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FY25 Annual Report on Pacific Missile Range Facility Marine Mammal Monitoring

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14. ABSTRACT
EXECUTIVE SUMMARY
This report documents the Naval Information Warfare Center (NIWC) Pacific Whale Acoustic Reconnaissance Project (WARP) Laboratory's marine mammal monitoring efforts in fiscal year (FY) 2025 for Commander, Pacific Fleet (COMPACFLT) at the Pacific Missile Range Facility (PMRF), Kaua'i, Hawai'i. The following list highlights tasks completed in FY25 in support of COMPACFLT monitoring goals:

- Raw acoustic data from 63 bottom-mounted hydrophones at PMRF were recorded at a sampling rate of 96 kHz. This report describes the collection, processing, and analysis of 5,200.6 hours of new data collected and analyzed from September 2024 to August 2025 for FY25.
- The Baseline 5 code base was finalized, which involved formalizing improvements to the localization, tracking, and autogrouping algorithms, switching to a kernel-matching based beaked whale detector, and refining the snapshot metrics used to measure tracked species.
- Since the installation of the new recording system at PMRF in June 2021, the mean beaked whale acoustic detection rate increased up to 48%. Causes for this increase were investigated this FY, and were due partially to changes to the data acquisition system (different full-scale inputs, on site cabling, and inclusion of a digital low pass filter at 45 kHz) and an overall increase in the amount of data being recorded which may better capture the species' maximum presence on the range.

- Abundance results for baleen whales from September 2024 through August 2025 are presented using the mean number of whale tracks present in 2.5-minute snapshots per hour and for each month. Note this is using the new analysis method that includes data with zero detections, so the mean number of tracks is lower than has been reported in prior years. The highest monthly mean numbers of baleen whales were: 0.95 for minke (*Balaenoptera acutorostrata*) (January); 0.23 for humpback (*Megaptera novaeangliae*) (January); 0.16 for sei (*Balaenoptera borealis*) (December); 0.66 for fin (*Balaenoptera physalus*) song (January) and 0.05 for fin non-song (January); 0.05 for Bryde's (*Balaenoptera brydei*) (October); 0.03 for the 20-Hz downsweep category (January); and 0.009 for the 40-Hz downsweep category (January). Automatically detected and localized blue whale (*Balaenoptera musculus*) calls were manually verified in December and January; as in previous years these included both northwestern Pacific and northeastern Pacific B blue whale vocalizations, as well as an additional 54-Hz tonal. In previous years this was tentatively attributed to the Watkin's (or 52 Hz) whale, but additional features noted this year suggest it is a distinct type of tonal signal. In addition, for the first time blue whale D-call downsweeps were detected at PMRF in January.
- Abundance results of odontocetes from September 2024 to August 2025 included dense-beaked whales (*Mesoplodon densirostris*), goose-beaked whales (*Ziphius cavirostris*), Cross Seamount beaked whales, tropical bottlenose whales (*Indopacetus pacificus*), killer whales (*Orcinus orca*), and sperm whales (*Physeter macrocephalus*). The highest group vocal period (GVP) rates for a full month of data for each beaked whale species were: 3.0 GVPs/hour in July for dense-beaked whales; 0.3 GVPs/hour in June for goose-beaked whales; 0.3 GVPs/hour in December for Cross Seamount beaked whales; and 0.3 GVPs/hour in November for tropical bottlenose whales. Killer whales were detected throughout the available FY25 data and eight manually validated groups occurred. The highest mean number of sperm whale tracks in all 2.5-minute snapshots in a month was 0.08 in December.
- During the February 2025 Submarine Command Course (SCC) a total of four acoustically tracked whales were exposed to mid-frequency active sonar (MFAS). One sperm whale was exposed to surface ship MFAS, and two minke whales and one humpback whale were exposed to both surface ship and sonobuoy MFAS. Median received levels were estimated using propagation modeling over a three-dimensional area around each animal's location along their tracks. The highest median estimated received levels for all four whales were from the surface ship exposures; these ranged from 122 dB re 1 μPa for one of the minke whales to 152 dB re 1 μPa for the humpback whale. The received levels for the sonobuoys were much lower, with median levels ranging between 92 and 99 dB re 1 μPa. No changes in movement behavior along their tracks were noted for any of the animals; all animals maintained their headings throughout their exposure periods.
- Group foraging dive rates for all beaked whale species were analyzed before, during, and after the February and August 2025 SCCs. From Before to Phase A, rates of GVPs/hour decreased for dense-beaked (from 3 and 3.3 in February and August, respectively, to 1.6 and 2.0), goose-beaked (from 0.07 and 0.22, respectively, to 0 and 0.14), and Cross Seamount beaked whales (from 0.17 and 0.11, respectively, to 0.17 and 0.05). Rates held constant for dense-beaked and goose-beaked whales from Phase A through the Interphase in both SCCs. Cross Seamount GVP/hr rates decreased (from 0.17 to 0.04) from Phase A through the Interphase in February but increased from 0.05 to 0.11 in August. From the Interphase to Phase B, the GVP/hour rates decreased further for dense-beaked (from 1.5 to 0.7 and 2.0 to 1.2, respectively) and goose-beaked whales (stayed at 0 in February, and went from 0.17 to 0 in August), but increased for Cross Seamount beaked whales (from 0.04 to 0.09 and 0.11 to 0.15, respectively). From Phase B to After, the GVP/hour rates increased for dense-beaked (from 0.7 to 2.2 and 1.2 to 2.0, respectively), goose-beaked (from 0 to 0.1 and 0 to 0.09, respectively), and Cross Seamount beaked whales (0.09 to 0.17 and 0.15 to 0.29, respectively), and returned to normal rates in the following month, at least in March (as the data from September following the August SCC is not analyzed for this report). Tropical bottlenose whales had no detections at all in February, and had very low rates Before the August SCC, which increased slightly during Phase A (from 0.01 to 0.05 GVPs/hr), and then there were no further detections for the remainder of August.
- The two RIMPAC SINKEX exercises that occurred near the PMRF range in July 2024 were analyzed to assess 1) how far down range the different event sounds propagated, and 2) whether any noticeable acoustic or possible movement effects occurred in any odontocete species that were on the range at the time. While some possible vocal responses were detected, with both increased and decreased vocalizations following different events, both sperm whales and delphinids continued to be detected throughout the SINKEX, with one or more groups of delphinids appearing to cross the range. The sounds of most events propagated long distances (64-83 km), but there were some interaction effects with bottom topography that blocked some sound transmissions from propagating.

15. SUBJECT TERMS

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ACRONYMS

ASWEX	Anti-submarine warfare exercise
BSURE	Barking Sands Underwater Range Expansion
COMPACFLT	Commander, Pacific Fleet
CPA	Closest point of approach
CRC	Cascadia Research Collective
DCL	Detection, classification, localization
FY	Fiscal year
GPL	Generalized power law
GVP	Group vocal period
HFM	High-frequency modulated
HST	Hawaiian standard time
INI	Inter-note interval
LAT	Localization association tracker
LMR	Living Marine Resources Program
LSQ	Least squares
M3	Marine Mammal Monitoring
MFAS	Mid-frequency active sonar
NARWHAL	Navy Acoustic Range Whale Analysis Algorithm
NIWC Pacific	Naval Information Warfare Center Pacific
NUWC Newport	Naval Undersea Warfare Center Newport
ONR	Office of Naval Research
PAM	Passive acoustic monitoring
PMRF	Pacific Missile Range Facility
RIMPAC	Rim of the Pacific
SCC	Submarine Command Course
SINKEX	Sinking exercise
SOAR	Southern California Anti-Submarine Warfare Range
US	United States
UTC	Universal Coordinated Time
WARP	Whale Acoustic Reconnaissance Project

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1. INTRODUCTION

In fiscal year (FY) 2025, the Naval Information Warfare Center (NIWC) Pacific Whale Acoustic Reconnaissance Project (WARP) Laboratory (San Diego, California) utilized passive acoustic data recordings from bottom-mounted range hydrophones at the Pacific Missile Range Facility (PMRF), Kaua‘i, Hawai‘i to monitor vocalizing cetaceans both during baseline periods and during United States (US) Navy training activities.

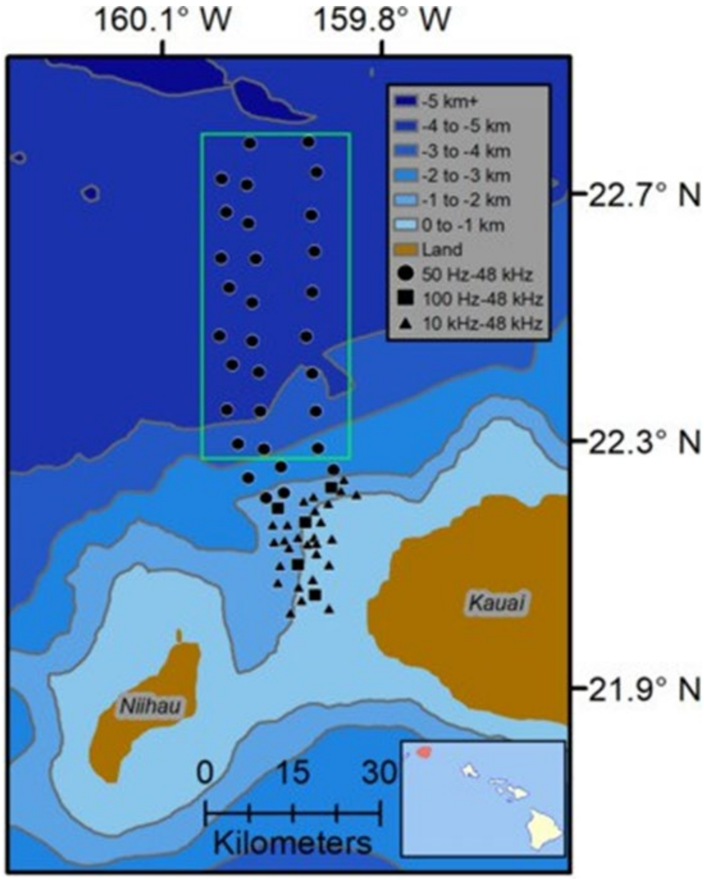
The FY25 goals of this ongoing effort were to:

- Collect raw acoustic data for cetacean species detection, classification, localization (DCL), and tracking, and perform movement and acoustic cue rate analyses;
- Understand short-term baseline occurrence patterns and quantify minimum (snapshot) abundance estimates for multiple cetacean species;
- Continue to update our processing algorithms in order to add new species, improve existing tools, and integrate additional tools as developed;
- Estimate sound levels received by cetaceans during US Navy training with mid-frequency active sonar (MFAS) from multiple sources;
- Investigate potential behavioral responses of tracked whales to sound exposures as well as vessel presence and movement, and investigate changes in dive rates across training phases for beaked whales;
- Analyze Rim of the Pacific (RIMPAC) data for three anti-submarine warfare exercises (ASWEXs) and two sinking exercises (SINKEXs);
- Assess the cause of increased beaked whale detections starting in 2021; and
- Collaborate with researchers conducting other monitoring efforts (e.g., MFAS exposure and response by tagged animals) – including other US Navy laboratories, academic institutions, and research organizations – to fill data gaps and provide a more complete monitoring data product.

2. METHODS

2.1 PMRF RANGE DATA

Passive acoustic monitoring (PAM) data were recorded for 63 of the PMRF bottom-mounted hydrophones (Figure 1) to support analyses of marine mammal vocalizations and MFAS transmissions. Full-bandwidth (96 kHz sampling rate) recordings were conducted from September 2024 through August 2025.



- The green box outlines the approximate boundary offshore Kaua'i, Hawai'i (shaded red in the inset map) of the area used for tracking whales in data collected from September 2024 to August 2025. Black symbols indicate approximate hydrophone locations.

Figure 1. Hydrophone array configuration at PMRF's instrumented range for data collected from September 2024 to August 2025.

2.2 NAVY ACOUSTIC RANGE WHALE ANALYSIS ALGORITHM SUITE

2.2.1 Automated Detection, Classification, Localization, and Tracking Algorithms

The Navy Acoustic Range Whale Analysis (NARWHAL) suite of algorithms was used to process recorded data. These algorithms have been previously described in Helble et al. (2012, 2015, 2016, 2020a); Henderson et al. (2016, 2018); Manzano-Roth et al. (2016), and Martin et al. (2015). One custom C++ algorithm automatically detects and classifies two types of baleen whale vocalizations 1) minke whale (*Balaenoptera acutorostrata*) boing calls and 2) low-frequency downsweep calls that could be attributable to several baleen whale species; six odontocete vocalizations 1) dense-beaked (*Mesoplodon densirostris*), 2) goose-beaked (*Ziphius cavirostris*), 3) tropical bottlenose (*Indopacetus pacificus*), and 4) Cross Seamount beaked whale clicks, 5) sperm whale (*Physeter macrocephalus*) clicks, and 6) killer whale (*Orcinus orca*) high-frequency modulated [HFM] signals; and MFAS transmissions. A second C++ algorithm localizes detected baleen whale calls, sperm whale clicks, and MFAS transmissions. A separate Matlab Generalized Power Law (GPL) algorithm detects and localizes humpback whale (*Megaptera novaeangliae*) song and certain types of blue whale (*Balaenoptera musculus*) calls. A localization association tracker (LAT) algorithm in Matlab (Klay et al., 2015) uses spatial and temporal parameters based on general calling rate expectations for different species to connect localizations into tracks.

A human analyst manually reviews spectrograms of the data and call intervals along the tracks produced from low-frequency downsweep calls to examine call characteristics and patterns to classify the tracks as fin whales (*Balaenoptera physalus*), sei whales (*Balaenoptera borealis*), Bryde's whales (*Balaenoptera brydei*), and non-specific categories of 20-Hz and 40-Hz downsweeps. Tracks were assigned as fin whales if they contained "A" and/or "B" notes (after Helble et al., 2020). If tracks contained note types in regular patterns for over half the track, these were further classified as "fin song", while the rest were considered non-song. Sei whale tracks needed at least one paired call (though usually a triple or more) during the manual validation process, as this seems to be a feature ascribed exclusively to sei whales (Baumgartner et al., 2008; Español-Jiménez et al., 2019). Bryde's whale calls are distinctive and not easily confused with any other vocalization. Calls in the 20 Hz and 40 Hz downsweep frequencies are reserved for the low-frequency downsweep category with an end frequency near 20 Hz (usually sweeping from about 40 Hz) or 40 Hz (usually sweeping from about 100 Hz), respectively. As described in more detail in the FY23 annual report (Martin et al., 2024), calls in the 20-Hz category tend to appear very similar to fin whale B notes but vary more in frequency within a track and are believed to belong to either fin or sei whales (Martin et al, 2024, Rankin & Barlow, 2007) while 40-Hz downsweeps have been described for several baleen whale species (Martin et al., 2024). In past years, the GPL algorithm also produced tracks of various low-frequency calls, but because there is substantial overlap with the results produced by the C++ algorithm, only the latter are presented in this report. There is also an "unknown" category that encompasses signals grouped into tracks that correspond to unfamiliar signals which could be biologic or non-biologic in nature. These may be used for reference in future analyses and investigations but are not presented in this report.

Whale track abundance results (Sections 3.2 and 3.3.6) are presented as the mean number of whale tracks during an instantaneous snapshot every 2.5 minutes. A track is counted in all snapshots that are within the start and end time of a track. The mean number of tracks per snapshot are then aggregated on an hourly basis, by averaging over a maximum of 24 snapshots (i.e., the maximum number of snapshots per hour), and monthly, by averaging over a maximum of 576 snapshots in a day. Systematic snapshots of whale tracks enable a census-type abundance estimate for calling whales that could be localized and tracked. For individual whale track results presented under Sections 3.2 and 3.3.6, a study area of ~1,200 km^2 (22.8° to 22.275°N-S and -159.85° to -160.05°E-W), encompassing the hydrophone array, was used for tracking minke, fin, sei, Bryde's, and sperm whales, as well as tracks composed of 20-Hz and 40-Hz downsweeps (Figure 1). Because of differences in the localization algorithm, tracks generated by the separate Matlab GPL algorithm for humpback whales could allow more distant localizations to be tracked if present.

Beaked whale frequency-modulated pulses and killer whale HFM signals are not currently localized at PMRF, but another Matlab-based algorithm was used to group those vocalizations when they occurred on neighboring hydrophones within a certain timeframe. Beaked whales emit echolocation pulses at depth while they are diving with other group members; therefore, groups of their pulses are referred to as group vocal periods (GVPs), which are used here to quantify abundance. A subset of six unclassified and two classified datasets of dense-beaked whale detections were randomly selected and manually validated using raw acoustic data. All goose-beaked, Cross Seamount, and tropical bottlenose whale detections were manually validated. Killer whale HFM signals were also grouped by this algorithm when they occurred close enough in space and time. As they are comparatively rare, all such groups were manually validated. Co-occurrences of HFM signals are simply referred to as groups.

Relative abundance estimates based on track snapshots and GVPs are constrained by the number of animals vocalizing, which can depend on life stage, sex, and behavioral state. Cue rates and intraspecies proximity (relative to localization precision) are also confounding factors. These metrics therefore correspond to a minimum abundance of vocalizing animals in the study area. As with any PAM analysis, population abundance estimates require additional baseline population information, including the ratio of calling animals to all animals.

2.2.1.1 Transition to Baseline 5

This FY, efforts to consolidate two different code baselines within the NARWHAL suite were finalized, yielding a final set of common Baseline 5 detection, localization, and tracking algorithms for all call types run with C++ custom detectors. This was necessary to reconcile additional improvements made to the odontocete detectors beyond what had been completed in FY25.

These Baseline 5 changes included finalizing the killer whale HFM signal detector and improving the sperm whale detector and localizer. Changes were also made to the LAT algorithm and the beaked whale autogrouper. Attempts to add tropical bottlenose whales to the beaked whale detection algorithm prompted a shift from a descriptive, if-then approach using spectral measurements to a kernel-matching method now implemented in Baseline 5. Details about this shift and the new approach can be found in last year's report, including a comparison of performance for a subset of datasets (Martin et al., 2025). Further refinements to the method have been made that have drastically reduced the false positive rate at the GVP level to under 10% for all species and has reduced the effort required for manually validating autogrouped dives.

Changes were also made to refine the snapshot metrics after tracking. Snapshot periods are now established using all recorded data across individual datasets, which can be up to 5.6 days each. In comparison, prior analyses (i.e., Martin et al., 2025 and earlier) established snapshot periods using only individual datasets that contained tracks. This caused the number of snapshots to vary between tracked species and did not account for time periods when there were no tracks. The hourly mean number of tracks per snapshot and monthly trends in abundance as measured in previous years remain comparable to the results in Sections 3.2 and 3.3.6. However, the monthly mean number of tracks per snapshot in prior reports may be higher and values are not directly comparable to the monthly mean results in Sections 3.2 and 3.3.6.

Due to these myriad changes, caution should be used for now when interpreting any comparisons to previous years until that archived data can be reprocessed and reported using these new metrics.

2.2.2 Behavioral Response Analysis

The Behavioral Response Analysis process investigates whether whale presence overlaps with and is affected by anthropogenic activities. Received levels from MFAS transmissions from surface ship hull-mounted sonar, helicopter-dipping sonar, and active sonobuoys are estimated. The result is an abbreviated opportunistic passive acoustic behavioral response study to US Navy MFAS sources during training activities. This is accomplished using MFAS localizations, which have been a longstanding output from the NARWHAL suite, combined with platform location information provided by the PMRF range. When overlap occurs with whale tracks, a variety of metrics are calculated and estimated such as whale orientations (i.e., moving towards or away from the source), source orientations relative to the whale, and distances relative to all active sources. When sources are transmitting sonar, propagation modeling is conducted to calculate received sound levels while individual acoustically-tracked whales were calling.

2.3 RIMPAC ANALYSIS

In 2024, WARP was tasked with recording data during the RIMPAC training event that took place throughout the Hawaiian Islands. Specifically, WARP recorded data on the PMRF instrumented range during three ASWEXs and two SINKEXs. The ASWEX data were processed, and only one exercise had associated MFAS data. For the SINKEX data, WARP was tasked with determining how sounds from different events in the exercise could be detected, as well as if any marine mammals were present and if any behavioral responses could be identified. For both SINKEX exercises, subsets of hydrophones were manually reviewed for the duration of the recorded data to identify detections of impulsive signals as well as odontocete vocalizations. These results are summarized in Section 4.3.

2.4 BEAKED WHALE OCCURRENCE ANALYSIS

The FY22 report (Martin et al., 2023) included the first dataset entirely collected on the new recording system installed at PMRF in June 2021. In the FY22 report, an increase in beaked whale GVPs/hr compared to data from the previous recording system was observed. When these data were compared to those from the FY19, FY20, and FY21 reports (Martin et al., 2020, Martin et al., 2021, Martin et al., 2022), there was a mean increase of beaked whale GVPs/hr up to 48%. Potential causes for elevated GVPs/hr were discussed in the FY22 report, but a dedicated analysis had not been conducted to date. It seemed likely that the trend of elevated GVPs/hr was tied to the new recording system, i.e., that the change in the gain or sensitivity of the system led to an increased number of automated beaked whale detections. In FY25, an investigation was undertaken to assess the potential causes, and specific tests and results are described in Section 5.

