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Passive Acoustic Monitoring for Marine Mammals in the SOCAL Range Complex May 2022–July 2023 and Marine Mammal Presence from CalCOFI Visual Surveys 2022–2023

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Cuvier's beaked whale
Photo by Jennifer S. Trickey, taken under SEMARNAT permit SGPA/DVGS/00451/18

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N.P. wrote and edited the report, produced all plots of acoustic results, and conducted MFA sonar analysis. L.M.B. conducted beaked whale, MFA sonar, and explosion analysis. CS conducted beaked whale, MFA sonar and, explosion analysis and served as an observer on the CalCOFI surveys, J.M.J managed CalCOFI surveys, served as an observer on the surveys, and produced plots of marine mammal presence from surveys, M.A. produced plots of marine mammal presence from surveys and served as an observer on the CalCOFI surveys, K.W. served as an observer on the CalCOFI surveys, J.E. served as an observer on the CalCOFI surveys, S.M.W., K.L., and B.J.T. lead HARP data acquisition operations, B.J.T. contributed to algorithm development. K.E.F., S.B.P., and J.A.H. developed and managed the project.

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14. ABSTRACT
Passive acoustic monitoring was conducted in the Navy's Southern California (SOCAL) Range Complex from May 2022 to July 2023 to detect marine mammal and anthropogenic sounds. High-frequency Acoustic Recording Packages (HARPs) recorded sounds between 10 Hz and 100 kHz at four locations: one site west of San Nicolas Island (1,100 m depth, site SN), two sites west of San Clemente Island (1,300 m depth, site E and 1,200 m depth, site H), and one site southwest of San Clemente Island (1,300 m depth, site N) to improve noise monitoring for the SOCAL range.

While a typical southern California marine mammal assemblage is consistently detected in these recordings (Hildebrand et al., 2012), only Cuvier's beaked whales were analyzed for this report. The low-frequency ambient soundscape and the presence of mid-frequency active (MFA) sonar and explosions were also analyzed.

Ambient sound levels were highest for frequencies greater than ~200 Hz at site SN, likely due to the site's exposure to the entire North Pacific. Ambient sound levels were similar at sites E, H, and N, likely more locally influenced perhaps related to wind. Peaks in sound levels below 100 Hz at all sites are related to the seasonally increased presence of blue whales and fin whales.

For marine mammal and anthropogenic sounds, data analysis was performed using automated computer algorithms. Frequency modulated (FM) echolocation pulses from Cuvier's beaked whales were regularly detected at all sites but were detected in much higher numbers at site E with the highest detections from December 2022 to June 2023.

Two anthropogenic signals were detected: MFA sonar and explosions. MFA sonar was detected at all sites with the highest number of detections occurring during October 2022. Site N had the most MFA sonar packet detections normalized per year and the highest cumulative sound exposure levels. Excluding site SN where none of the analyst-defined encounters remained after filtering due to their low received levels, Site E had the lowest number of sonar packet detections and the lowest maximum cumulative sound exposure level. Explosions were detected at all sites, but the number of explosions was highest at site H and lowest at site SN. A peak in number of explosions occurred in July at sites H and N, with a second peak in October through December only at site H. At all sites, temporal and spectral characteristics suggest association with fishing, specifically with the use of seal bombs.

Cetacean distribution, density, and abundance in the Southern California Bight were assessed through visual and acoustic surveys during four California Cooperative Oceanic Fisheries Investigations (CalCOFI) cruises from fall 2022 to summer 2023. Visual monitoring incorporated standard line-transect protocol during all daylight transits, while daytime acoustic monitoring employed sonobuoys deployed at oceanographic sampling stations. Visual effort included 534 observation hours covering 4,104 kilometers. A total of 352 sightings were made, which included 12 different cetacean species. Acoustic effort included 233 sonobuoy deployments.

Fin whales and humpback whales were the most frequently sighted mysticetes. Humpback whales were observed year-round, while fin whales were observed in the fall, winter, and summer. Blue whales were observed during summer and fall. Gray whale sightings only occurred during winter and spring, and minke whales were sighted fall, winter, and spring. Short-beaked and long-beaked common dolphins were the most frequently encountered odontocetes, while bottlenose dolphins were also observed somewhat regularly. Seasonally, short-beaked common dolphins were most abundant in winter and spring, whereas long-beaked common dolphins were most abundant in summer and fall. Sightings of Pacific white-sided dolphins only occurred in the spring, whereas Risso's dolphins were encountered in the winter and spring.

15. SUBJECT TERMS
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Project Background

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

In January 2009, an acoustic monitoring effort was initiated within the SOCAL Range Complex with support from the U.S. Pacific Fleet. The goal of this effort was to characterize the vocalizations of marine mammal species present in the area, determine their seasonal presence, and evaluate the potential for impact from naval training. In this current effort, the goal was to explore the seasonal presence of beaked whales. In addition, the low-frequency ambient soundscape, as well as the presence of Mid-frequency active (MFA) sonar and explosions, were analyzed.

This report documents the analysis of data recorded by High-frequency Acoustic Recording Packages (HARPs) that were deployed at four sites within the SOCAL Range Complex and collected data between May 2022 and July 2023 (Table 1; Table 2; Table 3; Table 4). The four recording sites include one to the west of San Nicolas Island (site SN), two to the west of San Clemente Island (sites E and H), and one to the south-southwest of San Clemente Island (site N; Figure 1; Figure 2). This report also documents the sightings and distribution for marine mammal species observed during quarterly CalCOFI cruises in the Southern California Bight from fall 2022 to summer 2023.

Long-term assessments of abundance, density, and distribution are central to evaluating potential effects of anthropogenic activities and ecosystem variability on cetacean populations (Carretta *et al.*, 2016). The California Current Ecosystem (CCE) is a productive and dynamic habitat (Hayward and Venrick, 1998; Chhak and Di Lorenzo, 2007) that supports a diverse community of cetacean species as well as an array of human activities including commercial fishing, shipping, and naval exercises. The intersection between cetacean and human use of the CCE has resulted in entanglements in fishing gear (Carretta *et al.*, 2013), ship strikes (Berman-Kowalewski *et al.*, 2010), and disturbances from anthropogenic sound (McDonald *et al.*, 2006; Hildebrand, 2009; Goldbogen *et al.*, 2013).

California Cooperative Oceanic Fisheries Investigation (CalCOFI) cruises, conducted in the Southern California Bight (SCB) four times per year, provide a unique and valuable platform to document spatial and temporal variations in cetacean abundance, density, distribution, and habitat use patterns. Cetacean surveys have been integrated into (CalCOFI) quarterly cruises off southern California since 2004 using both visual and acoustic detection methods (Soldevilla *et al.*, 2006; Munger *et al.,* 2009; Campbell *et al.,* 2014). The objectives of the cetacean monitoring program are to make seasonal, annual, and long-term estimates of cetacean density and abundance within the study area, to determine the temporal and spatial patterns of cetacean distribution, and for future habitat-based density modeling efforts (Munger *et al.,* 2009; Campbell *et al.,* 2014; Giddings 2022)

Table 1. SOCAL Range Complex acoustic monitoring at site SN since May 2009. Periods of instrument deployment analyzed in this report are shown in bold.

Deployment #	Monitoring Period	# Hours
33	5/19/09 – 6/2/10	9096
40	7/22/10 – 11/6/10	2568
53	7/29/14 – 8/8/14	233
56	6/11/15 – 10/2/15	2710
57	3/17/16 – 1/7/17	7104
58	3/5/17 – 9/10/17	4553
59	10/4/17 – 8/2/18	7234
60	11/20/21 – 5/28/22	4544
61	**5/28/222 – 10/19/22**	**3456**
62	**10/19/22 – 4/17/23**	**4320**

Table 2. SOCAL Range Complex acoustic monitoring at site E since January 2009. Periods of instrument deployment analyzed in this report are shown in bold. Deployment 66 did not record due to implosion of instrument floats during deployment.

Deployment #	Monitoring Period	# Hours
31	1/13/09 – 3/9/09	1302
32	3/13/09 – 5/7/09	1302
33	5/19/09 – 7/12/09	1302
34	7/24/09 – 9/16/09	1302
61	3/5/17 – 7/10/17	3063
62	7/11/17 – 2/10/18	5148
63	3/15/18 – 7/11/18	2843
64	7/12/18 – 11/28/18	3356
65	11/29/18 – 5/7/19	3838

66	-	-
67	11/9/19 – 5/8/20	4362
68	5/9/20–10/29/20	4170
69	10/29/20–4/24/21	4247
70	4/25/21 – 10/28/21	4474
71	11/19/21 – 5/24/22	4435
72	**5/24/22 – 10/13/22**	**3408**
73	**10/13/22 – 7/02/23**	**6288**

Table 3. SOCAL Range Complex acoustic monitoring at site H since January 2009. Periods of instrument deployment analyzed in this report are shown in bold. Missing deployments are the result of hydrophone failures.

Deployment #	Monitoring Period	# Hours
31	1/13/09 – 3/8/09	1320
32	3/14/09 – 5/7/09	1320
33	5/19/09 – 6/13/09	600
34	7/23/09 – 9/15/09	1296
35	9/25/09 – 11/18/09	1320
36	12/6/09 – 1/29/10	1296
37	1/30/10 – 3/22/10	1248
38	4/10/10 – 7/22/10	2472
40	7/23/10 – 11/8/10	2592
41	12/6/10 – 4/17/11	3192
44	5/11/11 – 10/12/11	2952
45	10/16/11 – 3/5/12	3024
46	3/25/12 – 7/21/12	2856
47	8/10/12 – 12/20/12	3192
48	12/21/12 – 4/30/13	3140
49	-	-
50	9/10/13 – 1/6/14	2843
51	1/7/14 – 4/3/14	2082
52	4/4/14 – 7/30/14	2814
53	7/30/14 – 11/5/14	2340
54	11/5/14 – 2/4/15	2198
55	2/5/15 – 6/1/15	2800
56	6/2/15 – 10/3/15	2952
57	-	-
58	11/21/15 – 4/25/16	3734
59	7/6/16 – 11/9/16	3011
60	-	-
61	2/22/17 – 6/6/17	2518
62	6/7/17 – 10/4/17	2879
63	10/5/17 – 11/3/17	707

65	7/9/18 – 11/28/18	3413
66	11/29/18 – 5/5/19	3784
67	6/1/19 – 12/8/19	4557
68	12/8/19 – 5/8/20	3644
69	5/9/20–10/29/20	4172
70	10/29/20–4/24/21	4245
71	4/25/21 – 7/30/21	2321
72	7/30/21 – 12/18/21	3387
73	12/21/21 – 5/22/22	3667
74	**5/23/22 – 10/15/22**	**3480**
75	**10/16/22 – 4/17/23**	**4392**

Table 4. SOCAL Range Complex acoustic monitoring at site N since January 2009.
Periods of instrument deployment analyzed in this report are shown in bold. Deployment 50 yielded no usable data due to flooding of the instrument from a hardware failure. Data from deployment 58 in italics were only used for high frequency analysis with failure of the low frequency hydrophone component.

Deployment #	Monitoring Period	# Hours
31	1/14/09 – 3/9/09	1296
32	3/14/09 – 5/7/09	1320
33	5/19/09 – 7/12/09	1296
34	7/22/09 – 9/15/09	1320
35	9/26/09 – 11/19/09	1296
36	12/6/09 – 1/26/10	1224
37	1/31/10 – 3/26/10	1296
38	4/11/10 – 7/18/10	2352
40	7/23/10 – 11/8/10	2592
41	12/7/10 – 4/9/11	2952
44	5/12/11 – 9/23/11	3216
45	10/16/11 – 2/13/12	2904
46	3/25/12 – 8/5/12	3216
47	8/10/12 – 12/6/12	2856
48	12/20/12 – 5/1/13	3155
49	5/2/13 – 9/11/13	3156
50	-	-
51	1/7/14 – 2/16/14	956
52	4/4/14 – 7/30/14	2817
53	7/30/14 – 11/5/14	2342
54	11/4/14 -2/5/15	2196
55	2/5/15 – 2/23/15	433
56	6/2/15 – 10/3/15	2966
57	10/3/15 – 11/21/15	1168
58	*11/21/15 – 4/18/16*	*3578*

59	7/7/16 – 11/8/16	2999
60	11/9/16 – 2/21/17	2457
61	2/21/17 – 6/7/17	2528
62	6/7/17 – 12/21/17	4723
63	2/4/18 – 7/9/18	3722
64	7/9/18 – 11/28/18	3417
65	11/29/18 – 5/5/19	3768
66	5/5/19 – 11/7/19	4481
67	11/8/19 – 4/29/20	4148
68	4/29/20–10/15/20	4058
69	11/6/20–4/15/21	3861
70	4/16/21 – 10/13/21	4337
71	11/19/21 – 5/13/22	4215
72	**5/13/22 – 10/10/22**	**3600**
73	**11/12/22 – 4/18/23**	**3528**

