Submitted in Support of the U.S. Navy's 2023 Annual Marine Species Monitoring Report for the Pacific

DRAFT

Marine Mammal Monitoring on Navy Ranges (M3R) for Beaked Whales on the Southern California Anti-Submarine Warfare Range (SOAR) and the Pacific Missile Range Facility (PMRF), 2023

Marine Mammal Monitoring on Navy Ranges (M3R) Program
Ranges, Engineering and Analysis Department
Naval Undersea Warfare Center
Newport RI 02841

Prepared to and funded by: U.S. Navy, Commander Pacific Fleet
Contract #N0007023WR0EOH1
9 July 2024

NAVSEA WARFARE CENTERS
NEWPORT

DISTRIBUTION STATEMENT A.

Suggested Citation: Dolan, K., Carroll, A., Moniz, L., Tovar, R., DiMarzio, N., Watwood, S. 2024. Marine Mammal Monitoring on Navy Ranges (M3R) for beaked whales on the Southern California Anti-Submarine Warfare Range (SOAR) and the Pacific Missile Range Facility (PMRF), 2023. Prepared for: U.S. Navy, U.S. Pacific Fleet, Pearl Harbor, HI. Prepared by: Naval Undersea Warfare Center Newport, Newport, RI. 68 pp.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
09-07-2024

2. REPORT TYPE
Monitoring report

3. DATES COVERED *(From - To)*
May 2010 to July 2023

4. TITLE AND SUBTITLE
MARINE MAMMAL MONITORING ON NAVY RANGES (M3R) FOR BEAKED WHALES ON THE SOUTHERN CALIFORNIA ANTI-SUBMARINE WARFARE RANGE (SOAR) AND THE PACIFIC MISSILE RANGE FACILITY (PMRF), 2023

5a. CONTRACT NUMBER
N62470-15-D-8006

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
K. Dolan
A. Carroll
L. Moniz
R. Tovar
N. DiMarzio
S. Watwood

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Undersea Warfare Center
Newport, RI 02841

8. PERFORMING ORGANIZATION REPORT NUMBER

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

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSORING/MONITORING AGENCY REPORT NUMBER

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

13. SUPPLEMENTARY NOTES

14. ABSTRACT
In the Pacific, the Marine Mammal Monitoring on Navy Ranges (M3R) program maintains systems that continuously run algorithms to detect, classify and localize marine mammals year-round on the U.S. Navy's deep-water Southern California Antisubmarine Warfare Range (SOAR) in Southern California and the Pacific Missile Range Facility (PMRF) off Kaua'i, Hawai'i. Long-term archive data collected on these ranges allow for numerous types of studies on species inhabiting the ranges, including the monitoring of abundance, behavioral responses to naval activities, and habitat usage. They also provide the opportunity to study ambient sound levels and soundscapes.

In FY23 the M3R program had 5 goals for SOAR and PMRF:
1. Support real-time monitoring of on-water tagging operations.
2. Collect M3R binary archives and periodic broadband recordings.
3. Analyze long-term abundance estimates for Blainville's beaked whales (*Mesoplodon densirostris, Md*) and Cuvier's beaked whales (*Ziphius cavirostris, Zc*).
4. Consolidation and streamlining of beaked whale distribution and abundance analysis scripts, and documentation of the analysis process
5. Publication development on beaked whale occurrence and abundance

Submitted in Support of the U.S. Navy's 2023 Annual Marine Species Monitoring Report for the Pacific

15. SUBJECT TERMS					
Acoustic monitoring, marine mammals, beaked whales, Southern California Anti-Submarine Warfare Range, Pacific Missile Range Facility, Hawaii Range Complex, Southern California Range Complex					
16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT** UU	**18. NUMBER OF PAGES** 70	**19a. NAME OF RESPONSIBLE PERSON** Department of the Navy
a. REPORT Unclassified	**b. ABSTRACT** Unclassified	**c. THIS PAGE** Unclassified			**19b. TELEPONE NUMBER (*Include area code*)** 808-471-6391

Executive Summary

In the Pacific, the Marine Mammal Monitoring on Navy Ranges (M3R) program maintains systems that continuously run algorithms to detect, classify and localize marine mammals year-round on the U.S. Navy's deep-water Southern California Antisubmarine Warfare Range (SOAR) in Southern California and the Pacific Missile Range Facility (PMRF) off Kauaʻi, Hawaiʻi. Long-term archive data collected on these ranges allow for numerous types of studies on species inhabiting the ranges, including the monitoring of abundance, behavioral responses to naval activities, and habitat usage. They also provide the opportunity to study ambient sound levels and soundscapes.

In FY23 the M3R program had 5 goals for SOAR and PMRF:

1. Support real-time monitoring of on-water tagging operations.
2. Collect M3R binary archives and periodic broadband recordings.
3. Analyze long-term abundance estimates for Blainville's beaked whales (*Mesoplodon densirostris*, *Md*) and Cuvier's beaked whales (*Ziphius cavirostris*, *Zc*).
4. Consolidation and streamlining of beaked whale distribution and abundance analysis scripts, and documentation of the analysis process.
5. Publication development on beaked whale occurrence and abundance.

Suggested Citation: Dolan, K., Carroll, A., Moniz, L., Tovar, R., DiMarzio, N., Watwood, S. 2024. Marine Mammal Monitoring on Navy Ranges (M3R) for beaked whales on the Southern California Anti-Submarine Warfare Range (SOAR) and the Pacific Missile Range Facility (PMRF), 2023. Prepared for: U.S. Navy, U.S. Pacific Fleet, Pearl Harbor, HI. Prepared by: Naval Undersea Warfare Center Newport, Newport, RI. 68 pp.

TABLE OF CONTENTS

List of Figures

List of Tables

Abbreviations and Acronyms

Acronym	Definition
A/D	Analog to Digital
ASW	Anti-Submarine Warfare
AUTEC	Atlantic Undersea Test and Evaluation Center
BARSTUR	Barking Sands Tactical Underwater Range
BSURE	Barking Sands Underwater Range Expansion
CF	Correction Factor
CI	Confidence Interval
CRC	Cascadia Research Collective
CS-SVM	Class-Specific Support Vector Machine classifier
CTP	Click Train Processor
CV	Coefficient of Variation
DCL	Detection, Classification and Localization
FFT	Fast Fourier Transform
FY	Fiscal Year
GVP	Group Vocal Period
FN	False Negative
FP	False Positive
Hrs	Hours
ICI	Inter-Click Interval
kHz	kilohertz
LF	Low-frequency
LIMPET	Low Impact Minimally Percutaneous Electronic Transmitter
M3R	Marine Mammal Monitoring on Navy Ranges
MarEcoTel	Marine Ecology and Telemetry Research
Md	*Mesoplodon densirostris*
MFAS	Mid-Frequency Active Sonar
Min	Minutes
MMAMMAL	Marine Mammal Monitoring And Localization
ms	milliseconds
n	Number of samples analyzed
PCoD	Population Consequences of Disturbance

Acronym	Definition
PD	Probability of Detection
PMRF	Pacific Missile Range Facility
RHIB	Rigid Hull Inflatable Boat
SCI	San Clemente Island
SES	Shore Electronics System
SMRT	Sound and Motion Recording Tags
SOAR	Southern California Anti-Submarine Warfare Range
SWTR	Shallow Water Training Range
T	Time
Whdetect	Whale Detection algorithm
Zc	*Ziphius cavirostris*

1 Introduction

1.1 Background

The Marine Mammal Monitoring on Navy Ranges (M3R) program utilizes the U.S. Navy's instrumented hydrophone ranges for passive acoustic detection of marine species (Jarvis et al. 2014). This important resource allows for long-term monitoring of populations of interest and provides data for answering key questions regarding basic biology, habitat usage, and behavioral responses to Navy training and testing activities. This report presents the results of annual baseline monitoring on two ranges managed by Commander, U.S. Pacific Fleet; the Southern California Anti-Submarine Warfare Range (SOAR), located off San Clemente Island, California, and the Pacific Missile Range Facility (PMRF), located off Kauaʻi, Hawaiʻi.

1.2 Study Goals

The goals of the FY23 monitoring effort included the following:

1. Support real-time monitoring of on-water tagging operations at SOAR and PMRF
2. Collect M3R archives at both SOAR and PMRF
3. Analyze long-term abundance estimates for Blainville's beaked whales (*Mesoplodon densirostris*, *Md*) and Cuvier's beaked whales (*Ziphius cavirostris*, *Zc*).
4. Consolidation and streamlining of beaked whale occurrence and abundance analysis scripts, and documentation of the analysis process.
5. Publication development on beaked whale occurrence and abundance

1.3 Study Sites

SOAR is located west of San Clemente Island (SCI), CA, in the San Nicolas Basin (Figure 1). SOAR is an Anti-submarine Warfare (ASW) training range on which sound sources, including mid-frequency active sonar (MFAS), are routinely used. Beaked whales are regularly detected at SOAR both acoustically and visually, displaying a high level of site fidelity to the area (Falcone et al. 2009, Schorr et al. 2014, Schorr et al. 2020). The SOAR range consists of an array of 177 bottom-mounted hydrophones covering an area of about 2200 square kilometers (km^2). The SOAR hydrophone separation ranges from about 2.5 to 6.5 kilometers (km) and hydrophones are at average depths of 1600-1800 meters (m). The 88 original, or legacy, hydrophones have a bandwidth of ~8 to 40 kilohertz (kHz), while the newer refurbished 89 hydrophones have a bandwidth of ~50 Hz to 48 kHz.

PMRF is located off the northwest coast of Kauaʻi, Hawaiʻi (Figure 2). The range consists of three distinct areas, known as the Barking Sands Tactical Underwater Tracking Range (BARSTUR), the Barking Sands Underwater Range Expansion (BSURE) and the Shallow Water Training Range (SWTR). BARSTUR consists of 42 hydrophones with a bandwidth of approximately 8 - 45 kHz, with 6 broadband hydrophones that cover a bandwidth of approximately 20 Hz to 45 kHz. BSURE has 41 newer hydrophones (BSURE refurb) with a bandwidth of 50 Hz to 45 kHz, and the original 18 hydrophones with a bandwidth of 50 Hz to 18 kHz. This analysis used all hydrophones from the BARSTUR and BSURE portions of the range, aside from the original 18 in BSURE, due to restricted frequency range. Note that over the years the hydrophone configuration has changed due to certain hydrophones becoming nonfunctional.

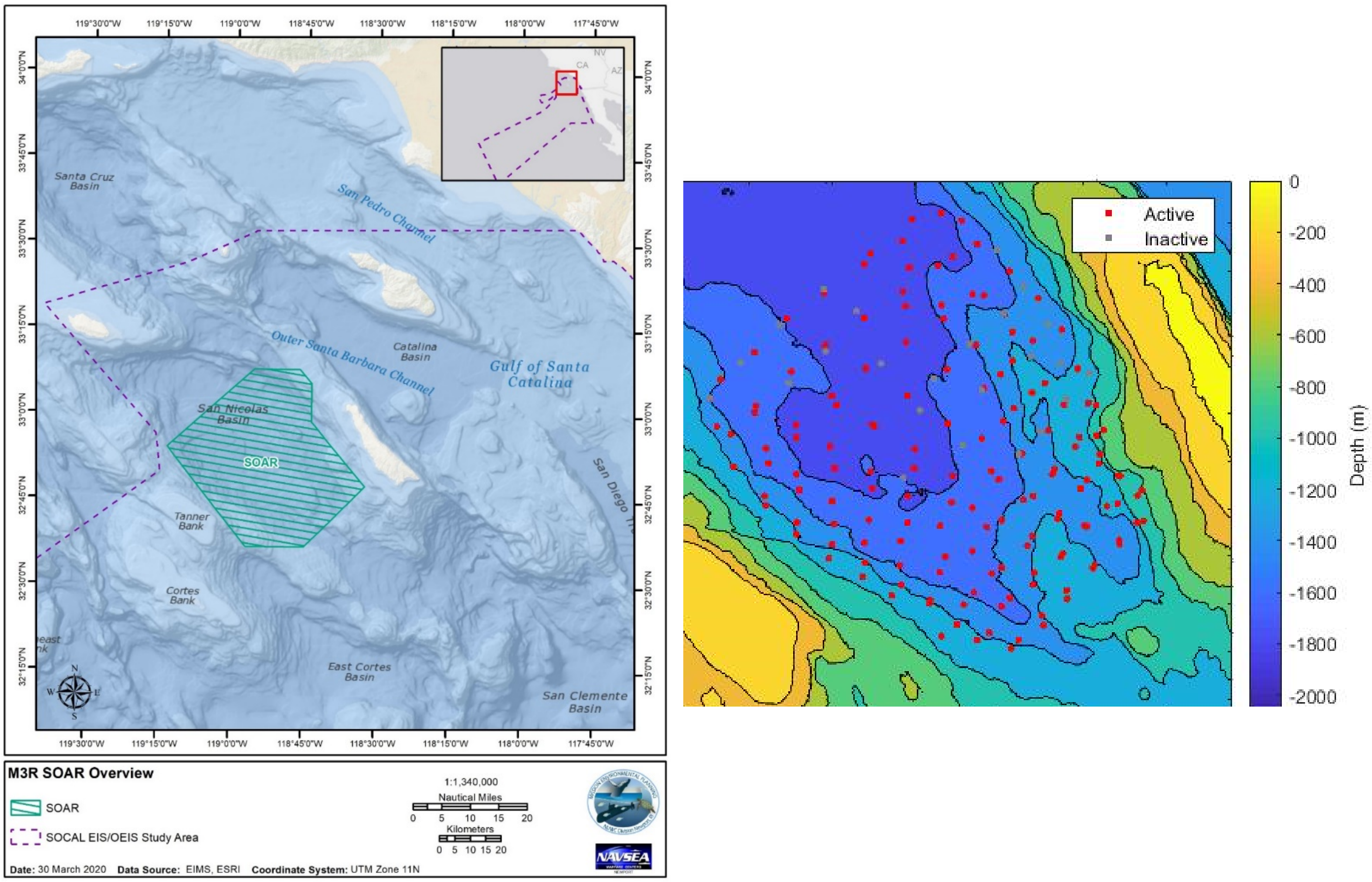


Figure 1. Location of SOAR hydrophone range, west of San Clemente Island off southern California (left). Hydrophone layout and bathymetry (right).

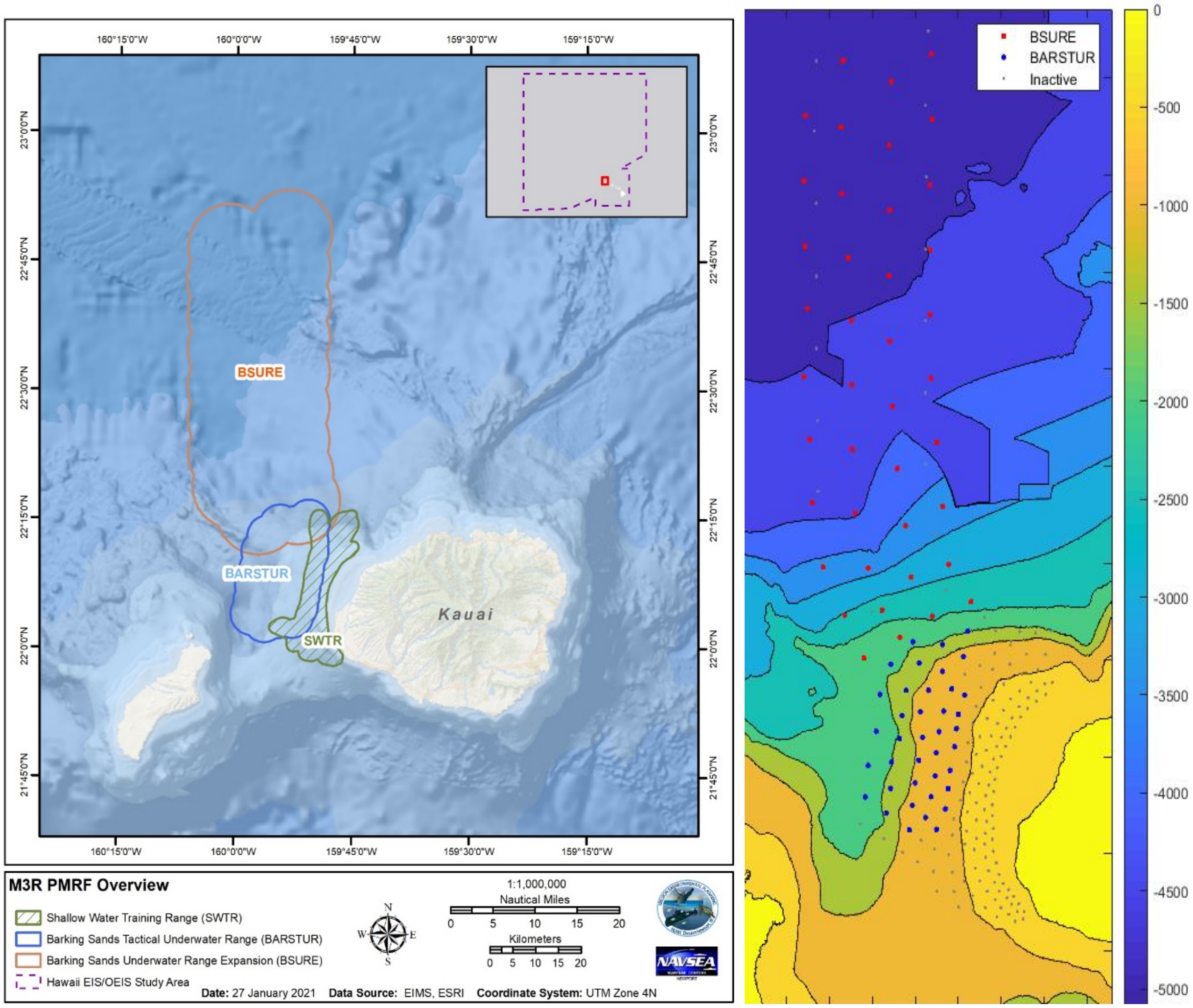


Figure 2. Location of PMRF hydrophone range, west of Kauaʻi, Hawaiʻi (left). Hydrophone layout with bathymetry (right).

1.4 Data Collection Summary

The M3R system processes incoming data from all range hydrophones simultaneously through detection, classification, and localization (DCL) algorithms on a nearly continuous basis. The algorithm reports are then archived to binary files (termed archive files) for later playback and analysis. In addition to archives, broadband acoustic data is collected opportunistically when M3R personnel are on site.

Three detector/classifiers are employed by the M3R System:

1. Full bandwidth Fast Fourier Transform (FFT)
    a. 2048 FFT, 50% overlap, frequency resolution of 46.875 Hz, time resolution of 10.67 ms
2. Low-frequency bandwidth FFT (0 – 600 Hz)
    a. 2048 FFT, 90% overlap, frequency resolution of 2.92 Hz, time resolution of 21.33 ms
3. Class-Specific Support Vector Machine (CS-SVM) (Jarvis et al. 2008)

The CS-SVM classifier was installed in May 2010 at SOAR and May of 2011 at PMRF. Its output is utilized for the abundance analysis. The version currently running at SOAR has four classes: Cuvier's beaked whale foraging and buzz clicks, sperm whale clicks, and 'generalized dolphin' clicks. The CS-SVM classifier currently running at PMRF runs an additional two: Blainville's beaked whale foraging and buzz clicks. The generalized dolphin class was formed to reduce false positive beaked whale detections. This class was trained on echolocation clicks from four delphinid species: pantropical spotted dolphin (*Stenella attenuata*), Risso's dolphin (*Grampus griseus*), short-fin pilot whale (*Globicephala macrorhynchus*), and common dolphins (*Delphinus delphis*). (Jarvis et al. 2008, Jarvis et al. 2014).

1.4.1 SOAR

Archives have been collected on a total of 2,949 days since the CS-SVM classifier was installed in 2010 (Figure 3). A total of 248.4 days have been collected and processed for analysis during FY23. Archives collected after July 2023 are still in transit from SOAR and are not described in this report. Broadband recordings were first collected in 2012 in the current format. A total of 2,451 hours of recordings have been collected at SOAR since 2012 (Figure 4), with 716.1 hours collected and analyzed during FY23. Efforts are being made in FY24 to convert older broadband recordings to the current format to preserve the data and increase accessibility.

