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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), 2024

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

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6. AUTHOR(S)
K. Dolan
A. Carroll
L. Moniz
N. DiMarzio
S. Watwood
F.B. Hoyer
R.P. Morrissey

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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 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 FY24 the M3R program had five goals for SOAR and PMRF: Support real-time monitoring of on-water tagging operations Collection and post-processing of M3R binary archives and periodic broadband recordings Data preservation: conversion of Alesis recordings to M3R packet recorder format SOAR Continuous Active Sonar Behavioral Response Study (CAS BRS) DICASS sonobuoy receiver adaption in preparation for deployment at SOAR

Goal 1: M3R supported two real-time monitoring efforts in collaboration with the Marine Ecology and Telemetry Research (MarEcoTel) in February and November 2024 at SOAR. A total of 300 acoustic detections were logged using the M3R system during these efforts. Of the 300 acoustic detections, M3R directed the on-water team from team to 46 vocal groups resulting in MarEcoTel visually verifying 23 of the acoustic detections which included the species goose-

beaked whale (*Ziphius cavirostris*) (20), fin whale (*Balaenoptera physalus*) (two), and Risso's dolphin (*Grampus griseus*) (one). Detailed information on the M3R real-time monitoring effort can be found in Schorr et al., 2025. A single real-time monitoring effort was conducted in collaboration with Cascadia Research Collective (CRC) in February 2024. A total of 128 acoustic detections, of which CRC was directed to nine groups. CRC visually verified five of the acoustic detections, which included the species dense-beaked whale (*Mesoplodon densirostris*) (one), short-finned pilot whales (*Globicephala macrorhynchus*) (three), and bottlenose dolphin (*Tursiops truncatus*) (one).

Goals 2 and 3: At SOAR, over of 310 days of archive data were collected during calendar year 2024. Over 160 hours of broadband recordings were collected between February and March 2024. Additional broadband recordings were collected between November and December of 2024, but have yet to be processed for inclusion in this report. Additionally, over 400 hours of recordings collected between 2006 and 2014 were preserved from SOAR as a part of the data preservation effort. Data collection efforts at PMRF resulted in 337 days of archives collected in 2023 and 48 days of archives collected in Jan-Feb of 2024. Additional data was recorded in 2024, however remaining data is either on site or hardware issues are requiring data restoration efforts. Recovered data will be reported in the 2025 annual report. Over 55 hours of broadband data collection also occurred in January of 2024. Additionally, data collected between 2005 and 2007 at PMRF are being transferred for long term storage, and channel maps have been verified with the original data collection entity, NIWC.

Goal 4: The Sonar Positional Reporting System (SPORTS) database was used to access potential CAS events between 2018 and 2023 along with passive acoustic data collected from tags deployed by MarEcoTel. No on-range events were identified, however 24 off-range events were identified for analysis, as signals were detected on-range. Of the 24 events eight had no sonar, eight had Pulse Active Sonar (PAS) only, and eight had CAS or CAS+PAS. Each event was broken down into 30-minute intervals (starting on the hour), and given a designation of before, during, and after. M3R archives were analyzed to determine the presence of group vocal periods (GVPs) beginning in each of the 30-minute intervals. Results did not indicate a significant effect of before, during, and after period on the number of GVPs, and there was only a relatively weakly significance effect on the number of GVPs from the No sonar cases. The model, however, did not explain much of the variation in the number of GVPs detected. Data collection efforts are ongoing in 2025 and 2026, and this analysis can be revisited with an increased sample size.

Goal 5: Efforts are underway to adapt a sonobuoy receiver to enable MarEcoTel to activate these sonobuoys from their rigid hull inflatable boats. This will facilitate the addition of controlled exposure events of DICASS on tagged marine mammals to behavioral effects analysis. Modifications include the addition of a small RF amplifier and encasement of the entire assembly in a waterproof case.

