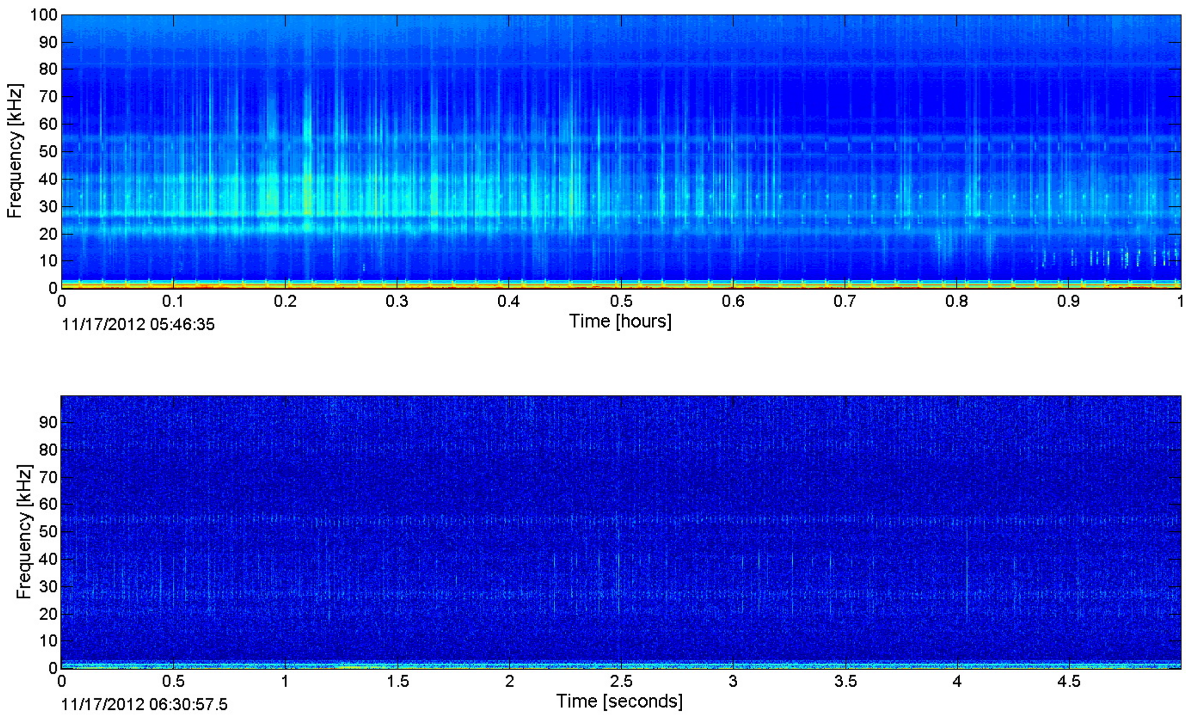

Figure 15. Pacific white-sided dolphin type A echolocation clicks in LTSA (top) and spectrogram (bottom).

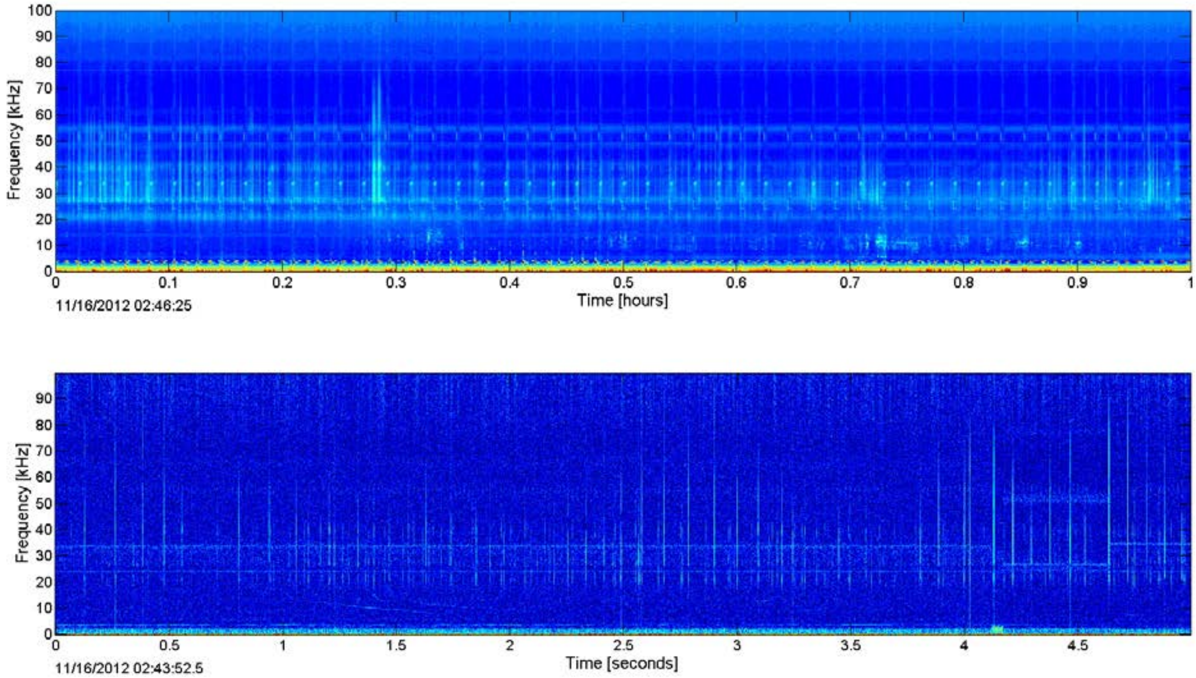

Figure 16. Pacific white-sided dolphin type B echolocation clicks in the LTSA (top) and spectrogram (bottom).

Killer Whales

Killer whales are known to produce two high-frequency call types: echolocation clicks and high-frequency modulated (HFM) signals (Ford 1989, Samarra *et al.* 2010, Simonis *et al.* 2012). These are in addition to whistles and pulsed calls described in the mid-frequency data analysis. HFM signals have only recently been attributed to killer whales in both the Northeast Atlantic (Samarra et al. 2010) and the North Pacific (Filatova *et al.* 2012, Simonis et al. 2012). These signals have fundamental frequencies between 17 and 75 kHz, the highest of any known delphinid tonal calls. Killer whale clicks (Figure 17), pulsed calls, and HFM signals (Figure 18) were used for killer whale species identification in this analysis. No pulsed calls or HFM signals were detected.

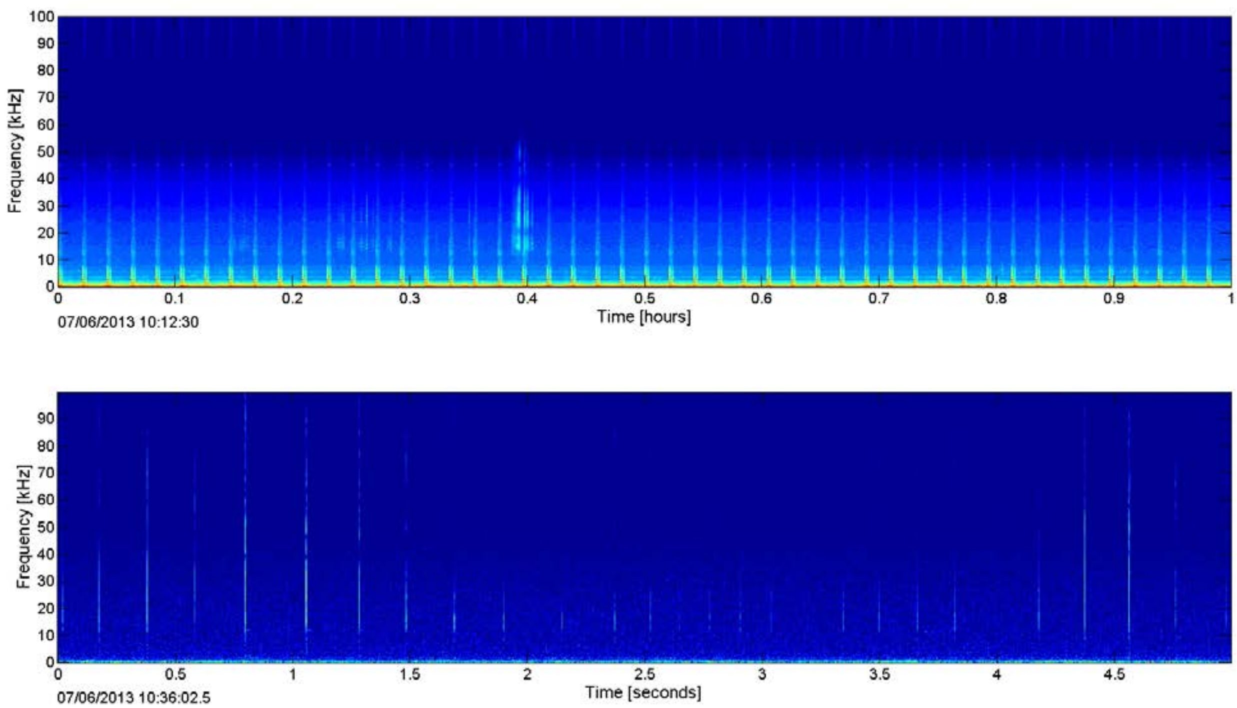

Figure 17. Killer whale clicks in LTSA (top) and spectrogram (bottom) at site M.

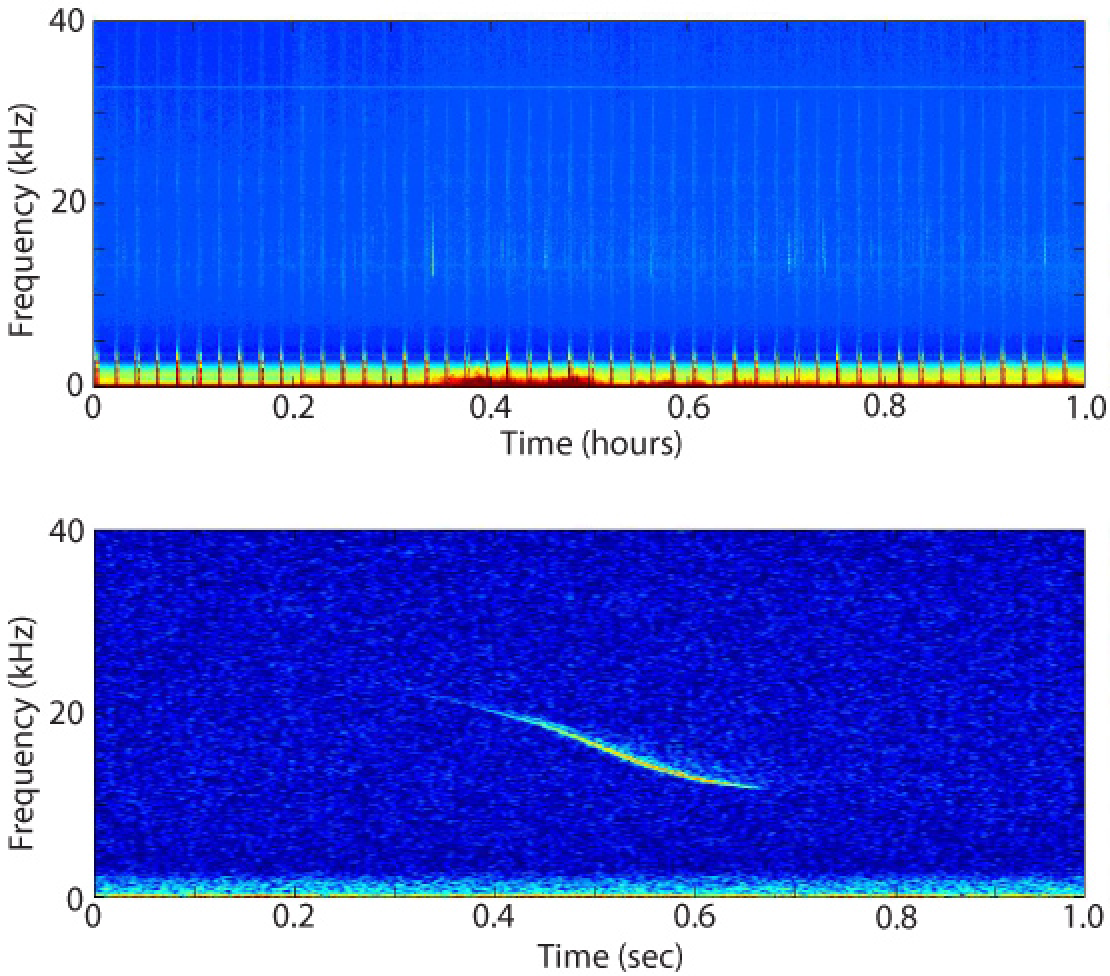

Figure 18. Killer whale HFM signals in the LTSA (top) and spectrogram (bottom) from a HARP recording site in the Gulf of Alaska.

Sperm Whales

Sperm whale clicks generally contain energy from 2-20 kHz, with the majority of energy between 10-15 kHz (Møhl *et al.* 2003) (Figure 19). Regular clicks, observed during foraging dives, demonstrate a uniform inter-click interval from 0.25-2 s (Goold & Jones 1995, Madsen *et al.* 2002). Short bursts of closely spaced clicks called creaks are observed during foraging dives and are believed to indicate a predation attempt (Watwood *et al.* 2006). Slow clicks are used only by males and are more intense than regular clicks with long inter-click intervals (Madsen *et al*., 2002). Codas are stereotyped sequences of clicks which are less intense and contain lower peak frequencies than regular clicks (Watkins & Schevill 1977).

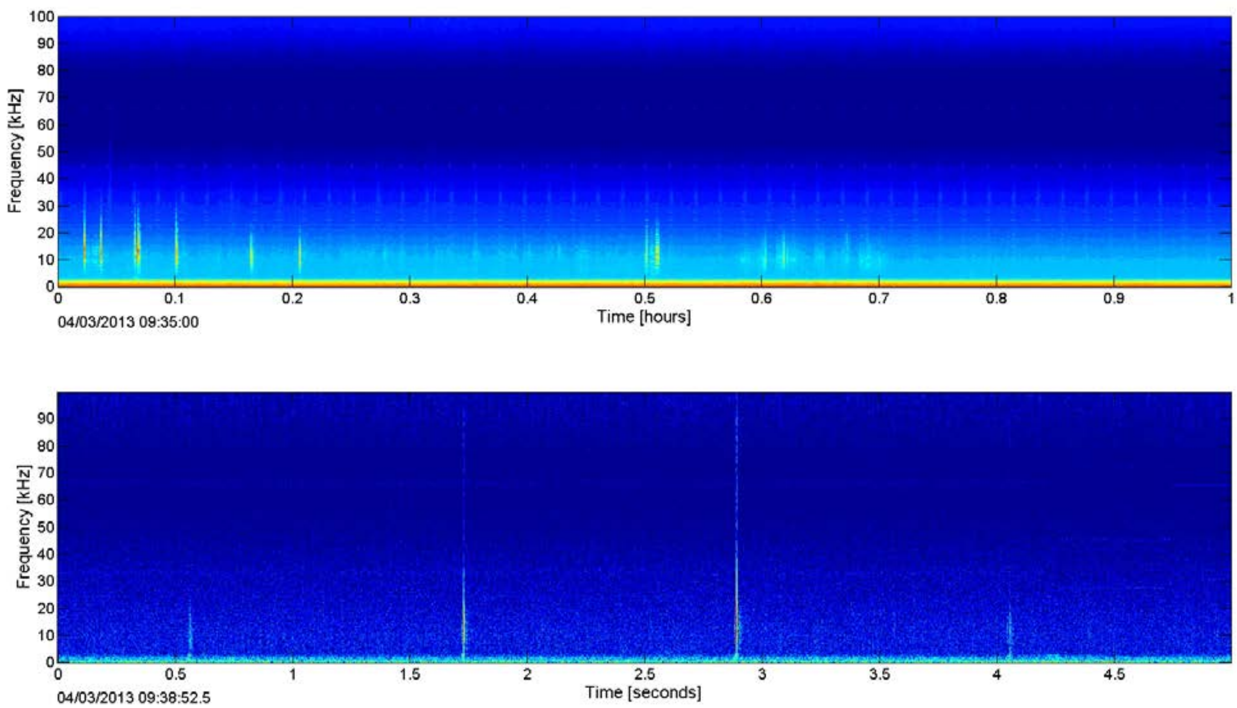

Figure 19. Sperm whale echolocation clicks in LTSA (top) and spectrogram (bottom) at site N.

Beaked Whales

Beaked whales expected in the Southern California Bight include Baird’s beaked whales, Blainville’s beaked whales, Cuvier’s beaked whales, and Stejneger’s beaked whales. Other beaked whale signals detected in the Southern California Bight include frequency-modulated upsweep pulses known as BW40, BW43, and BW70, which appear to be species specific and distinguishable by their spectral and temporal features.

Baird’s Beaked Whales

Baird’s beaked whale is the most commonly visually observed beaked whale species within their range (>30° N, North Pacific Ocean and adjacent seas), probably since they are relatively large and travel in groups of up to several dozen individuals (Allen & Angliss 2010). Baird’s beaked whale echolocation signals are distinguishable from other species’ acoustic signals and, aside from dolphin-like clicks, one of their signal types demonstrates the typical beaked whale polycyclic, FM pulse upsweep (Dawson *et al.* 1998). These FM pulses and clicks are identifiable due to their comparably low-frequency content. Spectral peaks are notable around 9, 16, 25 and 43 kHz (Baumann-Pickering *et al.* 2013b). Unlike other beaked whales in the area, Baird’s beaked whales incorporate whistles and burst pulses into their acoustic repertoire (Dawson et al. 1998).

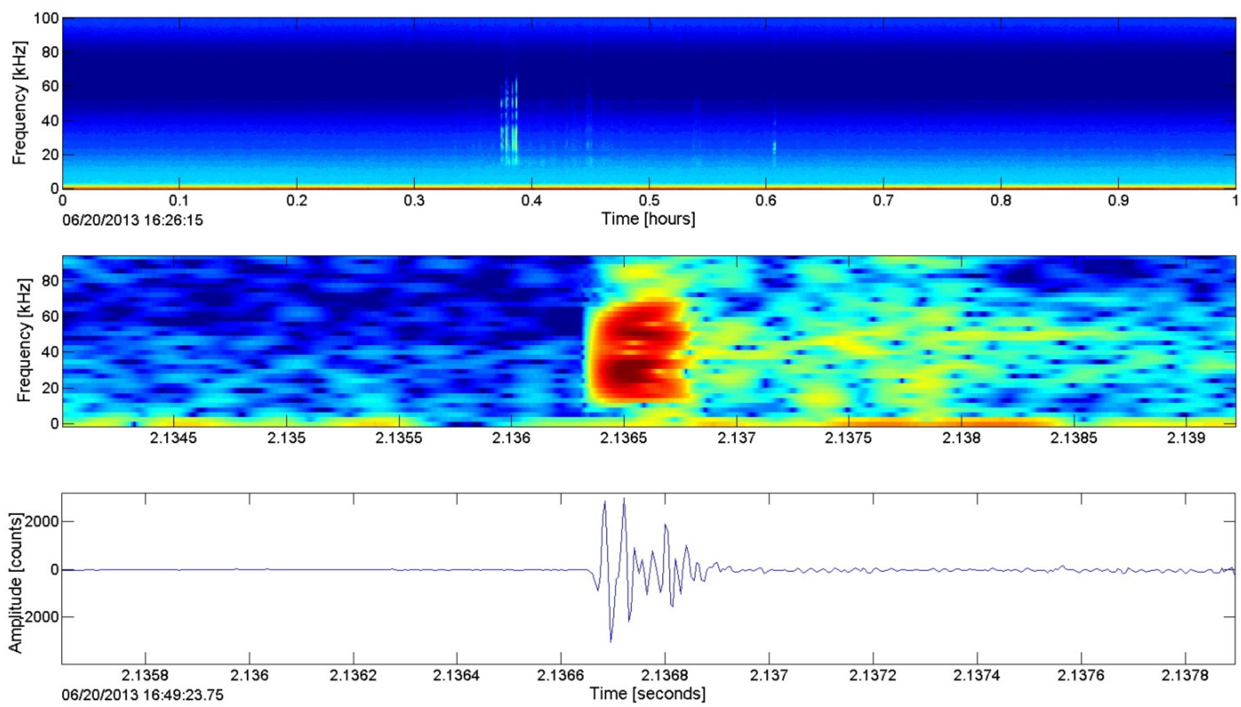

Figure 20. Echolocation sequence of Baird’s beaked whale in LTSA (top) and example dolphin-like click in spectrogram (middle) and time series (bottom) at site N. Note the typical banding pattern around 9, 16, 25 and 43 kHz.

Cuvier's Beaked Whales

Cuvier's echolocation signals are also 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 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 two characteristic spectral peaks around 17 and 23 kHz (Figure 21).

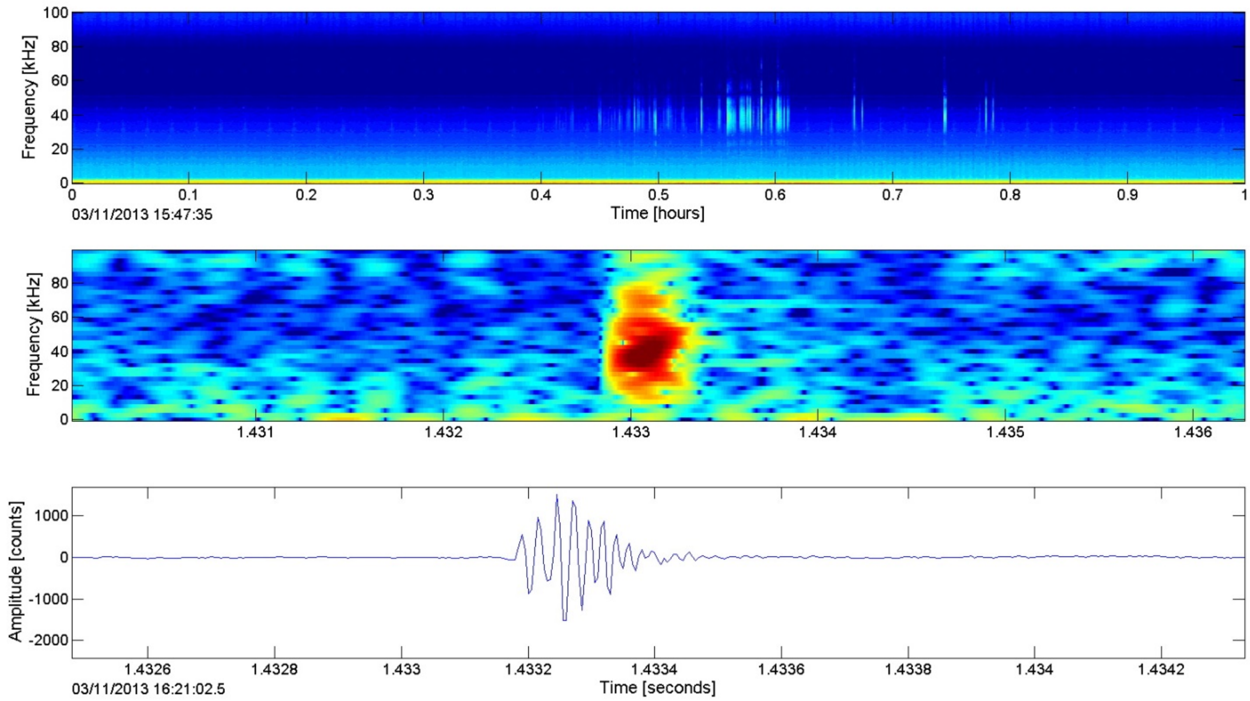

Figure 21. Echolocation sequence of Cuvier's beaked whale in LTSA (top) and example FM pulse in spectrogram (middle) and timeseries (bottom) at site N.

BW43

The BW43 FM pulse has yet to be linked with a specific species. These FM pulses are distinguishable from other species' signals with a peak frequency around 43 kHz and uniform inter-pulse interval around 0.2 s (Figure 22) (Baumann-Pickering *et al.* 2013a). A possible candidate species for producing this FM pulse type may be Perrin's beaked whale (Baumann-Pickering et al. 2014).

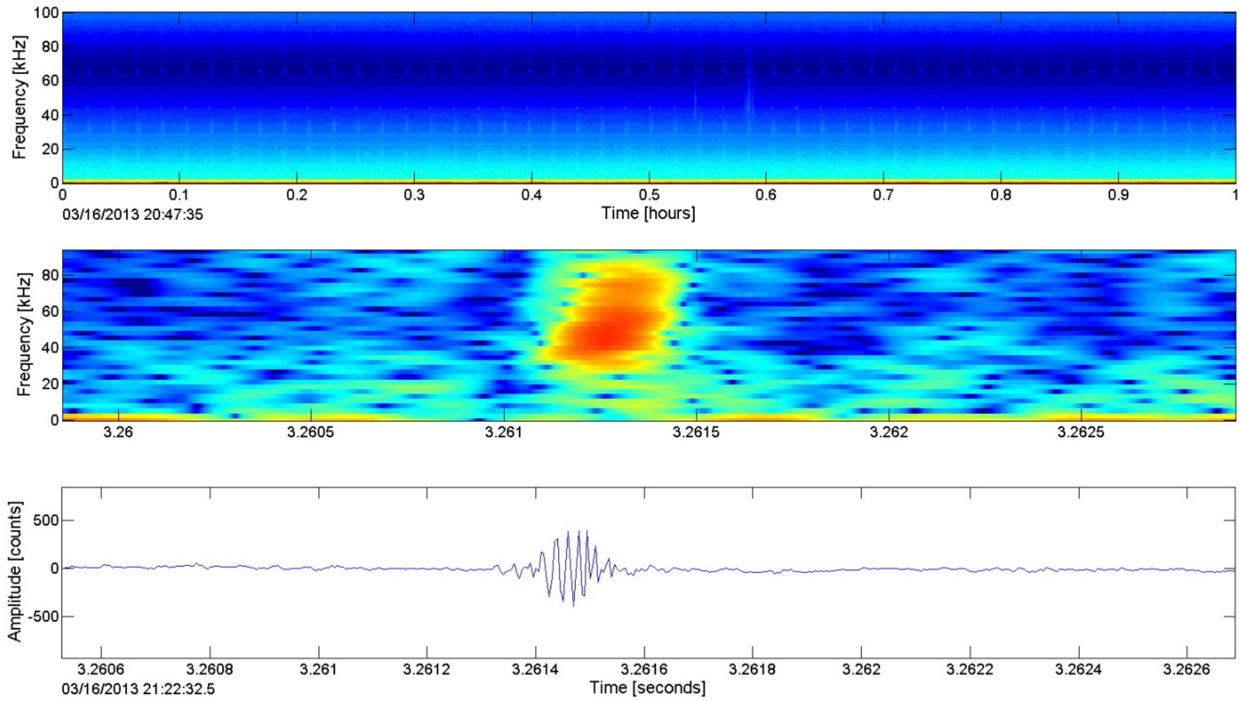

Figure 22. Echolocation sequence of BW43 in LTSA (top) and example FM pulse in spectrogram (middle) and timeseries (bottom) at site N.

Anthropogenic Sounds

Several anthropogenic sounds were monitored for this report: broadband ship noise, Mid-Frequency Active (MFA) sonar, Low-Frequency Active (LFA) sonar, echosounders, underwater communications, and explosions. The LTSA search parameters used to detect each sound at low and mid-frequencies are given in Table 2. The start and end of each sound or session was logged and their durations were added to estimate cumulative hourly presence.

Table 2. Low and mid-frequency anthropogenic sound data analysis parameters.

Sound Type	LTSA Search Parameters	
	Plot Length (hr)	Frequency Range (Hz)
Broadband Ship Noise	3.0	10 – 5,000
MFA Sonar	0.75	1,000 – 5,000
LFA Sonar	1.0	100 – 1000
Echosounders	0.75	10 – 5,000
Underwater Communications	0.75	10 – 5,000
Explosions	0.75	10 – 5,000

Broadband Ship Noise

Broadband ship noise occurs when a ship passes relatively close to the hydrophone. Ship noise can occur for many hours at a time, but broadband ship noise typically lasts from 10 minutes up to 3 hours. Ship noise has a characteristic interference pattern in the LTSA (McKenna *et al.* 2012). Combination of direct paths and surface reflected paths produce constructive and destructive interference (bright and dark bands) in the spectrogram that varies by frequency and distance between the ship and the receiver (Figure 23). Noise can extend above 10 kHz, though it typically falls off above a few kHz.

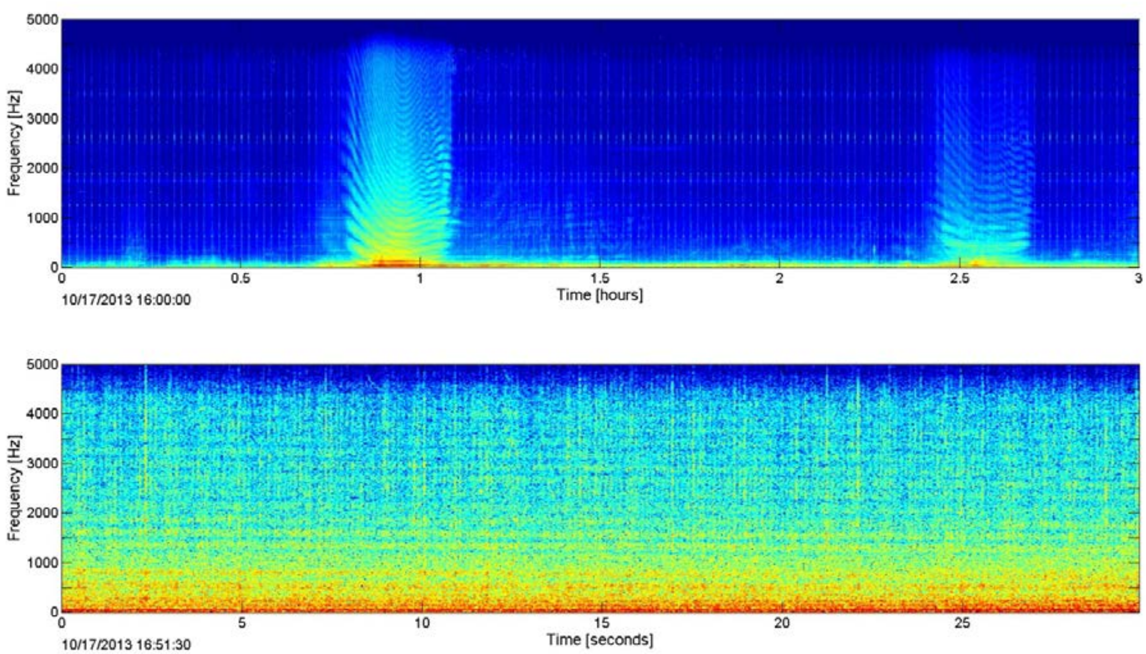

Figure 23. Broadband ship noise in LTSA (top) and spectrogram (bottom) at site M.

Mid-Frequency Active Sonar

Sounds from MFA sonar vary in frequency and duration and are a combination of frequency modulated (FM) sweeps and continuous wave (CW) tones. While they can span frequencies from about 1 kHz to over 50 kHz, many are between 2.0 and 5.0 kHz and are sometimes generically known as '3.5 kHz' sonar (Figure 24). Analysts manually scanned LTSAs for sonar bout start and end times, both at mid-frequencies (1-5 kHz) and at high frequencies (> 5 kHz).