3. RESULTS AND DISCUSSION

3.1 PMRF RANGE DATA COLLECTION RESULTS

The FY25 data processed for this report spanned September 10, 2024 through August 30, 2025. A total of 5,200.6 hours of data were recorded which includes 242.6 and 204.1 hours of classified data collected during the February and August SCC training events, respectively (Table 1). The total number of hours recorded and analyzed during this performance period decreased by 1,800.5 hours from the FY24 reporting period (Martin et al., 2025). The FY25 recording effort satisfied the planned recording schedule of two separate recordings per month. However, from March to June 2024, between 52% and 126% more hours of data were recorded compared to the same months in 2025. Diminished recording effort particularly in the spring and early summer may have obscured the true end of the whale season for some tracked baleen whales (e.g., minke and humpback whales) since presence can be sparse during the start and end of the whale season.

Table 1. Total monthly hours of recording effort for FY25 data from September 10, 2024 to August 30, 2025.

Month	Hours	% of Month Recorded
September-24	399.2	55%
October-24	585	79%
November-24	639.1	89%
December-24	583.6	78%
January-25	433.9	58%
February-25	362.5	90%
March-25	294.7	40%
April-25	271.2	38%
May-25	271.2	36%
June-25	406.8	57%
July-25	524.1	70%
August-25	429.3	85%
Total	5200.6	64%

3.2 BALEEN WHALE ABUNDANCE AND DISTRIBUTION

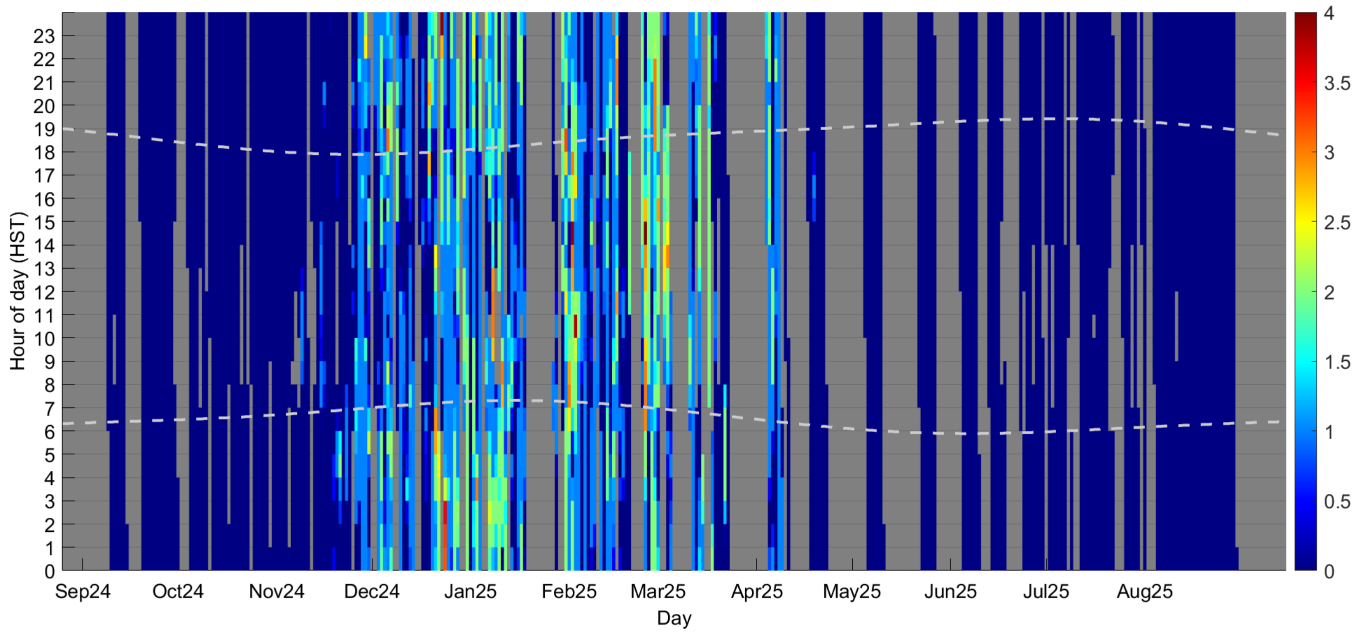
The mean number of automatically tracked, individual calling baleen whales in 2.5-minute snapshot periods from all recordings made between September 2024 and August 2025 is presented per month in Table 2 with standard deviations in parentheses

Table 2: Monthly number of baleen whales detected in 2.5-minute snapshots divided by the total number of available snapshots per month.

Month	# of Snapshots	Mean # of Tracks Per Snapshot and (Standard Deviation)							
		Minke	Humpback	Sei	Fin Song	Fin Non-Song	Bryde's	20-Hz	40-Hz
Sep-24	9,366	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Oct-24	14,005	0 (0)	0 (0)	0.002 (0.05)	0 (0)	0 (0)	0.05 (0.27)	0 (0)	0 (0)
Nov-24	15,395	0.18 (0.44)	0.02 (0.14)	0.05 (0.24)	0.05 (0.25)	0 (0)	0.005 (0.07)	0.006 (0.08)	0 (0)
Dec-24	13,945	0.88 (0.79)	0.09 (0.29)	0.16 (0.47)	0.40 (0.63)	0.04 (0.20)	0 (0)	0.006 (0.08)	0 (0)
Jan-25	10,410	0.95 (0.81)	0.23 (0.48)	0.05 (0.21)	0.66 (0.94)	0.05 (0.23)	0 (0)	0.03 (0.17)	0.009 (0.09)
Feb-25	13,288	0.94 (0.86)	0.10 (0.33)	0.004 (0.07)	0.34 (0.53)	0.005 (0.07)	0 (0)	0 (0)	0 (0)
Mar-25	7,311	0.81 (0.88)	0.12 (0.33)	0 (0)	0.01 (0.10)	0.004 (0.07)	0 (0)	0 (0)	0 (0)
Apr-25	6,507	0.37 (0.59)	0.05 (0.21)	0 (0)	0.01 (0.12)	0 (0)	0 (0)	0 (0)	0 (0)
May-25	6,506	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Jun-25	9,740	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Jul-25	12,353	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Aug-25	15,313	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

3.2.1 Minke Whales

The mean number of automatically tracked, individual calling minke whales in 2.5-minute snapshot periods from all recordings made between September 2024 and August 2025 is presented per hour in Figure 2 and per month in Table 2. During the current reporting period, minke whales were present from early November 2024 to late April 2025, which agrees with typical seasonal presence from fall to spring (e.g., Martin et al., 2020; 2025). While there is a strong seasonal pattern, minke whale tracks had no apparent diel pattern. Monthly mean presence was highest in January 2025 (0.95 whales/snapshot) and was elevated from December 2024 to March 2025. Mean hourly presence was typically between 1 and 2 whales/snapshot, and the highest hourly mean presence of 4 whales/snapshot occurred once near the end of February. For comparison, in the FY24 report (Martin et al., 2025) minke whales were tracked from late October 2023 to early May 2024, and a peak hourly mean of 6 whales/snapshot occurred three times in December 2023.

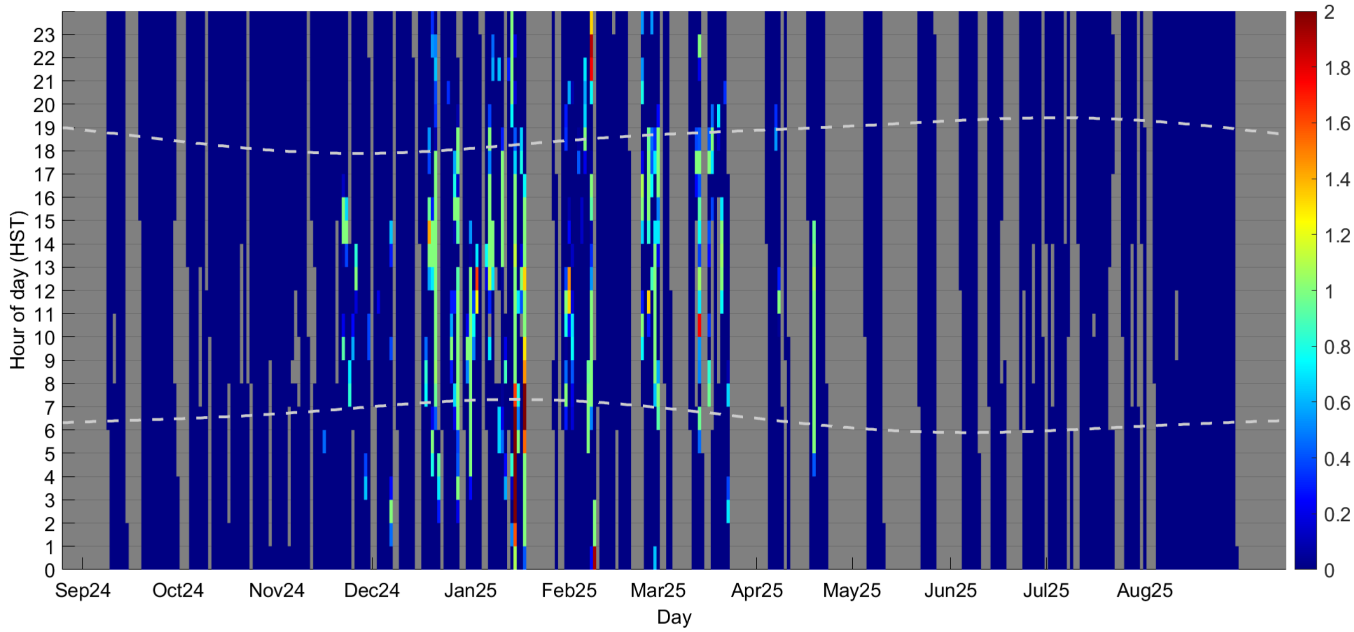


- Dark blue regions indicate periods of effort when acoustic recordings were collected and zero whale tracks were present. Results include classified data collected in February and August 2025. Gray shaded regions indicate periods of no recorded data. The light gray dotted lines indicate sunrise and sunset times.

Figure 2: The mean number of minke whales detected in 2.5-minute snapshot periods for each hour of the day from September 2024 to August 2025 ranged from 0.4 (blue) to 4 (dark red).

3.2.2 Humpback Whales

The mean number of automatically tracked, individual calling humpback whales in 2.5-minute snapshot periods from all recordings made between September 2024 and August 2025 is presented per hour in Figure 3 and per month in Table 2. During the current reporting period, humpback whales were present from mid November 2024 to late April 2025, which agrees with typical seasonal presence from fall to spring (e.g., Martin et al., 2020; 2025). Monthly mean presence was highest in January 2025 (0.23 whales/snapshot). Mean hourly presence was typically ≤1 whale/snapshot, while the highest hourly mean presence of 2 whales/snapshot occurred 5 times in mid-January. For comparison, in the FY24 report (Martin et al., 2025) humpback whales were tracked from late October 2023 to June 2024, and a peak hourly mean of 3 whales/snapshot occurred once in December 2023.

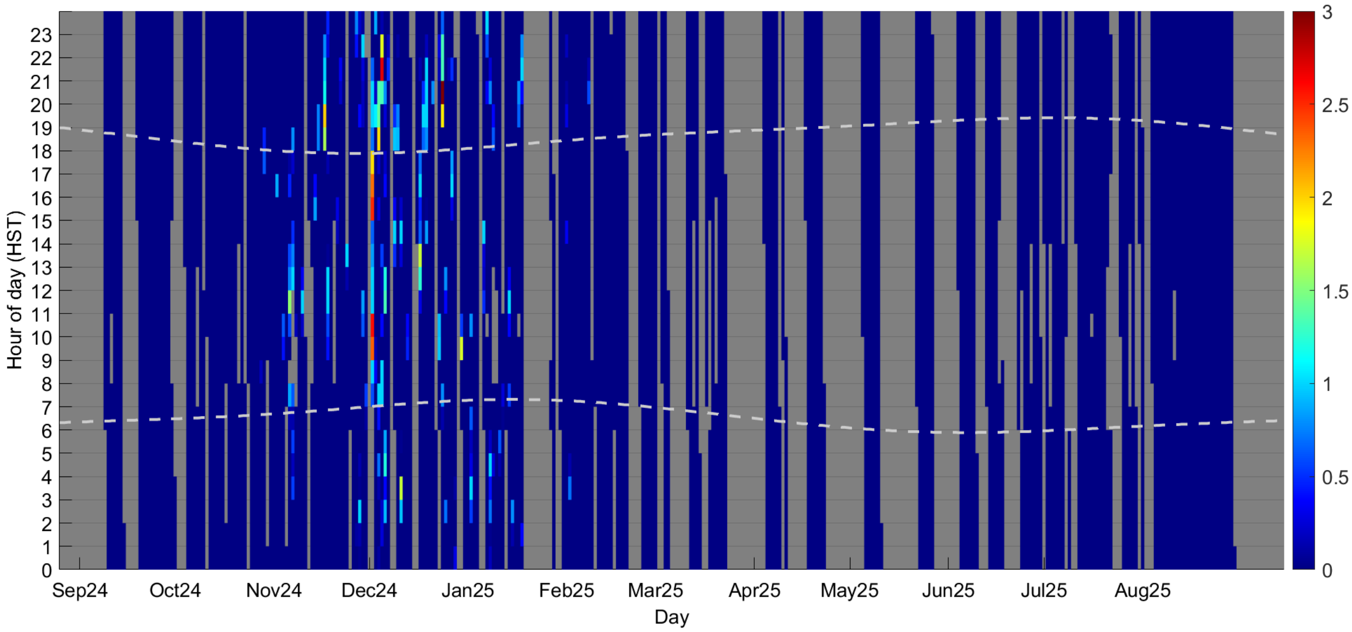


- Dark blue regions indicate periods of effort when acoustic recordings were collected and zero whale tracks were present. Results include classified data collected in February and August 2025. Gray shaded regions indicate periods of no recorded data. The light gray dotted lines indicate sunrise and sunset times.

Figure 3: The mean number of humpback whales detected in 2.5-minute snapshot periods for each hour of the day from September 2024 to August 2025 ranged from 0.04 (blue) to 2 (dark red).

3.2.3 Sei Whales

The mean number of automatically tracked, individual calling sei whales in 2.5-minute snapshot periods from all recordings made between September 2024 and August 2025 is presented per hour in Figure 4 and per month in Table 2. During the current reporting period, sei whales were present from late October 2024 to early February 2025, which agrees with currently available sei whale abundance and presence results in the FY23 and FY24 reports (Martin et al., 2024; 2025). Monthly mean presence was highest in December 2024 (0.16 whales/snapshot). Mean hourly presence was typically ≤1 whale/snapshot, while the highest hourly mean presence of 3 whales/snapshot occurred once in late December. For comparison, in both the FY23 and FY24 reports sei whales were tracked from October to March. In the FY23 report, peak hourly presence of 4 whales/snapshot occurred in January 2023, and in FY24 a peak of 3.08 whales/snapshot occurred in January 2024.



- Dark blue regions indicate periods of effort when acoustic recordings were collected and zero whale tracks were present. Results include classified data collected in February and August 2025. Gray shaded regions indicate periods of no recorded data. The light gray dotted lines indicate sunrise and sunset times.

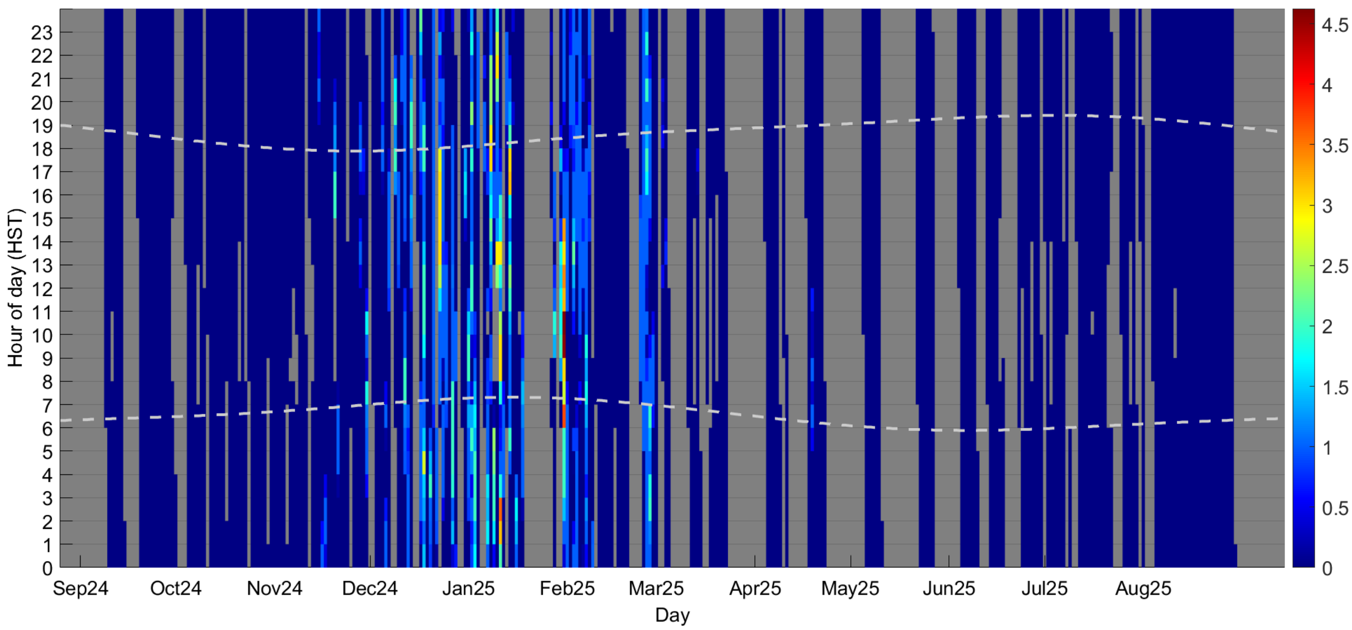
Figure 4: The mean number of sei whale tracks detected in 2.5-minute snapshot periods for each hour of the day from September 2024 to August 2025 ranged from 0.04 (blue) to 3 (dark red).

3.2.4 Fin Whales

This is this first reporting period where fin whale tracks are presented separately as either song or non-song. This was primarily done as a refinement of fin whale vocalization classification since prior reports presented fin whale results as a combination of song and non-song tracks. By separating song tracks, we can do a deeper analysis of singing behavior, which has the potential to help us better understand population connectivity throughout the North Pacific (Helble et al. 2020, 2025). The mean number of automatically tracked, individual calling fin whales in 2.5-minute snapshot periods from all recordings made between September 2024 and August 2025 is presented below for fin whales, separated into song tracks (Figure 5 and Table 2), which are primarily made up of A and/or B notes in regular inter-note-intervals, and non-song tracks (Figure 6 and Table 2), which contain A and/or B notes but in inconsistent patterns. The latter could be due to truncated tracks that did not extend long enough to produce a consistent note pattern or could be actual vocalization series that are not following a strong song pattern.

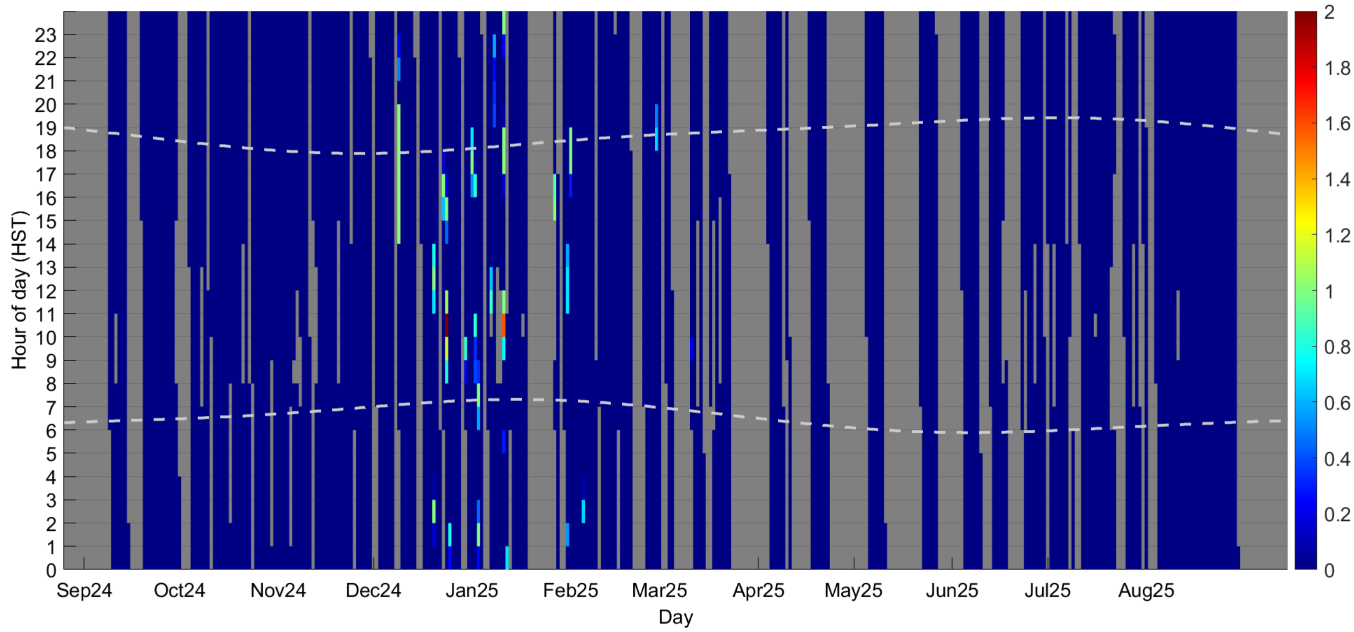
Fin whale song tracks were present from November 2024 to April 2025. Monthly mean presence was highest in January 2025 (0.66 whales/snapshot). Mean hourly presence was typically ≤1 whale/snapshot, while the highest hourly mean presence of 4.63 whales/snapshot occurred once at the end of January. Fin whale non-song tracks whales were present from December 2024 to March 2025. Monthly mean presence was highest in January 2025 (0.05 whales/snapshot). Mean hourly presence was typically ≤1 whale/snapshot, while the highest hourly mean presence of 2 whales/snapshot occurred once at the end of December. Fin song and non-song presence agrees with typical seasonal presence from fall to spring (e.g., Martin et al., 2022; 2025). Although fin presence in prior reports is a combination of fin song and non-song tracks, it provides a relative comparison to the current results. For example, in the FY24 report, fin whales were present from November 2023 to March 2024 and had a peak hourly mean of 3.1 whales/snapshot which occurred in November 2023.