15. SUBJECT TERMS
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Executive Summary

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In FY24 the M3R program had five goals for SOAR and PMRF:

Support real-time monitoring of on-water tagging operations

Collection and post-processing of M3R binary archives and periodic broadband recordings

Data preservation: conversion of Alesis recordings to M3R packet recorder format

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DICASS sonobuoy receiver adaption in preparation for deployment at SOAR

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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
dB	decibels
DCL	Detection, Classification and Localization
DICASS	Directional Command Activated Sonobuoy System
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
LCSR	Low Cost Sonobuoy Receiver
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

Acronym	Definition
n	Number of samples analyzed
PCoD	Population Consequences of Disturbance
PD	Probability of Detection
PMRF	Pacific Missile Range Facility
RF	Radio-Frequency
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

In FY24 the M3R program had five goals for SOAR and PMRF:

- Support real-time monitoring of on-water tagging operations

Collection and post-processing of M3R binary archives and periodic broadband recordings

Data preservation: conversion of Alesis recordings to M3R packet recorder format

SOAR Continuous Active Sonar Behavioral Response Study (CAS BRS)

DICASS sonobuoy receiver adaption in preparation for deployment at SOAR

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 six 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. Most SWTR hydrophones are nonfunctional and have been removed from the M3R data-stream. Note that over the years the hydrophone configuration has changed due to certain hydrophones becoming nonfunctional.

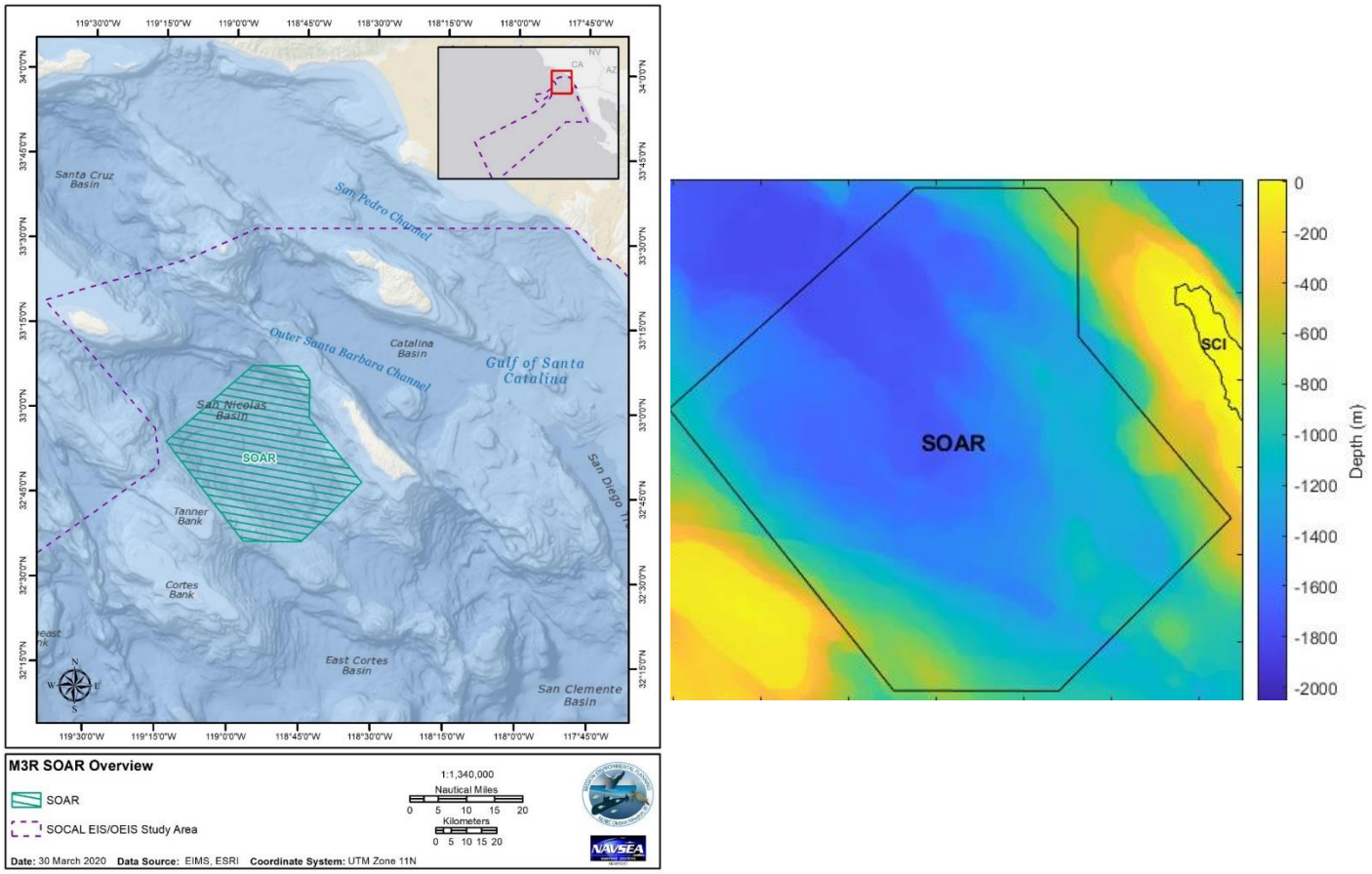


Figure 1. Location of SOAR hydrophone range, west of San Clemente Island off southern California (left). Hydrophone layout and bathymetry (right).