A custom software routine was used to detect sonar pings within the analyst-defined bouts and to calculate peak-to-peak (PP) received sound pressure levels. For this detector, a sonar ping is defined as the presence of sonar within a 5 s window and may contain multiple individual pings. The detector calculates the average spectrum level across the frequency band from 2.4 to 4.5 kHz for each 5 s time bin. This provides a time series of the average received levels in that frequency band. Minimum values were noted for each 15 time bins, and used as a measure of background noise level over the sonar event period. Spectral bins that contained system noise (disk writing) were eliminated to prevent contaminating the results. Each of the remaining average spectral bins was compared to the background minimum levels. If levels were more than 3 dB above the background, then a detection time was noted. These detection times were then used to index to the original time series to calculate PP levels. Received PP levels were calculated by differencing the maximum and minimum amplitude of the time series in the 5 s window. The raw time series amplitudes are in units of analog-to-digital converter (ADC) counts. These units were corrected to µPa by using the calibrated transfer function for this frequency band. Since the instrument response is not flat over the 2.4 – 4.5 kHz band, a middle value at 3.3 kHz was used. For sonar pings less than this middle frequency, their levels are overestimated by up to about 5 dB and for those at higher frequency their levels are underestimated up to about 4 dB.

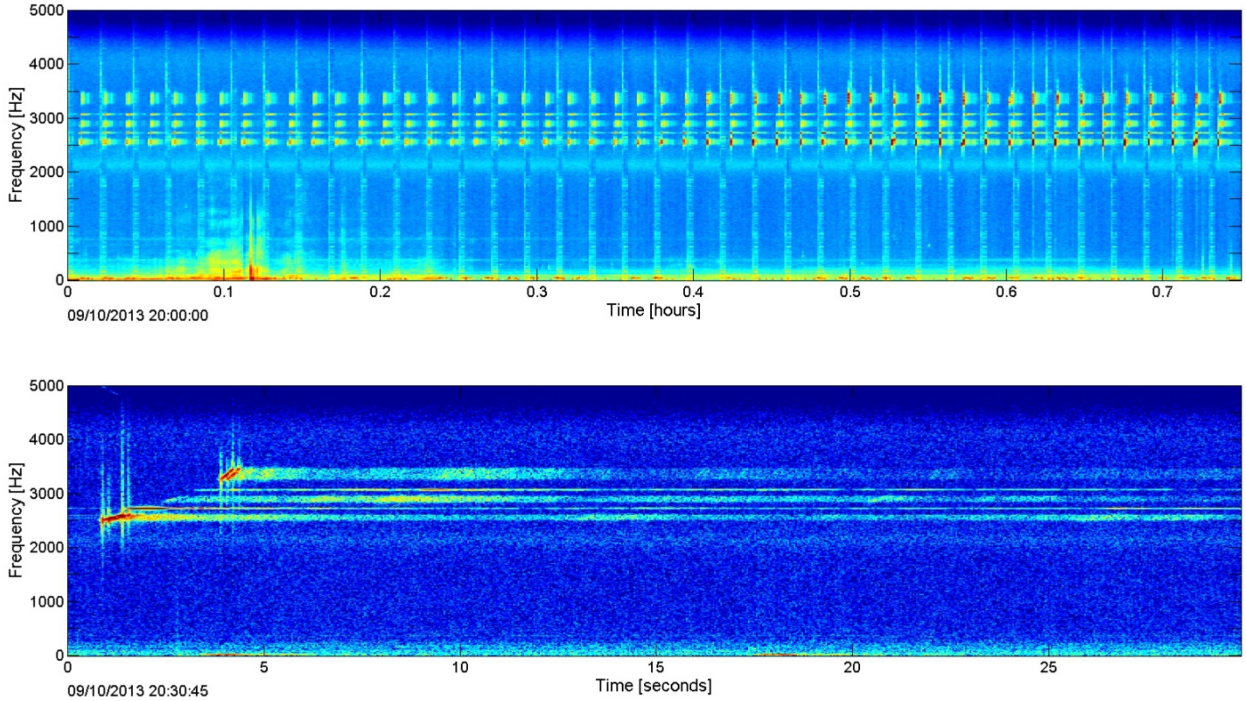

Figure 24. MFA in LTSA (top) and spectrogram (bottom) at site H.

Low-Frequency Active Sonar

Low-frequency active sonar includes military sonar between 100 and 500 Hz and other sonar systems up to 1 kHz. Effort was expended for LFA sonar between 100 Hz and 1 kHz (Figure 25).

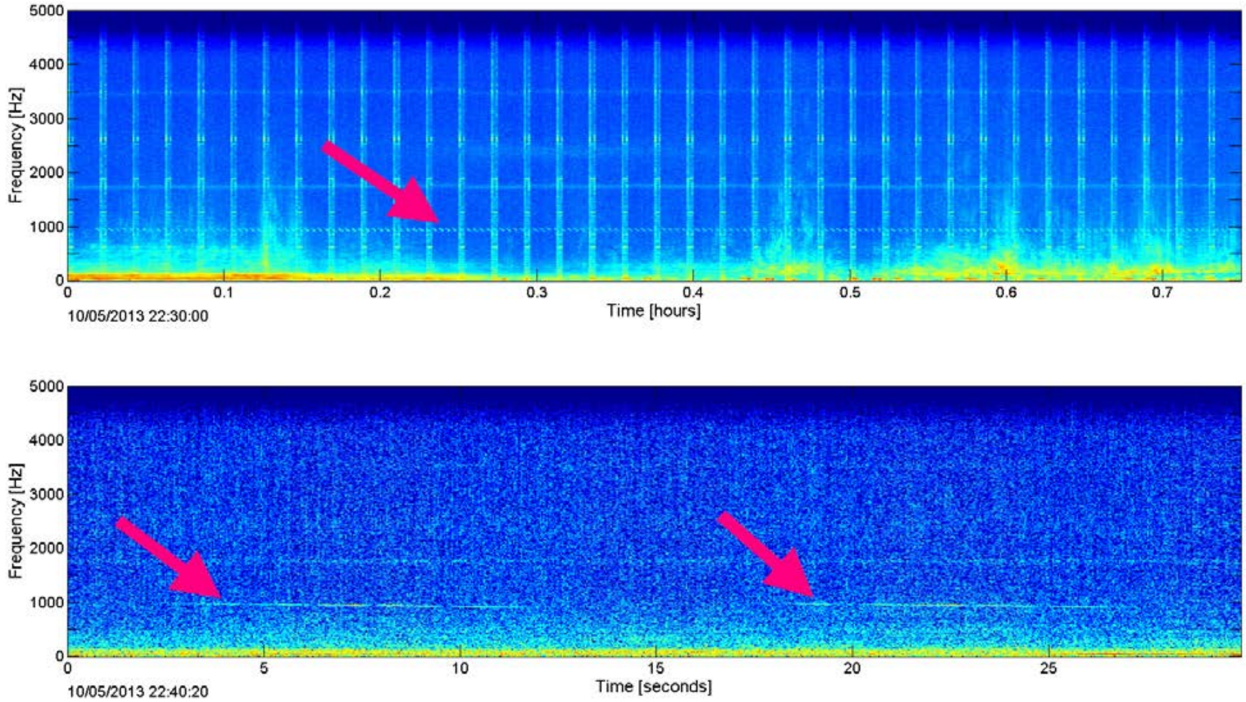

Figure 25. LFA at 950 Hz in the LTSA (top) and spectrogram (bottom) at site M.

Echosounders

Echosounding sonars transmit short pulses or frequency sweeps, typically in the high-frequency (above 5 kHz) band (Figure 26), though echosounders are occasionally found in the mid-frequency range (2-5 kHz) (Figure 27). Many large and small vessels are equipped with echosounding sonar for water depth determination; typically these echosounders are operated much of the time a ship is at sea, as an aid for navigation. In addition, sonars may be used for sea bottom mapping, fish detection, or other ocean sensing. Echosounders were detected by analysts using the LTSA plots at both mid- and high-frequency.

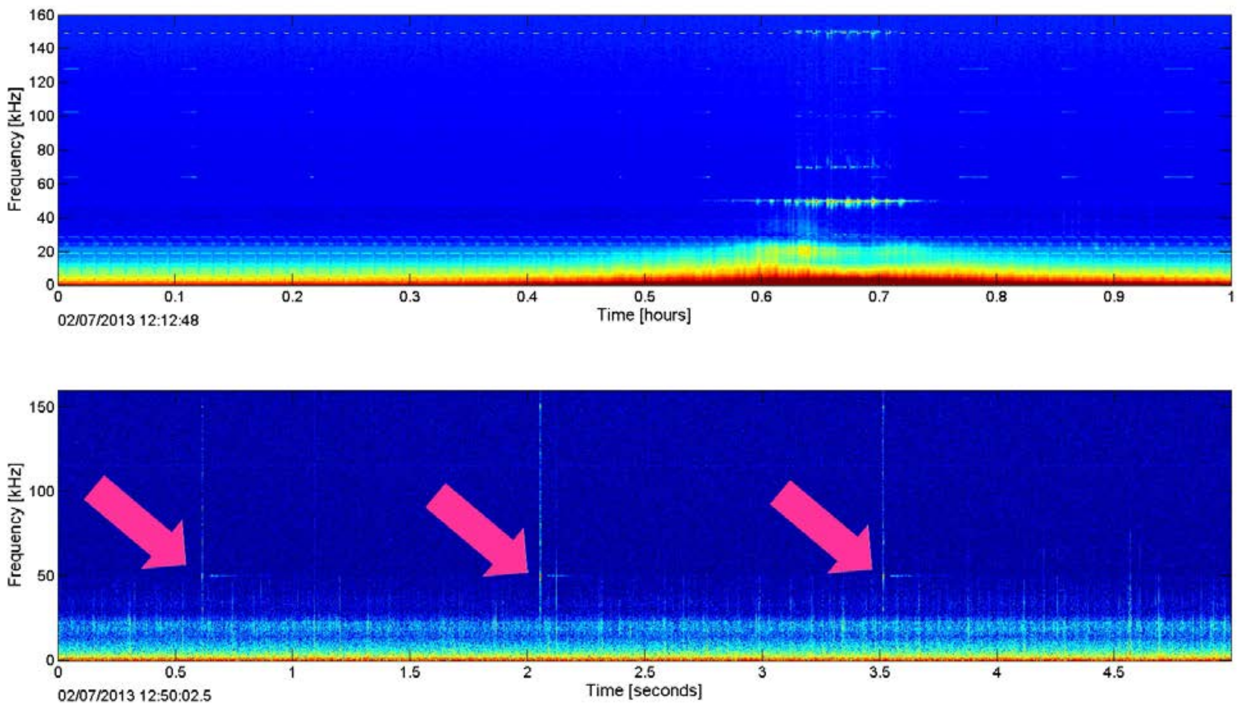

Figure 26. High-frequency echosounder pings in LTSA (top) and spectrogram (bottom) at site H.

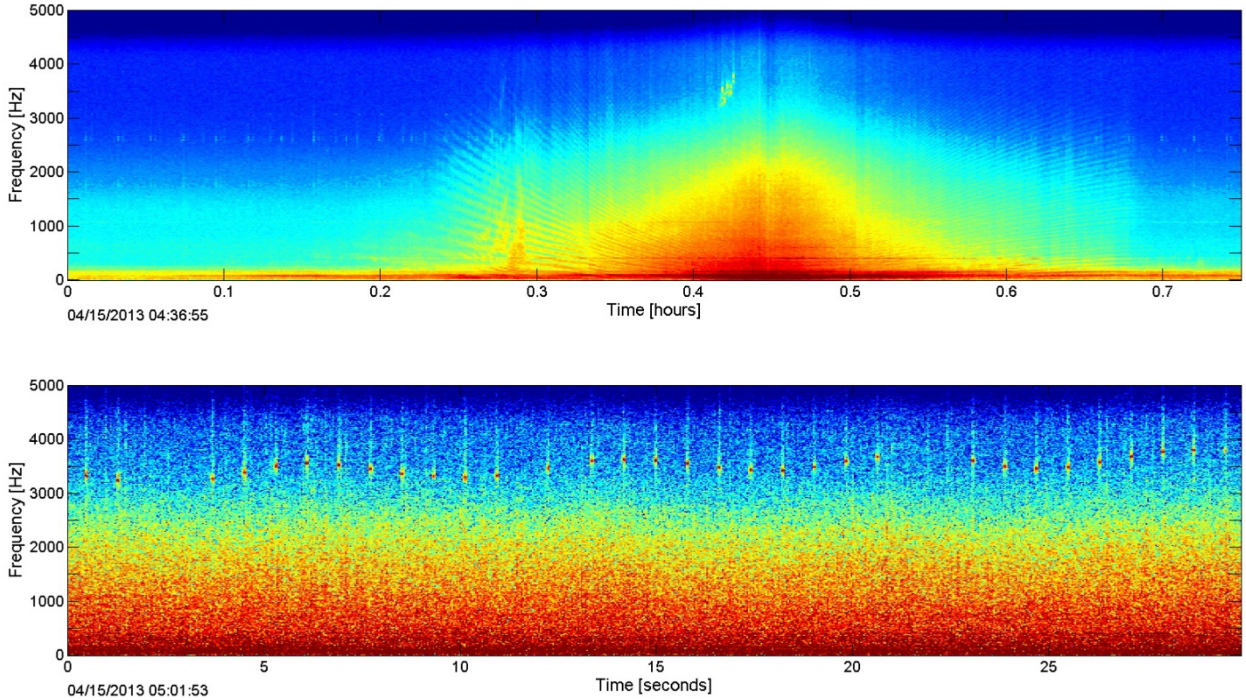

Figure 27. Mid-frequency echosounder pings in the LTSA (top) and spectrogram (bottom) at site N.

Explosions

Effort was directed toward finding explosive sounds in the data including military explosions, shots from sub-seafloor exploration, and seal bombs used by the fishing industry. An explosion appears as a vertical spike in the LTSA that, when expanded in the spectrogram, has a sharp onset with a reverberant decay (Figure 28). Explosions were detected automatically using a matched filter detector on data decimated to 10 kHz sampling rate. The timeseries was filtered with a 10th order Butterworth bandpass filter between 200 and 2,000 Hz. Cross correlation was computed between 75 seconds of the envelope of the filtered timeseries and the envelope of a filtered example explosion (0.7 s, Hann windowed) as the matched filter signal. The cross correlation was squared to 'sharpen' peaks of explosion detections. A floating threshold was calculated by taking the median cross correlation value over the current 75 seconds of data to account for detecting explosions within noise, such as shipping. A cross correlation threshold of $3*10^{-6}$ above the median was set. When the correlation coefficient reached above threshold, the timeseries was inspected more closely. Consecutive explosions were required to have a minimum time distance of 0.5 seconds to be detected. A 300-point (0.03 s) floating average energy across the detection was computed. The start and end above threshold was determined when the energy rose by more than 2 dB above the median energy across the detection. Peak-to-peak (pp) and rms received levels (RL) were computed over the potential explosion period and a timeseries of the length of the explosion template before and after the explosion. The potential explosion was classified as false detection and deleted if 1) the dB difference pp and rms between signal and time AFTER the detection was less than 4 dB or 1.5 dB, respectively; 2) the dB difference pp and rms between signal and time BEFORE signal was less than 3 dB or 1 dB, respectively; and 3) the detection was shorter than 0.03 and longer than 0.55 seconds of duration. The thresholds were evaluated based on the distribution of histograms of manually verified true and false detections. A trained analyst subsequently verified the remaining potential explosions for accuracy. Explosions have energy as low as 10 Hz and often extend up to 2,000 Hz or higher, lasting for a few seconds including the reverberation.

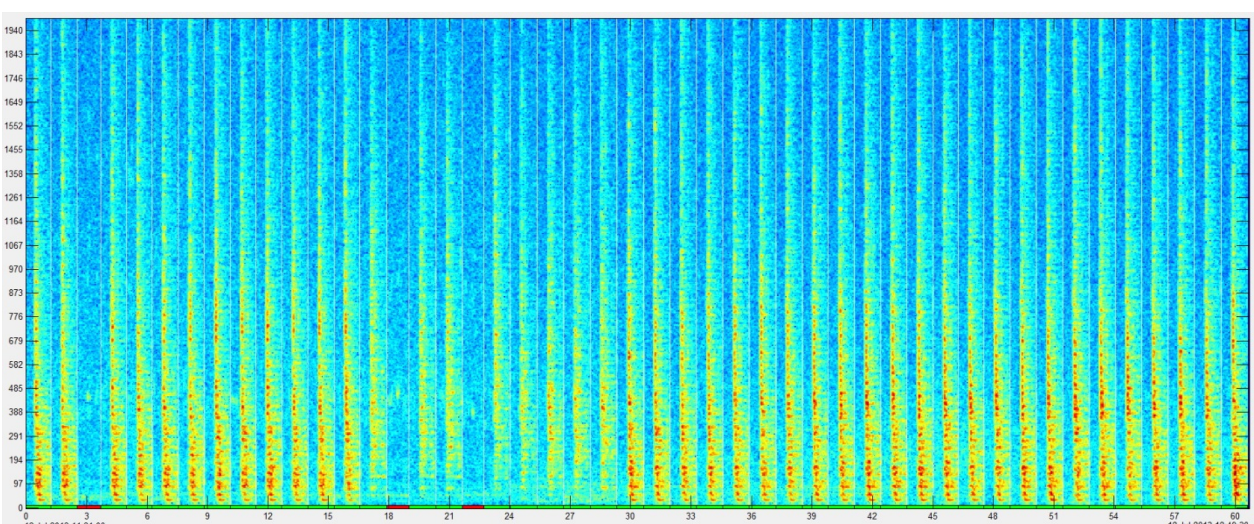

Figure 28. Explosions from site M in the analyst verification stage of the detector. Green in the bottom evaluation line indicates true and red indicates false detections.

Underwater Communications

Underwater communications sonars are used to transmit information, such as when used for acoustic telemetry. They are highly modulated signals that can sound like distorted voices (Figure 29) or other electronic transmissions (Figure 30).

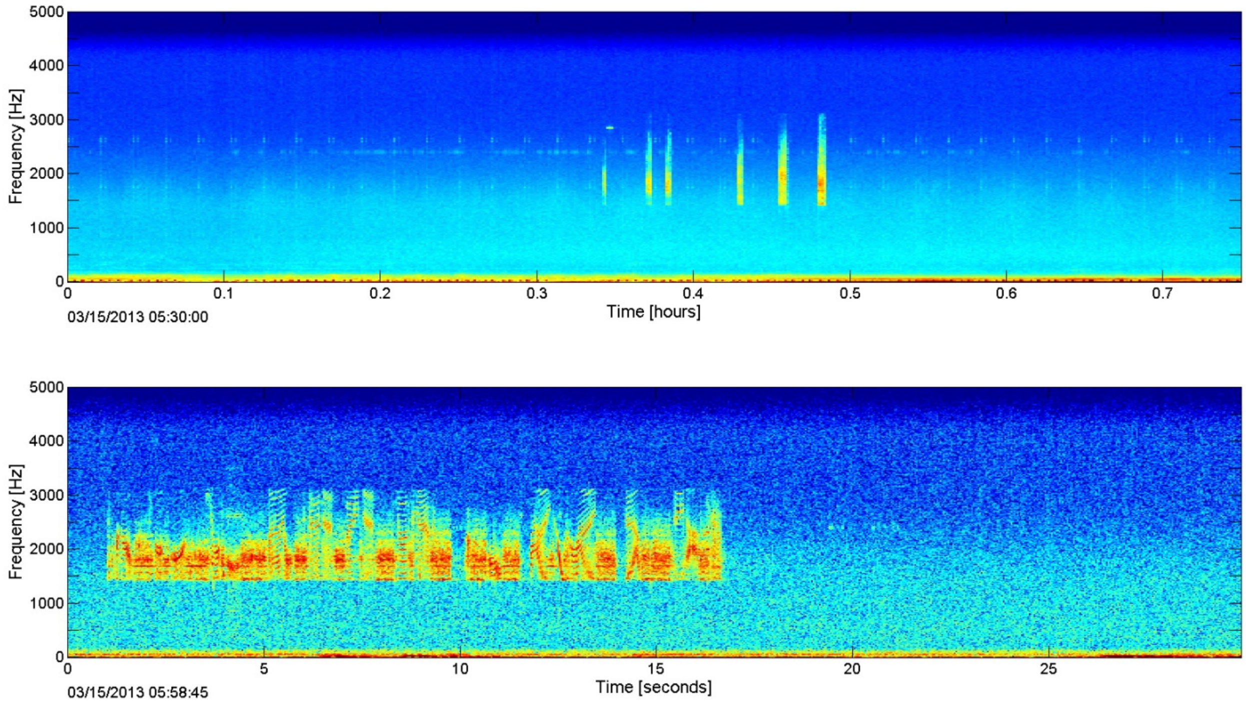

Figure 29. Underwater communications in LTSA (top) and spectrogram (bottom) at site N.

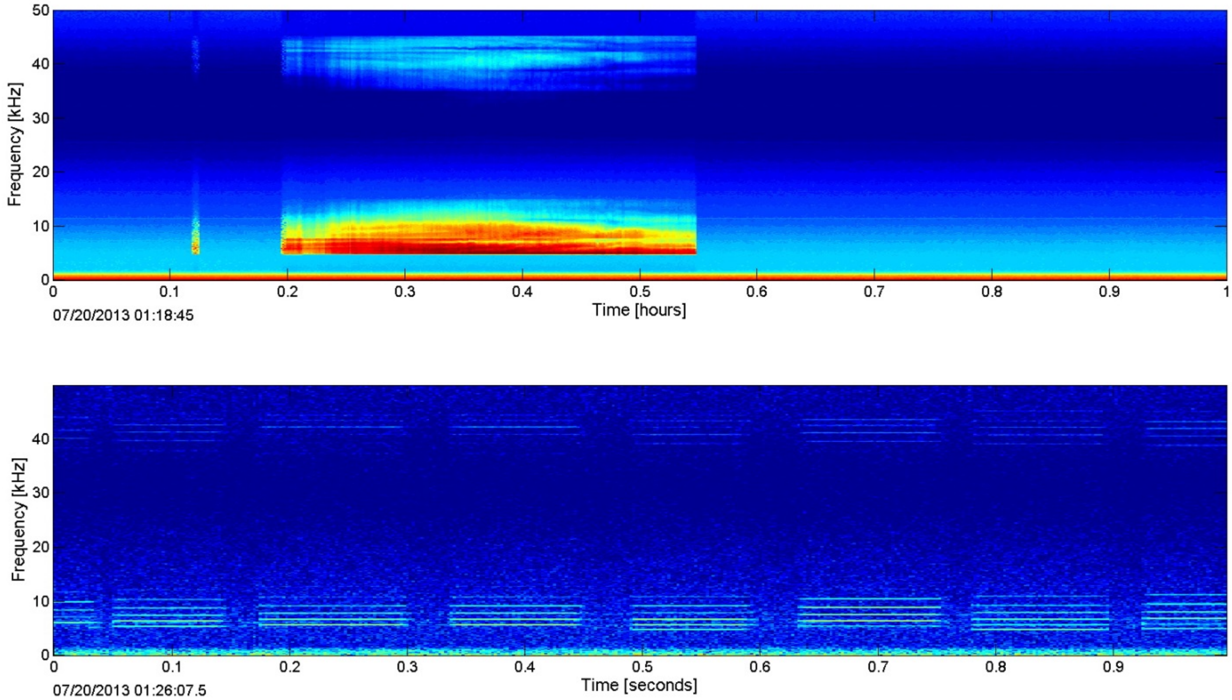

Figure 30. Electronic transmissions in the LTSA (top) and spectrogram (bottom) at site N.

Other Low-Frequency Anthropogenic Signals

A previously undetected anthropogenic signal occurring around 180 Hz (Figure 30) was also detected on multiple occasions in these data. The characteristics of these signals suggest that they are anthropogenic rather than biologic, but they do not conform to LFA sonar parameters, at least as understood by us. These signals were found by manually scanning the LTSAs and further inspection of the spectrogram.

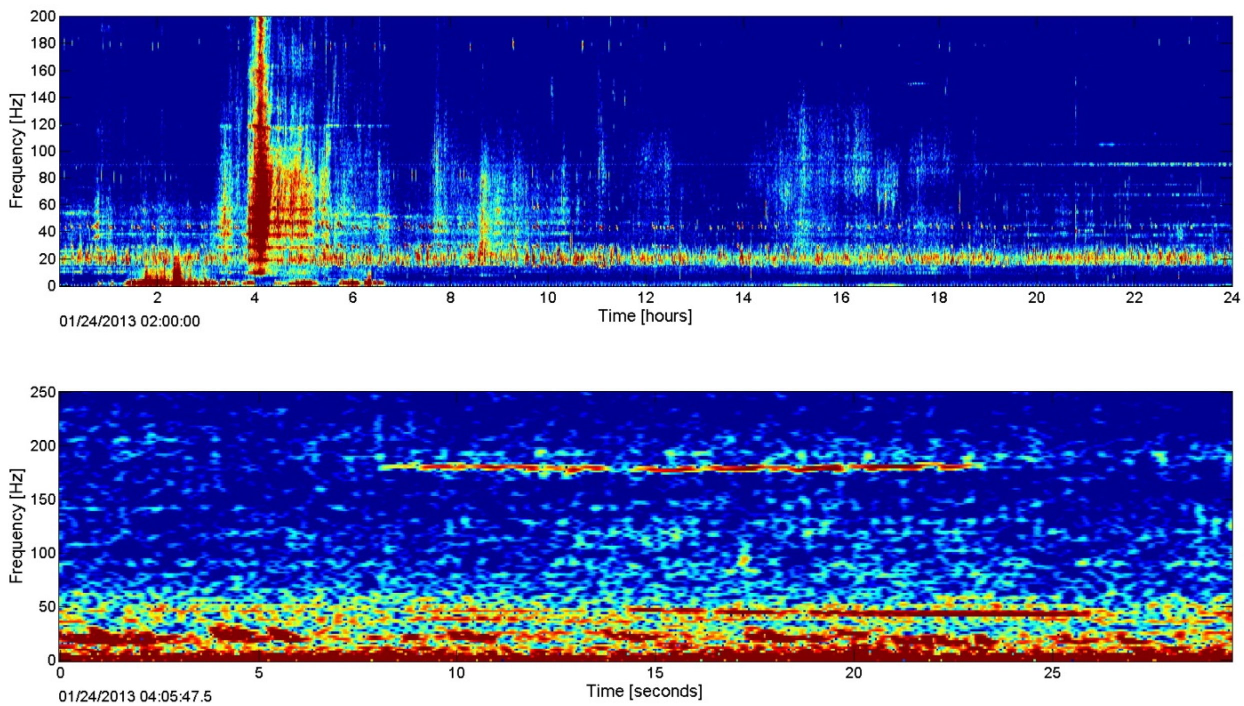

Figure 31. Low-frequency tonal signals near 180 Hz in LTSA (top) and spectrogram (bottom) site N.

Results

The results of acoustic data analysis at sites M, H, and N from December 2012 through January 2014 are summarized. We describe ambient noise, the seasonal occurrence and relative abundance of marine mammal acoustic signals and anthropogenic sounds.

Ambient Noise

- Underwater ambient noise at sites M, H, and N had spectral shapes with higher levels at low frequencies, owing to the dominance of ship noise at frequencies below 100 Hz and local wind and waves above 100 Hz (Figure 32, Figure 33, and Figure 34 respectively) (Hildebrand 2009).
- Site H has the lowest spectrum levels for both ship and wind bands. This is expected owing to the fact that site H is away from shipping routes and is located in a basin shielded from the deep ocean (McDonald *et al.* 2008).
- Prominent peaks in noise were observed at the frequency band 15-30 Hz at sites H and N and are related to seasonally increased presence of fin whale calls.
- Seasonal peaks at 45-47 Hz at all three sites are related to blue whale B calls.
- The peaks at 700-800 Hz at site H are tones from instrumental noise.

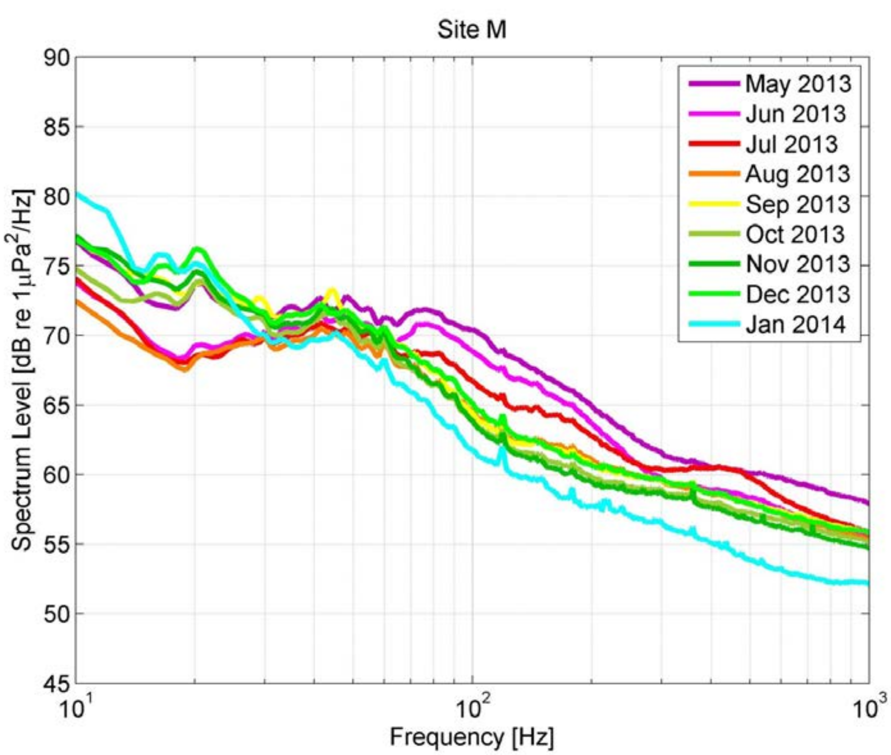

Figure 32. Monthly averages of ambient noise at site M. Legend gives color-coding by month.

