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Passive Acoustic Monitoring in the SOCAL Range Complex and offshore Morro Bay from November 2024 to December 2025 and 2025 CalCOFI Surveys

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HARP deployment off the R/V Bob and Betty Beyster.

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14. ABSTRACT
The Marine Physical Laboratory at Scripps Institution of Oceanography continued its long-term passive acoustic monitoring program off Southern California from November 2024 to December 2025. This year's report summarizes data collection efforts during this period as part of a continuous time series monitoring initiative that began in 2009. Additionally, visual and passive acoustic data were collected during California Cooperative Oceanic Fisheries Investigations (CalCOFI) cruises off the California coast between January and November 2025.
Key Accomplishments in 2025

- Passive Acoustic Monitoring:
  - Collected 43,869 hours of broadband passive acoustic data from four monitoring sites in Southern California and one monitoring site offshore Morro Bay between November 2024 and December 2025 (see Figure 1).
  - Since the program's inception in 2009, a cumulative total of 375,606 hours of data have been recorded across these sites.
- CalCOFI Cruise Participation:
  - Conducted marine mammal visual and passive acoustic surveys across four CalCOFI cruises, covering all four seasons.
  - CalCOFI data continues to inform marine mammal density estimates, particularly for the spring and winter seasons, where corresponding National Marine Fisheries Service (NMFS) data have been limited.
- Scientific Contributions:

- Three peer-reviewed publications based on Navy-funded passive acoustic data collection efforts were released in 2025.
- Three conference presentations highlighted passive acoustic data collection findings.
- One graduate thesis utilizing collected passive acoustic data was completed.
- Two International Baccalaureate reports utilizing collected passive acoustic data from CalCOFI surveys were completed.

Future Directions

Ongoing analysis of accumulated data will support future publications and project-specific technical reports through 2026. This work will continue to enhance understanding of marine mammal presence and behavior in the region, contributing to mitigation and management efforts.

15. SUBJECT TERMS

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Executive Summary

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Data Collection

Passive Acoustic Monitoring

Passive acoustic monitoring was conducted in the Navy's Southern California (SOCAL) Range Complex and offshore Morro Bay from November 2024 to December 2025 to detect marine mammal and anthropogenic sounds.

High-frequency Acoustic Recording Packages (HARPs) recorded sounds between 10 Hz and 100 kHz at four locations in the SOCAL range: one site south of the Channel Islands (33° 32.350'N, 120° 15.415'W, 1,300 m depth, site W), two sites west of San Clemente Island (32° 39.559'N, 119° 28.756'W, 1,300 m depth, site E and 32° 51.703'N, 119° 08.152'W, 1,200 m depth, site H), and one site southwest of San Clemente Island (32° 22.196'N, 118° 33.908'W, 1,300 m depth, site N) to continue noise monitoring for the SOCAL range (Figure 1; Table 1-4). The new monitoring site offshore Morro Bay (35° 32.165'N, 121° 46.843'W, 1000 m depth, site WEA_MBA) recorded for 13 months (Figure 1; Table 5).

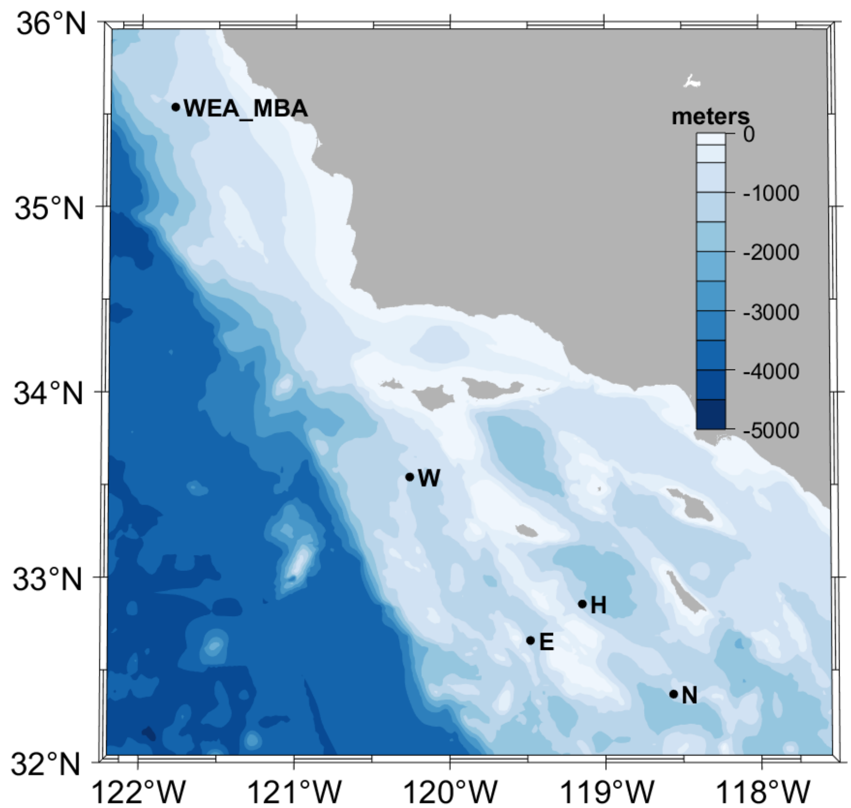

Figure 1. Locations of High-frequency Acoustic Recording Package (HARP) deployment sites W, E, H, and N in the SOCAL study area and WEA_MBA in Morro Bay from November 2024 to December 2025. Color indicates bathymetric depth; shading represents 500 m depth increments.