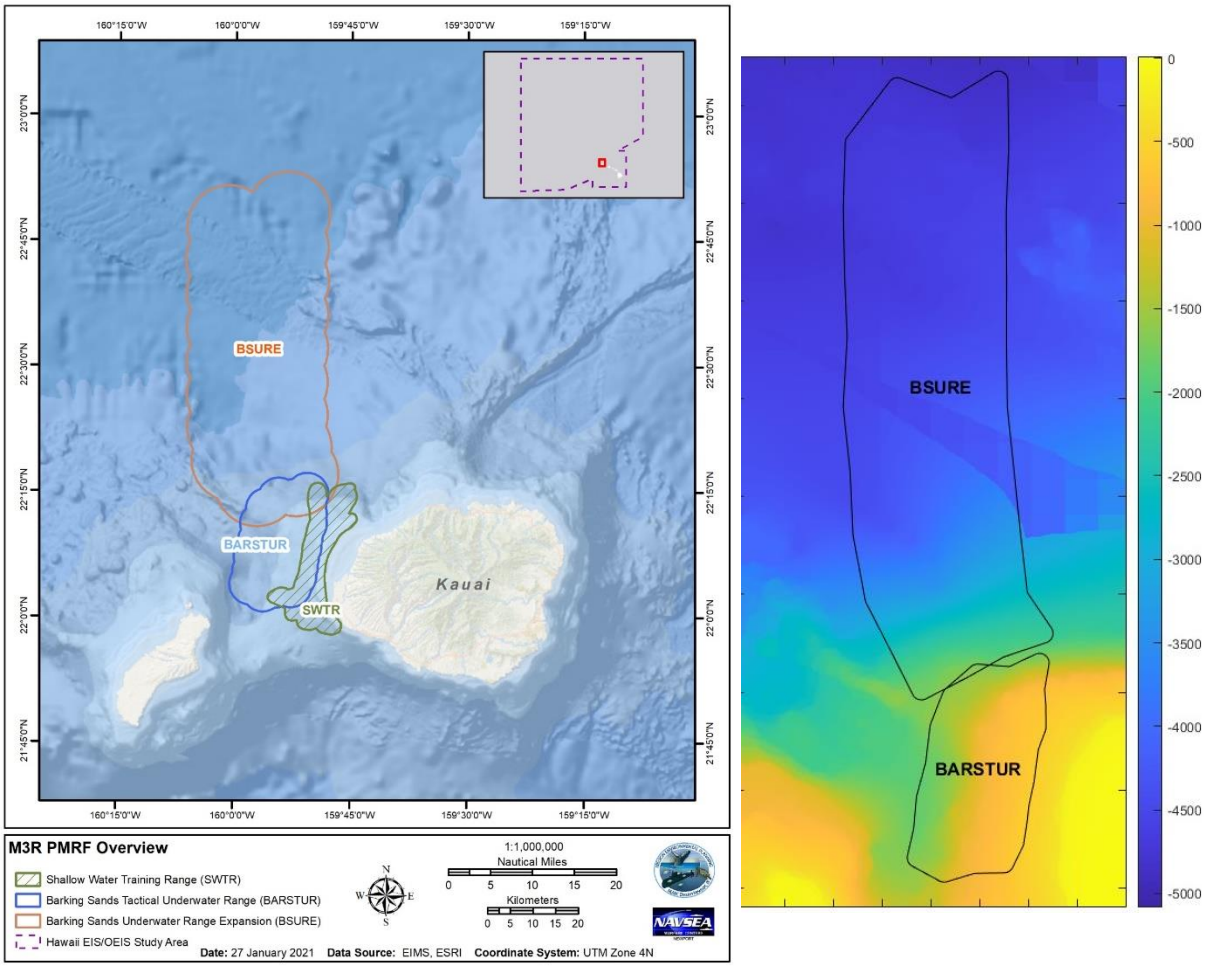


Figure 2. Location of PMRF hydrophone range, west of Kauai, Hawai'i (left). Hydrophone layout with bathymetry right).