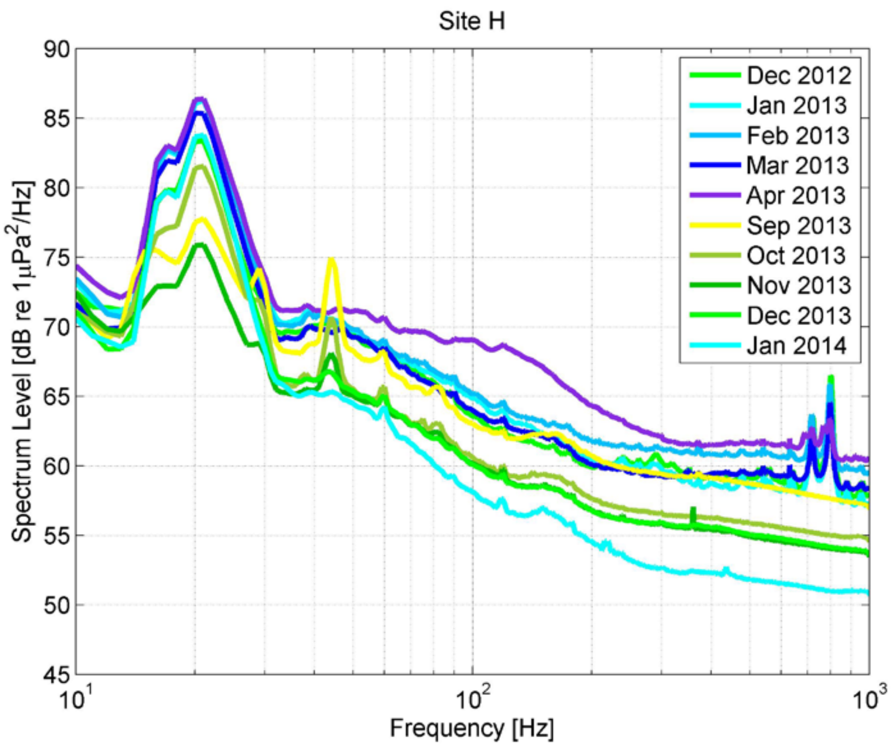

Figure 33. Monthly averages of ambient noise at site H. Legend gives color-coding by month.

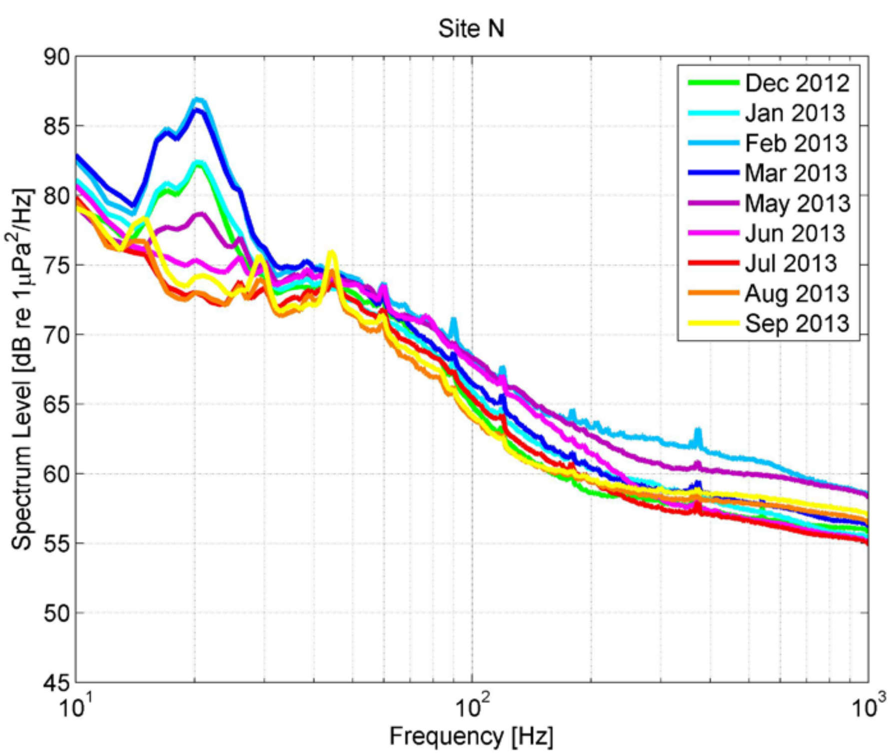

Figure 34. Monthly averages of ambient noise at site N. Legend gives color-coding by month.

Mysticetes

Six baleen whale species were recorded between December 2012 and January 2014: blue whales, fin whales, Bryde's whales, gray whales, humpback whales, and minke whales. In general, fewer baleen whale vocalizations were detected at site M than at sites H and N. More details of each species' presence at these sites are given below.

Blue Whales

Blue whale calls were detected from December 2012 through February 2013 and May 2013 through January 2014.

- Blue whale Northeast (NE) Pacific B calls were detected at each site with a peak in detections September through October 2013. Site M had the fewest calls detected (Figure 35)
- There was no discernable diel pattern in NE Pacific B calls (Figure 36).
- D call detections were the highest from June to July 2013 at sites M and N. Few D calls were detected at site H (Figure 37).
- The seasonal difference in the occurrence of B and D calls likely reflects the transition of blue whale behavior from feeding during the summer to pairing and mating in the fall.
- There was no discernable diel pattern for blue whale D calls (Figure 38).
- The results for blue whale B calls are consistent with earlier recordings at these sites; however, it appears that 2012 may have been anomalous with D calls at site N peaking later in fall than usual (Kerosky *et al.* 2013).

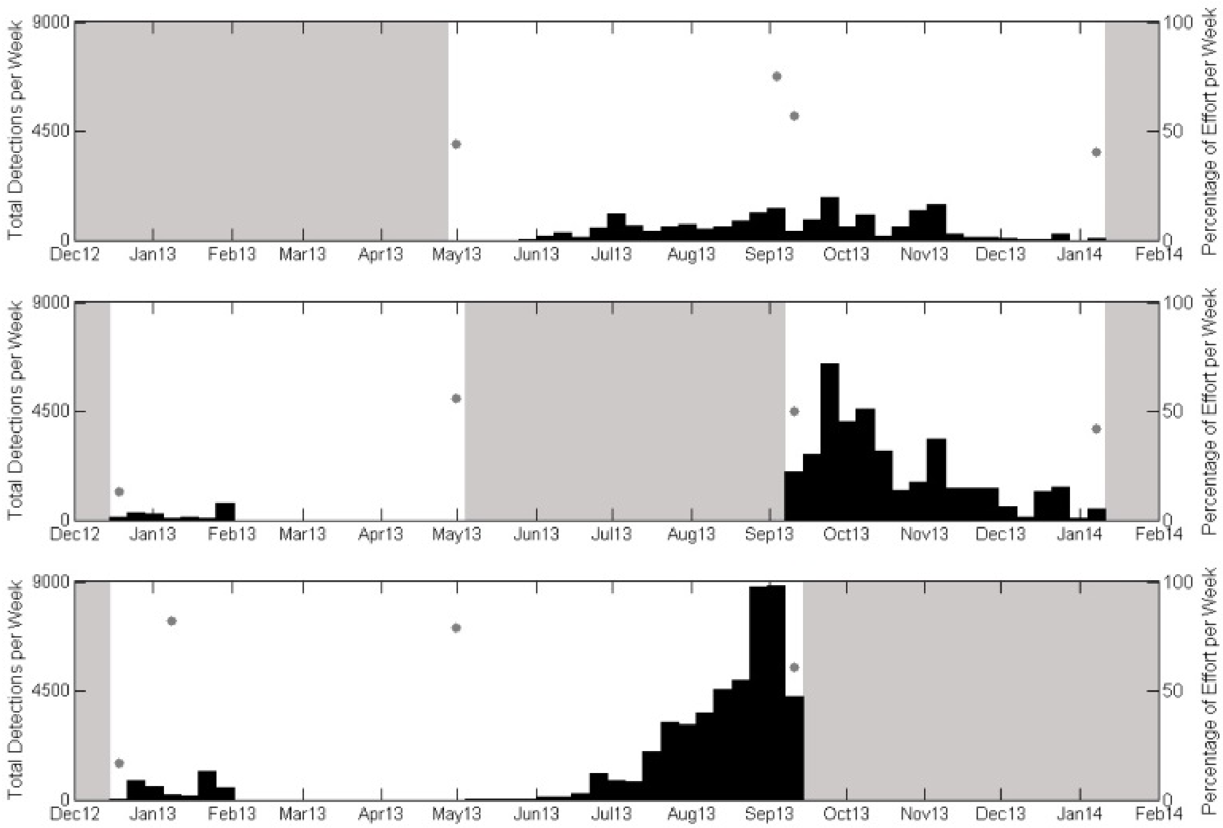

Figure 35. Weekly presence of NE Pacific blue whale B calls between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Gray dots represent percent of effort per week in weeks with less than 100% recording effort, and gray shading represents periods with no recording effort. Where gray dots or shading are absent, full recording effort occurred for the entire week.

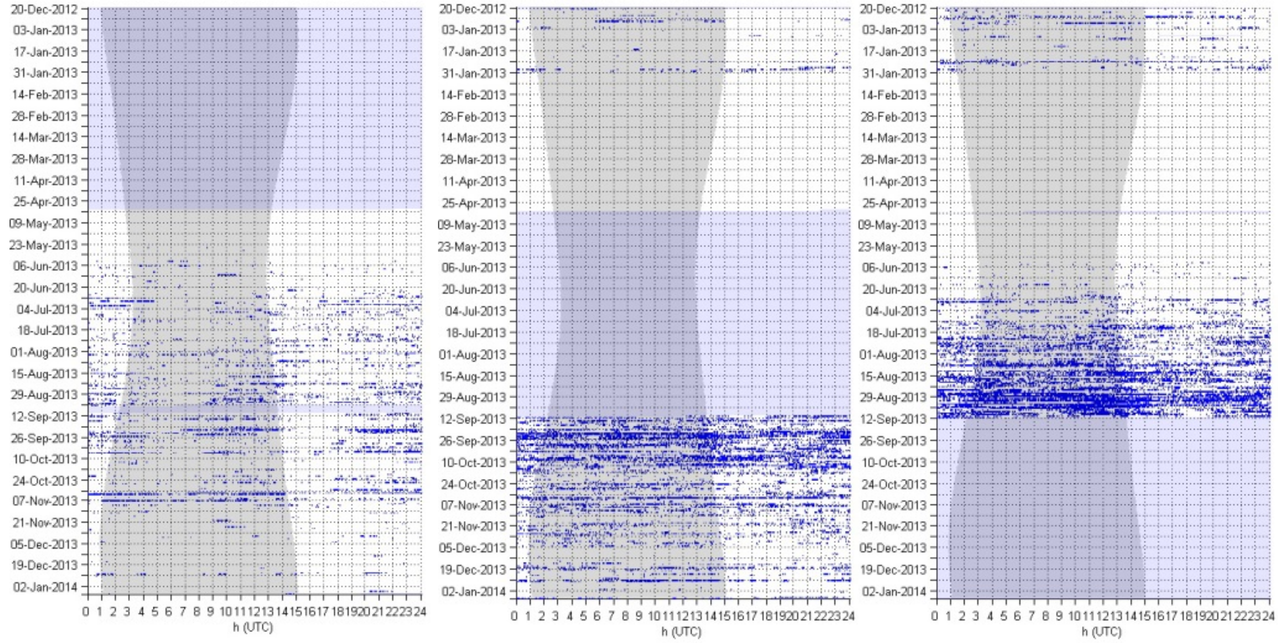

Figure 36. NE Pacific blue whale B calls in one-minute bins at sites M (left), H (middle), and N (right). Gray vertical shading denotes nighttime and light purple horizontal shading denotes absence of acoustic data.

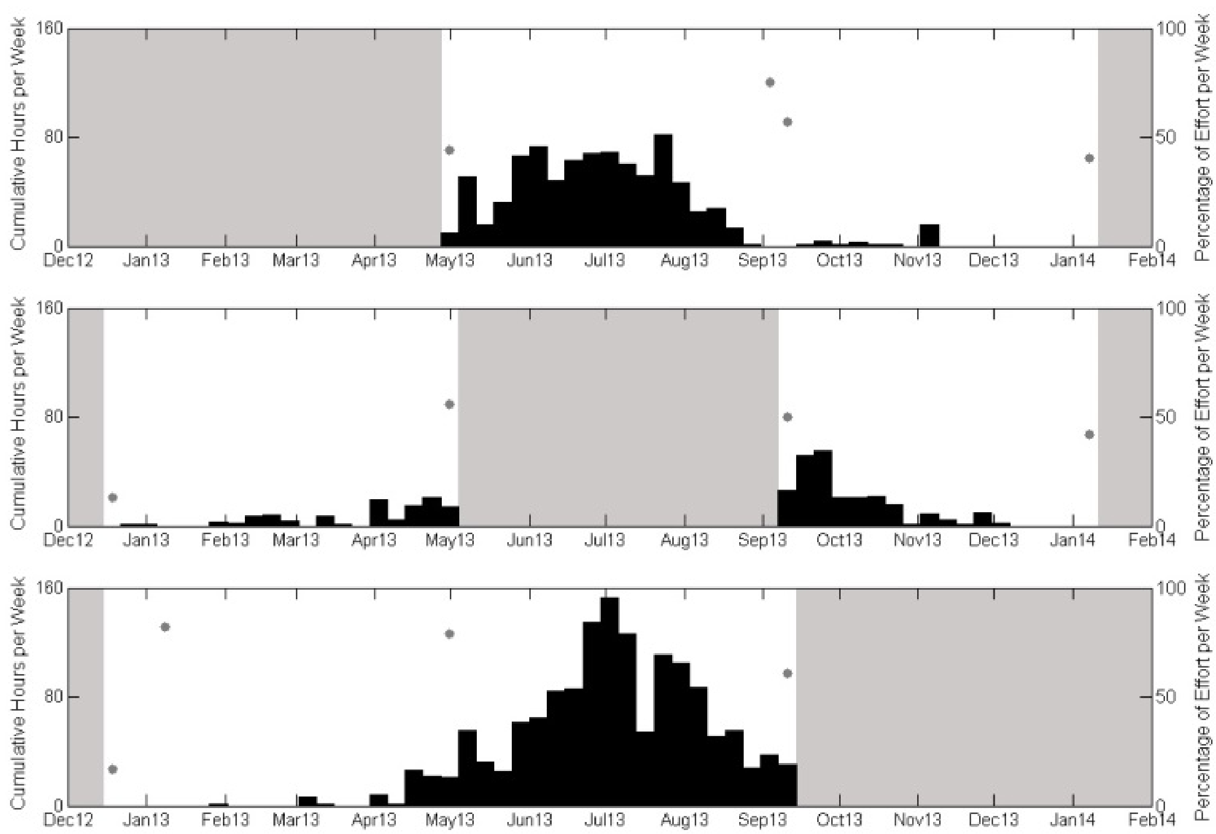

Figure 37. Weekly presence of blue whale D calls between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

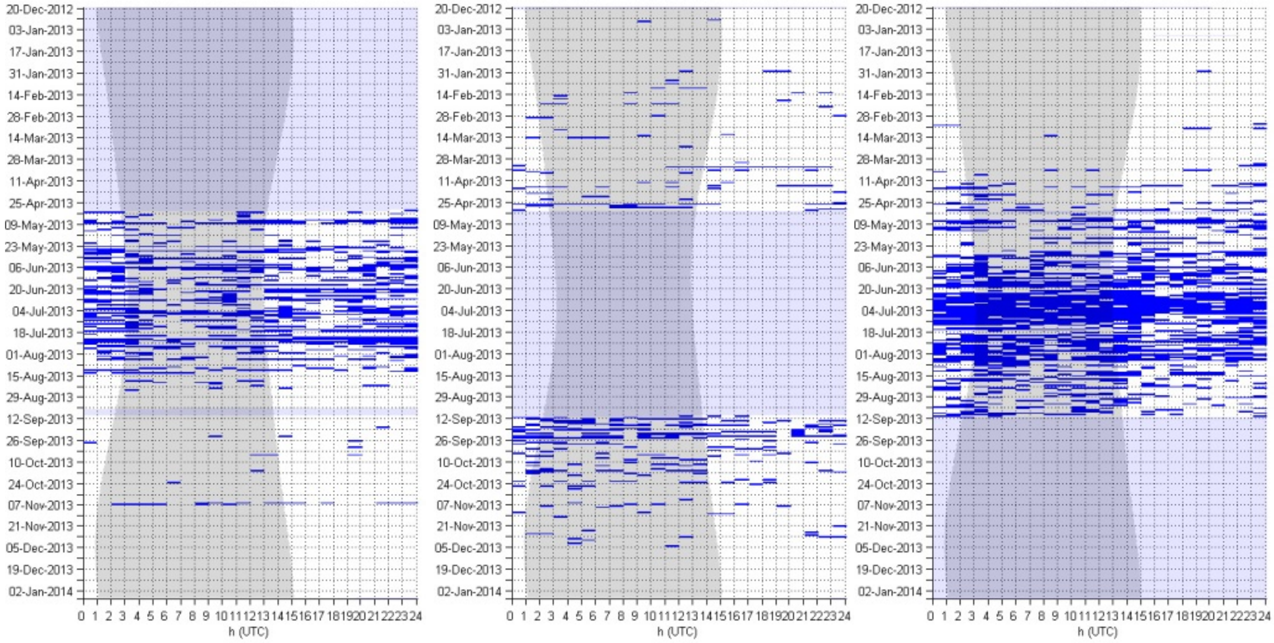

Figure 38. Blue whale D calls in hourly bins at sites M (left), H, (middle), and N (right). Effort markings are described in Figure 36.

Fin Whales

Fin whales were one of the most commonly detected baleen whale throughout the recordings.

- Fin whale 20Hz calls, associated with singing and call-countercall among animals, were the dominant fin whale call type. Peaks in fin whale acoustic index representative of 20 Hz calls occurred January – April 2013 at sites H and N, and again in January 2014 at site H. Site M had the lowest values of fin whale acoustic index with a slight increase in October – December 2013 (Figure 39).
- Fin whale 40 Hz calls were frequently recorded throughout the recordings. Hourly presence of calls peaked in January – February and in April 2013 at site H, while it was high May – August 2013 at sites M and N (Figure 40).
- There was no discernable diel pattern for fin whale 40 Hz calls (Figure 41).
- Differences in the timing of peak calling presence per call type may indicate distinct behavioral functions associated with these call types (Širović *et al.* 2013).
- These results are consistent with earlier recordings (Kerosky et al. 2013).

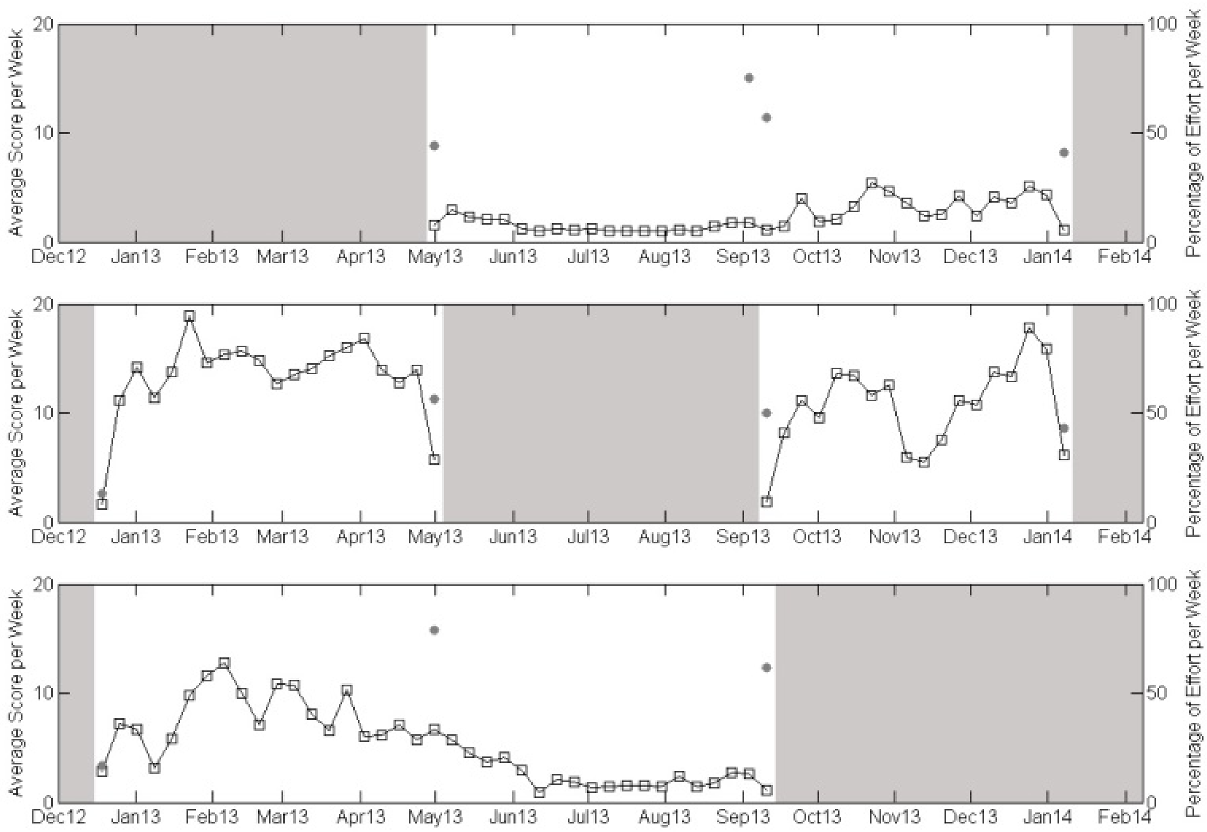

Figure 39. Weekly value of fin whale call index (proxy for 20 Hz calls) between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

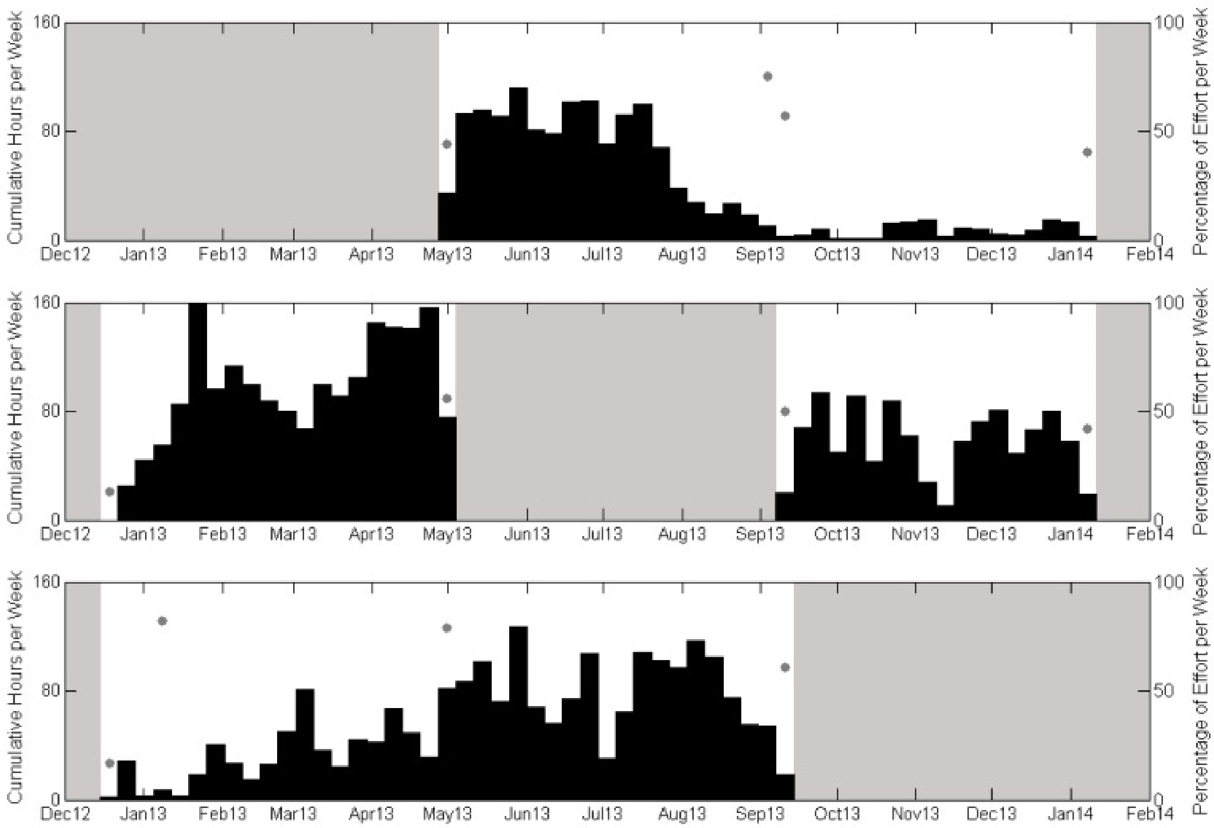

Figure 40. Weekly presence of fin whale 40 Hz calls between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

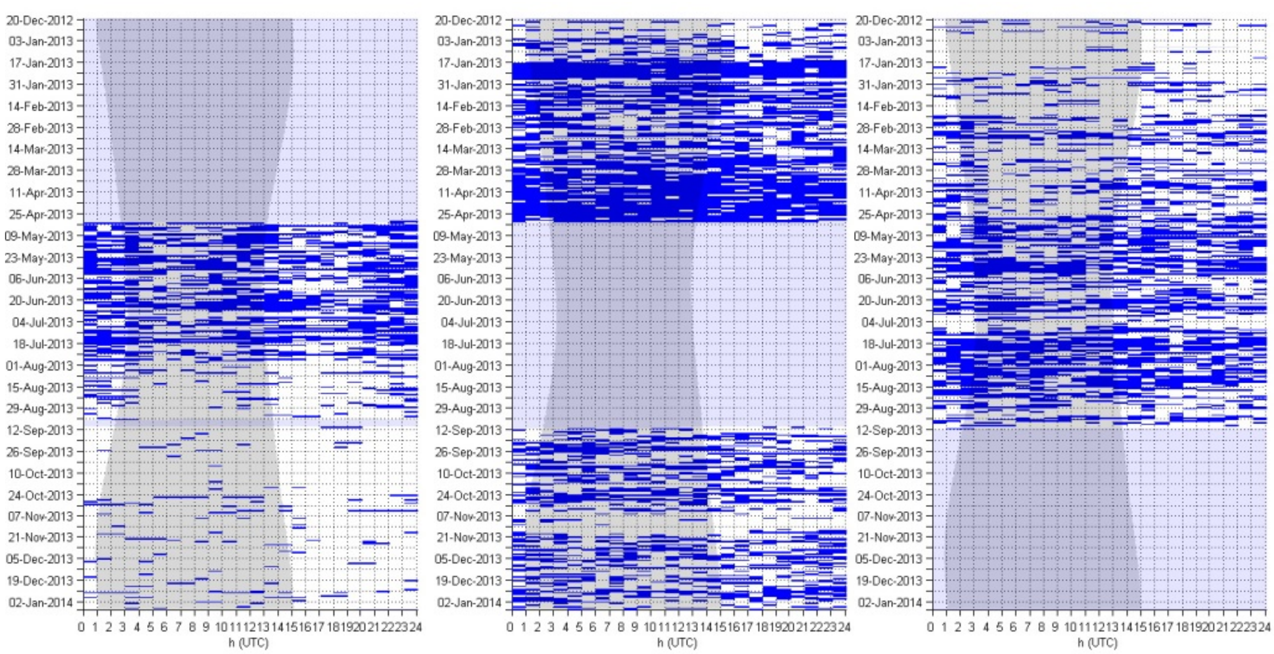

Figure 41. Fin whale 40 Hz calls in hourly bins at sites M (left), H (middle), and N (bottom). Effort markings are described in Figure 36.

Bryde's Whales

- Bryde's whale Be4 calls were most common at site H with peaks in detections occurring October and November 2013. Few Bryde's whale Be4 calls were detected at sites M and N (Figure 42).
- There was no discernable diel pattern for Bryde's whale Be4 calls (Figure 43).
- While the seasonal pattern in consistent with previously observed patterns (Kerosky et al. 2011), these results vary somewhat from Bryde's whale Be4 detections in 2012. Detections at site H peaked earlier in August and September, and more detections occurred at site N in 2012, with a peak in detections at site N occurring in July (Kerosky et al. 2013).

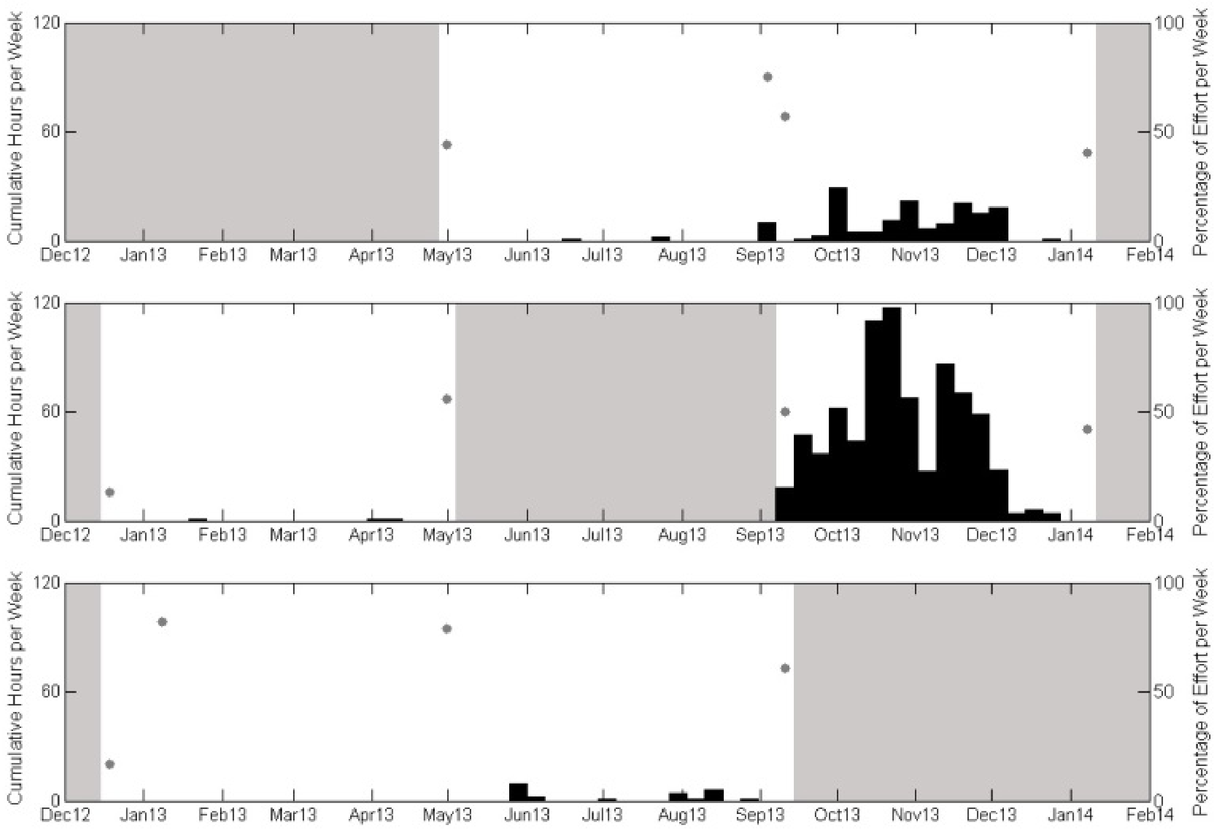

Figure 42. Weekly presence of Bryde's whale Be4 calls between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

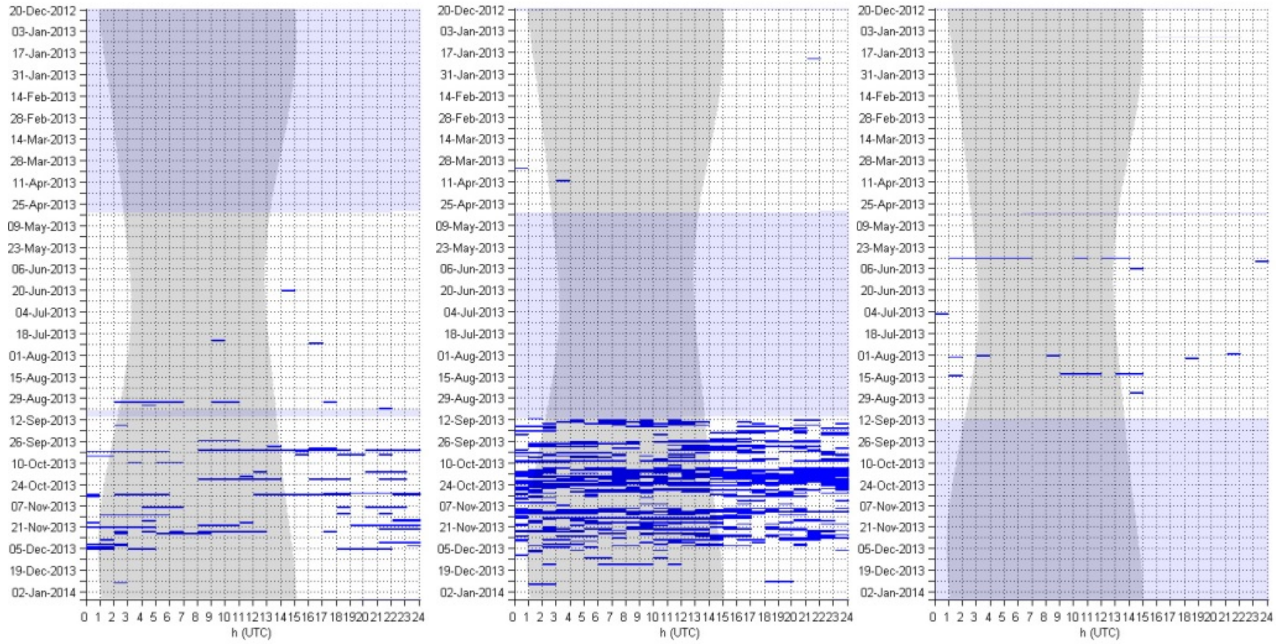

Figure 43. Bryde's whale Be4 calls in hourly bins at sites M (left), H (middle), and N (bottom). Effort markings are described in Figure 36.

