GOOSE-BEAKED WHALE AND FIN WHALE SURVEYS AT THE SOUTHERN CALIFORNIA OFFSHORE ANTI-SUBMARINE WARFARE RANGE (SOAR)

Annual Report

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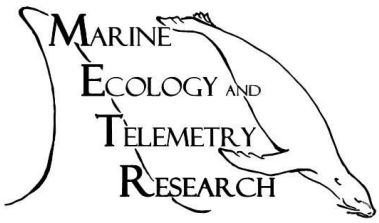

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14. ABSTRACT
This document provides a summary of work conducted via a collaboration between the Naval Undersea Warfare Center and the Foundation for Marine Ecology and Telemetry Research (MarEcoTel) and is part of a broad project to monitor the populations of goose-beaked whales (*Ziphius cavirostris*) and fin whales (*Balaenoptera physalus*) in the Southern California Testing and Training Range (SCTTR).

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Summary statement

This document provides a summary of work conducted via a collaboration between the Naval Undersea Warfare Center and the Foundation for Marine Ecology and Telemetry Research (MarEcoTel) and is part of a broad project to monitor the populations of goose-beaked whales (*Ziphius cavirostris*) and fin whales (*Balaenoptera physalus*) in the Southern California Testing and Training Range (SCTTR).

1. MarEcoTel Field Data Summary

Federal travel restrictions in early 2025, the government shutdown in late 2025, and weather conditions significantly impacted work at SOAR this year. Several scheduled surveys at SOAR were either cancelled or shifted to coastal areas. After shifting trips several times, surveys were ultimately conducted on 18 calendar days in the months of January, February, March, April, and November representing 131.5 hours of effort covering 1276.9 nautical miles (Table 1, Figure 1). An additional seven field days of ancillary effort were conducted under funding from ONR in January (with transit to SCORE on 12/31/2024), September, and October 2025, representing 49.0 hours of effort, covering 681.6 nautical miles (Table 2, Figure 2).

The percentage of time by project within Navy range boundaries are presented in Table 3. Ninety-five total sightings of 11 different species were documented (Table 4). Fin whale sightings were comparable to the previous year, with forty sightings of an estimated 69 individuals; twenty of these sightings totaling 29 individuals occurred in November 2025, when animals were sighted regularly both on SOAR and in the Catalina Basin to the east of San Clemente Island (Figures 3, 4). A total of 12 sightings of an estimated 41 individual goose-beaked whales were documented in January and November (Figures 3,4). Limited access to SOAR in 2025 contributed to lower numbers of goose-beaked whale sightings than is typical. Non-focal species sighted across the SCTTR included gray, humpback, minke whales, and small delphinids (Figure 5).

One SMRT tag was deployed on a goose-beaked whale in January with a duration of 2.5 days (Figure 6). Three SPLASH10-A tags were deployed on fin whales in March and April 2025. Median tag duration was 6.9 days (range = 0.92 – 10.9). A small tissue sample was collected from the goose-beaked whale tag and a single biopsy was collected from a fin whale.

Photogrammetry data collection at SOAR, using a Freefly Astro unmanned aerial system, initiated in 2024 and was continued during this year, primarily under funding from ONR. Aerial imagery was collected from an estimated 30 goose-beaked (73% of sighted individuals) and 25 fin whales in 2025.

Table 1. Summary of daily survey effort under U.S. Pacific Fleet Monitoring funding.

Date	Hrs On Effort	Distance (nmi)
1/2/2025	11.2	82.5
1/3/2025	10.2	75
1/5/2025	6.7	82
2/19/2025	4.2	32.4
2/20/2025	8.1	71.7
3/21/2025	5.4	51.3
3/22/2025	6.7	87.2
3/23/2025	7.4	76.3
4/20/2025	2.6	11.4
4/22/2025	3.6	61.4
4/23/2025	9.5	109
4/24/2025	4.7	48.4
11/25/2025	4.6	73.5
11/26/2025	11.2	85
11/27/2025	10.4	87
11/28/2025	10.2	88.5
11/29/2025	10.2	94.7
11/30/2025	3.1	59.6
18 days	**131.5**	**1276.9**

Table 2. Summary of daily survey effort under ONR funding.

Date	Hrs On Effort	Distance (nmi)
12/31/2024	2.13	53.5
1/1/2025	10.8	86.2
1/6/2025	2.2	51.5
9/27/2025	10.7	162
9/28/2025	10.7	168
9/30/2025	3.8	24.4
10/1/2025	8.7	136
6 days	**46.9**	**628.1**

Table 3**.** Percentage of effort spent within U.S. Navy range boundaries. Note that SOAR is a sub-range within the bounds of the SOCAL Range Complex.

	Point Mugu Sea Range	SOCAL[1] Range Complex	SOAR[2]
Pacific Fleet Monitoring	0%	98%	42%
Ancillary	4%	88%	40%

[1]SOCAL = Southern California Range Complex
[2]SOAR = Southern California Anti-submarine Warfare Range