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 recordings from all range hydrophones are collected opportunistically when M3R personnel are on site.

Three detector/classifiers are employed by the M3R System:

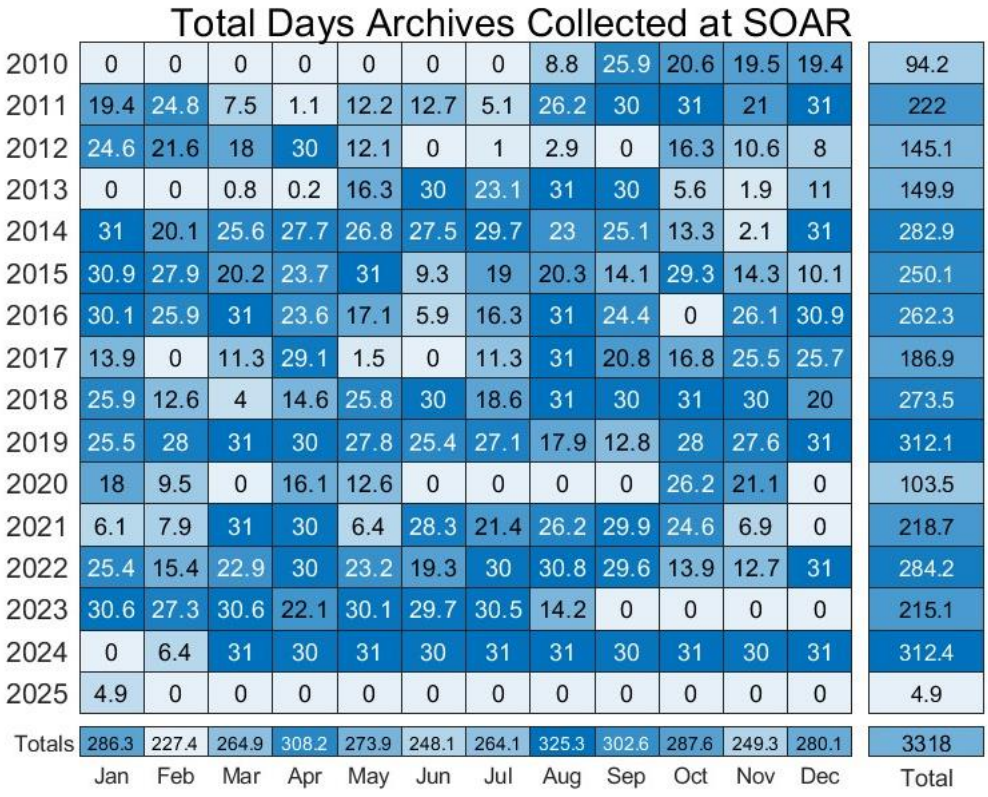
1. Full bandwidth Fast Fourier Transform (FFT)
    a. 2048 FFT, 50% overlap, frequency resolution of 46.875 Hz, time resolution of 10.67 ms
2. Low-frequency bandwidth FFT
    a. 2048 FFT, 90% overlap, frequency resolution of 2.92 Hz, time resolution of 21.33 ms
3. Class-Specific Support Vector Machine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

The CS-SVM classifier was installed in May 2010 at SOAR and May of 2011 at PMRF. The version currently running at SOAR has four classes: goose-beaked whale (*Ziphius cavirostris, Zc*) foraging and buzz clicks, sperm whale foraging clicks (*Physeter macrocephalus*, *Pm*), and 'generalized dolphin' clicks. The CS-SVM classifier currently running at PMRF has an additional two classes: dense-beaked whale (*Mesoplodon densirostris, Md)* 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-finned pilot whale (*Globicephala macrorhynchus*), and common dolphins (*Delphinus delphis*) (Jarvis et al. 2008, Jarvis et al. 2014).