Table 1. SOCAL Range Complex acoustic monitoring at site E since January 2009. Periods of instrument deployment funded over the last year are shown in bold. Deployment 66 did not record due to the 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
74	7/05/23 – 10/31/23	2856
75	11/01/23 – 05/15/24	4704
76	5/16/24 – 11/10/24	4272
77	**11/10/24 - 04/16/25**	**3774**
78	**04/16/25 – 12/13/25**	**5760**

Table 2. SOCAL Range Complex acoustic monitoring at site H since January 2009. Periods of instrument deployment funded over the last year 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
76	04/18/23 – 10/12/23	4248
77	11/01/23 – 05/15/24	4704
78	05/15/24 - 11/10/24	4296
79	**11/10/24 - 4/17/25**	**3789**
80	**4/17/25 – 12/13/25**	**5736**

Table 3. SOCAL Range Complex acoustic monitoring at site N since January 2009. Periods of instrument deployment funded over the last year 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
74	04/19/23 – 10/16/23	4320
75	11/04/23 – 5/24/24	4848
76	5/24/24 – 12/16/24	4944
77	**12/17/24 - 04/16/25**	**2898**
78	**04/16/25 – 10/16/25**	**4368**

Table 4. SOCAL Range Complex acoustic monitoring at site W since July 2021. Periods of instrument deployment funded over the last year are shown in bold.

Deployment #	Monitoring Period	# Hours
01	7/29/21 – 1/22/22	4248
02	3/10/22 – 5/27/22	1892
03	5/27/22 – 10/14/22	3359
04	10/17/22 – 4/15/23	4321
05	4/16/23 – 9/25/23	3889
06	9/26/23 – 5/13/24	5520
07	5/16/24 – 11/19/24	4273
08	**11/09/24 - 4/17/25**	**3816**
09	**4/17/25 – 10/6/2025**	**4344**

Table 5. Acoustic monitoring at site WEA_MBA since November 2024. Periods of instrument deployment funded over the last year are shown in bold.

Deployment #	Monitoring Period	# Hours
01	**11/7/24 – 12/03/25**	**9384**

CalCOFI Shipboard Visual and Acoustic Surveys

Four CalCOFI cruises were conducted from winter 2025 to fall 2025 and included a total of 83 days at sea (Table 6). During the surveys, visual monitoring incorporated standard line-transect protocol during all daylight transits, while daytime acoustic monitoring employed sonobuoys deployed at oceanography sampling stations.

Table 6. Summary data from CalCOFI cruises between winter 2025 and fall 2025.

Cruise	Cruise Dates	# of group sightings (on effort)	# of Sonobuoys Deployed
2501RL	01/03/25 – 01/30/25	151	47
2504SH	03/20/25 – 04/21/25	203	58
2507SR	07/18/25 – 07/29/25	108	29
2511SR	11/9/25-11/18/25	54	16
Total		516	150

Science Products

Several active research projects within our lab group utilize data from Navy funded sites, contributing to significant advancements in marine mammal acoustics and ecosystem monitoring. In 2025 alone, these projects have resulted in multiple publications and conference presentations. A summary of the scientific products that have leveraged passive acoustic data funded by the Navy can be found below, followed by more details on each respective product.

Publications

Baggett, L.M., Snyder, E.R., Solsona-Berga, A., Curran, I.J., Wiggins, S.M., Hildebrand, J.A., Širović, A., Frasier, K.E. and Baumann-Pickering, S., 2025. Long-term monitoring of *Ziphius cavirostris* behavior using 3D tracking from fixed hydrophone arrays off Southern California. *Scientific Reports*, *15*(1), p.40859.

Bloom, S., Alksne, M., Rice, A., Lankhorst, M., Širović, A., Warren, J. and Baumann-Pickering, S., 2025. Seasonal changes in physical oceanography modulate cetacean predator-prey dynamics in the San Diego Trough. Marine Ecology Progress Series, 762, pp.111-133.

ZoBell, V.M., Posdaljian, N., Lenssen, K.L., Wiggins, S.M., Hildebrand, J.A., Baumann-Pickering, S. and Frasier, K.E., 2025. Climatic and economic fluctuations revealed by decadal ocean soundscapes. *The Journal of the Acoustical Society of America*, *157*(6), pp.4233-4251.

Conferences

Alksne, M.N.. Adesanya, D., Zingale, J., Zhang, X., Liu, X., Jones, J.J., Hildebrand, J.A., Širović, A., Frasier, K.E., Roch, M.A., Baumann-Pickering, S. (December, 2025). Big whales and big data: a convolutional neural network approach to investigating long-term biogeographic patterns of blue and fin whales in the Southern California Bight. Oral presentation: Meeting of the Acoustical Society of America, Honolulu, HI.

Alksne, M.N., Semmens, B.X., Solsona Berga, A., Wisely, E., Patin, N., Jacobson, E., Dinasquet, J., Thomas, L., Ward, E., Thorson, J., Baumann-Pickering, S. (October, 2025). An integrated species distribution model for humpback whales in the California Current Ecosystem. Oral presentation: Humpback Whale World Congress, Tadoussac, Québec.

Alksne, M.N.. Adesanya, D., Zingale, J., Zhang, X., Liu, X., Jones, J.J., Hildebrand, J.A., Širović, A., Frasier, K.E., Roch, M.A., Baumann-Pickering, S. (September, 2025). Big whales and big data: a convolutional neural network approach to investigating long-term biogeographic patterns of blue and fin whales in the Southern California Bight. Poster presentation: International Bioacoustics Congress, Kerteminde Denmark.

Theses

Miotto, C. 2025. Acoustic Detection Ranges of Blue Whale *(Balaenoptera musculus*) D Calls Under Changing Ocean Conditions. MS Thesis. University of California San Diego, La Jolla, CA.