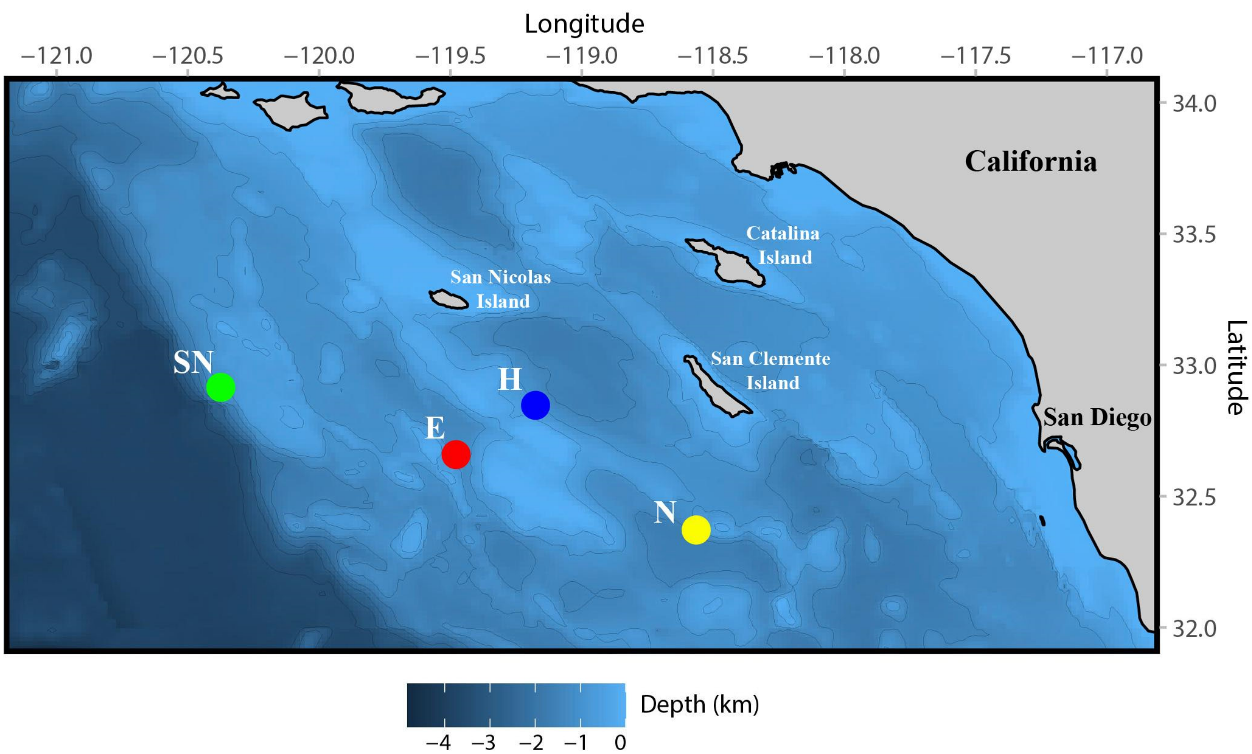

Figure 1. Locations of High-frequency Acoustic Recording Package (HARP) deployment sites SN, E, H, and N (circles) in the SOCAL study area from May 2022 through July 2023. Color indicates bathymetric depth. Contour lines represent 500 m depth increments.

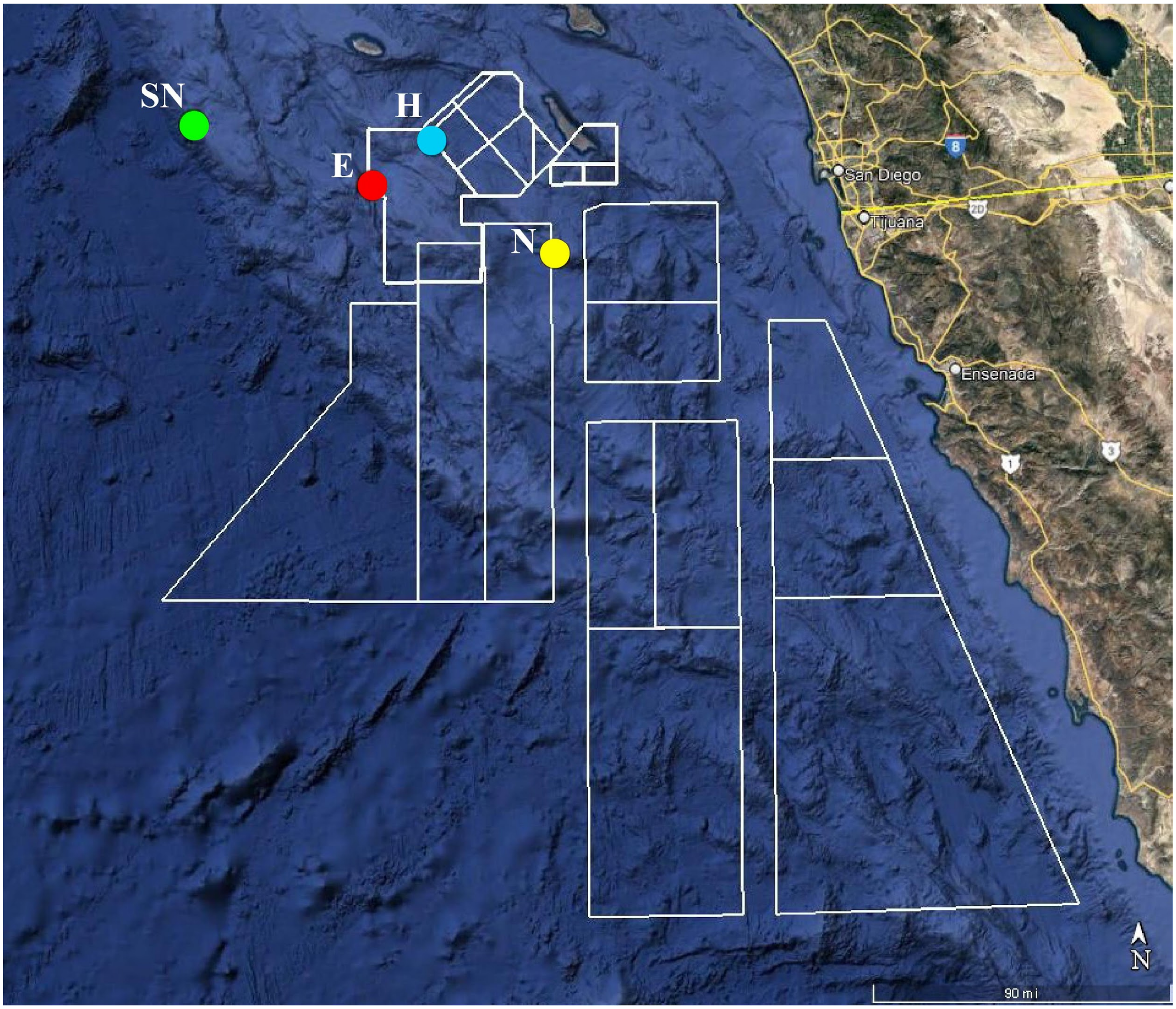

Figure 2. Locations of High-frequency Acoustic Recording Package (HARP) deployments in the SOCAL study area (colored circles) and US Naval Operation Areas (white boxes).

Methods

Passive Acoustic Monitoring

High-frequency Acoustic Recording Package (HARP)

HARPs were used to record the low-frequency ambient soundscape as well as marine mammal and anthropogenic sounds in the SOCAL area. HARPs can autonomously record underwater sounds from 10 Hz up to 160 kHz and are capable of up to approximately one year of continuous data storage. The HARPs were deployed in a seafloor mooring configuration with the hydrophones suspended at least 10 m above the seafloor. Each HARP hydrophone was calibrated in the laboratory before initial deployment to provide a quantitative analysis of the received sound field. Representative data loggers and hydrophones were also calibrated at the Navy's

Transducer Evaluation Center facility to verify the laboratory calibrations (Wiggins and Hildebrand, 2007).

Data Collected

Acoustic recordings have been collected within the SOCAL Range Complex near San Clemente Island since 2009 (Table 1; Table 2; Table 3; Table 4) using HARPs sampling at 200 kHz. The sites analyzed in this report are designated site SN (32° 54.92' N, 120° 22.50' W, depth 1,100 m), site E (32° 39.56' N, 119° 28.76' W, depth 1,300 m), site H (32° 51.27'N, 119° 08.95' W, depth 1,200 m), and site N (32° 22.18' N, 118° 33.90' W, depth 1,300 m).

Site SN recorded from May 28, 2022 to April 17, 2023. Site E recorded from May 24, 2022 to July 2, 2023. Site H recorded from May 23, 2022 to April 17, 2023. Site N recorded from May 13, 2022 to October 10, 2022 and November 11, 2022 to April 18, 2023. For all four sites, a total of 32,472 h (1,353 days) of acoustic data were recorded in the deployments analyzed in this report.

Data Analysis

Recording over a broad frequency range of 10 Hz to 100 kHz allows quantification of the low-frequency ambient soundscape, detection of baleen whales (mysticetes), toothed whales (odontocetes), and anthropogenic sounds. Analyses were conducted using appropriate automated detectors for whale and anthropogenic sound sources (Roch *et al.*, 2011; Frasier *et al.,* 2017; Frasier 2021; Baggett 2023). Biological sound source analysis was focused on Cuvier's beaked whales (*Ziphius cavirostris*). A description of relevant signal types can be found below. Individual beaked whale echolocation clicks, as well as MFA sonar occurrence and levels were detected automatically using computer algorithms. For analysis of MFA sonar, data were decimated by a factor of 20 for an effective bandwidth of 10 Hz to 5 kHz and Long-term spectral averages (LTSAs) were created using a time average of 5 seconds and frequency bins of 10 Hz. Full bandwidth data were used for the analysis of beaked whale signals and LTSAs were created using a time average of 5 seconds and a frequency bin size of 100 Hz. Details of all detection methods are described below.

Low-frequency Ambient Soundscape

HARPs write sequential 75-s acoustic records, from which sound pressure levels were calculated. Five, 5-s, 1-Hz sound pressure spectrum levels from the middle of each 75-s acoustic record were averaged to avoid system self-noise (specifically hard drive disk writes). Spectra from each day were subsequently combined as daily spectral averages.

Beaked Whales

Although a variety of beaked whales can be potentially found in the Southern California Bight, only Cuvier's were analyzed for this report. Cuvier's beaked whales can be identified acoustically by their echolocation signals (Baumann-Pickering *et al.*, 2014). These signals are FM upswept pulses, which appear to be species specific and are distinguishable by their spectral and temporal features. These signals are described below in more detail.

A machine learning workflow for detecting and classifying odontocete echolocation clicks (Frasier *et al.,* 2017; Frasier 2021) was applied to the acoustic data to identify Cuvier's beaked whale echolocation clicks. Zc echolocation clicks were detected and classified using the MATLAB (Mathworks, Natick, MA)-based software Triton (Wiggins *et al.,* 2010). A customized energy detector (Frasier 2021) applied a five-pole Butterworth bandpass filter with edges at 5 kHz and 95 kHz and extracted signals with peak-to-peak received level ≥ 118 dB re 1 μPa and durations 30 to 1200 μs. A two-phase unsupervised clustering algorithm identified and grouped recurring signals based on spectra and waveform (Frasier *et al.,* 2017; Frasier 2021). These clusters were assigned a label by a neural network that had previously been trained for use in this region (Baggett 2023). The neural network was trained to recognize biological signals (echolocation clicks from Lagenorhynchus obliquidens, Grampus griseus, Ziphius cavirostris, and presumed Delphinus capensis and Delphinus delphis) (Soldevilla *et al.,* 2008; Zimmer *et al.,* 2005; Zimmer *et al.,* 2008) as well as anthropogenic signals (boats, echosounders) common in data from this region. The neural network labels were manually verified in the MATLAB-based software DetEdit (Solsona-Berga *et al.,* 2020). This workflow culminated with the successful identification of times when Zc echolocation clicks were recorded and the start and end of each segment containing beaked whale signals was logged and their durations were added to estimate cumulative weekly presence.

Cuvier's Beaked Whales

Cuvier's beaked whale echolocation signals (Figure 3) are well differentiated from other species' acoustic signals as polycyclic, with a characteristic FM pulse upsweep, peak frequency around 40 kHz, and uniform inter-pulse interval of about 0.4–0.5 s (Johnson *et al.*, 2004; Zimmer *et al.*, 2005). An additional feature that helps with the identification of Cuvier's beaked whale FM pulses is that they have characteristic spectral peaks around 17 and 23 kHz.