Gray Whales

Gray whale M3 calls were detected in low numbers.

- Gray whale M3 calls were detected January – April 2013 at site H and in January 2013 at site N. Calls were detected in May 2013 and December 2013 – January 2014 at site M (Figure 44).
- There was no discernable diel pattern for gray whale M3 calls (Figure 45).
- The small peaks in calling presence probably represent the migration patterns of gray whales. The scarcity of calls at site H in December is likely due to the offshore location of this site, while site M is on a path between the northern Channel Islands and Catalina or San Clemente Islands, which some migrating gray whales are known to use (Sumich & Show 2011).
- These results are somewhat different from those in 2012. Site M was the only site at which there were gray whale detections in 2012 (Kerosky et al. 2013).

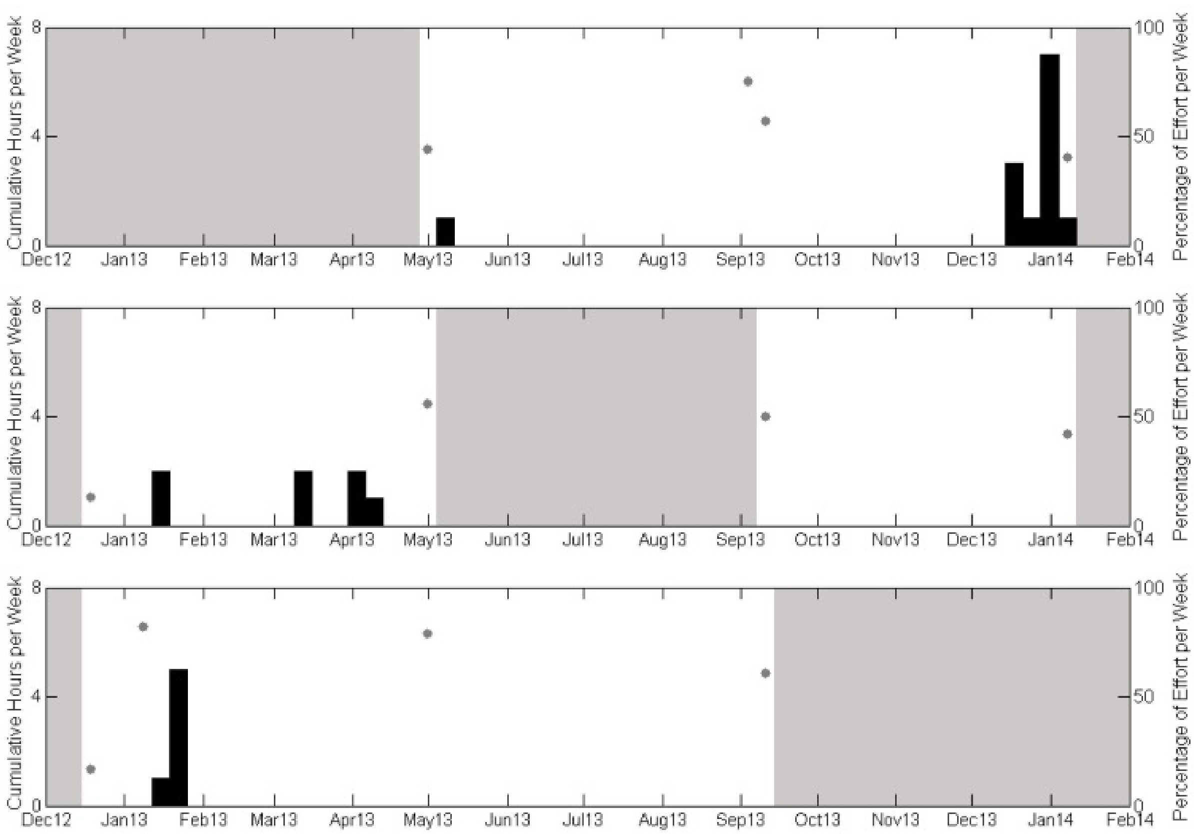

Figure 44. Weekly presence of gray whale M3 calls between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

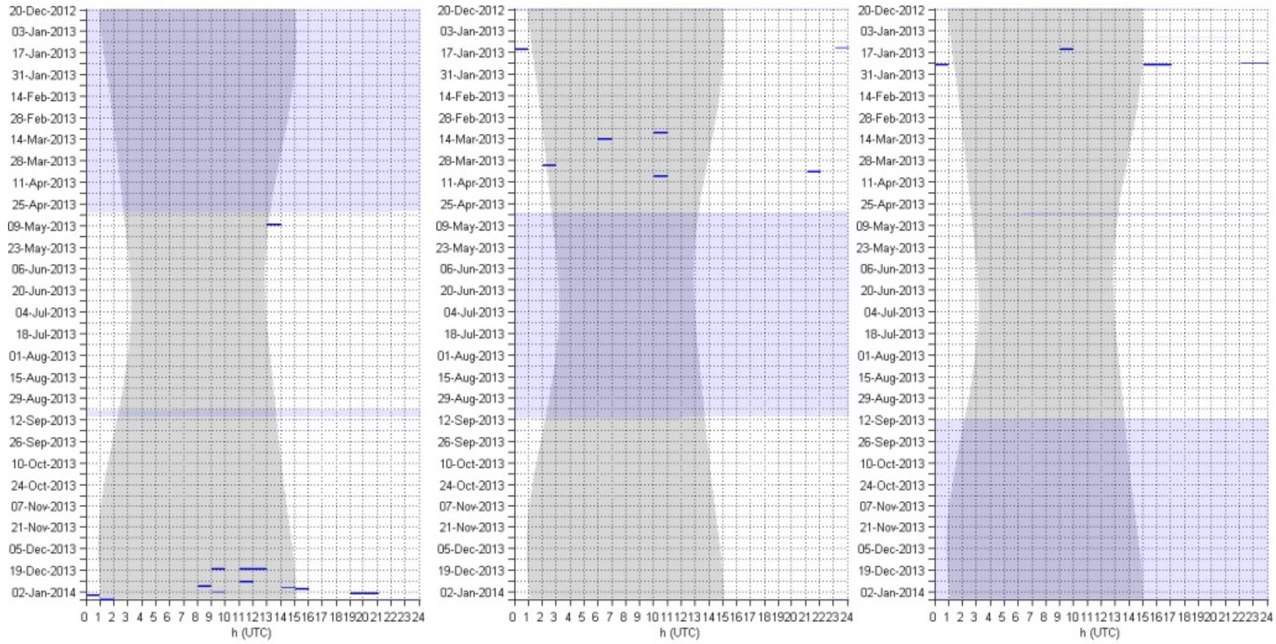

Figure 45. Gray whale M3 calls in hourly bins at sites M (left), H (middle), and N (right). Effort markings are described in Figure 36.

Humpback Whales

Humpback whales were one of the most commonly detected baleen whales throughout the recordings.

- Humpbacks whales were detected year-round and they were more common at sites H and N than at site M. Detections peaked in winter months at each site. Additional peaks in calling occurred March – April 2013 at sites H and N (Figure 46).
- There may have been slightly more calling at nighttime at sites H and M, while there was no discernable diel pattern at site N (Figure 47).
- Humpback whales are known to feed off California in spring, summer, and fall (Calambokidis *et al.* 1996). While song and non-song call types were grouped together for this analysis, peaks in calling during the winter months are likely due to song, reflecting a possible shift in primary behavior from foraging to pairing and mating.
- These results are similar to earlier reports (Kerosky et al. 2013).

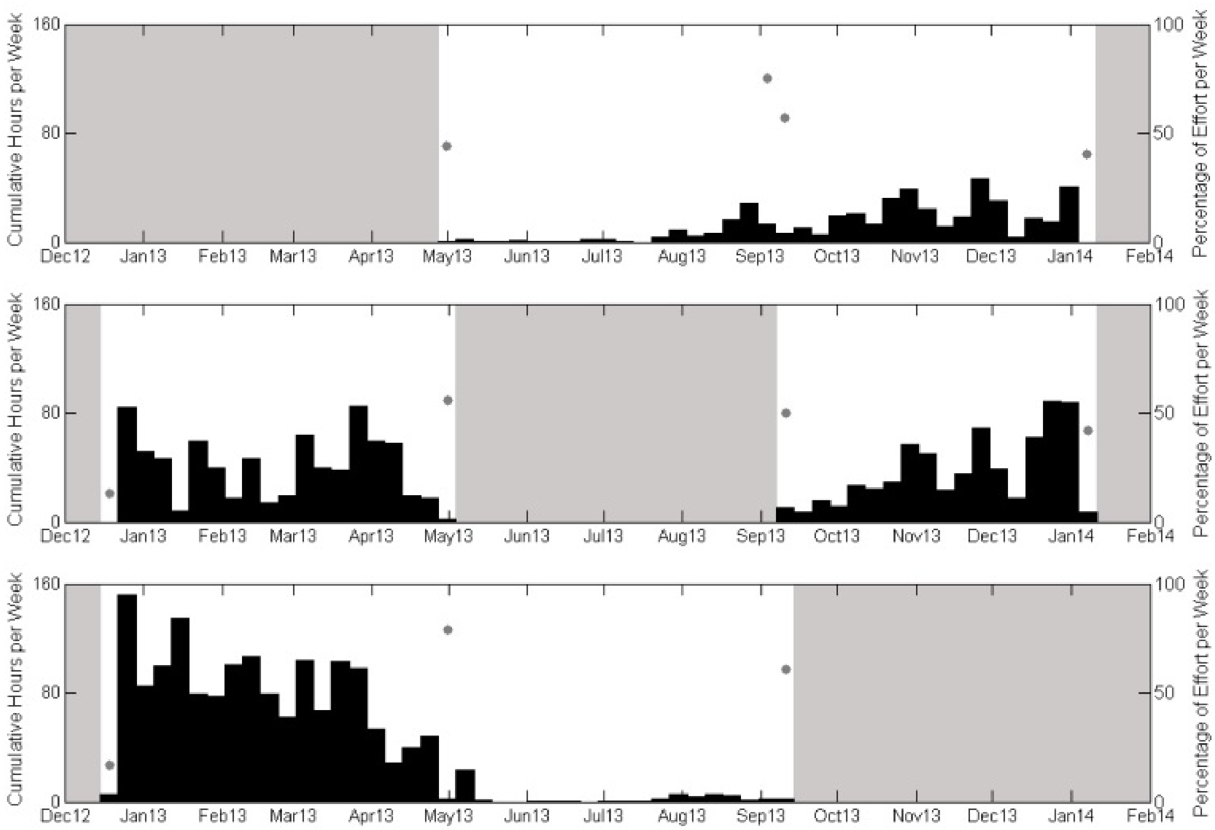

Figure 46. Weekly presence of humpback whale calls between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

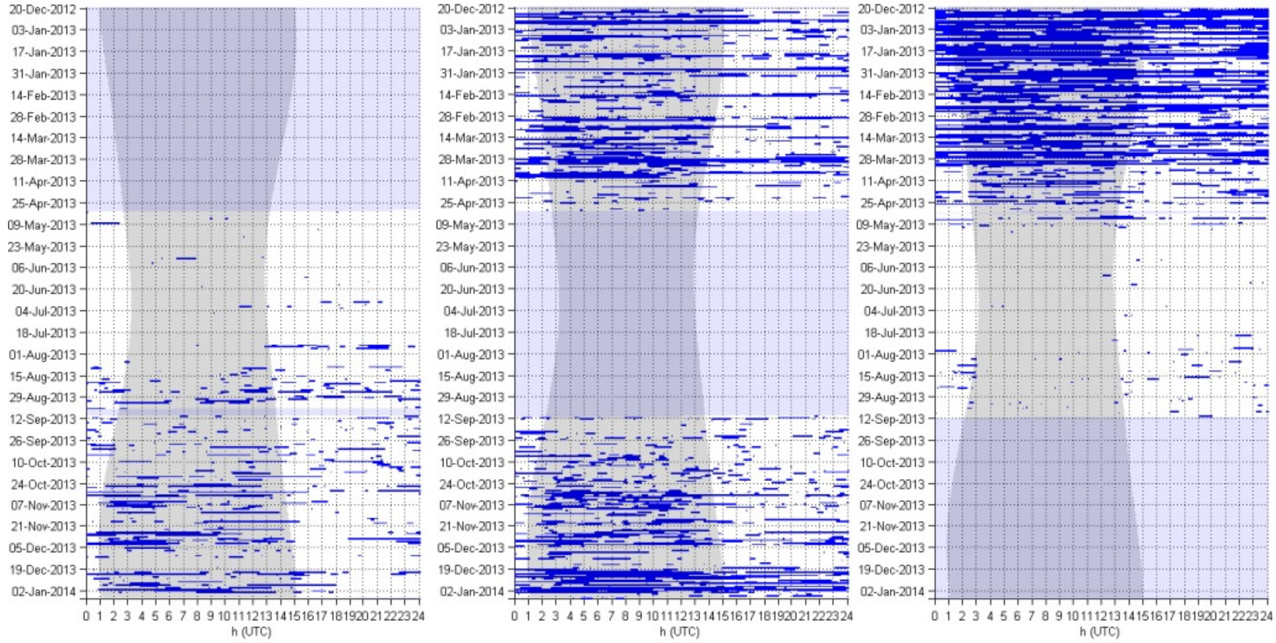

Figure 47. Humpback whale calls in one-minute bins at sites M (left), H (middle), and N (bottom). Effort markings are described in Figure 36.

Minke Whales

Minke whale boings were detected at sites H and N.

- Minke boing detections peaked in April 2013 at site N, but were detected from February through June 2013. In November there were a few detections at site H, and there were no detections at site M (Figure 48).
- There was no discernable diel pattern for minke boings (Figure 49).
- These detections are consistent with previous reports showing only occasional minke boing presence, particularly in spring and late fall (Hildebrand *et al.* 2010c, Hildebrand *et al.* 2010d, Kerosky et al. 2013).

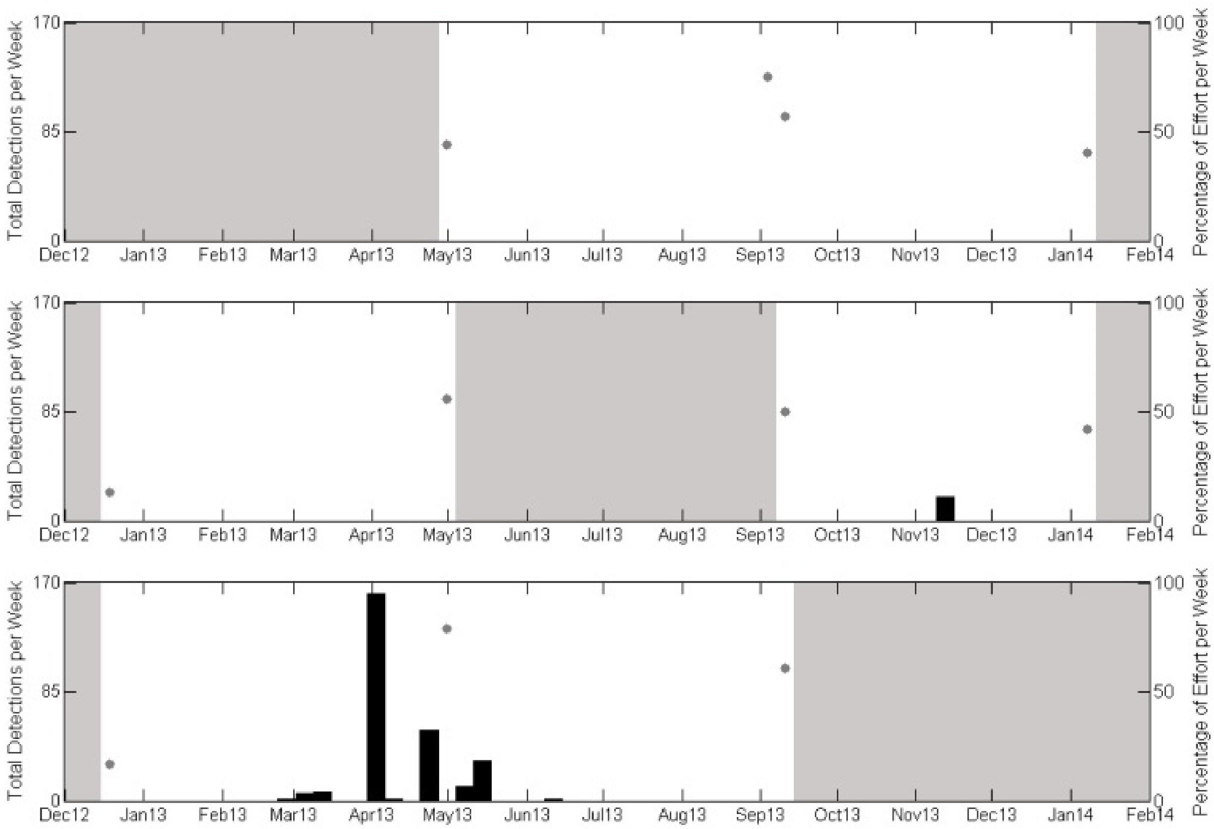

Figure 48. Weekly presence of minke whale boings between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

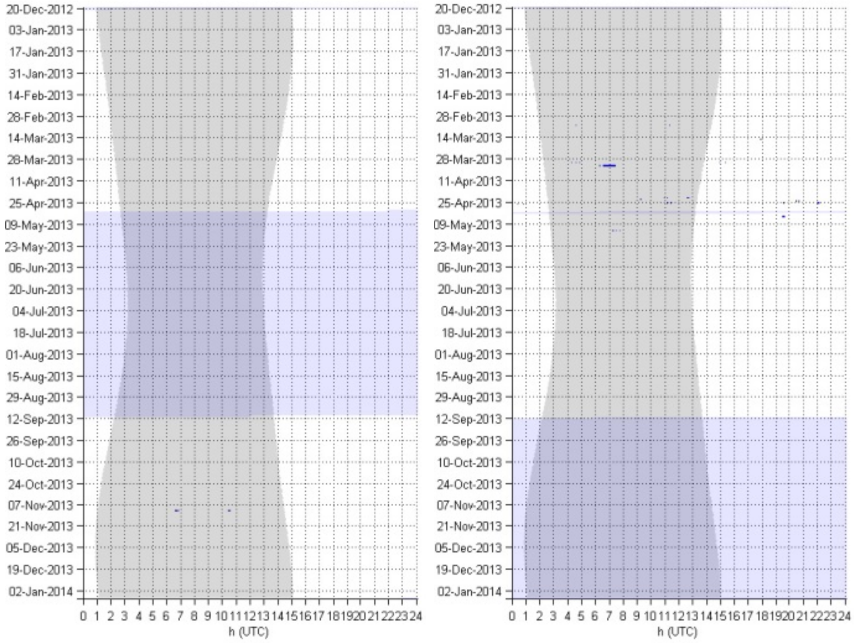

Figure 49. Minke whale boings in one-minute bins at sites H (left) and N (right). No detections occurred at site M. Effort markings are described in Figure 36.

Odontocetes

At least seven odontocete species were detected between December 2012 and January 2014: Risso's dolphins, Pacific white-sided dolphins, killer whales, sperm whales, Baird's beaked whales, and Cuvier's beaked whales. There was also an additional beaked whale-like FM pulse type, BW43, possibly produced by Perrin's beaked whales (Baumann-Pickering et al 2014). More details of each species' presence at these sites are given below.

Unidentified Odontocetes

Signals that had characteristics of odontocete sounds (both whistles and clicks), but could not be classified to species were grouped together as unidentified odontocetes.

- The largest number of detections for odontocete signals were attributed to the category "unidentified dolphin" which is most likely primarily comprised of short- and long-beaked common dolphin, and to a lesser degree bottlenose dolphin signals.
- Unidentified odontocete signals were detected throughout the year with peak acoustic activity in January 2013 and late-summer 2013 (Figure 50 and Figure 52).
- Most click and whistle activity occurred during nighttime hours, suggesting foraging at night (Figure 51 and Figure 53).
- These results are very similar to those from previous recordings (Kerosky et al. 2013).

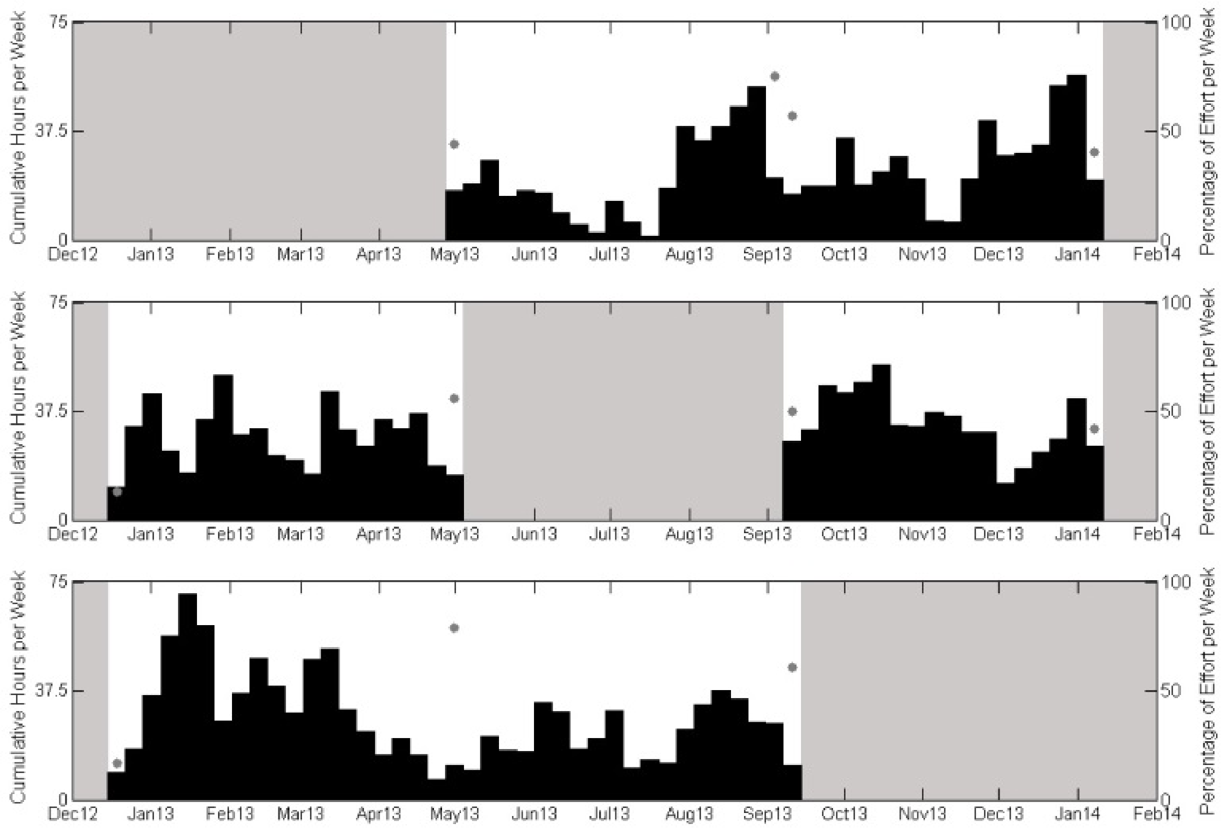

Figure 50. Weekly presence of unidentified odontocete echolocation clicks between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

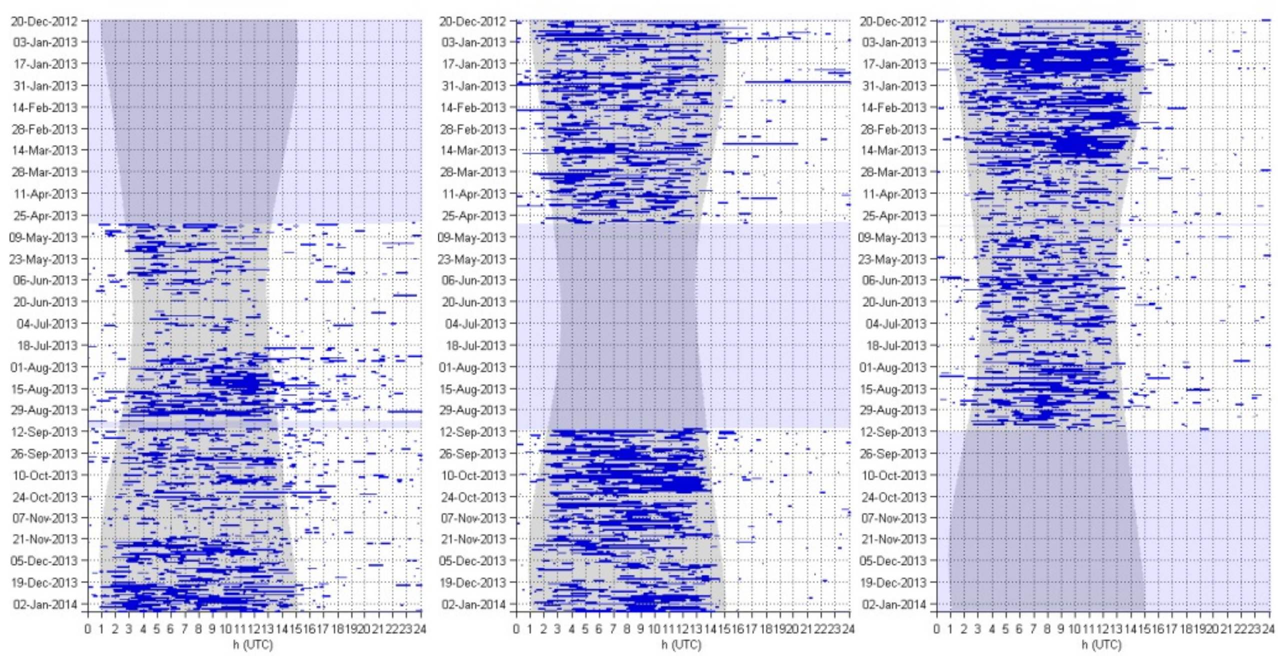

Figure 51. Unidentified odontocete clicks in one-minute bins at sites M (left), H (middle), and N (bottom). Effort markings are described in Figure 36.