International Baccalaureate Reports

Delaney, D. 2025. Spatio-seasonal Patterns of Humpback Whales in Spring of 2023

Fioresi, I. 2025. Spatio-seasonal Patterns of Humpback Whales in Fall of 2023

Abstracts

Long-term monitoring of *Ziphius cavirostris* behavior using 3D tracking from fixed hydrophone arrays off Southern California

Lauren M. Baggett, Eric R. Snyder, Alba Solsona-Berga, Isabelle J. Curran, Sean M. Wiggins, John A. Hildebrand, Ana Širović, Kaitlin E. Frasier, Simone Baumann-Pickering

Scientific Reports volume 15, Article number: 40859 (2025)

Abstract

Goose-beaked whales (*Ziphius cavirostris*) are a deep-diving toothed whale species and top predators in deep sea ecosystems. Much is yet to be learned about their social and foraging strategies due to their elusive behavior, but this information is increasingly relevant given their demonstrated behavioral changes in association with anthropogenic sound. This study used direction-of-arrival (DOA) localization to track the position of goose-beaked whales from echolocation clicks recorded on seafloor-mounted hydrophone arrays offshore Southern California. Overall, 2738 tracks of diving goose-beaked whales were processed from acoustic recordings collected at four long-term monitoring sites between 2018 and 2023. Results highlight distinct spatial use patterns driven by bathymetric features at each site, with whales foraging closer to the seafloor at sites with complex bathymetry and showing a preference for certain bathymetric features. Group sizes at depth ranged from 1 to 9 individuals with a mean of 2.34 and exhibited site-specific seasonal variability as well as a strong diel trend at one site. During many of these encounters, individuals exhibited highly coordinated behaviors. This study demonstrates the value of long-term passive acoustic tracking for studying elusive, deep-diving species and provides significant advancements in understanding goose-beaked whale behavior at depth over long time scales.

Seasonal changes in physical oceanography modulate cetacean predator-prey dynamics in the San Diego Trough

Shelby G. Bloom, Michaela N. Alksne, Ally Rice, Matthias Lankhorst, Ana Širović, Joseph. D. Warren, Simone Baumann-Pickering

Marine Ecology Progress Series 762:111-133 (2025)

Abstract

In marine ecosystems, cetaceans are large mobile predators that depend on maximizing foraging efficiency. Their presence within a habitat can therefore be strongly related to the modulation of local prey by oceanographic conditions. Understanding how cetaceans are impacted by prey responses to the physical environment is challenging due to the difficulty of collecting presence data of cetaceans and their prey over long, comparable time periods. We used passive and active acoustic recordings collected from moorings within the San Diego Trough, along with physical oceanographic sampling (i.e. in situ, satellite-derived, and ocean general circulation model measurements), to elucidate relationships between cetaceans, their prey, and the physical environment. Our results show that the predator-prey dynamics of some cetaceans within the San Diego Trough are influenced by seasonal changes in the physical oceanographic conditions and processes that shape their prey resources. Specifically, common dolphin Delphinus delphis foraging activity increased during conditions associated with increased presence of diel vertically migrating fish prey. Blue whale Balaenoptera musculus foraging-associated acoustic activity increased during periods with increased presence of mid-water crustacean zooplankton and was replaced with breeding-associated acoustic activity during conditions associated with the waning of mid-water crustacean zooplankton. Fin whale B. physalus foraging-associated calling activity was more complex to model, most likely because these animals have a generalist diet and occupy this area year-round. Our results highlight environmental conditions and features relevant to cetaceans inhabiting this region and may aid in developing better spatially explicit management actions.

Climatic and economic fluctuations revealed by decadal ocean soundscapes

Vanessa M. ZoBell, Natalie Posdaljian, Kieran L. Lenssen, Sean M. Wiggins, John A. Hildebrand, Simone Baumann-Pickering, Kaitlin E. Frasier

JASA 157, 4233-4251 (2025)

Abstract

Decadal variations of ocean soundscapes are intricately linked to large-scale climatic and economic fluctuations. This study draws on over 15 years of acoustic recordings at six sites within the Southern California Bight, investigating interannual, seasonal, and diel variations. By examining acoustic energy from fin and blue whales along with sounds from ships and wind, we identified changes in soundscape over time and space. This study reveals that sound levels associated with both biological and non-biological sound sources varied seasonally and correlated with large-scale climatic patterns and long-term oceanographic fluctuations. Baleen whale sound levels before, during, and after a marine heatwave were assessed; sound levels decreased in southern sites and increased in northern sites adjacent to the California Current, underscoring the potential for range shifts and habitat compression during warm years for these species. Ship-generated sound levels at high-traffic sites reflected economic events such as recessions, labor shortages and negotiations, and changes to port activities. Marine soundscapes offer an approach to assess the ocean's condition amid ongoing climatic and economic fluctuations.

Big whales and big data: a convolutional neural network approach to investigating long-term biogeographic patterns of blue and fin whales in the Southern California Bight

Alksne, M.N., Adesanya, D., Zingale, J., Zhang, X., Liu, X., Jones, J.J., Hildebrand, J.A., Širović, A., Frasier, K.E., Roch, M.A., Baumann-Pickering, S.

Oral presentation: Journal of Acoustical Society of America, Honolulu, HI. (2025)

Poster: International Bioacoustics Congress, Kerteminde Denmark.(September, 2025).

Abstract

Blue and fin whales produce low-frequency calls tied to foraging and reproduction. Using sonobuoy recordings from CalCOFI surveys, we fine-tuned a Faster-R-CNN detector on 15,659 labeled calls and refined it through human-in-the-loop annotation. Model performance was high (AP: 0.80–0.93), except for fin whale 40 Hz calls (0.71). Applied to the twenty-year time series, we found seasonal patterns consistent with prior work and a long-term increase in blue whale calls (Figures 2-3). During the 2014–2016 marine heatwave, blue and fin whale foraging-associated calls declined and were compressed to the shelf break. This work highlights the value of integrating passive acoustic monitoring and deep learning to investigate ecological patterns and track species' responses to environmental change.