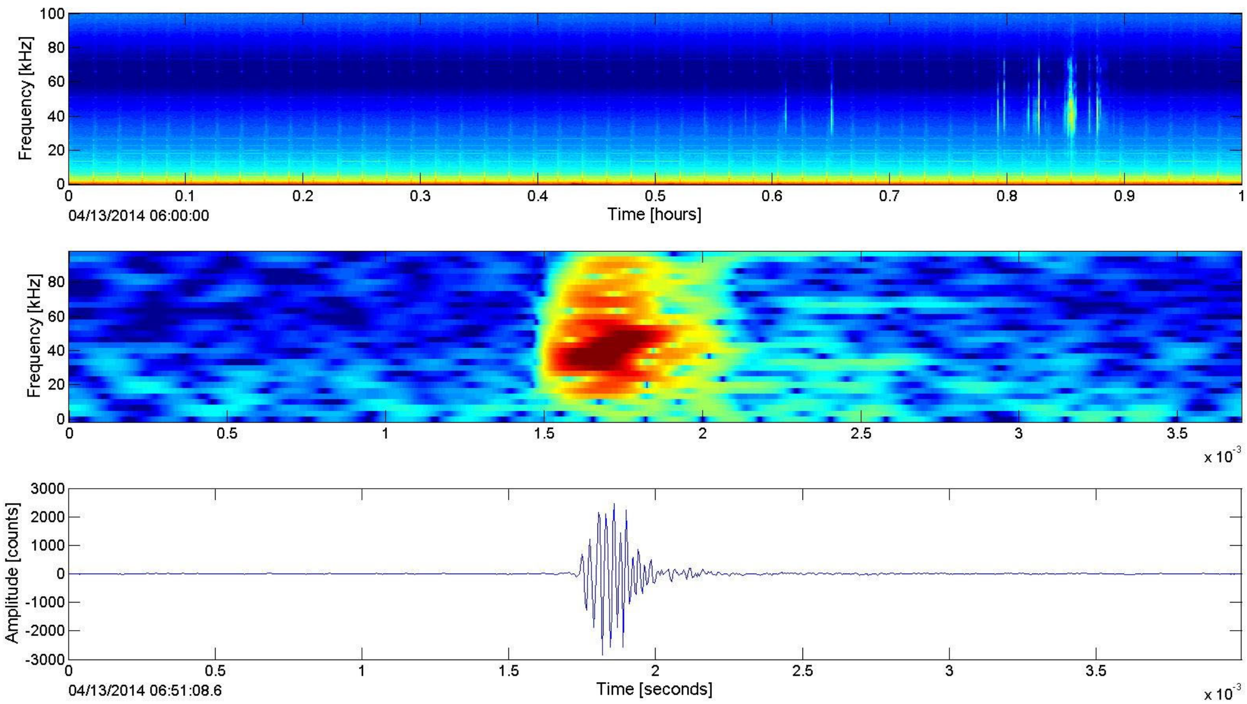

Figure 3. Echolocation sequence of Cuvier's beaked whale in an LTSA (top) and example FM pulse in a spectrogram (middle) and corresponding time series (bottom) previously recorded at site N.

Anthropogenic Sounds

Mid-frequency active (MFA) sonar was monitored for this report and detected by computer algorithms. For MFA sonar, the start and end of each sound or session was logged and their durations were added to estimate cumulative weekly presence.

Mid-frequency active Sonar

Sounds from MFA sonar vary in frequency (1–10 kHz) and are composed of pulses of both frequency-modulated (FM) sweeps and continuous wave (CW) tones that have durations from less than 1 s to greater than 5 s, respectively. Groups of pulses, or pings, constitute a packet. Packets are transmitted repetitively with inter-packet-intervals typically greater than 20 s (Figure 4). Groups of packets constitute a wave train (sometimes called an event). A 1-h separation between packets is used to delineate between wave trains. In the SOCAL Range Complex, the most common MFA sonar signals are between 2 and 5 kHz and are more generically known as '3.5-kHz' sonar.

In the first stage of MFA sonar detection, we used a modified version of the *Silbido* detection system (Roch *et al.*, 2011), originally designed for characterizing toothed whale whistles. The algorithm identifies peaks in time-frequency distributions (e.g., spectrogram) and determines which peaks should be linked into a graph structure based on heuristic rules that include examining the trajectory of existing peaks, tracking intersections between time-frequency trajectories, and allowing for brief signal dropouts or interfering signals. Detection graphs are then examined to identify individual tonal contours looking at trajectories from both sides of time-frequency intersection points. For MFA sonar detection, parameters were adjusted to detect tonal contours at or above 2 kHz in data decimated to a 10-kHz sample rate with time-frequency peaks with signal to noise ratios of 5 dB or above and contour durations of at least 200 ms with a frequency resolution of 100 Hz.

The detector frequently triggered on noise produced by instrument disk writes that occurred at 75-s intervals. Over periods of several months, these disk-write detections dominated the number of detections and could be eliminated using an outlier detection test. Histograms of the detection start times that remained once disk write periods were removed were constructed and outliers were discarded. This removed some valid detections that occurred during disk writes, but as the disk writes and sonar signals are uncorrelated, this is expected to only have a minor impact on analysis. As the detector did not distinguish between sonar and non-anthropogenic tonal signals within the operating band (e.g., humpback whales), human analysts examined detection output and accepted or rejected contiguous sets of detections, thereby removing any false detections. Start and end times of these cleaned sonar events were then used in further processing.

In the second stage of MFA sonar detection, the start and end times of MFA events from both methods were then used to read segments of waveforms upon which a 2.4 to 4.5 kHz bandpass filter and a simple waveform amplitude energy detector was applied to detect and measure various packet parameters after correcting for the instrument calibrated transfer function (Wiggins, 2015). For each packet, maximum peak-to-peak (pp) received level (RL), sound exposure level (SEL), root-mean-square (RMS) RL, date/time of packet occurrence, and packet RMS duration (10dB lower than max RL_{pp}) were measured and saved.

Various filters were applied to the detections to limit the MFA sonar detection range to ~20 km for off-axis signals from an AN/SQS 53C source, which resulted in a RL detection threshold of 130 dB pp re 1 μPa (Wiggins, 2015). Instrument maximum received level was ~165 dB pp re 1 μPa, above which waveform clipping occurred. Packets were grouped into wave trains separated by more than 1 h. Packet received levels were plotted along with the number of packets and cumulative SEL (CSEL) in each wave train over the study period. Wave train duration and total packet duration were also calculated. Wave train duration is the difference between the first and last packet detections in an event. The total packet duration of a wave train is the sum of the individual packet (i.e., group of pings) durations, which is measured as the period of the waveform that is 0 to 10 dB less than the maximum peak-to-peak received level of the ping group.

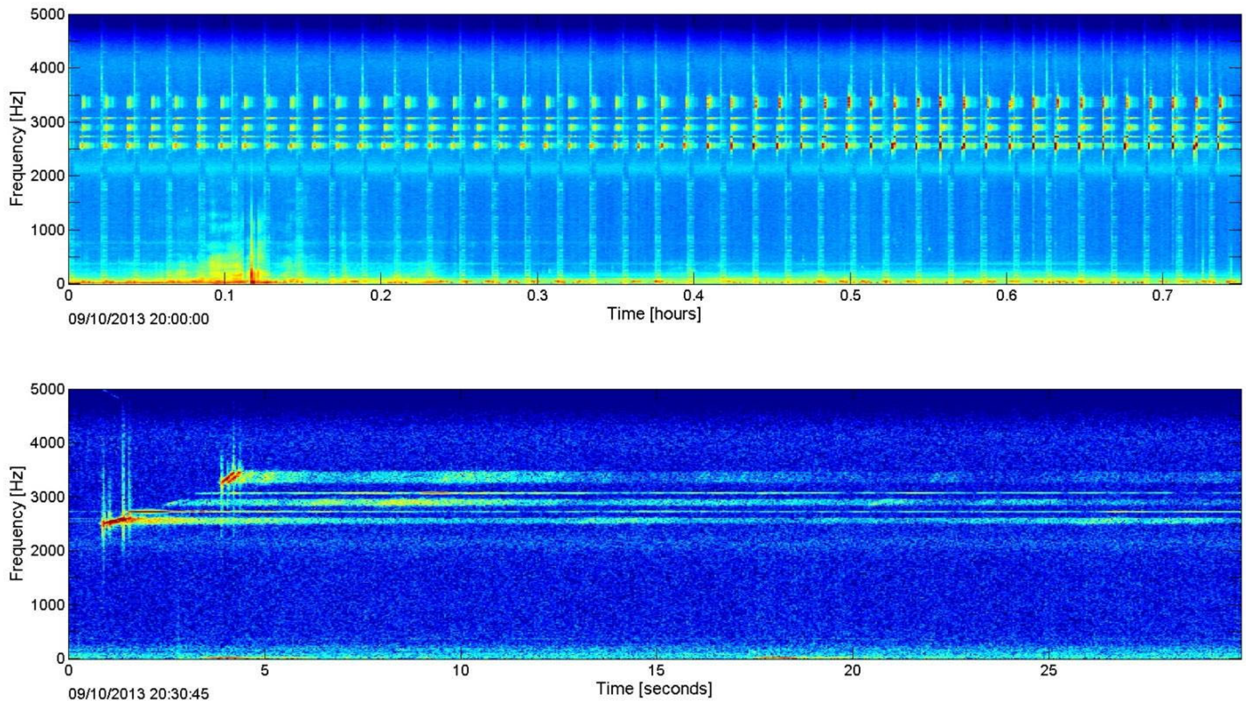

Figure 4. MFA sonar previously recorded at site H and shown as a wave train event in a 45-minute LTSA (top) and as a single packet with multiple pulses in a 30 second spectrogram (bottom).

Explosions

Effort was directed toward finding explosive sounds in the recordings including military explosions, shots from geophysical exploration, and seal bombs used by the fishing industry. 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. 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 5). Explosions were detected automatically for all deployments using a matched filter detector on data decimated to a 10-kHz sampling rate.

The explosion detector starts by filtering the time series with a 10^{th} order Butterworth bandpass filter between 200 and 2,000 Hz. Next, cross-correlation was computed between 75 s of the temporal envelope (i.e., Hilbert transform lowpass filter) of the filtered time series and the temporal 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 s of data to account for detecting explosions within noise, such as shipping. A cross-correlation threshold above the median was set. When the correlation coefficient reached above the threshold, the time series was inspected more closely.

Consecutive explosions were required to have a minimum time separation of 0.5 s to be detected. A 300-point (0.03 s) floating average energy across the detection was computed. The start and end of the detection above threshold was determined when the energy rose by more than 2 dB above the median energy across the detection. Peak-to-peak and RMS RLs were computed over the potential detection period and a time series of the length of the explosion template before and after the detection.

The potential detection was classified as false 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 or longer than 0.55 seconds. The thresholds were evaluated based on the distribution of histograms of manually verified true and false detections. By design, this detector produces a low number of false-negative detections but a high number of false-positive detections (>85%). To reduce the number of false-positive detections, each automated detection was manually reviewed and verified by a trained analyst.

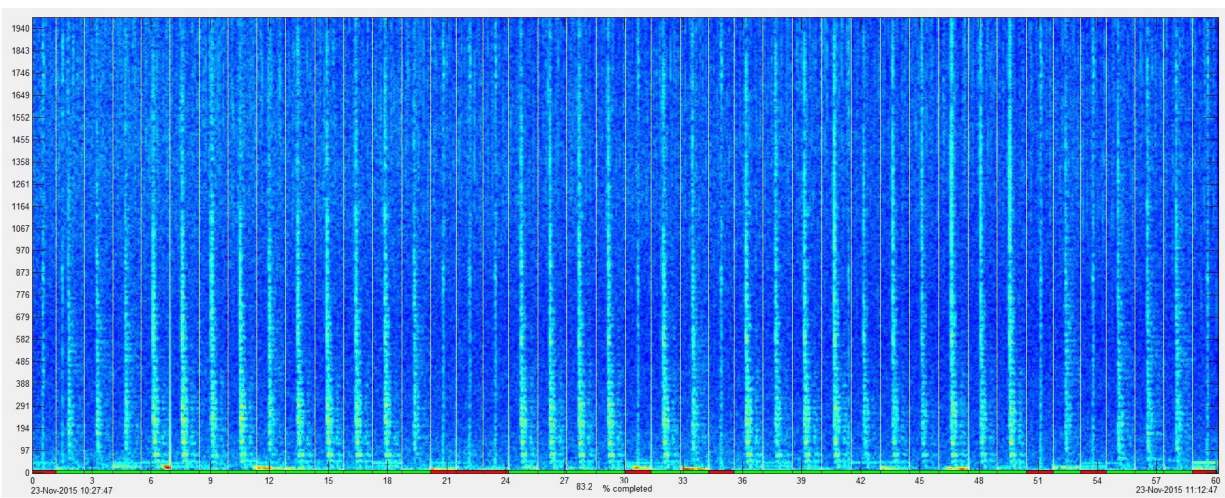

Figure 5. Explosions previously detected at site H in the analyst verification stage where events are concatenated into a single spectrogram. Green along the bottom indicates true and red indicates false detections.