Though the sample size is too low to draw any firm conclusions, there may be some slight suggestion of a diurnal pattern to non-song, with a preference for daylight hours (Figure 6). It will be interesting to see if this pattern solidifies as more years are monitored with this separation.



- Dark blue regions indicate periods of effort when acoustic recordings were collected and zero whale tracks were present. Results include classified data collected in February and August 2025. Gray shaded regions indicate periods of no recorded data. The light gray dotted lines indicate sunrise and sunset times.

Figure 5: The mean number of fin song tracks detected in 2.5-minute snapshot periods for each hour of the day from September 2024 to August 2025 ranged from 0.04 (blue) to 4.6 (dark red)



- Dark blue regions indicate periods of effort when acoustic recordings were collected and zero whale tracks were present. Results include classified data collected in February and August 2025. Gray shaded regions indicate periods of no recorded data. The light gray dotted lines indicate sunrise and sunset times.

Figure 6: The mean number of fin non-song tracks detected in 2.5-minute snapshot periods for each hour of the day from September 2024 to August 2025 ranged from 0.04 (blue) to 2 (dark red).

3.2.4.1 Fin Whale Song Evolution and Cue Rate Drift

A current ONR funded project called "Fin whale song evolution and cue rate drift over 12 years in the central and eastern North Pacific" (PIs R. Guazzo and T. Helble) aims to improve cue rate-based density estimation for fin whales and assess population connectivity by comparing song patterns across the central and eastern North Pacific. So far, this project has analyzed fin whale calls at PMRF and is currently analyzing fin whale calls from the Southern California Anti-Submarine Warfare Range (SOAR) located west of San Clemente Island. By examining fin whale populations in two U.S. Navy training areas, this project will explore potential interactions and examine the assumption of separate stocks. Expanding the time series of fin whale songs in Hawaiian waters and analyzing songs recorded off San Clemente Island will enable direct comparison of these two groups. Additionally, calculating cue rates for fin whales will help advance passive acoustic monitoring for estimating baleen whale density and abundance, ultimately informing conservation and management strategies.

Recently, this project expanded work from Helble et al. (2020), in which songs were analyzed from 2012 – 2016, and Helble et al. (2025) which incorporated an additional 335 fin whale tracks from 2017 to 2023. Overall, fin whale song offshore Kaua'i is continuing to evolve, notably, the inter-note interval (INI) continues to lengthen, with the time between A and B notes increasing from roughly 10 seconds in 2012 to 16 seconds in 2023 (Helble et al., 2020; Helble et al., 2025). The time between B and A notes increased from roughly 17 seconds in 2012 to 23 seconds in 2023 (Figure 7). The INIs between A-A note and B-B note pairings also increased over these years. Additionally, although there is much variation, there were fewer A-A note pairings in more recent years than observed earlier in the record, and B-B notes were more prevalent (Figure 7).

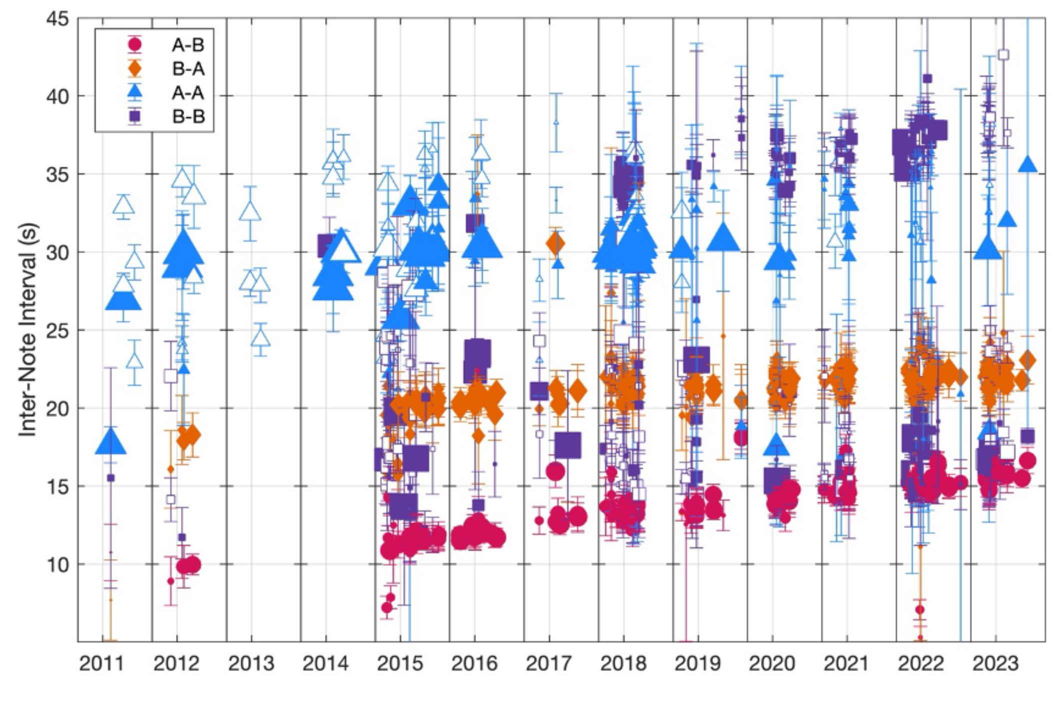
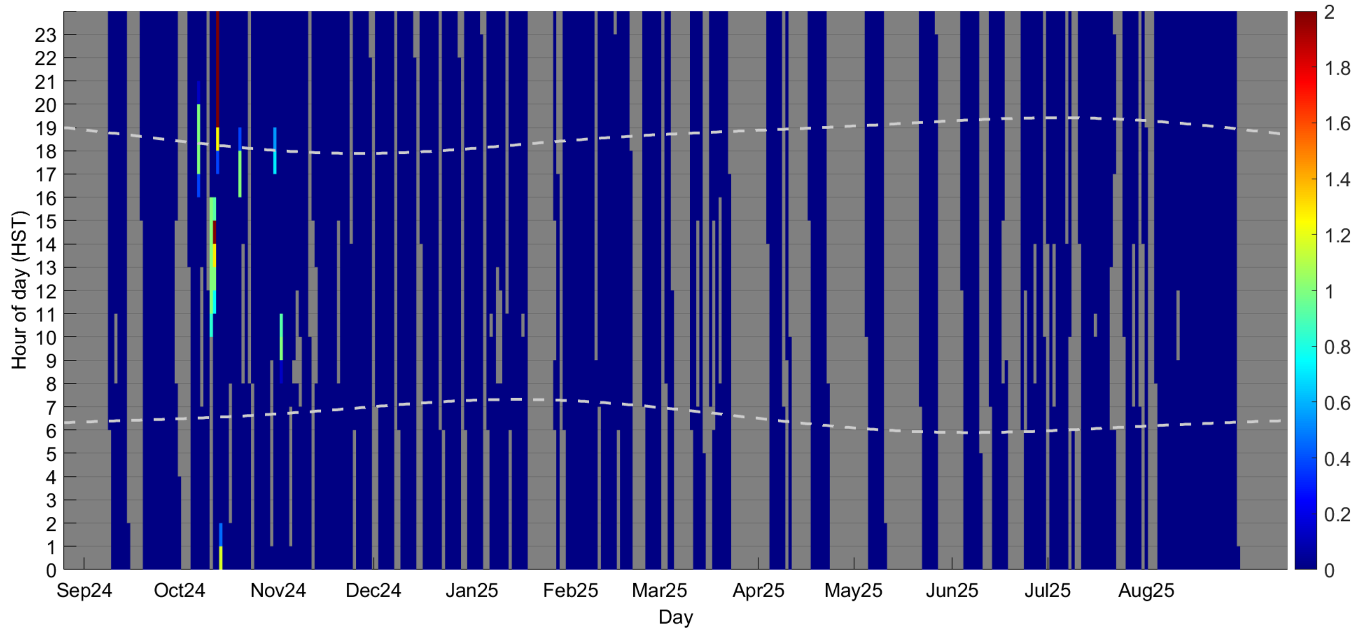


Figure 7: The inter-note interval for different fin whale note-type pairings from 2011-2023 (2011-2017 was published in Helble et al., 2020). The size of the markers is representative of the percentage of notes of that note type for the track. Figure from Helble et al., 2025

3.2.5 Bryde's Whales

The mean number of automatically tracked, individual calling Bryde's whales in 2.5-minute snapshot periods from all recordings made between September 2024 and August 2025 is presented per hour in Figure 8 and per month in Table 2. During the current reporting period, Bryde's whales were present from early October 2024 to early November 2024, which overlaps with times of previously documented presence (e.g., Martin et al., 2022; 2025). At PMRF, Bryde's whales can be present year-round and have been documented to occur year-round (Martin et al., 2022; Martin and Matsuyama, 2014; Helble et al., 2016; and Martin et al., 2025); however, in FY25 they were only detected in the fall. Monthly mean presence was highest in October 2024 (0.05 whales/snapshot). Mean hourly presence was typically ≤1 whale/snapshot, while the highest hourly mean presence of 2 whales/snapshot occurred 6 times in mid-October. For comparison, in the FY24 report (Martin et al., 2025) Bryde's whales were tracked from September to October 2023 and June to August 2024 and had a peak hourly mean of 1 whale/snapshot in every month they were detected.

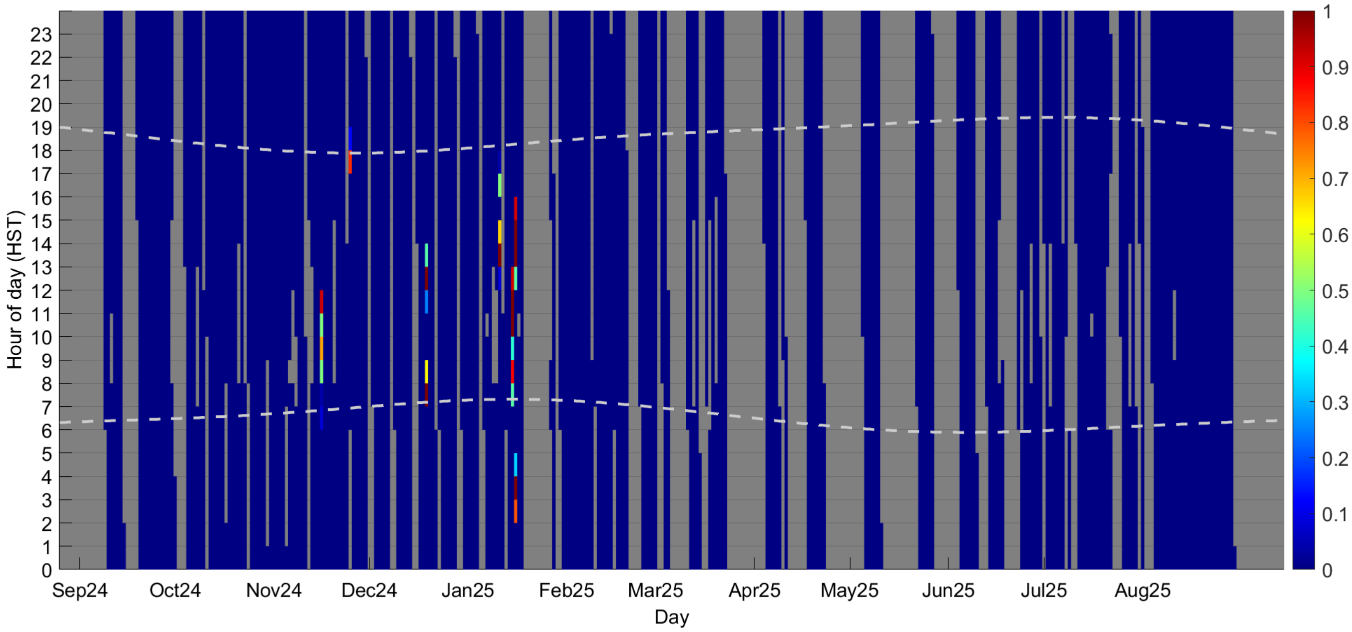


- Dark blue regions indicate periods of effort when acoustic recordings were collected and zero whale tracks were present. Results include classified data collected in February and August 2025. Gray shaded regions indicate periods of no recorded data. The light gray dotted lines indicate sunrise and sunset times.

Figure 8: The mean number of Bryde's whale tracks detected in 2.5-minute snapshot periods for each hour of the day from September 2024 to August 2025 ranged from 0.1 (blue) to 2 (dark red).

3.2.6 20-Hz Downsweeps

The mean number of automatically tracked 20-Hz downsweeps (likely produced by fin or sei whales) detected in a 2.5-minute snapshot period from all recordings made between September 2024 and August 2025 is presented per hour in Figure 9 and per month in Table 2. Downswept 20-Hz calls were also detected during periods when sei (Figure 4 and Table 2) and fin (Figure 5, Figure 6, and Table 2) whales were detected, and as noted in Section 2.2.1 are not classified to either species as these calls do not meet the pre-defined criteria. During the current reporting period, 20-Hz downsweeps were present from mid-November 2024 to mid-January 2025. Monthly mean presence was highest in January 2025 (0.03 whales/snapshot). Mean hourly presence was typically <1 whale/snapshot, while the highest hourly mean presence of 1 whale/snapshot occurred 8 times in December and January. For comparison, in the FY24 report (Martin et al., 2025) 20-Hz downsweeps were tracked from November 2023 to May 2024, and a peak hourly mean of 1.6 whales/snapshot occurred once in December 2023. Part of the impetus for creating a fin non-song category this FY (see Sections 2.2.1 and 3.2.4) was to reserve this category for a specific type of 20-Hz downsweep that notably deviates from fin A/B calls that do not form a song pattern (for more details and example spectrograms, see Martin et al., 2024). Thus, as our detection and classification methods for low-frequency calls have improved, fewer calls are falling into this category than in previous years. As noted in the FY24 annual report (Martin et al., 2025), there may be some preference for producing this call during the day, which is also suggested by the fin non-song category (Figure 6). This could suggest that this is a calling mode that fins switch to during the day between singing, or – if it belongs to another baleen whale – that its functionality is like that of fin non-song (e.g., perhaps social behavior).

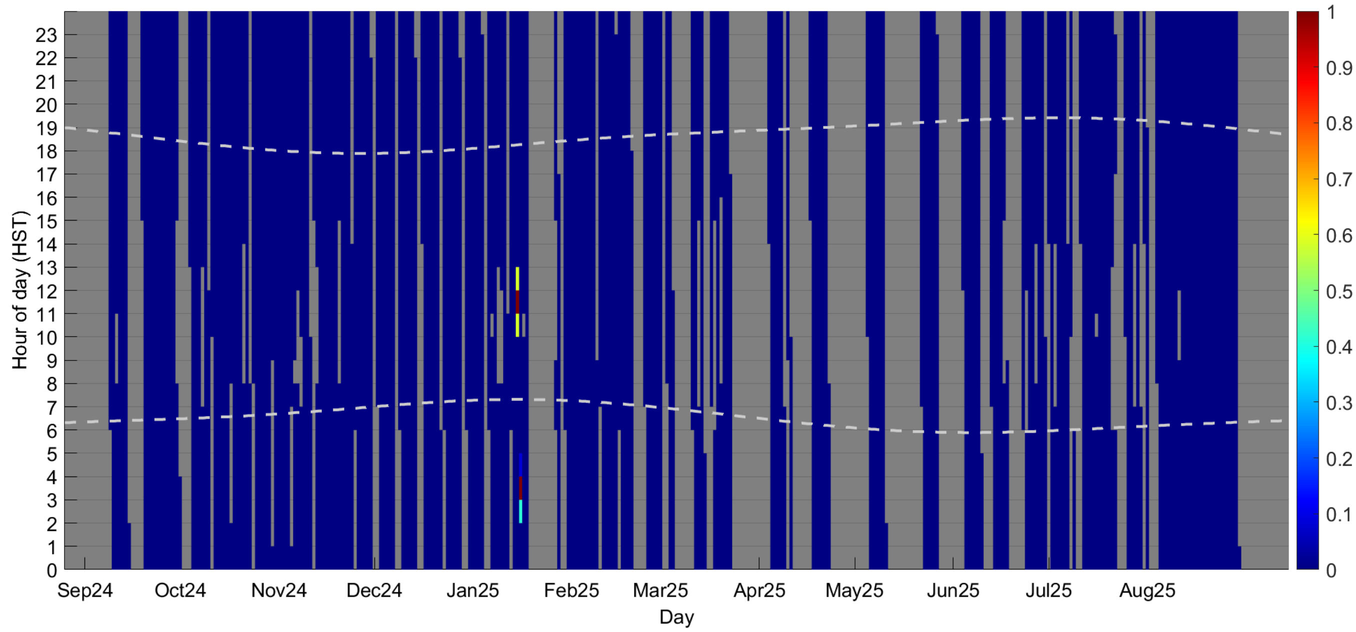


- Dark blue regions indicate periods of effort when acoustic recordings were collected and zero whale tracks were present. Results include classified data collected in February and August 2025. Gray shaded regions indicate periods of no recorded data. The light gray dotted lines indicate sunrise and sunset times.

Figure 9: The mean number of tracks composed of 20-Hz downsweeps (suspected to be either fin or sei whales) detected in 2.5-minute snapshot periods for each hour of the day from September 2024 to August 2025 ranged from 0.04 (blue) to 1 (dark red).

3.2.7 40-Hz Downsweeps

The mean number of automatically tracked 40-Hz downsweeps (potentially attributable to fin, sei, or blue whales) detected in a 2.5-minute snapshot period from all recordings made between September 2024 and August 2025 is presented per hour in Figure 10 and per month in Table 2. Downswept 40-Hz calls were also detected during periods when sei (Figure 4 and Table 2) and fin (Figure 5, Figure 6, and Table 2) whales were detected, and as noted in Section 2.2.1 are not classified to either species as these calls do not meet the pre-defined criteria. During the current reporting period, 40-Hz downsweeps were only detected in January 2025 and had a monthly mean presence of 0.03 whales/snapshot. The highest hourly mean presence of 1 whale/snapshot occurred 2 times in January. For comparison, in the FY24 report (Martin et al., 2025) 40-Hz downsweeps were tracked from December 2023 to March 2024, and a peak hourly mean of 1 whale/snapshot occurred once in December 2023 and in February 2024.



- Dark blue regions indicate periods of effort when acoustic recordings were collected and zero whale tracks were present. Results include classified data collected in February and August 2025. Gray shaded regions indicate periods of no recorded data. The light gray dotted lines indicate sunrise and sunset times.

Figure 10: The mean number of tracks comprised of 40-Hz downsweeps (possibly attributable to several baleen whale species) detected in 2.5-minute snapshot periods for each hour of the day from September 2024 to August 2025 ranged from 0.08 (blue) to 1 (dark red).

3.2.8 Blue Whales

Two different calls attributed to blue whales and one to an unknown species (but likely also a blue whale) have been detected on PMRF using a version of the GPL algorithm modified to suit the long-duration tonal signals. These calls exhibit minimal frequency modulation and include blue whale northwestern Pacific calls with a fundamental frequency (usually its strongest component in our recordings, Figure 11; Stafford et al., 2001) of about 18 Hz. Our data also include northeastern Pacific B calls with a fundamental frequency (often invisible in our recordings due to roll-off) of around 15 Hz and a very strong third harmonic between 40 and 50 Hz, which is usually the strongest component in our recordings (Figure 11; Stafford et al., 2001). The third call type usually consists of a single visible component at 54 Hz that is of similar duration and character to the two known blue whale calls (Figure 11, Martin et al., 2024). This call type is similar to the 52 Hz call known as the Watkins' call (Watkins et al., 2004).