Total Days Archives Collected at SOAR

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2010	0	0	0	0	0	0	0	8.8	25.9	20.6	19.5	19.4	94.2
2011	14	24.8	7.5	1.1	12.2	12.7	5.1	26.3	30	31	21	31	216.7
2012	24.6	21.6	18	30	14.4	4.2	1.5	4	0	16.3	10.6	8	153.2
2013	0	0	0.8	0.2	16.3	30	23.1	31	30	5.6	1.9	11	149.9
2014	31	20.1	25.6	27.7	26.8	27.5	29.7	23	25.1	13.3	2.1	31	282.9
2015	30.9	27.9	20.2	23.7	31	9.3	19	20.3	14.1	29.3	14.3	10.1	250.1
2016	30.1	25.9	31	23.6	17.1	5.9	16.3	31	24.4	0	26.1	30.9	262.3
2017	13.9	0	11.3	29.1	1.5	0	11.3	31	20.8	16.8	25.5	25.7	186.9
2018	25.9	12.6	4	14.6	25.8	30	18.6	31	30	31	30	20	273.5
2019	25.5	28	31	30	27.8	25.4	27.1	17.9	12.8	28	27.6	31	312.1
2020	18	9.5	0	16.1	12.6	0	0	0	0	26.2	21.1	0	103.5
2021	6.1	7.9	31	30	6.4	28.3	21.4	26.2	29.9	24.6	6.4	0	218.2
2022	25.4	15.4	22.9	30	23.2	19.3	30	30.8	29.6	13.9	12.7	31	284.2
2023	30.6	27.3	30.6	22.1	30.1	6.9	13.6	0	0	0	0	0	161.2
Totals	276	221	233.9	278.2	245.2	199.5	216.7	281.3	272.6	256.6	218.8	249.1	2949

Figure 3. Total days archives have been collected at SOAR from 2010-2023.

Total Hours Broadband Recording at SOAR

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2012	7.3	0	24.9	0	1.1	0	19	0	0	50.1	0.6	0	103
2013	3.1	0	0	0	0	0	19	0	1.6	0	0	0	23.7
2014	25.9	0	56.9	0	40.3	12.7	6.6	9.4	0	49.4	0	0	201.2
2015	55.7	0	0	0	0	0	50.3	75.9	0	0	0	0	181.9
2016	0	0	0	0	0	0	0	0	0	0	16.9	10.7	27.6
2017	70.1	0	0	0	0	0	0	0	0	0	0	0	70.1
2018	28	0	0	7.8	4.2	30.1	0	0	0	0	0	0	70.1
2019	148.6	0	9	0	0	0	4.5	0	0	33.7	77	65.3	338.1
2020	17.1	2.2	0	0	0	0	0	0	0	19.5	71.9	45.1	155.8
2021	23.8	0	0	0	8.6	0	0	0	67.7	59.9	0	0	160
2022	236.7	0	0	0	0	166.2	0	0	0	0	158.6	0	561.5
2023	120.8	18.6	0	0	156.8	0	130.4	0	0	130.9	0	0	557.5
Totals	737.1	20.8	90.8	7.8	211	209	229.8	85.3	69.3	343.5	325	121.1	2451

Figure 4. Total hours of broadband recordings collected at SOAR from 2012 to 2023.

1.4.2 PMRF

Archives have been collected on a total of 2,217 days from 2011-2023, with the number of days increasing substantially starting in 2017 (Figure 5). A total of 274.6 days of archives have been collected and processed for analysis during FY23. Archives collected since September 2023 are still in transit to NUWC NPT and are thus not included in this report. A total of 467.4 hours of broadband recordings have been collected since 2011, with 50.8 hours collected and analyzed during FY23 (Figure 5). Broadband recordings collected since October 2023 are still in transit to NUWC NPT and are thus not included in this report.

Total Days Archives Collected at PMRF

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2011	4.8	21.1	10.2	0	0	0.4	9.6	0.7	0	0	0	0	46.8
2012	9.2	0	0	0	0	17.8	2	0	0	0	0	0	29
2013	0	8	0	0	0	0	6.1	19	0	0	0	0	33.1
2014	0.1	26	14.1	0	4.3	30	31	19.4	0	10.7	0	0	135.6
2015	0	19.4	31	16.1	0	0	0	0	24.9	0.5	0	0	91.9
2016	0	9.4	0	0	0	0	0	4.9	0	0	0	0	14.3
2017	31	26.4	31	30	31	29.9	31	28.6	29.2	28.6	30	31	357.7
2018	0	27.4	31	11.4	7	11.1	30.7	18.6	10.1	30.6	24.5	0	202.4
2019	2.1	14.8	30.7	30	31	28.4	21	0	0	0	28.2	24	210.2
2020	25.2	13.9	25.5	9.3	30.6	28.9	20.5	28.2	30	30.7	29.9	12.1	284.8
2021	19.7	28	31	28.7	30.9	29.1	30.5	23.5	30	30.9	30	22.6	334.9
2022	30.8	28	31	30	31	30	12.4	8	2.1	28.7	30	18.5	280.5
2023	8	28	31	29.7	30.9	29.3	30.7	7.7	0	0	0	0	195.3
Totals	130.9	250.4	266.5	185.2	196.7	234.9	225.5	158.6	126.3	160.7	172.6	108.2	2217

Figure 5. Total days in which archives reports were collected at PMRF from 2011-2023.

Total Hours Broadband Recording at PMRF

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2011	0	0	0	0	0	0	50.9	0.6	0	0	0	0	51.5
2012	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	12.2	0	0	0	0	0	0	0	0	0	0	12.2
2014	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	0.1	55	0	0	0	0	0	0	35.8	0	0	0	90.9
2016	0	0	0	0	0	0	0	2	0	0	0	0	2
2017	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	0	0	0	0	0	0	23.6	0	0	0	0	23.6
2019	0	0	0	0	0	0	0	0	0	0	0	0	0
2020	0	9.7	0	0	0	0	0	0	0	0	0	0	9.7
2021	0	0	0	0	0	0	2.3	22.3	0	0	0	0	24.6
2022	76.8	0	30	29.2	46.1	0	0	20	0	0	0	0	202.1
2023	0	0	0	0	0	0	0	50.8	0	0	0	0	50.8
Totals	76.9	76.9	30	29.2	46.1	0	53.2	119.3	35.8	0	0	0	467.4

Total hours of broadband recordings collected at PMRF from 2011-2023.

2 Abundance and Temporal Occurrence of Cuvier's and Blainville's Beaked Whales

2.1 Methods

The long-term detection archives recorded at SOAR and PMRF allow for analysis of trends in detections over time. Changes in relative detections could indicate changes in foraging behavior, prey quality or density, or animal abundance. The abundance estimation methods developed here utilize archive data that are collected on the ranges over long time periods at a relatively low cost. This passive acoustic method of abundance estimation provides insights into the populations of species on range, along with potential changes in these populations over time. However, these methods only account for vocalizing individuals.

Substantial effort went into streamlining the abundance estimation process. Extensive quality assessments were also performed on the original archives collected from the range as well as the data products produced in the pre-processing stage of analysis. Once data products are reviewed they are included in the M3R_Data repository, which is accessible to all team members on all net connected government computers.

Analysis and processing scripts were written using R (version 4.2). Modular programming was utilized to streamline and increase the flexibility of the code (e.g., enabling switching between ranges via the use of configuration files), ensuring a consistent methodology across all ranges. The modularized code allows for additional data to be added seamlessly as it is collected from the ranges, without the need for manual insertion of additional lines of code. This makes the code easier to execute and understand, thus allowing for more stream-lined updates to methods in the future. In addition to modularizing the code, analysis tools for pre-processing and abundance estimation were included in a code repository to ensure access and proper version control. A detailed flow chart of these methods can be seen in Appendix A.

2.1.1 Pre-processing

Archives collected on the range are processed through several standard Java and MATLAB based programs before analysis.

A Java-based indexer program reads the binary archive files collected from the range, documenting the start and stop time of every archive file collected. The output is a CSV file listing these times, which is used to assist in quality control of the archives. This file is also used during the abundance and temporal occurrence analysis to determine the hours of effort.

The archives are then processed through the click train processor (CTP): a Java-based program that associates click detections from the binary archive files into click trains. Detections for a particular class are grouped into click trains on a per hydrophone basis. A click train is initiated when a click is detected, and clicks are added to the click train until at least three minutes pass without detections. At this point, if the click train has at least five clicks a click train report is generated and saved in a CSV file; otherwise, the click train is discarded.

A MATLAB-based script called auto-grouper imports the click trains of a single species class from the CTP CSV, then uses a set of rules based on time and location of the click trains to associate the CTP click trains into Group Vocal Periods (GVPs). For Cuvier's beaked whales, only click trains with an inter-click interval (ICI) greater than or equal to 0.35 sec and an ICI less than or equal to 0.75 sec are used in the grouping process. For Blainville's beaked whales, click trains with an ICI between 0.23 and 0.4 sec are used. For both species only click trains with durations greater than 1 min and less than 60 min are used. Locations are based on the hydrophone locations, with the beaked whale group center being the hydrophone with the highest click density (number of clicks per min). To form a GVP the click trains must be within 9.75 km[1] of the group center.

A MATLAB-based script called missing hydrophones also imports click train CSVs, and lists hydrophones where no CS-SVM classifier detections were made. This approximates times hydrophones were down over the course of continuous time periods, under the assumption that over the course of several days at least one echolocating animal will be detected if the hydrophone was working. The script results are reviewed manually to reduce the effects of shorter time periods.

2.1.2 Temporal Occurrence and Abundance Estimation (R-based)

2.1.2.1 Determine Hours of Effort

Index CSV files for the required time periods are read into R. Continuous archives are determined by delays less than 2 seconds between the end of one archive and the start of the next archive. Time is divided into one-hour bins and only bins containing a complete hour worth of data are used for analysis. At this stage, an effort data frame consisting of effort for all hydrophones at every hour bin is initialized. The effort matrix is then updated to account for individual, nonoperational hydrophones at various times indicated in the missing hydrophones CSV produced by the MATLAB script during the preprocessing. The total number of hydrophone hours are averaged to produce the percent effort for every one-hour bin.

2.1.2.2 Finalize group vocal periods and calculate abundance

Additional processing is required to finalize the GVP counts before statistical modeling and abundance estimation can occur. R generates summary data for each group after filtering the GVPs based on duration and total number of clicks. For Cuvier's beaked whales, GVPs with fewer than 300 clicks or more than 43,400 clicks are removed, where the number of clicks is filtered based on a minimum of one animal clicking for 2.5 min and a maximum of six animals clicking for 60 min, at a click rate of two clicks per sec. For Blainville's beaked whales the GVPs must contain between 360 and 64,800 clicks, where the number of clicks is filtered based on a minimum of one animal clicking for 2 min and the maximum is six animals clicking for 60 min at a click rate of three clicks per sec. GVPs less than 5 min or greater than 90 min are also removed to reduce the rate of false positives. The remaining GVPs are then summed on a

[1] Group radius is based on observed spread of detections during real-time monitoring and manual review of the archives

hydrophone-hour basis, attributing the group to a single central hydrophone for the vocal group. The GVP counts are collected in a data frame mirroring the hours of effort data frame where there is a column for each hydrophone and the rows are one-hour bins. Additionally, the GVP count is summed for all hydrophones and corrected by dividing by the percent effort and applying a correction factor derived from the detection statistics (Table 1) using Equation 1:

$$\textbf{Equation 1: } \boldsymbol{GVP_{corr} = \frac{\sum GVP}{PE} * CF_N * CF_P}$$

where PE is the percent effort (i.e., proportion of hydrophones producing data), GVP is the sum of all GVPs in that hour, CF_N is the correction factor for false negatives and CF_P is the correction factor for false positive. The resulting GVP_{corr} value is used in the statistical model.

Moretti et al. (2010) described a passive acoustic method for determining Blainville's beaked whale density and abundance at the U.S. Navy's Atlantic Undersea Test and Evaluation Center (AUTEC) using a dive counting method. This method uses the start of a deep foraging dive (indicated by the first detected click) as the cue for determining density and abundance. Since this analysis is conducted using over more than a decade's worth of data with automated tools, as opposed to the manual analysis carried out by Moretti at AUTEC, the abundance equation is modified to account for both the probability of detection and the proportion of false positives. The equation used for abundance in this analysis is:

$$\textbf{Equation 2: } \boldsymbol{N = \frac{n_d * s * (1-FP)}{r_d * PE * PD}}$$

where n_d is the total number of dive starts (or GVPs), s is the average group size, r_d is the dive rate (dives/unit time), PE is the percent effort, FP is the proportion of false positive detections, and PD is the probability of detection. Values used in the calculations for this report are given in Table 1.

Table 1. Variables used in abundance calculations

Variable	*SOAR*		*PMRF*	
	Value (CV)	*Reference*	*Value*	*Reference*
s	3.18 (0.62)	E. Falcone, pers. comm., December 06, 2017	3.6 (*Md*) / 2.6 (*Zc*)	Baird et al. 2006
r_d	0.3 (0.17)	Schorr et al. 2014	0.42 (*Md*) / 0.40 (*Zc*)	Baird et al. 2008
FP	0.185 (0.32)	Calculated[2]	0.188 (*Md*)	Calculated[3]
PD	0.76 (0.05)	Calculated[2]	0.283 (*Md*)	Calculated[3]

[2] Values calculated using methods in DiMarzio and Jarvis (2016). Efforts are underway to finalize and document these values.

[3] Efforts to update detection statistics for *Zc* and *Md* at PMRF are being finalized and documented. Updated statics will be used for final publication but were not available for report analysis.

2.1.2.3 Statistical Model

To examine the long-term and seasonal trends in abundance and occurrence, a Generalized Additive Model (GAM) was used to model the number of GVPs per day on range (GVP). First an analysis data frame was created, summarizing the total number of GVPs per day. The response of GVP's is not normally distributed, so two families of GAMs, Tweedie (R-Model 1) and Negative Binomial (R-Model 2), were tested for each range and species. The GAM producing the lowest AIC was utilized for the analysis. In both models day of year (DOY) was used as a predictor for seasonal occurrence, and year was used as a predictor for long-term trends. The log of the effort (logEff) was used as an offset to account for the spatial variation in effort (i.e., the fact that at times data were not obtained from select hydrophones). Note in seasonal trend plots using day of year as a predictor, month names were utilized on the x-axis for legibility. All plots show the partial effect of each predictor on the y-axis.

R-Model 1:
```
TW_GAM <- gam(tot_gvp + 0.000001 ~ s(DOY, bs="cc") + s(year) +
    offset(logEff), family = tw(), data = gamDF)
```

R-Model 2:
```
NB_GAM <- gam(tot_gvp + 0.000001 ~ s(DOY,bs="cc") + s(year) +
    offset(logEff), family = negbin(3), data = gamDF)
```

2.2 SOAR

Cuvier's beaked whale temporal occurrence was analyzed using CS-SVM archives from SOAR May 2010 through July 2023. After removing partial hours of effort and scaling by the number of hydrophones per hour on which data were collected, a total of 48,495 hours of data were processed, with the number of hours per year varying from a low of 1,073 hours in 2012 to a high of 6,113 hours in 2019 (Table 2).

Table 2: Total number of hours of effort per year analyzed from 2010 to 2023 at SOAR

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Hours	1073	3001	1375	1822	3804	2895	3115	3699	5706	6113	1847	4160	4332	5553

2.2.1 SOAR: Cuvier's Beaked Whale Abundance and Temporal Occurrence

Table 3 shows the mean hourly abundance of *Zc* at SOAR with the upper and lower limits of the 95% confidence interval. These results show higher abundances from December through May, with a maximum mean monthly abundance of 67.5 animals/hour in January. The lowest mean monthly abundance occurred in September (20.2 animals/hour). The Tweedie family generalized additive model (GAM) had the best fit for *Zc* at SOAR, and showed both year and day of year predictors were very significant ($p < 2^{-16}$) for determining the number of GVPs per day at SOAR. Detailed metrics relating to the GAM can be seen in Appendix B. Figure 6 shows the seasonal occurrence using the day of year predictor from the GAM. This confirms that the abundance of *Zc* peaks from December through May with local maximums around January and May, while the abundance of *Zc* declines in the fall, particularly in September and October.

Table 3: Mean monthly abundance (animals/hour) of *Zc* at SOAR with 95% confidence intervals from 2010-2023.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lower Limit	65.9	51.3	59.8	54.6	63.2	41.6	33.3	25.7	19.6	21.5	32.7	53.8
Mean	67.5	52.6	61.2	55.7	64.4	42.7	34.2	26.4	20.2	22.3	33.8	55.1
Upper Limit	69.0	53.8	62.5	56.8	65.7	43.8	35.1	27.0	20.8	23.0	34.8	56.4

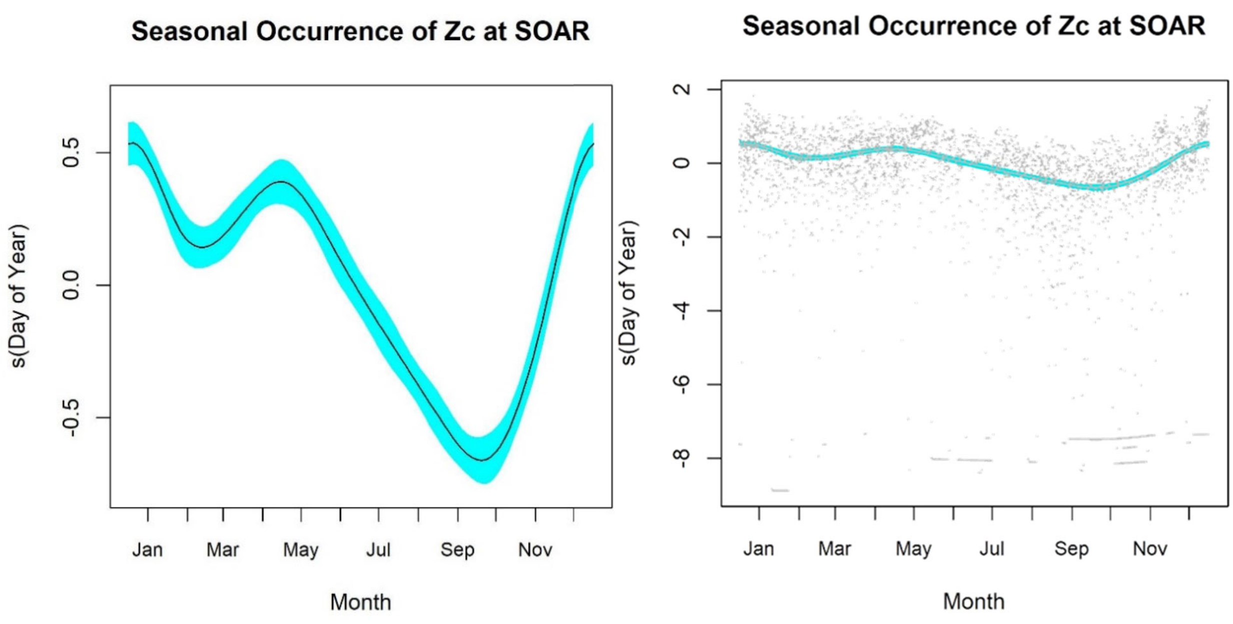


Figure 6: Seasonal Occurrence of Cuvier's beaked whale at SOAR, smooth of Day of Year predictor (left) with residuals (right) from Tweedie family GAM

Table 4 shows the mean abundance (animals/hour) of *Zc* at SOAR. The maximum calculated abundance occurred in January 2023 at 110.3 animals/hour, and the lowest calculated mean abundance was 0 animals/hour which occurred in June 2011 and October 2018. The long-term trend of *Zc* abundance at SOAR (Figure 7) shows fluctuations with a global minimum in 2018, and peaks around 2012, 2016, and 2020.