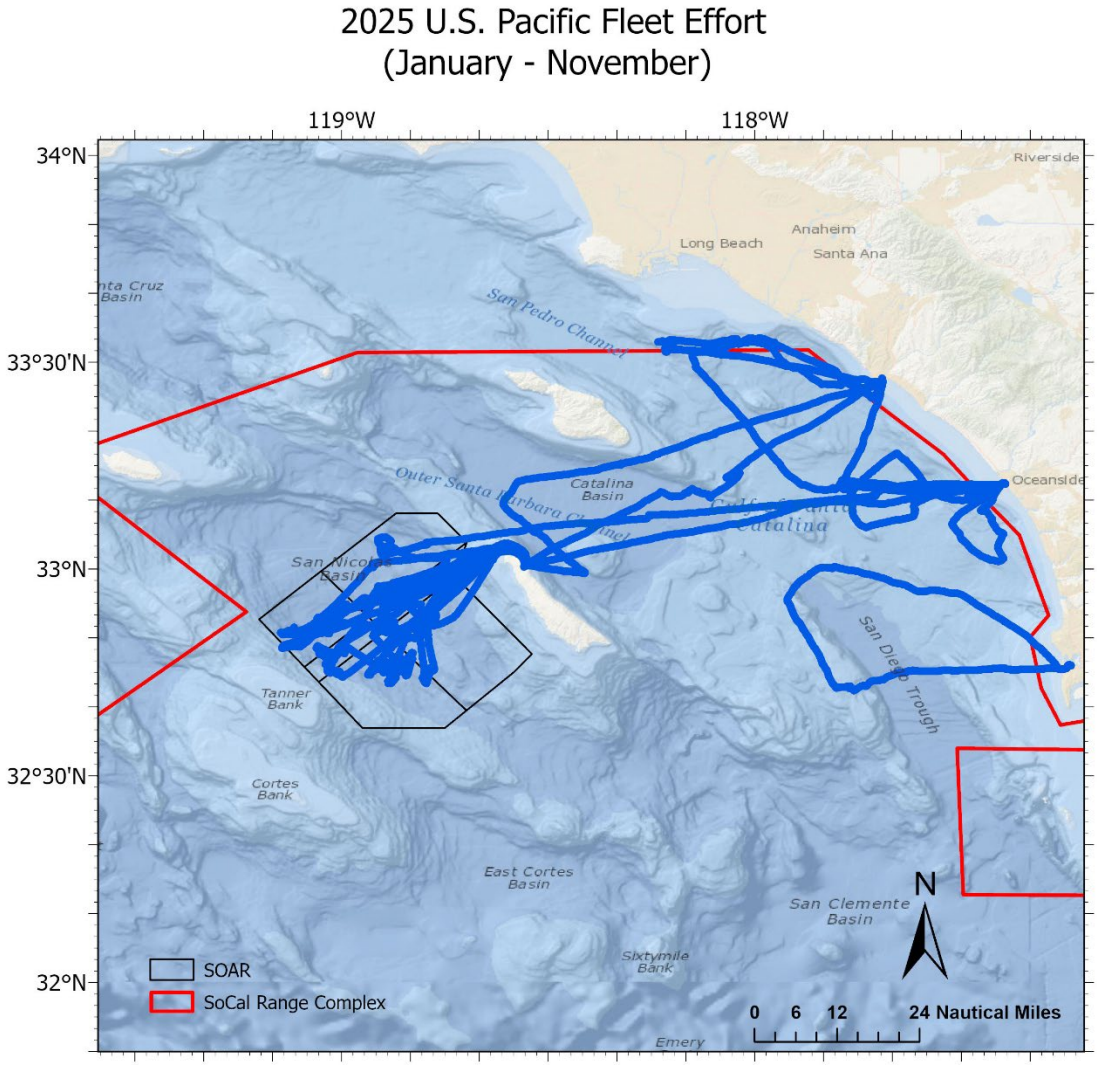

Figure 1. Map showing vessel track lines associated with U.S. Pacific Fleet monitoring surveys and tag recoveries conducted during this project period.

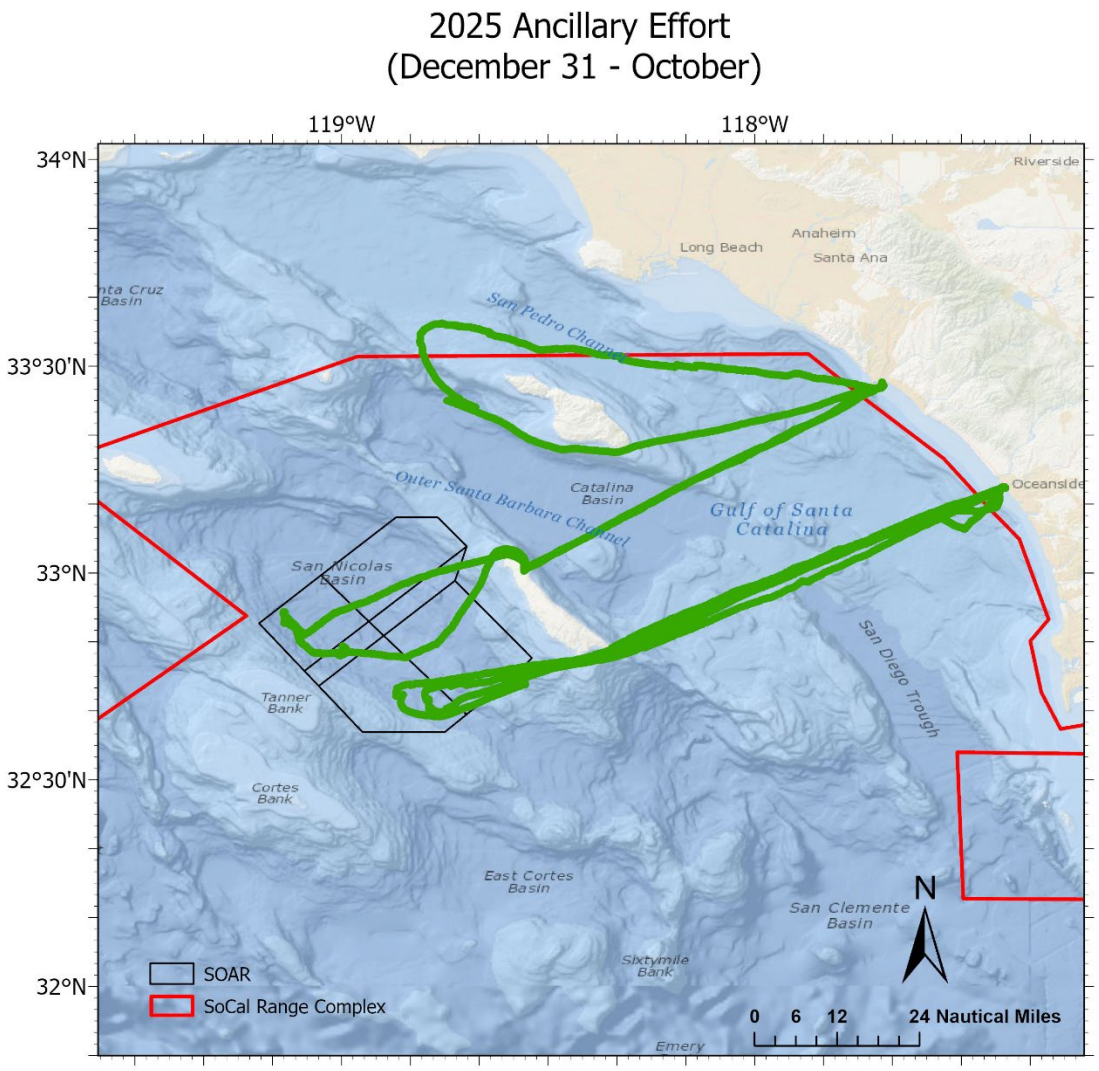

Figure 2. Map showing vessel track lines associated with ancillary surveys conducted during this project period.

Table 4. Sighting details, by species. Number of individuals represents the sum of the best group estimate size for each encounter.

Species	No. sightings	No. individuals	No. estimated IDs
Minke whale	1	1	1
Fin whale	40	69	54
Long-beaked common dolphin	4	272	0
Short-beaked common dolphin	3	247	0
Delphinus sp.	8	1138	0
Gray whale	1	2	0
Risso's dolphin	11	442	20
Northern right whale dolphin	2	95	0
Pacific white-sided dolphin	2	82	0
Humpback whale	7	8	0
Bottlenose dolphin	9	179	53
Goose-beaked whale	12	41	40
Total	**103**	**2579**	**168**