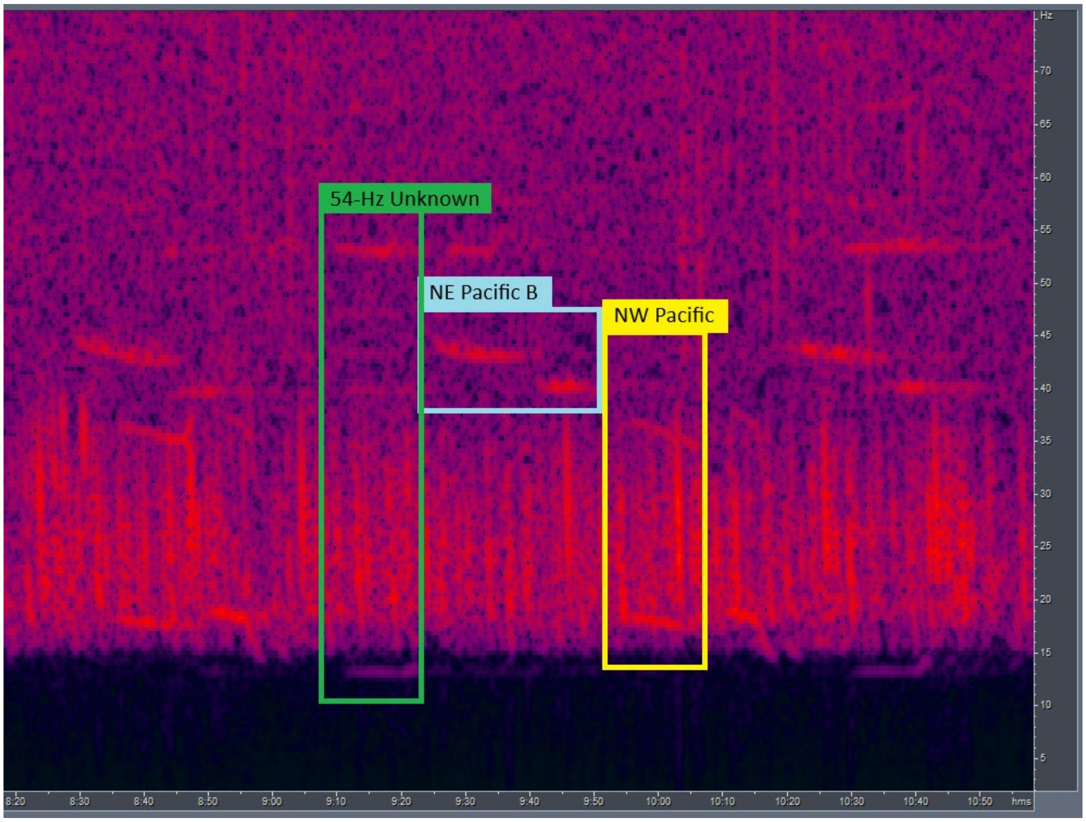


Figure 11: The three tonal calls ascribed to blue whales as seen on PMRF. In this case, a fundamental frequency for the 54-Hz call is visible at about 13 Hz.

Though the detections are processed with the same cross-correlation-based localization algorithm as humpbacks, due to their call characteristics and the fact that the low-frequency calls can be detected despite coming from far off-range (usually to the north and west), they rarely produce good quality localizations. Consequently, we assess these calls for presence/absence only, rather than any track metrics. Only datasets with at least 20 localizations with a least-squares error (LSQ) error below 0.1 sec proceed to manual validation to identify and confirm call type presence.

As in most years, in this FY all three call types were identified at some point, with at least one call type present in most data between December 16 and January 17, often with all three call types detected in the same dataset. Northeastern Pacific B calls were the most common, occurring on their own during two datasets in early January and with 54-Hz calls in a dataset starting January 13. Most calls regardless of type were localized in the northern part of the range or off-range to the north or west. Because of the rarity of measuring long, high-quality tracks through the range, it remains unclear whether it is possibly one individual producing multiple call types or if the different call types correspond to separate individuals and/or populations (as the traditional names of the two definitive blue whale calls suggest).

Validation of the call types in the raw data revealed some more structure to the unknown 54-Hz call type, probably due to occasional increased proximity of calling animals to the hydrophones this year. The component that is mostly – if not solely – visible is that around 53 or 54 Hz. However, at times this year sidebands were visible at about 40, 67, and 80 Hz (Figure 11 and Figure 12). Of note are suggestions of a fundamental frequency (Figure 11) and concurrent pulses immediately following – or as an extension of – the tone (Figure 12) around 13-14 Hz that are faintly visible in the dark area of the spectrogram below the filter roll-off on the hydrophones. Sideband patterns and the presence of any fundamental frequency further distinguish it from how Watkins' (or 52-Hz) whale calls have been described (Watkins et al., 2004), although the similarity between these two and the other Pacific blue whale tonal calls is striking. Furthermore, since blue whale song has been documented to be decreasing in frequency over time (e.g. McDonald et al., 2009), it would be surprising if the Watkins' call was now higher in frequency than when it was recorded in 1989-1993. The fact that this call type regularly overlaps in presence with known blue whale calls on PMRF does suggest that this is likely some type of blue whale call.

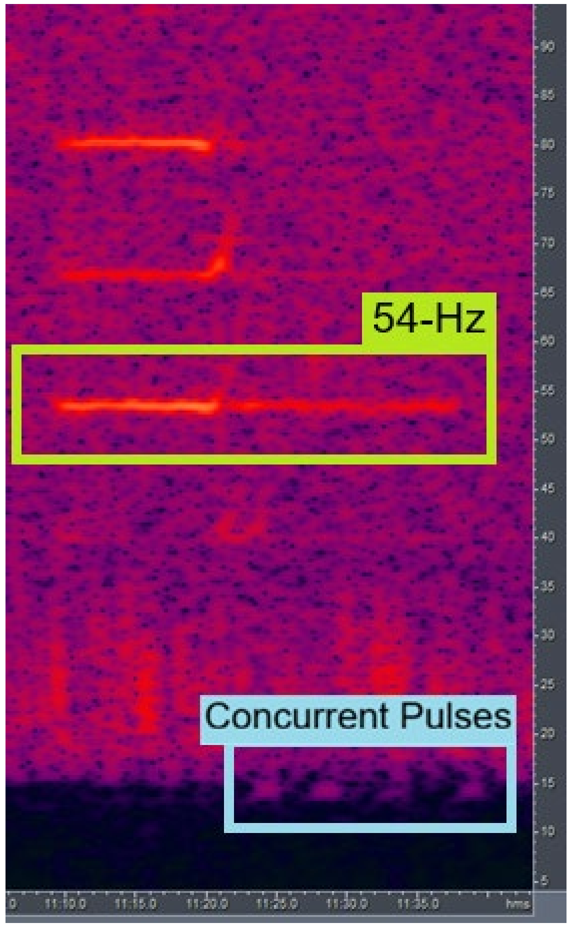


Figure 12: A 54-Hz tonal call tentatively ascribed to blue whales as seen on PMRF. In this instance, the animal was vocalizing close enough to hydrophones for more structure to be visible in the call than in previous years, including sidebands and some concurrent pulses at about 14 Hz.

Although the northwestern Pacific and northeastern Pacific B calls are labeled based on descriptions by Stafford et al. (2001), there are certain aspects that make them an imperfect match to those labels. For example, on PMRF, the pulsed A component has never been found to accompany the B component in the northeastern Pacific call. Although singular B calls have been noted in other northeast Pacific data in certain behavioral contexts (Oleson et al., 2007), the calling rates in these cases are intermittent, whereas on PMRF these almost always occur in consistent sequences, suggesting song (Martin et al., 2020, 2024). The northeastern Pacific B calls recorded on PMRF are similar in structure to those reported by Carbaugh-Rutland et al. (2021) in Hawaiian waters and the Gulf of Alaska with a step-down in frequency (though on PMRF the step tends to be more dramatic and the second component a more significant portion of the call), which they propose could indicate that this is a distinct subpopulation from the blue whales off southern California. The northwestern Pacific call is described in Stafford et al. (2001) as either a two- or three-part tone between 20.2 and 18.2 Hz or a single tone paired with a D-call-like downsweep (Figure 13). The northwestern Pacific calls as seen on PMRF do sometimes have two segments but often are just one continuous segment and regardless are never accompanied by anything resembling a D-call in a pattern (see Martin et al., 2024 for strong examples of both side by side, likely produced by the same individual). Furthermore, the frequency usually starts around 18-Hz and decreases from there, though this could be due to the long-term decrease in frequency noted by McDonald et al. (2009).

Other research – including the described 52-Hz (Watkins, 2004) and our own 54-Hz calls – suggests a wide range of plasticity with regards to these tonal blue whale calls. These call variations exist across regions (McDonald et al., 2006) and in at least one documented instance within a single individual combining elements of northwestern and northeastern B call types (Stafford & Moore, 2005). It is therefore perhaps more appropriate to generally refer to them as they appear on PMRF simply as tonal blue whale calls, pending further research on call type variation or longer-term tracking of individuals visiting PMRF (e.g., via tagging or visual survey) that would allow definitive assignment to geographic populations.

For the first time in our recorded data, blue whale D-calls were identified in the dataset starting January 10 (Figure 13). These are downsweeps between about 80 and 30 Hz that are highly variable in frequency and are of longer and more variable duration as compared to the highly stereotyped low-frequency downsweeps produced by fin or sei whales (see Sections 3.2.3 and 3.2.4). Enough of these calls were detected and localized to produce some small tracks, apparently from a pair of whales west of the range moving northeast. Thought to function as a contact call, often between feeding bouts, they are not regionally specific, occurring in blue whale populations throughout the world (McDonald et al., 2006; McDonald et al., 2001; Mellinger & Clark, 2003; Oleson et al., 2007; Rankin et al., 2005; Thompson et al., 1996).

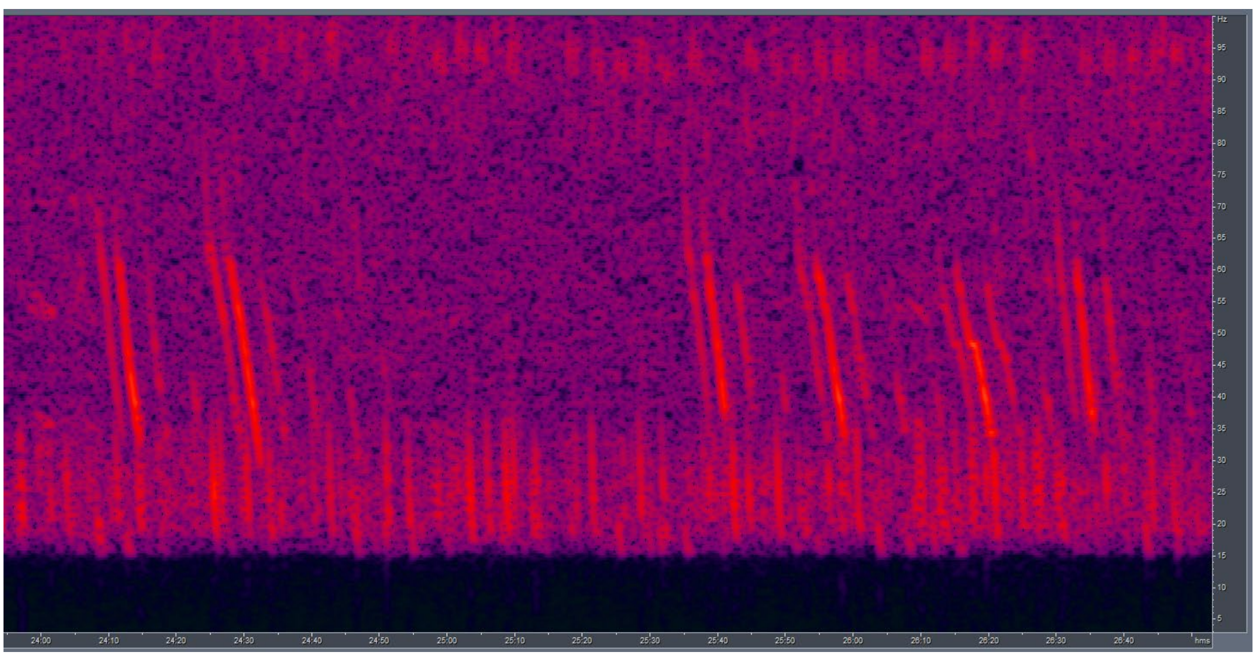


Figure 13: Blue whale D-call downsweeps as seen on PMRF.

3.3 ODONTOCETE ABUNDANCE AND DISTRIBUTION

The number of beaked whale GVPs from all recordings made between September 2024 and August 2025 is presented in Table 3 with GVPs/hr in parentheses. Similarly, the mean number of automatically tracked, individual calling sperm whales in 2.5-minute snapshot periods is presented per month in Table 4 with standard deviations in parentheses.

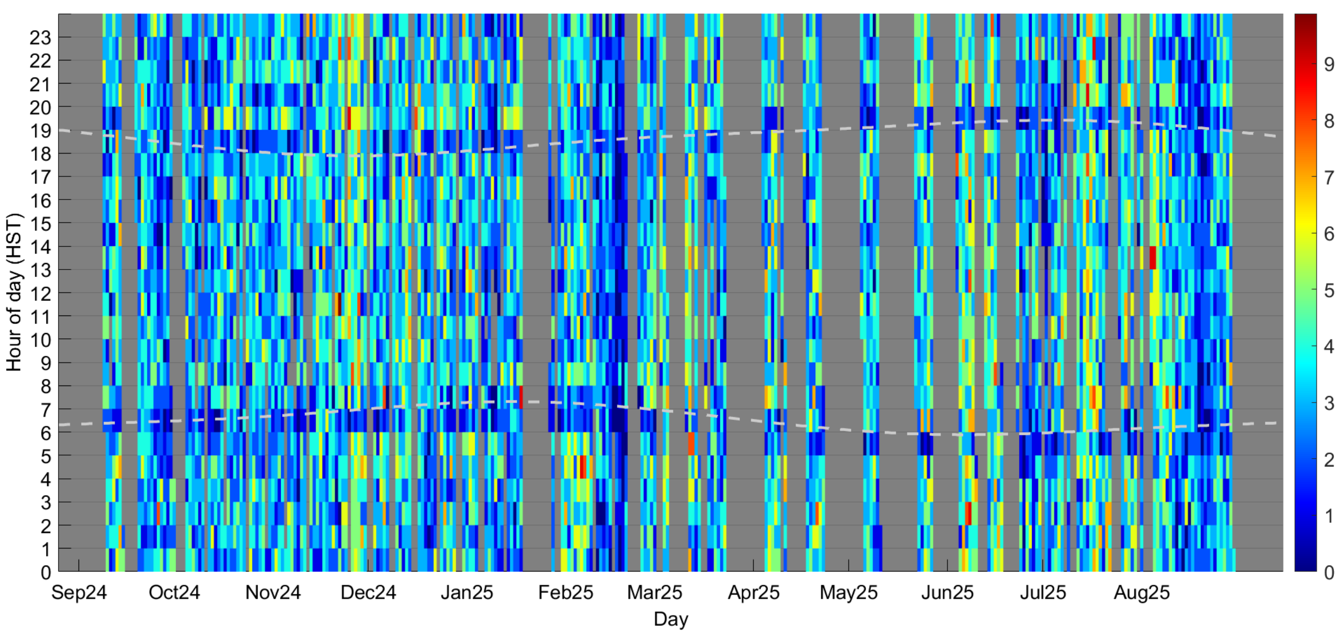
Table 3: Monthly number of beaked whale group vocal periods and hours of recorded data

Month	Hours	Total # of GVPs/month and (GVPs/hr)			
		Dense-beaked	Goose-beaked	Cross Seamount	Tropical Bottlenose
Sep-24	399.2	931 (2.3)	16 (0.04)	99 (0.25)	19 (0.05)
Oct-24	585.0	1379 (2.4)	35 (0.06)	61 (0.10)	71 (0.12)
Nov-24	639.1	1843 (2.9)	121 (0.19)	92 (0.14)	210 (0.33)
Dec-24	583.6	1513 (2.6)	80 (0.14)	150 (0.26)	48 (0.08)
Jan-25	433.9	1031 (2.4)	72 (0.17)	74 (0.17)	1 (0.002)
Feb-25	362.5	1226 (2.2)	45 (0.08)	81 (0.15)	0 (0)
Mar-25	294.7	865 (2.9)	48 (0.16)	72 (0.24)	16 (0.05)
Apr-25	271.2	779 (2.9)	40 (0.15)	15 (0.06)	29 (0.11)
May-25	271.2	751 (2.8)	20 (0.07)	46 (0.17	15 (0.06)
Jun-25	406.8	1191 (2.9)	122 (0.30)	56 (0.14)	27 (0.07)
Jul-25	524.1	1577 (3.0)	115 (0.22)	59 (0.11)	10 (0.02)
Aug-25	429.3	1497 (2.4)	86 (0.14)	98 (0.16)	5 (0.01)

3.3.1 Dense-Beaked Whales

As has historically been the case, dense-beaked whales were the most abundant beaked whale detected at PMRF by at least an order of magnitude. Using the new detection algorithm with a very low false positive rate (1% for unclassified data, 7% for classified data), and the new auto-grouping algorithm, dense-beaked echolocation pulses were grouped into GVPs. Six 24-hour subsets of baseline data randomly selected from across the year and two full 5-day datasets from each SCC were manually validated to verify the false positive rate, test the new algorithms, and compare them against previous baselines. The performance was outstanding (false positive rates in FY24 were 8.8% and 14.7% for baseline and training data, respectively); between this analysis and the assessment of the GVP count differences across recorders (Section 5).

The FY25 monthly GVP rates are highlighted in Table 3 and the hourly rates in Figure 14. GVP rates were very consistent this year, only varying between 2.2 and 3.0 GVPs/hour (Table 3). As mentioned in Section 5, while dense-beaked whales have no obvious diel (except at dawn/dusk) or seasonal dive cycles, there is some periodicity in their presence at PMRF, with fluctuations in presence that can vary by week or month. This is likely due to movement and variation in the presence of their prey, which could in turn be driven by changing wind patterns. While the monthly mean GVP/hour rate was more consistent this year, there was still periodicity in their hourly dive data, as can be seen in Figure 14. GVPs/hour ranged between one and 9.9, with the maximum occurring in November. This species also has a strong crepuscular dip in dives at dawn and dusk as is evident in Figure 14. The two annual minimums occurred during the February and August SCCs and is examined more in Section 4.2.

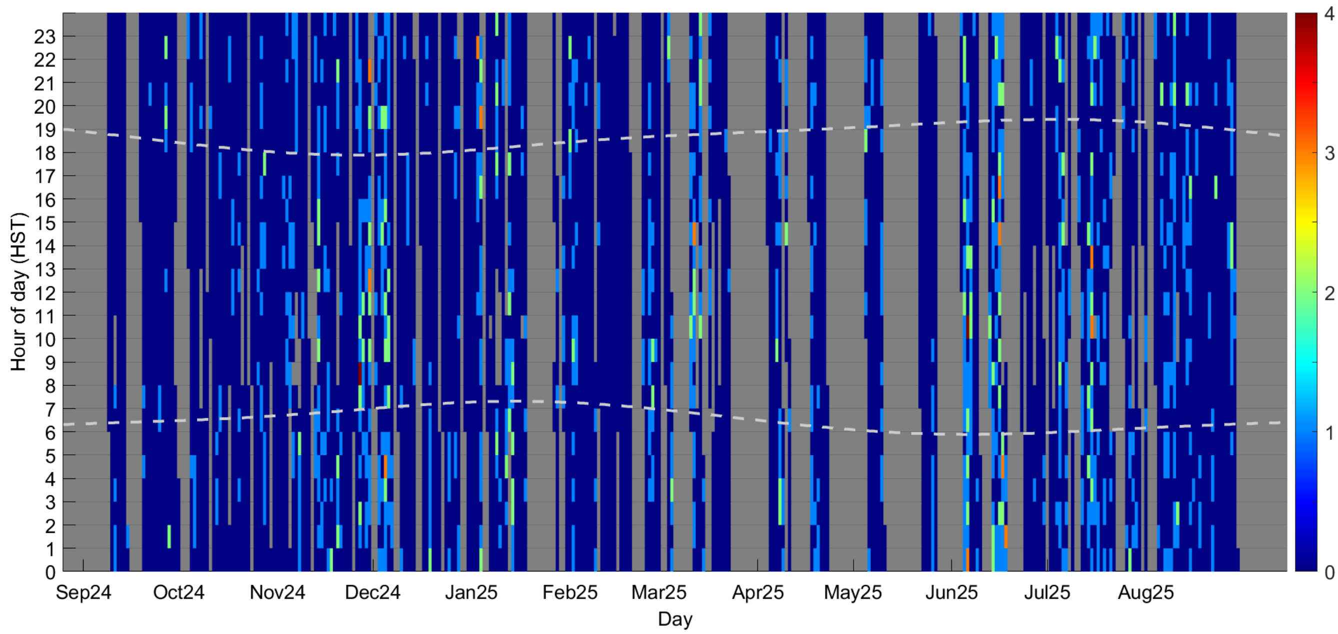


- Dark blue regions indicate periods of effort when acoustic recordings were collected and zero whale tracks were present. Results include classified data collected in February and August 2025. Gray shaded regions indicate periods of no recorded data. The light gray dotted lines indicate sunrise and sunset times.

Figure 14: Dense-beaked whale GVPs/hour corrected using manually validated dives from six unclassified datasets and two classified datasets from September 2024 to August 2025 ranged from 0.99 (blue) to 9.88 (dark red).

3.3.2 Goose-Beaked Whales

Goose-beaked whales are the third most common beaked whale detected at PMRF. Although their monthly dive rates are similar to those of Cross Seamount beaked whales (see Section 3.3.3), their dives occur throughout the diel cycle. There is also clear periodicity in their presence at PMRF, much like dense-beaked whales but at a lower order of magnitude. Their monthly GVP/hour rate peaked in June at 0.3 GVPs/hour (Table 3), while their hourly GVP/hour rates varied between zero and four, with one GVP/hour occurring most frequently but four GVPs/hour occurring occasionally throughout the year (Figure 15). This species also seems to have a dip in detections at the crepuscular periods (dawn and dusk), similar to dense-beaked whales but not as obvious due to the lower dive rates. These detections were fully manually validated.