Table 4: Mean monthly abundance per hour of *Zc* at SOAR per year from 2010-2023. NA indicates no data were available for analysis.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	NA	NA	NA	NA	NA	NA	NA	25.2	27.8	17.9	54.6	72.3
2011	80.3	42.4	44.2	58.8	62.2	0	31.4	33.5	7.6	10.9	17.5	51.7
2012	78.1	73.2	77.1	53.2	58.2	NA	17.9	20.6	NA	42.5	30.5	16.8
2013	NA	NA	56.4	32.0	105.2	69.4	39.8	20.0	17.1	22.4	31.4	63.8
2014	58.6	46.8	53.3	66.5	66.9	35.2	10.9	18.2	22.3	31.4	59.7	59.8
2015	55.4	34.2	39.7	46.4	42.7	40.4	24.8	19.2	26.2	39.8	39.8	89.8
2016	80.4	59.9	47.8	61.5	50.3	46.4	48.3	33.7	22.1	NA	44.5	83.4
2017	61.3	NA	38.4	53.4	42.9	NA	32.3	30.8	25.7	21.8	29.0	50.3
2018	47.4	48.95	47.8	36.6	50.2	41.7	44.3	27.8	14.2	0	10.6	42.2
2019	44.0	41.0	32.8	43.8	59.1	50.0	42.4	35.1	18.6	16.5	27.8	29.0
2020	39.6	60.5	NA	62.0	50.9	NA	NA	NA	NA	32.2	43.4	NA
2021	64.8	49.0	50.4	43.2	35.6	34.1	37.2	33.6	32.4	23.2	24.0	NA
2022	37.2	33.0	37.5	18.1	23.0	21.6	30.7	14.1	13.6	28.2	65.0	48.3
2023	110.3	68.4	109.5	100.1	100.0	74.9	41.2	NA	NA	NA	NA	NA

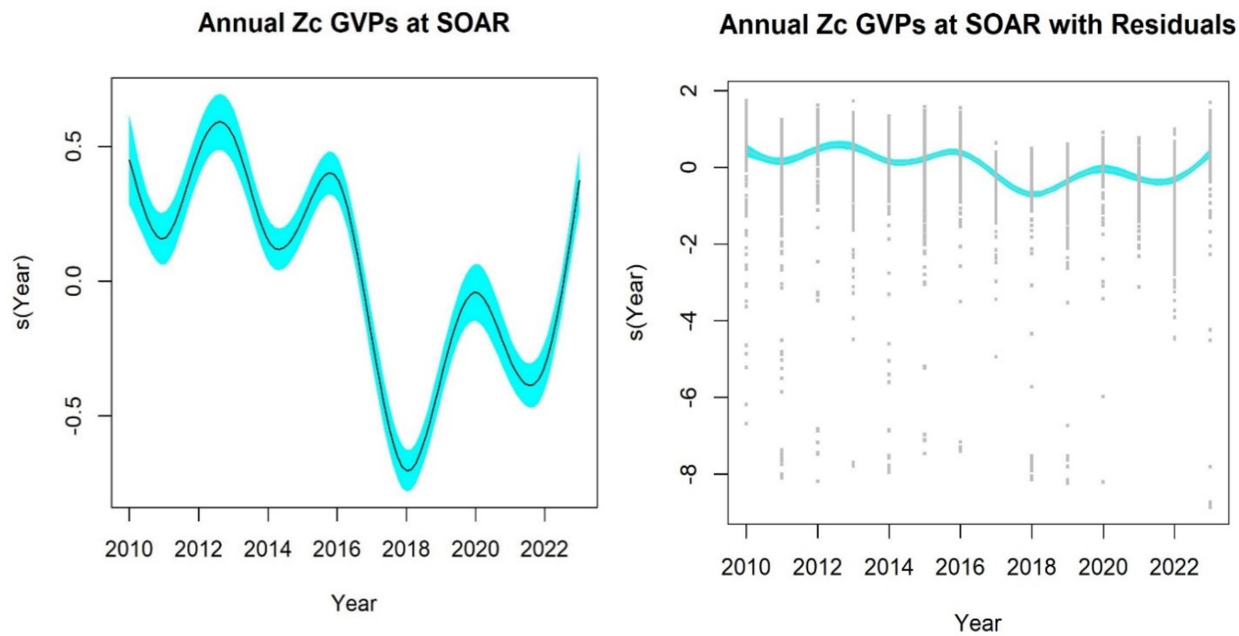


Figure 7: Long-term trend of Cuvier's beaked whale abundance at SOAR, smooth of year predictor (left) with residuals (right) from Tweedie family GAM.

2.3 PMRF

Blainville's and Cuvier's beaked whale occurrence and abundance were analyzed using PMRF CS-SVM archives from 2011 through 2023. After removing partial hours of effort and scaling by the number of hydrophones per hour where data were collected, a total of 40,213 hours of data were processed with the number of hours per year ranging from 239 hours in 2011 to 8,368 hours in 2017 (Table 5). During FY22, we discovered a large portion of the data collected April-July 2021 only contained data from the BSURE portion of the range (Dolan et al. 2023). Due to the different spatial occurrences and to account for any resulting issues or discrepancies in abundances estimates, the full abundance and temporal occurrence analysis were completed at BARSTUR and BSURE separately as well as on the entire range (described as PMRF in the following text, tables, and figures).

Table 5. PMRF: Total number of hours of effort per year of processed data.

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Hours	239	654	738	2943	2074	330	8368	3762	4739	4545	3975	5627	2219

2.3.1 PMRF: Blainville's Beaked Whale Abundance and Temporal Occurrence

Table 6 shows the mean hourly abundance calculated separately for BARSTUR, BSURE, and the whole range (PMRF) as well as the sum of the means calculated for BARSTUR and BSURE. These results suggest a slightly larger number of animals per hour present at BARSTUR most of the year; however, this trend is not seen in June or July. Additionally, the values representing the entire range in Table 7, closely resemble the combined mean monthly values of BARSTUR and BSURE, suggesting any period without BARSTUR or BSURE data will not have a large effect on the abundance estimate for Blainville's beaked whales.

Table 6. Mean hourly Blainville's beaked whale abundance at PMRF averaged monthly from 2011-2023, shown at whole range, BARSTUR and BSURE.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BARSTUR	8.6	9.8	10.5	11.2	11.0	9.9	8.6	9.1	8.3	8.9	5.7	7.6
BSURE	6.1	6.8	7.9	9.6	11.0	11.3	11.1	8.1	7.8	7.9	6.5	8.1
PMRF	14.8	16.6	18.7	20.9	22.6	22.3	21.3	16.8	15.2	16.5	12.6	16.3
BSURE + BARSTUR	14.7	16.7	18.4	20.8	21.9	21.3	19.7	17.2	16.1	16.8	12.2	15.7

Results from the GAM show that both the day of the year and year predictors were very significant ($p < 2e^{-16}$) for determining the number of GVPs per day at PMRF. For all three iterations of this analysis, the Tweedie distribution was chosen due to having a lower AIC than negative binomial distribution. Detailed metrics on model fit can be found in Appendix B. Figure 8 shows the seasonal occurrence of *Md* at PMRF, and BARSTUR and BSURE using the day of year predictor from the GAM. Overall, the seasonal occurrence of *Md* peaks March through July, with BARSTUR showing a peak abundance from March through May, while the peak occurs later at BSURE from May through July.

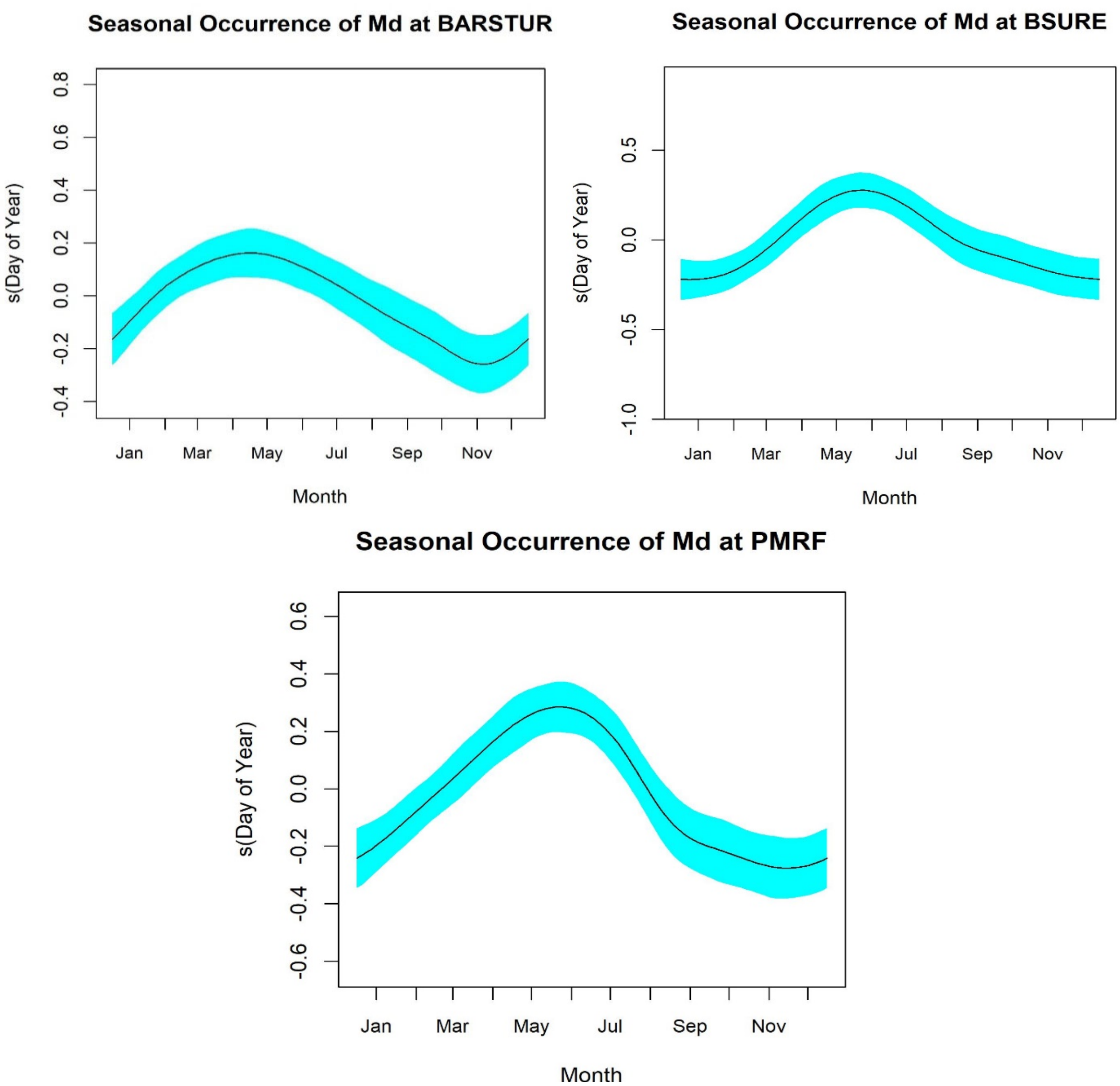


Figure 8. Seasonal Occurrence of Blainville's beaked whales at BARSTUR (upper left), BSURE (upper right), and PMRF (bottom).

The long-term trend of *Md* abundance at PMRF (Figure 7) appears to have fluctuated with peaks around 2014 and 2017, and lower levels in 2016 and 2019. The low in 2019 was likely the result of limited data collection during high peak abundance periods (Table 18).

Table 7. Mean hourly abundance of Blainville's beaked whales per month at PMRF from 2011 - 2023. NAs indicate periods without data.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011	NA	NA	NA	NA	NA	22.94	29.43	29.31	NA	NA	NA	NA
2012	27.65	NA	NA	NA	NA	23.95	22.94	NA	NA	NA	NA	NA
2013	NA	26.42	NA	NA	NA	NA	22.59	12.58	NA	NA	NA	NA
2014	0	14.78	7.75	NA	18.98	18.18	16.05	18.38	NA	23.71	NA	NA
2015	NA	10.61	13.21	11.70	NA	NA	NA	NA	18.83	14.73	NA	NA
2016	NA	10.68	NA	NA	NA	NA	NA	12.67	NA	NA	NA	NA
2017	0	16.53	23.60	26.09	25.78	36.03	29.52	15.97	16.57	20.72	16.49	21.53
2018	14.69	11.93	17.10	14.30	28.15	18.84	17.91	21.37	NA	NA	NA	NA
2019	12.35	18.29	19.23	15.64	16.49	8.61	16.48	NA	NA	NA	10.52	10.21
2020	16.90	16.41	12.18	24.90	20.17	15.05	3.96	4.55	4.06	8.34	8.94	10.04
2021	7.41	8.91	11.59	11.05	19.10	22.50	27.26	17.88	19.77	29.49	23.45	27.22
2022	20.22	19.70	21.18	24.88	26.08	27.61	25.66	39.66	0	0.51	0	0.90
2023	30.71	25.23	26.53	24.78	NA	NA	NA	22.76	NA	NA	NA	NA

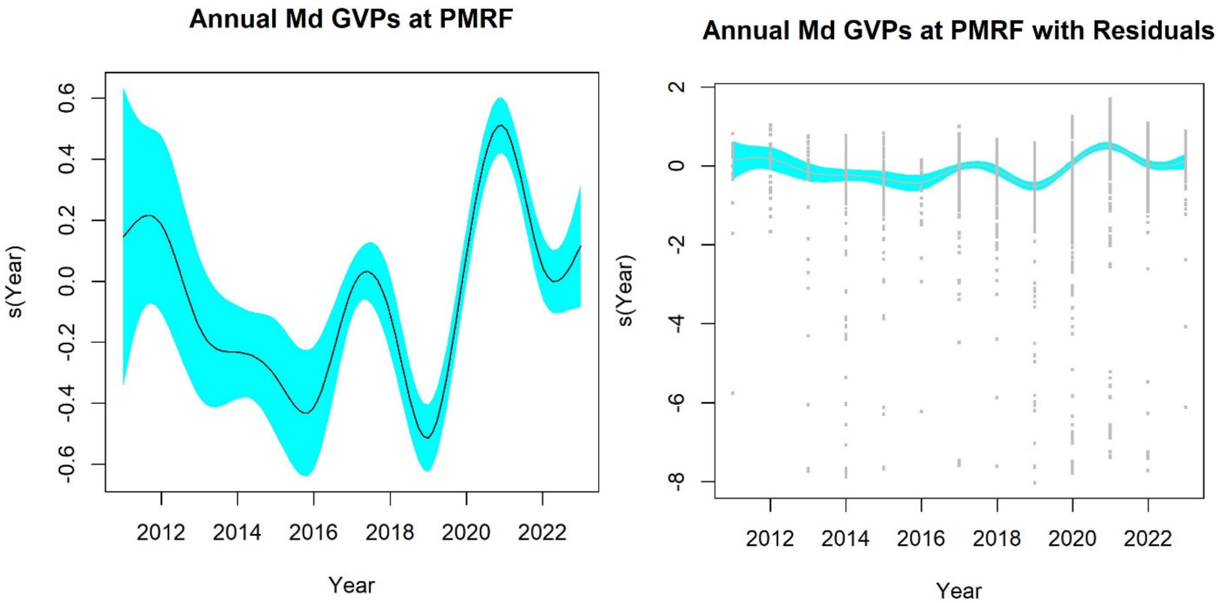


Figure 9. Long term trends of Blainville's beaked whales at PMRF.

2.3.2 PMRF: Cuvier's Beaked Whale Abundance and Temporal Occurrence

Table 8 shows the mean hourly abundances for BARSTUR, BSURE, and the whole range (PMRF) as well as the sum of the means calculated for BARSTUR and BSURE. Results depict most animals are at BARSTUR from February through August, and about the same the remainder of the year. In Table 8 the calculated values from the whole range are higher than the combined mean monthly values from BARSTUR and BSURE, especially from April through July. This suggests this species prefers the deeper waters at the BSURE portion of the range. It should also be noted that if any data collected from the range is missing a significant portion of either of these locations then it will be biased if treating the range as a whole. Any future estimations of abundance of *Zc* at PMRF should calculate abundances for BARSTUR and BSURE separately.

Table 8. Mean hourly abundance of Cuvier's beaked whales at PMRF averaged monthly from 2011-2023 for the whole range (PMRF), and BARSTUR and BSURE individually.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BARSTUR	1.83	3.16	3.65	3.20	2.64	1.95	1.02	0.83	0.92	0.41	0.61	0.78
BSURE	1.45	3.12	2.55	4.38	8.91	7.06	6.94	0.65	0.62	0.90	0.70	1.03
PMRF	3.09	5.92	6.04	9.93	19.14	15.12	14.04	1.33	1.31	1.25	1.19	1.74

BSURE + BARSTUR	3.28	6.28	6.2	7.58	11.55	9.01	7.96	1.48	1.54	1.31	1.31	1.81

According to the GAM results, both the day of the year and year predictors were very significant ($p < 2e^{-16}$) for determining the number of GVPs per day at PMRF. For all three iterations of this analysis, the

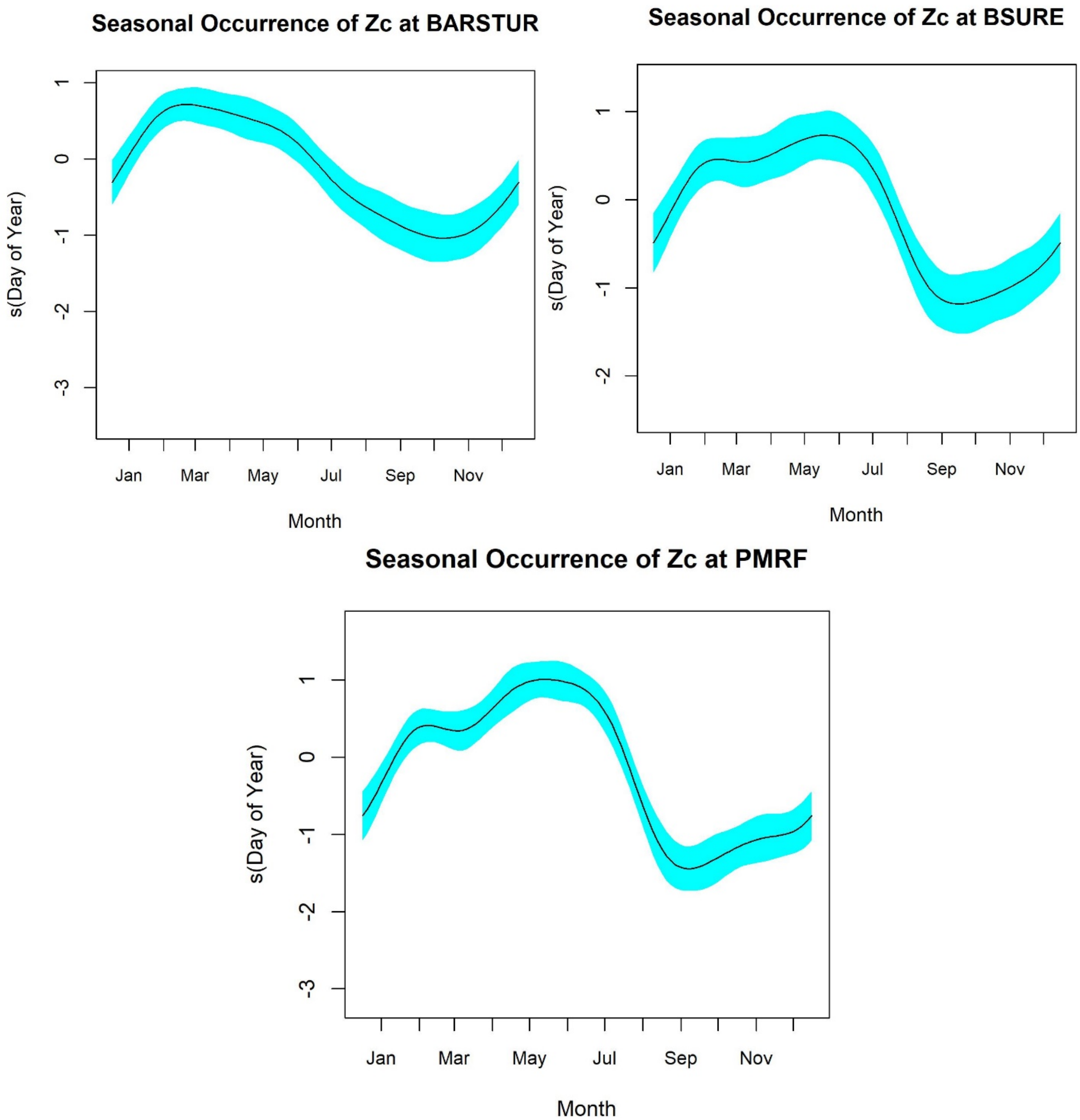


Figure 10. Seasonal Occurrence of Cuvier's beaked whales at BARSTUR (upper left), BSURE (upper right), and PMRF (bottom).