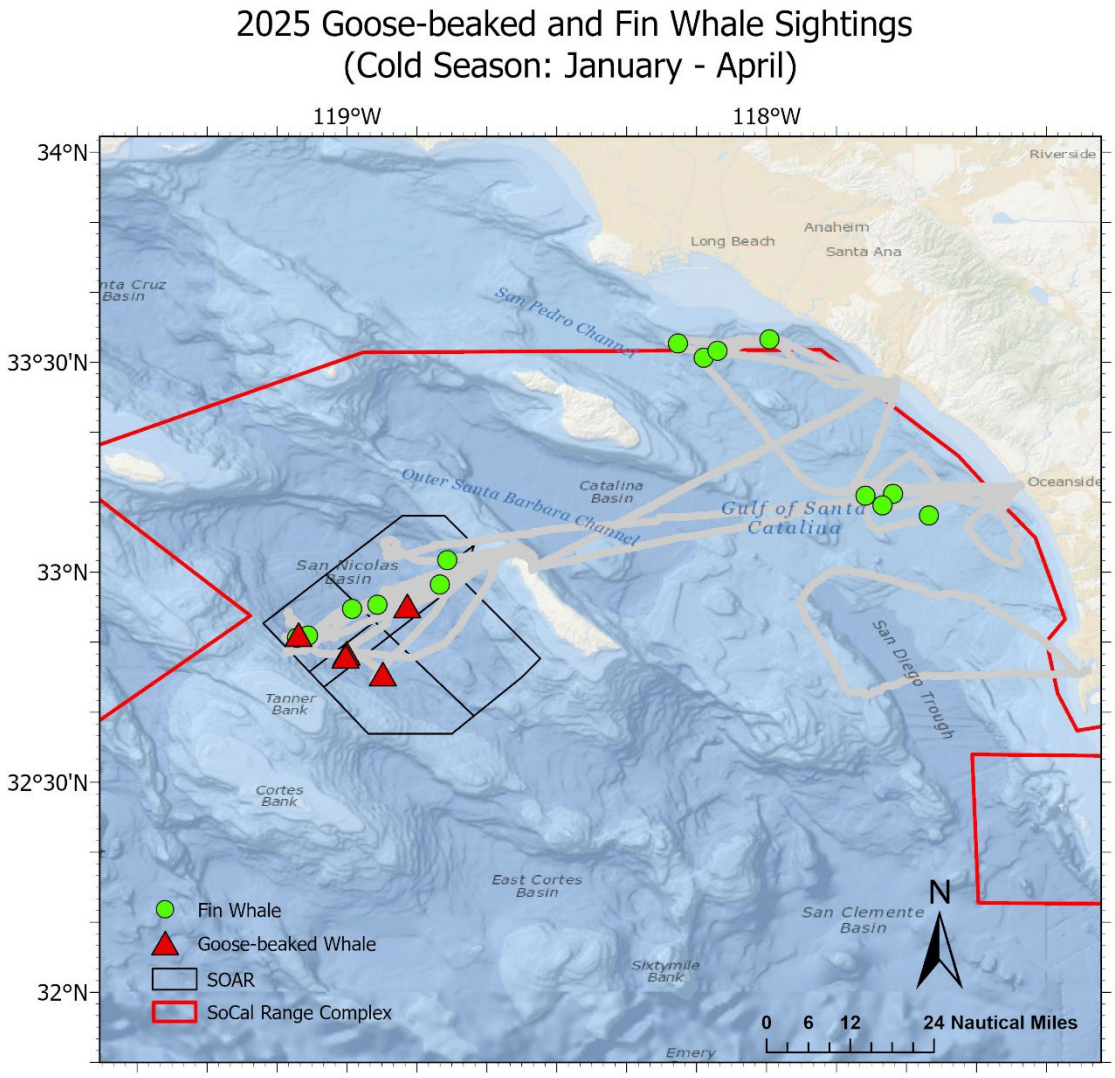

Figure 3. Map showing seasonal sighting locations for goose-beaked and fin whales sighted during field efforts.

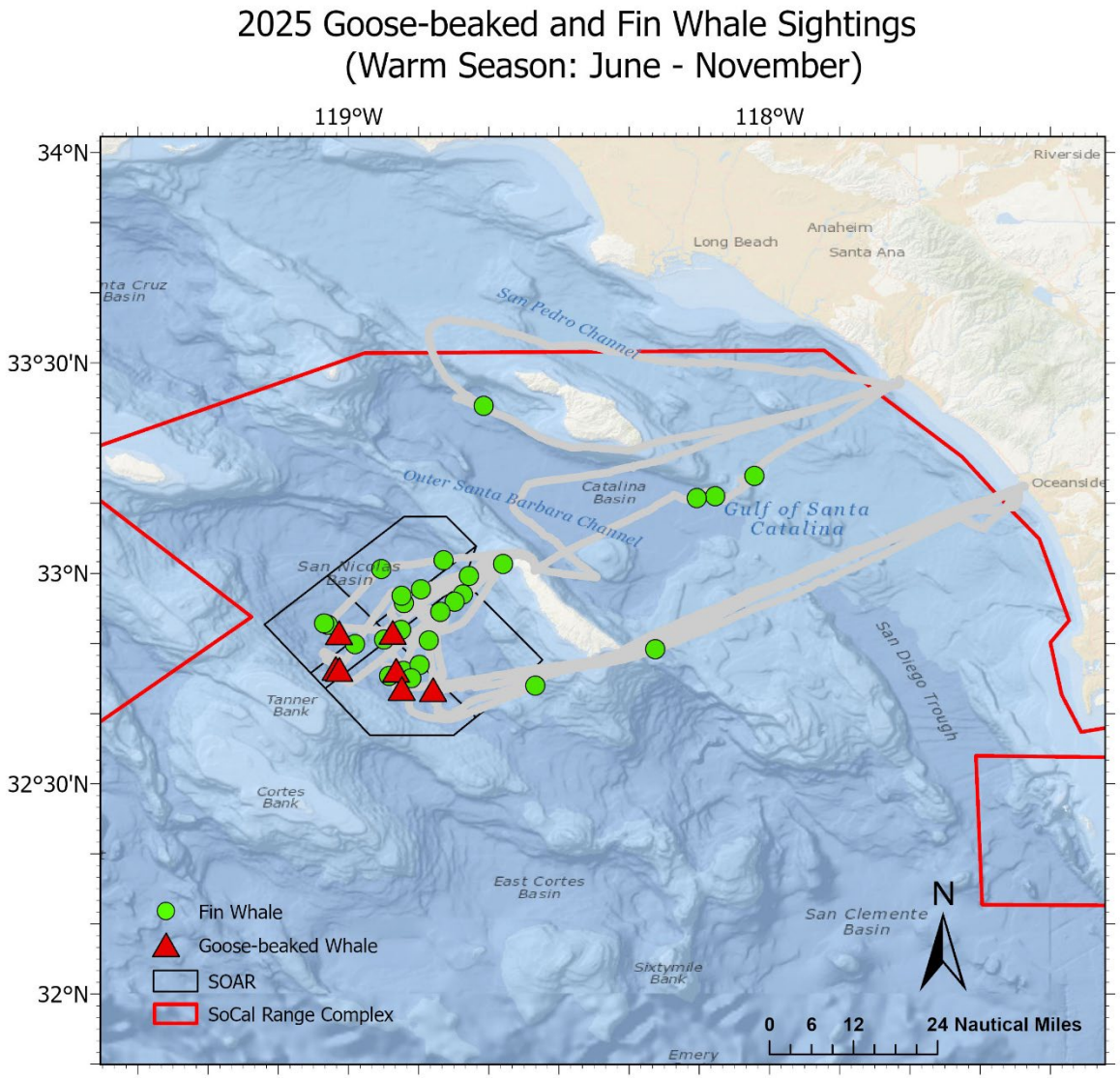

Figure 4. Map showing seasonal sighting locations for goose-beaked and fin whales sighted during field efforts.