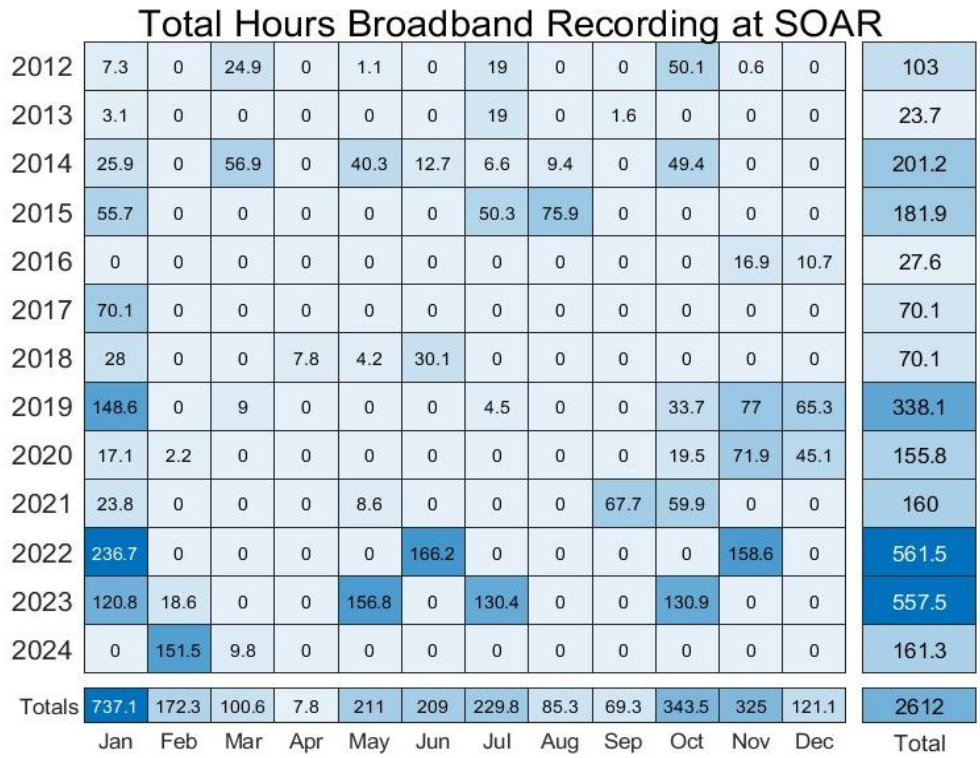
1.4.1 SOAR

Archives have been collected on a total of 3,318 days since the CS-SVM classifier was installed in 2010 (Figure 3). A minimum of 312.4 days of archive data were collected during calendar year 2024. Additional data were collected between September 2023 and January 2024, but they were inaccessible for post-processing and inclusion in this report due to hardware issues. These hardware issues are currently being addressed, and the recovered data will be included in the 2025 report. Broadband recordings were first collected in 2012 in the current packet recorder format. A total of 2,612 hours of full-bandwidth recordings have been collected at SOAR since 2012 (Figure 4), with 161.3 hours collected between February and March 2024. Additional packet recorder data were collected between November and December of 2024, but have yet to be processed for inclusion in this report.



	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	19.4	24.8	7.5	1.1	12.2	12.7	5.1	26.2	30	31	21	31	222
2012	24.6	21.6	18	30	12.1	0	1	2.9	0	16.3	10.6	8	145.1
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	6.9	0	218.7
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	29.7	30.5	14.2	0	0	0	0	215.1
2024	0	6.4	31	30	31	30	31	31	30	31	30	31	312.4
2025	4.9	0	0	0	0	0	0	0	0	0	0	0	4.9
Totals	286.3	227.4	264.9	308.2	273.9	248.1	264.1	325.3	302.6	287.6	249.3	280.1	3318

Figure 3. Total days archives have been collected at SOAR from 2010 – January of 2025.



	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
2024	0	151.5	9.8	0	0	0	0	0	0	0	0	0	161.3
Totals	737.1	172.3	100.6	7.8	211	209	229.8	85.3	69.3	343.5	325	121.1	2612

Figure 4. Total days archives have been collected at SOAR from 2010 – January of 2025.

1.4.2 PMRF

Archives have been collected at PMRF on a total of 2,341 days from January 2011 – February 19, 2024, with the number of days increasing substantially starting in 2017 (Figure 5). A total of 378.3 days of archives have been collected since the publication of the FY23 report. Archives collected post February 19, 2024, are still in transit to NUWC NPT and are thus not included here. 523.3 hours of broadband recordings have been collected since 2011, with 55.9 hours recorded during FY24 (Figure 6).

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	0	0	0	0	137.2
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	29.6	23.5	30	30.9	30	22.6	334
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	30.7	29.8	30.8	28.1	30.9	337.9
2024	30.6	17.8	-	-	-	-	-	-	-	-	-	-	48.4
Totals	161.5	268.2	266.5	185.2	196.7	234.9	224.6	181.6	146	160.9	176.2	139.1	2341

Figure 5. Total days in which archives reports were collected at PMRF from 2011-2024. Dashes indicate time periods being recovered due to hardware issues.