Marine Mammal Presence from Shipboard Visual and Acoustic Surveys

Marine mammal surveys were initiated as part of the California Cooperative Oceanic Fisheries Investigation (CalCOFI) cruises beginning in 2004 and consisted of both visual observations and passive acoustic effort. Visual monitoring incorporated standard line-transect survey protocol (Buckland *et al.*, 1993; Barlow, 1995; Barlow and Forney, 2007) that includes two experienced observers scanning for marine mammals during transits between CalCOFI stations (Campbell *et al.*, 2015). Information on all cetacean sightings was logged systematically, including species, group size, reticle of cetacean position relative to the horizon, relative angle from the bow, latitude, longitude, ship's heading, behavior, environmental data, and comments. Acoustic monitoring at CalCOFI oceanographic sampling stations was also conducted with passive SSQ-53G sonobuoys. Sonobuoys were deployed one nautical mile before each daylight station and recorded for 2-4 hours while oceanographic sampling was underway. One omni-directional sonobuoy was deployed at each station where acoustic sampling was done. In some cases, a second DIFAR sonobuoy was deployed and the data from both Omni and DIFAR recorded separately. The following report summarizes the marine mammal visual sightings and sonobuoy deployment effort associated with four CalCOFI surveys conducted from fall 2022 to summer 2023.

Results

Passive Acoustic Monitoring

The results of acoustic data analysis at sites SN, E, H, and N from May 2022 to July 2023 are summarized below.

We describe the low-frequency ambient soundscape and the seasonal occurrence of beaked whale acoustic signals and anthropogenic sounds of interest.

Low-frequency Ambient Soundscape

- The underwater ambient soundscape at all sites had spectral shapes with higher levels at low frequencies (Figure 6) owing to the dominance of ship noise and whale calls at frequencies below 100 Hz and local wind and waves above 100 Hz (Hildebrand, 2009).
- Site H generally had lower spectrum levels (dB re 1 μPa^2 /Hz), compared to the other sites, below 100 Hz (Figure 6). This is expected because 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 sound spectrum levels observed in the frequency band 15–30 Hz during fall and winter at all sites were related to the seasonally increased presence of fin whale calls. The highest levels during this period occurred at site E, narrowly followed by site H (Figure 6).
- Spectral peaks around 42 Hz from July to December at all sites were related to blue whale B calls. The highest levels during this period occurred at site N. The peaks at 14 and 20 Hz at sites H and N were also a result of blue whale B calls (Figure 6).

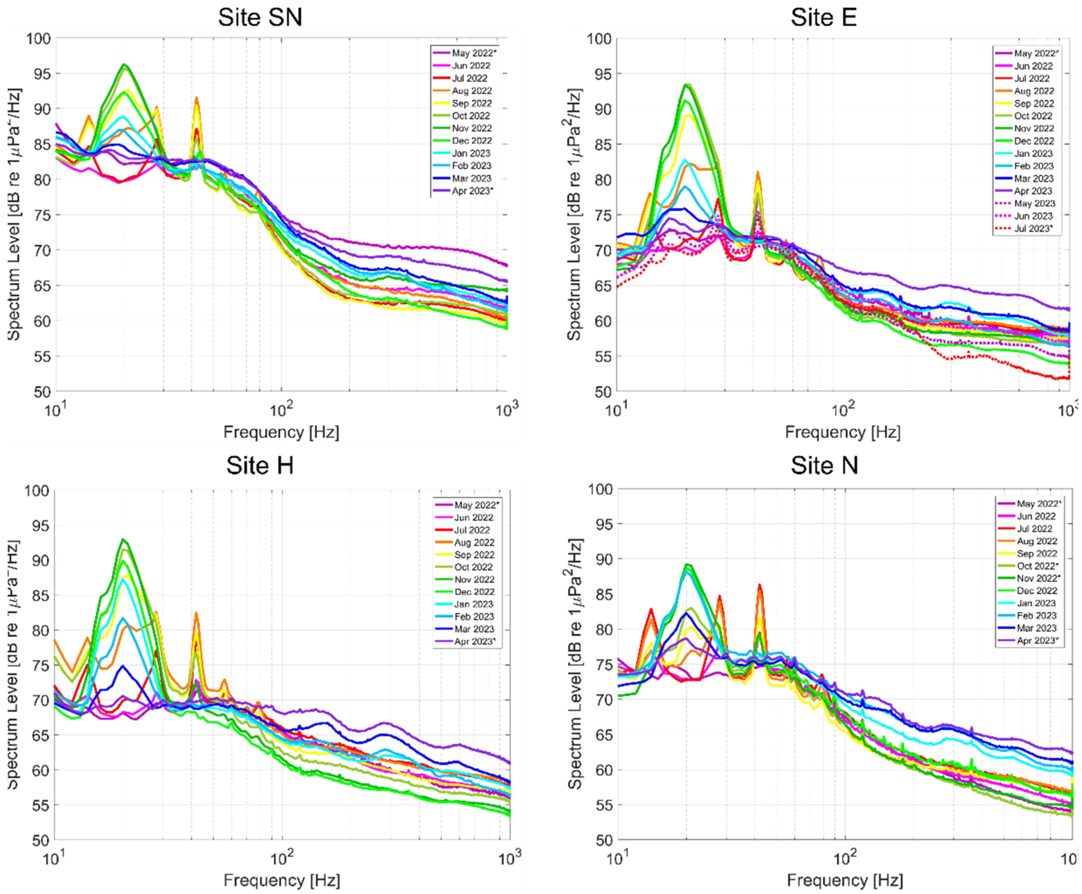

Figure 6. Monthly averages of sound spectrum levels at sites SN, E, H, and N. Legend gives color-coding by month. * denotes months with partial (< 90%) effort.

Beaked Whales

Cuvier's beaked whales were the only cetacean species monitored during this reporting period. Cuvier's beaked whales were detected throughout all four sites.

Cuvier's Beaked Whales

- Cuvier's beaked whale FM pulses were detected most at site E and least at site N (Figure 7).
- At site SN, detections peaked in spring/summer and were low in the fall/winter. At site E, detections were low August through October and highest December to June. At site H, detections were low in the fall, but relatively consistent the remainder of the year. Detections were low throughout the monitoring period at site N, with a slight increase in January (Figure 7).
- There was no discernable diel pattern for Cuvier's beaked whale detections (Figure 8).
- Detections were generally consistent with previous reports (Kerosky *et al.*, 2013; Debich *et al.*, 2015a; Debich *et al.*, 2015b; Širović *et al.*, 2016; Rice *et al.*, 2017; Rice *et al.*, 2018; Rice *et al.*, 2019; Rice *et al.*, 2020; Rice *et al.*, 2021; Rice *et al.*, 2022).

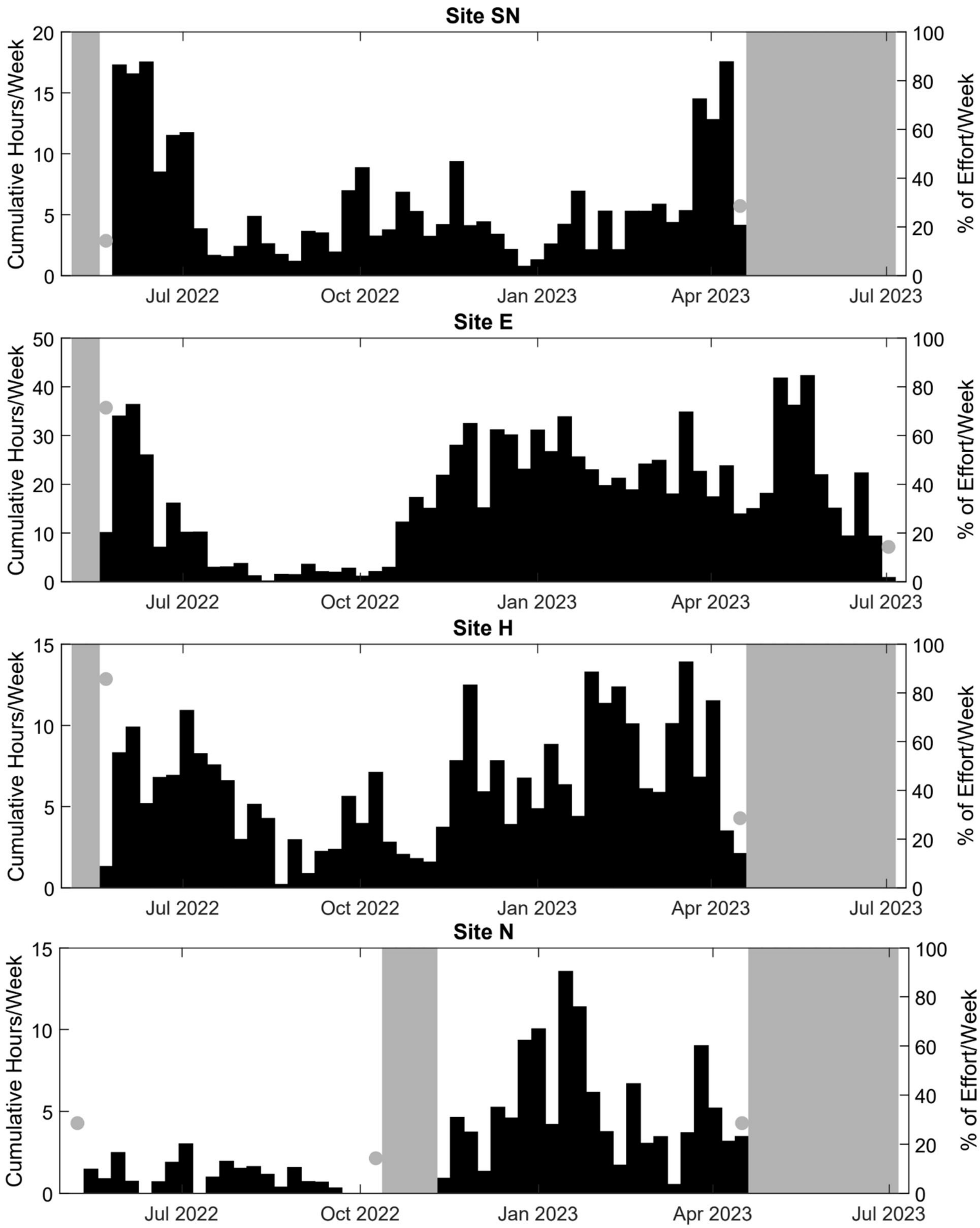

Figure 7. Weekly presence of Cuvier's beaked whale FM pulses between May 2022 and July 2023 at sites SN, E, H, and N. Gray dots represent percent of effort per week in weeks with less than 100% recording effort, and gray shading represents periods with no recording effort. Where gray dots or shading are absent, full recording effort occurred for the entire week. Note the higher y-axis value for site SN and E.

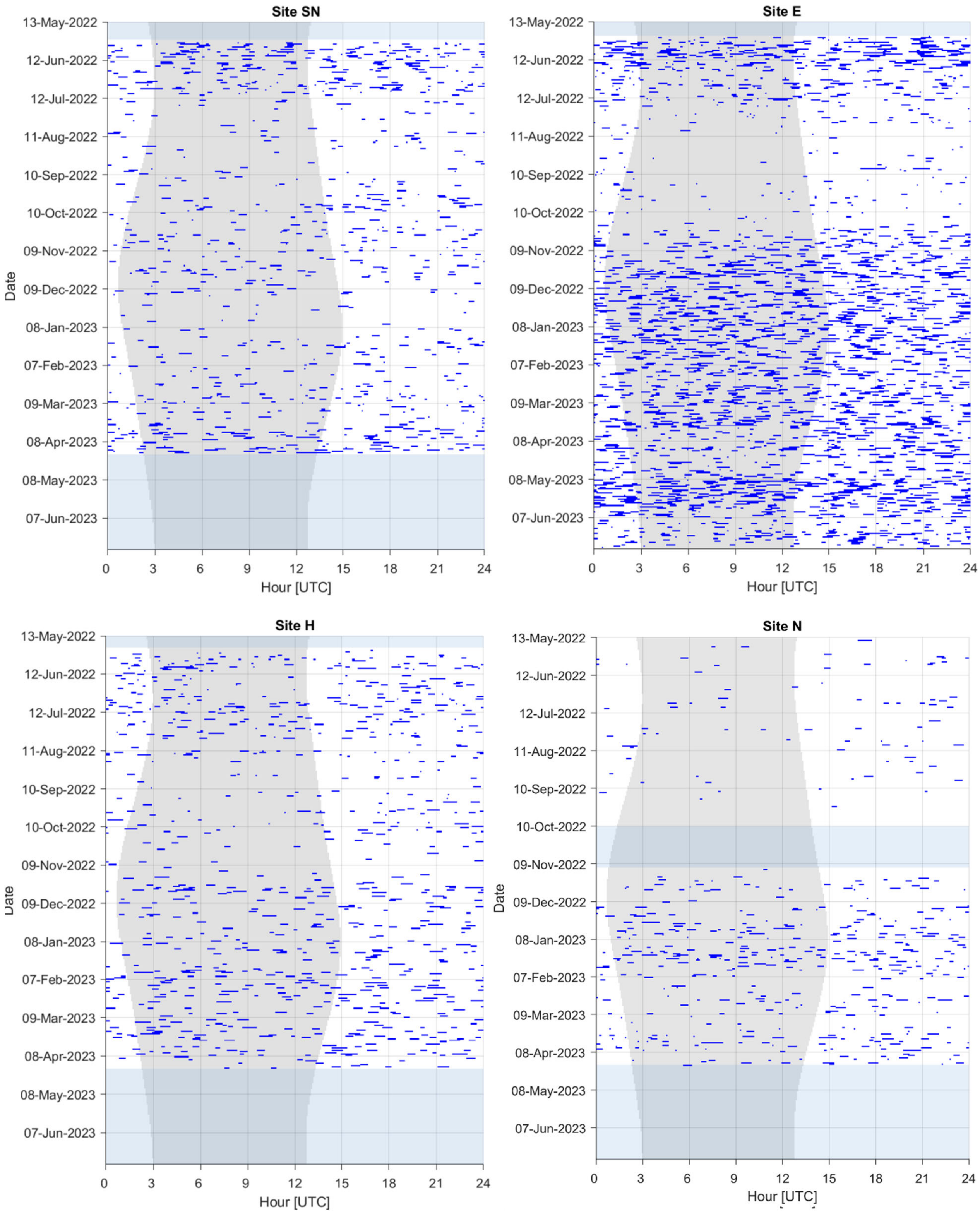

Figure 8. Cuvier's beaked whale FM pulses, indicated by blue dots, in one-minute bins at sites SN, E, H, and N. Gray vertical shading denotes nighttime and light purple horizontal shading denotes absence of acoustic data.