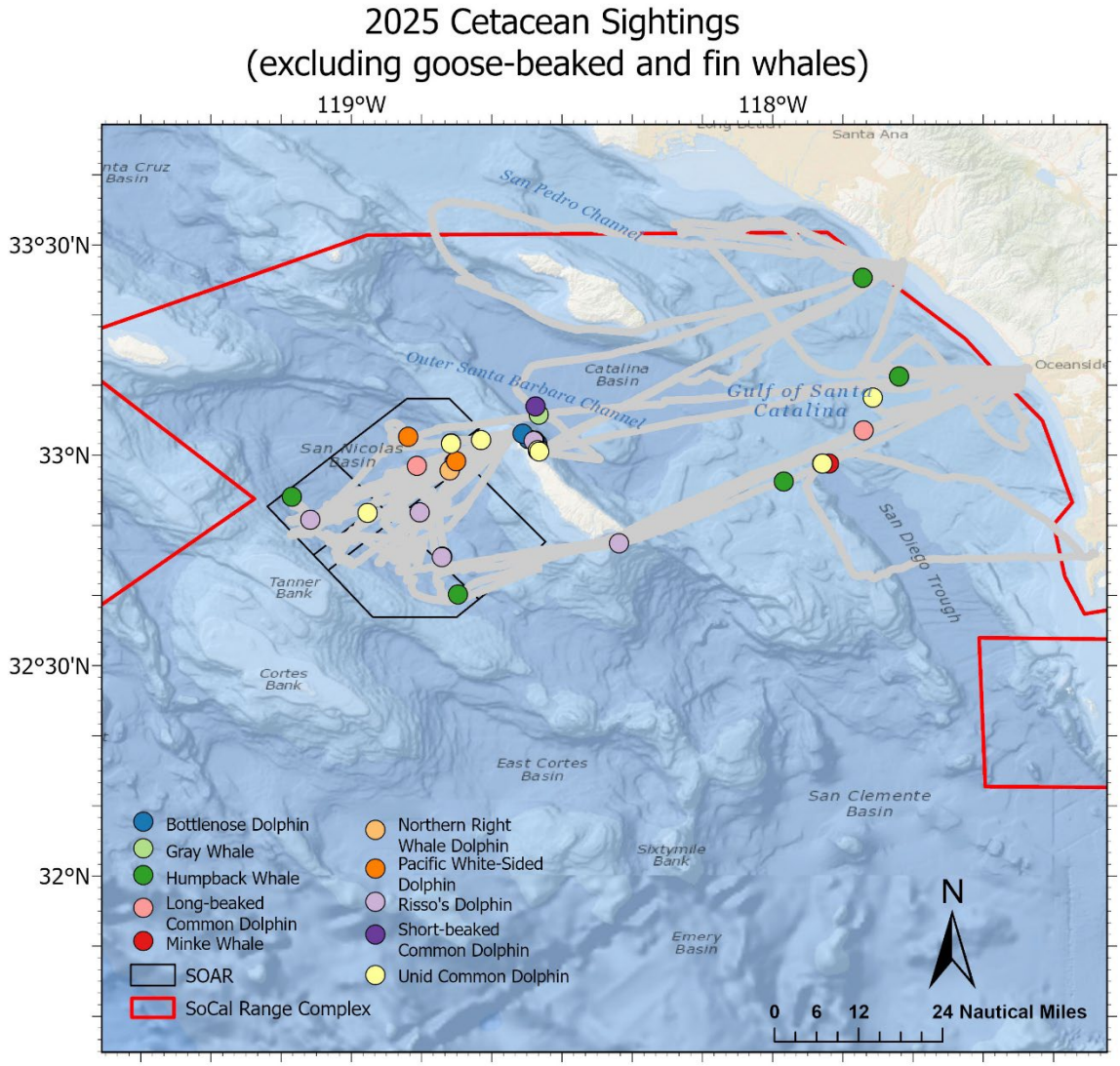

Figure 5. Sighting locations for all species other than goose-beaked and fin whales.

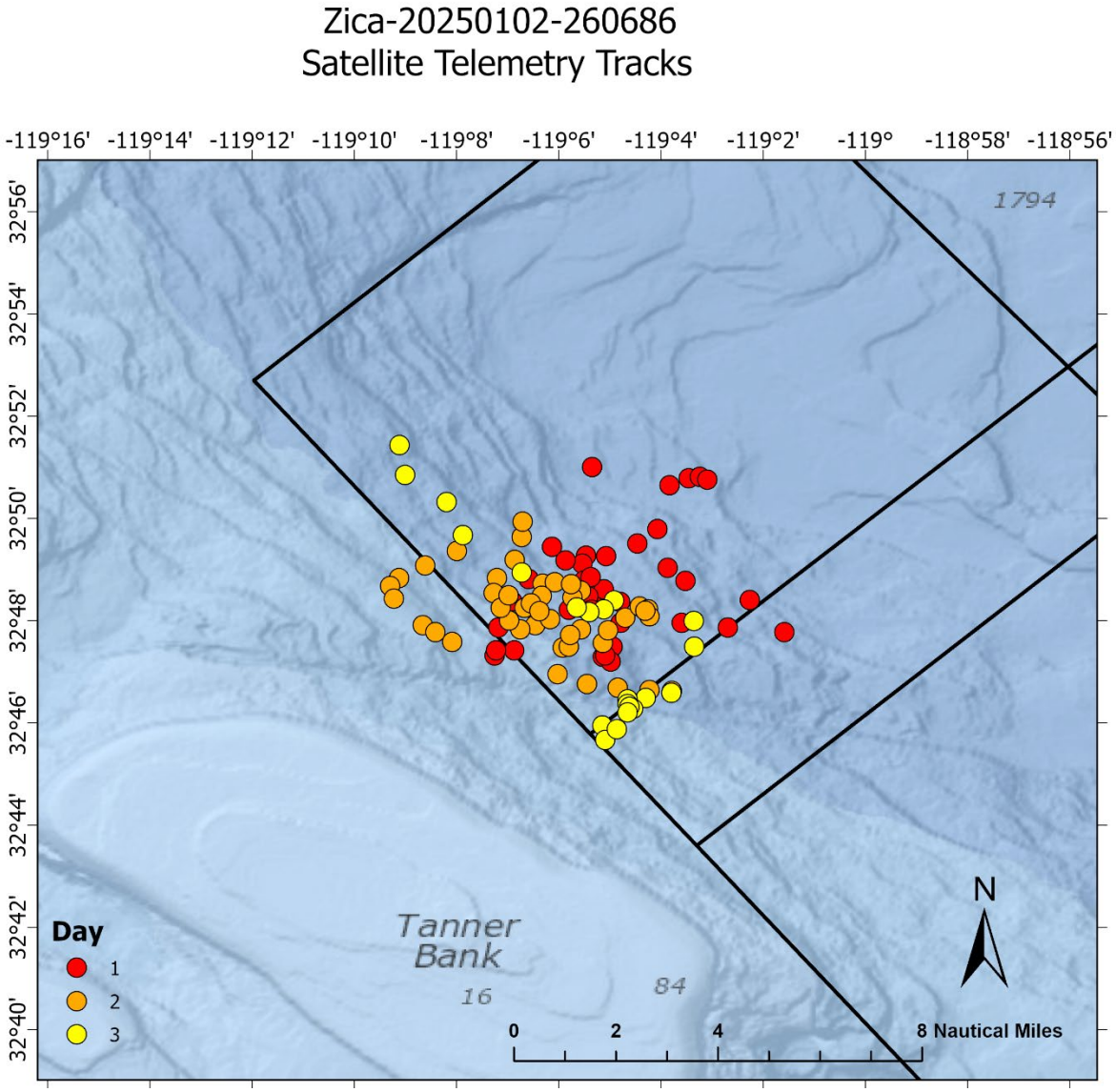

Figure 6. SMRT deployment on a goose-beaked whale (tag ID Zica-20250102-260686) tagged under U.S. Pacific Fleet monitoring effort in 2025.