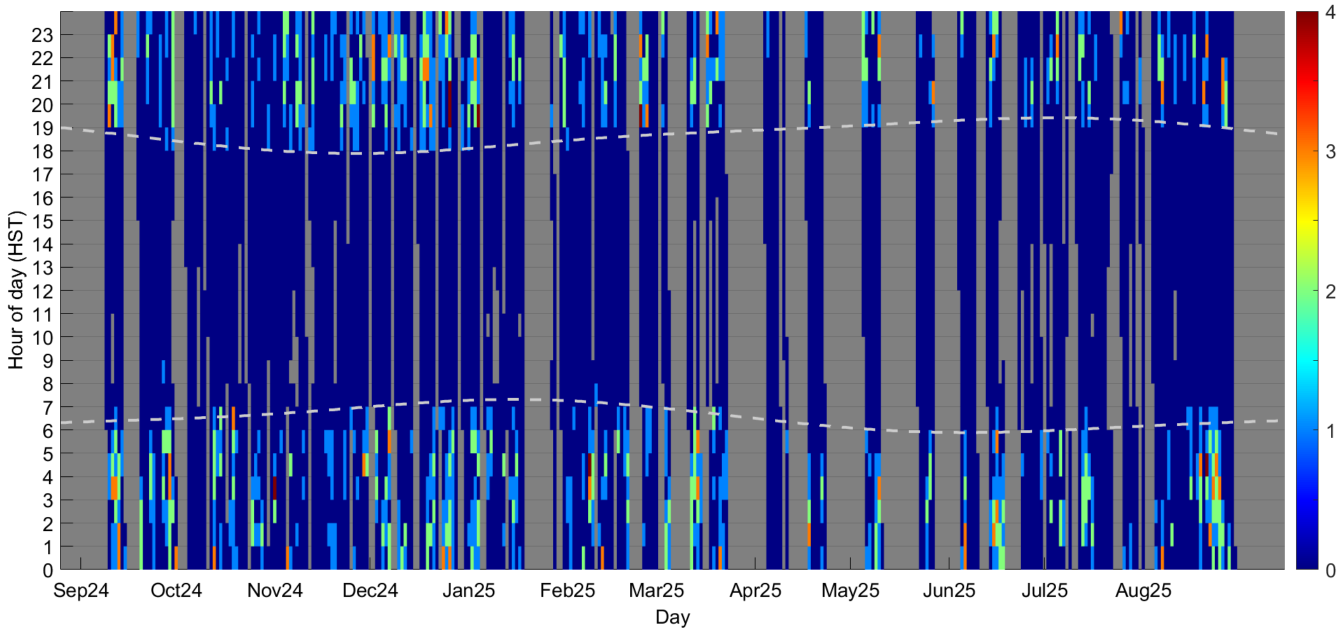
- Dark blue regions indicate periods of effort when acoustic recordings were collected and zero whale tracks were present. Results include classified data collected in February and August 2025. Gray shaded regions indicate periods of no recorded data. The light gray dotted lines indicate sunrise and sunset times.

Figure 15: Fully validated goose-beaked whale GVPs/hour from September 2024 to August 2025 ranged from 1 (blue) to 4 (dark red).

3.3.3 Cross Seamount Beaked Whales

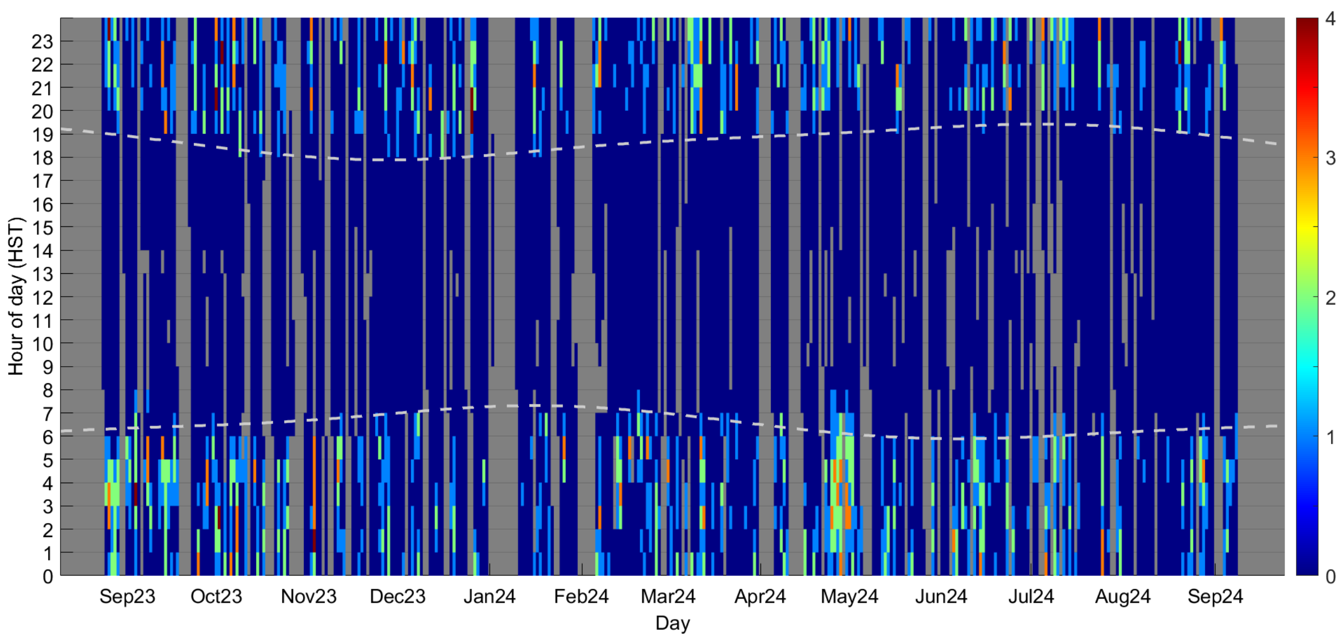
Cross Seamount beaked whales are the second most abundant beaked whale at PMRF. Their monthly dive rates are comparable to those of goose-beaked whales although they only conduct foraging dives at night, which is clear in Figure 16. While their mean monthly GVP/hour rates are less than one per hour, their hourly rates are higher, between one and four dives per hour, with four GVPs/hour occurring frequently throughout the year.

All the Cross Seamount GVPs generated from the FY25 acoustic data were validated. In FY24, we were unable to fully validate all automatically generated GVPs, and the presence of false positives meant that daytime dives were present in last year's figure. Due to the improvements to the beaked whale detector (see Section 2.2.1.1), the false positive rate is much lower now (in fact 0% for the nine dives fully validated last year). Consequently, we were able to re-run the FY24 data and spot-checked dives that were present during daylight hours (between 6:30 and 18:00) or had unusual inter-pulse interval modes (lower than 0.05 sec or higher than 0.24 sec). Of the 46 GVPs that fit these criteria, 21 were false positives and were removed from the re-made figure (Figure 17). Thus, as suspected, the large number of daytime dives last year were indeed false positives.



- Dark blue regions indicate periods of effort when acoustic recordings were collected and zero whale tracks were present. Results include classified data collected in February and August 2025. Gray shaded regions indicate periods of no recorded data. The light gray dotted lines indicate sunrise and sunset times.

Figure 16: Fully validated cross seamount beaked whale GVPs/hour from September 2024 to August 2025 ranged from 1 (blue) to 4 (dark red).

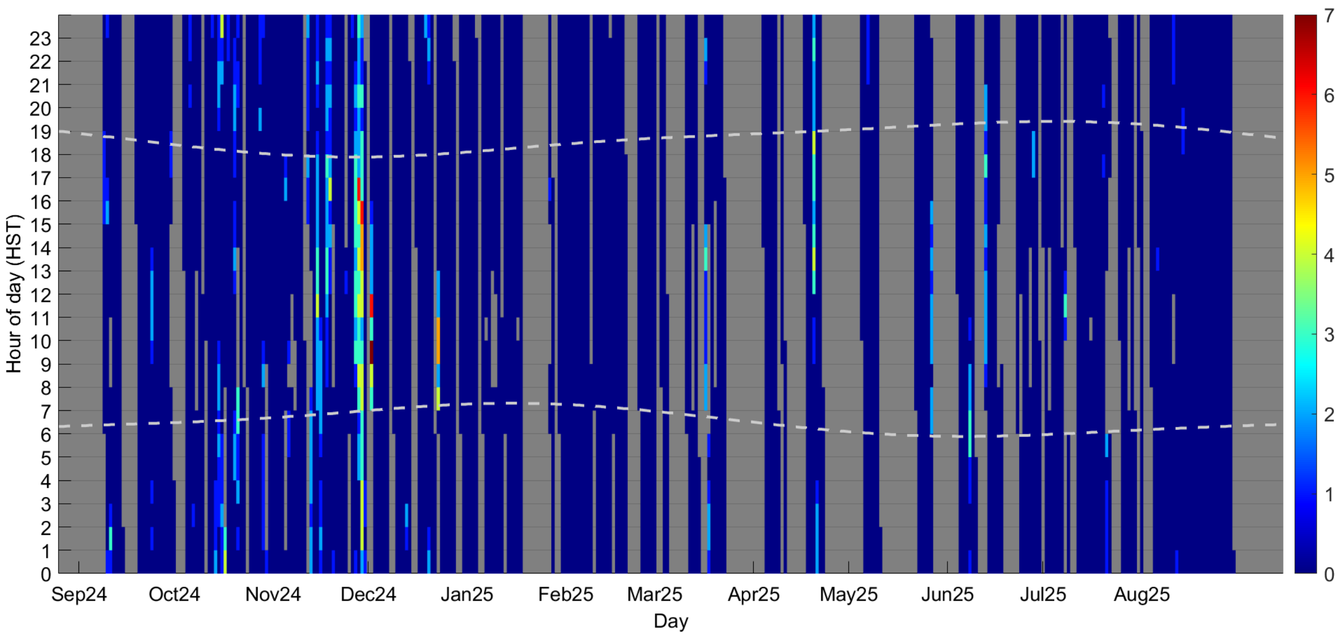


- Dark blue regions indicate periods of effort when acoustic recordings were collected and zero whale tracks were present. Results include classified data collected in February and August 2024. Gray shaded regions indicate periods of no recorded data. The light gray dotted lines indicate sunrise and sunset times.

Figure 17: Semi-validated Cross Seamount beaked whale GVPs/hour from the FY24 report (August 2023 to September 2024) ranged from 1 (blue) to 4 (dark red).

3.3.4 Tropical Bottlenose Whales

Tropical bottlenose whales are the least commonly detected species of beaked whale at PMRF, and appear to arrive periodically, with one or more groups spending hours to days on the range before moving on. Therefore, most of our dive rates over the year are zero, and when the animals are present the most frequent GVP/hour rate is one dive per hour, although GVP/hour rates can be as high as seven, which occurred several times in December (Figure 18). Similarly in November, which was our most monitored month, one or more groups stayed on the range long enough to lead to 210 GVPs or 0.33 GVPs/hour (Table 3). It is possible that conditions that month made the PMRF area appealing to beaked whales in general, as dense-beaked and goose-beaked whales also had relatively high GVP rates in November (exceeding their median monthly GVP rate), though not quite as dramatically. On the other hand, GVP rates for tropical bottlenose whales were lowest in February and August, which is when the SCCs occur, but were also very low for all of January, well before the start of the SCC. When conducting our long-term re-analysis of all the beaked whale data, it will be interesting to see if the other, regularly occurring species change their behavior or habitat use at all when this species is present. These detections were fully manually validated.



- Dark blue regions indicate periods of effort when acoustic recordings were collected and zero whale tracks were present. Results include classified data collected in February and August 2025. Gray shaded regions indicate periods of no recorded data. The light gray dotted lines indicate sunrise and sunset times.

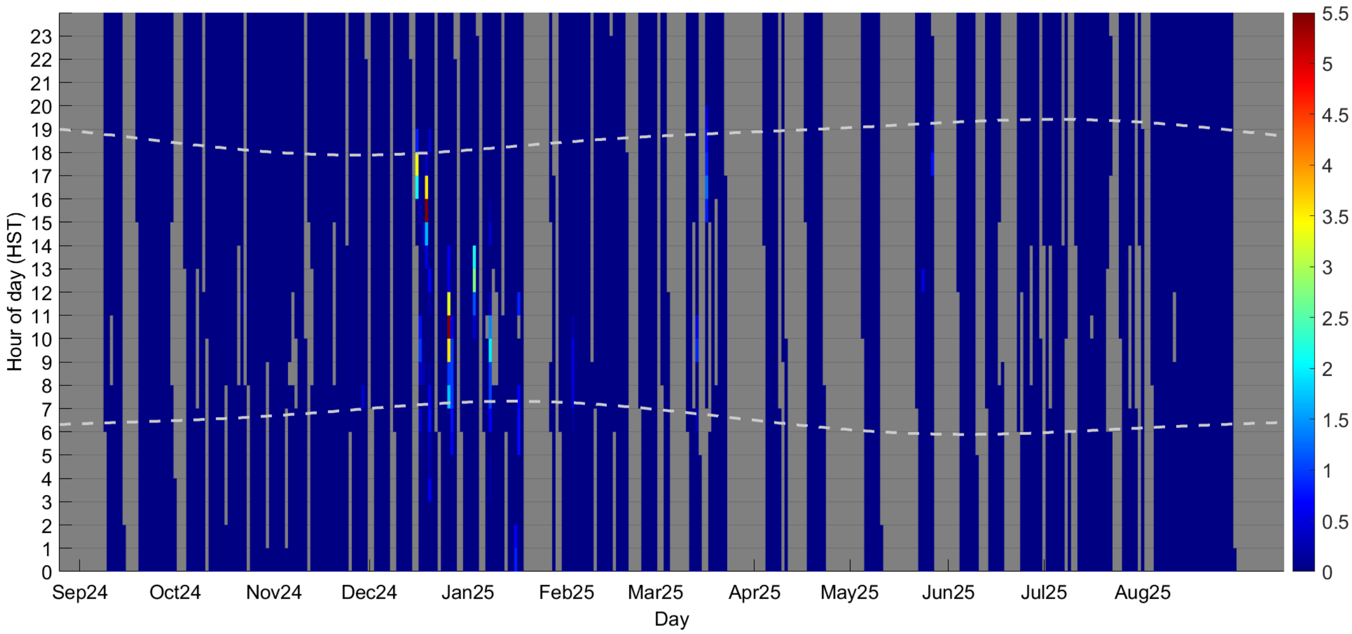
Figure 18: Fully validated tropical bottlenose whale GVPs/hour from September 2024 to August 2025 ranged from 1 (blue) to 7 (dark red).

3.3.5 Killer Whales

Killer whale detections on PMRF are currently limited to HFM signals as described in Simonis et al. (2012) and Samarra et al. (2010), and as seen on PMRF in Henderson et al. (2018). HFM signals have been informally associated with apparent quieting of other odontocete vocalizations on the range (e.g. Jarvis et al., 2019), including disrupting a previous attempt to identify the species associated with Cross Seamount beaked whale pulses (Martin et al., 2018, 2024). Between September 2024 and August 2025, there were eight total groups over seven different dates – October 11, November 29, December 3, 4, and 17, January 28, and June 5. Two "groups" of vocalizations were detected on December 17 two hours apart and likely belonged to the same group of individuals. Though this and some other years have suggested heightened presence of HFM signals during the fall and winter (Martin et al., 2018, 2025), they have been known to occur throughout the year (Martin et al., 2024) and formal seasonality has yet to be assessed due to the relatively low sample size of these signals as detected at PMRF. As is typical of these signals, they all occurred during periods of high illumination and in fact, this year, they all occurred during daylight hours (as opposed to some past occurrences during the night while the moon is mostly full and risen; Martin et al. 2025).

3.3.6 Sperm Whales

The mean number of automatically tracked, individual calling sperm whales in 2.5-minute snapshot periods from all recordings made between September 2024 and August 2025 is presented per hour in Figure 19 and per month in Table 4. During the current reporting period, sperm whales were present from October 2024 to late May 2025 which happens to align with the season typically exhibited by baleen whales, though sperm whales are not expected to adhere to any particular seasonality in this area. Monthly mean presence was highest in December 2024 (0.08 whales/snapshot). Mean hourly presence was typically ≤1 whale/snapshot, while the highest hourly mean presence of 5.5 whales/snapshot occurred once in December. For comparison, in the FY24 report (Martin et al., 2025) sperm whales were tracked from late October 2023 to June 2024, and a peak hourly mean of 3 whales/snapshot occurred once in December 2023.



- Dark blue regions indicate periods of effort when acoustic recordings were collected and zero whale tracks were present. Results include classified data collected in February and August 2025. Gray shaded regions indicate periods of no recorded data. The light gray dotted lines indicate sunrise and sunset times.

Figure 19: The mean number of sperm whale tracks detected in 2.5-minute snapshot periods for each hour of the day from September 2024 to August 2025 ranged from 0.04 (blue) to 5.5 (dark red).

Table 4: Monthly number of sperm whales detected in 2.5-minute snapshots divided by the total number of available snapshots per month.

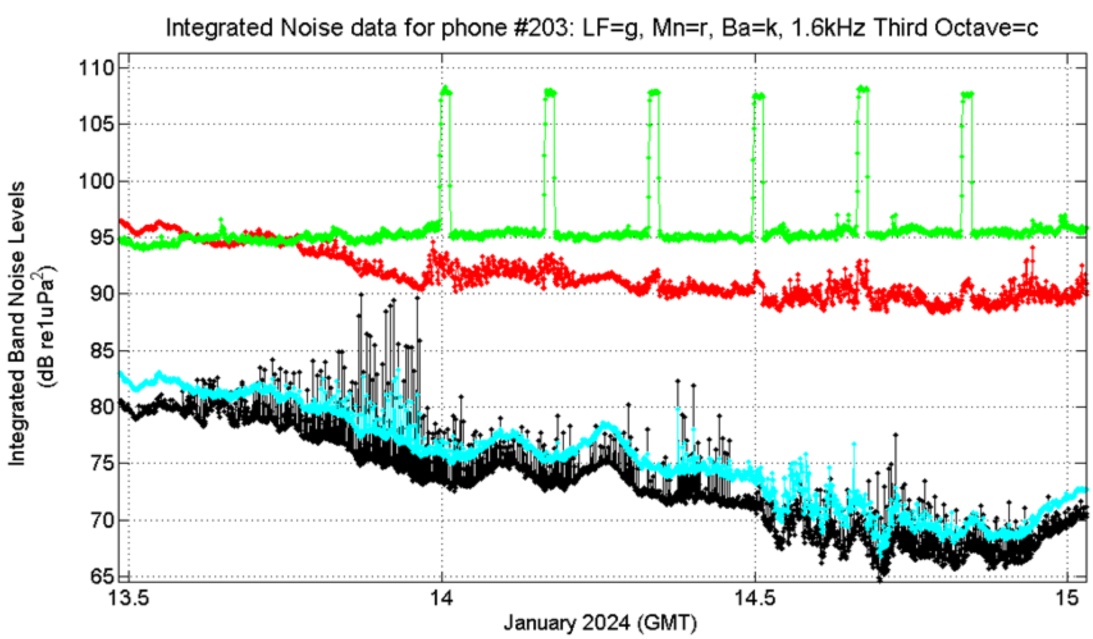
Month	# of Snapshots	Mean # of Tracks Per Snapshot and (Standard Deviation)
Sep-24	9,366	0 (0)
Oct-24	14,005	0.0003 (0.02)
Nov-24	15,395	0.0006 (0.03)
Dec-24	13,945	0.08 (0.52)
Jan-25	10,410	0.04 (0.26)
Feb-25	13,288	0.003 (0.06)
Mar-25	7,311	0.02 (0.19)
Apr-25	6,507	0 (0)
May-25	6,506	0.006 (0.08)
Jun-25	9,740	0 (0)
Jul-25	12,353	0 (0)
Aug-25	15,313	0 (0)

3.4 NOISE ANALYSIS

One of the WARP lab's standard internal products is an analysis of recorded data noise levels up to 3 kHz from a single hydrophone located near the center of the PMRF underwater range (hydrophone # 203/K-5). Four frequency bands are included to provide insight into the noise levels integrated over bands of interest. Prior noise analyses have shown high levels during environmental wind/wave activities which affect DCL and tracking of low frequency whales first reported in the FY18 report (Martin et al., 2020) with subsequent noise related effects to NARWHAL processing (Martin et al., 2021 and Martin et al., 2022). More recently, increased noise levels were observed at frequencies near the minke whale detector band and were determined to be from chorusing fishes when rising in the evening from deep to shallower waters (Martin et al., 2024).

This FY, we are highlighting PMRF range hydrophone detections of a low frequency (75 Hz center frequency) acoustic source located north of Kauaʻi, Hawaiʻi designed for ocean basin scale studies called the Kauaʻi-Beacon (Munk 2006). This source was active 1997-1999 and 2002-2006 (Dushaw et al. 2009), typically transmitting six times a day on a 4-day interval schedule as a part of the Acoustic Thermometry of the Ocean Climate program (Worcester and Spindel 2005). The Beacon is located north of Hanalei Bay, Kauaʻi, Hawaiʻi at 22.35º N latitude and 159.57º W longitude and is mounted in a heavy steel tripod about 2 m from the seafloor at 811 m depth which is near the depth of the deep sea sound channel. The Kauaʻi-Beacon was refurbished and re-activated in November 2022 (Gemba et al. 2023) and continues operations on a schedule similar to the earlier transmissions of 4-day intervals 6 times a day at the top of the universal coordinated time (UTC) hour (i.e. 0000, 0400, 0800, 1200, 1600 and 2000). Details of the recent transmissions are provided at https://marasondo.org.