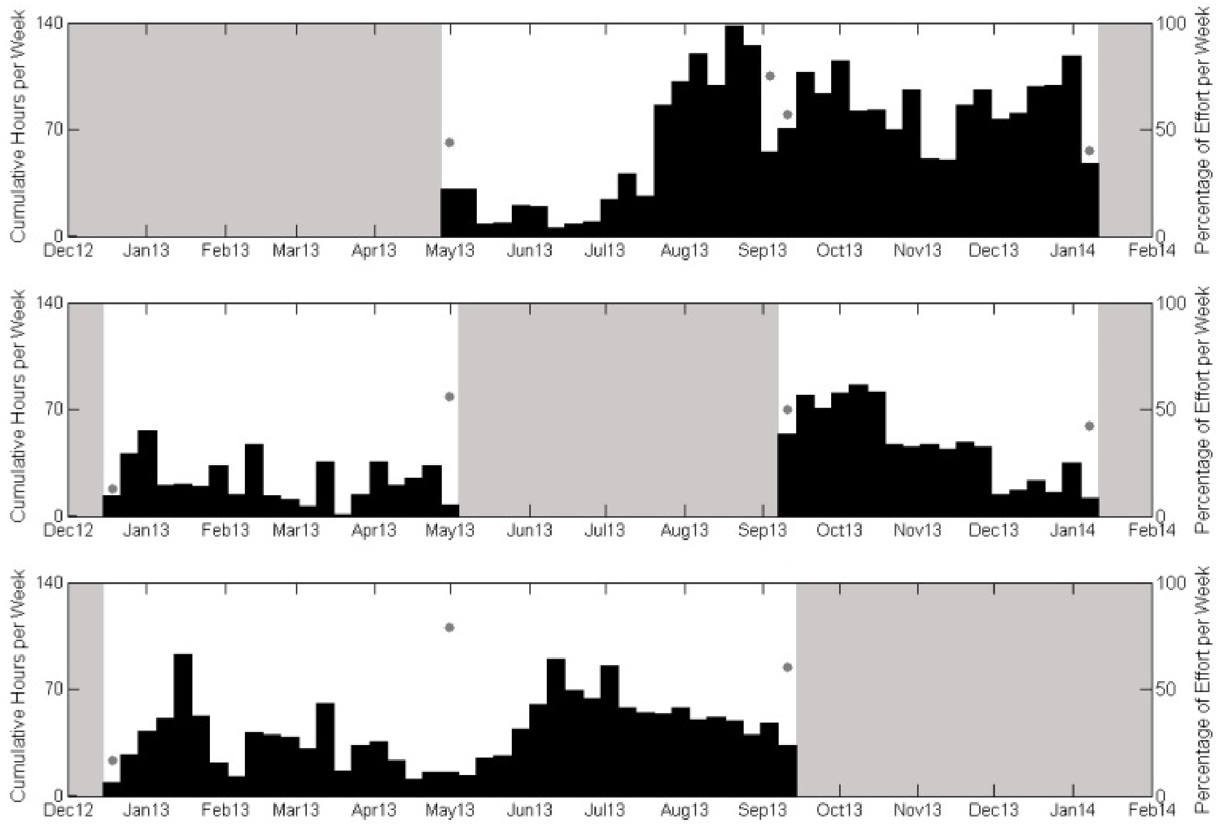

Figure 52. Weekly presence of unidentified odontocete whistles between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

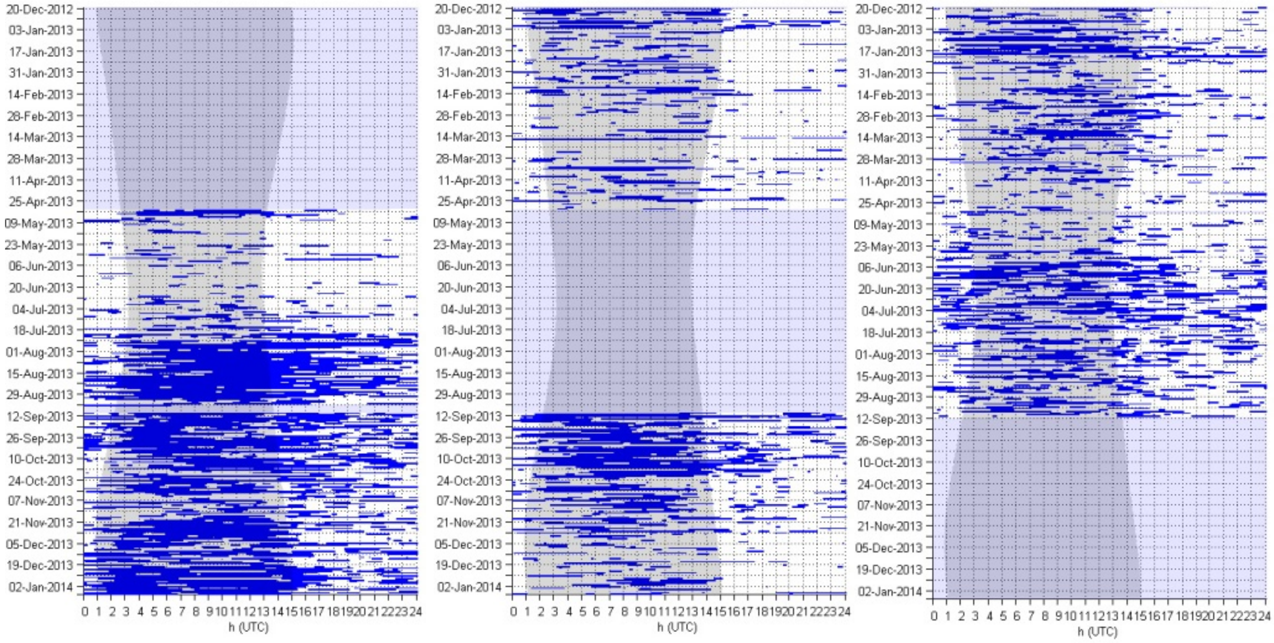

Figure 53. Unidentified odontocete whistles in one-minute bins at sites M (left), H (middle), and N (bottom). Effort markings are described in Figure 36.

Unidentified Odontocete Whistles Less Than 5 kHz

Whistles less than 5 kHz were logged as unidentified odontocete whistles less than 5 kHz.

- Unidentified whistles less than 5 kHz were recorded at all three sites, though were most common at site H (Figure 54). A peak in detections occurred at site H in late-October 2013.
- There was no discernable diel pattern for these detections (Figure 55).
- Killer whales most likely produced these whistles, though it is possible they are from blackfish or Baird's beaked whales.

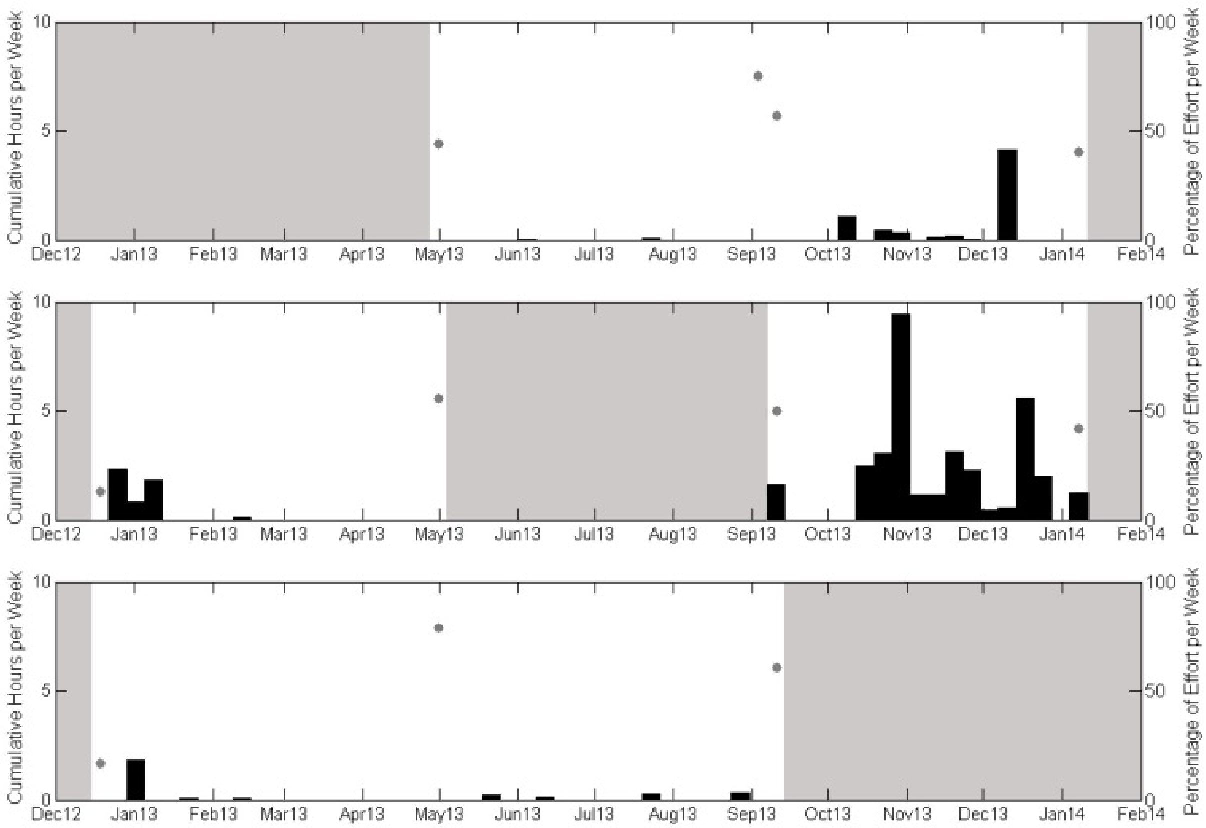

Figure 54. Weekly presence of unidentified odontocete whistles less than 5 kHz between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

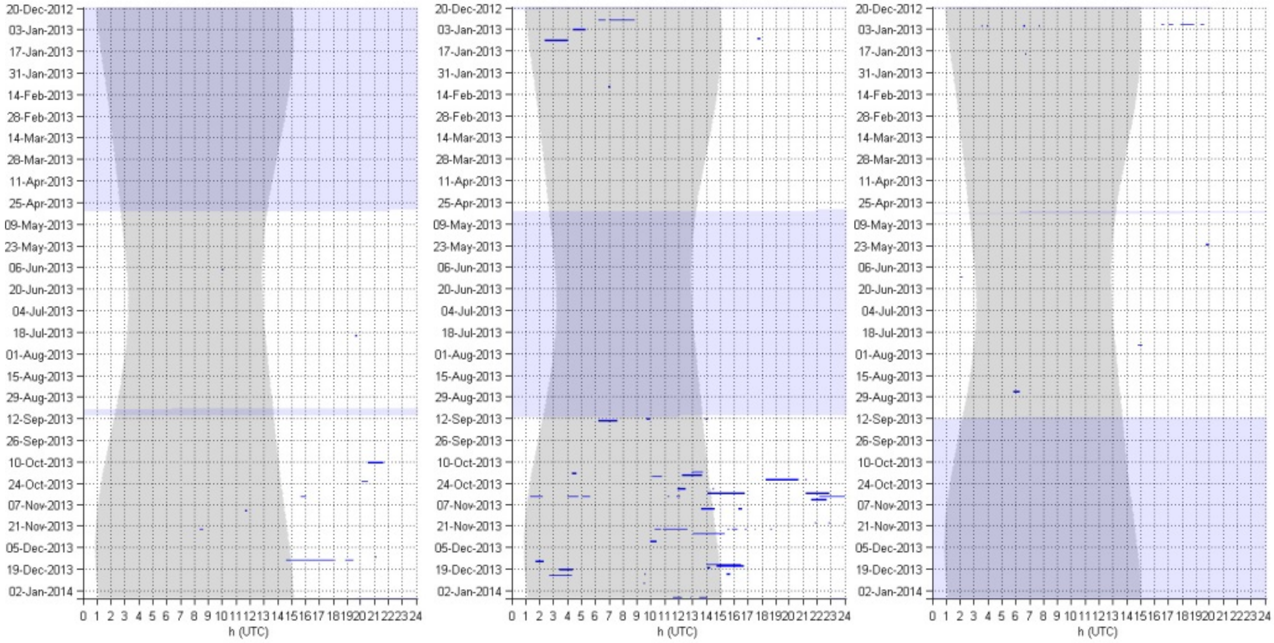

Figure 55. Unidentified odontocete whistles less than 5 kHz in one-minute bins at sites M (left), H (middle), and N (bottom). Effort markings are described in Figure 36.

Risso's Dolphins

Risso's dolphin echolocation clicks were recorded at all three sites.

- Risso's dolphin echolocation click detections peaked in February 2013 at sites H and N and in July and August 2013 at site M (Figure 56).
- A diel pattern existed for Risso's dolphin echolocation clicks with higher activity at night, indicating nighttime foraging (Figure 57). This diel pattern is consistent with other studies in the area (Soldevilla *et al.* 2010a).
- These results are similar to earlier recordings at sites M and N; however, site H has typically had fewer detections in previous years (Kerosky et al. 2013).

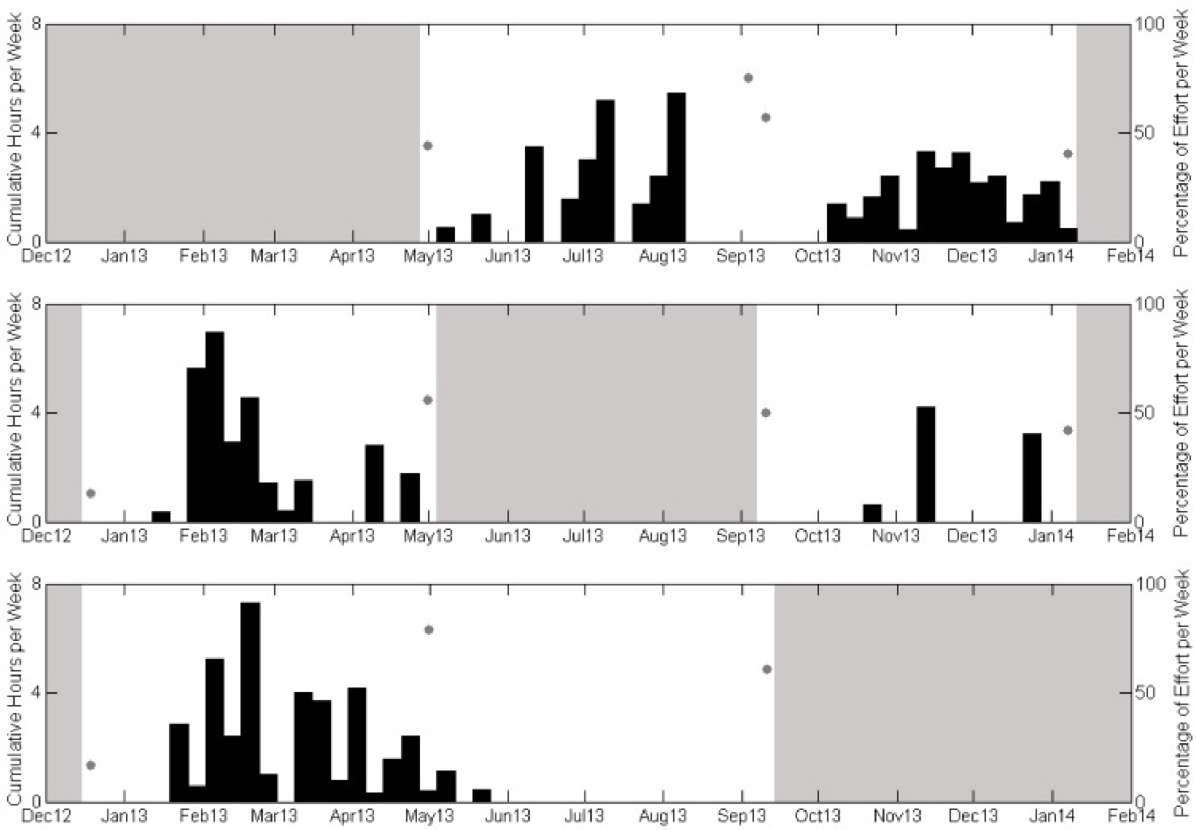

Figure 56. Weekly presence of Risso's dolphin echolocation clicks between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

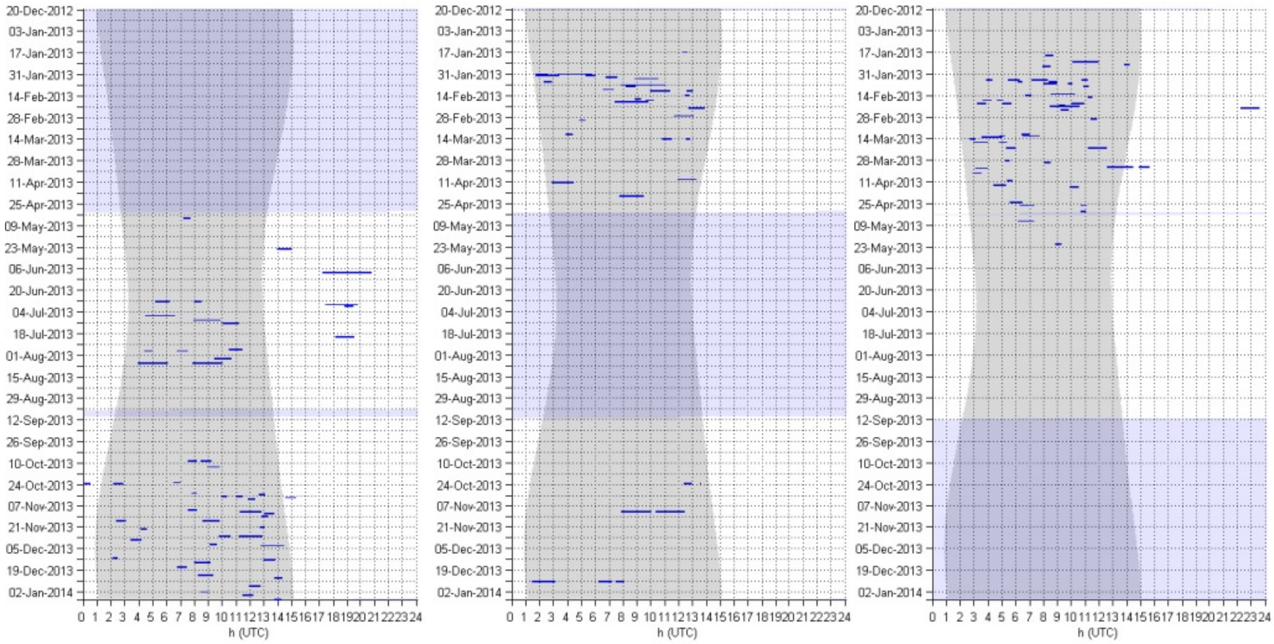

Figure 57. Risso's dolphin echolocation clicks in one-minute bins at sites M (left), H (middle), and N (bottom). Effort markings are described in Figure 36.

Pacific White-Sided Dolphins

Pacific white-sided dolphins were detected in low numbers.

- Pacific white-sided dolphin echolocation clicks were most commonly observed at site M. Detections at site M occurred in November and December 2013, as expected (Soldevilla et al. 2010b). Few Pacific white-sided dolphin echolocation clicks were detected at site N and no echolocation clicks were detected at site H (Figure 58).
- Although few clicks were detected, a possible diel pattern for Pacific white-sided dolphin clicks existed, with higher activity at night, indicating nighttime foraging (Figure 59).
- Click type A was the only type of Pacific white-sided dolphin echolocation click detected. Click type B was not detected at any of the sites.
- These results differ from those in earlier recordings. In 2012, Pacific white-sided dolphin detections were more common at site H, with peaks in detections in November 2012 at that site. There were detections of type B clicks in earlier recordings (Kerosky et al. 2013).

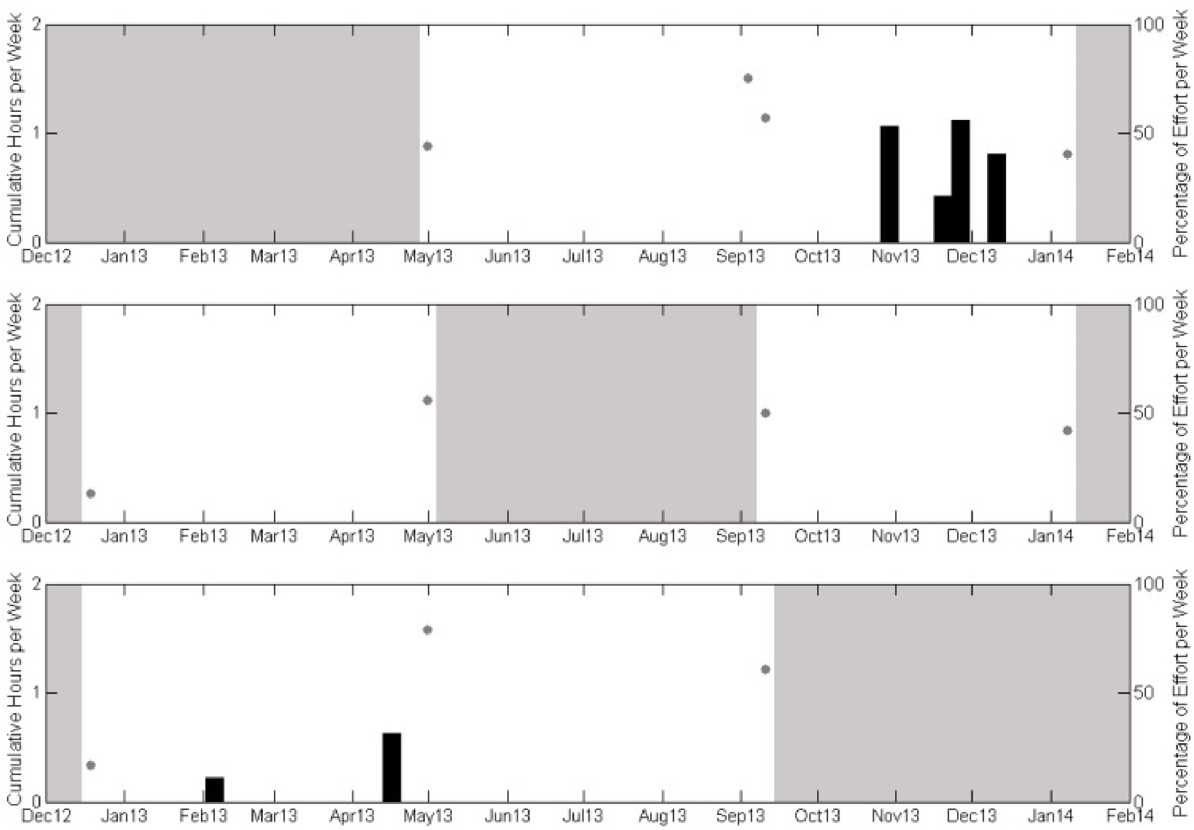

Figure 58. Weekly presence of Pacific white-sided dolphin echolocation clicks type A between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

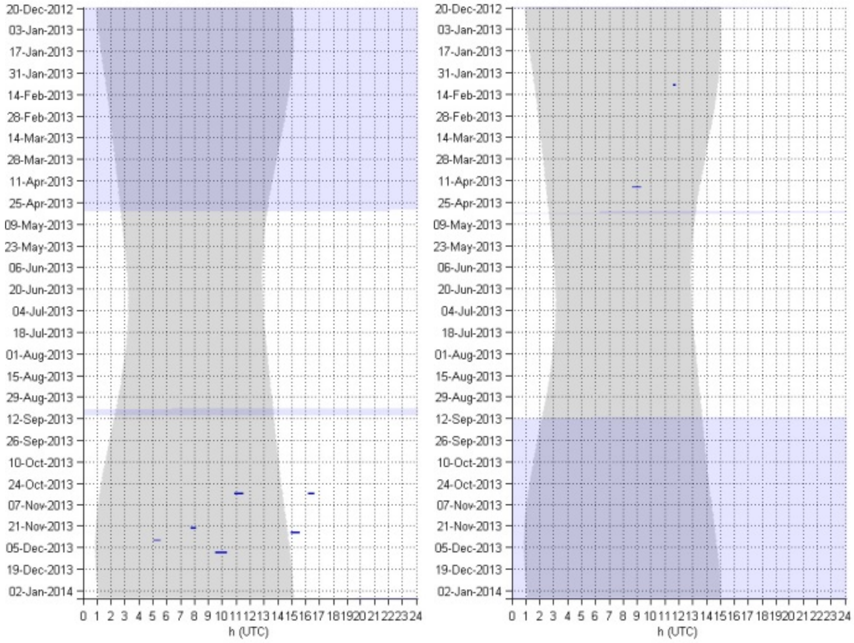

Figure 59. Pacific white-sided dolphin echolocation clicks type A in one-minute bins at sites M (left) and N (right). Effort markings are described in Figure 36.

Killer Whales

Killer whales were detected in low numbers.

- Killer whale clicks were more commonly detected at site H than sites M or N. Detections at site H peaked late-October 2013 (Figure 60).
- There was no discernable diel pattern for killer whale detections (Figure 61).
- There were no detections for pulsed calls or HFM signals.
- These results are similar to those in previous monitoring periods (Kerosky et al. 2013).

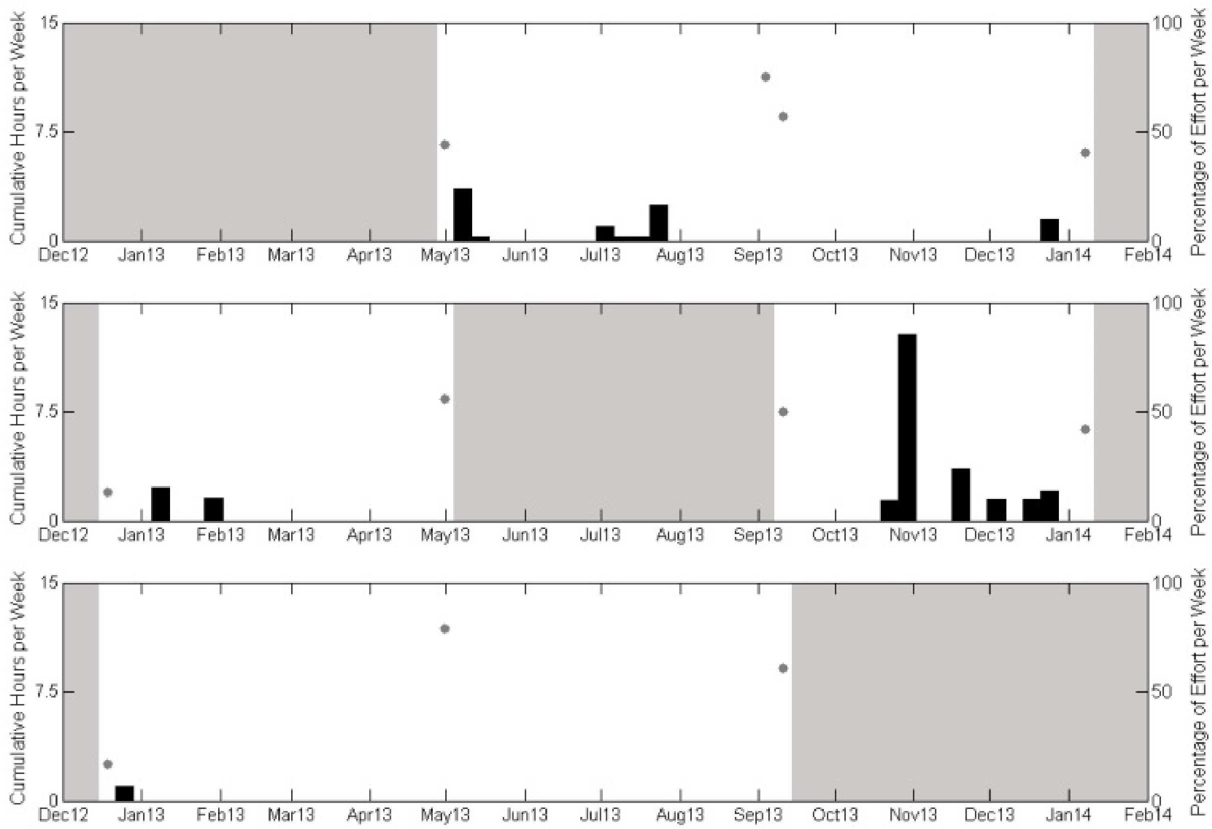

Figure 60. Weekly presence of killer whale echolocation clicks between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

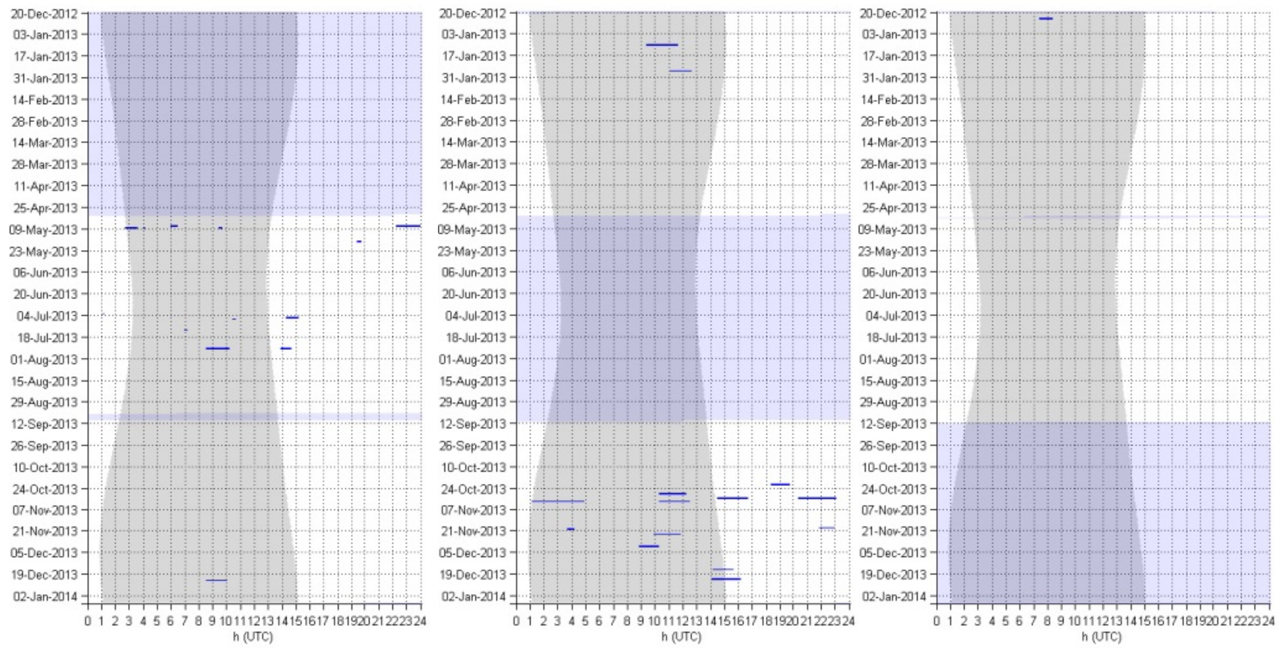

Figure 61. Killer whale echolocation clicks in one-minute bins at sites M (left), H (middle), and N (right). Effort markings are described in Figure 36.

Sperm Whales

Sperm whale echolocation clicks were detected at each site.

- Sperm whale clicks were most prevalent at site N, with a peak in detections in June 2013. Most detections at site H occurred in April 2013 and at site M in November 2013 (Figure 62).
- There was no discernable diel pattern for sperm whale echolocation clicks (Figure 63).
- In 2012 recordings there were no sperm whale detections at sites H and M (Kerosky et al. 2013).