Tweedie family had a better fit than the negative binomial family. Detailed metrics on model fit can be found in Appendix B. Figure 10 shows the GAM representation of seasonal occurrence of *Zc* at PMRF, BARSTUR and BSURE separately. Overall, the seasonal distribution of *Zc* peaks in February through July and declines in September/October period, with BSURE mirroring this overall trend while the peak at BARSTUR occurs over the same period but is less pronounced.

The long-term trend of *Zc* at PMRF (Figure 11) fluctuates over the years but suggests a slight increase in population overall. The low in 2016 was likely caused by limited data collection during high peak abundance periods (Table 9), and the peak in 2021 is due to the abnormally high abundances seen (in red) from April through July in that year. While calculating the abundance of *Zc* at BARSTUR and BSURE separately has reduced the effects of these months, these abundances are still suspect. Further investigation into source data are underway, and are contributing to the delay of a peer-reviewed publication.

Table 9. Mean hourly abundance of Cuvier's beaked whale at PMRF per month from 2011 - 2023. NAs indicate periods without data. Values represent BARSTUR+BSURE. Period under investigation highlighted with red text

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011	NA	NA	NA	NA	NA	0	1.07	2.20	NA	NA	NA	NA
2012	2.29	NA	NA	NA	NA	1.59	0.44	NA	NA	NA	NA	NA
2013	NA	3.58	NA	NA	NA	NA	1.78	0.33	NA	NA	NA	NA
2014	0.00	4.56	2.06	NA	0.41	1.31	1.13	1.06	NA	4.16	NA	NA
2015	NA	7.86	4.80	5.73	NA	NA	NA	NA	2.24	1.56	NA	NA
2016	NA	4.71	NA	NA	NA	NA	NA	1.82	NA	NA	NA	NA
2017	0.00	6.17	10.49	6.71	3.80	4.51	3.19	2.28	2.75	1.63	1.59	2.81
2018	5.84	10.63	6.81	4.18	6.83	4.08	2.51	1.27	NA	NA	NA	NA
2019	5.35	6.25	6.29	4.34	3.76	3.59	3.14	NA	NA	NA	2.69	2.66
2020	2.05	5.05	4.87	7.64	3.22	2.24	0.60	0.00	0.04	0.11	0.04	0.09
2021	0.12	0.16	0.09	28.90	42.08	43.74	41.72	0.82	0.45	1.96	1.72	1.53
2022	5.30	6.95	5.14	1.57	4.84	3.61	1.55	6.48	0.00	0.07	0.00	0.00
2023	6.16	6.84	7.66	7.89	NA	NA	NA	2.21	NA	NA	NA	NA

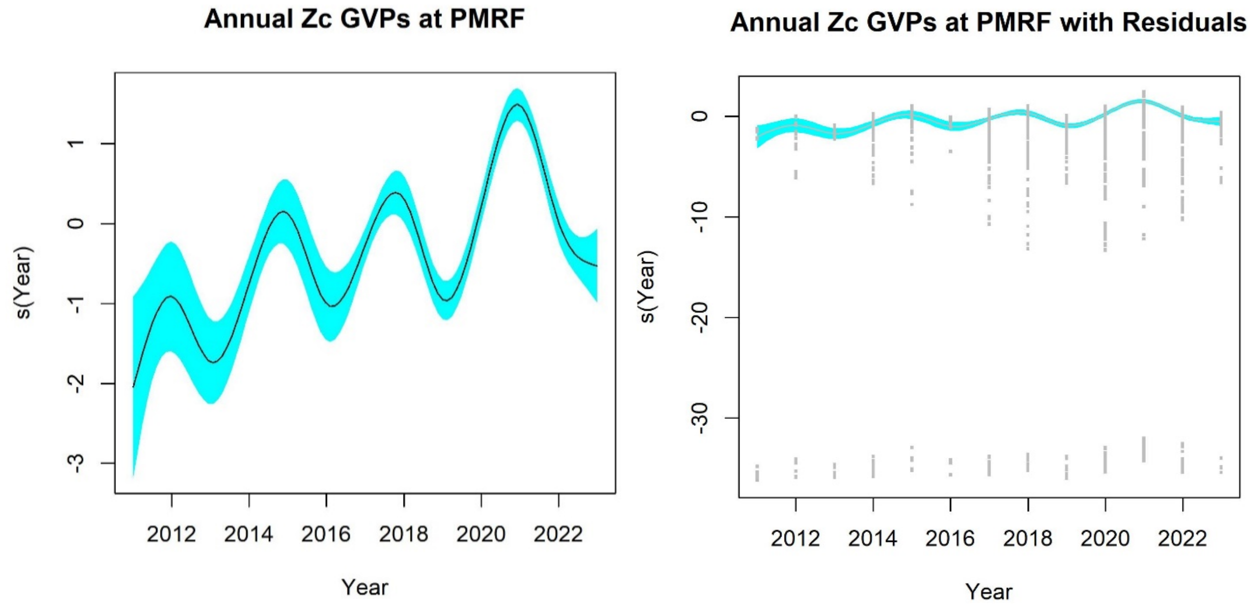


Figure 11. Long term trends of Cuvier's beaked whale abundance at PMRF (left) with residuals (right).

3 Real-Time Monitoring of On-Water Operations

3.1 SOAR

3.1.1 Data Summary

Five field surveys were conducted in fiscal year (FY) 2023 on SOAR in coordination with Marine Ecology and Telemetry Research (MarEcoTel). They took place in November 2022, and February, May, July and October 2023. An additional survey was attempted in January 2023, but was canceled due to poor weather conditions. Effort was primarily focused on collecting data on Cuvier's beaked and fin whales present on SOAR, though data on other species was collected opportunistically. Using a Rigid Hull Inflatable Boat (RHIB), MarEcoTel personnel would transit daily from San Clemente Island (SCI) at sunrise to locations of marine mammals on SOAR provided by M3R personnel. The locations were mostly generated automatically by the M3R signal processing cluster localization code, which indicate a level of confidence for each position. M3R personnel use both these automated outputs, and real-time review of binary spectrograms to identify relevant species and determine the best locations to communicate. Manual localization is also employed when necessary. Raven Pro Sound Analysis Software (Cornell University, Ithaca, NY) has also been modified to stream M3R data in real-time allowing M3R personnel to view non-binary spectrograms (i.e. spectrograms with complete magnitude information) on individual hydrophones on demand, which assists with species identification. These data and additional notes are recorded in a Logger program; raw acoustic data from the whole range or from selected hydrophones may be recorded; and all automated detections, localizations, and ancillary data are automatically saved to binary archive files ('spc archive' files) on a continuous basis. Animal location and start/stop times of vocalizing groups are communicated to MarEcoTel via satellite texts and calls. Upon finding animals, MarEcoTel collects photo-ID and behavioral data and biopsy samples, and potentially places Sound and Motion Recording Tags (SMRT tags) or Low Impact Minimally Percutaneous Electronic Transmitter (LIMPET) satellite tags on individuals.

Table 10 lists the marine mammal species acoustically identified using the M3R system during the five field surveys in FY23, along with summary information extracted from the associated SOAR field logs. More detailed information from these field logs can be found in Appendix A, section 8.1.

A total of 555 acoustic detections were logged (Figure 12-Figure 16), including 359 for Cuvier's beaked whales, 51 for fin whales, 44 for blue whales, 11 for humpback whales, 10 for sperm whales, five for short-beaked common dolphins, four for Risso's dolphins, as well as single detections for minke whales, Northern right whale, striped, and bottlenose dolphins. Three rare detections included two for short-finned pilot whales, which prior to 2022 hadn't been seen in over a decade near SOAR, and one for Gervais beaked whales, the later only detected acoustically. There were acoustic detections that were unable to be identified to the species level, including 60 for delphinid species, three for baleen whales and one for beaked whales. Note that the detections do not necessarily indicate unique groups; in fact, Cuvier's beaked whale detections often recur in the same area periodically throughout the day, which may indicate a unique foraging group in a particular location. In addition, not all species that were present were logged. Due to M3R personnel constraints and species priority, not all dolphin and baleen whales present on range were logged.

M3R directed MarEcoTel to animals of interest for 87 of the acoustic detections. Here 'directed' acoustic detections are considered those in which a location was sent, and the field team decided to go to the location. MarEcoTel visually verified 22 groups of Cuvier's beaked whales, eight of fin whales, three blue whales, as well as single groups of humpback whales, sperm whales, short-finned pilot whales, short-beaked common, and Northern right whale dolphins. Numerous photos and behavioral data were collected from all visually verified species. Seven groups of Cuvier's beaked whales, two groups of blue whales, one group of fin whales, and one group of short-finned pilot whale were successfully tagged. In addition, a single blue whale and short-beaked common dolphin were biopsied. See MarEcoTel monitoring report (Schorr et al. 2023) for details on sightings, tags, and biopsies.

Table 10. Species acoustically identified with the M3R system at SOAR in fiscal year (FY) 2023. Data are extracted from field test logs from FY23.

Species			Acoustic Detections Logged	Acoustic Detections Directed	Acoustic Detections Visually Verified	No. of Tags Deployed
ID	Common Name	Scientific Name				
Zc	Cuvier's beaked whale	*Ziphius cavirostris*	359	59	22	7
Me	Gervais beaked whale	*Mesoplodon europaeus*	1	0	0	0
Bp	Fin whale	*Balaenoptera physalus*	51	14	8	2
Bm	Blue whale	*Balaenoptera musculus*	44	4	3	1
Ba	Minke whale	*Balaenoptera acutorostrata*	1	0	0	0
Mn	Humpback whale	*Megaptera novaeangliae*	11	2	1	0
Pm	Sperm whale	*Physeter macrocephalus*	10	2	1	0
Gm	Short-finned pilot whale	*Globicephala macrorhynchus*	2	1	1	1
Gg	Risso's dolphin	*Grampus griseus*	4	0	0	0
Dd	Short-beaked common dolphin	*Delphinus delphinus*	5	1	1	0
Lb	Northern right whale dolphin	*Lissodelphis borealis*	1	1	1	0
Sc	Striped dolphin	*Stenella coeruleoalba*	1	0	0	0

Tt	Common bottlenose dolphin	*Tursiops truncatus*	1	0	0	0
UZ	Unidentified beaked whale	Ziphius sp.	1	0	0	0
UD	Unidentified dolphin	Delphinidae sp.	60	2	0	0
UM	Unidentified baleen whale	Mysticeti sp.	3	1	0	0

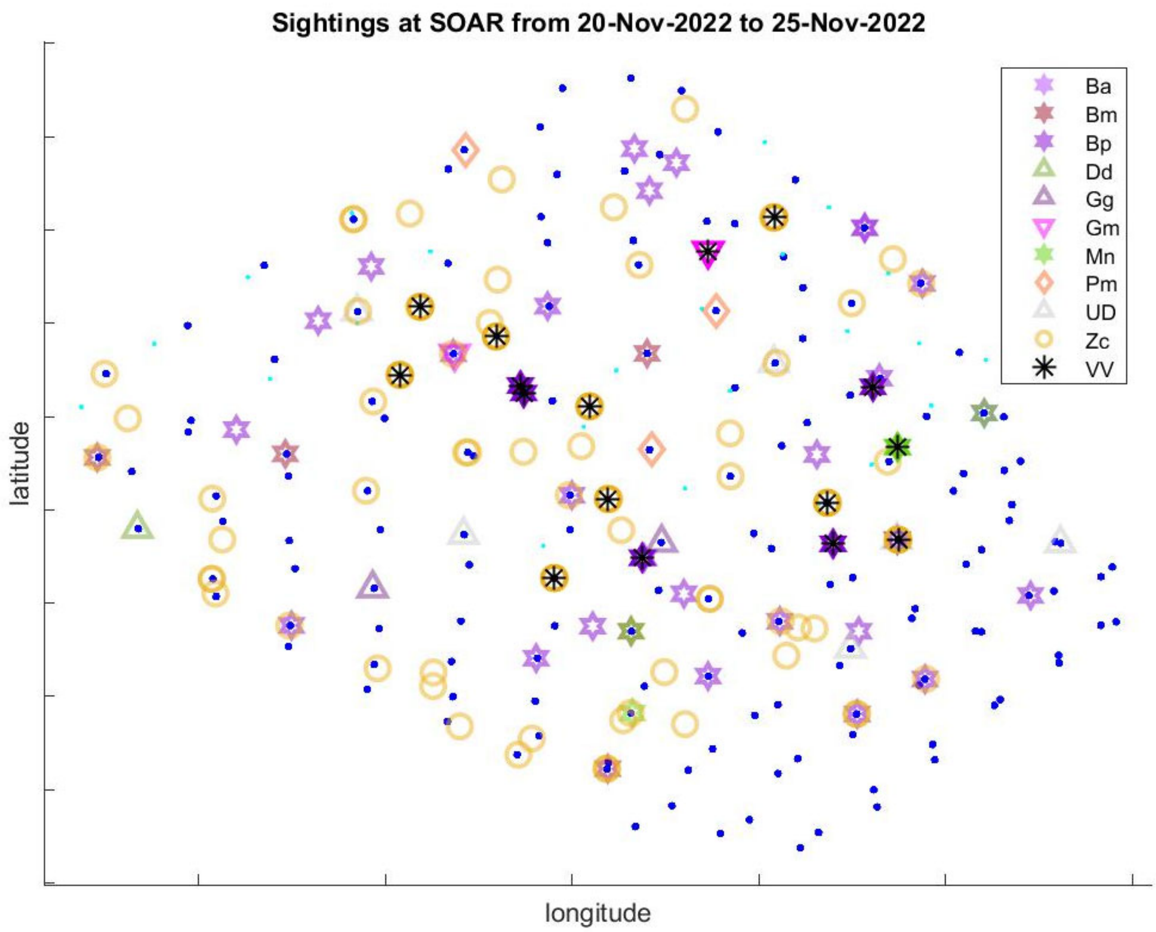


Figure 12. Acoustic detections (sightings) at SOAR from November 20 - 25, 2022. Species included blue whale (Bm), fin whale (Bp), Minke whale (Ba), short-beaked common dolphins (Dd), Risso's dolphin (Gg), short-finned pilot whale (Gm), humpback whale (Mn), sperm whale (Pm), Cuvier's beaked whale (Zc), and unknown delphinidae species (UD). Detections that were visually verified (VV) by MarEcoTel are overlaid with an asterisk.

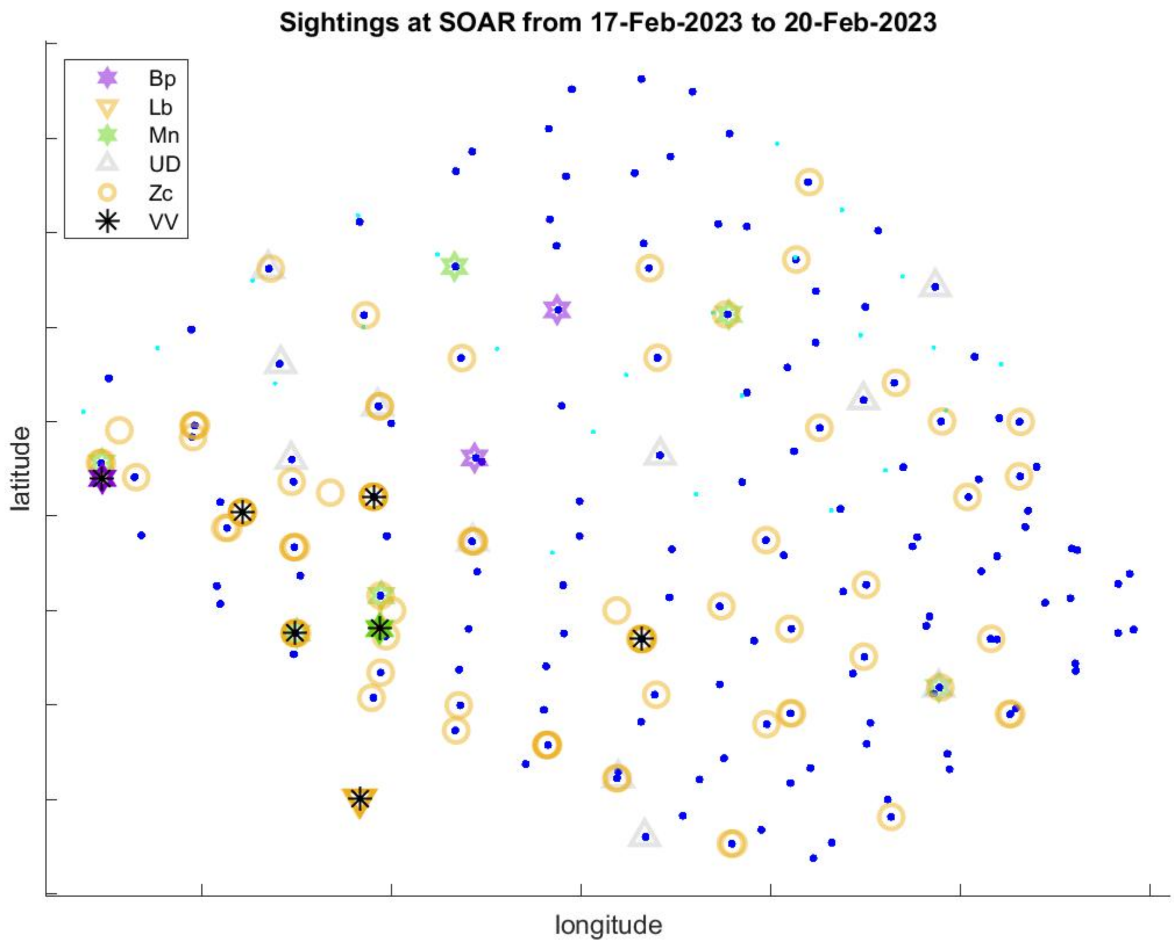


Figure 13. Acoustic detections (sightings) at SOAR from February 17 - 20, 2023. Species included fin whale (Bp), northern right whale dolphin (Lb), humpback whale (Mn), Cuvier's beaked whale (Zc), and unknown delphinidae species (UD). Detections that were visually verified (VV) by MarEcoTel are overlaid with an asterisk.