The 75 Hz coded signals (bandwidth 56-94 Hz) are approximately 25 min in duration with a source level up to 185 to 190 dB re 1 µPa. The Kauaʻi-Beacon is located approximately 42 km at a bearing angle of 100° True from the hydrophone utilized for standard 3 kHz noise analysis. Figure 20 illustrates results of the NARWHAL 3 kHz noise analysis of 4 bands of interest for one sample day on January 14, 2024; the noise results are similar to those for all other days of the Kauaʻi-Beacon transmissions. The red curve shows only a dB or two increased noise levels in the humpback whale call detector band (150 to 1000 Hz) during the Kauaʻi-Beacon transmissions and no observable impacts to calls in both the minke whale ‘boing’ detector band (black curve 1320 to 1450 Hz) and the 1.6 kHz 3rd octave band (cyan curve 1413 to 1778 Hz) for detection of chorusing fish. The Kauaʻi-Beacon signals are observed as an over 10 dB increase in the low-frequency band noise levels on PMRF hydrophones as shown in the green curve (for low frequencies up to 100 Hz). These transmissions can potentially mask biologic signals which are automatically detected, classified, localized, and tracked with the NARWHAL suite of algorithms primarily for calls under 100 Hz. Spikes observed in the curves shown in Figure 20 are typically from calling whales that are near the focal hydrophone and most evident in the minke whale boing detector band but also evident to a lesser extent in the other bands.



Green line represents the 10-100 Hz LF band, Red line represents the 150 – 1000 Hz band, Cyan line represents the 1413 to 1778 Hz band, and black line represents the 1320 to 1450 Hz. Humpback whale song is detected in the red band, minke boing calls are detected in the black bad, and fish chorusing is detected in the cyan band.

Figure 20: A sample of the NARWHAL standard 3 kHz noise analysis for hydrophone # 203/K-5 from noon January 13 to January 15, 2024 showing a sequence of six Kauaʻi-Beacon transmissions on January 14, 2024 in the low-frequency band (green curve, 10-100 Hz).

4. BEHAVIORAL RESPONSE ANALYSES

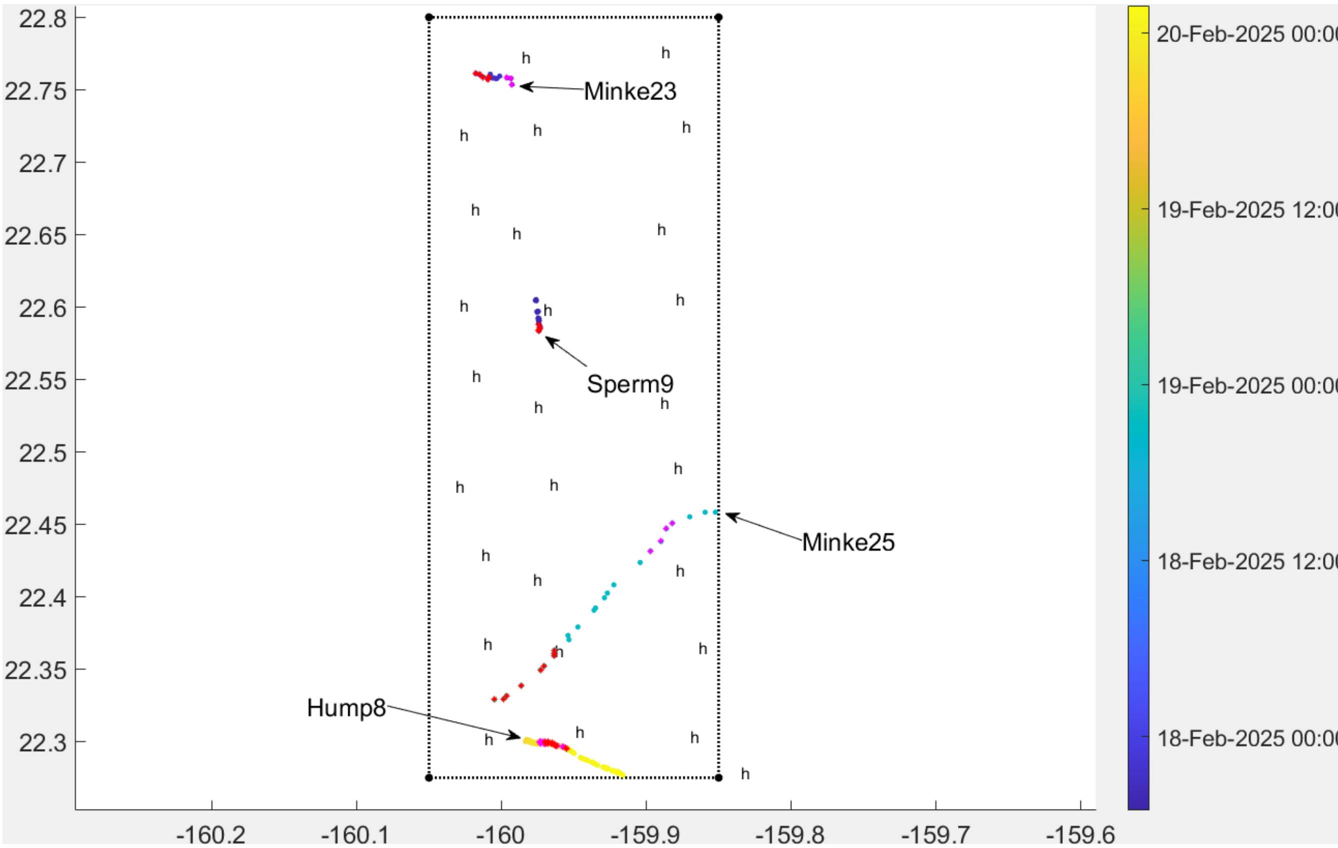
4.1 TRACKED WHALES

We were able to acoustically track four whales exposed to MFAS during the February 2025 SCC. One sperm whale was exposed to surface ship sonar transmissions only, two minke whales were exposed to surface ship and sonobuoy transmissions, and one humpback whale was exposed to surface ship and sonobuoy sonar transmissions (Table 5). Estimated exposures use propagation modeling methods and standardized metrics as reported in Henderson et al. (2025). Table 5 shows the highest median received level during a whale track, and two times the standard deviation (2*SD) in parentheses to provide a range of possible exposure values, with levels in units dB re 1 μPa. Levels were estimated using propagation modeling with nominal source levels and depths and an omnidirectional beam pattern. Animals were assumed to be located near the surface where they were likely to receive the highest levels. Reporting the median received level accounts for whale location uncertainty by summarizing received levels within approximately +/-100 m of an animal's localized position, and from 1 to 54 m of depth. The distances in Table 5 are the closest points of approach (CPA) for each source type that overlaps with a whale track and do not necessarily correspond to the distance for the given estimated levels. Movement of these exposed whale tracks are shown in Figure 21 with track color indicating time and asterisks indicating when a track was exposed to surface ship hull-mounted sonar (red asterisks) or sonobuoy sonar (magenta asterisks).

Table 5: Tracked whale exposures during the February 2025 SCC.

- Exposure levels and standard deviations are in parentheses along with closest distance of the source.

Track	Start (HST)	End (HST)	Ship (dB re 1 μPa)	Sonobuoy (dB re 1 μPa)
Sperm9	2/17 08:57	2/17 09:40	144 (0.4) 16.2 km	–
Minke23	2/17 11:02	2/17 11:50	149 (0.7) 25.0 km	92 (1.3) 23.1 km
Minke25	2/18 10:12	2/18 12:32	122 (1.1) 42.4 km	98 (1.1) 22.8
Hump8	2/19 12:46	2/19 14:35	152 (1.6) 35.0 km	99 (0.8) 23.9 km



Tracks are color-coded by time as shown in the color bar; however, exposures are overlaid on the track, with exposures from surface ships in red and from sonobuoys in magenta.

Figure 21: Overview of exposures during the February 2025 SCC.

Figure 22 to Figure 25 depict the exposure history for sperm whale track 9, minke whale tracks 23 and 25, and humpback whale track 8 and include the highest median received level in a 5-minute bin by source type. Error bars are ± two times the standard deviation for the ping that produced the highest median received level in each 5-minute bin. The exposure history figures also include two 5-minute bins before the start and after the end of a whale track. Since the number of pings cannot be publicly stated, the symbols in Figure 22 to Figure 25 are color coded to indicate the level of sonar activity in a 5-minute bin by green (low), yellow (medium), and red (high). Symbols and line colors indicate source types with diamonds with blue lines for surface ship hull-mounted MFAS, and circles with black lines for sonobuoy sonar.

Sperm whale track 9 started on February 17 at 8:57 and was located at 22.58° latitude and -159.97° longitude (Figure 21). The whale was immediately exposed to surface ship transmissions which began shortly before the start of the track. From 8:54 to 9:04 the whale was exposed to surface ship MFAS and had the highest median received level of 144 dB re 1 µPa (SD = 0.4) at 9:04, and a CPA of 16.2 km at 8:54 (Table 5 and Figure 22). After exposures stopped at 9:04, the whale continued to travel north then ceased calling at 9:40. While the whale was tracked, there was not an apparent change in movement due to MFAS exposures.

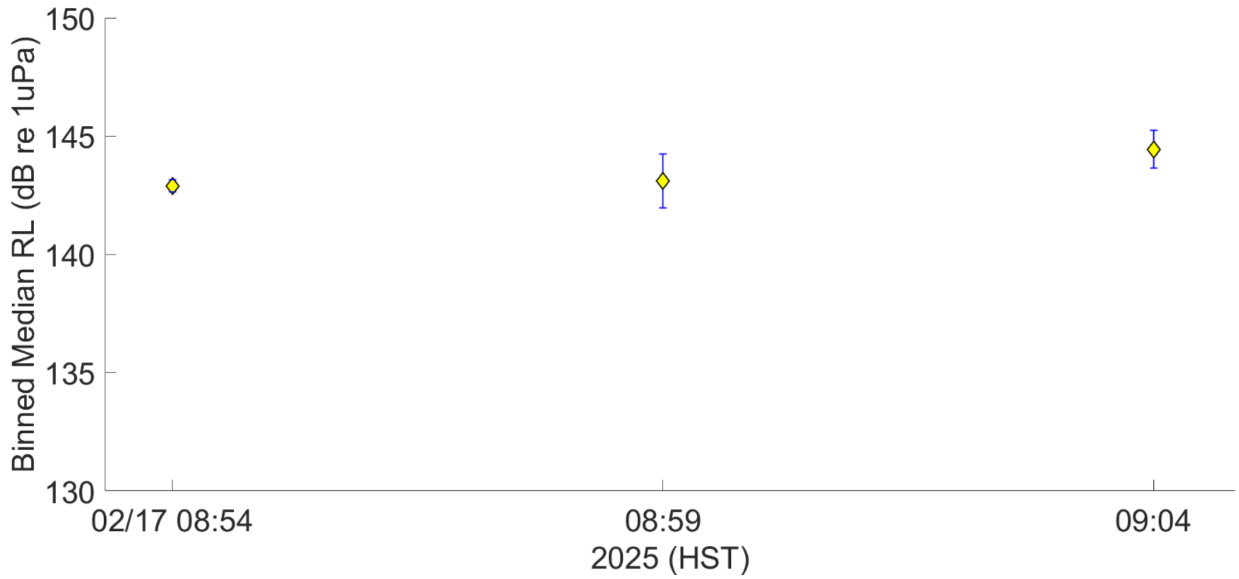


Figure 22: Sperm whale track 9 exposure history for surface ship hull-mounted sonar.

Minke whale track 23 started on February 17 at 11:02 and at 22.75° latitude and -159.99° longitude (Figure 21). Sonobuoy transmissions had begun shortly before the start of the track at 10:55 and so the onset of the acoustic track began with exposures. Sonobuoy exposures lasted until 11:10 and resulted in the highest median received level of 92 dB re 1 µPa (SD = 1.3) at 11:05 and a CPA of 23.1 km at 10:55 (Table 5 and Figure 23). There was a brief break in exposures from 11:15 to 11:25, which was followed by surface ship exposures from 11:30 to 11:50. During surface ship exposures, the whale continued calling until it received the highest median received level of 149 dB re 1 µPa (SD = 0.7) at the end of the exposure history (11:50), which coincided with a CPA of 25 km (Table 5 and Figure 23). While the whale was tracked, it was on a west/northwest heading and did not have an apparent change in movement or calling behavior in response to MFAS exposures.

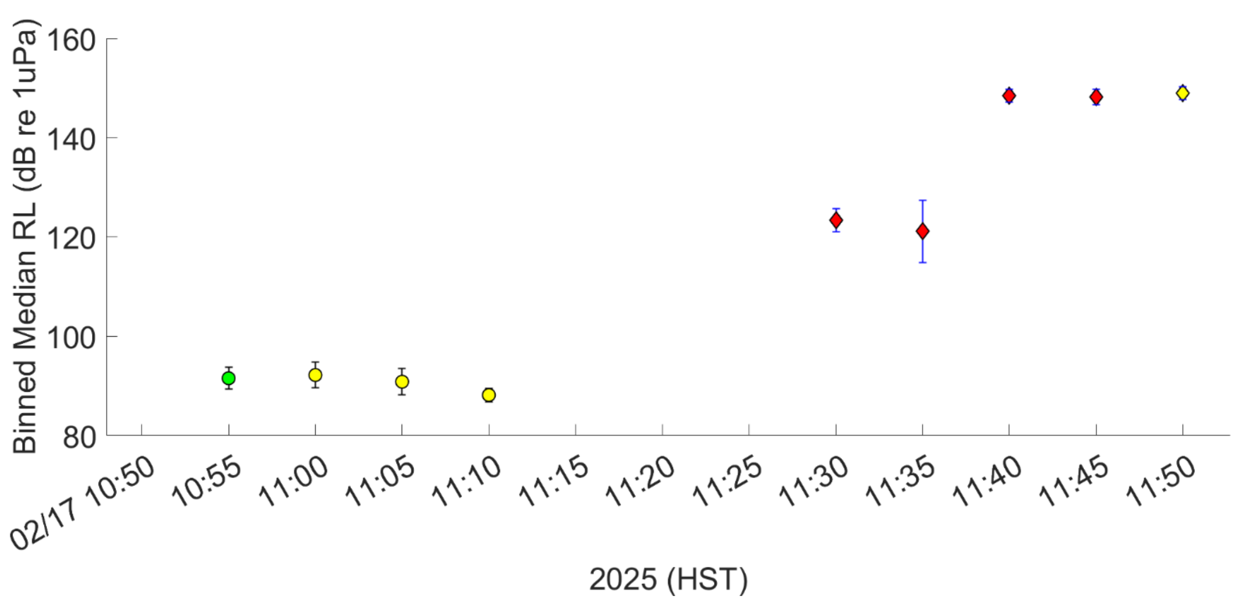


Figure 23: Minke whale track 23 exposure history for surface ship hull-mounted sonar and sonobuoy sonar.

Minke whale track 25 started on February 18 at 9:53 and at 22.46° latitude and -159.85° longitude (Figure 21). The whale was traveling west/southwest before being exposed to sonobuoy transmissions, and continued to travel southwest while exposed to sonobuoy transmissions from 10:11 to 10:31. The highest median received level from sonobuoy exposures was 98 dB re 1 µPa (SD = 1.1) at 10:16, and the CPA was 22.8 km at 10:21 (Table 5 and Figure 24). The whale continued on a southwest heading when no exposures occurred from 10:36 to 11:31. From 11:36 to 12:31 the whale was exposed to surface ship transmissions with a highest median received level of 122 dB re 1 µPa (SD = 1.1), which occurred in the middle of the surface ship exposure history at 12:01, coinciding with the CPA of 42.4 km (Table 5 and Figure 24). Even when exposed to surface ship transmissions, the whale maintained a southwest heading, and throughout the track there was no apparent change in movement or calling behavior in response to MFAS exposures.

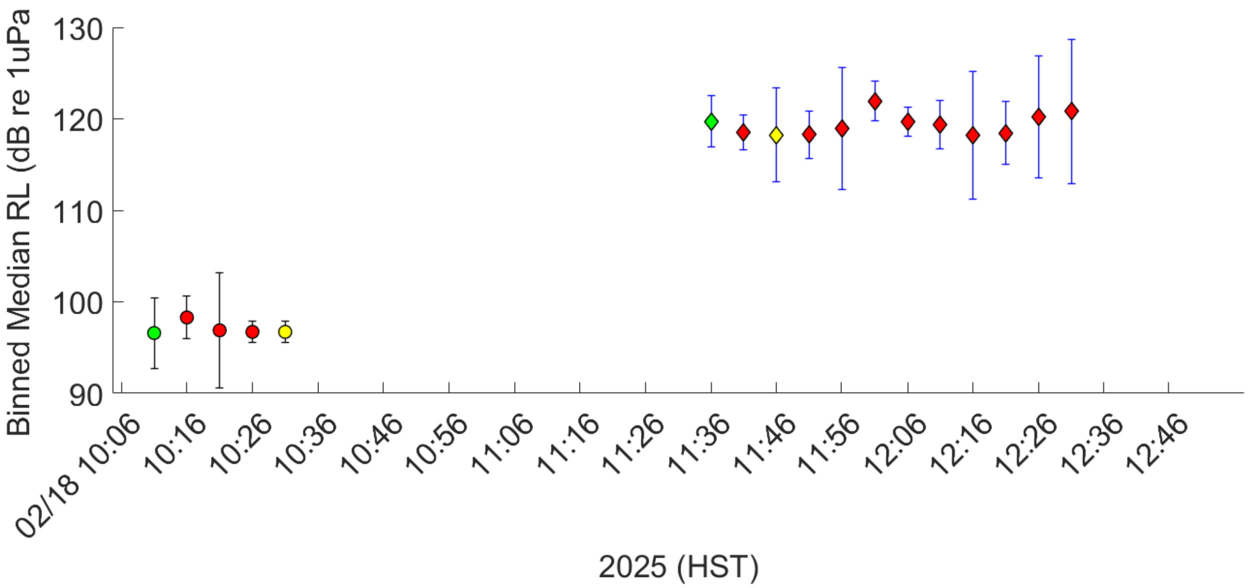


Figure 24: Minke whale track 25 exposure history for surface ship hull-mounted sonar and sonobuoy sonar.

Humpback whale track 8 started on February 18 at 10:35 22.30° latitude and -159.98° longitude (Figure 21). Exposures to sonobuoys began at 12:43, then concurrent exposures to sonobuoys and surface ship sonar lasted from 13:28 until 14:33. The highest median exposure from sonobuoys was 99 dB re 1 µPa (SD = 0.8) near the end of the exposure history (14:28) while the closest point of approach to sonobuoys was 23.9 km and occurred near the start of exposures at 13:03 (Table 5 and Figure 25). During surface ship exposures the distance from the whale to surface ship MFAS closed from 41.8 km to 35.0 km, opened to 41.8 km, then closed to 41.1 km. The highest median received level to surface ship MFAS was 152 dB re 1 µPa (SD = 1.6) near the start of the surface ship exposure history (13:33) while the closest point of approach to ships was 35.0 km and occurred in the middle of the surface ship exposure history at 13:53 (Table 5 and Figure 25). For the duration of the whale track it was on a southeast heading. While there was minor variance in the whale's heading, the level of variance was not appreciably different before, during, or after exposures, and there was no apparent change in movement due to MFAS exposures.

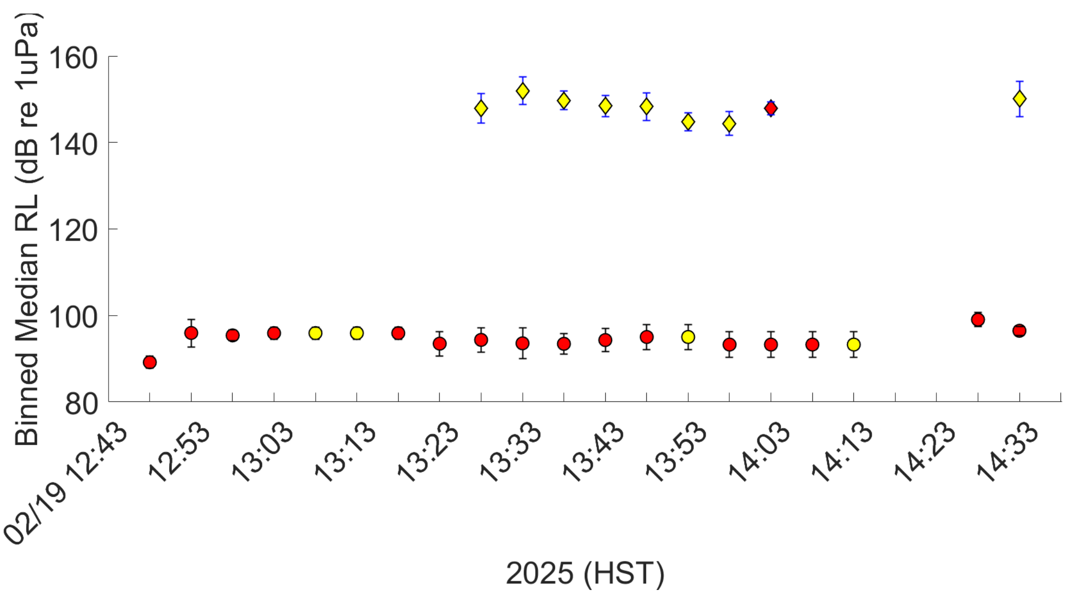


Figure 25: Humpback whale track 8 exposure history for surface ship hull-mounted sonar and sonobuoy sonar.

4.2 BEAKED WHALES

In FY25, data were recorded before, during, and after the February and August SCCs. Data were manually validated for one dataset from each SCC for dense-beaked whales and the true positive rate was applied to the remaining During data as described in Section 3.3.1. For goose-beaked whales, Cross Seamount beaked whales, and tropical bottlenose whales, all data in the time periods reported below were fully validated due to both species' relatively sparse occurrence.