2. MarEcoTel Data Analyses

2.1 SMRT

In 2025, we analyzed data from six SMRT tags deployed on goose-beaked whales in 2024 and 2025, which recorded a combined total of 43.8 d (1050 hours) of acoustic, kinematic, and positional data (Table 5). Tagged whales performed 1833 dives, 325 of which contained echolocation pulses indicating the presence of foraging activity (Figure 7). Maximum dive depth ranged from 53-969 m (median = 235-295 m) for non-foraging dives and 596-1796 m (median = 1043-1498 m) for foraging dives. Foraging dive durations ranged from 32.3-112.8 minutes (median = 54.5-75.4 minutes; Table 6), with echolocation durations from 3.8-58.3

minutes (median = 31.4-40.4). Non-foraging dive durations ranged from 3.3 to 53.6 minutes (median = 19.6-23.9).

Echolocation start depth ranged from 219-1101 m (median = 365-441 m) and end depth ranged from 559-1571 m (median = 919-1003 m; Figure 8). The logging of buzzes, the acoustic signal associated with prey capture attempts, is still underway. Because buzzes have a lower amplitude level in the tag recording than regular echolocation pulses, buzzes are only logged when reliably audible or visible in a spectrogram. Therefore, the number of buzzes provided for those tags in which buzz logging is complete represents a minimum value. There were 199 anthropogenic events (periods in which a recurring series of similar anthropogenic signals) detected across the six tags, of which 28 were MFAS and 89 were impulsive (Table 5). Some events could not be classified as a known signal type.

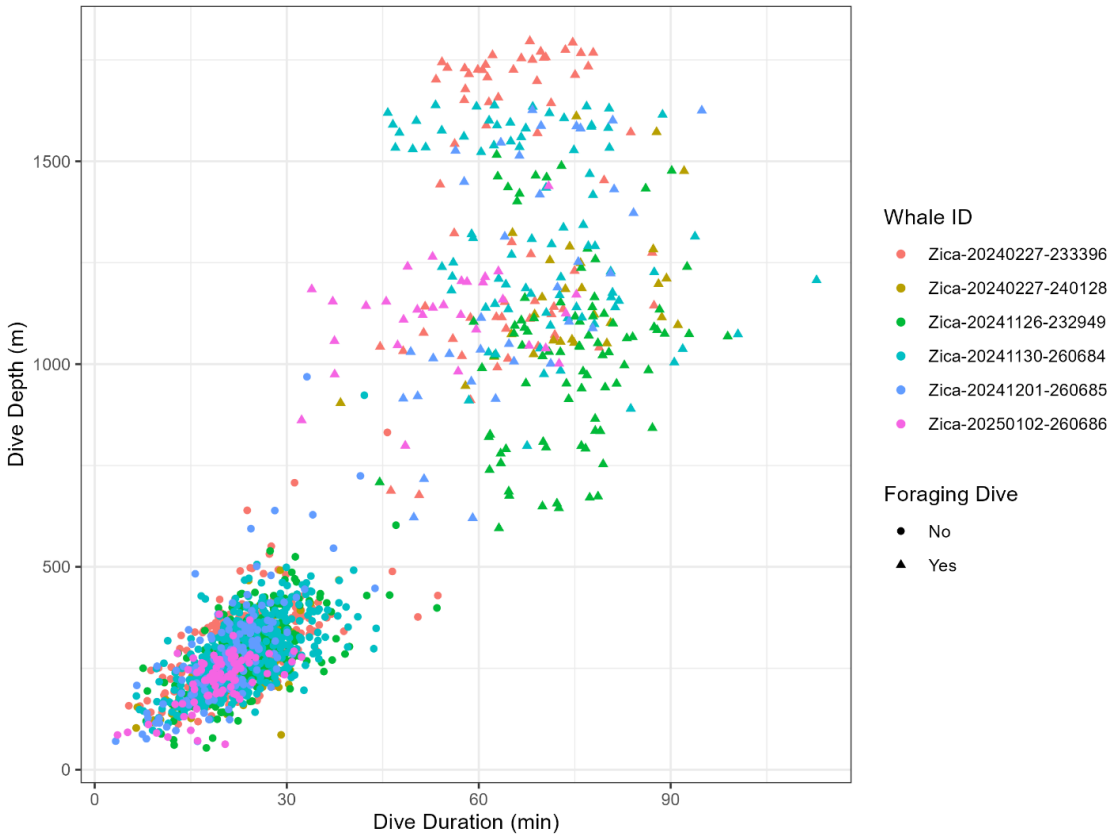

Figure 7. Dive depth and duration for all goose-beaked whale dives recorded by SMRT tags, 2024–2025