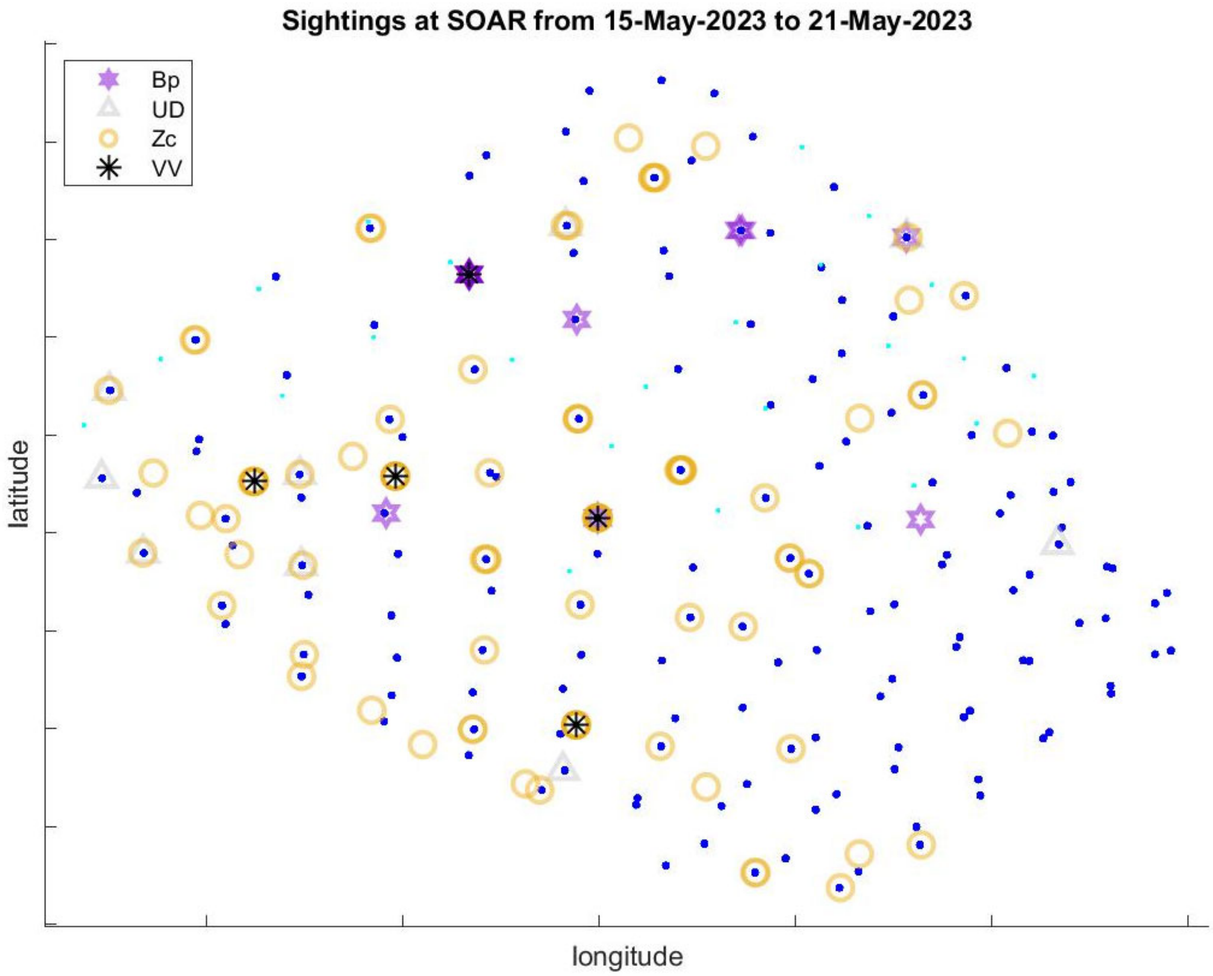


Figure 14. Acoustic detections (sightings) at SOAR from May 15 - 21, 2023. Species included fin whale (Bp), Cuvier's beaked whale (Zc), and unknown delphinidae species (UD). Detections that were visually verified (VV) by MarEcoTel are overlaid with an asterisk.

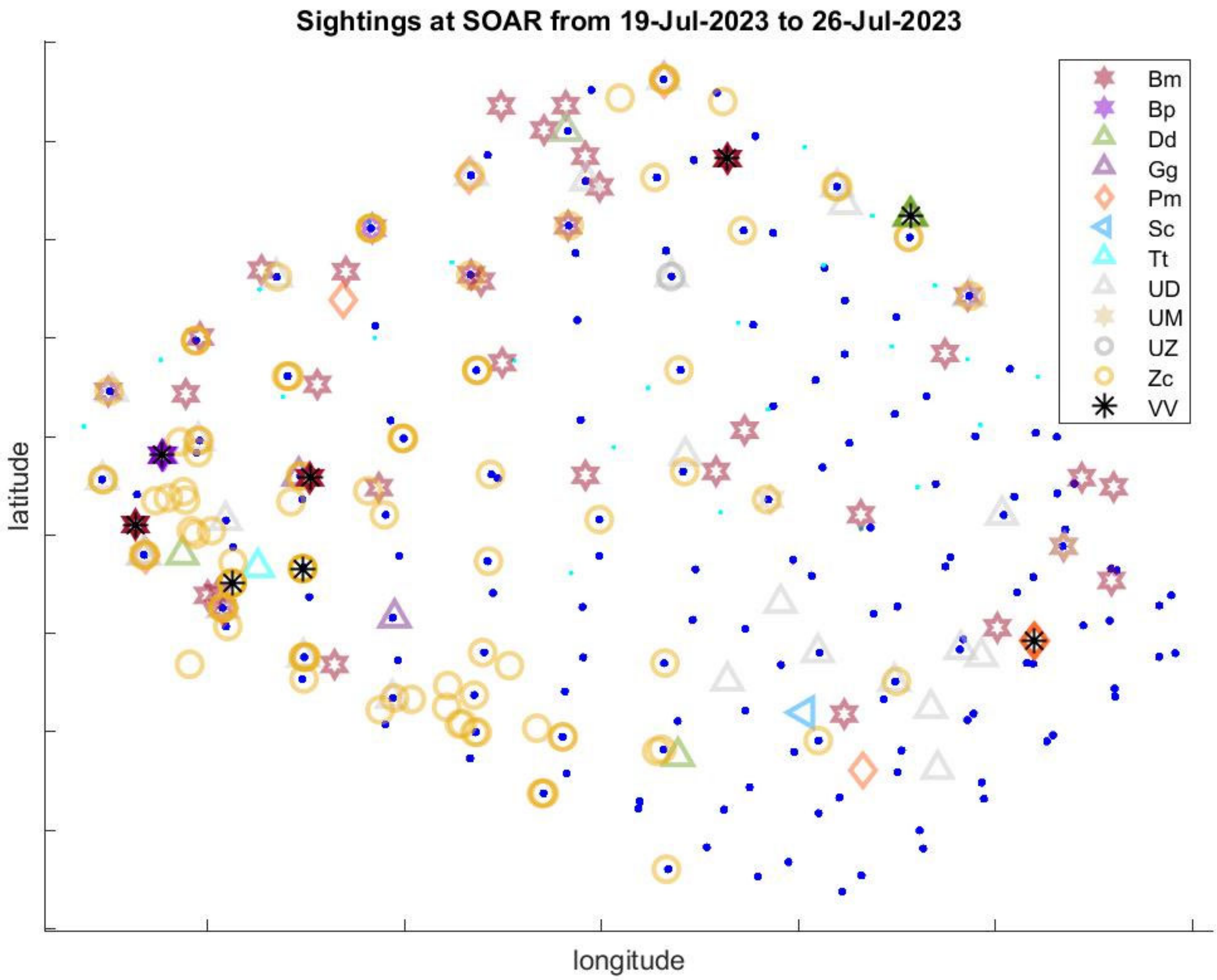


Figure 15. Acoustic detections (sightings) at SOAR from July 19 - 26, 2023. Species included blue whale (Bm), fin whale (Bp), short-beaked common dolphins (Dd), Risso's dolphin (Gg), sperm whale (Pm), striped dolphin (Sc), common bottlenose dolphin (Tt), Cuvier's beaked whale (Zc), and unknown delphinidae (UD), mysticeti (UM), and ziphius (UZ) species. Detections that were visually verified (VV) by MarEcoTel are overlaid with an asterisk.

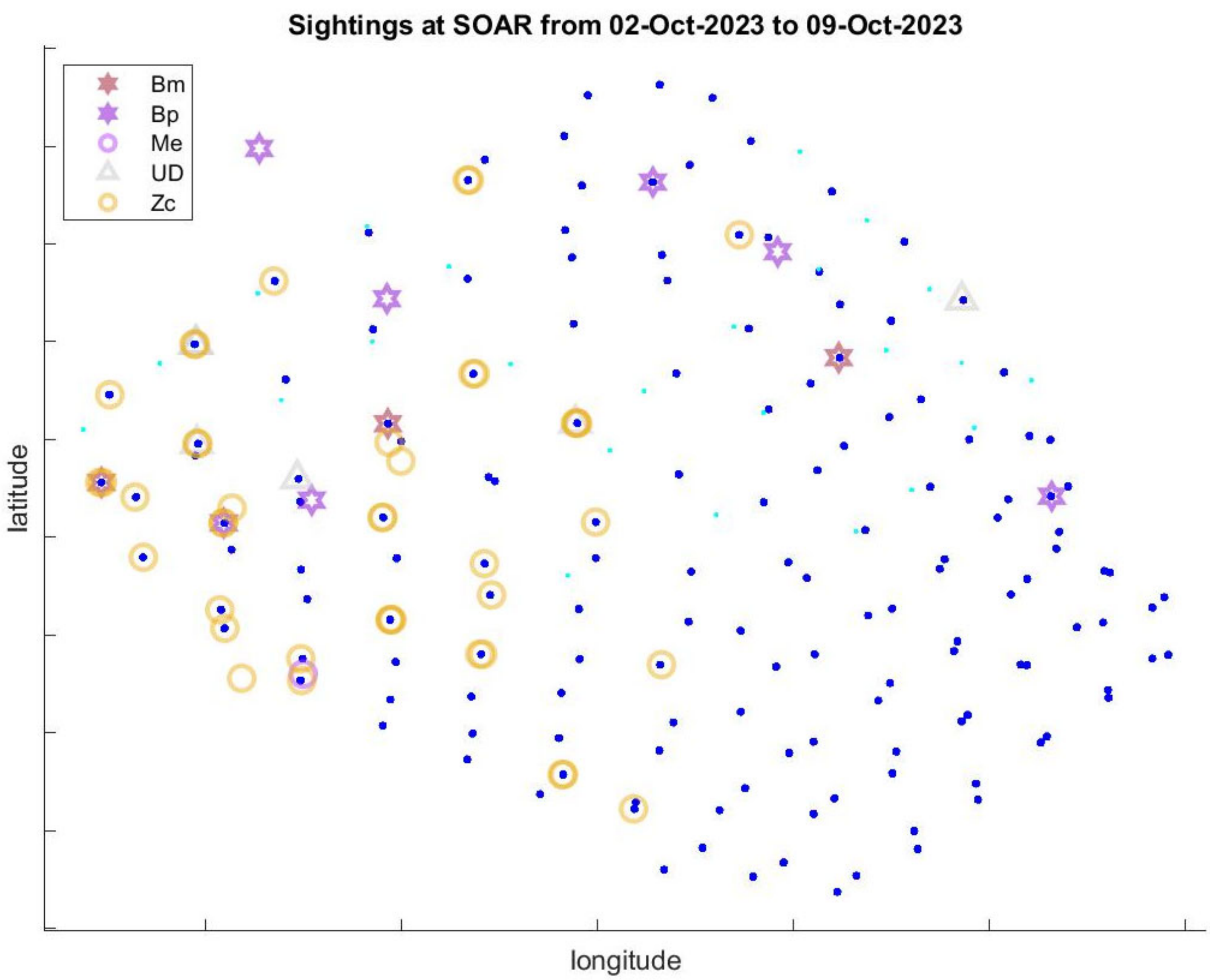


Figure 16. Acoustic detections (sightings) at SOAR from October 2 - 9, 2023. Species included blue whale (Bm), fin whale (Bp), Gervais beaked whale (Me), Cuvier's beaked whale (Zc), and unknown delphinidae species (UD). Detections that were visually verified (VV) by MarEcoTel are overlaid with an asterisk.

3.2 PMRF

3.2.1 Fiscal Year 2023

M3R personnel completed one field survey in 2023 in conjunction with the Cascadia Research Collective (CRC), from August 5 – 13 2023. CRC personnel typically transit from Kikiaola Harbor at sunrise to locations of marine mammals of interest on PMRF provided by M3R personnel. Locations are derived using the M3R signal-processing cluster, as outlined in section 3.1.1. Communications are maintained via radio and cell phone. Upon finding animals, CRC personnel collect photo-ID and behavioral data, as well as biopsy samples, and potentially place tags on the animals with the tag type varying depending on the focus of the particular effort for that survey.

Table 11 lists the marine mammal species acoustically identified using the M3R system during the 2023 field survey, along with summary information extracted from the associated PMRF field logs. More detailed information from these field logs can be found in Appendix A, section 8.2.

Ninety-nine acoustic detections (Figure 17) were logged in total, including 46 for Blainville's beaked whales, 16 for rough-toothed dolphins, eight for bottlenose dolphins, three for sperm and killer whales, two for short-finned pilot whales, and one for melon headed whales. Twenty of the sightings could not be identified to species and remained labeled as unidentified delphinidae. Each acoustic detection may represent either a single animal or a group of animals; however, note that each detection is not necessarily a new individual or a new group, as the same animal or group could be detected more than once over the course of the day. In addition, individuals could potentially move between groups. M3R directed CRC personnel to 19 of these 99 sightings. Here 'directed' sightings are considered those in which a location was sent and the field team decided to go to the location. CRC visually verified eight of these sightings, including three groups of rough-toothed and bottlenose dolphins, and single groups of killer, short-finned pilot, and melon-headed whales. Numerous photo-ID and behavioral data were collected on each group. Four tags were deployed successfully including on two individuals from one of the three visually verified bottlenose dolphin groups and on a single individual in each of the short-finned pilot whale and melon-headed whale groups. Additional groups of short-finned pilot whales and rough-toothed, bottlenose, spinner, and pantropical dolphins were visually verified off-range, where multiple short-finned pilot whales were tagged. Detailed information of these sightings can be found in the notes section of Table 11.

Table 11. Species acoustically identified with the M3R system at PMRF in 2023. Data are extracted from field test logs in FY23. Visual sightings without a corresponding acoustic detection are noted below the table.

Species			Acoustic Detections Logged	Acoustic Detections Directed	Acoustic Detections Visually Verified	No. of Groups Tagged
ID	Common Name	Scientific Name				
Md	Blainville's beaked whale	*Mesoplodon densirostris*	46	5	0	0
Pm	Sperm whale	*Physeter macrocephalus*	3	0	0	0
Gm	Short-finned pilot whale	*Globicephala macrorhynchus*	2	1	1	1
Pe	Melon-headed whale	*Peponocephala electra*	1	1	1	1

Oo	Killer whale	*Orcinus orca*	3	1	1	0
Sb	Rough-toothed dolphin	*Steno bredanesis*	16	4	3	0
Tt	Bottlenose dolphin	*Tursiops truncatus*	8	5	3	1
UD	Unidentified dolphin	Delphinidae sp.	20	2	0	0

Notes: On Aug 5th, a group of rough-toothed dolphins (Sb) was visually verified off range at 21.98852, -159.92 at 1655UTC.

On Aug 6th, two groups of short-finned pilot whales (Gm) were visually verified off range at 21.8918, -159.796 at 1607UTC and 21.91543, -159.801 at 1807UTC. Three tags were deployed. One group of Pantropical spotted dolphin (Sa) were visually verified off range at 21.92804, -159.84218 at 1919UTC. One group of spinner dolphins (Sl) were visually verified off range at 21.95912, -159.721 at 2318. Two groups of rough-toothed dolphins (Sb) were visually verified off range at 21.9012, -159.776 at 1712UTC and 21.9301, -159.843 at 1922UTC.

On Aug 10th, one group of Pantropical spotted dolphin (Sa) were visually verified off range at 22.00006, -159.88 at 1712- 1725UTC. Two groups of rough-toothed dolphins (Sb) were visually verified off range at 22.00006, -159.88 at 1702UTC and 22.02936, -159.894 1922UTC.

On Aug 12th, An off-range group of spinner dolphins (Sl) were visually verified at 21.94562, -159.6924 at 1555UTC. A group of rough-toothed dolphins (Sb) were visually verified off range at 21.9181, -159.839. A group of off-range bottlenose dolphins (Tt) were visually verified at 1559UTC at 22.018585, -159.823395. A group of off-range short-finned pilot whales (Gm) were visually verified with two tags deployed at 1629UTC at 21.89149, -159.78407.

On Aug 13th, Two groups of bottlenose dolphins (Tt) were visually verified off range at 21.92804, -159.94218 at 2122UTC and 21.9815, -159.9 at 2138UTC respectively. Additionally, two groups of rough toothed dolphins were visually verified off range at 22.08967, -159.89365 at 2018UTC and 21.91398, -159.81214 at 2122UTC respectively.

3.2.2 2022 Field Test Logs

Field log files from the 2022 field survey were corrupted during transit and were still in the process of being recovered as of the publication date of last year's annual report (Dolan et al. 2023), allowing only estimated minimums to be reported. The complete summary of these results is now documented in Table 12, and described below. More detailed information from these field logs can be found in Appendix C, section 8.2.

Fifty-four acoustic detections (Figure 18) were logged in total, including 44 for Blainville's beaked whales, four for short-finned pilot whales, three for bottlenose dolphins and Cuvier's beaked whales, two for melon headed whales, and single detections for rough-toothed and striped dolphins. Each acoustic detection may represent either a single animal or a group of animals; however, note that each detection is not necessarily a new individual or a new group, as the same animal or group could be detected more than once over the course of the day. In addition, individuals could potentially move between groups. There were acoustic detections that were unable to be identified to the species level, including 61 for unidentified delphinids and nine for unidentified beaked whales.

M3R directed CRC personnel to 18 of these 54 acoustic detections. Here 'directed' acoustic detections are considered those in which a location was sent and the field team decided to go to the location. CRC visually verified 10 acoustic detections, including three groups of Blainville's beaked whales, two groups of melon-headed whales and bottlenose dolphins, and a single group of short-finned pilot whales, rough-toothed, and striped dolphins. Photo-ID and behavioral data were collected on all verified sightings, and a tag was successfully deployed in both groups of melon-headed whales and bottlenose dolphins, as well as the single groups of short-finned pilot whales and striped dolphins.

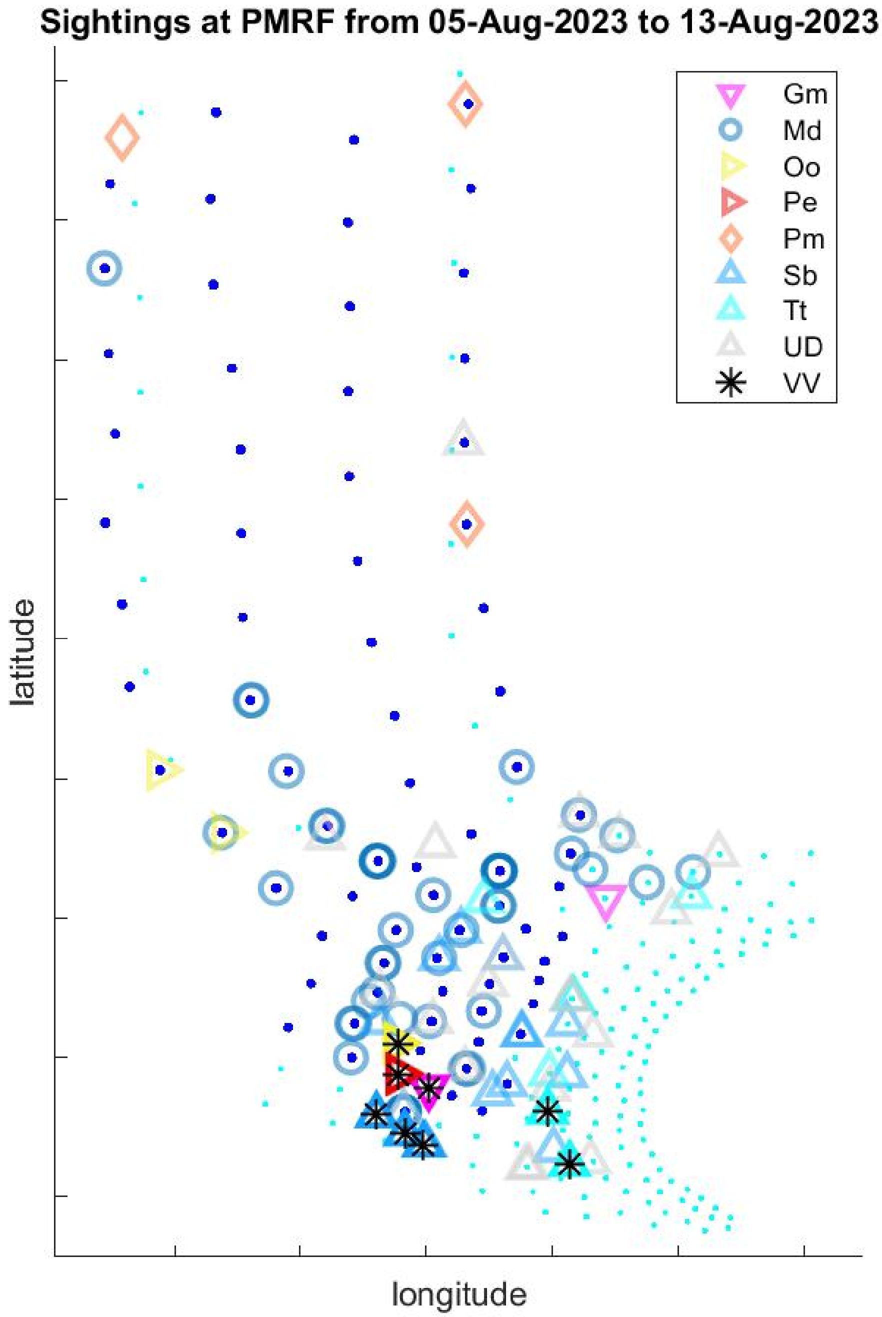


Figure 17. Acoustic detections (sightings) at PMRF from August 5 - 13, 2023. Species included short-finned pilot whales (Gm), Blainville's beaked whales (Md), killer whales (Oo), melon-headed whales (Pe), sperm whales (Pm), rough-toothed dolphins (Sb), bottlenose dolphins (Tt), and unknown delphinid species (UD). Detections that were visually verified (VV) by CRC are overlaid with an asterisk.