4.2.1 Dense-Beaked Whales SCC

Dense-beaked whale GVP detections were similar in FY25 as in previous years; GVP/hour rates started at levels comparable to or higher than the highest monthly average rate in the Before period for each SCC, then decreased by 1/3 to 1/2 that rate in Phase A (Table 6). The GVPs remained at that reduced rate during the Interphase in both SCCs, then dropped again by about 1/2 during Phase B. As is typical, the GVP/hour rate rose again immediately after both SCCs in the After period to similar rates or higher than those during Phase A and the Interphase, and returned to pre-SCC rates shortly thereafter, as evidenced by the 2.9 GVP/hour rate in March (no data yet for September to compare).

Beaked whale "chorusing" has been noted previously at this range and at other ranges (D. Moretti, pers. comm.), where multiple groups of dense-beaked whales appear to dive and echolocate simultaneously on the range. The reason for this behavior is unknown; perhaps it functions as a communication mechanism between widely spaced groups, but it is especially evident during the SCC training events. Dense-beaked whales appear to cluster their dives between periods of training activity during these events, particularly activities that include acoustic components. Therefore, while overall GVP/hour rates are reduced, there are periods of increased GVPs/hour within the training activity. In future long-term analyses, this chorusing behavior could be quantified during both baseline and training periods and the degree of the chorusing activity (i.e. number of simultaneous groups and duration of overlapped diving activity) could be compared.

Table 6: Dense-beaked whale GVPs before, during, and after the February and August SCCs.

Period	Start Date (HST)	End Date (HST)	Duration (hours)	GVP Count	GVPs/ Hour
February 2025 SCC					
Before	2/4/2025 1:42	2/11/2025 7:14	149.6	456	3.0
Phase A	2/11/2025 7:14	2/14/2025 16:48	81.6	128	1.6
Interphase	2/14/2025 16:48	2/17/2025 7:45	55.0	81	1.5
Phase B	2/17/2025 7:45	2/19/2025 14:31	54.8	41	0.7
After	2/19/2025 14:31	3/2/2025 9:29	172.8	377	2.2
August 2025 SCC					
Before	8/4/2025 18:44	8/12/2025 6:07	175.8	578	3.3
Phase A	8/12/2025 6:07	8/15/2025 18:13	84.0	168	2.0
Interphase	8/15/2025 18:13	8/18/2025 16:18	70.1	137	2.0
Phase B	8/18/2025 16:18	8/20/2025 13:59	45.7	54	1.2
After	8/20/2025 13:59	8/29/2025 0:39	201.2	412	2.0

4.2.2 Goose-Beaked Whales SCC

Although an order of magnitude lower, the GVP/hour rates for goose-beaked whales during the two SCCs at PMRF followed a similar trend to that of the dense-beaked whales, with typical GVP/hour rates in the Before periods and then reduced rates during the events (Table 7). However, it is interesting to note that the starting GVP/hour rate for the February SCC was at the low end (0.07 GVP/hour) for the year, while the starting GVP/hour rate for the August SCC was at the high end (0.22 GVP/hour). Perhaps due to that low starting rate, the GVP/hour rate dropped to 0 in Phase A and remained at 0 throughout the SCC, then increased to 0.10 GVP/hour After the SCC. In contrast, during the August SCC, the GVP/hour rate dropped during Phase A, remained at a similar level during the Interphase, then again dropped to 0 during Phase B, and increasing to about half of the Before GVP/hour rate After the SCC. Goose-beaked whale GVP/hour rates also dropped to 0 in both SCCs in FY24, and in both of the August SCCs in FY22 and FY23, but not in February (Martin et al. 2023, 2024, 2025).

Table 7: Goose-beaked whale GVPs before, during, and after the February and August SCCs.

Period	Start Date (HST)	End Date (HST)	Duration (hours)	GVP Count	GVPs/ Hour
February 2025 SCC					
Before	2/4/2025 1:42	2/11/2025 7:14	149.6	10	0.07
Phase A	2/11/2025 7:14	2/14/2025 16:48	81.6	0	0
Interphase	2/14/2025 16:48	2/17/2025 7:45	55.0	0	0
Phase B	2/17/2025 7:45	2/19/2025 14:31	54.8	0	0
After	2/19/2025 14:31	3/2/2025 9:29	172.8	18	0.10
August 2025 SCC					
Before	8/4/2025 18:44	8/12/2025 6:07	175.8	38	0.22
Phase A	8/12/2025 6:07	8/15/2025 18:13	84.0	12	0.14
Interphase	8/15/2025 18:13	8/18/2025 16:18	70.1	12	0.17
Phase B	8/18/2025 16:18	8/20/2025 13:59	45.7	0	0
After	8/20/2025 13:59	8/29/2025 0:39	201.2	18	0.09

4.2.3 Cross Seamount Beaked Whales SCC

Cross Seamount beaked whales often demonstrate an inverse pattern in their GVP behavior during SCCs compared to the other beaked whale species, and this year is no exception. In February, GVP/hour rates did not decrease at all during Phase A, were at their lowest during the Interphase, started increasing again during Phase B, and returned to the same rate as Before in the After period (Table 8).

In August, their GVP/hour rate did decrease by half during Phase A, then increased back to the Before rate during Interphase, increased further during Phase B, and then doubled during the After period. Although the training activity does occur equally day and night during the SCCs, perhaps by diving only at night, diving further inshore, and diving to shallower depths (100-200 m, McCullough et al. 2023), they are receiving lower levels of MFAS than the other beaked whale species, and so the Cross Seamount beaked whales' feeding behavior is less perturbed by the training activity.

Table 8: Cross Seamount beaked whale GVPs before, during, and after the February and August SCCs.

Period	Start Date (HST)	End Date (HST)	Duration (hours)	GVP Count	GVPs/ Hour
February 2025 SCC					
Before	2/4/2025 1:42	2/11/2025 7:14	149.6	26	0.17
Phase A	2/11/2025 7:14	2/14/2025 16:48	81.6	14	0.17
Interphase	2/14/2025 16:48	2/17/2025 7:45	55.0	2	0.04
Phase B	2/17/2025 7:45	2/19/2025 14:31	54.8	5	0.09
After	2/19/2025 14:31	3/2/2025 9:29	172.8	29	0.17
August 2025 SCC					
Before	8/4/2025 18:44	8/12/2025 6:07	175.8	20	0.11
Phase A	8/12/2025 6:07	8/15/2025 18:13	84.0	4	0.05
Interphase	8/15/2025 18:13	8/18/2025 16:18	70.1	8	0.11
Phase B	8/18/2025 16:18	8/20/2025 13:59	45.7	7	0.15
After	8/20/2025 13:59	8/29/2025 0:39	201.2	59	0.29

4.2.4 Tropical Bottlenose Whales SCC

This is the second year we are presenting SCC data for tropical bottlenose whales, and similar to last year they were not present for much of either SCC. In fact, they were not present at all during the February SCC (Table 9), and were only present during the Before and Phase A periods of the August SCC, and at very low rates, although the GVP/hour rate did increase slightly for Phase A from Before.

These low GVP/hour rates are not a surprise for this species. As discussed in Section 3.3.4, they are rarely present at PMRF and appear to come in pulses and remain for short periods of time. Given this pattern of behavior, it is likely that the GVPs that are detected are from the same group or groups of animals that are remaining on the range, rather than from different groups of animals passing through the range. However, without tag data there is no way to know this for certain. It is also difficult to assess any change in GVP rates as a possible response to training activity versus simply leaving the area.

Table 9: Tropical bottlenose whale GVPs before, during, and after the February and August SCCs.

Period	Start Date (HST)	End Date (HST)	Duration (hours)	GVP Count	GVPs/ Hour
February 2025 SCC					
Before	2/4/2025 1:42	2/11/2025 7:14	149.6	0	0
Phase A	2/11/2025 7:14	2/14/2025 16:48	81.6	0	0
Interphase	2/14/2025 16:48	2/17/2025 7:45	55.0	0	0
Phase B	2/17/2025 7:45	2/19/2025 14:31	54.8	0	0
After	2/19/2025 14:31	3/2/2025 9:29	172.8	0	0
August 2025 SCC					
Before	8/4/2025 18:44	8/12/2025 6:07	175.8	1	0.01
Phase A	8/12/2025 6:07	8/15/2025 18:13	84.0	4	0.05
Interphase	8/15/2025 18:13	8/18/2025 16:18	70.1	0	0
Phase B	8/18/2025 16:18	8/20/2025 13:59	45.7	0	0
After	8/20/2025 13:59	8/29/2025 0:39	201.2	0	0

4.3 RIMPAC ANALYSIS

4.3.1 ASWEX Exercises

While three ASWEX exercises were conducted at PMRF during the 2024 RIMPAC, only one of them had MFAS. On July 13, 2024, active sonobuoys were detected for a two-hour period from 10:12-12:13 (HST). No baleen whales nor sperm whales were present this time of year, so only beaked whale dives were examined for two-hour periods before (8:10 – 10:11 HST), during (10:12 – 12:13 HST), and after (12:14 – 14:14 HST) this bout of MFAS. These counts represent GVPs that started within these periods; the GVPs may have carried over into the next period. As demonstrated in Table 10, dense-beaked whale GVPs were fairly consistent across the entire 6 hours, with most GVP starts occurring during the ASWEX period. There was only one goose-beaked whale GVP start that occurred after the ASWEX, and no Cross Seamount or tropical bottlenose whale GVPs occurred at all; not a surprise since this was during the day and in a month of very low tropical bottlenose whale presence. Previous analyses have indicated that dense-beaked whales do not seem to be responsive to active sonobuoys (Henderson et al. 2025). This is likely due to a combination of their lower source levels and being deployed typically in the central or northern region of Barking Sands Underwater Range Expansion (BSURE), where the dense-beaked whales occur at a very low rate.

Table 10: Beaked whale GVP counts before, during, and after July 13, 2024 ASWEX. BWC refers to the Cross Seamount beaked whale signal.

Period	Md GVP Count	Zc GVP Count	BWC GVP Count	Ip GVP Count
Before	6	0	0	0
During	8	0	0	0
After	5	1	0	0

4.3.2 SINKEX Exercises

In 2024, two SINKEX exercises were conducted north of the PMRF range as part of the larger RIMPAC training event conducted in the Hawaiian Islands. The first took place July 11, and the second took place over July 18 and 19. The WARP lab was tasked with assessing how far the sounds from the various events of each SINKEX propagated, what species of marine mammals were present during the events, and if any behavioral responses could also be detected.

4.3.2.1 SINKEX July 18-19

This exercise began at 8:19 HST on July 18 and ended at 10:35 HST on July 19. The "hulk", or ship to be sunk, was located 32 km from the northern edge of the instrumented range. Five hydrophones were examined, at ranges of 32 to 65.4 km from the hulk, and at varying angles from due south to approximately 30° west. Ten events were conducted over the two days, with nine events on July 18 and the final, sinking event taking place on the morning of July 19. Table 11 provides information on what hydrophones detected each event from the subset analyzed, as baseline information on the propagation distance of each event. Interestingly, sound from some events traveled a farther distance when transmitting directly south (e.g. hydrophone 216, 55.5 km) rather than at an angle away from the source (e.g., hydrophone 186), possibly due to constructive and destructive interference along the propagation pathway. Detections occurred on the order of 1.6 sec to 5.6 min after each hit during an event, highlighting the long propagation times for these impulsive sounds. To keep this report unclassified, no details on each event and no further descriptions of the impulsive sounds are included herein.

Table 11: Times of each SINKEX event from July 18 to 19 and whether they were detected on each of the hydrophones manually investigated, with an X indicating detection. Hydrophones 183 and 204 were the most distant and were only examined for the final event. The distances indicate the distance of each hydrophone to the hulk that was sunk.

Date	Event	Phone 209 32.0 km	Phone 186 45.5 km	Phone 207 46.6 km	Phone 216 55.5 km	Phone 183 65.4 km	Phone 204 63.7 km
7/18/24 18:19	Start event 1						
7/18/24 19:34	Hit	X					
7/18/24 19:40	End event 1						
7/18/24 20:25	Start event 2						
7/18/24 21:43	Hit	X	X	X	X		
7/18/24 21:45	End event 2						

Date	Event	Phone 209 32.0 km	Phone 186 45.5 km	Phone 207 46.6 km	Phone 216 55.5 km	Phone 183 65.4 km	Phone 204 63.7 km
7/18/24 22:00	Start event 3						
7/18/24 22:31	Hit	X		X	X		
7/18/24 22:35	End event 3						
7/18/24 22:52	Start event 4						
7/18/24 23:17	Hit	X	X	X			
7/18/24 23:22	End event 4						
7/18/24 23:24	Start event 5						
7/19/24 0:33	Hit	X	X	X	X		
7/19/24 0:36	End event 5						
7/19/24 0:39	Start event 6						
7/19/24 1:01	Hit	X	X	X	X		
7/19/24 1:17	End event 6						
7/19/24 1:19	Start event 7						
7/19/24 1:39	Hit	X	X	X	X		
7/19/24 2:07	Hit	X	X	X	X		
7/19/24 2:19	Hit	X	X	X	X		
7/19/24 2:30	Hit	X	X	X	X		
7/19/24 2:42	Hit	X	X	X	X		
7/19/24 2:44	End event 7						
7/19/24 2:45	Start event 8						
7/19/24 3:17	Hit	X	X	X	X		
7/19/24 3:28	End event 8						
7/19/24 3:32	Start event 9						
7/19/24 3:45	Hit	X					
7/19/24 4:06	Hit						
7/19/24 4:06	Hit						
7/19/24 4:06	Hit						
7/19/24 4:07	Hit						
7/19/24 4:10	Hit						
7/19/24 4:10	Hit						
7/19/24 4:11	Hit						
7/19/24 4:11	Hit						
7/19/24 4:21	Hit						
7/19/24 4:21	Hit						
7/19/24 4:21	Hit						
7/19/24 5:06	Hit				X		
7/19/24 5:06	Hit						
7/19/24 5:06	Hit						
7/19/24 5:07	Hit						
7/19/24 5:10	Hit				X		
7/19/24 5:10	Hit						

Date	Event	Phone 209 32.0 km	Phone 186 45.5 km	Phone 207 46.6 km	Phone 216 55.5 km	Phone 183 65.4 km	Phone 204 63.7 km
7/19/24 5:10	Hit						
7/19/24 5:10	Hit				X		
7/19/24 5:25	Hit						
7/19/24 5:26	Hit						
7/19/24 5:26	Hit						
7/19/24 5:29	Hit						
7/19/24 5:29	Hit						
7/19/24 5:29	Hit						
7/19/24 5:29	Hit						
7/19/24 5:33	Hit				X		
7/19/24 5:33	Hit						
7/19/24 5:40	Hit	X		X			
7/19/24 6:51	End event 9						
7/19/24 17:00	Start event 10						
7/19/24 20:03	Hit	X	X	X	X	X	X
7/19/24 20:33	Sink	X	X	X	X	X	X
7/19/24 20:35	End event 10						

Sperm whale echolocation clicks and dolphin whistles, clicks, and some burst pulses were also detected on the hydrophones throughout the exercise. Sperm whales were detected periodically on the northernmost hydrophones, starting around 9:37 on hydrophone 209 and 9:42 on hydrophone 186, but not until 14:58 on hydrophone 207. The animals were likely off-range given that only individual and periodic click trains (codas) were detected. However, they persisted throughout the day until 17:30 on hydrophone 186 and did not appear to leave the area in response to the impulsive sounds from the SINKEX activity. In fact, in several cases the sperm whale codas were detected just after an impulsive event was detected, indicating that perhaps the sperm whales were vocally responding to the impulsive sounds.

One or more groups of dolphins seem to have crossed the range during the event, as there were whistles detected on all the hydrophones throughout both days of the SINKEX. The whistles were loudest first on hydrophone 216, where the whistles were detected as multiple overlapping whistles in the 5-10 kHz band, indicating the detection of a larger and/or closer group of dolphins. These were initially faint but got louder around 13:00; then around 14:00, clicks were visible as well, indicating the animals were likely within a few kilometers. At 14:57 there were also burst pulses detected, which are often used in communication and are typically not detected unless the group is within about a kilometer of the hydrophone. This seemed to be the closest point of approach for this group, as by 15:37 there were few clicks detected, and shortly afterwards the whistles became less overlapping and more individual, which is an indication that the group is moving away from the hydrophone. Dolphin clicks and whistles were also detected on hydrophone 186 at 16:45; this could be the same group that had now traveled across the range to this hydrophone, or could be a different group, as faint whistles had been detected since around 12:00 on this hydrophone. Clicks and whistles lasted on this hydrophone at least through 20:49, which could indicate that the group stopped traveling and spent a longer time in that area, possibly foraging. In addition, burst pulses were also detected on hydrophone 186 at 19:25.

Interestingly, there appeared to be some vocal responses by the dolphins to the impulsive sounds as well. In some instances, the vocal activity decreased directly after an impulsive event, and then increased in amplitude and vocal rate again, and in other cases whistle activity would briefly increase in rate and amplitude after an impulsive event. These behaviors are similar to what was described for common dolphins (*Delphinus* spp.) by Casey et al. (2024) after controlled exposures to MFAS, although rather than occurring on scales of 5-30 sec as in that study, the responses noted here occurred on the scales of seconds to minutes.

Another vocalization pattern that was noted was a series of repeated stereotyped whistles. These occurred in conjunction with impulsive events; for example, on hydrophone 209 during event 7, a series of flat 5 kHz whistles was noted. However, repeated whistles patterns were noted at other times as well; for example, on hydrophone 209 during event 9, when no impulsive detections were noted, there was a series of V-shaped whistles that were detected, and during the same event on hydrophone 207 a series of repeated upsweeps occurred. It should be noted that these were during the period of multiple hits during event 9 (see Table 11), so if the dolphins were located between the hydrophone and the hulk, it is possible they could hear the impulsive sounds and were acoustically responding, even when the impulsive sounds were not detected on the hydrophones.

Other than these anecdotal acoustic responses, there were no apparent behavioral responses to the SINKEX event by the dolphins. For example, it was evident that one or more groups passed over the range over the course of the day, but there did not appear to be any change in direction based on vocal behavior in response to the impulsive sounds. However, a limited number of hydrophones were manually reviewed; with future software improvements (e.g., the integration of the MAMBAT software with which odontocete groups can be tracked; Gruden et al., 2025) this can be revisited to look more closely for changes in movement patterns relative to the SINKEX activity.

4.3.2.2 SINKEX July 11

This SINKEX was much shorter than the one on July 18-19, with only four events. Unfortunately, the first six hours of this SINKEX were not recorded, so acoustic data were only recorded for the final two hours of the activity, covering part of the third event and all the fourth event. For this exercise, acoustic data were examined on seven hydrophones: four along the midpoint of BSURE and three along the bottom edge of BSURE (Table 12).

Table 12: Times of each SINKEX event and an X indicating detections of acoustic activity during the third and fourth events. Distances indicate the distance of each hydrophone from the hulk. Gray shading indicates no data were recorded.

Date	Event	Phone 217 50 km	Phone 216 56 km	Phone 212 83 km	Phone 205 57 km	Phone 201 82 km	Phone 185 49 km	Phone 180 82 km
7/11/24 21:42	Start event 1							
7/11/24 22:42	End event 1							
7/11/24 22:43	Start event 2							
7/12/24 0:36	End event 2							
7/12/24 1:17	Start event 3							
7/12/24 3:05	Hit	X	X	X	X	X	X	X
7/12/24 3:08	End event 3							
7/12/24 3:10	Start event 4							
7/12/24 3:13	Hit							
7/12/24 3:18	Hit	X	X	X	X	X	X	X
7/12/24 3:21	Hit							
7/12/24 3:25	Hit							
7/12/24 3:28	Hit							
7/12/24 3:53	Hit							
7/12/24 4:17	Hit							
7/12/24 4:28	Hit	X	X	X	X	X	X	X
7/12/24 4:49	Hit							
7/12/24 4:51	Hit	X	X	X	X	X	X	X
7/12/24 5:02	Hit	X	X	X	X	X	X	X
7/12/24 5:53	End event 4							

Once again, the hydrophones in a more southerly path (hydrophones 185 and 180) from the hulk had more intense detections than the other hydrophones, even on the hydrophones midway down BSURE compared to hydrophone 180. However, all seven hydrophones detected all the same event impulses; there were no missed detections even at distances greater than 80 km for signals that were detected on at least one hydrophone (some of the "hits" in Event 4 may not have had an underwater acoustic signal). The three hydrophones further south also experienced some masking from a nearby vessel. This masking was most prevalent on hydrophone 201, but it did not prevent the detection of the impulsive signals. In the July 18-19 SINKEX, the earlier events were less intense, and it would have been interesting to see if that was the case in this SINKEX as well, and if activities in all four events would have been detected on those more distant phones.

There was much less marine mammal activity on these hydrophones during this two-hour period than during the July 18-19 SINKEX. There were dolphin whistles detected on hydrophones 205, 216, 201, and 212, with the loudest detections on 216 and 212, indicating the animals were likely somewhere on the western edge of the range. However, throughout this period the whistles on all four hydrophones remained relatively faint, and were never overlapping (i.e., only one individual animal was detected at a time), indicating the presence of either one or more small groups, or a larger group of which these phones were only detecting the edge. There were once again instances of repeated series of the same whistles on hydrophones 216 (two different whistle patterns, one downsweep at 3:44 and one flattish whistle at 4:01); on hydrophone 212 (similar flattish whistles at 4:02 with a secondary upsweep pattern and another flattish whistle series at 4:19); and on hydrophone 201 (similar flattish whistles at 4:25 and 4:29). None of these occurred in conjunction with an event and so don't appear to have been a response. Given a very similarly shaped whistle was seen on three different hydrophones over a large area in a relatively small amount of time, this could either be one individual with a whistle that is propagating tens of kilometers, which is very unlikely, or could perhaps be a species-specific whistle. The frequency range (5 -12 kHz) and shapes and durations of these whistles strongly suggest they were produced by rough-toothed dolphins. It would be constructive to look back at known rough-toothed dolphin detections to look for this whistle pattern and further explore this hypothesis. None of the whistle detections changed appreciably in intensity or abundance following any impulse detection related to the SINKEX, but the group(s) producing the whistles were also distant to these hydrophones so a change may have been difficult to detect.