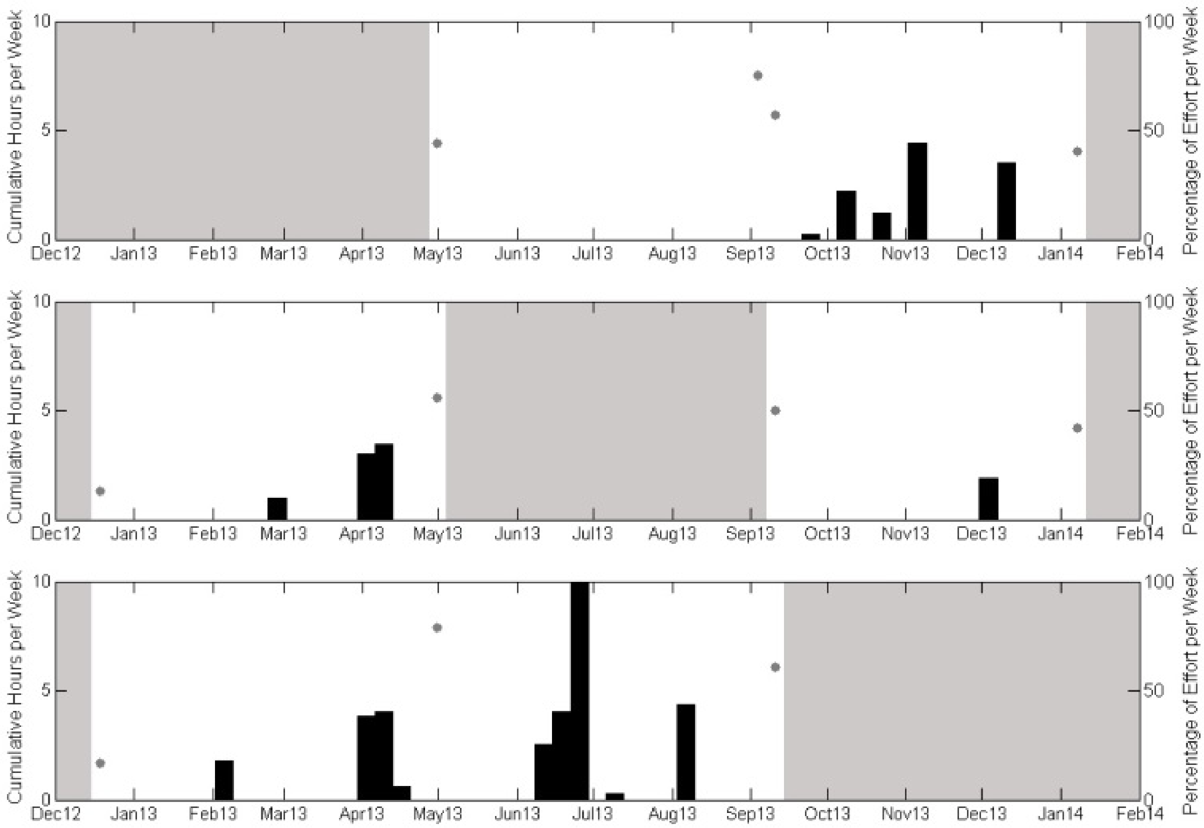

Figure 62. Weekly presence of sperm whale echolocation clicks between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

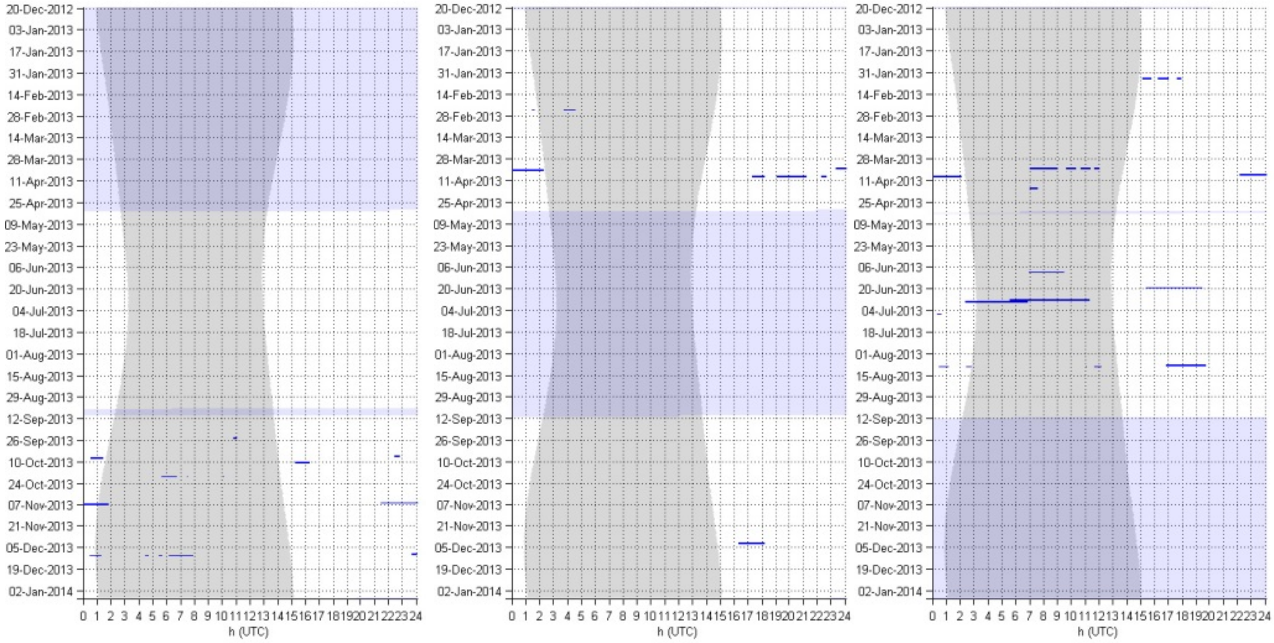

Figure 63. Sperm whale echolocation clicks in one-minute bins at sites M (left), H (middle), and N (bottom). Effort markings are described in Figure 36.

Beaked Whales

Baird's Beaked Whales

There were few detections of Baird's beaked whales.

- Baird's beaked whale FM pulses were detected in low numbers at sites M and N, mainly in June and July. There were no detections at site H (Figure 64).
- There were too few detections to determine a diel pattern for Baird's beaked whale FM pulses (Figure 65).
- These results are similar to those in previous reports (Kerosky et al. 2013).

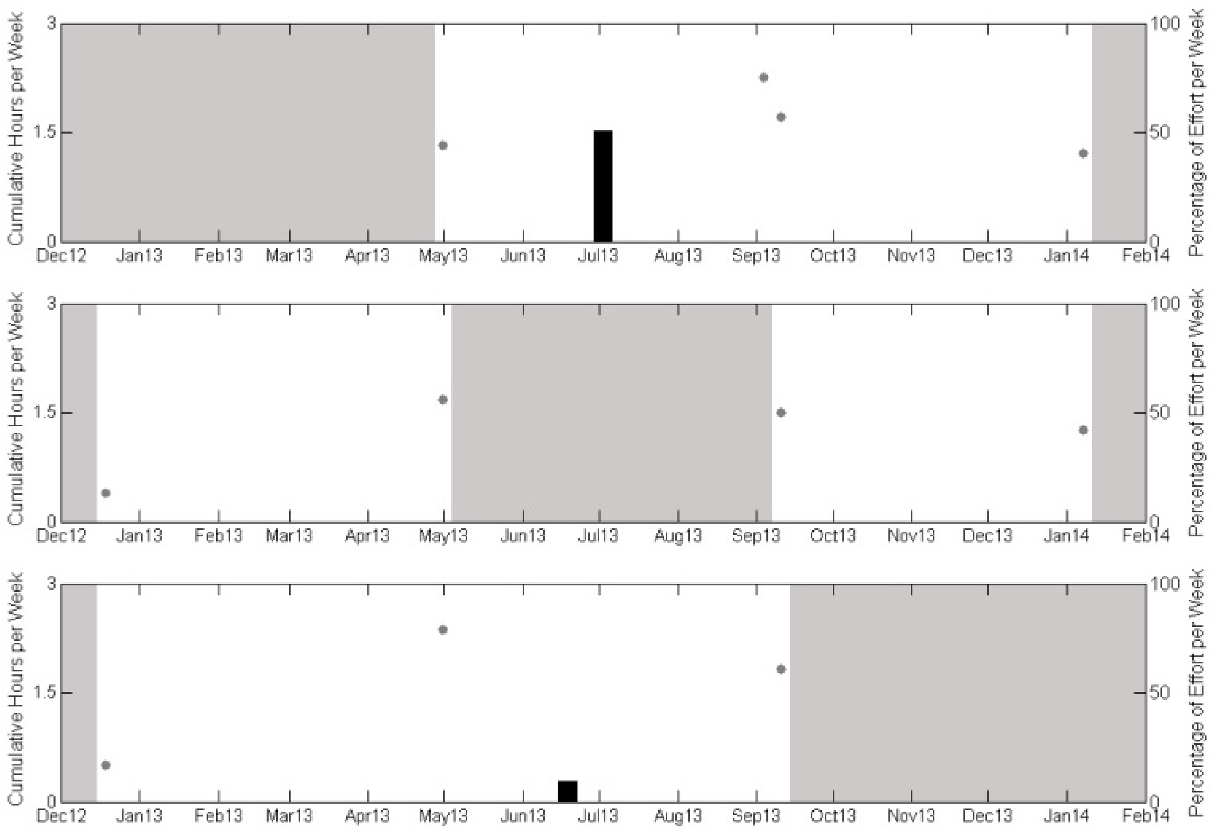

Figure 64. Weekly presence of Baird's beaked whale FM pulses between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

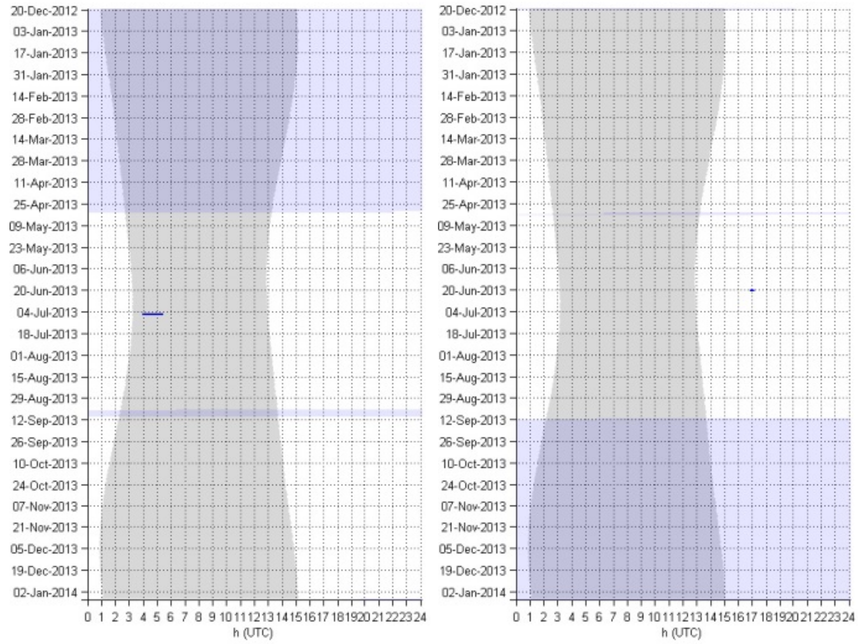

Figure 65. Baird's beaked whale FM pulses in one-minute bins at sites M (left) and N (right). Effort markings are described in Figure 36.

Cuvier's Beaked Whales

Cuvier's beaked whale was the most commonly detected beaked whale.

- Cuvier's beaked whale FM pulses were detected at each site. Detections at site H peaked in April 2013 and again in December 2013. Detections at site M were high from October to December 2013, while detections at site N peaked in May 2013 (Figure 66). There were no Cuvier's beaked whale detections in late August and early September 2013 at any of the sites.
- There was no discernable diel pattern for Cuvier's beaked whale FM pulses (Figure 67).
- These results are somewhat similar to recordings in 2012; however the peak in detections at site H occurred earlier in the year in October 2012. There were also more Cuvier's beaked whale detections overall in 2012 (Kerosky et al. 2013).

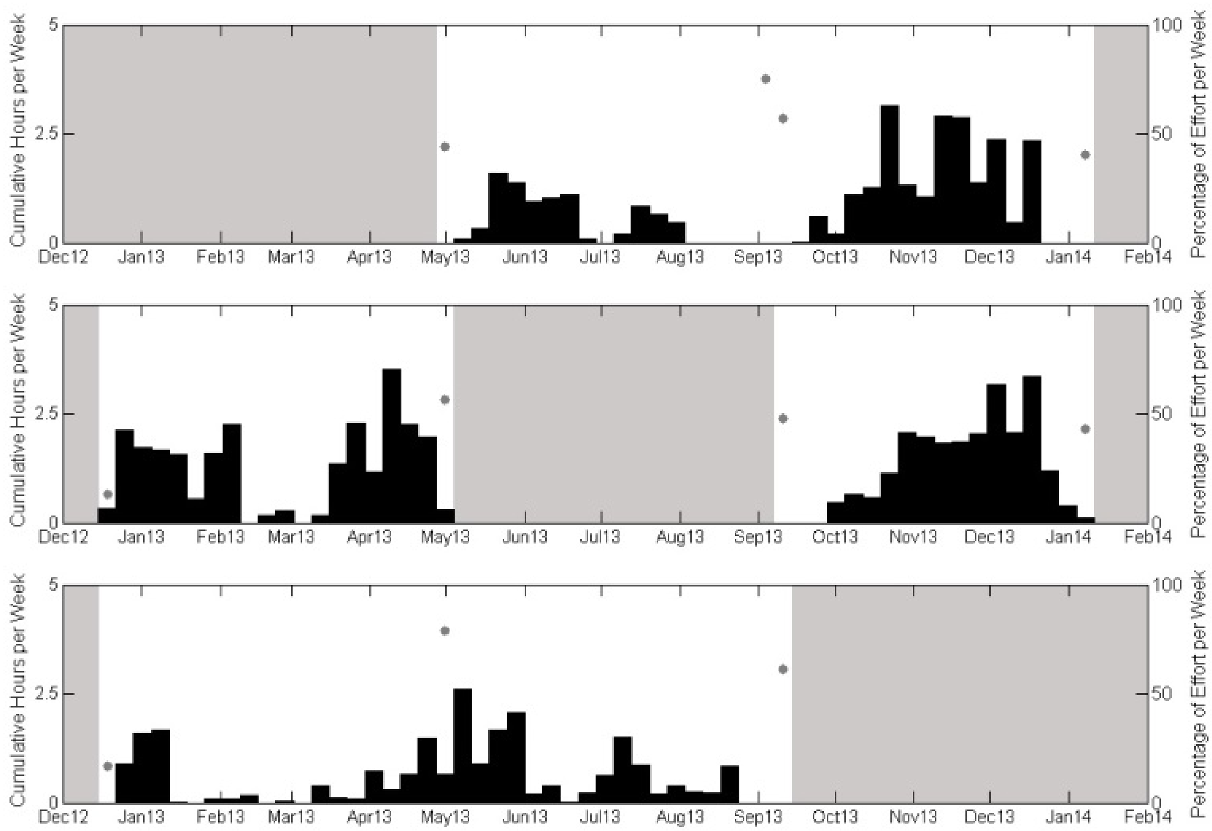

Figure 66. Weekly presence of Cuvier's beaked whale FM pulses between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

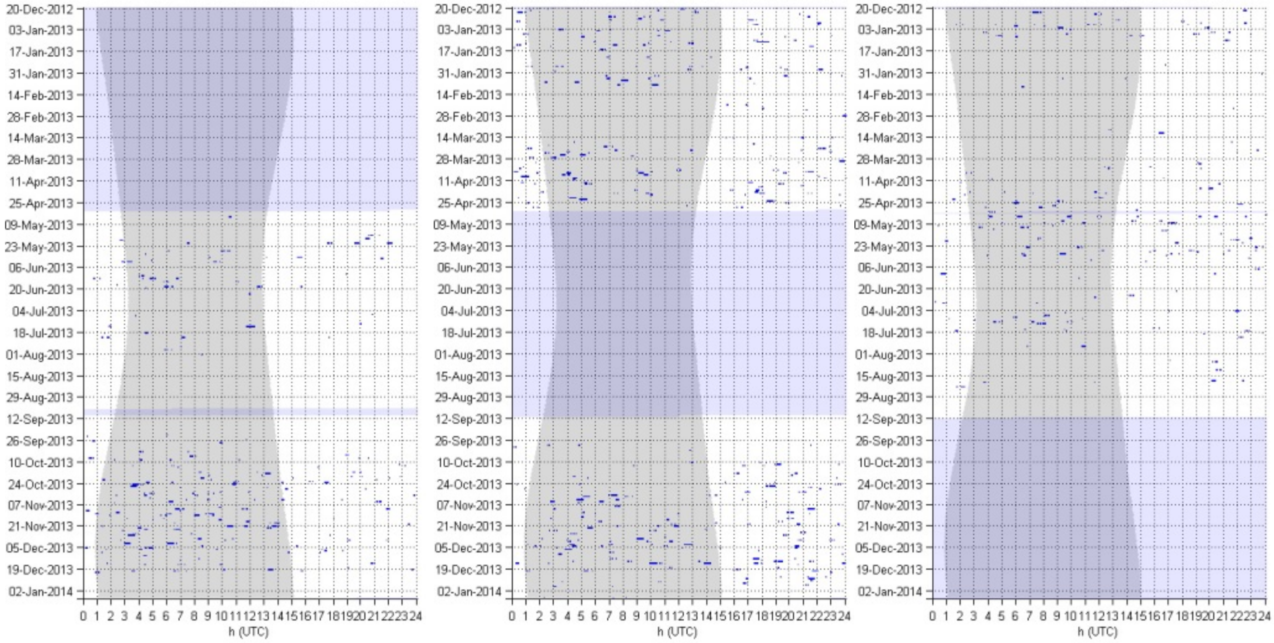

Figure 67. Cuvier's beaked whale FM pulses in one-minute bins at sites M (left), H (middle), and N (right). Effort markings are described in Figure 36.

BW43

There were very few detections of BW43 FM pulses.

- BW43 FM pulses were detected in low numbers at site N. Most detections occurred in June 2013 at site N. There were no BW43 detections at sites H or M (Figure 68).
- There were too few detections to determine a diel pattern for BW43 detections (Figure 69).
- This signal type is possibly produced by Perrin's beaked whale (Baumann-Pickering et al. 2014) a species that has only been known from five strandings along the southern California coast (Jefferson *et al.* 2008).
- These results are similar to previous recordings (Kerosky et al. 2013).

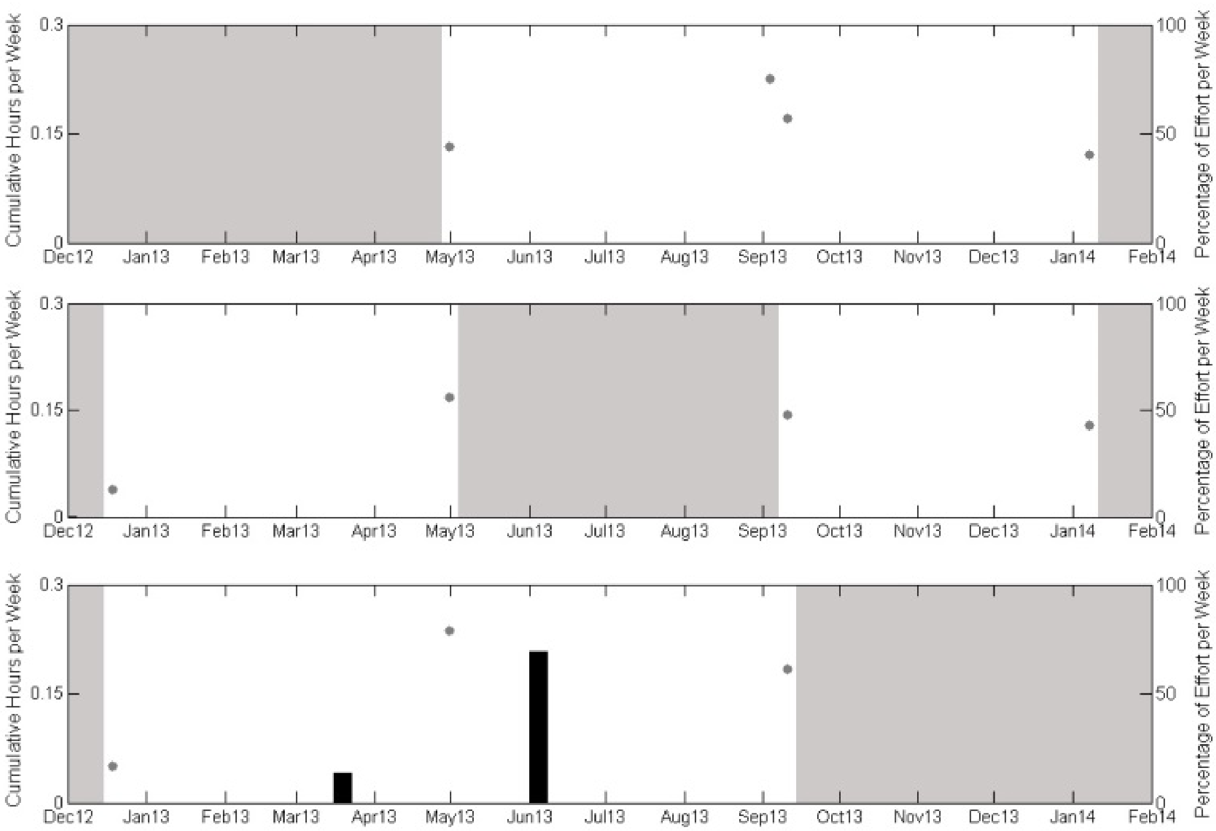

Figure 68. Weekly presence of BW43 FM pulses between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

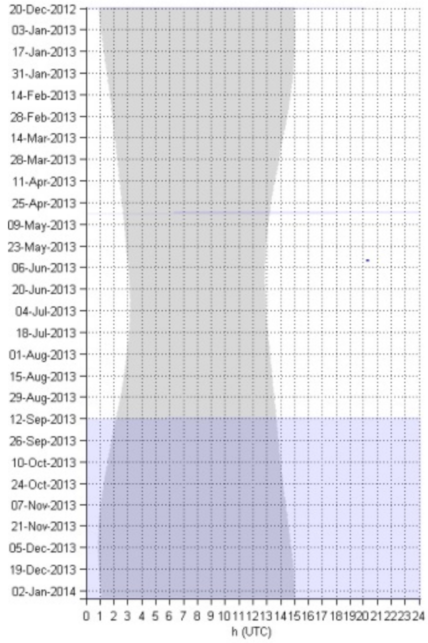

Figure 69. BW43 FM pulses in one-minute bins at site N. No BW 43 FM pulses were detected at site H and M. Effort markings are described in Figure 36.

Anthropogenic Sounds

Seven types of anthropogenic sounds were detected between December 2012 and January 2014: broadband ship noise, echosounders, explosions, underwater communications, LFA greater than 500 Hz, MFA sonar, and a new low-frequency anthropogenic tonal sound.

Broadband Ship Noise

Broadband ship noise was a common anthropogenic sound.

- Broadband ship noise was detected in every recording, though site H had the fewest detections. Site N had the most broadband ship detections with peaks in January and June 2013 (Figure 70).
- There was no discernable diel pattern for broadband ship detections at sites H and N; however, there was a slight peak in nighttime detections around 10 pm to midnight local time, and another peak just after sunrise at site M (Figure 71), indicating the preference in time of ship arrival to and departure from port.

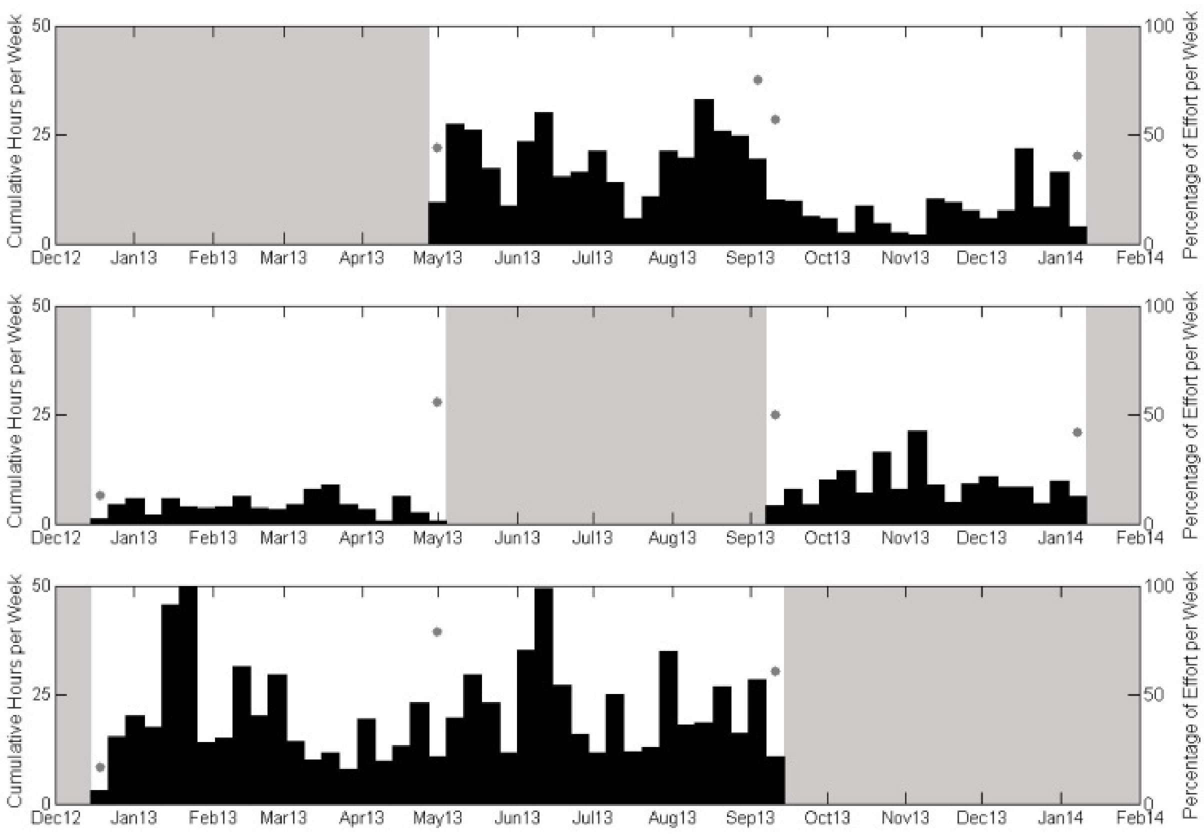

Figure 70. Weekly presence of broadband ships between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

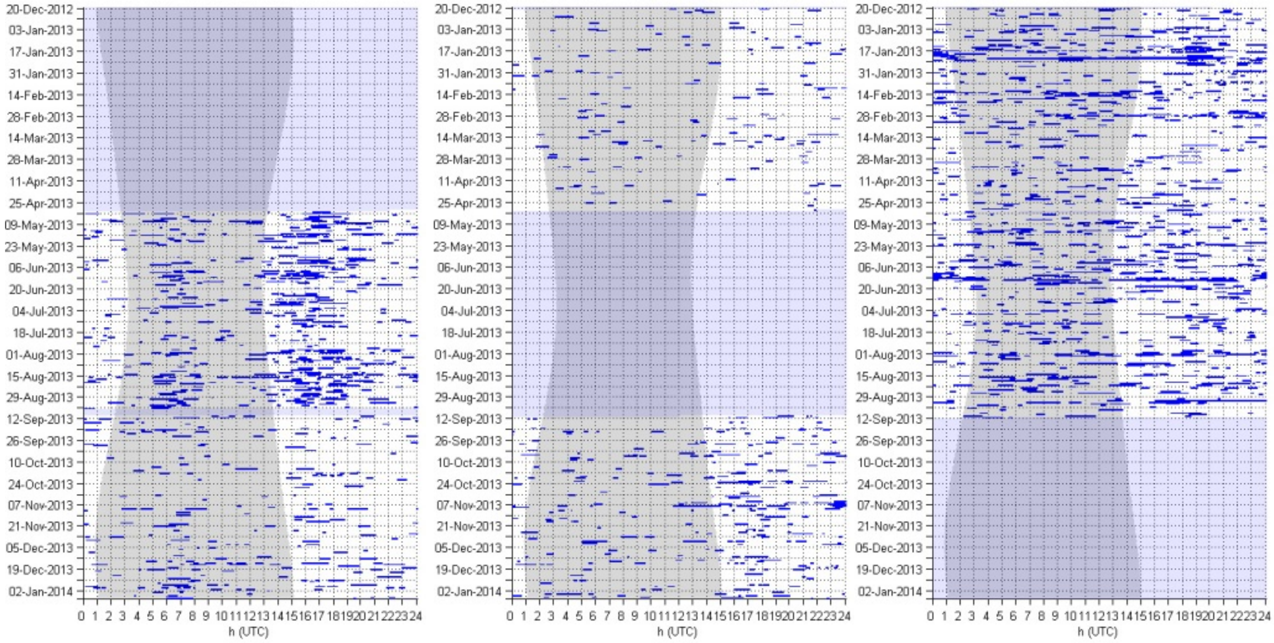

Figure 71. Broadband ship noise in one-minute bins at sites M (left), H (middle), and N (right). Effort markings are described in Figure 36.

MFA

MFA sonar was a common anthropogenic sound. The dates for major naval training exercises that were conducted in the SOCAL region between December 2012 and January 2014 are listed in Table 3. Sonar usage outside of designated major exercises is likely attributable to unit-level training. The number of sonar bouts and pings detected at each site is given in Table 4. The following bullets relate to MFA sonar less than 5 kHz:

- MFA was detected intermittently at all sites. There was a slight peak in detections in May 2013 at site M, while detections at site N peaked in April 2013 (Figure 72). The peak in April 2013 at site N is coincident with the Naval Sustainment Exercise.
- There were fewer MFA detections during the second half of the night and first few hours of the morning at sites H and N. There was no discernable diel pattern for MFA at site M (Figure 73).
- At site M, a total of 1,988 pings were detected in the frequency range 2.4 – 4.5 kHz, with a maximum received level of 140 dB pp re 1 µPa (Figure 74), and a median received level of 111 dB pp re 1 µPa (Figure 75).
- At site H, a total of 25,846 pings were detected in the frequency range 2.4 – 4.5 kHz, with a maximum received level of 164 dB pp re 1 µPa (Figure 76), and a median received level of 118 dB pp re 1 µPa (Figure 77).
- At site N, a total of 16, 397 pings were detected in the frequency range 2.4 – 4.5 kHz, with a maximum received level of 172 dB pp re 1 µPa (Figure 78), and a median received level of 132 dB pp re 1 µPa (Figure 79).
- These results are somewhat different from previous recordings. In 2012, site N had the most detections (Kerosky et al. 2013), whereas site H had the most detections in the current reporting period .

Table 3. Major naval training events in the SOCAL region between December 2012 and January 2014.

Begin Date	Type of Exercise
April 2 - 18, 2013	Sustainment Exercise
July 8 – 19, 2013	Composite Training Unit Exercise
November 6 – 15, 2013	Integrated Anti-Submarine Warfare Course II

Table 4. MFA sonar detection by site with the number of days, bouts and pings detected, along with peak-to-peak maximum and median received level in dB re: 1 µPa.