Table 12. Species acoustically identified with the M3R system at PMRF in 2022. Data are extracted from field test logs in FY22 that were recovered after the FY22 annual report was published.

Species			Acoustic Detections Logged	Acoustic Detections Directed	Acoustic Detections Visually Verified	No. of Groups Tagged
ID	Common Name	Scientific Name				
Md	Blainville's beaked whale	*Mesoplodon densirostris*	44	5	3	0
Zc	Cuvier's beaked whale	*Ziphius cavirostris*	3	0	0	0
Gm	Short-finned pilot whale	*Globicephala macrorhynchus*	4	1	1	1
Pe	Melon-headed whale	*Peponocephala electra*	2	2	2	2
Sb	Rough-toothed dolphin	*Steno bredanesis*	1	1	1	0
Sc	Striped dolphin	*Stenella coeruleoalba*	1	1	1	1
Tt	Bottlenose dolphin	*Tursiops truncatus*	3	2	2	1
UZ	Unidentified beaked whale	Ziphius sp.	9	1	0	0
UD	Unidentified dolphin	Delphinidae sp.	61	5	0	0

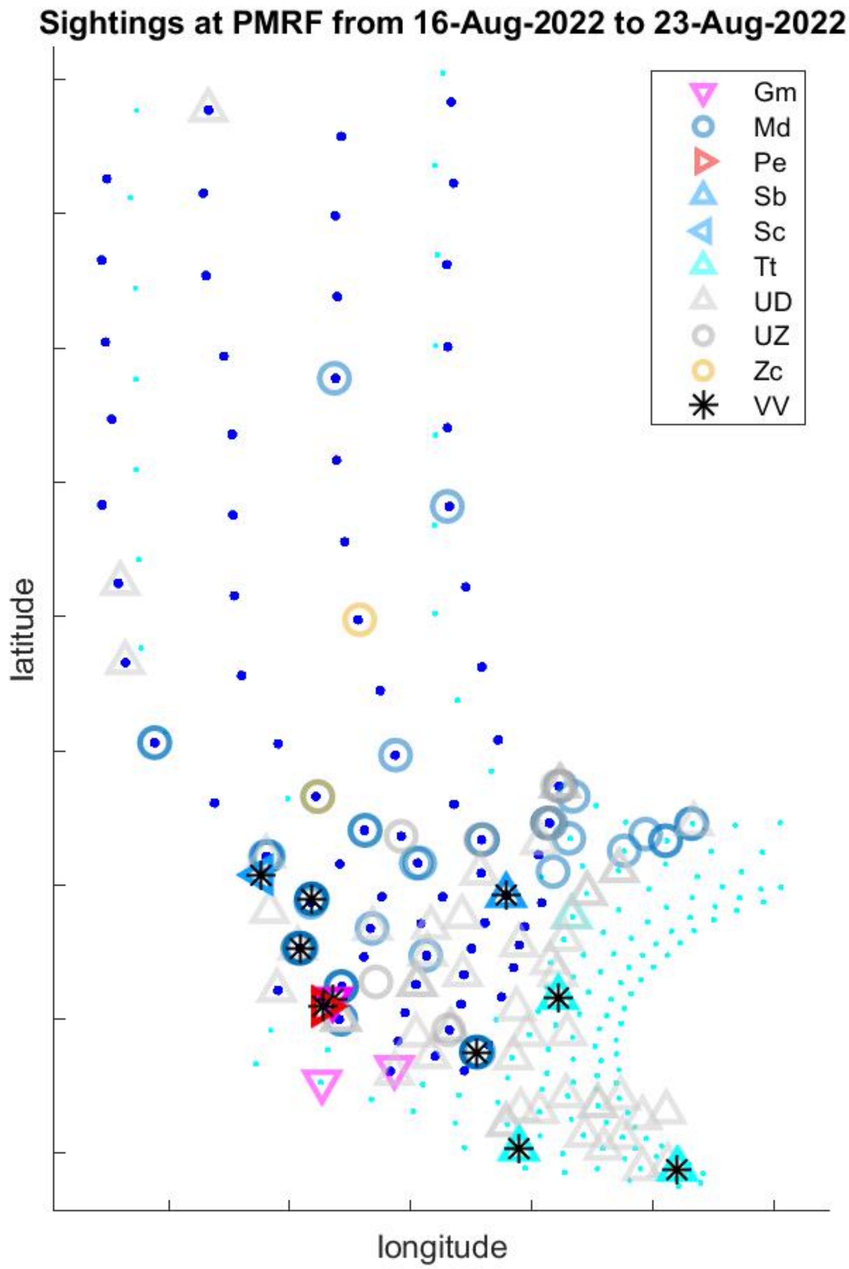


Figure 18. Acoustic detections (sightings) at PMRF from August 16 - 23, 2022. Species included short-finned pilot whales (Gm), Blainville's beaked whales (Md), melon-headed whales (Pe), rough-toothed dolphins (Sb), striped dolphins (Sc), bottlenose dolphins (Tt), unknown delphinid species (UD), ad Cuvier's beaked whales (Zc). Detections that were visually verified (VV) by CRC are overlaid with an asterisk.

4 Development of Beaked Whale Publication

4.1 Overview

A paper is under development on the occurrence, abundance and long-term trends of Blainville's and Cuvier's beaked whales on the U.S. Navy's three deep-water undersea ranges: SOAR, PMRF, and the Atlantic Undersea Test and Evaluation Center (AUTEC) off Andros Island in the Bahamas (Figure 19). Due to the primary author's (Nancy DiMarzio) limited availability over the past year it has not been completed, but significant progress has been made, including an initial draft of the paper and completion of two prerequisites for the paper: 1) development of code to find times and locations of hydrophones that appear to have either not been running the detection algorithms or not been functional, and 2) development of PMRF Autogrouper detection statistics for both Blainville's and Cuvier's beaked whales. The final model for the paper needs to be completed. Work on the modeling is through informal consultation with the University of St. Andrews.

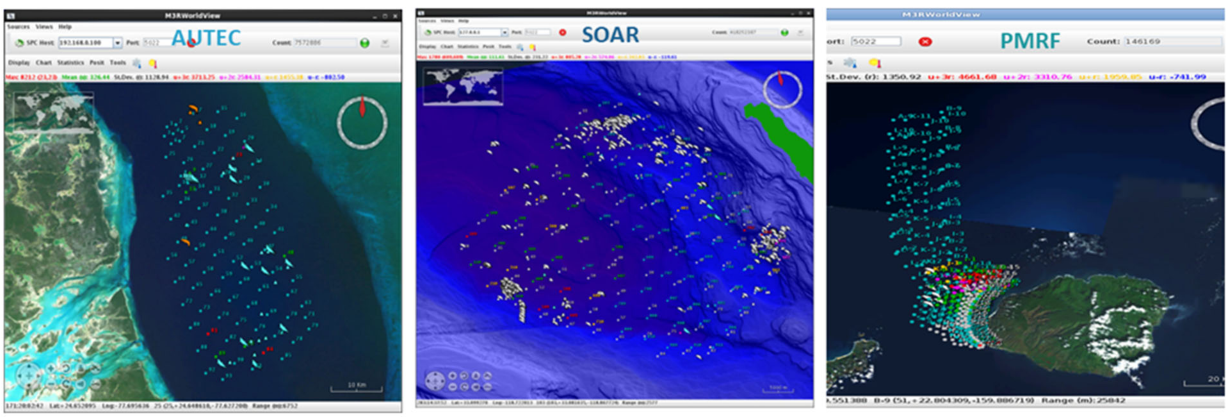


Figure 19. U.S. Navy's deep-water undersea ranges: left - AUTEC, center - SOAR, right - PMRF.

4.2 Missing Hydrophone Code

There are times over the years when certain hydrophones on the ranges may have either not been functional for some period of time, not been running the detection algorithm, or been associated with hardware (a node or A/D card) that temporarily was down. These cases resulted in missing data for those hydrophones. As these cases affect the spatial data collection effort across the range, it is important to be aware of when these conditions existed.

Previously, a MATLAB script was run on the click train processor (CTP) output files to get an approximation of these 'missing' hydrophones. This past year Python code was developed that runs directly on the spc archives files and generates a report of the missing hydrophones for each individual archive, and a report of the common missing hydrophones across all archives that are processed. The resulting data will be used to account for spatial variation in effort when determining beaked whale occurrence and abundance.

4.3 PMRF Detection Statistics

4.3.1 Overview

PMRF Autogrouper (AG) detection statistics for both Blainville's and Cuvier's beaked whales were derived by comparing the AG output to a manual review of a set of systematic random samples of the data. For each species, the beaked whale Group Vocal Periods (GVPs) that were determined by manual review were considered the 'truth,' and the probability of detection (PD), percent of false-negatives (FNs), and percent of false-positives (FPs) were calculated. Correction factors (CF) were also derived that can be used to recover the 'true' number of beaked whale GVPs from the AG output. The overall CF is calculated from the false negative CF_N and the false positive CF_P. The BARTSUR and BSURE refurb hydrophones were used for the analysis. Due to the age, noise levels, and shallow depths of the SWTR hydrophones, they were excluded from the analysis.

4.3.2 Methods

4.3.2.1 Manual Review

Thirty-nine random one-hour samples between 2011 and 2023 from the PMRF range were manually reviewed using the MMAMMAL program to identify the presence of Blainville's and Cuvier's beaked whale GVPs. Blainville's and Cuvier's beaked whales can be identified in binary spectrograms by the pattern, frequency range, and Inter- Click Interval (ICI) of their echolocation clicks (Figure 20).

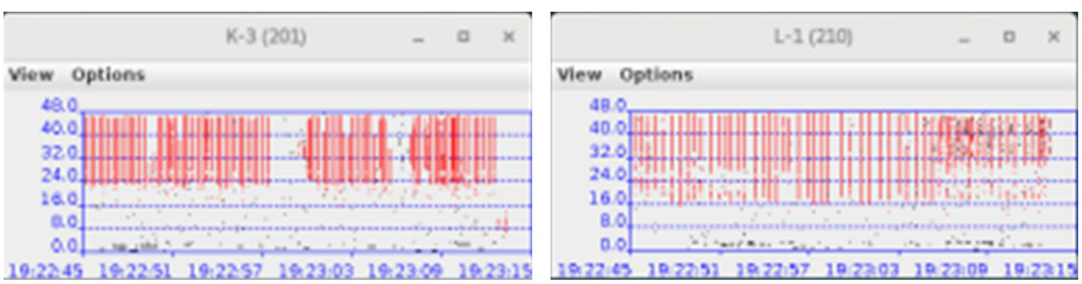


Figure 20. Binary spectrograms with typical echolocation clicks from: Left) Blainville's beaked whales and Right) Cuvier's beaked whales.

A two-step process was used to identify the Blainville's and Cuvier's beaked whale GVPs. First, the part of the PMRF range being analyzed was divided into three sections with 27-28 hydrophones per third (Figure 21). All hydrophones in each section were manually reviewed by playing back the archive files through MMAMMAL and identifying any hydrophones that potentially had Blainville's or Cuvier's beaked whale clicks. Brief notes were also made of any inactive hydrophones and of the presence of dolphins or other sounds.

After the archive data were reviewed, those identified in the first pass as potentially containing Blainville's or Cuvier's beaked whales were plotted on a map of the range. A second manual review of these archives was conducted to determine which hydrophones constituted beaked whale GVPs. At the conclusion of the second pass, each GVP was recorded along with the species, hydrophones belonging to the group, and the GVP start and stop time. A section of the GVP results is shown in Figure 22. These results were then compared to the automated results produced by the AG algorithm. At times the manual groups were adjusted if it was determined that a group was not correctly classified manually.

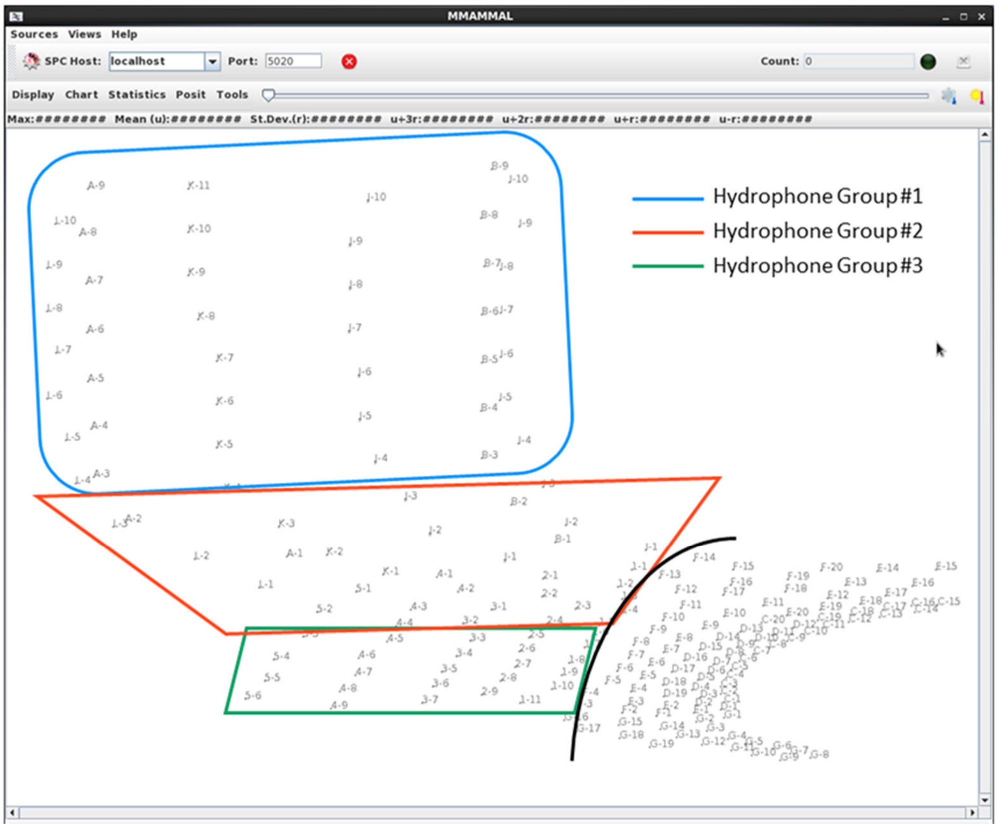
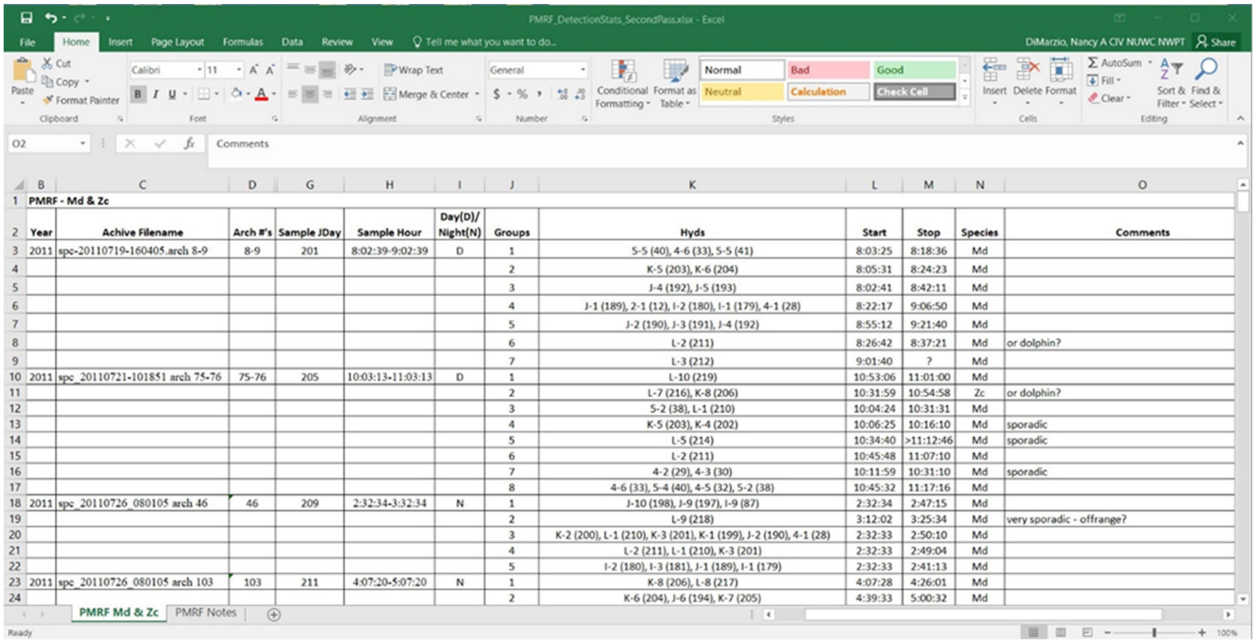


Figure 21. Three hydrophone groups used in the first pass for the manual review. The black line demarcates the hydrophones not used in the analysis.



PMRF - Md & Zc

Year	Achive Filename	Arch #'s	Sample JDay	Sample Hour	Day(D)/ Night(N)	Groups	Hyds	Start	Stop	Species	Comments
2011	spc-20110719-160405.arch 8-9	8-9	201	8:02:39-9:02:39	D	1	5-5 (40), 4-6 (33), 5-5 (41)	8:03:25	8:18:36	Md	
						2	K-5 (203), K-6 (204)	8:05:31	8:24:23	Md	
						3	J-4 (192), J-5 (193)	8:02:41	8:42:11	Md	
						4	J-1 (189), 2-1 (12), I-2 (180), I-1 (179), 4-1 (28)	8:22:17	9:06:50	Md	
						5	J-2 (190), J-3 (191), J-4 (192)	8:55:12	9:21:40	Md	
						6	L-2 (211)	8:26:42	8:37:21	Md	or dolphin?
						7	L-3 (212)	9:01:40	?	Md	
2011	spc_20110721-101851 arch 75-76	75-76	205	10:03:13-11:03:13	D	1	L-10 (219)	10:53:06	11:01:00	Md	
						2	L-7 (216), K-8 (206)	10:31:59	10:54:58	Zc	or dolphin?
						3	5-2 (38), L-1 (210)	10:04:24	10:31:31	Md	
						4	K-5 (203), K-4 (202)	10:06:25	10:16:10	Md	sporadic
						5	L-5 (214)	10:34:40	>11:12:46	Md	sporadic
						6	L-2 (211)	10:45:48	11:07:10	Md	
						7	4-2 (29), 4-3 (30)	10:11:59	10:31:10	Md	sporadic
						8	4-6 (33), 5-4 (40), 4-5 (32), 5-2 (38)	10:45:32	11:17:16	Md	
2011	spc_20110726_080105 arch 46	46	209	2:32:34-3:32:34	N	1	J-10 (198), J-9 (197), I-9 (87)	2:32:34	2:47:15	Md	
						2	L-9 (218)	3:12:02	3:25:34	Md	very sporadic - offrange?
						3	K-2 (200), L-1 (210), K-3 (201), K-1 (199), J-2 (190), 4-1 (28)	2:32:33	2:50:10	Md	
						4	L-2 (211), L-1 (210), K-3 (201)	2:32:33	2:49:04	Md	
						5	I-2 (180), I-3 (181), J-1 (189), I-1 (179)	2:32:33	2:41:13	Md	
2011	spc_20110726_080105 arch 103	103	211	4:07:20-5:07:20	N	1	K-8 (206), L-8 (217)	4:07:28	4:26:01	Md	
						2	K-6 (204), J-6 (194), K-7 (205)	4:39:33	5:00:32	Md	

Figure 22. Manual review: 2nd pass to determine Blainville's and Cuvier's GVPs.