Anthropogenic Sounds

Anthropogenic sounds from MFA sonar (2.4–4.5 kHz) between May 2022 and July 2023 were analyzed for this report.

Mid-frequency active Sonar

MFA sonar was a commonly detected anthropogenic sound. The dates of major naval training exercises that were conducted in the SOCAL region between May 2022 and July 2023 are listed in Table 5 (C. Johnson, personal communication). Sonar usage outside of designated major exercises is likely attributable to unit-level training. The automatically detected packets and wave trains show the highest level of MFA sonar activity (> 130 dB_{pp} re 1 µPa) when normalized per year at site N, while site E showed the lowest levels (Table 6).

- MFA sonar was detected throughout the recording period at sites E, H, and N. At these sites, detections were generally highest in summer and fall. At site SN, MFA sonar primarily occurred in October 2022 to March 2023; however, none of the analyst-defined encounters remained after filtering, indicating that these MFA detections had received levels below 130 dB_{pp} re 1 µPa (Figure 9).
- There was no consistent diel pattern to MFA sonar detections, but at sites E, H and N there was a general decrease in detections in the hours before sunrise when training exercises were occurring (Figure 10).
- At site E, a total of 242 packets were detected, with a maximum received level of 165 dB_{pp} re 1 µPa at clipping level (Figure 11). Total wave train duration was 5.8 h (Figure 13), but the total packet duration was only about 0.1 h (423.6 s; Table 6; Figure 14).
- At site H, a total of 8,606 packets were detected, with a maximum received level of 160 dB_{pp} re 1 µPa (Figure 11). Total wave train duration was 143.7 h (Figure 13), but the total packet duration was only about 5.3 h (18,917.9 s; Table 6; Figure 14).
- At site N, a total of 11,859 packets were detected, with a maximum received level of 165 dB_{pp} re 1 µPa at clipping level (Figure 11). Total wave train duration was 215.7 h (Figure 13), but the total packet duration was only 6.0 h (21,725.8 s; Table 6; Figure 14).
- Maximum cumulative sound exposure levels (SELs) of wave trains were highest at site N, reaching a level of 174.0 dB re 1 $\mu Pa^2 s$ during October 2022. At site H, maximum SELs of 166.6 dB re 1 $\mu Pa^2 s$ occurred in January 2023 and at site E, maximum SELs of 160.6 dB re 1 $\mu Pa^2 s$ occurred in October 2022 (Figure 12).
- The majority of MFA sonar was detected outside of periods when training exercises occurred (Table 5; Figure 9).

Table 5. Major naval training exercises in the SOCAL region between May 2022 and July 2023.

Exercise Dates
September 23, 2022 to November 22, 2022

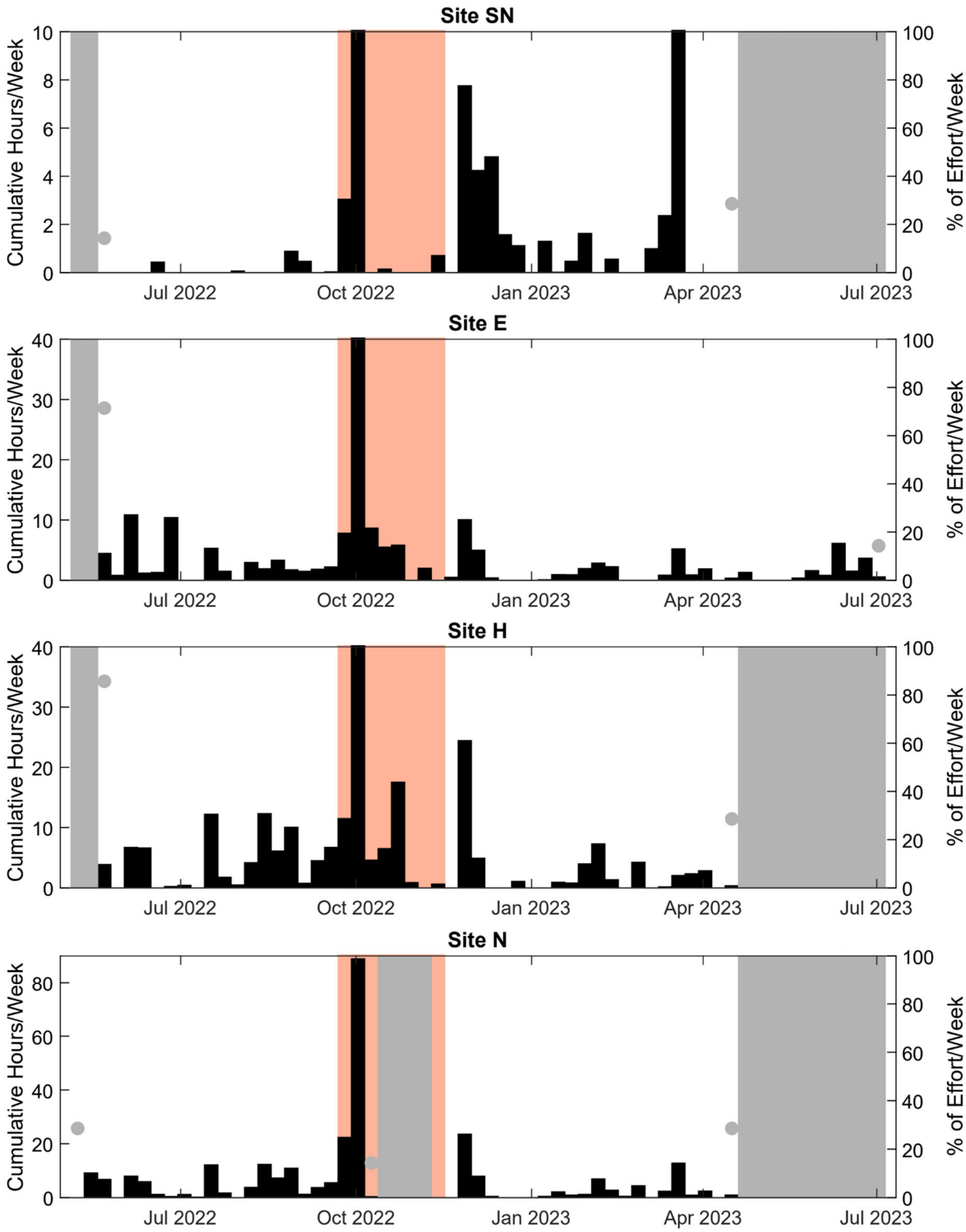

Figure 9. Major naval training events (shaded light red, from Table 5) overlaid on weekly presence of MFA sonar < 5kHz from the *Silbido* detector between May 2022 to July 2023 at sites SN, E, H, and N. Gray dots represent percent of effort per week in weeks with less than 100% recording effort, and gray shading represents periods with no recording effort. Where gray dots or shading are absent, full recording effort occurred for the entire week. Note the different y-axis for SN and N.

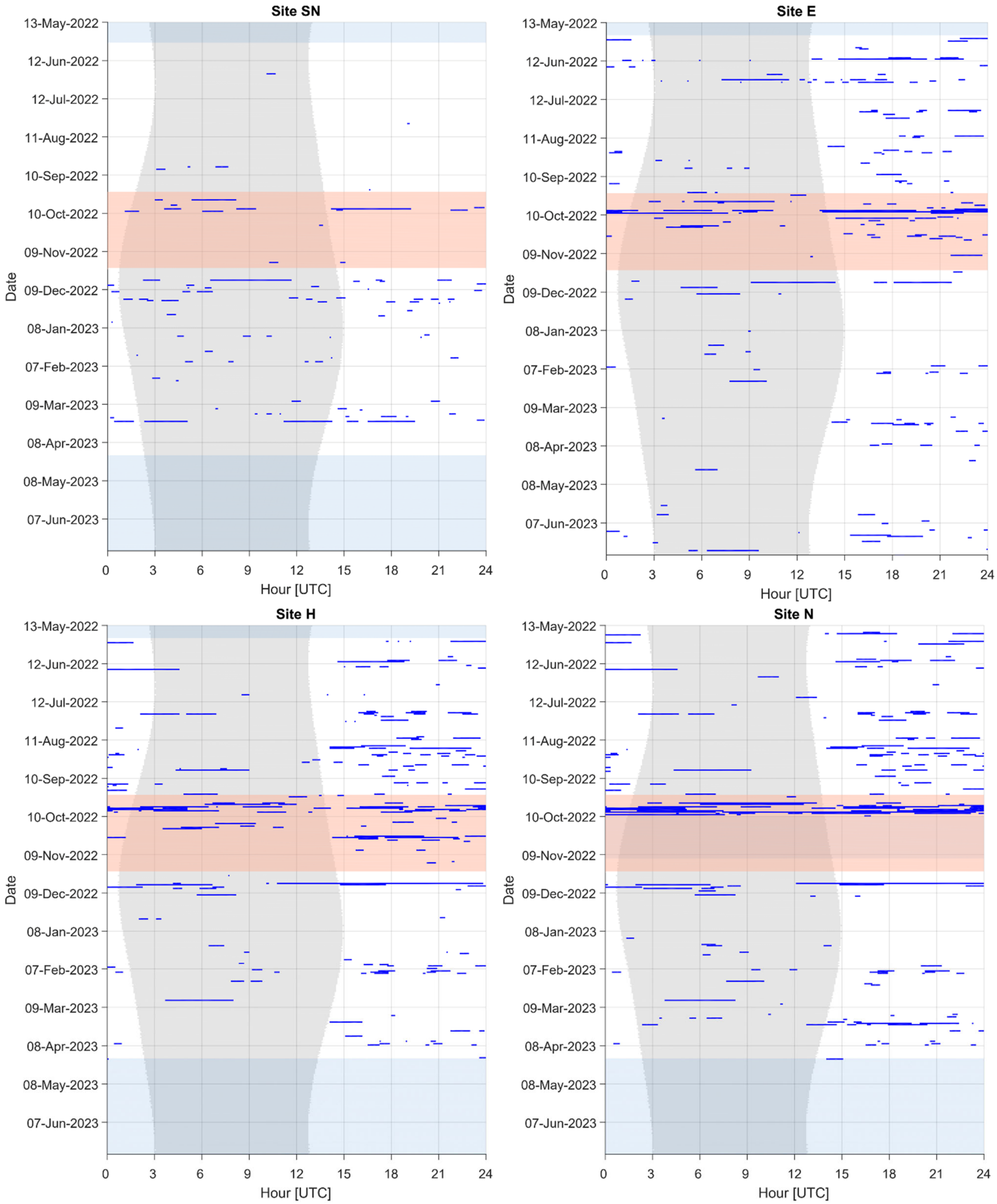

Figure 10. Major naval training events (shaded light red, from Table 5) overlaid on MFA sonar < 5 kHz signals from the *Silbido* detector, indicated by blue dots, in one-minute bins at sites SN, E, H, and N. Gray vertical shading denotes nighttime and light purple horizontal shading denotes absence of acoustic data.

Table 6. MFA sonar automated detector results for sites E, H, and N.
Total effort at each site in days (years), number of and extrapolated yearly estimates of wave trains and packets at each site (> 130 dB_{pp} re 1 µPa), total wave train duration, and total packet duration.