Site	# Days	# Bouts	# Pings	Maximum_{pp} dB re: 1 µPa	Median_{pp} dB re: 1 µPa
M	246	244	1988	140	111
H	249	169	25846	164	118
N	262	183	16397	172	132

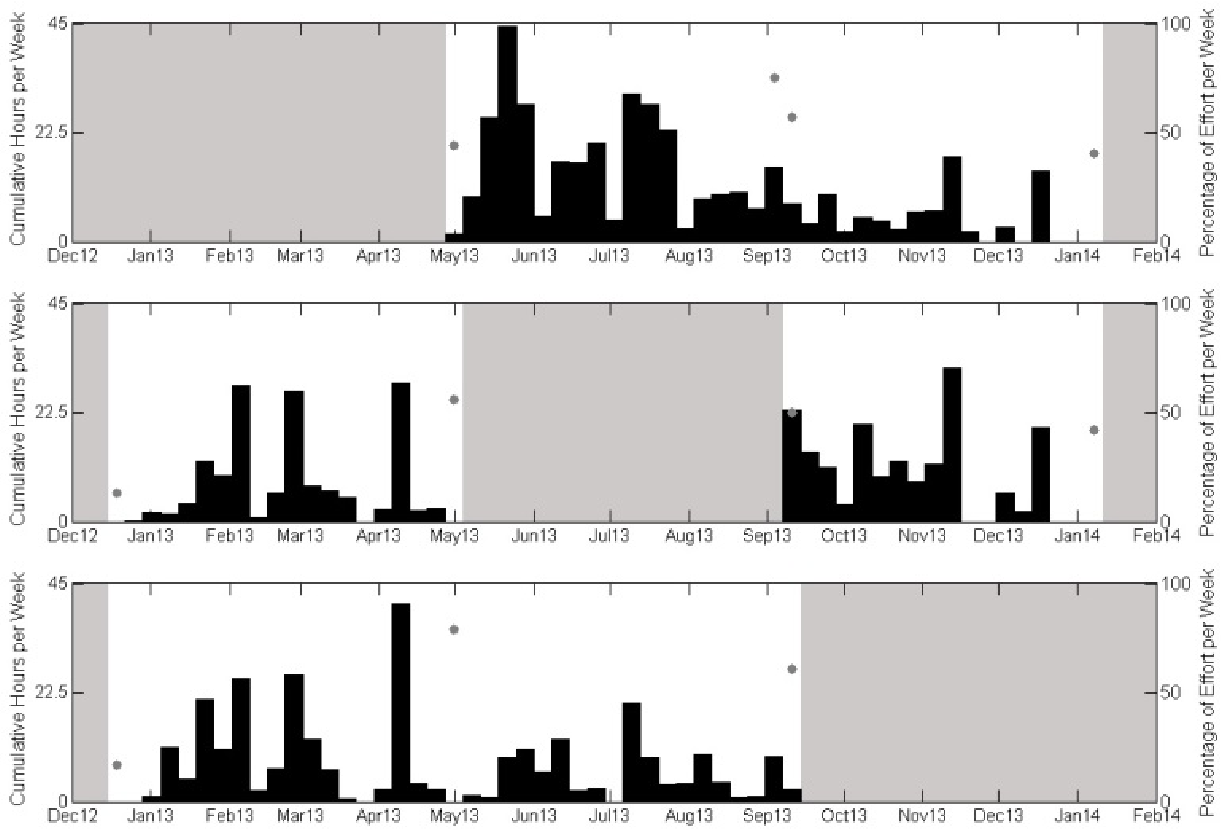

Figure 72. Weekly presence of MFA less than 5 kHz between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

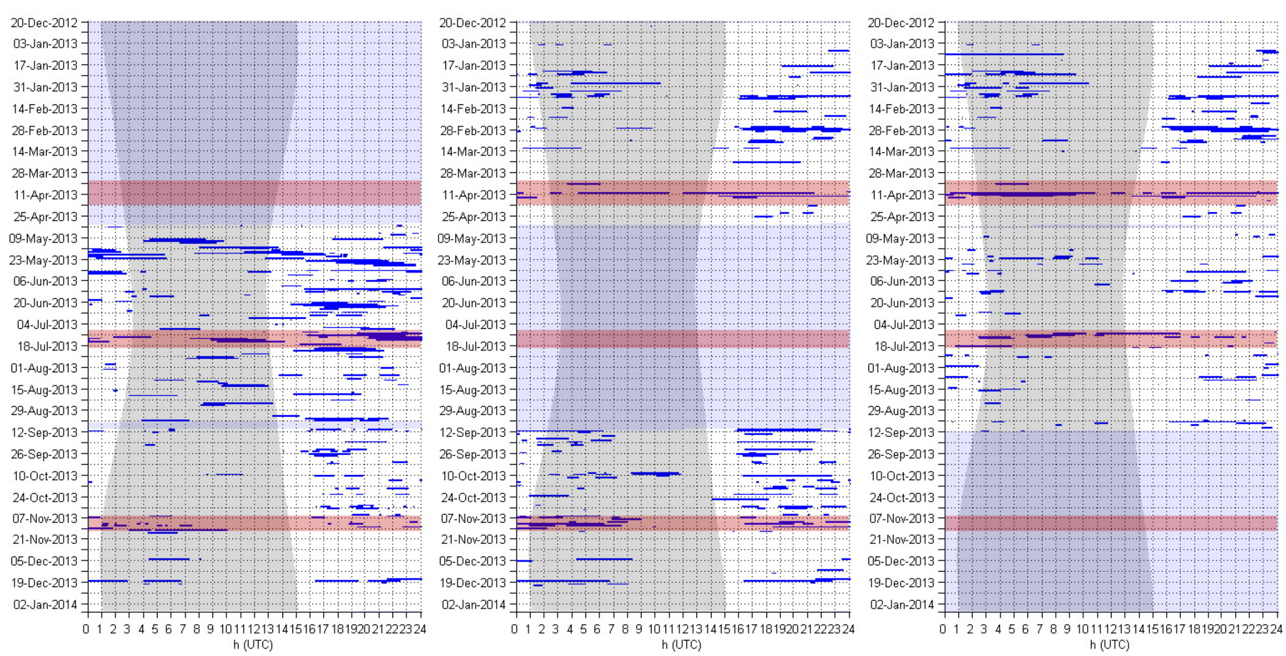

Figure 73. Major naval training events (shaded red) overlaid on MFA less than 5 kHz signals in one-minute bins at sites M (left), H (middle), and N (right). Effort markings are described in Figure 36.

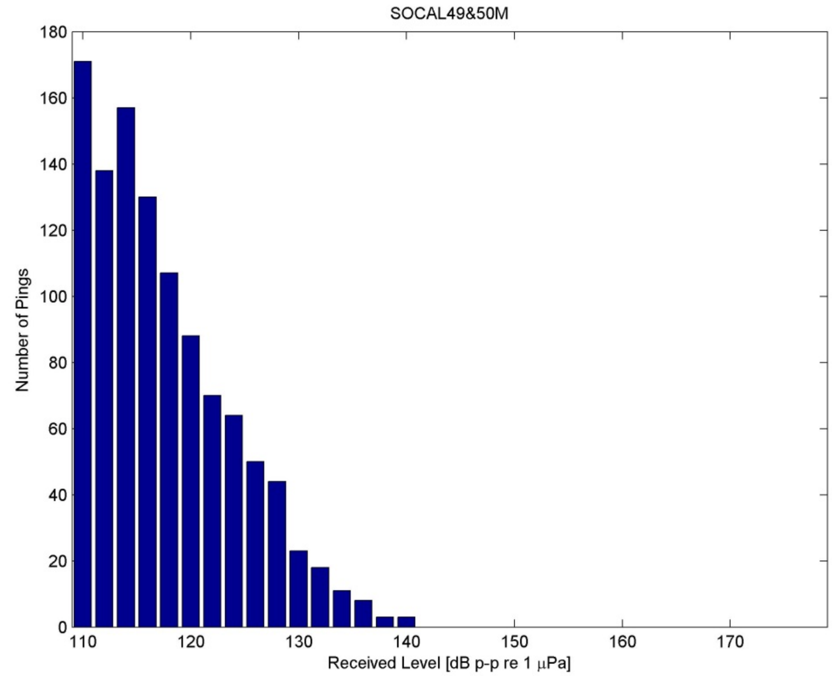

Figure 74. Distribution of number of MFA sonar pings by peak-to-peak received levels at site M.

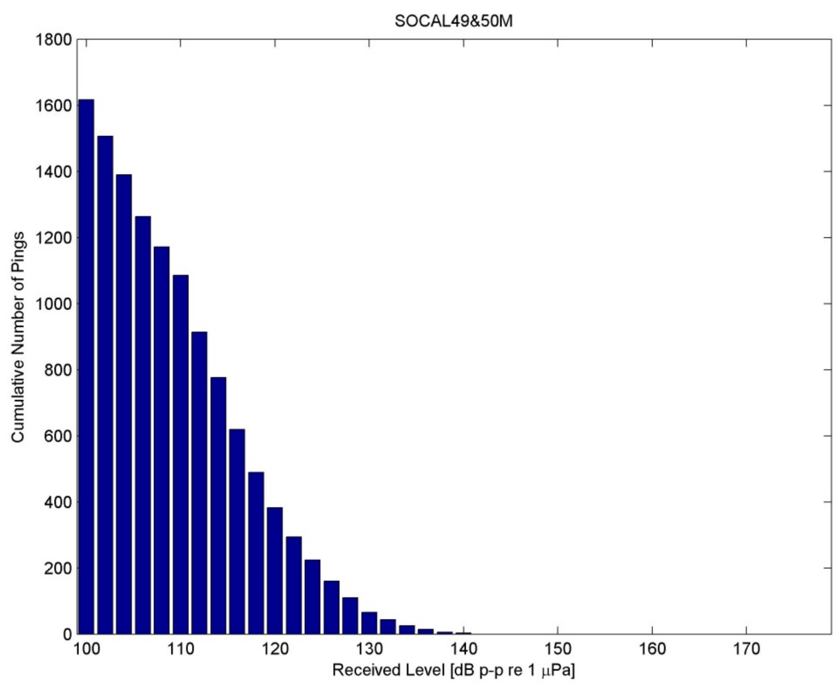

Figure 75. Cumulative distribution of MFA sonar peak-to-peak received levels at site M.

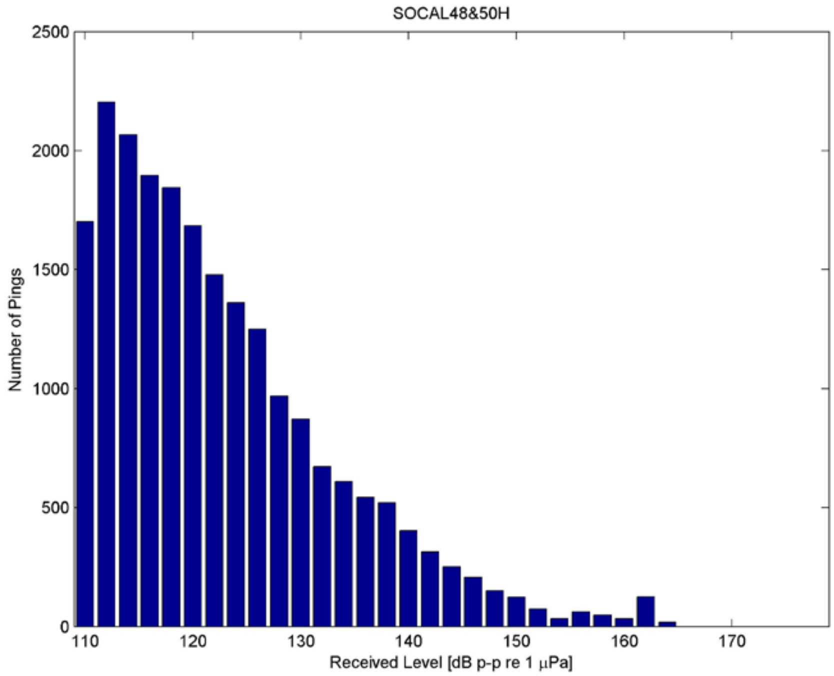

Figure 76. Distribution of number of MFA sonar pings by peak-to-peak received levels at site H.

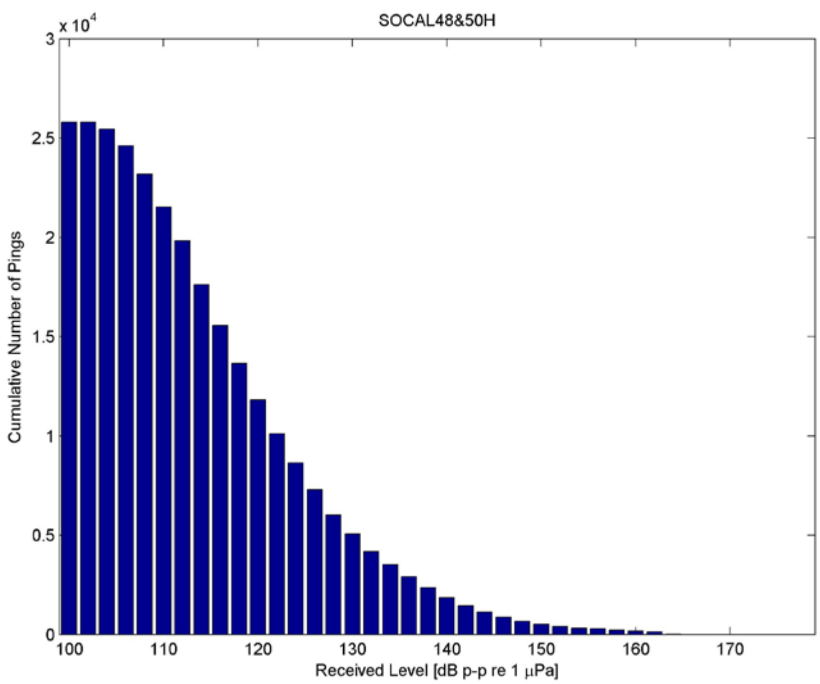

Figure 77. Cumulative distribution of MFA sonar peak-to-peak received levels at site H.

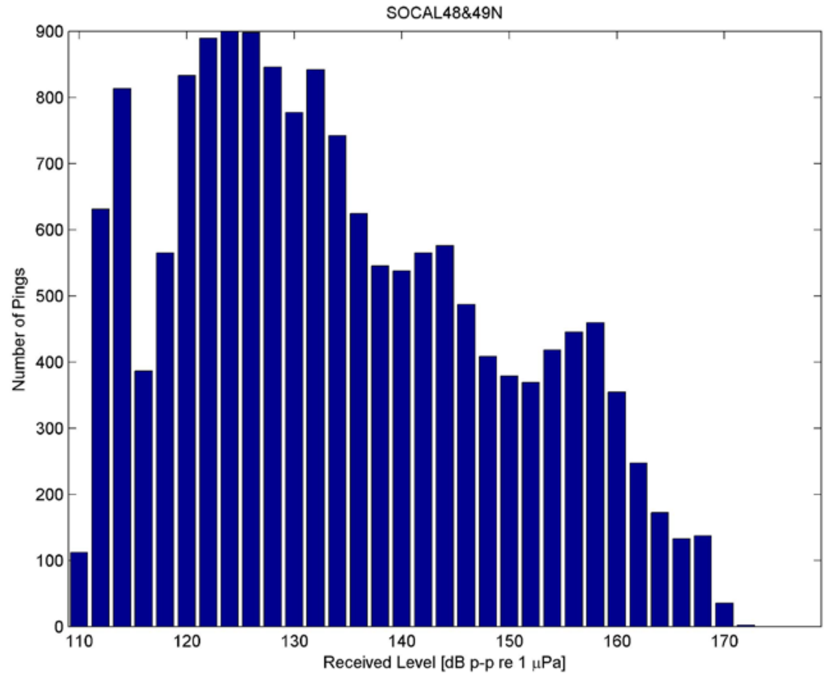

Figure 78. Distribution of number of MFA sonar pings by peak-to-peak received levels at site N.

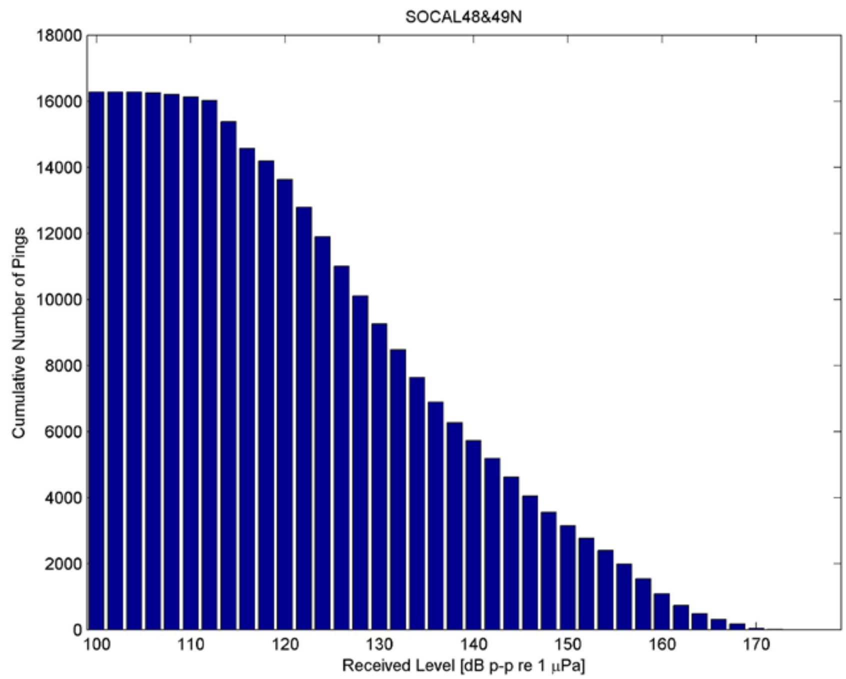

Figure 79. Cumulative distribution of MFA sonar peak-to-peak received levels at site N.

MFA sonar at frequencies greater than 5 kHz was observed at all three sites (Figure 80), albeit at a much lower rate than for sonar less than 5 kHz. The diel patterns for MFA sonar greater than 5 kHz at sites M and H suggest more sonar usage during daylight, while no diel pattern for MFA detections occurred at site N (Figure 81).

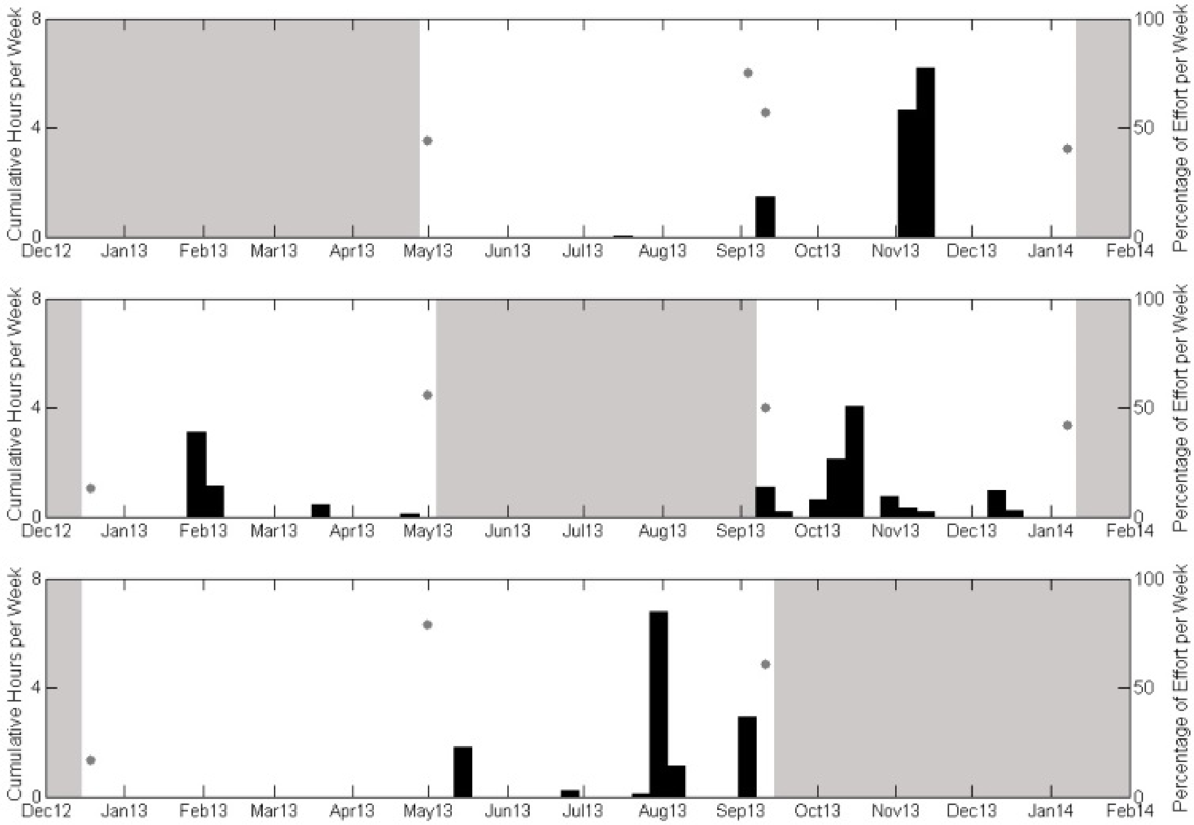

Figure 80. Weekly presence of MFA greater than 5 kHz between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

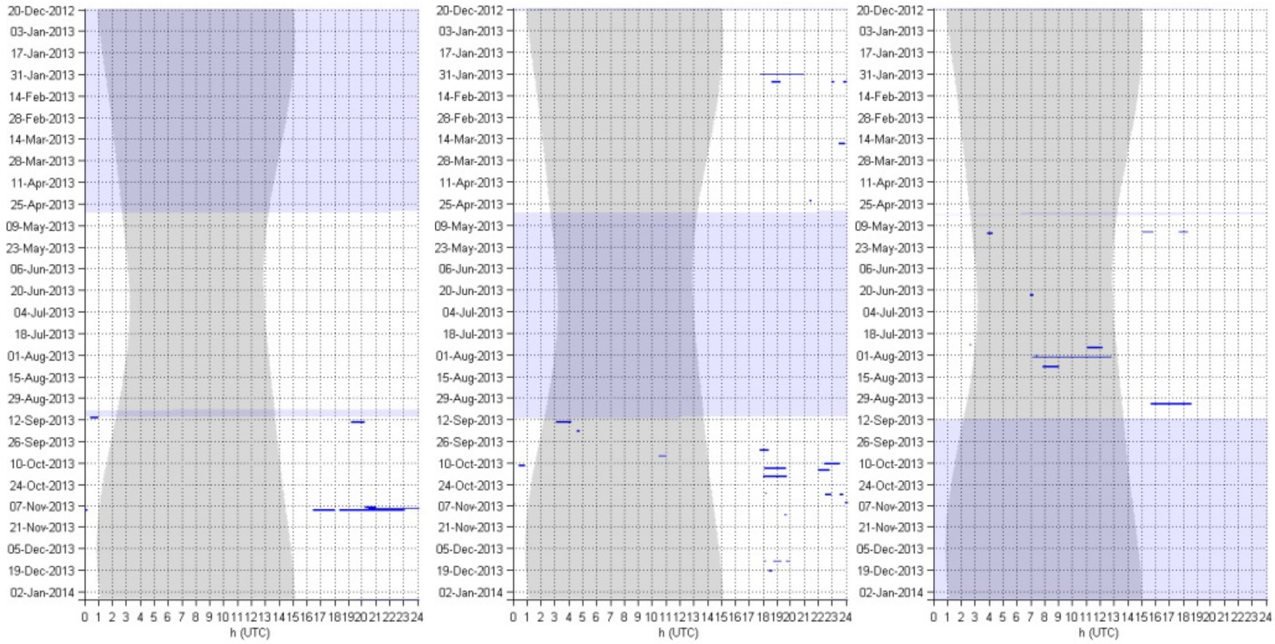

Figure 81. MFA greater than 5 kHz signals in one-minute bins at sites M (left), H (middle), and N (right). Effort markings are described in Figure 36.

Low-Frequency Active Sonar

LFA sonar between 500 Hz and 1 kHz was detected at each site.

- LFA sonar between 500 Hz and 1 kHz was detected intermittently at site H and peaked in November 2013. Detections at site M occurred August – October 2013, while detections at site N were limited to late-January 2013 (Figure 82).
- Most detections at sites M and N occurred during daytime hours. Detections at site N occurred during both daytime and nighttime hours (Figure 83).

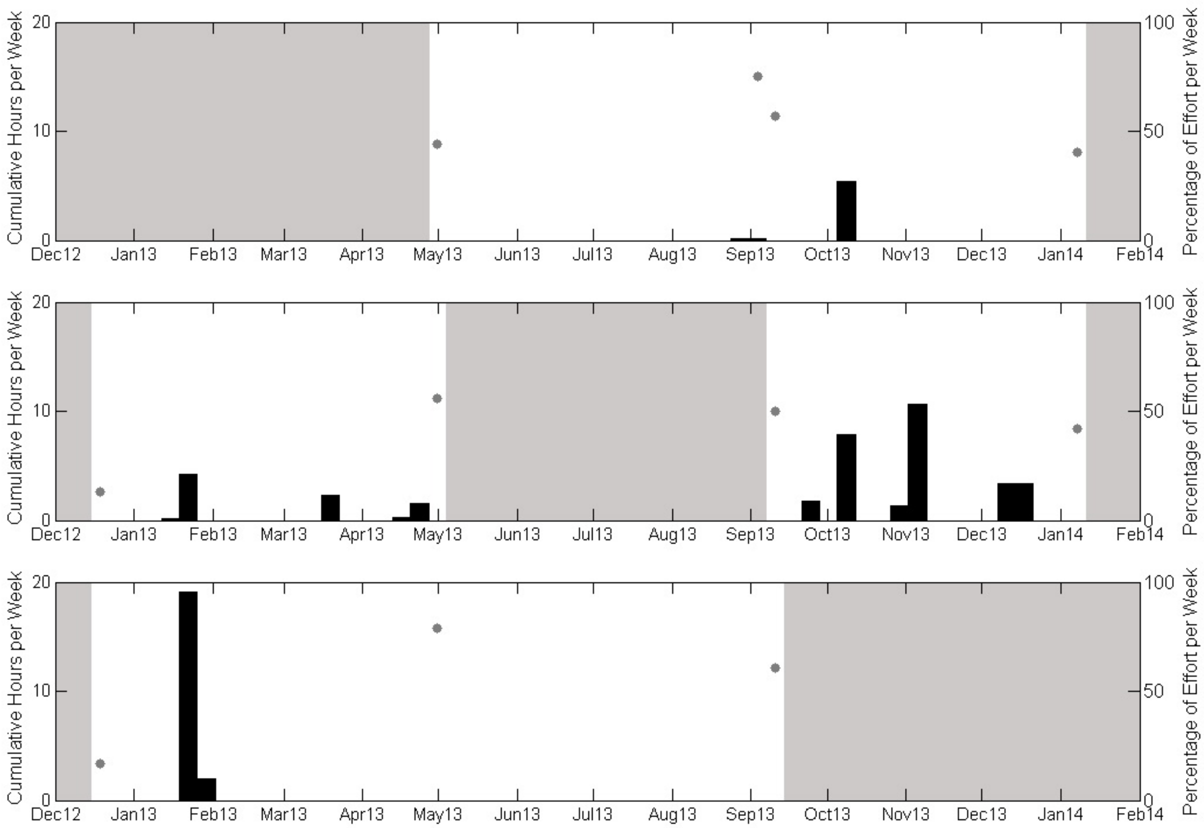

Figure 82. Weekly presence of LFA sonar between 500 Hz and 1 kHz between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

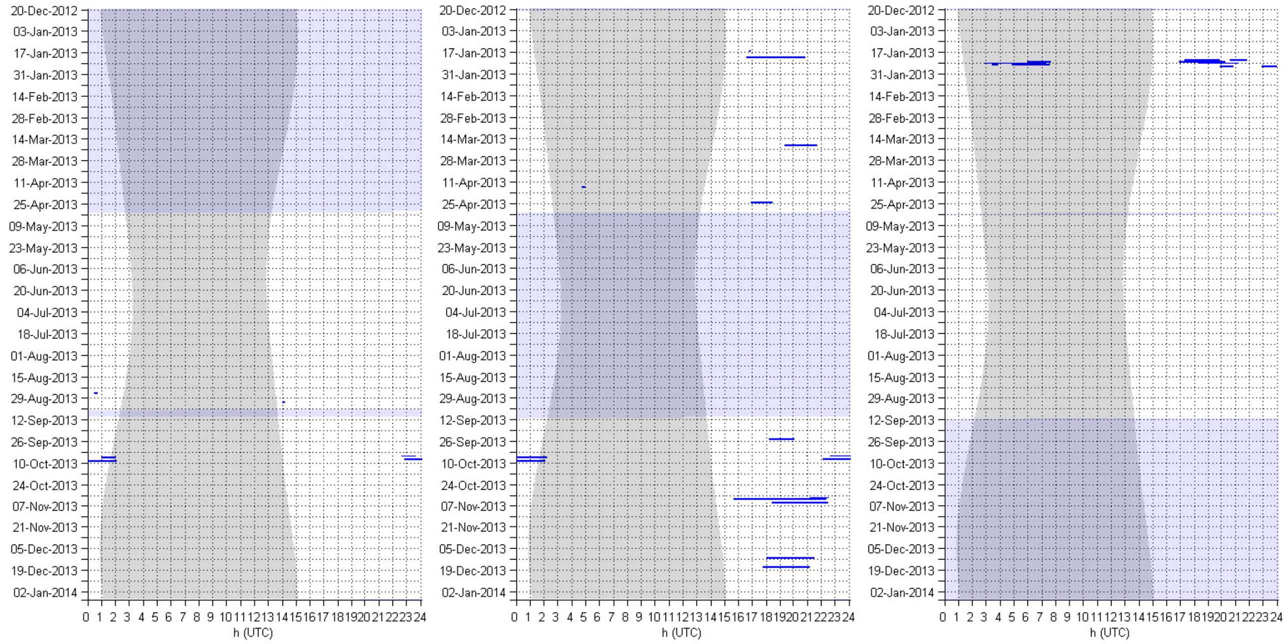

Figure 83. LFA signals between 500 Hz and 1 kHz in one-minute bins at sites M (left), H (middle), and N (right). Effort markings are described in Figure 36.

Echosounders

Echosounder pings from a variety of frequencies were detected at each site.

- Echosounder pings were more prevalent at site N than sites H or M. Peaks in detections at site N occurred in February 2013 (Figure 84).
- There was no discernable diel pattern for echosounder pings (Figure 85).