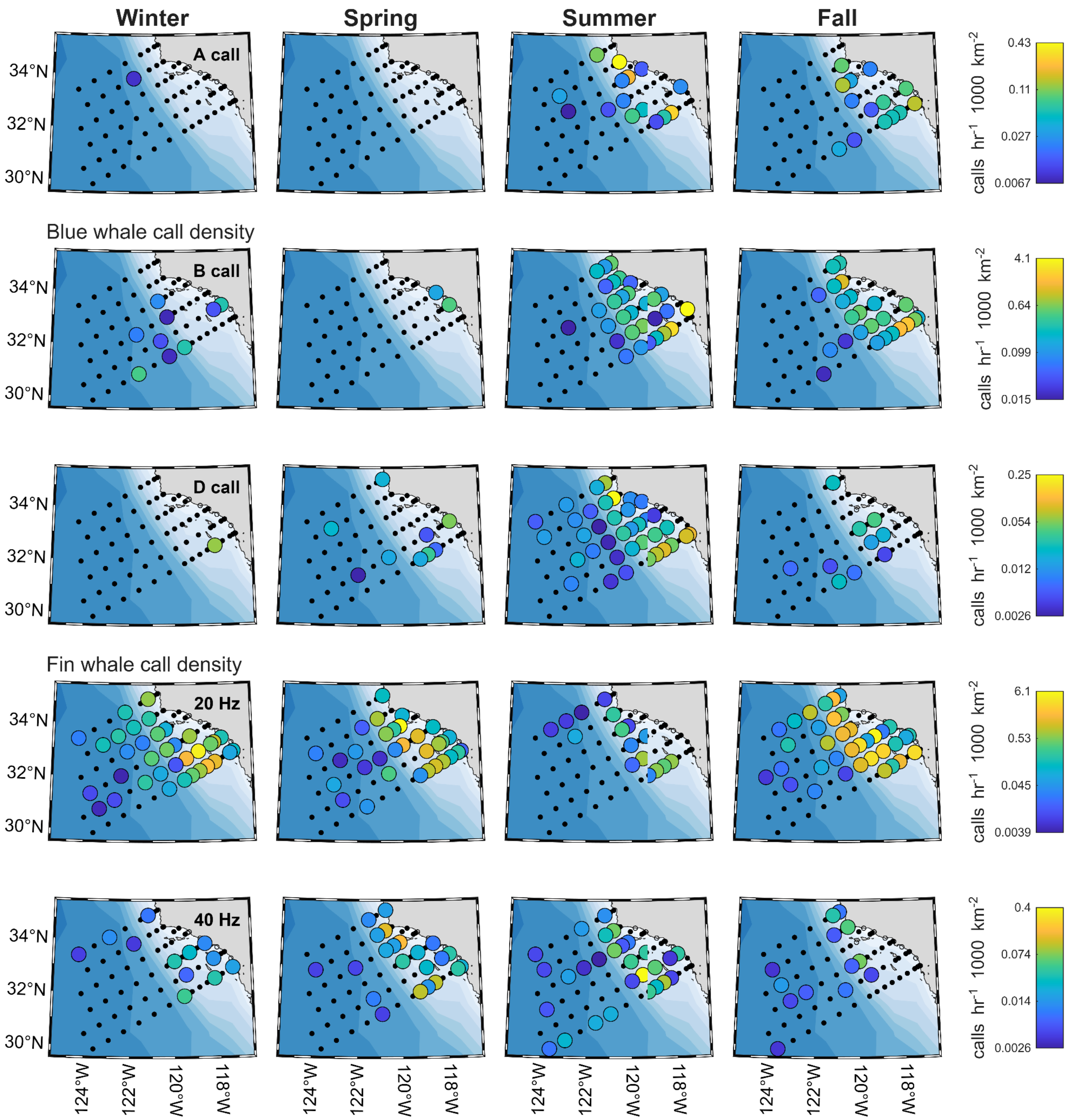

Figure 2. Seasonal and spatial patterns in blue and fin whale call density across the southern California Current Ecosystem aggregated by CalCOFI stations between 2004 and 2024. Maps show effort-weighted mean call density (calls hr^{-1} 1000 km^{-2}) aggregated by season (columns: Winter, Spring, Summer, Fall) and station. Circle color indicates log-transformed call density. Open circles indicate deployments with recording effort but no detections during a given season. Bathymetry is contoured at 500 m intervals from 0 to 7000 m depth.