Site	Period Analyzed Days (Years)	Number of Wave Trains	Wave Trains per year	Number of Packets	Packets per year	Total Wave Train Duration (h)	Total Packet Duration (s)
E	407 (1.12)	5	4	242	216	5.8	423.6
H	331 (0.91)	104	114	8,606	9,457	143.7	18,917.9
N	309 (0.85)	87	102	11,859	13,952	215.7	21,725.8

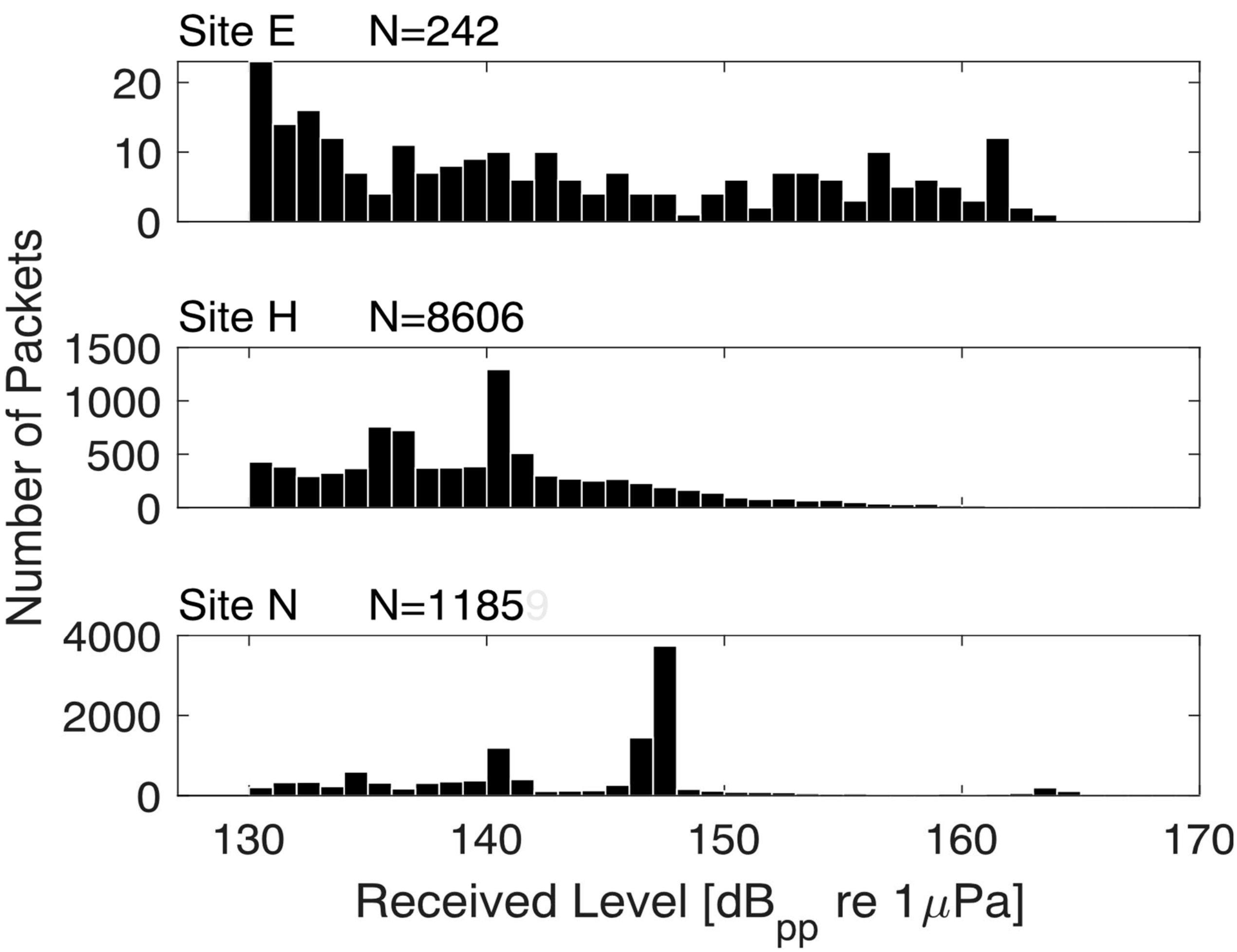

Figure 11. MFA sonar packet peak-to-peak received level distributions for sites E, H, and N.
The total number of packets detected at each site is given in the upper left corner of each panel. Instrument clipping levels typically occur around 165 dB_{pp} re 1 µPa. Note the vertical axes are at different scales.

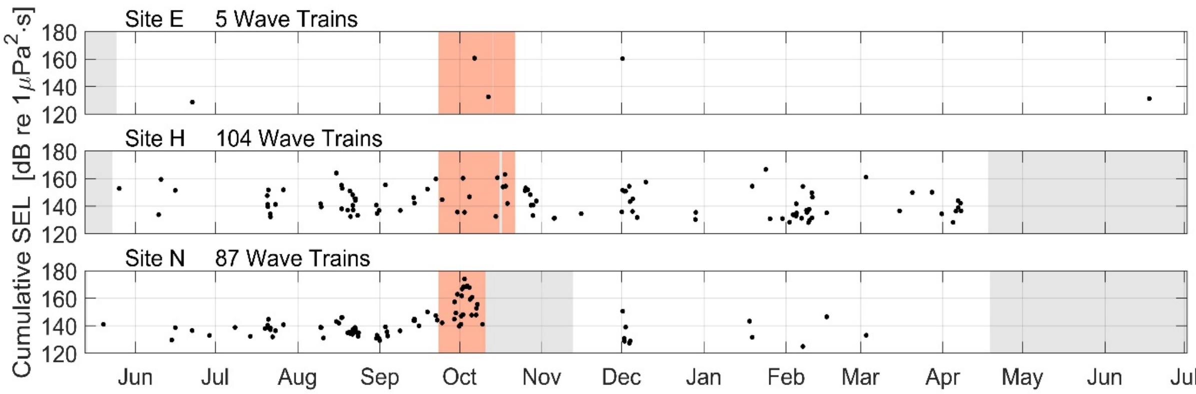

Figure 42. Cumulative sound exposure level for each wave train at sites E, H, and N.
Light red shading indicates major naval training events (Table 5).

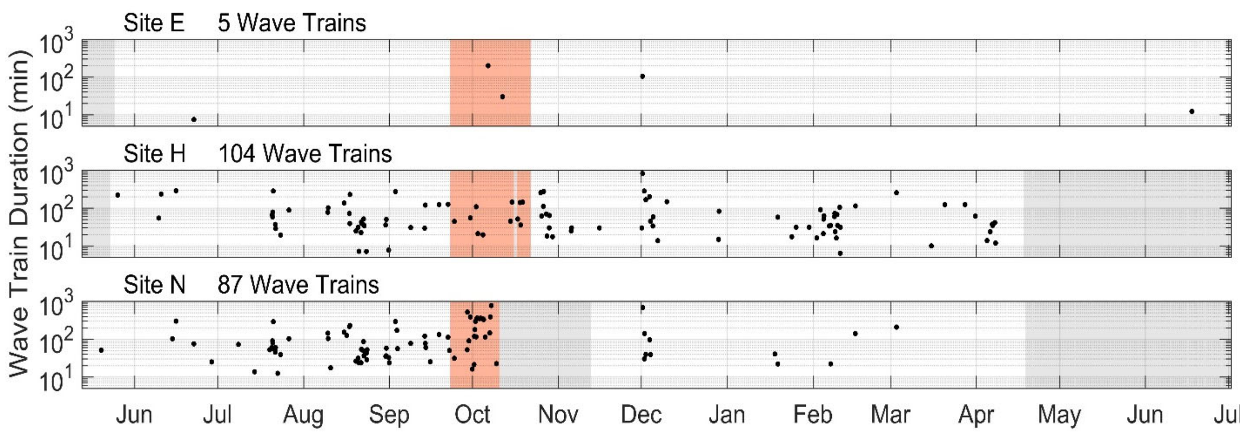

Figure 13. Wave train duration at sites E, H, and N.
Light red shading indicates major naval training events (Table 5). Note the vertical axes are logarithmic base-10.

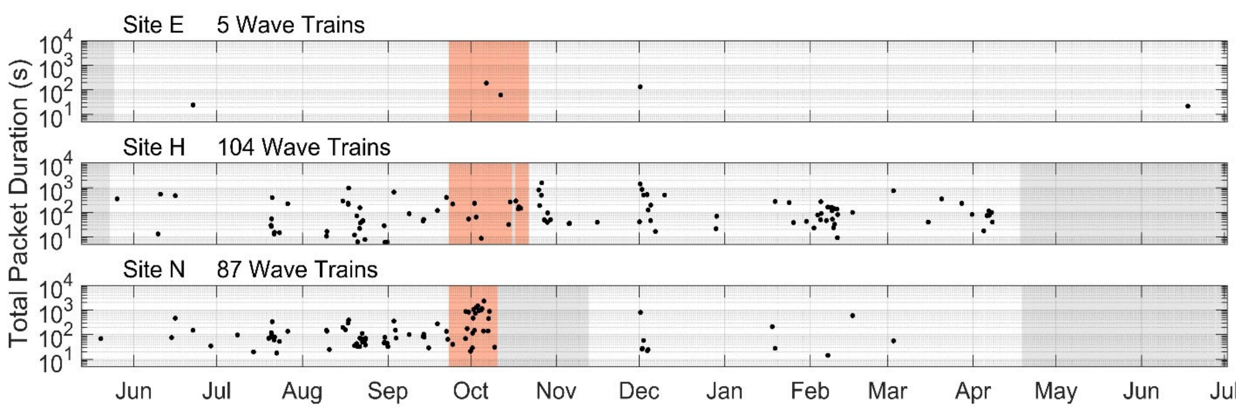

Figure 14. Total packet duration for each wave train at sites E, H, and N.
Light red shading indicates major naval training events (Table 5). Note the vertical axes are logarithmic base-10.

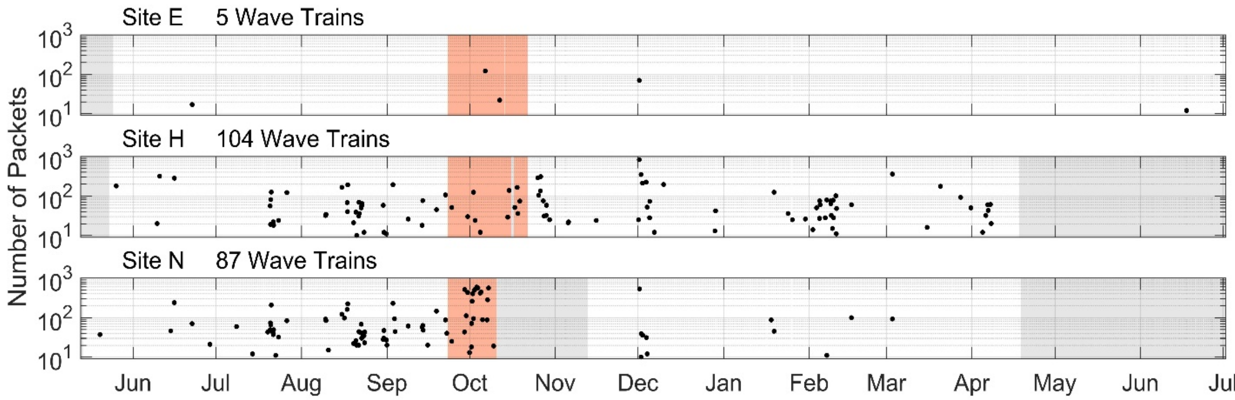

Figure 15. Number of MFA sonar packets for each wave train at sites E, H, and N.
Light red shading indicates major naval training events (Table 5). Note the vertical axes are logarithmic base-10.

Explosions

Explosions were detected at all four sites.

- Explosions occurred throughout the monitoring periods at all sites. The highest number of explosions occurred at site N and H, with peaks in July and October 2022. There were no clear patterns at site E where detections were low, except for June 2022. There was a December peak at SN, the site with the lowest number of detections overall (Figure 16).
- Cumulatively, 2,220 explosive events were detected during this reporting period. Total explosion counts at each site were as follows:
  - 329 at site SN
  - 349 at site E
  - 740 at site H
  - 802 at site N
- There was no strong diel pattern at sites SN or N, although there does appear to be a slight shift from initial nighttime preference to daytime preference as an indication of shift in fishing type. At sites E and H, there were more explosions at night (Figure 17). The predominant nighttime pattern at these sites suggests potential use of seal bombs by the squid fishery. The squid fishery in Southern California operates from October through March. However, daytime use at all sites may indicate another fishery using seal bombs. Additionally, the squid fishery has historically shifted effort among coastal pelagic finfish species (i.e., Pacific sardine, Pacific and jack mackerel, and northern anchovy) as a means of dealing with changes in resource availability (Pomeroy *et al.*, 2002; Aguilera *et al.*, 2015; Powell *et al.*, 2022).