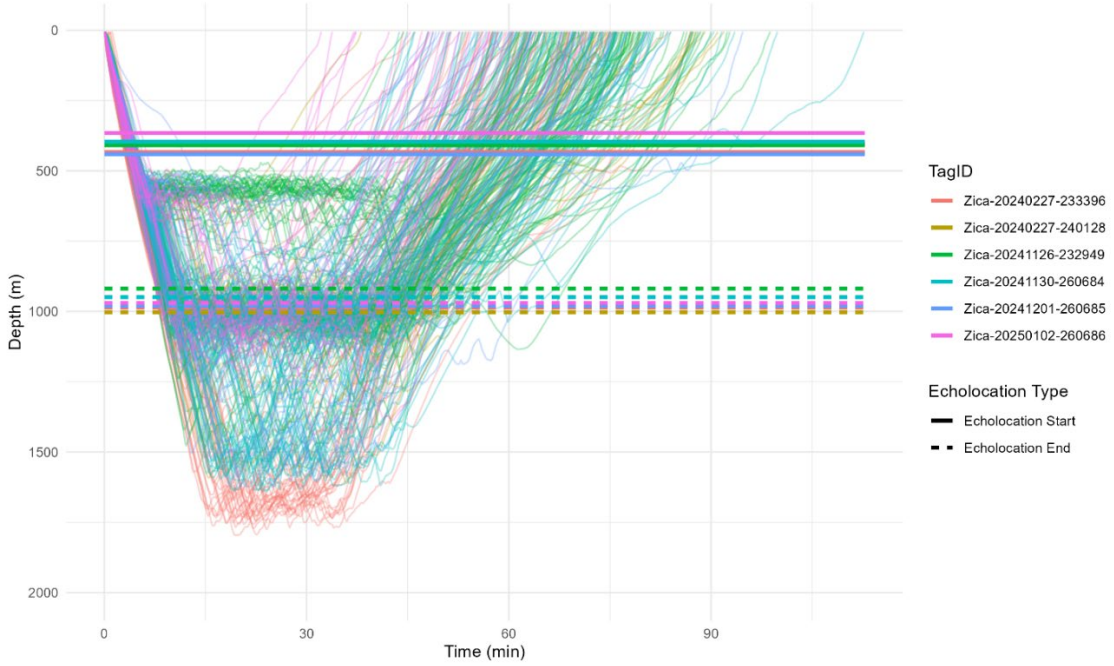

Figure 8. Dive profiles for the six SMRT tags deployed on goose-beaked whales, 2024–2025. Dives were defined as submergences beyond 50 m for more than 30 s. The dashed horizontal lines represent the median echolocation start and end depths for each tag.

Table 5. Dive and acoustic summary table for SMRT tag deployments at SOAR, 2024–2025.

Whale ID	Tag Duration (decimal hrs)	Dive type	No. of Dives	Median Max. Dive Depth (m) (range)	Median Dive Duration (mins) (range)	Median Echolocation Duration (mins) (range)	No. of Buzzes	No. of Anthro. Events Detected
Zica-20240227-233396	241.8	Non-foraging	342	295 (112 – 832)	23.3 (5.3 – 53.6)	NA	NA	42 (9 MFAS, 3 echosounder; 11 impulsive; 19 unknown)
		Foraging	66	1498 (677 – 1796)	64.4 (44.5 – 87.4)	37.3 (3.8 – 48.3)	1831	
Zica-20240227-240128	97.0	Non-foraging	146	238 (86 – 491)	23.2 (6.5 – 38.1)	NA	NA	12 (2 MFAS, 10 unknown)
		Foraging	28	1122 (904 – 1611)	74.7 (38.4 – 92.1)	37.7 (10.4 – 48.7)	968	
Zica-20241126-232949	281.5	Non-foraging	395	291 (53 - 602)	23.9 (7.6 – 53.5)	NA	NA	61 (4 MFAS, 3 echosounder; 38 impulsive; 16 unknown)
		Foraging	84	1043 (596 - 1516)	75.4 (44.5 – 98.9)	40.4 (19.1 – 50.3)	174*	
Zica-20241130-260684	273.2	Non-foraging	401	270 (93 – 923)	22.4 (6.5 – 44.0)	NA	NA	56 (6 MFAS, 1 echosounder; 29 impulsive; 20 unknown)
		Foraging	82	1302 (798 – 1638)	69.0 (45.8 – 112.8)	38.0 (21.6 – 58.3)	2181	
Zica-20241201-260685	97.6	Non-foraging	143	280 (70 – 969)	21.9 (3.3 – 43.8)	NA	NA	20 (7 MFAS, 1 echosounder; 5 impulsive; 7 unknown)
		Foraging	34	1152 (621 – 1626)	65.1 (48.2 – 94.9)	31.7 (5.0 – 51.1)	123	
Zica-20250102-260686	59.2	Non-foraging	81	235 (63 – 384)	19.6 (3.6 – 32.3)	NA	NA	8 (6 impulsive; 2 unknown)
		Foraging	31	1139 (799 – 1439)	54.5 (32.3 – 75.3)	31.4 (4.2 – 47.0)	257	

*The logging of buzzes is ongoing

The analysis of 13 SMRT tags deployed on Ziphius (through the February 2024 tags) has been completed, and a paper titled "Assessment of Goose-beaked whale responses to mid-frequency active sonar using a hierarchical hidden Markov model" by DeRuiter et al. (In Review) has been submitted to Movement Ecology. The abstract from the submission is included below.

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Background:

Acoustic disturbance is increasingly recognized as an ecological concern, particularly at sea. In light of marine mammal stranding events associated with use of naval mid-frequency active sonar (MFAS), which often involve goose-beaked whales (Ziphius cavirostris), research has sought to detect and characterize Ziphius behavioral responses to MFAS.

Methods:

We deployed Sound and Motion Recording and Telemetry (SMRT) tags on 13 Ziphius in the Southern California Bight. The study area includes the United States Navy's Southern California Anti-submarine Warfare Range (SOAR), and deployments overlapped temporally with training exercises including MFAS use. We used hierarchical hidden Markov models (HHMMs), which provided a framework to model whale behavior and putative responses to MFAS at two relevant time scales: foraging dive cycles, which may last hours, and five-minute intervals, where finer-scale changes in movement and behavior are evident.

Results:

We analyzed 70.7 days of tag data (1697.6 h) representing 361 Ziphius foraging dive cycles, 52 with MFAS detections. Cumulative MFAS sound energy level (cSEL) per dive cycle was 69.9 - 160.3 dB re 1µPa^{2}s (median 121.3, IQR 21.7). We identified two dive-cycle states: "Typical" and "Variant." In Variant state, durations of dive cycles, foraging dives, non-foraging dives, and echolocation durations were shorter on average but more variable, while time spent near the surface and net distance traveled were longer and more variable. According to Akaike's information criterion (AIC), MFAS cSEL (rather than per-sound maximum received level) increased the probability of switching from Typical to Variant dive-cycle state, with MFAS cSEL also modulating transition rates between four fine-scale behavior states during Variant dive cycles only. Whales transitioned to Variant state in 12 of 52 MFAS-exposed dive cycles (23.1%), with observed Variant state dwell times ranging from 1 - 72.4 hours (median 9.0, IQR 9.2).

Conclusions:

This work has relevance for conservation and management, enhancing our understanding of Ziphius behavioral responses to operational MFAS in an area where naval training activities occur regularly. These analysis tools may prove useful in assessing responses to

other acoustic disturbance and understanding how shorter-term behavior changes translate to longer-term consequences.

2.2 Photo-Identification

During 2025, we processed all photo-ID data collected from goose-beaked whales and fin whales in 2025 and updated sighting history data (i.e., compared processed identifications to the historical catalog) for goose-beaked whales through early 2025 and for fin whales through 2024. Sighting history data processing for fin whales typically runs a year behind our field data collection due to the large sample of opportunistic contributions we receive for this species, most of which arrive the year after the photos were collected. In this case, 2024 represented the single largest annual sample we have ever received for this species, at 825 identifications (the photo documentation of an individual whale in a group). This was due to expanded data collection from offshore areas along the US West Coast related to the broadscale NOAA California Current survey in 2024, and also an unusually high number of sightings along the central and northern California coasts, which brought larger numbers of fin whales within reach of coastal ecotourism.