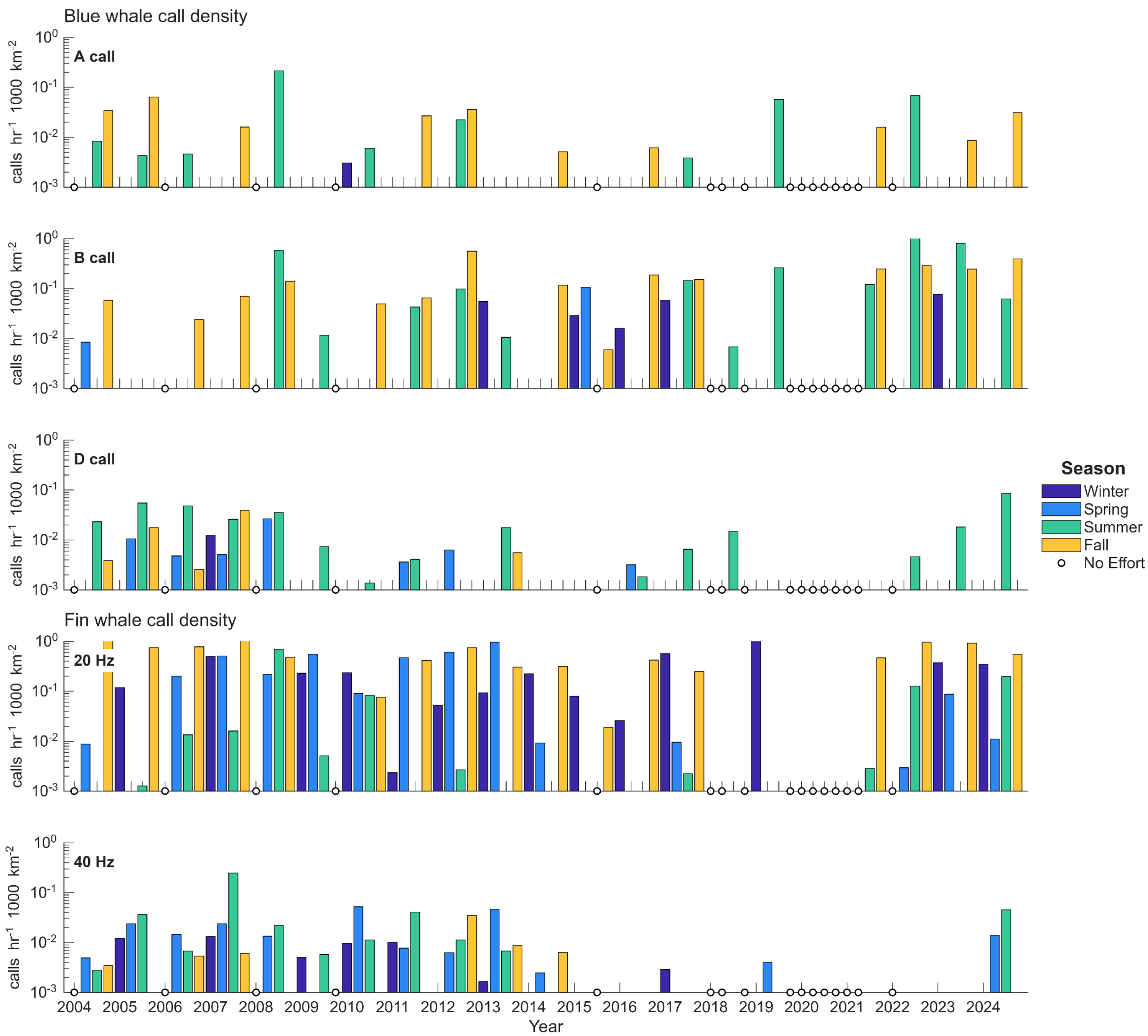

Figure 3. CalCOFI-cruise level seasonal timeseries of effort-weighted blue and fin whale call density across the southern California Current Ecosystem (2004–2024). Panels show cruise-level, effort-weighted mean call density (calls hr^{-1} 1000 km^{-2}) for each call type (A, B, D, 40 Hz, and 20 Hz), with bars colored by season (Winter, Spring, Summer, Fall). Densities are plotted on a logarithmic y-axis to accommodate the wide dynamic range in acoustic activity across years and call types. Open circles indicate year–season combinations with no recording effort.

An integrated species distribution model for humpback whales in the California Current Ecosystem

Alksne, M.N., Semmens, B.X., Solsona Berga, A., Wisely, E., Patin, N., Jacobson, E., Dinasquet, J., Thomas, L., Ward, E., Thorson, J., Baumann-Pickering, S.

Oral presentation: Humpback Whale World Congress, Tadoussac, Québec. (October 2025)

Abstract

Species distribution models (SDMs) are powerful tools for understanding marine mammal habitat use. This work describes the steps towards building an integrated SDM for baleen whales in the California Current Ecosystem using multi-modal CalCOFI data: passive acoustic detections, line-transect visual sightings, and environmental DNA (eDNA). Acoustic data included manually and automatically detected calls; visual data provided density estimates; and eDNA revealed species presence (Figures 4-6). Using a flexible spatiotemporal model, we are mapping habitat suitability and quantifying detection variability across methods. At nearshore stations within biologically important areas, all three methods consistently detected blue, fin, and humpback whales, highlighting the value of integrating multi-modal data to support conservation and management.