Near the end of the exercise, a faint, short burst of dolphin clicks was detected with no concurrent whistles on Phone 184; these occurred at 4:44 prior to the final impact in Event 4. Another brief click train and a few burst pulses were also detected on hydrophone 216 at 5:04 and 5:08, after the final impact in Event 4 was detected, along with continued whistles; this could have been a vocal response to this impact, or could have indicated the group was approaching this hydrophone more closely. Finally, very faint beaked whale echolocation pulses with an inter-pulse interval of 260 – 295 ms were detected on hydrophone 212 at the onset of recording at 3:07. These remained very faint until 3:21, at which point they were no longer detectable.

4.4 SUMMARY OF PAM OBSERVATIONS DURING MFAS

The table below summarizes the previously discussed acoustically detected whales that were exposed to MFAS during U.S. Navy acoustic and explosive training activities at PMRF during the FY25 reporting period.

Table 13: Summary of acoustic observations of PAM detected and tracked whales

Species	Event	Exposure	Description of Observations	Section
Sperm whale	SCC	MFAS (ship)	No change in movement behavior or direction of travel during MFAS; max RL 144 ± 0.4 dB re 1 µPa, ship CPA 16.2 km	4.1
Minke whale	SCC	MFAS (ship and sonobuoy)	No change in movement or calling behavior during MFAS, max RL 149 ± 0.7 dB re 1 µPa, ship CPA 25 km	4.1
Minke whale	SCC	MFAS (ship and sonobuoy)	Maintained direction of travel, no change in movement or calling behavior; max RL 122 ± 1.1 dB re 1 µPa, ship CPA 42.4 km	4.1
Humpback whale	SCC	MFAS (ship and sonobuoy)	Minor changes in whale heading, no change in overall direction of travel; max RL 152 ± 1.6 dB re 1 µPa, ship CPA 35 km	4.1

Species	Event	Exposure	Description of Observations	Section
Dense-beaked whales	ASWEX	MFAS (sonobuoy)	Increase from 6 GVPs Before to 8 GVPs in 2-hr period During MFAS, decrease to 5 GVPs After	4.3.1
Sperm whales	SINKEX	Explosives	Continued vocalizations throughout SINKEX; some coda production directly after impulsive events	4.3.2
Unidentified dolphins	SINKEX	Explosives	Continued vocalizations throughout SINKEX; some changes to vocal activity after impulsive events; some stereotyped whistles noted	4.3.2

5. BEAKED WHALE OCCURRENCE ANALYSIS

Beaked whale echolocation pulses have been detected on the broadband hydrophones of the PMRF instrumented range since NIWC Pacific began recording at a high enough sample rate to detect them in 2006. Recording configuration changes occurred in 2006, 2007, 2011, 2012, 2018, and 2021 that led to increases in the detection rate of beaked whale echolocation pulses. These configuration changes included additions to the number of broadband hydrophones in the instrumented range (BSURE), an increase in the number of hydrophones that NIWC Pacific recorded, a shift in the recorded area to habitat more favored by beaked whale species, and a change to the recording system that NIWC Pacific was using. In 2021, NIWC Pacific installed a new recording system at PMRF, including a new analog-to-digital board and recorder software. After this installation, there was an apparent increase in detection rates of all three species of beaked whales monitored at the time. The new analog-to-digital board has a higher full scale input voltage than our previous board (+/-1.5V vs +/-1V), and it also has a steep roll-off digital low-pass filter at 45 kHz in the data acquisition software. It was unclear what effect this combination might have on the sensitivity of the system to high frequencies and whether that could account for the increased detection rates. Therefore, NIWC Pacific undertook an investigation to determine if the increase in detection rates was real, i.e., whether there was a real increase in the presence of beaked whales in Hawaiian waters starting in 2021 that might be related to oceanographic conditions, or if this increase could be traced back to changes in our recording system. If the change was the latter, we also wanted to try to account for it in a quantitative manner so that in long-term analyses of beaked whale presence, such as abundance or density estimates over time, we could correct for any systemic increases.

We came up with three approaches to determine what may have led to an increase in the number of beaked whale detections. For all exploratory analyses, we looked at dense-beaked whale pulse detections and/or GVP rates, as they are the most common beaked whale species detected on the range.

First, to test whether the new configuration affected sensitivity to beaked whale pulses, we played ~22 hours of data recorded in 2017 back through a local version of the new system to see if the low-pass filter ultimately changed the number of detections. There were some minor differences between detection rates, likely due to differences in the noise floor across systems that would impact the signal-to-noise ratios used in the detection algorithm. The degree of the effect seemed to vary by hydrophone, perhaps due to different ambient noise characteristics in different locations. Despite this variability in individual pulse detections, the overall GVP rate (detections grouped by time and on adjacent hydrophones) was not impacted, which suggests that this ultimate metric is robust to quite a bit of variation in pulse detection rate.

Second, as another approach to evaluating these known hardware differences – and to get a sense of how manipulating the noise floor specifically could impact results – we ran a 135-hr dataset from 2022 (i.e., from the new recorder) through our detection algorithm after right bit-shifting the data by one bit, thereby decreasing the gain by 6 dB. This had hardly any effect on the data, causing only a 0.5% reduction in overall pulse detections (though this time with no noticeable difference between hydrophones). Similarly, there was only one fewer GVP with the bit-shift applied.

Third, we considered the potential effect of recording more data on the new system with respect to sampling the presence of beaked whale GVPs. Previously, our system was limited to 2 TB hard drives, so if only two recordings were made in a month, only 90 hours of data would be recorded. The new system is not limited to a hard drive size, and we typically use 6 TB hard drives, so at minimum with two recordings per month we are getting over 240 hours per month. Furthermore, additional recordings are often made. To test whether the additional sampling accounted for the higher detection rate, we limited our comparison of recordings to 43 hours or less (i.e., a little under 2 TB) and measured the consequent GVP rates. Interestingly, this did seem to account for at least a portion of the increasing detection rate. When the median

GVPs per day within a dataset is plotted against the number of hours of recording in that dataset, similar increases in median GVPs/ hour per hour of recording in both systems become clear (Figure 26).

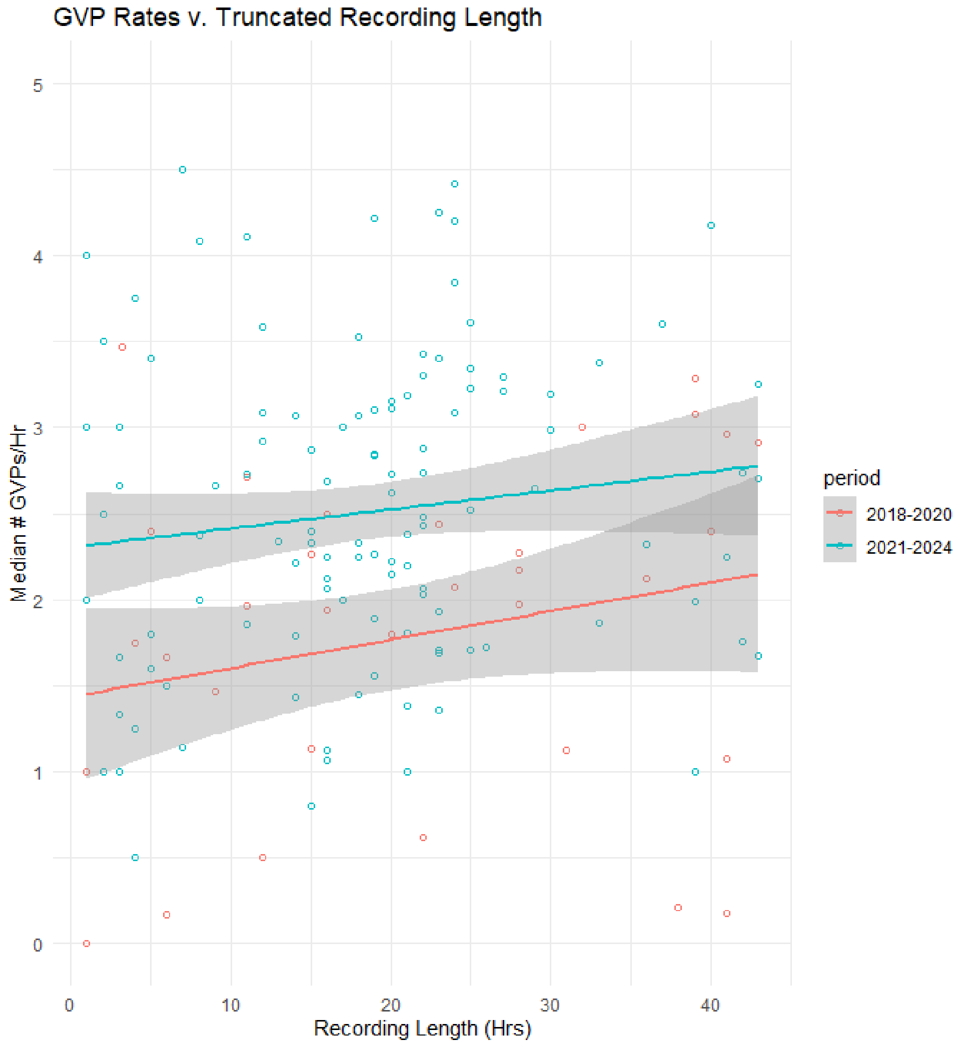


Figure 26: Comparison of median GVPs/hr from the legacy recorder and median GVPs/hr from the new recorder with truncated dataset lengths.

Furthermore, when those median values are displayed in a calendar heatmap, periodicity in beaked whale GVP rates are apparent at the higher monthly sampling rate (see Figure 27 for the example from 2022). This periodicity seems to be such that there is a higher likelihood of recording during a lower inflection point of beaked whale presence when sampling only two days twice per month, whereas when we are sampling at least five days twice per month, and often more, we have a better chance of sampling at a high inflection point and therefore getting a higher detection rate.

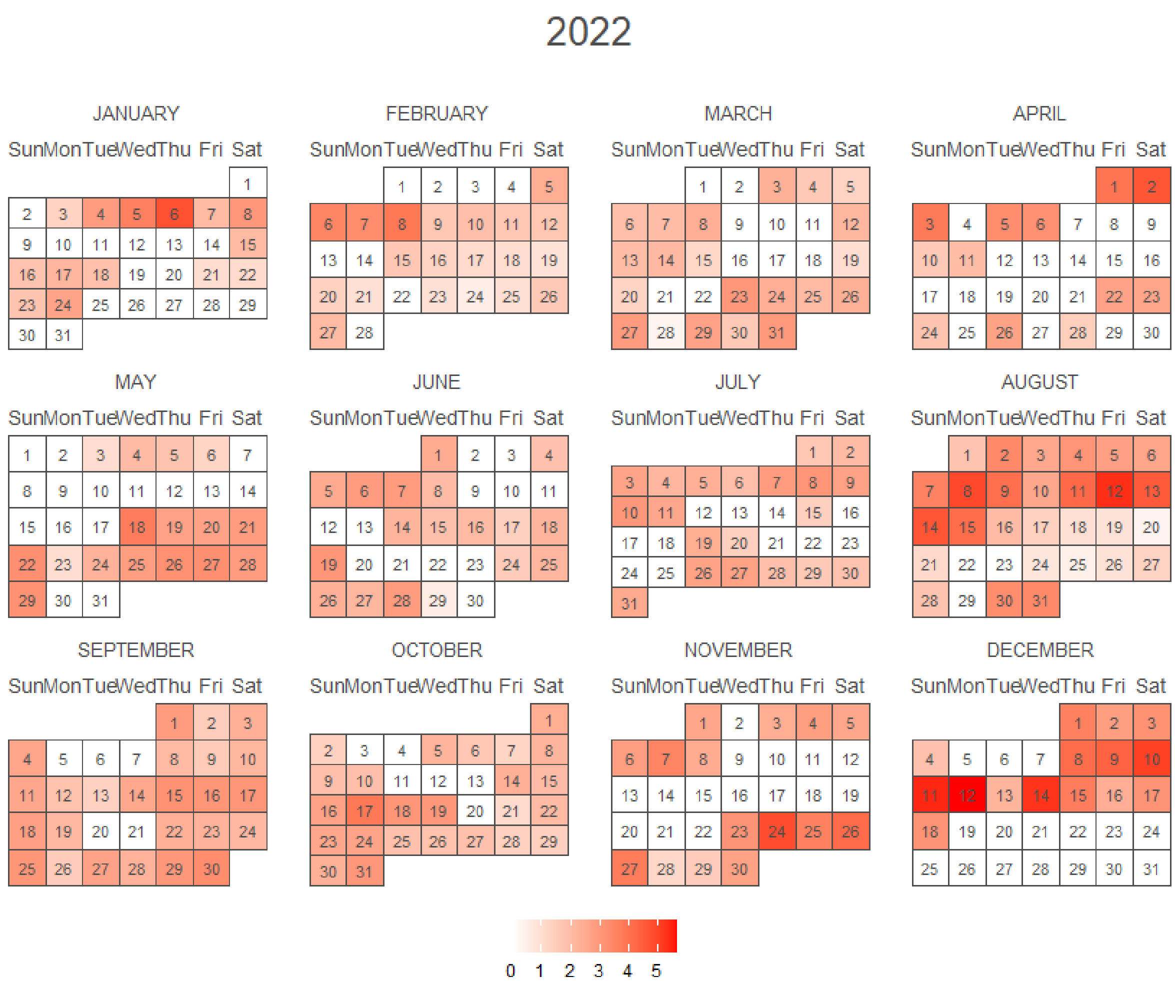


Figure 27: Calendar heatmap of median GVPs/hr from the new recorder.

Despite all this, there is still a vertical offset between the trendlines seen in Figure 26, suggesting that another underlying reason is also contributing to the increased GVP rates visible with the new recorder's data. Further exploration suggested that these increases were driven primarily by detections on hydrophones located on slope habitat, perhaps due to a combination of ambient noise factors (as noted while discussing the first test) and the fact that this is favored habitat for beaked whale species (Henderson et al., 2016). This overall offset – about 0.87 GVPs/hour difference in medians as measured via the y-intercepts – could represent a real increase in beaked whale presence on the PMRF range due to changes in oceanographic conditions or other unknown environmental or ecological factors. However, it is also possible that the combination of the new hard low-pass filter at 45 kHz and a slight shift in the dynamic range means that the net effect at PMRF is an increase in beaked whale detections. It is unlikely these two remaining possible factors – natural or mechanical – could be easily teased apart and accounted for (and they could be co-occurring), other than by continuing to monitor beaked whale GVP rates.

6. CONCURRENT AND RELATED EFFORTS

6.1 TAGGING AT PMRF

Cascadia Research Collective (CRC) conducted satellite tagging of odontocetes on PMRF February 9-18, 2025. Ten total tags were deployed on short-finned pilot whales (4), dense-beaked whales (1), rough-toothed dolphins (3), and false killer whales (2). In addition to supporting the tagging effort at PMRF, in FY25 NIWC Pacific worked with CRC to analyze the satellite tag data from the 2025 field season. Received levels and possible behavioral responses of the tagged animals are documented in a separate report (Henderson et al., 2026a).

6.2 MAMBAT SOFTWARE

In collaboration with the University of Hawai‘i, E. Henderson is supporting the development of an odontocete group tracking algorithm that can be utilized on a large, widely-spaced array such as PMRF. This software provides a model-based passive acoustic method to simultaneously track and localize multiple marine species, integrating all detections to track and then localize individuals in three-dimensional space. WARP has provided screened and cleared odontocete acoustic data from PMRF for sperm whales, killer whales, pilot whales, and rough-toothed dolphins for use in the development of the code. Some of these groups coincide with individuals tagged by CRC (Section 6.1), leveraging data across multiple projects and providing ground truth data for the acoustic tracks. The result of this project will be software that WARP can integrate into the NARWHAL algorithm suite to track groups of odontocetes across the PMRF range. This will allow us to monitor odontocete movement before, during, and after training events as well as during baseline periods to better understand how different odontocete species utilize the range as part of their home range, and how they may change their movements during testing and training activities.

6.3 RAVEN-X DEVELOPMENT

RAVEN-X is a joint project with Naval Undersea Warfare Center (NUWC) Newport aimed at enhancing the efficiency of processing and analytics for large-scale passive acoustic data. Many of the tools from the NIWC Pacific NARWHAL software suite used in this report are being integrated into the common processing software package of RAVEN-X, allowing them to be used at both NIWC Pacific and NUWC Newport in addition to other Navy stakeholders. RAVEN-X also allows for processing of multiple data formats, including binary archive data in addition to raw acoustic data from Navy ranges, which may prove useful for additional processing opportunities of historical data at PMRF, SOAR, and other Navy ranges.

6.4 FIN WHALE SONG EVOLUTION

R. Guazzo and T. Helble are being funded by ONR to quantify fin whale song patterns and cue rates over time in the central and eastern North Pacific. Understanding how fin whale songs change over time is crucial for accurate environmental impact assessments. This project aims to improve cue rate based density estimation for fin whales and assess population connectivity by comparing song patterns across the central and eastern North Pacific. By examining fin whale populations in two US Navy training areas (PMRF and SOAR), we will explore their potential interactions, examining the assumption of separate stocks.

Enhancements to the GPL detection and localization system were completed with the help of RAVEN-X to automatically detect, localize, track, and classify fin whale notes at both PMRF and SOAR. Building on our team's 2020 work (Helble et al., 2020), we analyzed fin whale song over 12 years at PMRF. Individual whales interwove multiple patterns in their songs, defined by both note type and the spacing between notes. Within each song these patterns were highly regular, but between songs and across time, they changed. The along-track cue rate was variable between tracks, but the average was remarkably stable over the full 2011—2023 period. Increased understanding of these songs, their changes over time, and fin whale cue rate can help refine population estimates, increasing the accuracy of environmental impact statements required for naval training and testing, and minimizing disruptions to critical operations. This work was published in Helble et al. (2025).

We are currently processing acoustic data collected at SOAR to detect, localize, and track fin whales there. While detection, localization, and tracking have been well-established at PMRF, the initial setup and testing at SOAR has taken considerable resources and time to ensure that our code translates to this new range. This is an iterative process between software development and manual validation on individual channels of the 89 hydrophones to ensure that we do not have gaps in coverage or other errors.

6.5 LARGE WHALE BEHAVIOR TRACKED WITH THE NAVY'S M3 SYSTEM

R. Guazzo has been studying large whale behavior through passive acoustic monitoring with US Navy Marine Mammal Monitoring (M3) arrays with support from the Living Marine Resources Program (LMR). This effort is in collaboration with Dorene Stevenson and Michael Edell from Marine Acoustics, Inc., who are funded by COMPACFLT to collect the data. The current effort is focused on quantifying how much time several species of baleen whales spend actively singing/calling across different times of the year. This information can support cue rate-based density estimation. Typically, passive acoustic data cannot be used to monitor whales when they stop singing for long gaps, but it is possible to connect tracks of vocalizing whales across long silent periods using this unique dataset. D. Stevenson and M. Edell annotated vocalization gaps of 30 minutes or longer for:

- 83 blue whales (including 3 unique whales)
- 160 fin whales
- 50 humpback whales
- 15 minke whales
- 20 sei whales

between January 2024 and September 2025. Three blue whales produced unique song vocalizations that made them identifiable from other blue whales and provided a rare opportunity to track individual whales for even longer durations because their vocalizations were not easily confused with another nearby animal. These unique whales were tracked during the summer and fall months in both years (3 individuals in 2024 and 2 of the same individuals in 2025), with individual tracks lasting from 1–3 months. The silent periods measured for these tracked whales will be applied to predict how many whales might be missed on other passive acoustic monitoring systems with smaller spatial coverage due to the whales being silent while they transit through the area.

6.6 PILOT WHALE BEHAVIORAL RESPONSE STUDY

A collaborative project between NIWC Pacific, Cascadia Research Collective, Southall Environmental Associates, Inc., and Duke University was initiated this year to quantitatively assess the large databases of satellite-tagged short-finned pilot whales from both PMRF and the Atlantic BRS study. By analyzing these data that include animals with very different residency patterns, social structures, and MFAS exposure histories, we hope to not only begin to understand behavioral responses of pilot whales to MFAS, but also place those responses into a larger social context to start to look at the influence of group dynamics, social networks, and exposure histories on responsiveness. A summary of the efforts from the first year can be found in Henderson et al., 2026b.

7. FY25 PUBLICATIONS

Helble, T. A., Guazzo, R. A., Dugan, P. J., Alongi, G. C., Martin, C. R., Martin, S. W., & Henderson, E. E. (2025). Twelve years of fin whale song evolution in the central North Pacific. Frontiers in Marine Science, 12, 1642598.

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8. FY25 PRESENTATIONS

Guazzo, R. A. 2024. Using passive acoustic tracks from a Navy array to study large whale behavior in the North Atlantic ID-65. U.S. Navy's Living Marine Resources Program IPR. Santa Barbara, CA. Oral Presentation.

Guazzo, R. A. 2025. Large whale behavior tracked with the Navy's M3 System. U.S. Navy Marine Species Monitoring Meeting. Norfolk, VA. Oral Presentation.

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