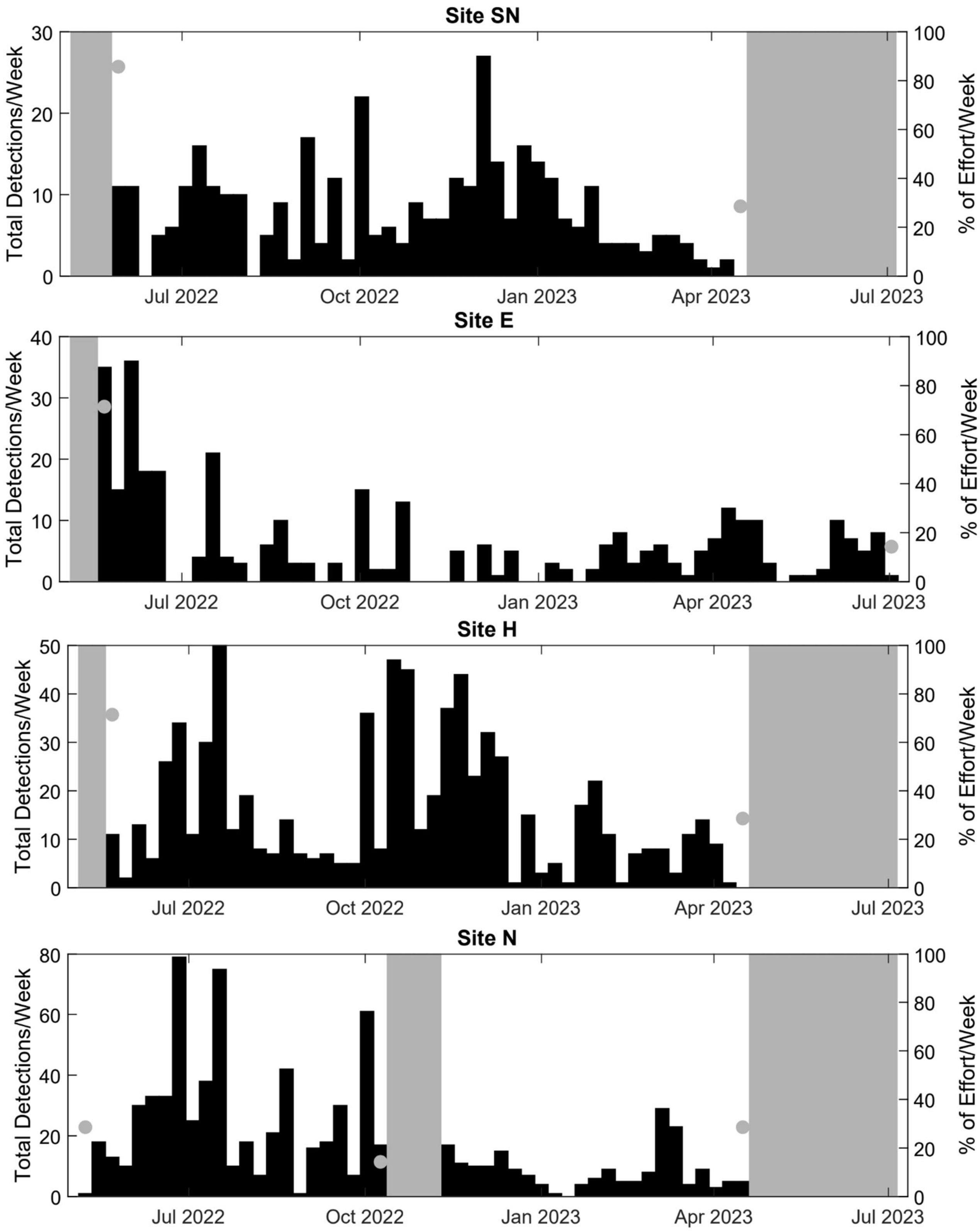

Figure 16. Weekly presence of explosions between May 2022 and July 2023 at sites SN, E, H, and N. Gray dots represent percent of effort per week in weeks with less than 100% recording effort, and gray shading represents periods with no recording effort. Where gray dots or shading are absent, full recording effort occurred for the entire week. Note the different y-axis values across sites.

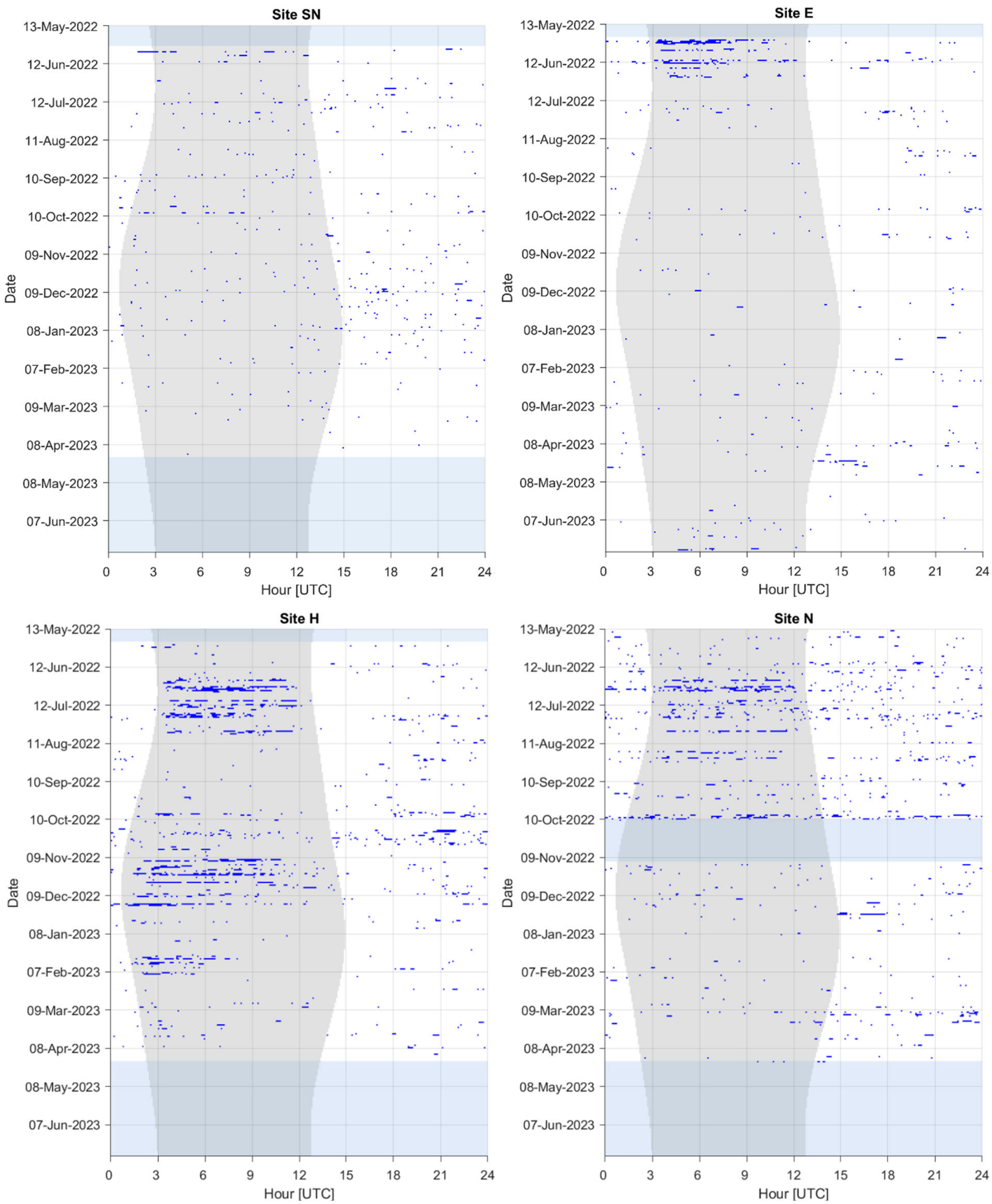

Figure 17. Explosion detections, indicated by blue dots, in five-minute bins at sites SN, E, H, and N. Gray vertical shading denotes nighttime and light purple horizontal shading denotes absence of acoustic data.

Marine Mammal Presence from Shipboard Visual and Acoustic Surveys

Four CalCOFI cruises were conducted from fall 2022 to summer 2023. This included 76 days at sea and 16,628 marine mammal visual observation hours on effort. Total effort included over 4,000 km of distance surveyed, yielding 352 sightings of 12 identified cetacean species (Table 7).

Table 7. Summary data from CalCOFI cruises between fall 2022 and summer 2023. The spring cruises in 2023 (2304SH) was an extended survey that also sampled further north up to San Francisco. The fall 2022 and winter 2023 cruises (2211SR and 2301RL) were shortened surveys.

Cruise	Cruise Dates	Survey Effort [hours]	Distance Surveyed [km]	# of sightings (on effort)	# Species
2211SR	11/05/22 – 11/19/22	88.7	710.2	88	12
2301RL	01/06/23 – 01/25/23	101.3	796.6	60	12
2304SH	03/24/23 – 04/22/23	253.9	1,385.4	69	11
2307SR	07/03/23 – 7/17/23	91.6	1,211.4	135	6
Total		**534**	**4,104**	**352**	**Max: 12**

Mysticete sightings

Five different species of mysticetes were identified on fall 2022 through summer 2023 cruises: minke (*Balaenoptera acutorostrata*), blue (*B. musculus*), fin (*B. physalus*), gray (*Eschrichtius robustus*), and humpback (*Megaptera novaeangliae*) whales. Large whales that could not be identified to species were logged as unidentified large whale (ULW).

Total numbers of on-effort groups and individuals sighted for each mysticete species are shown in Table 8. On-effort visual detections of mysticetes for 2022 through 2023 are shown in Figure 18. Spatial and temporal trends were apparent for several species. Fin whales and humpback whales were the most frequently sighted mysticetes. During winter and spring cruises, most mysticete sightings primarily occurred within ~350 km of the shoreline. During summer and fall cruises, mysticetes were frequently sighted along the continental slope and in offshore waters. Gray whale sightings were highly coastal or around the islands while minke whale sightings occuring far offshore in spring 2023. Blue whales were observed during summer and fall. Fin whales were observed during the summer, fall, and winter. Humpback whales were observed year-round. Gray whale sightings only occurred during winter and spring, and minke whales were encountered in fall, winter, and spring.

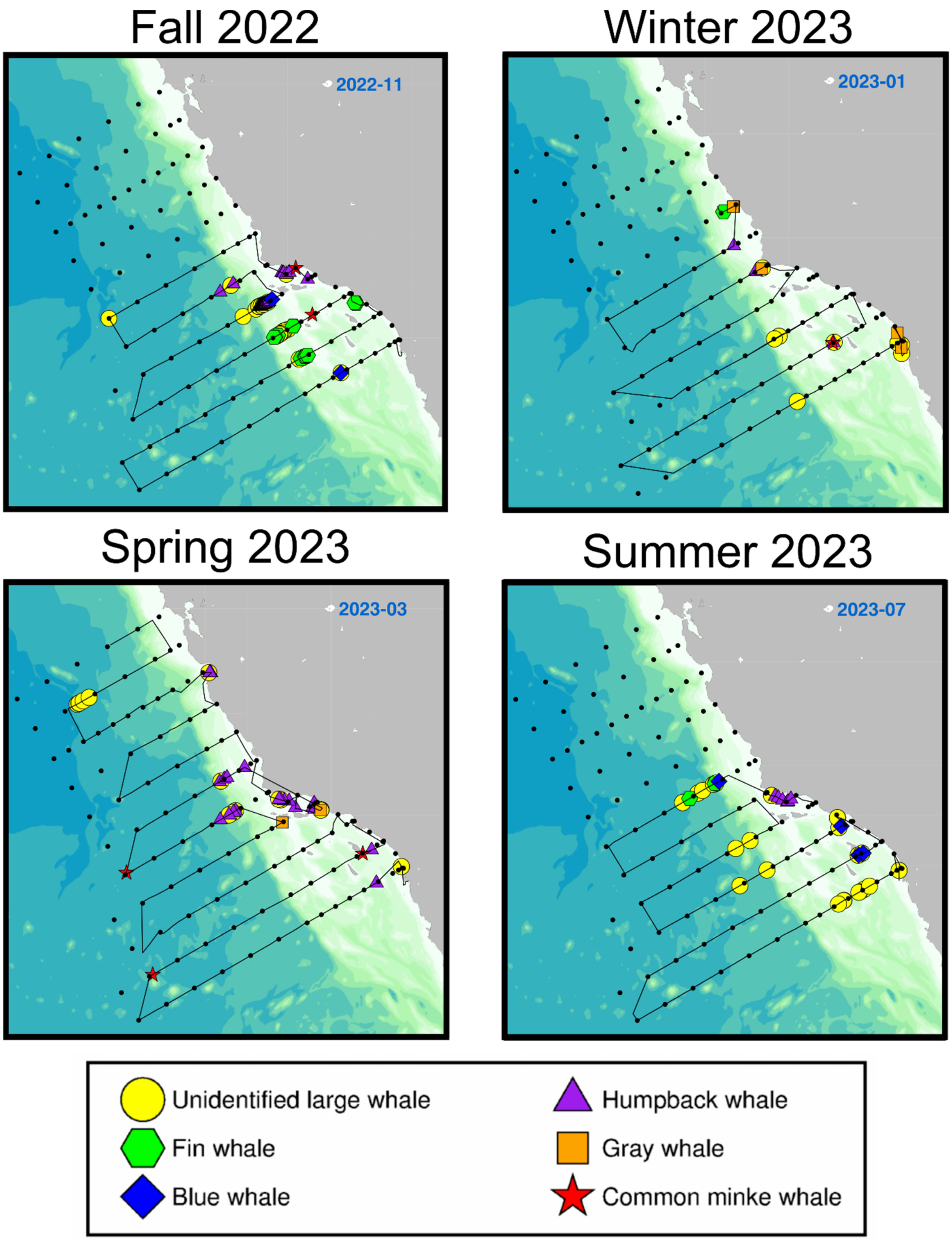

Figure 18. On-effort mysticete sightings during CalCOFI cruises fall 2022 to summer 2023. CalCOFI stations are represented by black dots and the ship's track line when observers were on effort is represented as a solid black line between stations. The spring cruise in 2023 was an extended survey up to San Francisco.