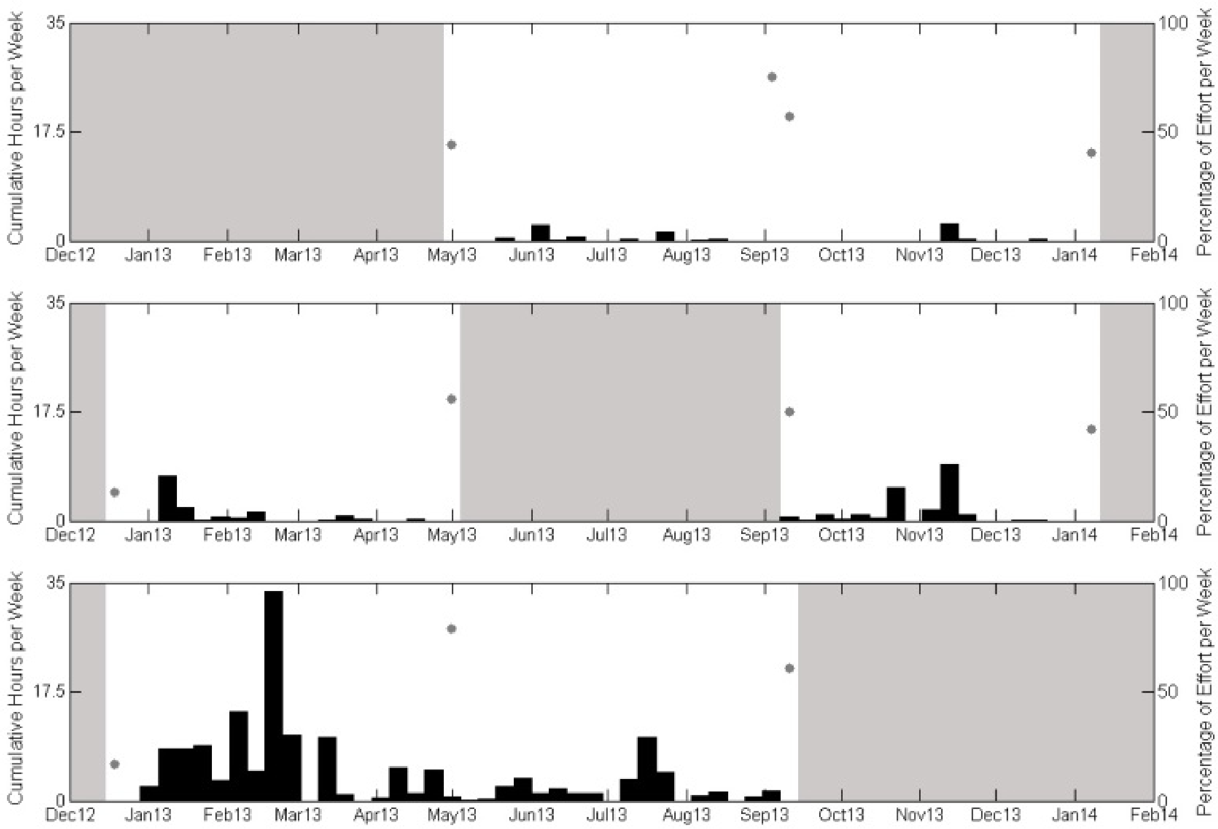

Figure 84. Weekly presence of echosounders between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

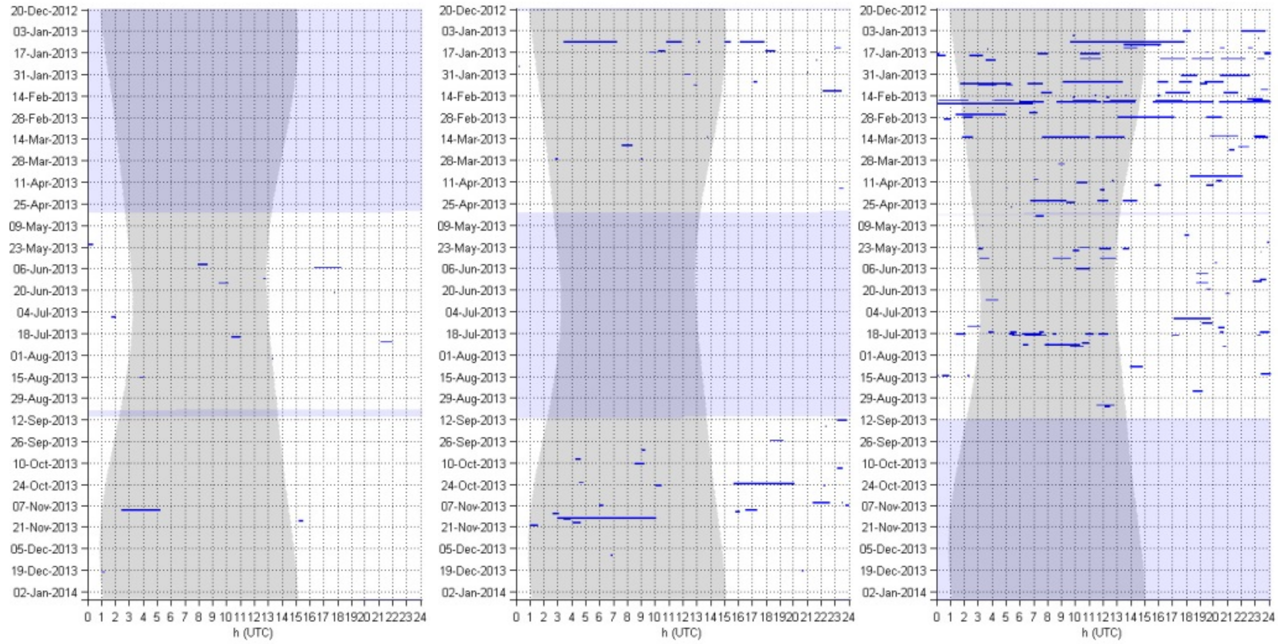

Figure 85. Echosounder detections in one-minute bins at sites M (left), H (middle), and N (right). Effort markings are described in Figure 36.

Explosions

Explosions were detected at all three sites.

- Explosions were most prevalent at site M, with peaks in detections in July 2013. Few explosions were detected at sites H and N (Figure 86), although the summer period was not monitored at site H.
- An abrupt cessation of explosions was observed in October 2013 at site M.
- 24,031 explosions were counted at site M, 2,869 at site H, and 1,927 at site N.
- The majority of explosions occurred during nighttime hours (Figure 87).
- The nighttime occurrence, relatively short duration of the explosion reverberations, and received levels suggest these explosions may be primarily seal bombs related to fishing activity.
- A decrease in detections occurred approximately on a weekly basis at site M, showing a short break in fishing activity over the weekend (Figure 87).
- These results differ from previous recordings in that explosion detections were distinctly more common at site H (Kerosky et al. 2013).

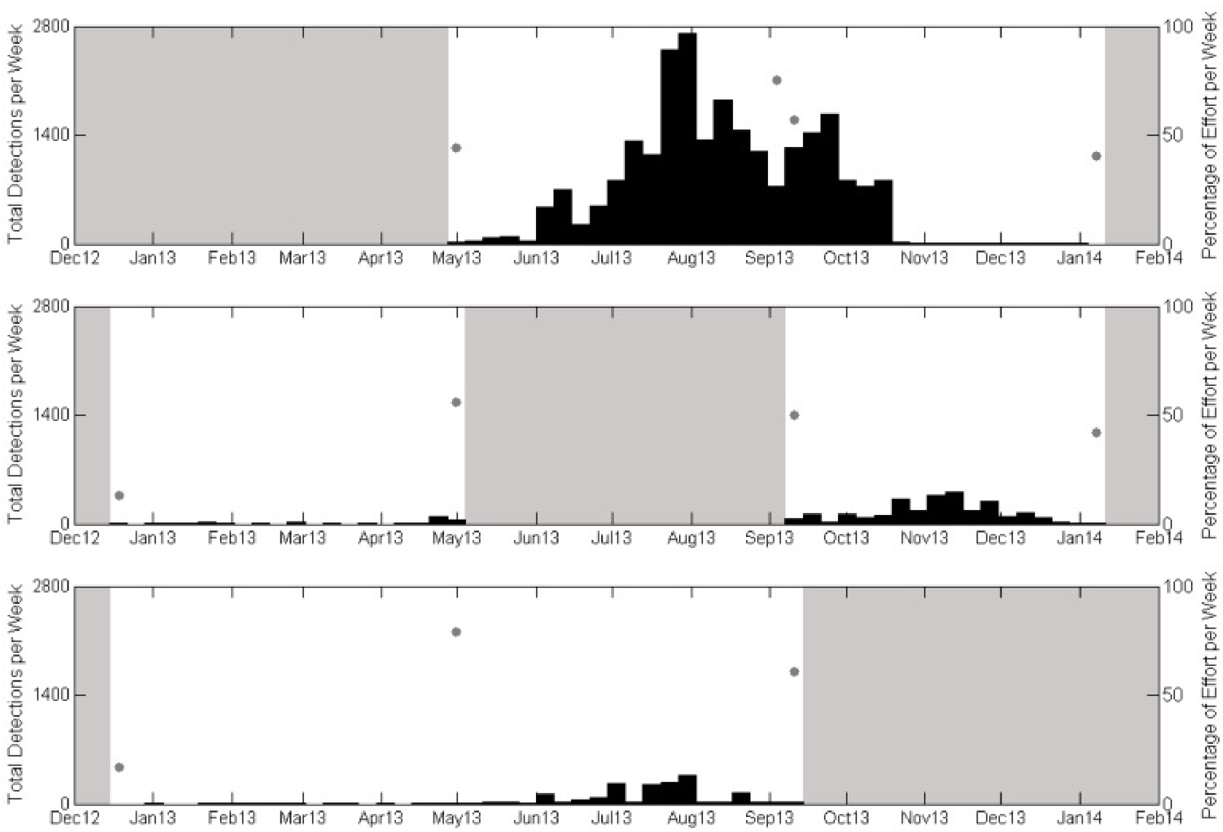

Figure 86. Weekly presence of explosions between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

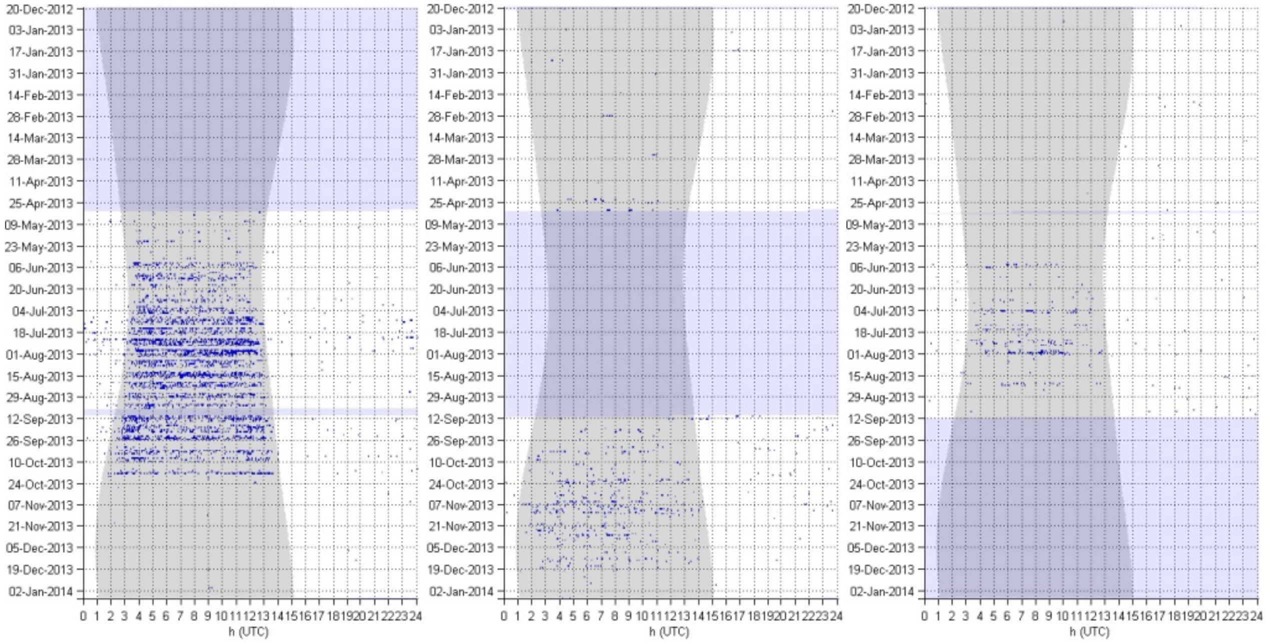

Figure 87. Explosion detections in one-minute bins at sites M (left), H (middle), and N (right). Effort markings are described in Figure 36.

Underwater Communications

Two types of underwater communications were detected in low numbers.

- Electronic communications were detected at site H. These detections peaked in April 2013 (Figure 88).
- Communications that sound like distorted voices underwater were detected in very low numbers at site N (Figure 88).
- There were no communications detected at site M.
- There was no discernable diel pattern for communications signals (Figure 89).

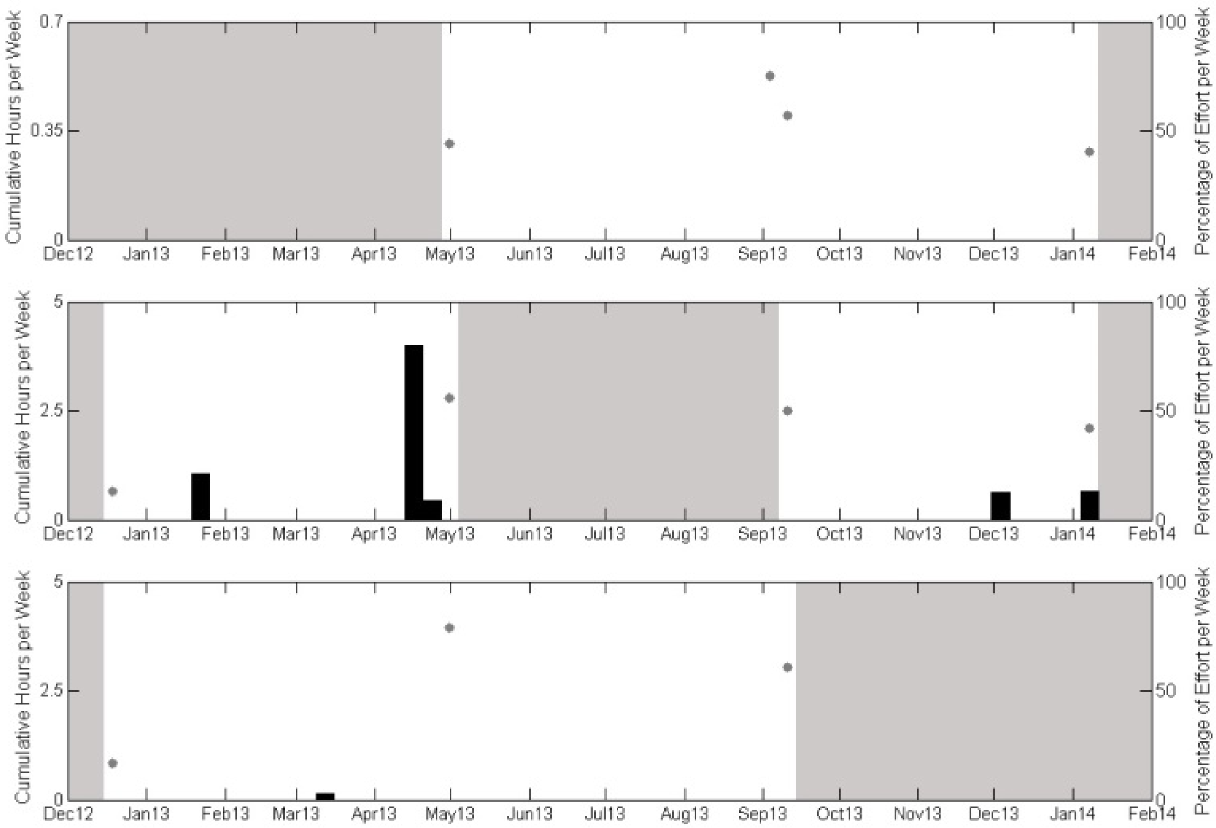

Figure 88. Weekly presence of underwater communications between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

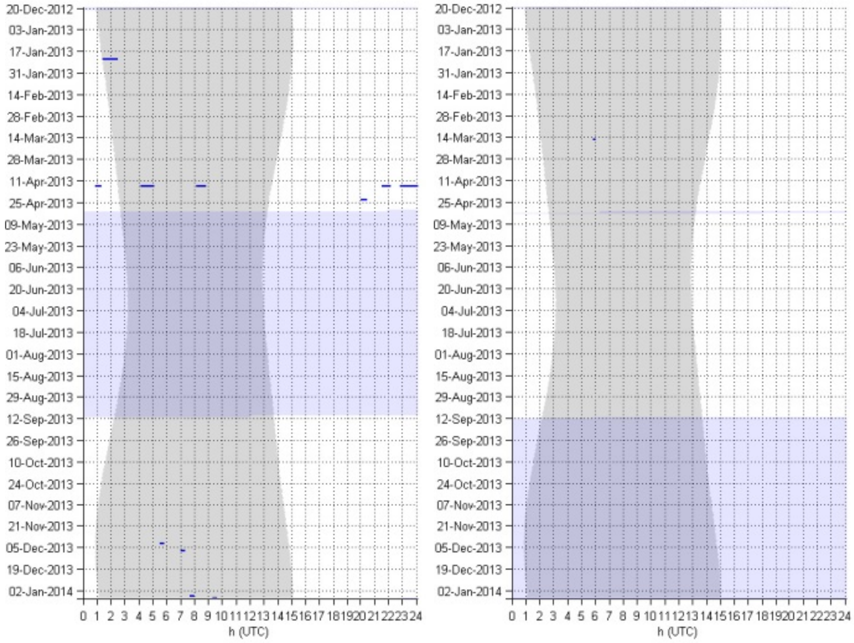

Figure 89. Underwater communications in one-minute bins at sites H (left) and N (right). No underwater communications were detected at site M. Effort markings are described in Figure 36.

Low-frequency Anthropogenic Signal

A low-frequency anthropogenic signal was detected at site N.

- This signal occurred at about 180 Hz and lasted approximately 15 seconds.
- This presumed anthropogenic signal was detected at site N, and primarily occurred January through February 2013 (Figure 90). There were no detections at sites H and M.
- There was no discernable diel pattern for this anthropogenic signal (Figure 91).

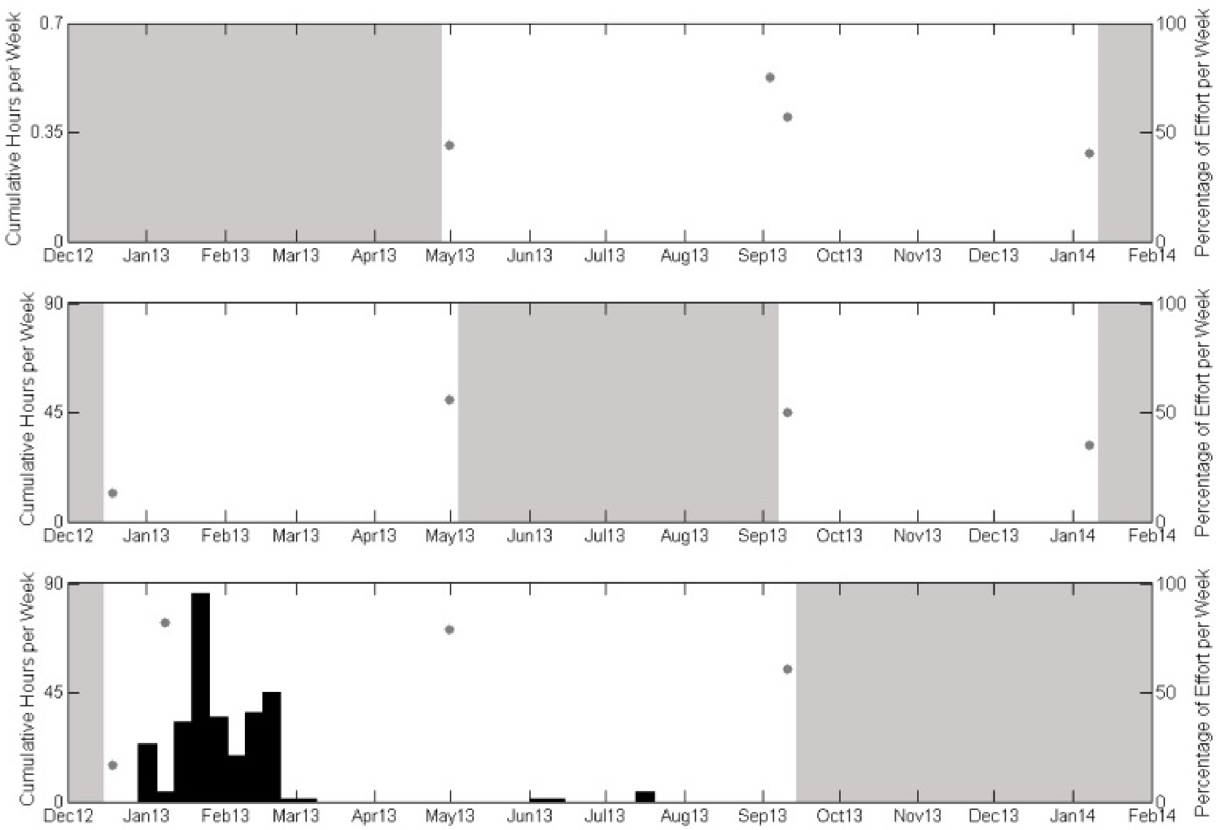

Figure 90. Weekly presence of new low-frequency anthropogenic sounds between December 2012 and January 2014 at sites M (top), H (middle), and N (bottom). Effort markings are described in Figure 35.

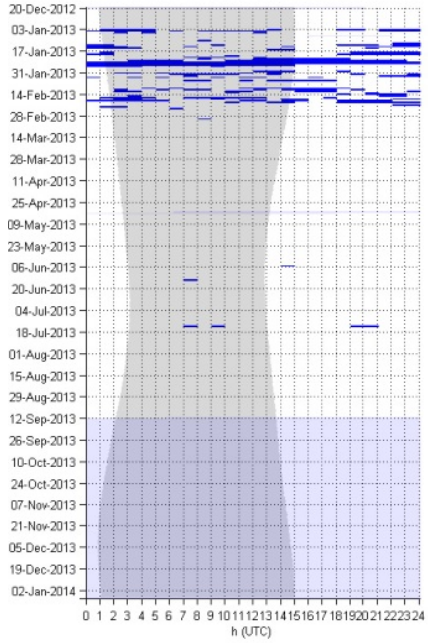

Figure 91. New low-frequency anthropogenic signals in hourly bins at site N. No new low-frequency anthropogenic signals were detected at sites H and M. Effort markings are described in Figure 36.

References

Allen, B. M. and R. P. Angliss. 2010. Alaska marine mammal stock assessments. NOAA National Marine Fisheries Service, Alaska Fisheries Science Center. pp.

Baumann-Pickering, S., M. A. Mcdonald, A. E. Simonis, *et al.* 2013a. Species-specific beaked whale echolocation signals. Journal of the Acoustical Society of America 134:2293-2301.

Baumann-Pickering, S., T. M. Yack, J. Barlow, S. M. Wiggins and J. A. Hildebrand. 2013b. Baird's beaked whale echolocation signals. Journal of the Acoustical Society of America 133:4321-4331.

Calambokidis, J., G. H. Steiger, J. R. Evenson, *et al.* 1996. Interchange and isolation of humpback whales off California and other North Pacific feeding grounds. Marine Mammal Science 12:215-226.

Crane, N. L. and K. Lashkari. 1996. Sound production of gray whales, *Eschrichtius robustus*, along the migration route: A new approach to signal analysis. Journal of the Acoustical Society of America 100:1878-1886.

Dawson, S., J. Barlow and D. Ljungblad. 1998. Sounds recorded from Baird's beaked whale, *Berardius bardii*. Marine Mammal Science 14:335-334.

Filatova, O. A., J. K. B. Ford, C. O. Matkin, L. G. Barrett-Lennard, A. M. Burdin and E. Hoyt. 2012. Ultrasonic whistles of killer whales (*Orcinus orca*) recorded in the North Pacific (L). Journal of the Acoustical Society of America 132:3618-3621.

Ford, J. B. 1989. Acoustic behaviour of resident killer whales (*Orcinus orca*) off Vancouver Island, British Columbia. Canadian Journal of Zoology 67:727-745.

Ford, J. K. B. and D. Fisher. 1983. Group-specific dialects of killer whales (*Orcinus orca*) in British Columbia. Westview Press, Boulder, CO.

Gillespie, D., M. Caillat, J. Gordon and P. White. 2013. Automatic detection and classification of odontocete whistles. Journal of the Acoustical Society of America 134:2427-2437.

Goold, J. C. and S. E. Jones. 1995. Time and frequency domain characteristics of sperm whale clicks. Journal of the Acoustical Society of America 98:1279-1291.

Helble, T. A., G. R. Ierley, G. L. D'spain, M. A. Roch and J. A. Hildebrand. 2012. A generalized power-law detection algorithm for humpback whale vocalizations. Journal of the Acoustical Society of America 131:2682-2699.

Hildebrand, J., H. Bassett, S. Baumann, *et al.* 2009a. High Frequency Acoustic Recording Package Data Summary Report May 17, 2009 – July 8, 2009 SOCAL 33, Site M. Marine Physical Laboratory. pp.

Hildebrand, J., H. Bassett, S. Baumann, *et al.* 2009b. High Frequency Acoustic Recording Package Data Summary Report May 19, 2009 – July 12, 2009 SOCAL 33, Site N. Marine Physical Laboratory. pp.

Hildebrand, J., H. Bassett, S. Baumann-Pickering, *et al.* 2010a. High Frequency Acoustic Recording Package Data Summary Report March 11, 2009 – March 25, 2010 SOCAL Site M. Marine Physical Laboratory. pp.

Hildebrand, J., H. Bassett, S. Baumann-Pickering, *et al.* 2010b. High Frequency Acoustic Recording Package Data Summary Report March 14, 2009 – March 26, 2010 SOCAL Site N. Marine Physical Laboratory. pp.

Hildebrand, J., S. Baumann-Pickering, A. Širović, *et al.* 2011. Passive Acoustic Monitoring for Marine Mammals in the SOCAL Naval Training Area 2010-2011. Scripps Institution of Oceanography, University of California San Diego. pp.

Hildebrand, J., S. Baumann-Pickering, A. Sirovic, *et al.* 2012. Passive Acoustic Monitoring for Marine Mammals in the SOCAL Naval Training Area 2011-2012. Scripps Institution of Oceanography, University of California San Diego. pp.

Hildebrand, J. A. 2009. Anthropogenic and natural sources of ambient noise in the ocean. Marine Ecology Progress Series 395:5-20.

Hildebrand, J. A., H. Bassett, S. Baumann, *et al.* 2010c. 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. 17 pp.

Hildebrand, J. A., H. Bassett, S. Baumann, *et al.* 2010d. 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. pp.

Jefferson, T. A., M. A. Webber and R. L. Pitman. 2008. Marine mammals of the world - A comprehensive guide to their identification. Elsevier, London, UK.

Johnson, M., P. T. Madsen, W. M. X. Zimmer, N. Aguilar De Soto and P. L. Tyack. 2004. Beaked whales echolocate on prey. Proceedings of the Royal Society B: Biological Sciences 271:S383-S386.

Kerosky, S. M., S. Baumann-Pickering, A. Širovic, *et al.* 2014. Passive Acoustic Monitoring for Marine Mammals in the SOCAL Range Complex 2012. . Scripps Institution of Oceanography, University of California San Diego. pp.

Kerosky, S. M., S. Baumann-Pickering, A. Širović, *et al.* 2013. Passive Acoustic Montoring for Marine Mammals in the SOCAL Range Complex during 2012. Marine Physical Laboratory, Scripps Institution of Oceanography. 74 pp.

Kerosky, S. M., A. Širović, L. K. Roche, S. Baumann-Pickering, S. M. Wiggins and J. A. Hildebrand. 2012. Bryde's whale seasonal range expansion and increasing presence in the Southern California Bight from 2000-2010. Deep-Sea Research I 65:125-132.

Leatherwood, S., R. R. Reeves, W. F. Perrin and W. E. Evans. 1988. Whales, dolphins, and porpoises of the eastern North Pacific and adjacent Arctic waters: A guide to their identification. Dover Publishing, New York, NY.

Madsen, P. T., M. Wahlberg and B. Møhl. 2002. Male sperm whale (*Physete macrocephalus*) acoustics in a high-latitude habitat: implications for echolocation and communication. Behavioral Ecology and Sociobiology 53.

Mcdonald, M. A., J. A. Hildebrand and S. C. Webb. 1995. Blue and fin whales observed on a seafloor array in the Northeast Pacific. Journal of the Acoustical Society of America 98:712-721.

Mcdonald, M. A., J. A. Hildebrand, S. M. Wiggins and D. Ross. 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., S. L. Mesnick and J. A. Hildebrand. 2006. Biogeographic characterisation of blue whale song worldwide: using song to identify populations. Journal of Cetacean Research and Management 8:55-65.

Mckenna, M. F., D. Ross, S. M. Wiggins and J. A. Hildebrand. 2012. Underwater radiated noise from modern commercial ships. Journal of the Acoustical Society of America 131:92-103.

Mellinger, D. K. and C. W. Clark. 1997. Methods of automatic detection of mysticete sounds. Marine and Freshwater Behaviour and Physiology 29:163-181.

Møhl, B., M. Wahlberg and P. T. Madsen. 2003. The monopulsed nature of sperm whale clicks. Journal of the Acoustical Society of America 114:1143-1154.

Oleson, E. M., J. Barlow, J. Gordon, S. Rankin and J. A. Hildebrand. 2003. Low frequency calls of Bryde's whales. Marine Mammal Science 19:160-172.

Oleson, E. M., J. Calambokidis, W. C. Burgess, M. A. Mcdonald, C. A. Leduc and J. A. Hildebrand. 2007. Behavioral context of call production by eastern North Pacific blue whales. Marine Ecology Progress Series 330:269-284.

Omura, H. 1959. Bryde's whale from the coast of Japan. Scientific Reports of the Whales Research Institute, Tokyo 14:1-33.

Payne, R. and S. Mcvay. 1971. Songs of humpback whales. Science 173:585-597.

Rankin, S. and J. Barlow. 2005. Source of the North Pacific "boing" sound attributed to minke whales. Journal of the Acoustical Society of America 118:3346-3351.

Roch, M. A., H. Klinch, S. Baumann-Pickering, D. K. Mellinger, S. Qui, M. S. Soldevilla and J. A. Hildebrand. 2011. Classification of echolocation clicks from odontocetes in the Southern California Bight. Journal of the Acoustical Society of America 129:467-475.

Samarra, F. I. P., V. B. Deecke, K. Vinding, M. H. Rasmussen, R. J. Swift and P. J. O. Miller. 2010. Killer whales (*Orciuns orca*) produce ultrasonic whistles. Journal of the Acoustical Society of America Express Letters 128:EL205-210.

Simonis, A. E., S. Baumann-Pickering, E. M. Oleson, M. L. Melcon, M. Gassman, S. M. Wiggins and J. A. Hildebrand. 2012. High-frequency modulated signals of killer whales (*Orcinus orca*) in the North Pacific. Journal of the Acoustical Society of America Express Letters 131:EL295-301.

Širović, A., L. Williams, S. M. Kerosky, S. M. Wiggins and J. A. Hildebrand. 2013. Temporal separation of two fin whale call types across the eastern North Pacific. Marine Biology 160:47-57.

Smultea, M. A., A. B. Douglas, C. E. Bacon, T. A. Jefferson and L. Mazzuca. 2012. Bryde's whale (*Balaenoptera brydei/edeni*) sightings in the Southern California Bight. Aquatic Mammals 38:92-97.

Soldevilla, M. S., E. E. Henderson, G. S. Campbell, S. M. Wiggins, J. A. Hildebrand and M. Roch. 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.

Soldevilla, M. S., S. M. Wiggins and J. A. Hildebrand. 2010a. Spatial and temporal patterns of Risso's dolphin echolocation in the Southern California Bight. Journal of the Acoustical Society of America 127:124-132.

Soldevilla, M. S., S. M. Wiggins and J. A. Hildebrand. 2010b. Spatio-temporal comparison of Pacific white-sided dolphin echolocation click types. Aquatic Biology 9:49-62.

Sumich, J. L. and I. T. Show. 2011. Offshore migratory corridors and aerial photogrammetric body length comparisons of southbound gray whales, *Eschrichtius robustus*, in the Southern California Bight, 1988-1990. Marine Fisheries Review 73:28-34.

Thompson, P. O., L. T. Findley and O. Vidal. 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.

Watkins, W. A. and W. E. Schevill. 1977. Sperm whale codas. Journal of the Acoustical Society of America 62:1485-1490.

Watwood, S., P. J. O. Miller, M. Johnson, P. T. Madsen and P. L. Tyack. 2006. Deep-diving behaviour of sperm whales (*Physeter macrocephalus*). Journal of Animal Ecology 75:814-825.

Wiggins, S. M. and J. A. Hildebrand. 2007. High-frequency Acoustic Recording Package (HARP) for broadband, long-term marine mammal monitoring. International Symposium on Underwater Technology 2007 and International Workshop on Scientific Use of Submarine Cables and Related Technologies 2007:551-557.

Zimmer, W. M. X., M. P. Johnson, P. T. Madsen and P. L. Tyack. 2005. Echolocation clicks of free-ranging Cuvier's beaked whales (*Ziphius cavirostris*). Journal of the Acoustical Society of America 117:3919-3927.