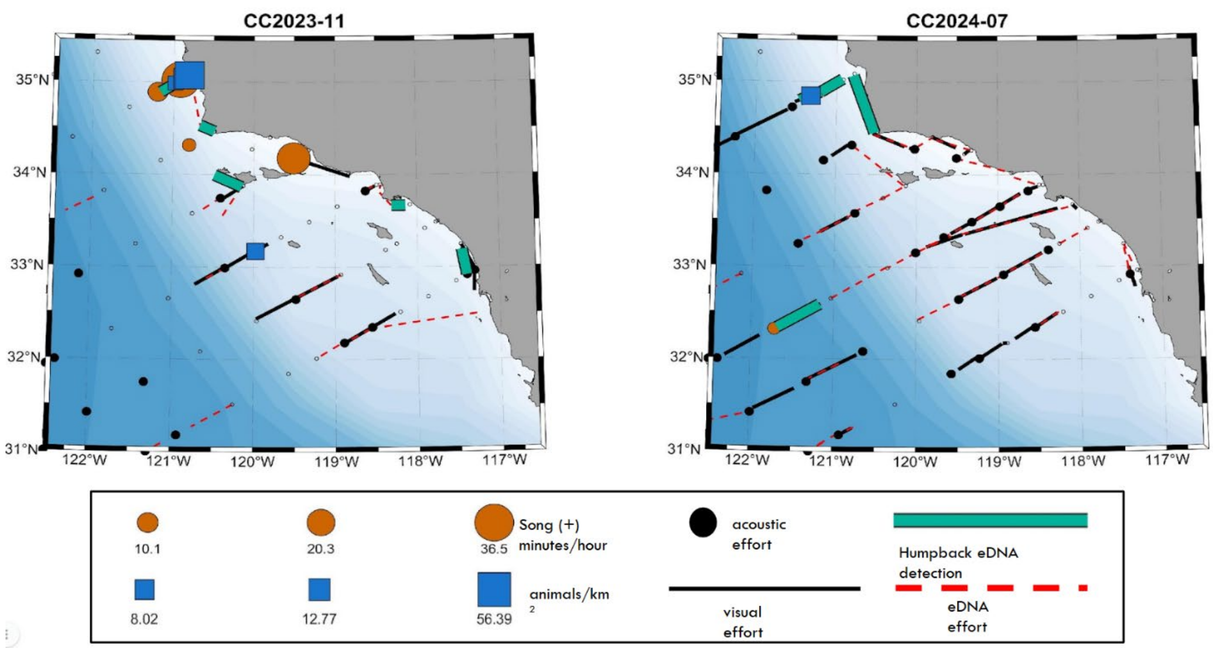

Figure 4. Multi-modal detections of humpback whales during two CalCOFI cruises in the Southern California Current Ecosystem. Panels compare spatial patterns between cruises (left: CC2023-11; right: CC2024-07). Circles indicate song presence quantified as minutes of song per hour, and squares indicate visual encounter density (animals km^{-2}). Black points show acoustic recording effort, black line segments show visual survey effort, red dashed lines indicate eDNA sampling effort, and green segments indicate positive eDNA detections. Together, these panels demonstrate how song activity, visual sightings, and eDNA detections provide complementary perspectives on humpback whale distribution.

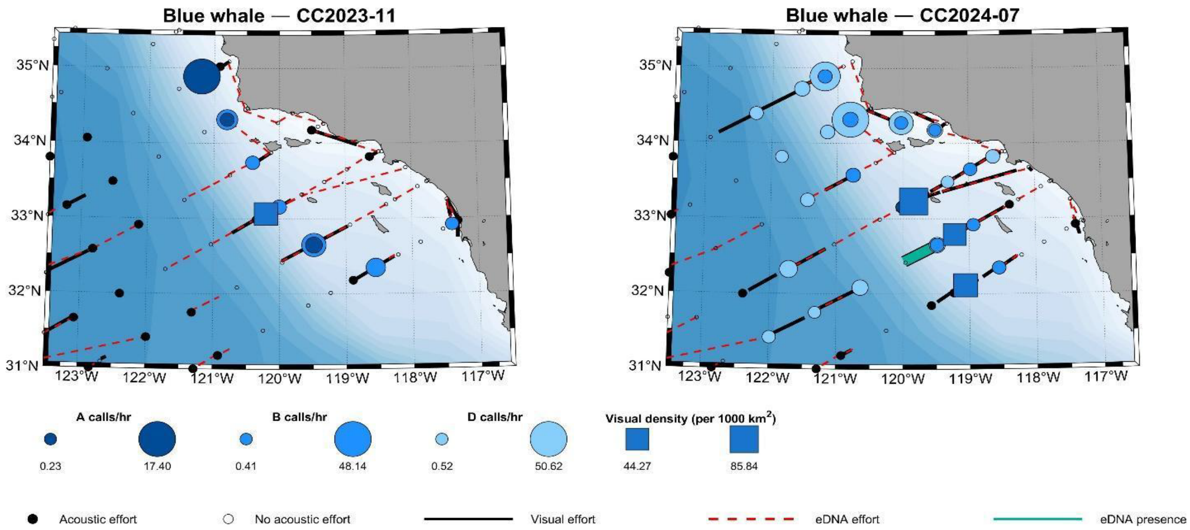

Figure 5. Multi-modal detections of blue whales during two CalCOFI cruises in the Southern California Current Ecosystem. Panels compare spatial patterns between cruises (left: CC2023-11; right: CC2024-07). Circles show acoustic call rates for A, B, and D calls, scaled by calls hr^{-1}, and squares show visual encounter density (animals km^{-2}). Black points indicate acoustic recording effort, black line segments indicate visual survey effort, red dashed lines indicate eDNA sampling effort, and green segments indicate positive eDNA detections.

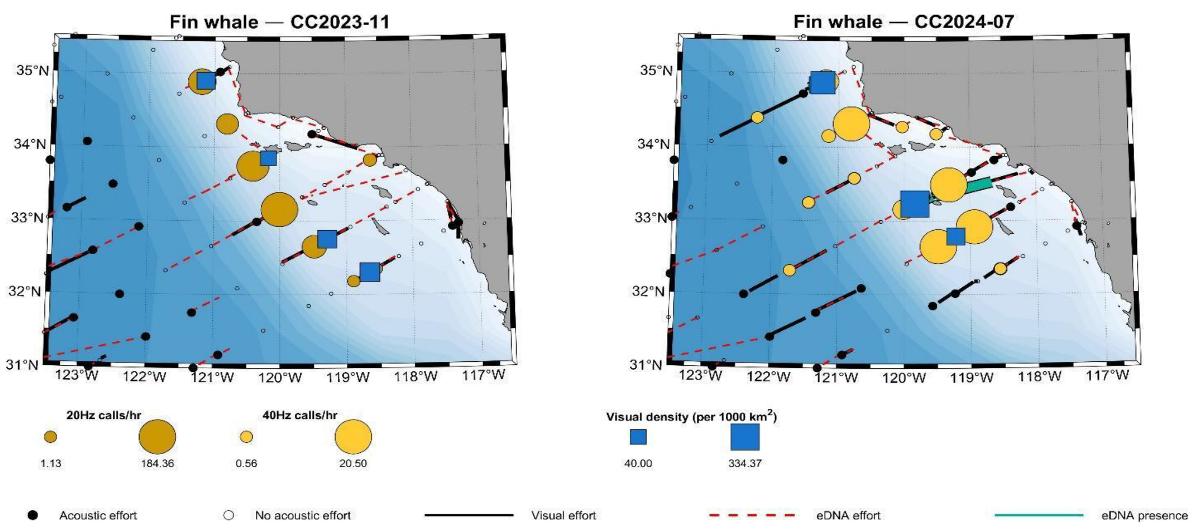

Figure 6. Multi-modal detections of fin whales during two CalCOFI cruises in the Southern California Current Ecosystem. Panels compare spatial patterns between cruises (left: CC2023-11; right: CC2024-07). Circles show acoustic call rates for 20 Hz and 40 Hz calls, scaled by calls hr^{-1}, and squares show visual encounter density (animals km^{-2}). Black points denote acoustic effort, black line segments denote visual survey effort, red dashed lines indicate eDNA sampling effort, and green segments indicate positive eDNA detections. Results illustrate spatial overlap and divergence among detection modalities across cruises.