4.3.2.2 Autogrouper (AG)

The Autogrouper algorithm was run on the output of the CTP program. Only Blainville's beaked whale foraging click trains derived by the CS-SVM algorithm with an ICI between 0.23 and 0.4 sec, and Cuvier's beaked whale click trains with an ICI between 0.35 and 0.75 sec were used (DiMarzio & Jarvis 2023). Prior to comparison with the manual groups, the AG output was filtered so that all Blainville's beaked whale GVPs had to have a total number of clicks between 360 and 64,800, and a duration between 5 and 90 min. Cuvier's beaked whale GVPs were constrained to between 300 and 43,200 clicks, and a duration from 5 to 90 minutes (DiMarzio & Jarvis 2023). The number of clicks for Blainville's beaked whales was based on a click rate of three clicks per second, and for Cuvier's two clicks per second, for one to six animals (DiMarzio & Jarvis 2023).

4.3.2.3 Comparison of Manual and AG GVPs

The total number of manual group GVPs and AG GVPs were first annotated for each sample. Then, for each sample, the GVPs were placed into one of four categories: (a) exact matches, (b) 'confused' matches, (c) manual only (false negatives, FN), or (d) AG only (false positives, FP). A GVP was considered an exact match if: (1) the GVPs had at least one hydrophone in common, (2) the hydrophones were not part of another GVP, and (3) the time periods overlapped. The 'confused' matches occurred when all or some of the same hydrophones were identified by both the manual process and the AG program, and the time periods overlapped, but the number of GVPs and/or the hydrophone combinations forming the GVPs were not the same. For the confused matches, both the total number of manual GVPs and the total number of AG GVPs were noted. The manual-only cases consisted of GVPs only identified manually (FN), and the AG only were those identified solely by the AG (FP) (Table 13, Table 14).

Prior to calculating the detection statistics from these data, the GVPs under the confused matches category were reassigned to either the exact matches, FN, or FP category with the following procedure (Table 13, Table 14):

1. The minimum of the manual and AG GVPs for the confused matches was calculated and added to the exact matches for each sample. This sum was listed under the heading "Correctly Detected."

2. Under the confused matches category, if there were more manual GVPs than AG GVPs, the difference was added to the FNs; otherwise the difference was added to the FPs. This was equivalent to calculating the new FN as the total number of manual GVPs minus the number correctly detected, and the new FP as the total number of AG GVPs minus the number correctly detected.

Table 13. Comparison of Blainville's beaked whale manual and AG GVPs for derivation of detection statistics.

Sample #	Total # Manual GVPs	Total # AG GVPs	# Exact Matches	# Confused Matches		Min of Confused	Correctly Detected	# GVPs Manual Only (FN)	# GVPs AG Only (FP)
				# Manual GVPs	# AG GVPs				
1	2	1	0	0	0	0	0	2	1
2	3	0	0	0	0	0	0	3	0
3	4	0	0	0	0	0	0	4	0
4	8	3	0	4	2	2	2	6	0
5	1	1	0	0	0	0	0	1	1
6	3	0	0	0	0	0	0	3	0
7	4	1	0	2	1	1	1	3	0
8	0	1	0	0	0	0	0	0	1
9	2	0	0	0	0	0	0	2	0
10	4	1	0	2	1	1	1	3	0
11	3	1	0	3	1	1	1	2	0
12	1	1	1	0	0	0	1	0	0
13	2	1	0	2	1	1	1	1	0
14	2	2	0	0	0	0	0	2	2
15	1	0	0	0	0	0	0	1	0
16	2	1	0	2	1	1	1	1	0
17	2	1	0	2	1	1	1	1	0

18	2	0	0	0	0	0	0	2	0
19	3	2	1	2	1	1	2	1	0
20	2	1	1	0	0	0	1	0	0
21	1	1	1	0	0	0	1	0	0
22	0	0	0	0	0	0	0	0	0
23	1	3	1	0	0	0	1	0	2
24	0	3	0	0	0	0	0	0	2
25	0	0	0	0	0	0	0	0	0
26	1	0	0	0	0	0	0	1	0
27	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0
29	1	2	1	0	0	0	1	0	1
30	2	2	2	0	0	0	2	0	0
31	1	1	0	0	0	0	0	1	1
32	0	1	0	0	0	0	0	0	1
33	2	2	2	0	0	0	2	0	0
34	0	0	0	0	0	0	0	0	0
35	1	1	1	0	0	0	1	0	0
36	2	0	0	0	0	0	0	2	0
37	2	0	0	0	0	0	0	2	0
38	2	1	0	2	1	1	1	1	0
39	4	0	0	0	0	0	0	4	0
	71	**35**	**11**	**21**	**10**	**10**	**21**	**49**	**12**

Table 14. Comparison of Cuvier's beaked whale manual and AG GVPs for derivation of detection statistics

Total # Manual GVPs	Total # AG GVPs	# Exact Matches	# Confused Matches		Min of Confused	Correctly Detected	# GVPs Manual Only (FN)	# GVPs AG Only (FP)
			# Manual GVPs	# AG GVPs				
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0

0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
1	2	0	1	2	1	1	0	1
0	0	0	0	0	0	0	0	0
2	2	0	2	2	2	2	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	3	0	0	0	0	0	0	3
1	2	1	0	0	0	1	0	1
0	2	0	0	0	0	0	0	2
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	1
0	1	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0
1	1	1	0	0	0	1	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	2	0	0	0	0	0	0	2
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
5	**17**	**2**	**3**	**4**	**3**	**5**	**0**	**12**

4.3.2.4 Derivation of Detection Statistics and Correction Factors

For each species, detection statistics were then calculated from the 39 archive samples. Correction factors were also calculated to derive the 'true' number of Blainville's or Cuvier's beaked whale GVPs present from the number of AG groups detected. The PD was calculated as the number of GVPs correctly detected by the AG divided by the number of manual GVPs. The percentage of FNs (GVPs missed by the AG) was the number of FNs divided by the number of manual GVPs; and the percentage of FPs (GVPs misidentified by the AG) was the number of FPs divided by the number of AG GVPs.

FP and FN correction factors for the AG GVP results were then derived as follows, using all samples combined:

1. The FP correction factor = 1 – (number of FP / number of AG GVPs)
2. The FN correction factor = 1 + (number of FN / (number of AG GVPs * FP correction factor)).

4.3.3 Results

The PMRF AG detection statistics and correction factors for Blainville's and Cuvier's beaked whales are reported in Table 14.

Table 14. Derived detection statistics and correction factors for Blainville's and Cuvier's beaked whales at PMRF.

Beaked whale Species	n	Probability of Detection (PD)	False Negative (FN)	False Positive (FP)	Correction Factors		
					FP	FN	CF = FP*FN
Blainville's	39	0.30	0.69	0.34	0.66	3.13	2.06
Cuvier's	39	1.00	0.00	0.71	0.29	1.00	0.29

4.3.4 Discussion

The Autogrouper algorithm only correctly detects about one third of the Blainville's beaked whale groups at PMRF, which is a much lower PD than that for Cuvier's beaked whales at PMRF (PD = 1.0) or SOAR (PD = 0.76) or Blainville's beaked whales at AUTEC (PD = 0.80). There are also a high number of false negatives (0.69), or cases in which the Blainville's beaked whale groups are missed by the Autogrouper, and the percentage of false positives is 0.34 (Table 14). However, as long as the detection statistics and correction factors are appropriately applied to the data, the correct abundance values should be recovered.

Cuvier's beaked whales appear on PMRF much less frequently than Blainville's beaked whales. The PD for Cuvier's is 1 and the FN is 0; however there a high percentage of false positives (FP), likely from confusion with dolphins.

The Autogrouper program clearly needs to be tuned for the different ranges, and in particular for PMRF. For example, often times it appears that, for a given GVP, fewer clicks are detected at PMRF as compared to AUTEC and SOAR; therefore, the restriction on the minimum number of clicks necessary to declare a group present may need to be lowered for PMRF. In reviewing the archives, the clicks were often correctly detected on the hydrophones, but the total click requirement was not met, and thus the GVP was not included.

5 References

Baird, R. W., Webster, D. L., McSweeney, D. J., Ligon, A. D., Schorr, G. S., & Barlow, J. (2006). Diving behaviour of Cuvier's (*Ziphius cavirostris*) and Blainville's (*Mesoplodon densirostris*) beaked whales in Hawaiʻi. Canadian Journal of Zoology, 84(8), 1120-1128.

Baird, R. W., Webster, D. L., Schorr, G. S., McSweeney, D. J., & Barlow, J. (2008). Diel variation in beaked whale diving behavior. Marine Mammal Science, 24(3), 630-642.

DiMarzio, N. and S. Jarvis. 2023. Temporal and Spatial Distribution and Habitat Use of Cuvier's Beaked Whales on the U.S. Navy's Southern California Antisubmarine Warfare Range (SOAR): Data Preparation. NUWC-NPT Technical Memo 16-090.

Dolan, K., Carroll, A., Jarvis, S., Morrissey, R., Vaccaro, S., DiMarzio, N., Muniz, A., Watwood, S. 2023. Marine Mammal Monitoring on Navy Ranges (M3R) for beaked whales on the Southern California Anti-Submarine Warfare Range (SOAR) and the Pacific Missile Range Facility (PMRF), 2021. Prepared for: U.S. Navy, U.S. Pacific Fleet, Pearl Harbor, HI. Prepared by: Naval Undersea Warfare Center Newport, Newport, RI. 68 pp.

Falcone, E.A., Schorr, G.S., Douglas, A.B., Calambokidis, J., Henderson, E., McKenna, M.F., Hildebrand, J., Moretti, D., 2009. Sighting characteristics and photo-identification of Cuvier's beaked whales (Ziphius cavirostris) near San Clemente Island, California: a key area for beaked whales and the military?. Marine Biology, 156(12), pp.2631-2640.

Jarvis, S., DiMarzio, N., Morrissey, R. and Moretti, D. 2008. A novel multi-class support vector machine classifier for automated classification of beaked whales and other small odontocetes. Canadian Acoustics, 36(1), pp.34-40.

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

Moretti, D, Marques, T.A., Thomas, L., DiMarzio, N., Dilley, A., Morrissey, R., McCarthy, E., Ward, J., Jarvis, S., 2010. A dive counting density estimation method for Blainville's beaked whale (*Mesoplodon densirostris*) using a bottom mounted-hydrophone field as applied to a Mid-Frequency Active (MFA) sonar operation. *Applied Acoustics*, 1(11), pp 1036-1042.

Schorr, G.S., Falcone, E.A., Rone, B.K., Keene, E.L., Sweeney, D.A., Coates, S.N. 2023. Cuvier's beaked whale and fin whale surveys at the Southern California Offshore Anti-Submarine Warfare Range (SOAR). Annual Report to the U.S. Navy Pacific Fleet Integrated Comprehensive Monitoring Program, Award No's. N62473-19-2-0025 and N66604-22-D-F200. 36 Pg.

Schorr, G.S., Falcone, E.A., Moretti, D.J., Andrews, R.D., 2014. First long-term behavioral records from Cuvier's beaked whales (*Ziphius cavirostris*) reveal record-breaking dives. *PloS one*, 9(3), p.e92633.

Schorr, G.S., Rone, B.K., Falcone, E.A., Keene, E.L., Sweeney, D.A. 2020. Cuvier's beaked whale and fin whale surveys at the Southern California Offshore Anti-Submarine Warfare Range (SOAR). Annual Report to the Cooperative Agreement Studies Unit, Award No. N62473-19-2-0025 for U.S. Navy, Pacific Fleet. 46 Pg.

6 Appendix A: Abundance Code Flowchart

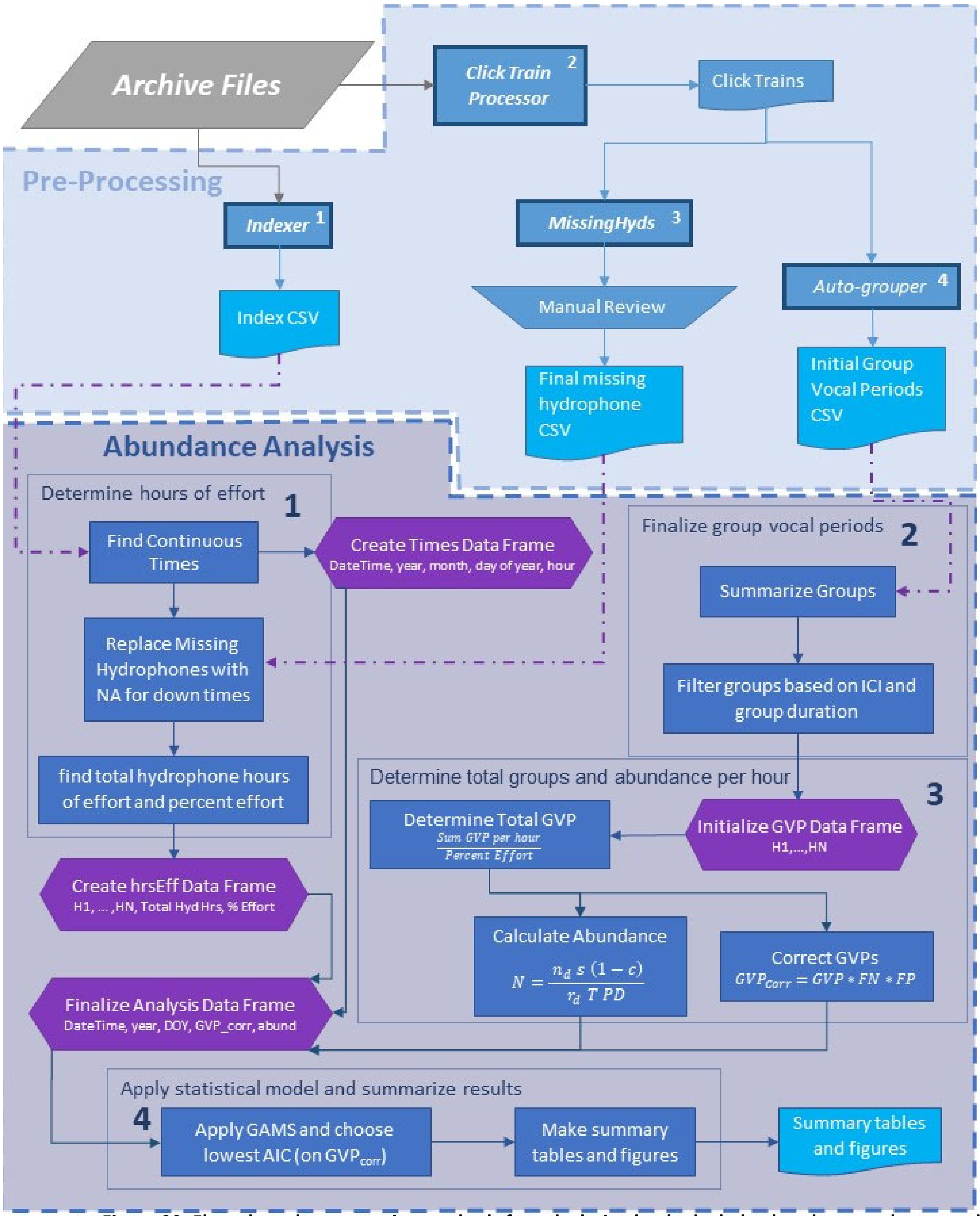


Figure 23. Flow chart demonstrating methods for calculating beaked whale abundance and temporal occurrence.

6.1 Pre Processing Steps

1. Indexer – JAVA based code to pull start and stop times of archive files brought back from the range
    a. Input: Archive File
    b. Output: Index file – contains start and stop time of every archive file.
2. Click Train Processor (CTP) – JAVA based code to group detection reports from a single species on a single hydrophone using a 3 min timeout for separation of click trains.
    a. Input: Archive File
    b. Output: Click Train CSV – contains classifier used, species type, hydrophone ID, click train start, click train stop, inter-click interval
3. Missing Hydrophones – MATLAB script which imports CTP output files, and lists hydrophones where no CSSVM classifier detections were made. This approximates times hydrophones are down over the course of continuous time periods, assuming over the course of several days every working hydrophone will detect an animal. The script results are reviewed manually to reduce the effects of shorter time periods.
    a. Input: Click Train CSV
    b. Output: Missing Hyd CSV – contains start and stop time of CTP file series, missing hydrophones
4. Auto-grouper – MATLAB script which creates vocal groups from click trains on multiple hydrophones based on time and space.
    a. Input: Click Train CSV
    b. Output: Groups CSV

6.2 Abundance Analysis

1. Determine Hours of Effort – find continuous times data was collected at the range and make data frame with hydrophone per hour effort. Only whole hours of data are utilized, missing hydrophones during hour are replaced with NA
    a. Input: Index CSV, missing hydrophone CSV
    b. Output:
        i. hrsEff data frame: effort per hyd per hour
        ii. times data frame: start time of hour bin in datetime format
2. Finalize group vocal periods – pull in groups determined by autogrouper, summarize, filter and count groups at each hydrophone during each hour of effort. Calculate total
    a. Input: Groups CSV
    b. Output: GVP data frame
3. Determine total groups and calculate abundance – Calculate total g groups on range and correct for range coverage and detection statistics.
    a. Input: GVP data frame
    b. Output: Final Analysis Data frame (gamDF)
4. Apply statistical model and summarize results
    a. Input: Final Analysis Data frame (gamDF)
    b. Output: summary tables, gam plots, gam metrics

7 Appendix B: GAM Metrics

Table 15. Results of the Tweedie family GAM for Z*c* at SOAR.