In addition to an unusually high number of fin whale identifications, 2024 also represented the first year in which we integrated the HappyWhale dorsal fin matching algorithm into our photo-ID workflow for both species. After several years of beta testing to help understand and refine the performance of this algorithm with our collections, we determined that with a properly curated reference catalog it would yield results slightly better than our existing in-house method of comparison and greatly improve efficiency. Thus, we have transitioned to using this algorithm for historical comparisons. This year has included continued beta testing a series of new research features in the platform, including the ability to internally reconcile annual collections, and though this development has delayed our sighting history data processing this year, we expect the resulting improvements will yield a stable platform for both us and the larger research community in the future.

As noted, encounters with beaked whales were low due to reduced access to our core study area in 2025. We have not finalized this collection as of the end of December 2025, as we anticipated being in the field in December. However, of the seventeen fully processed identifications from January 2025, all but two whales had been sighted previously at SOAR, including three calves that were first sighted with their mothers in 2024. This represents a remarkable previous-year resighting rate of 88% for whales in this small sample. We collected an additional 23 identifications in November 2025; ID assignments for these whales are pending. In both survey periods we encountered whales from the earliest years of our study, bringing our longest sighting histories to over 18 years for some individual whales.

The 825 fin whale identification records we are processing as our 2024 annual collection include 100 opportunistic records from 2023 and 38 from 2012-2022 that were not previously submitted to our catalog. As is typical, most identifications were from Southern California (483, 59% of data), but the remainder were from whales sighted elsewhere along the west coast, with the majority from central and northern California. While match results are preliminary, 256 identifications from Southern California (53% of the unfiltered sample) are known individuals in the catalog. Not surprisingly, preliminary match rates are much lower elsewhere, but 13% of identifications from central and northern California are whales already in the catalog. Resightings of whales outside Southern California will provide much needed insight into the population structure and movements of individuals outside our core study area, once these identifications are fully processed.

3. M3R Data Summary

The Marine Mammal Monitoring on Navy Ranges (M3R) program provided real-time acoustic monitoring for target species to the on-water MarEcoTel crews for each survey by utilizing the M3R system at SOAR, which continuously runs algorithms to passively detect, classify and localize marine mammals year-round (Jarvis et al. 2014). The locations of animals were generated automatically by the M3R system localization code. These localizations indicate a level of confidence for each position. M3R personnel use both these automated outputs and real-time review of binary spectrograms to identify relevant species and to determine the best locations to communicate. Manual localization is also employed when necessary. Raven Pro Sound Analysis Software (Cornell University, Ithaca, NY) has been modified to stream M3R data in real-time, allowing M3R personnel to view non-binary spectrograms (i.e. spectrograms with complete magnitude information) on individual hydrophones on demand, which assists with species identification. Due to the government shutdown, federal travel restrictions and poor weather several planned field tests were cancelled. Two field tests were completed in 2025.

While using the M3R system to monitor the range, M3R personnel keep track of groups of animals or individuals, as well as other sounds, using a manual logging tool. When a particular type of sound (representing an individual or group) is detected acoustically, it is logged as an 'acoustic detection.' The type of sound detected is logged, along with start and stop time, whether the acoustic detection was directed or visually verified, which hydrophones it occurred on, and other notes such as localizations and information on direction of movement, potential group size, etc. These acoustic detections may or may not represent a unique group or individual, as the same animals could be detected over the course of the day, and individuals may move between groups. In addition, due to limited manpower (often only one person monitoring), the large amount of acoustic activity on the range, and the primary focus on directing on-water colleagues to the species of interest, goose-beaked and fin whales, the numbers we report should be considered as minimum numbers of acoustic detections, and all species and acoustic activity present on range may not be logged. For instance, particularly if

there's a single person monitoring, we may focus on a portion of the range or on particular beaked and fin whale groups.

A total of 215 acoustic detections were logged using the M3R system during two field survey efforts that occurred between January 1 – 5 and November 26 – 29, 2025 (Table 6, Figure 9, Figure 10). Of the 215 acoustic detections, M3R directed the on-water team from the Marine Ecology and Telemetry Research (MarEcoTel) team to 26. Here 'directed' implies that the location of the acoustic detection was sent, and the field team decided to go to the location. MarEcoTel visually verified 11 of the acoustic detections which included the species goose-beaked whale (*Ziphius cavirostris*) (8 of the 11), fin whale (*Balaenoptera physalus*) (one), Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) (one), and long-beaked common dolphin (*Delphinus capensis*) (one). In addition the team acoustically detected three instances of sperm whales (*Physeter macrocephalus*) and two of humpback whales (*Megaptera novaeangliae)*. Some acoustic detections could not be identified to the species level, including unidentified dolphins, unidentified mysticetes, and low-frequency biological sounds.

Table 6. Species acoustically identified with the M3R system at SOAR in 2025. Data are extracted from field test logs in 2025.

Species			Acoustic Detections Logged	Acoustic Detections Directed	Acoustic Detections Visually Verified
ID	**Common Name**	**Scientific Name**			
Zc	Goose-beaked whale	*Ziphius cavirostris*	189	21	8
Bp	Fin whale	*Balaenoptera physalus*	10	2	1
Pm	Sperm whale	*Physeter macrocephalus*	3	0	0
Mn	Humpback whale	*Megaptera novaeangliae*	2	0	0
Lo	Pacific white-sided dolphin	*Lagenorhynchus obliquidens*	1	1	1
Dc	Long-beaked common dolphin	*Delphinus capensis*	1	1	1
UD	Unidentified dolphin	Delphinidae sp.	6	0	0
UM	Unidentified mysticete	Mysticete sp.	3	1	0
LF	Low Frequency Biologic	-	1	0	0
		Totals	**215**	**26**	**11**