Acoustic Detection Ranges of Blue Whale (*Balaenoptera musculus*) D Calls Under Changing Ocean Conditions

Carlotta Miotto, MS Thesis, UC San Diego

Abstract

Blue whale (*Balaenoptera musculus*) D calls are low-frequency vocalizations commonly produced during foraging, and although they are widely used in acoustic monitoring, the environmental factors that shape their detectability remain poorly quantified. Because blue whales are listed as an Endangered species, understanding how ocean variability affects the acoustic "visibility" of their calls is essential for accurate long-term monitoring and conservation efforts. Using the range-dependent parabolic-equation model RAMGeo, transmission loss was simulated at three monitoring sites spanning distinct bathymetric settings (submarine basin, shelf break, open ocean; Figure 7), and monthly detection areas were computed above five call received-level thresholds (80, 85, 90, 95, and 100 dB re 1 μPa) for the years 2007–2023 (Figure 8-9). Detection areas covaried strongly with upper-ocean temperature and sound-speed gradients, with the largest acoustic footprints occurring during cooler, weakly stratified months and the smallest during warm anomalies, including major marine-heatwave periods. Sensitivity was strongest at mid-range thresholds (85–95 dB), whereas near-field detections above the 100 dB threshold were largely invariant across environments. Taken together, these results demonstrate that blue-whale acoustic detectability is strongly shaped by regional physical oceanography and bathymetric features and highlight the importance of incorporating environmental context into passive-acoustic monitoring and interpretation of long-term trends for this endangered species.

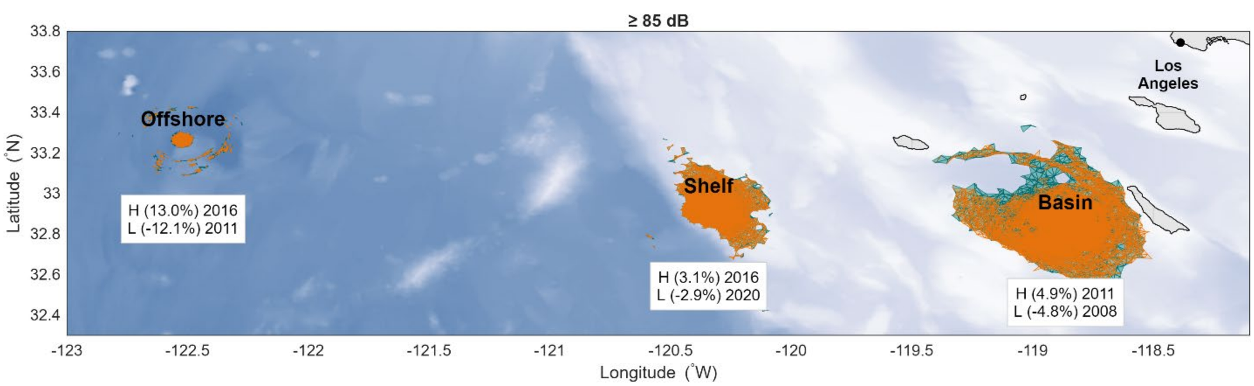

Figure 7. Modeled contours for the maximum (H, green polygons) and minimum (L, orange polygons) September detection areas at the 85 dB threshold across the basin (Site H), shelf (Site SN), and offshore (Site CCE) sites. The labels indicate the percentage deviation from the average area observed for September at that site, and in which year it occurred. Background shading indicates regional bathymetry depth.