Parametric coefficients:				
	Estimate	Std Error	t value	Pr(>|t|)
(Intercept)	-3.3759	0.0153	-220.6	<2e-16 ***
Approximate significance of smooth terms:				
	edf	Ref df	F	p-value
s(JDay)	7.246	8.000	72.48	<2e-16 ***
s(Year)	8.835	8.992	65.63	<2e-16 ***
Signif codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				
R-sq (adj) = 0.514 Deviance explained = 25.8%				
-REML = 14805 Scale est = 1.8952 n = 3100				

Table 16. Results of the Tweedie family GAM for *Md* on all PMRF

Parametric coefficients:				
	Estimate	Std Error	t value	Pr(>|t|)
(Intercept)	-3.76659	0.02229	-169	<2e-16 ***
Approximate significance of smooth terms:				
	edf	Ref df	F	p-value
s(Day of Year)	4.061	8.000	9.618	<2e-16 ***
s(Year)	8.467	8.912	17.228	<2e-16 ***
Signif codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1				
R-sq (adj) = 0.209 Deviance explained = 8.93%				
-REML = 7508.8 Scale est = 1.9951 n = 2085				

Table 17. Results of the Tweedie family GAM for *Md* on BARSTUR

Parametric coefficients:				
	Estimate	Std Error	t value	Pr(>|t|)
(Intercept)	-3.85544	0.02412	-159.8	<2e-16 ***
Approximate significance of smooth terms:				
	edf	Ref df	F	p-value
s(Day of Year)	3.288	8.000	3.756	5.30e-07 ***
s(Year)	7.927	8.679	4.163	1.93e-05 ***
Signif codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				
R-sq (adj) = 0.174 Deviance explained = 3.44%				
-REML = 5360.5 Scale est = 1.7092 n = 1781				

Table 18. Results of the Tweedie family GAM for *Md* on BSURE

Parametric coefficients:				
	Estimate	Std Error	t value	Pr(>|t|)
(Intercept)	-3.88252	0.02677	-145.1	<2e-16 ***
Approximate significance of smooth terms:				
	edf	Ref df	F	p-value
s(Day of Year)	3.498	8.000	5.69	<2e-16 ***
s(Year)	8.096	8.763	14.74	<2e-16 ***
Signif codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				
R-sq (adj) = 0.242 Deviance explained = 6.16%				

-REML = 5435.4	Scale est = 2.2792	n = 2085

Table 19. Results of the Tweedie family GAM for *Zc* on all PMRF

Parametric coefficients:				
	Estimate	Std Error	t value	Pr(>|t|)
(Intercept)	-6.26538	0.04953	-126.5	<2e-16 ***
Approximate significance of smooth terms:				
	edf	Ref df	F	p-value
s(Day of Year)	6.504	8.000	32.57	<2e-16 ***
s(Year)	8.742	8.978	28.64	<2e-16 ***
Signif codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				
R-sq (adj) = 0.2 Deviance explained = 21.8%				
-REML = -1420.5 Scale est = 5.2683 n = 2085				

Table 20. Results of the Tweedie family GAM for *Zc* on BARSTUR

Parametric coefficients:				
	Estimate	Std Error	t value	Pr(>|t|)
(Intercept)	-6.9071	0.0601	-114.9	<2e-16 ***
Approximate significance of smooth terms:				
	edf	Ref df	F	p-value
s(Day of Year)	4.452	8.000	12.40	<2e-16 ***
s(Year)	5.573	6.696	10.38	<2e-16 ***
Signif codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				

R-sq (adj) = 0.222	Deviance explained = 5.75%	
-REML = -4212.8	Scale est = 6.4228	n = 1781

Table 21. Results of the Tweedie family GAM for *Zc* on BSURE

Parametric coefficients:				
	Estimate	Std Error	t value	Pr(>|t|)
(Intercept)	-6.40557	0.06134	-104.4	<2e-16 ***
Approximate significance of smooth terms:				
	edf	Ref df	F	p-value
s(Day of Year)	5.258	8.000	14.42	<2e-16 ***
s(Year)	8.263	8.838	11.95	<2e-16 ***
Signif codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				
R-sq (adj) = 0.222	Deviance explained = 9.72%			
-REML = -6489.9	Scale est = 7.8655	n = 2085		

8 Appendix C: Field Work Logs

8.1 SOAR

Table 22 through Table 26 show excerpts from the M3R log files from the five field efforts conducted with MarEcoTel in FY23 on SOAR. The excerpts indicate the species acoustically identified and the number of such detections, along with the number of detections to which the RHIB was directed, the number of species detections visually verified, and the number of tags deployed. Note the detections do not necessarily indicate the number of groups present, as the same group may be re-sighted over the course of the day. In addition, these log excerpts indicate minimum numbers present on the range, as not all activity is logged. There is a variety of reasons for this, including the following: A particular species or parts of the range may be the focus on a particular day; personnel may have different levels of experience; and certain ever-present groups of animals such as dolphins are not usually logged.

Table 22. Excerpts from M3R log files from a field effort on SOAR from November 20 – 25 2022. Visual sightings without a corresponding acoustic detection are noted below the table.

Test Dates	Hours Monitored	Species	Acoustic Detections Logged	Acoustic Detections Directed	Visually Verified	Tagged	Notes
2022-11-20	9	*Zc*	13	2	2	0	Single female near hyd 13 (33.0067 -118.7917), averse to being tagged despite long follow. Group of 3 at 32.9223 -118.9921 near hyd 308.
		Bp	3	2	0	0	Posit track moving north for individual heard initially on hydrophone 705.
		Gm	1	1	1	1	Group of 9-11 traveling NW. Sighted at 32.9888 -118.7711, initially heard on hydrophone 203. Successfully deployed 1 tag
		Ba	1	0	0	0	Heard a boing vocalization on hydrophone 201. UDP listen was not up and running at the time.
		UD	3	0	0	0	Heard on hydrophones 9, 603, and 207
2022-11-21	10	*Zc*	13	2	1	1	Group of 7 found at 32.9588 -118.9812 near hydrophone 207. Successfully tagged 2 individuals with limpet tags.
		Bp	4	1	1	0	1 individual spotted at 32.9126 -118.926.

		Gm	1	0	0	0	Heard on hydrophone 307 mainly, most likely same group from previous day.
		Dd	1	0	0	0	Heard mainly on hydrophone 210
		Mn	1	0	0	0	Heard mainly on hydrophone 808
2022-11-22	9	*Zc*	8	2	0	0	Rough weather day had to call off both attempts to locate directed groups
		Bp	5	3	2	0	1 individual located at 32.9159 -118.7389. Super-fast swimmer (faster than noted speeds for this animal), booked it to the northern boundary where team was unable to follow. 1 individual at 32.9166 -118.9278.
		UD	2	0	0	0	Heard in southern portion of range, on hydrophones 705 and 801.
2022-11-23	10	*Zc*	11	5	1	0	Group of 4 seen at 32.8558 -118.8808.
		Bp	8	2	2	0	Pair found at 32.8243 -118.8625 near Zc group of 4 listed above. Single individual found at 32.8318 -118.7602.
		Mn	2	1	1	0	Individual seen at 32.8836 -118 7257 on route to second fin while directed sighting.
		Dd	1	0	0	0	Heard mainly on hydrophone 507.
		Pm	1	0	0	0	Heard off range
		Bm	4	0	0	0	Too far south for visuals to attempt
2022-11-24	10.5	*Zc*	8	2	0	0	Heard blows, but too foggy to visually locate either directed group. Great posits.
		Bp	7	0	0	0	
		Gg	2	0	0	0	Too far south for weather conditions
2022-11-25	10.5	*Zc*	14	3	2	0	Single animal seen at32.9055 -118.8908. Pair (adult female and either a calf or sub-adult) at 32.9429 -118.9407. Tagging was unsuccessful due to severely choppy water.
		Pm	2	0	0	0	Couldn't get good enough position to get visual team to them, spread out between a large area of hydrophones, and no automatically generated posits.
		Bp	4	0	0	0	Too far south to attempt

		Bm	1	0	0	0	Too far west to attempt in rough weather
		Mn	1	0	0	0	Too far south to attempt

Notes: Weather was rough for most of the trip, visual team had a hard time finding directed animals and tagging them.

Table 23. Excerpts from M3R log files from a field effort on SOAR from Feb 17 – 20 2023.

Test Dates	Hours Monitored	Species	Acoustic Detections	Acoustic Detections	Visually Verified	Tagged	Notes
2023-02-17	11	*Zc*	20	2	1	0	Around H509 @ 048:20:42 Lat 32.788 Long 119.051
		Mn	2	1	1	0	Too loud to localize on MMAMMAL MarEcoTel Log: 15:28, 32.7904, -119.0066
		Lb	1	1	1	0	@048:21:57 – Northern right whale dolphins 32 42.69N 119 1.3W
		UD	2	0	0	0	
2023-02-18	10	*Zc*	17	3	1	0	
		Bp	3	1	1	0	@ 049:19:46:19 Lat: 32.8628 Long: -119.8628
		Mn	2	0	0	0	
		UD	4	0	0	0	
2023-02-19	11	*Zc*	22	6	3	0	
		Mn	2	0	0	0	
		UD	3	0	0	0	
2023-02-20	10	*Zc*	15	2	0	0	
		Mn	1	0	0	0	
		UD	2	1	1	0	

Table 24. Excerpts from M3R log files from a field effort on SOAR from May 15 – 25 2023.

Test Dates	Hours Monitored	Species	Acoustic Detections Logged	Acoustic Detections Directed	Visually Verified	Tagged	Notes
2023-05-15	10	*Zc*	21	5	4	2	1-ZC @ 32.8907 , -119.0148 (ZULU 17:14) 2-ZC @ 32.7520, -118.9116 (Z 21:27) 5-Zc @ 5 Zc @ 506; -40 @ 23:59
		Bp	2	1	1	1	LIMPRT tag deployed, 32.8561, 118.0319 (Z 15:57)
		UD	3	0	0	0	
2023-05-16	17	*Zc*	17	2	0	0	
		Bp	2	0	1	0	
		UD	1	0	0	0	
2023-05-17	9	*Zc*	1	0	0	0	
2023-05-18	11	*Zc*	15	4	2	2	**H310** – 2 Zc @ 32.8764; -119.0760 @16:32 UTC **H308** - 32 52.7N, 119 4.1W @18:30 UTC (2 tags on)
		Bp	2	0	1	0	With a group of pacific white sided dolphins
		Lo	1	0	0	0	
		UD	2	0	0	0	
2023-05-19	10.5	*Zc*	20	4	4	2	**H36:** 2 Zc @ 32 52.6N, -119 10.2W @ 16:57 **H209:** 2 ZC @ 32 54.4N; -119 6.3W @19:32 (tagged)

							H507: 3 Zc @ 32 50.5N, -118 58.5N @ 22:49 (SMRT tag out)
		Bp	1	1	0	0	
		UD	2	0	0	0	
2023-05-20	10.5	*Zc*	5	0	0	0	
		Bp	2	0	0	0	
		UD	1	0	0	0	
2023-05-21	1	*Zc*	1	0	0	0	

Notes: bad weather on 05/17/2023, 05/20/2023, 05/21/2023 kept field team on land.

Table 25. Excerpts from M3R log files from a field effort on SOAR from July 19-28, 2023.

Test Dates	Hours Monitored	Species	Acoustic Detections Logged	Acoustic Detections Directed	Visually Verified	Tagged	Notes
2023-07-19	6	*Zc*	1	0	0	0	
		Pm	1	0	0	0	
		Gg	1	0	0	0	
2023-07-20	8	*Zc*	11	0	0	0	
		Pm	2	0	0	0	
		Bm	3	0	0	0	
		Ud	3	0	0	0	
2023-07-21	9	*Zc*	19	2	0	0	
		Bm	7	1	0	0	
		Pm	2	2	1	0	32.7186, -118.6667at 1650 UTC single animal
		Bp	1	0	0	0	
		UD	4	0	0	0	
2023-07-22	9.5	*Zc*	24	2	0	0	

		Bm	9	1	1	0	1 Bm at 33.0412 -118.8360 at 2240 UTC. Mainly D calls. Was booking it south fast. With the weather being sloppy, they couldn't keep up and tag it.
		Pm	2	0	0	0	
		Ud	1	0	0	0	
		Uz	1	0	0	0	
2023-07-23	11	*Zc*	25	4	1	1	Hyd 409, see Vv Screenshots
		Bm	11	0	0	0	
		Dd	3	0	0	0	
		Tt	1	0	0	0	
		Sc	1	0	0	0	
		Ud	5	0	0	0	
2023-07-24	11	*Zc*	13	2	0	0	
		Bm	5	2	2	2	Pair of 4 animals that quickly split into 2 pairs individuals seen at 1447UTC at 32.8790 -119.0480. 1 individual tagged at 21:21:46 UTC near H36/110 at 32.8553 -119.1365 in a fission fusion group of 6 individual. Assumed one of the animals seen earlier at 1447UTC.
		Gg	1	0	0	0	
		Bp	1	1	1	0	1 individual tagged at 20:02:59 UTC at 32.8905 -119.123.
		Ud	5	0	0	0	
2023-07-25	12	*Zc*	2	1	0	0	
		Dd	1	1	1	0	Manual posit (16:50 UTC, 33.011988,-118.743342) sent to Phoenix. Visually verified as common dolphins with neonates at 33.0096 -118.7417 at 17:57 UTC. MarEcoTel was with the group before, during, and after the explosives test, though the group left the area before the last two charges. Followed them, but were reactive to close approach once they left the area of the explosives. Got biopsy
		Ud	8	1	0	0	

		Um	3	1	0	0	Phoenix informed of animal near 504,505 but chose not to leave Diane G
2023-07-26	6.5	*Zc*	2	1	1	0	
		Ud	2	0	0	0	

Table 26. Excerpts from M3R log files from a field effort on SOAR from October 1-10 2023.

Test Dates	Hours Monitored	Species	Acoustic Detections Logged	Acoustic Detections Directed	Visually Verified	Tagged	Notes
2023-10-02	7	*Zc*	4	0	0	0	
2023-10-03	1	*Bp*	4	1	0	0	Posit near Hyd 105: 33.048842; -119.073675
2023-10-04	7	*Zc*	5	0	0	0	
		Bp	2	0	0	0	
2023-10-05	8	*Zc*	6	1	0	0	
		UD	1	0	0	0	
2023-10-06	8	*Zc*	7	1	0	0	
		Bp	4	3	0	0	
		Bm	2	0	0	0	
		UD	1	0	0	0	
2023-10-07	10	*Zc*	9	4	0	0	
		Bm	1	0	0	0	
		UD	2	0	0	0	
		Me	1	0	0	0	
2023-10-08	8	*Zc*	6	0	0	0	
		Bp	1	0	0	0	
2023-10-09	6	*Zc*	6	0	0	0	

		Bp	1	0	0	0	

8.2 PMRF

Table 27. Excerpts from M3R log files from a field effort on PMRF from August 5 – 13 2023. Visual sightings without a corresponding acoustic sighting are noted below the table.

Test Dates	Hours Monitored	Species	Acoustic Detections	Acoustic Detections	Visually Verified	Tagged	Notes
2023-08-05	6.5	*Oo*	3	1	1	0	Best posit: 22 6.608, -159 50.99 Hyds: 4-6, L-2, L-3
		Sb	4	0	0	0	Best posits: 22 2.03, -159 50.99; 22 5.24, -159 50.66; 22 4.46, -159 52.42 Hyds: 3-7, F-5, F-4, F-7
		Md	12	0	0	0	Hyds: 2-2, K-1, K-4, 3-1, 2-1, 4-4, 4-5, 4-7, I-2, K-4, 3-7, 4-3
		UD	1	0	0	0	Hyds: F-8
2023-08-06	7	*Md*	7	0	0	0	Best posit: 22.140333, -159.9223333 Hyds: L-9, K-3, 3-7, 2-2, 4-2, 3-3, 2-8
		Pm	2	0	0	0	Best posit: 22.759266, -160.021166 Hyds: L-10, I-10
		Sb	1	0	0	0	Hyds: 3-1 with the other groups being off range.
		UD	5	1	0	0	Best posits: 22.25216666, -159.896166; 22.20433, -159.80165; 22.25766, -159.940366 Hyds: I-1, F-13, F-14, F-17, K-1
2023-08-09	5	*Md*	2	0	0	0	Hyds: L-1, 2-1
		UD	2	0	0	0	Hyds: G-17, I-6
2023-08-10	4	*Md*	4	0	0	0	Hyds: K-2, 1-1, K-1, 2-8
		Gm	1	1	1	1	Hyds: H-16 Best posits: 22.11471, -159. 879797; 1751-1915UTC: 22.07828, -159.899 (Visually verified)
		Tt	2	1	1	0	Hyds: G-14 Best posits: 22.023621, -159.843505; 2020UTC: 22.02372, -159.843 (Visually verified)
		Pm	1	0	0	0	Hyds: I-5

		UD	6	1	0	0	Best posits: 22.116259,-159.834345; 22.077746, -159.851339 Hyds: 3-7, 2-8, 4-5, G-17, F-5, 1-10
2023-08-11	5.5	*Md*	4	2	0	0	Hyds: 4-6 (Directed), 4-6 (Directed), 3-4, 2-1
		Tt	1	1	0	0	Best posit: 22.075727; -159.851608; 22.044937; -159.847778 Hyds: F-8 (Directed)
		Sb	1	0	0	0	Hyds: 3-7
2023-08-12	6.5	*Sb*	6	0	0	0	Best posits: 22.125317, -159.9181137 Hyds: 2-4, 3-2, 1-8, 1-10, 2-6, 1-8
		Tt	1	1	1	0	VV: 21.93048 -159.699 group of 9
		Md	12	2	0	0	Best posits: 22.127733, -159.910019 Hyds: 3-7, I-1, K-2, 4-6, 3-7, F-14, K-1, 2-6, 3-2, L-1, F-19, 4-4
		Gm	1	0	0	0	Hyds: F-12
		Pe	1	1	1	1	Best posit: 1930UTC: 22.08812, -159.911(Visually verified) Hyds: 3-7
		UD	5	0	0	0	Hyds: F-8, 2-5, 2-4, G-14, F-19
		US	1	0	0	0	Hyds: G-15
2023-08-13	6.5	*Sb*	4	4	3	0	Best posits: 1722UTC: 22.0377, -159.90105 (Visually verified); 1732UTC: 22.04574, -159.90855 (Visually verified): 1749UTC: 22.05883, -159.91969 (Visually verified); 1656UTC: 22.140663, -159.872599; 22.0377, -159.90105 Hyds: 3-7, I-6
		Tt	4	2	1	2	Best posits: 1844UTC: 22.06126, -159.85158 (Visually verified); 1856UTC: 22.060268, -159.848465 Hyds: F-8, F-18, F-5, F-8
		Md	5	1	0	0	Best posits: 22.238144, -159.238144 Hyds: 2-1, K-1, F-13, 2-1, F-16

		UD	1	0	0	0	Hyds: 3-4

Notes: On Aug 5th, a group of rough-toothed dolphins (Sb) was visually verified off range at 21.98852, -159.92 at 1655UTC.

On Aug 6th, two groups of short-finned pilot whales (Gm) were visually verified off range at 21.8918, -159.796 at 1607UTC and 21.91543, -159.801 at 1807UTC. Three tags were deployed. One group of Pantropical spotted dolphin (Sa) were visually verified off range at 21.92804, -159.84218 at 1919UTC. One group of spinner dolphins (Sl) were visually verified off range at 21.95912, -159.721 at 2318. Two groups of rough-toothed dolphins (Sb) were visually verified off range at 21.9012, -159.776 at 1712UTC and 21.9301, -159.843 at 1922UTC.

On Aug 10th, one group of Pantropical spotted dolphin (Sa) were visually verified off range at 22.00006, -159.88 at 1712- 1725UTC. Two groups of rough-toothed dolphins (Sb) were visually verified off range at 22.00006, -159.88 at 1702UTC and 22.02936, -159.894 1922UTC.

On Aug 12th, An off-range group of spinner dolphins (Sl) were visually verified at 21.94562, -159.6924 at 1555UTC. A group of rough-toothed dolphins (Sb) were visually verified off range at 21.9181, -159.839. A group of off-range bottlenose dolphins (Tt) were visually verified at 1559UTC at 22.018585, -159.823395. A group of off-range short-finned pilot whales were visually verified with two tags deployed at 1629UTC at 21.89149, -159.78407.

On Aug 13th, Two groups of bottlenose dolphins (Tt) were visually verified off range at 21.92804, -159.94218 at 2122UTC and 21.9815, -159.9 at 2138UTC respectively. Additionally, two groups of rough toothed dolphins were visually verified off range at 22.08967, -159.89365 at 2018UTC and 21.91398, -159.81214 at 2122UTC respectively.

Table 28. Excerpts from M3R log files from a field effort on PMRF from AUG 16 – 23 2022.

Test Dates	Hours Monitored	Species	Acoustic Detections Logged	Acoustic Detections Directed	Visually Verified	Tagged	Notes
2022-08-16	9	*Gm*	1	0	0	0	
		Md	4	1	0	0	
		UD	9	0	0	0	
		Zc	1	0	0	0	
2022-08-17	9.5	Gm	2	1	1	1	5-2:(22.1149, -159.932)@2225 UTC
		Md	1	1	1	0	3-7:22.07553, -159.873@1923 UTC
		UD	6	0	0	0	
		UZ	6	0	0	0	

2022-08-18	8	Md	4	2	1	0	5-3:(22.1349, -159.932) 1830 UTC
		Pe	2	2	2	0	4-6: 17:27:52 @ 22.1257 -159.9331 5-3: 22.094, -159.947 @ 2036UTC
		Sb	1	1	1	0	2-3: 12:12:03 @ 22.1765 -159.8792
		Sc	1	1	1	1	K-1: 20:43:11 @ 22.08391, -160.004
		UD	13	0	0	0	
2022-08-19	4	Gm	1	0	0	0	
		Md	5	0	0	0	
		UD	1	0	0	0	
		UZ	3	0	0	0	
		Zc	2	0	0	0	
2022-08-20	6	Md	3	1	1	0	G-9: ? @ 1628 UTC
		UD	5	2	0	0	
2022-08-21	5	Md	14	0	0	0	
		Tt	1	1	1	0	G-18: 20:42:51 @ (22.0231, -159.8676)
		UD	7	0	0	0	
2022-08-22	3.5	Md	9	0	0	0	
		UD	12	2	0	0	
2022-08-23	6	Md	4	0	0	0	
		Tt	2	1	1	0	1-8: 21:31 UTC
		UD	8	1	0	0	