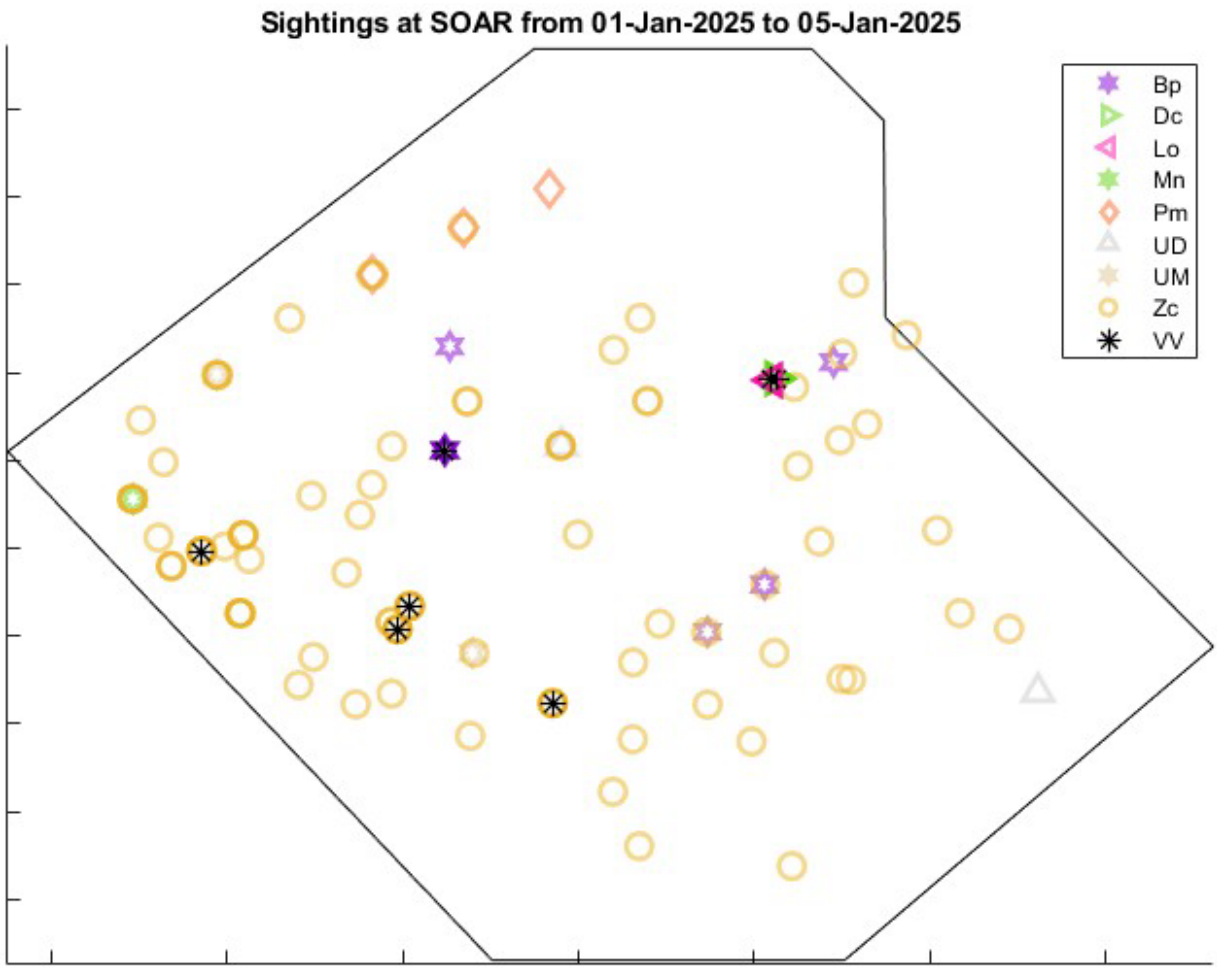

Figure 9. Acoustic detections at SOAR from January 1-5, 2025. Species included fin whale (*Bp*), goose-beaked whales (*Zc*), humpback whales (*Mn)*, sperm whales (*Pm*), Long-beaked common dolphin (*Dc*), Pacific white-sided dolphin (*Lo*), unknown mysticete species (UM) and unknown delphinidae species (UD). Detections that were visually verified (VV) by MarEcoTel are overlaid with an asterisk.

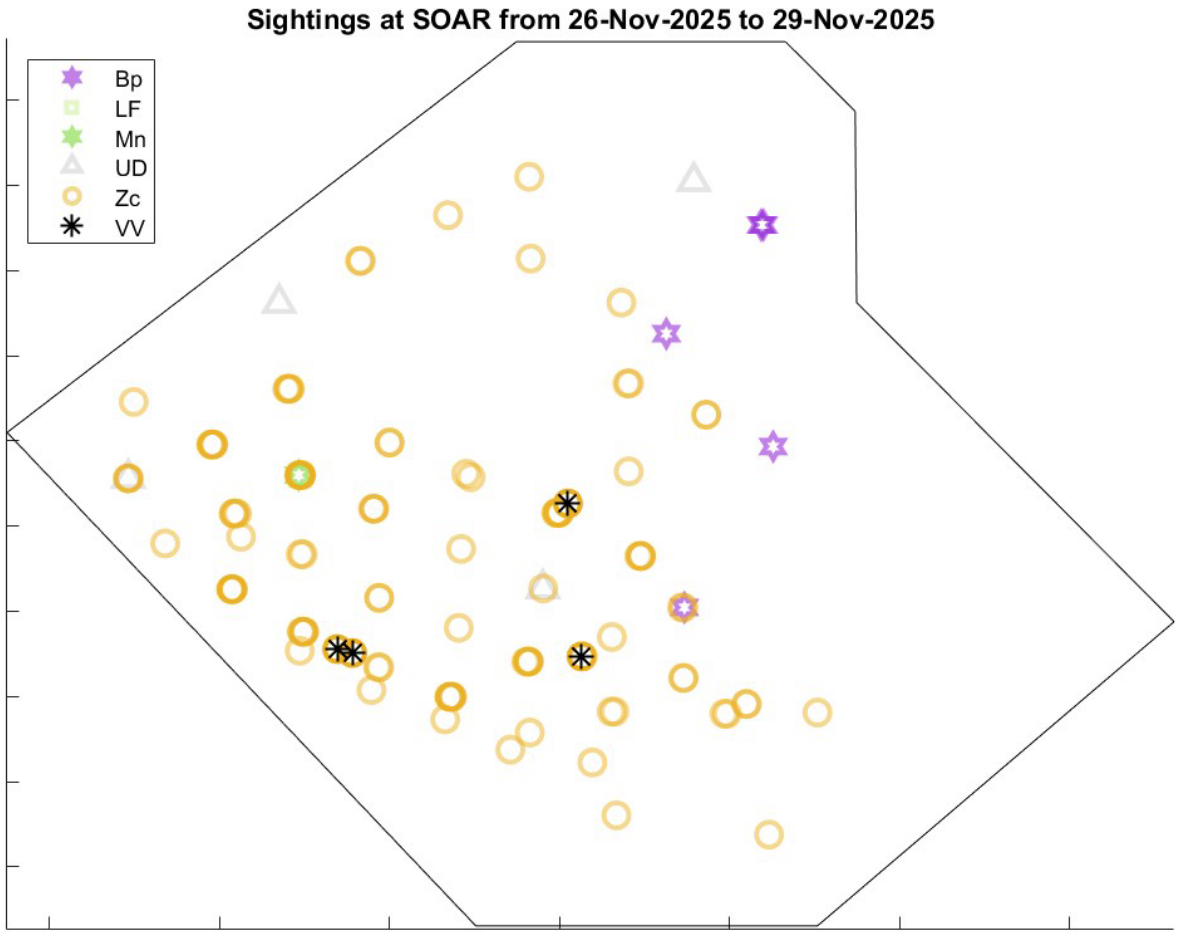

Figure 10. Acoustic detections at SOAR from November 26-29, 2025. Species included fin whale (Bp), goose-beaked whales (Zc), humpback whales (Mn), unknown low-frequency biologic (LF), and unknown delphinidae species (UD). Detections that were visually verified (VV) by MarEcoTel are overlaid with an asterisk.

4. Attendance of the Annual US Navy's Monitoring Program Review meeting

Greg Schorr attended and presented at the annual Program Review, held in Norfolk, VA from April 1-3, 2025. Nancy DiMarzio attended virtually due to the Government travel restrictions in place at the time of the meeting.

5. References

Jarvis, S.M., Morrissey, R.P., Moretti, D.J., DiMarzio, N.A., Shaffer, J.A. 2014. Marine Mammal Monitoring on Navy Ranges (M3R): A toolset for automated detection, localization, and monitoring of marine mammals in open ocean environments. Marine Technology Society Journal, 48(1), pp.5-20.

6. Publications and presentations

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