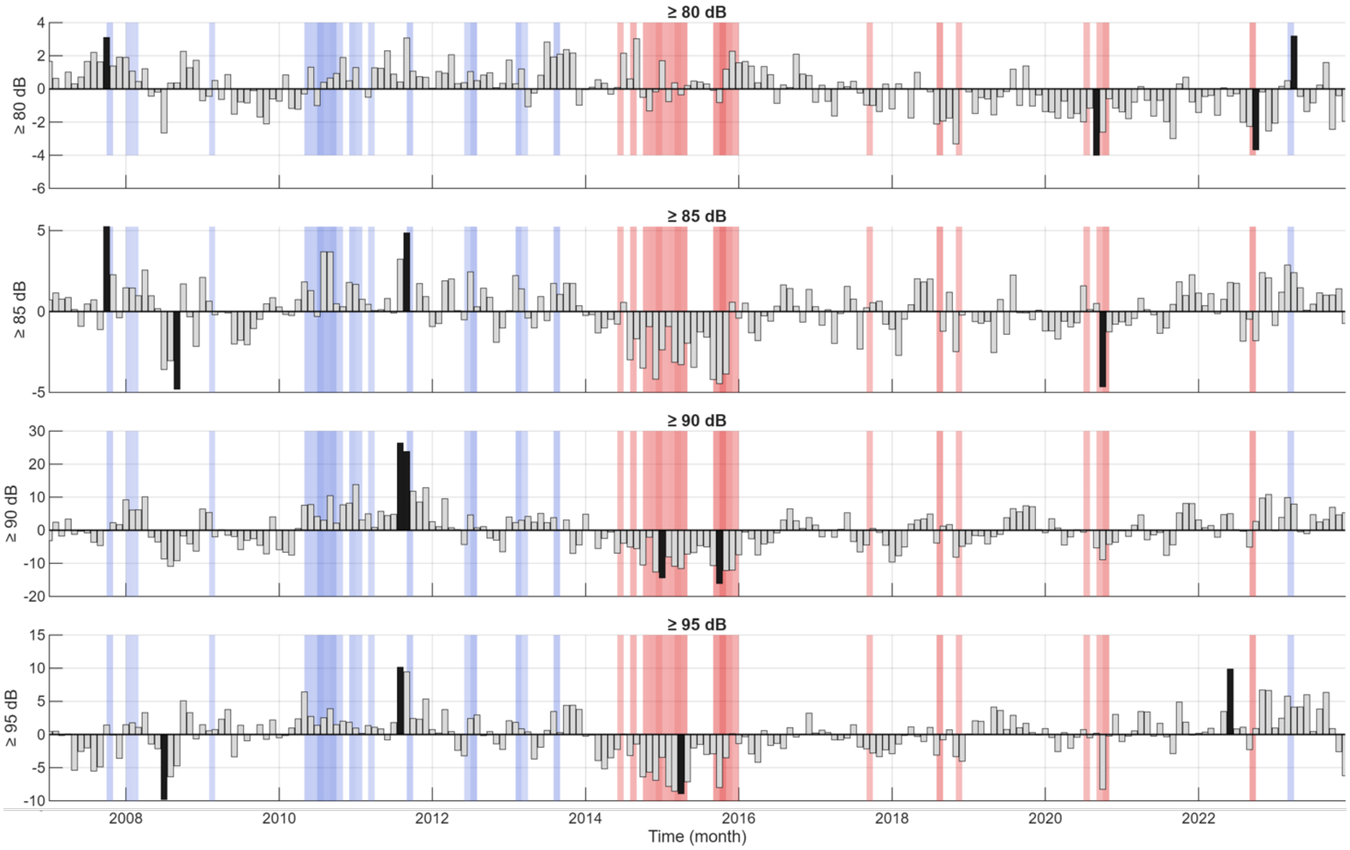

Figure 8. Basin site (Site H): monthly detection-area percent deviations for 2007–2023 across five received-level thresholds. Red/blue shading marks marine heatwave and cold-anomaly months. Darker bars mark the two most extreme positive and negative deviations for reference. Variability decreases with increasing received-level threshold, with no detectable temporal variability at ≥100 dB.

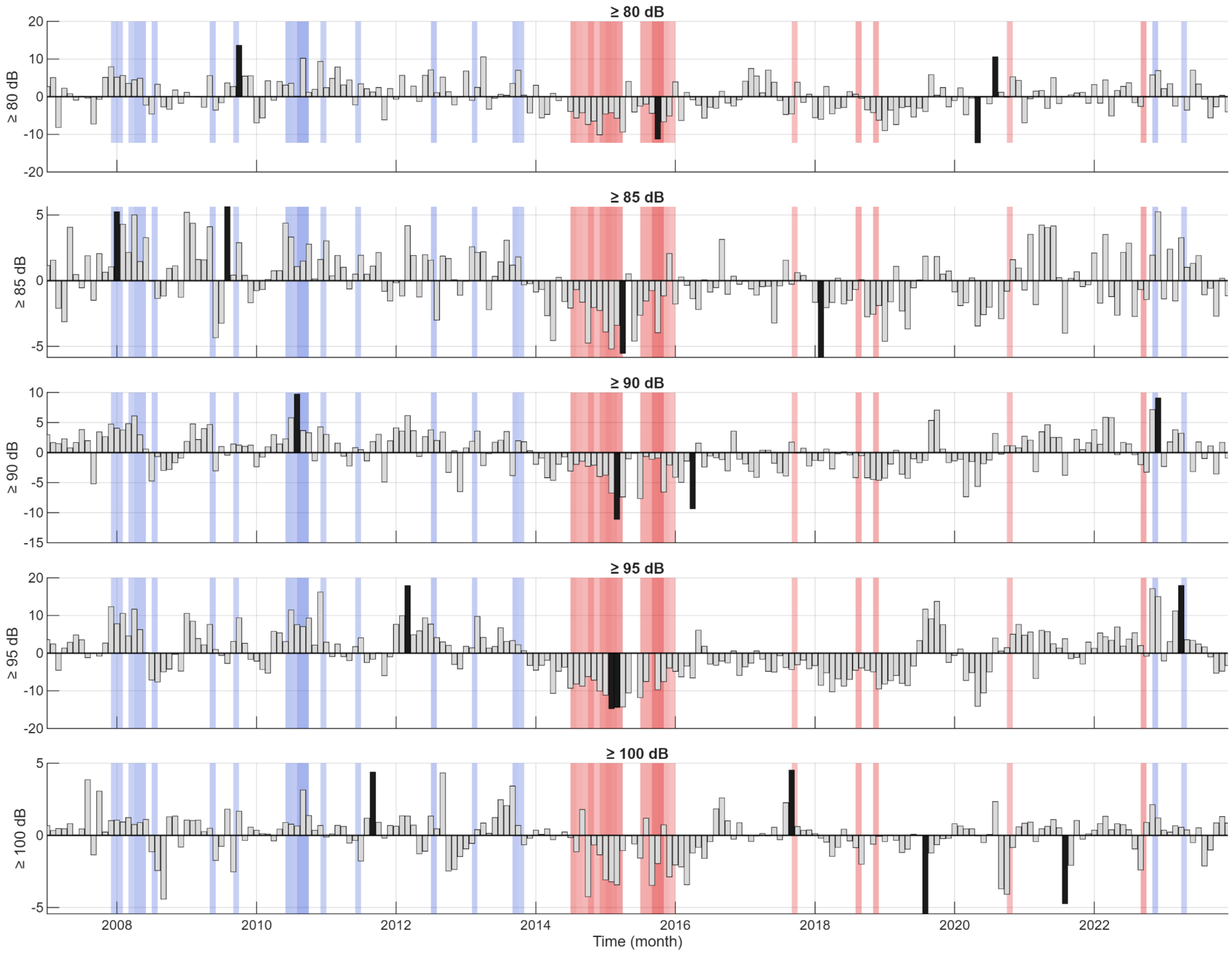

Figure 9. Shelf site (Site SN): monthly detection-area percent deviations for 2007–2023 across five received-level thresholds. Red/blue shading marks marine heatwave and cold-anomaly months. Darker bars mark the two most extreme positive and negative deviations for reference.