Table 8. On-effort mysticete sightings fall 2022 to summer 2023.

		Species	Minke	Blue	Fin	Gray	Humpback	ULW
2022	Fall	# Groups	1	2	13	0	29	19
		# Ind	1	2	30	0	101	27
	Winter	# Groups	1	0	1	5	3	9
		# Ind	1	0	1	15	6	14
2023	Spring	# Groups	3	0	0	2	24	14
		# Ind	3	0	0	3	168	16
	Summer	# Groups	0	3	3	0	6	20
		# Ind	0	5	16	0	26	28
Total # Groups			**5**	**5**	**17**	**7**	**62**	**96**
Total # Individuals			**5**	**7**	**47**	**18**	**301**	**378**

Odontocete sightings

Nine different species of odontocetes were identified on fall 2022 through summer 2023 cruises: long-beaked (*Delphinus capensis*) and short-beaked (*D. delphis*) common dolphins, Risso's dolphins (*Grampus griseus*), northern right whale dolphins (*Lissodelphis borealis*), Pacific white-sided dolphins (*Lagenorhynchus obliquidens*), Dall's porpoises (*Phocoenoides dalli*), sperm whales (*Physeter macrocephalus*), striped dolphins (*Stenella coeruleoalba*), and bottlenose dolphins (*Tursiops truncatus*). Common dolphins that could not be identified to species were logged as *Delphinus* species (Dsp). Any other dolphin that could not be identified to species was logged as unidentified dolphin (UD).

Total numbers of on-effort groups and individuals sighted for each odontocete species are shown in Table 9. Odontocete detections for fall 2022 through spring 2023 revealed spatial and temporal trends (Figure 19). Short-beaked and long-beaked common dolphins were the most frequently encountered odontocetes, while bottlenose dolphins were also observed somewhat regularly. Short-beaked common dolphins were detected offshore more frequently than inshore; in contrast, long-beaked common dolphins were more frequently detected in inshore waters. Seasonally, short-beaked common dolphins were most abundant in winter and spring, whereas long-beaked common dolphins were most abundant in summer and fall. Sightings of Pacific white-sided dolphins only occurred in the spring, whereas Risso's dolphins were encountered in the winter and spring.

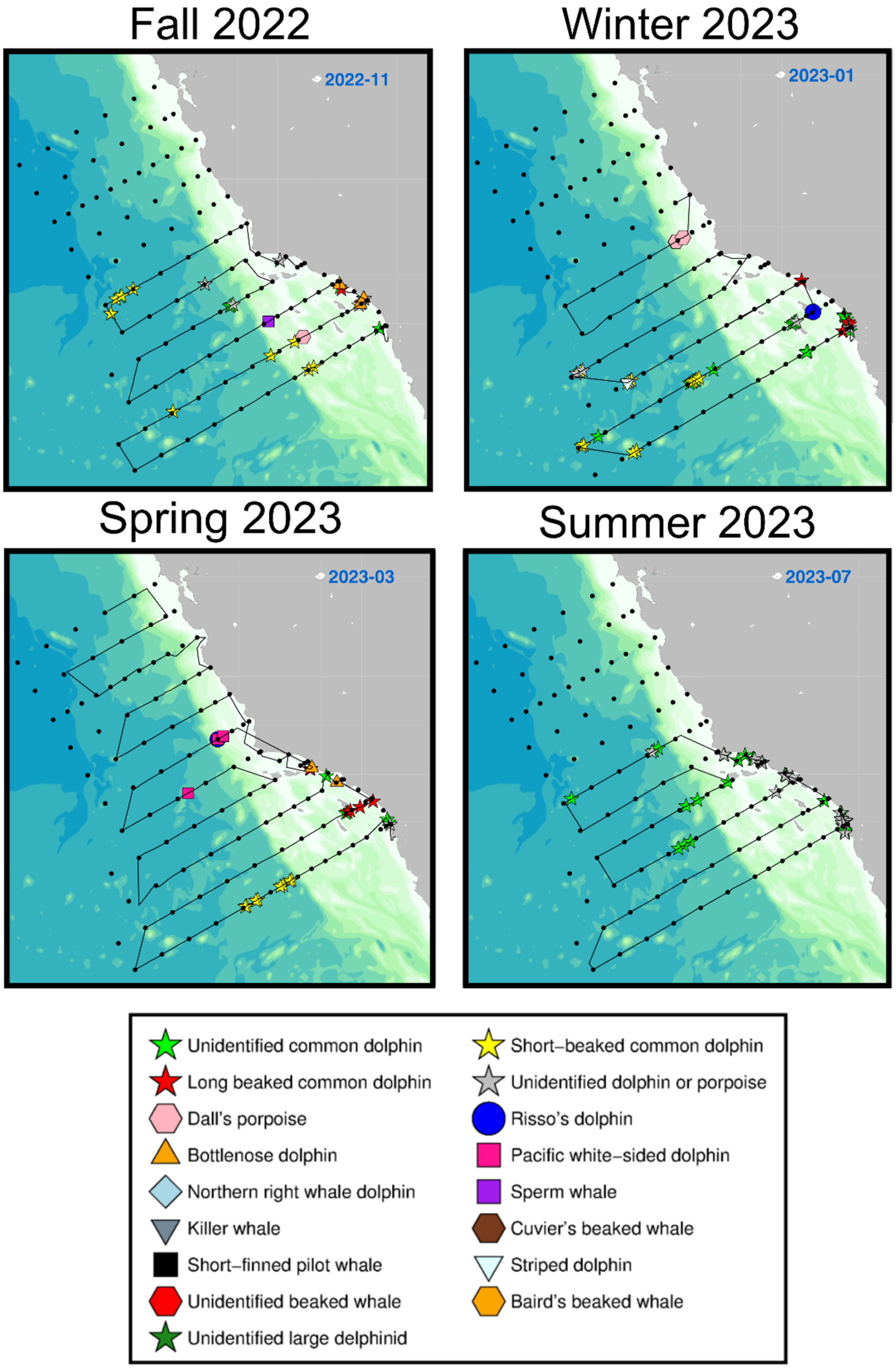

Figure 19. On-effort odontocete sightings during CalCOFI cruises fall 2022 to summer 2023. CalCOFI stations are represented by black dots and the ship's track line when observers were on effort is represented as a solid black line between stations. The spring cruise in 2023 was an extended survey up to San Francisco.

Table 9. On-effort odontocete sightings fall 2022 to summer 2023.

		Species	Dc	Dd	Dsp	Gg	Gm	Lb	Lo	Oo	Pd	Pm	Sc	Tt	UD	Zc
2022	Fall	# Groups	2	9	6	0	0	0	0	0	1	1	0	2	3	0
		# Ind	929	1601	522	0	0	0	0	0	3	12	0	10	57	0
	Winter	# Groups	5	11	15	1	0	0	0	0	3	0	1	0	5	0
		# Ind	2919	671	736	7	0	0	0	0	26	0	1	0	254	0
2023	Spring	# Groups	6	9	4	1	0	0	3	0	0	0	0	2	1	0
		# Ind	4970	268	390	6	0	0	516	0	0	0	0	39	11	0
	Summer	# Groups	0	0	29	0	0	0	0	0	0	0	0	0	14	0
		# Ind	0	0	1896	0	0	0	0	0	0	0	0	0	406	0
Total # Groups			**13**	**29**	**54**	**2**	**0**	**0**	**3**	**0**	**4**	**2**	**1**	**4**	**23**	**0**
Total # Individuals			**8818**	**2540**	**3544**	**13**	**0**	**0**	**516**	**0**	**29**	**12**	**1**	**49**	**728**	**0**

Acoustic effort

Acoustic effort on fall 2022 to summer 2023 cruises included 233 sonobuoy (Figure 20, Table 10).

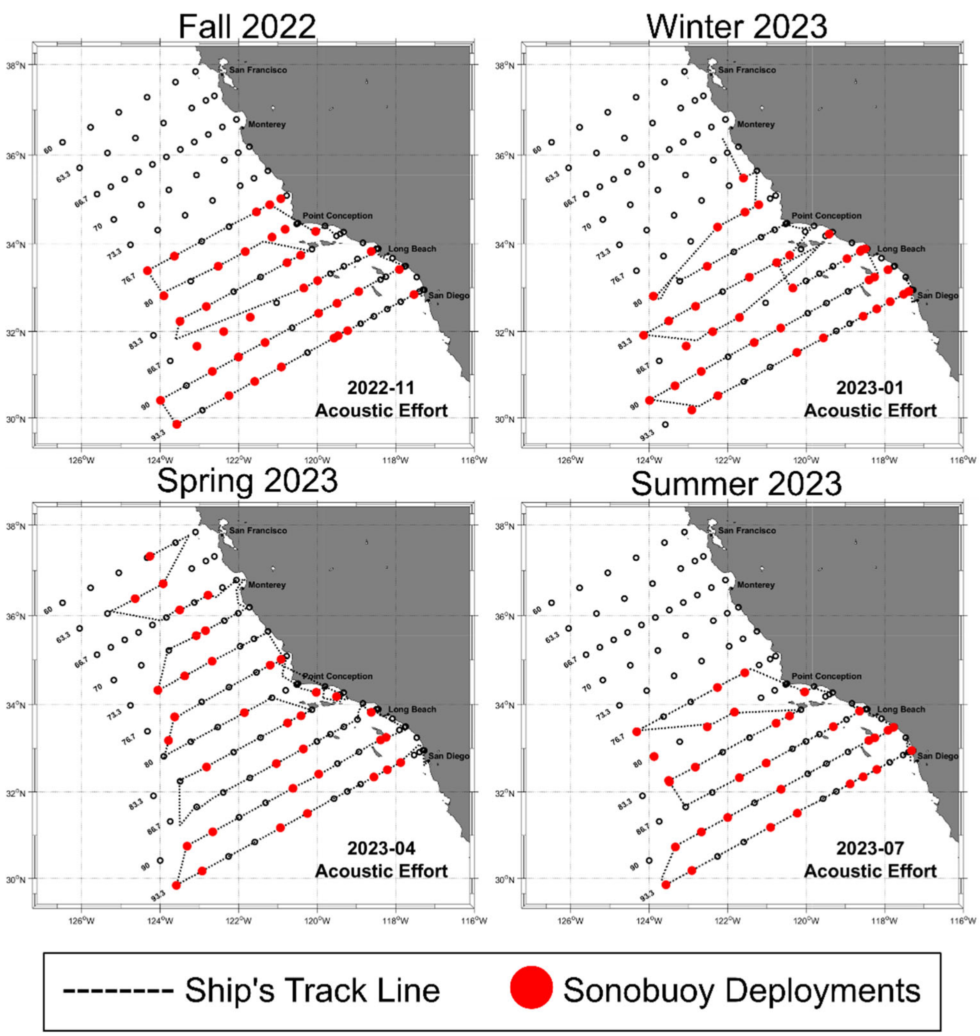

Figure 20. Acoustic effort fall 2022 to summer 2023. Red circles represent sonobuoy deployments and the dotted black line represents the ship's trackline.

Table 10. Acoustic deployments fall 2022 to summer 2023.

Year	Season	# sonobuoys deployed
2022	Fall	51
2023	Winter	80
	Spring	38
	Summer	64

Conclusions

The passive acoustic monitoring results from this report are generally consistent with previous reports for the SOCAL region. Site H and N had greater MFA wave trains and packets normalized per year than in the past monitoring period. In addition, detections of explosions were lower at sites than during past reporting periods. Passive acoustic monitoring will continue in the SOCAL range to document the seasonal presence of this subset of marine mammal species and to record anthropogenic activity.

CalCOFI visual surveys will continue in the SOCAL region to further document marine mammal distribution and abundance. Of the five mysticete species examined from 2022 to 2023, humpback whales and fin whales were the most sighted. Blue and fin whale sightings were higher in summer and fall, while humpback and gray whale sightings were higher in winter and spring. Of the nine odontocete species examined, common dolphins were most often sighted, followed by bottlenose dolphins who were also observed somewhat regularly. Bottlenose and common dolphin sightings were highest in spring, while Risso's dolphin, Pacific white-sided dolphin, and Dall's porpoise sightings were highest in the winter and spring.

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