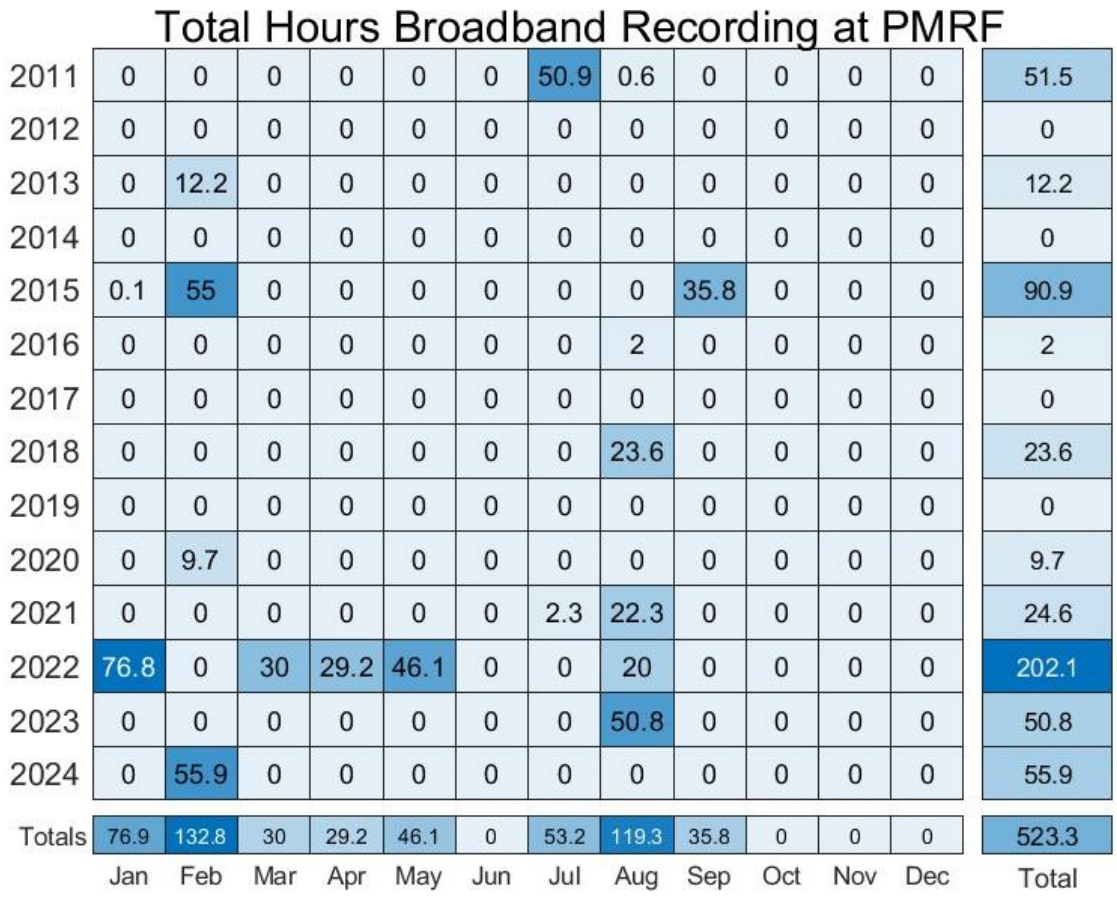


Figure 6. Total hours of broadband recordings collected at PMRF from 2011-2024.

2 Data Preservation

Background

The M3R program originally made broadband recordings from range hydrophones (at the Atlantic Undersea Test and Evaluation Center, AUTEC) using TASCAM recorders (Dolan et al. 2024), before switching to Alesis recorders circa 2004, and finally to a packet recorder system developed by M3R at NUWC Newport circa 2012. At the SOAR range Alesis broadband recordings began in 2006, when the M3R system was installed, and continued through 2014. The packet recorder was first used at SOAR in 2012, but between 2012 and 2014 both the Alesis recorders and the packet recorder were utilized. From 2014 to the present only the packet recorder has been used at SOAR. There are no Alesis recordings at PMRF, as this range only has recordings from the packet recorder, but the M3R program does have copies of some range recordings from the Naval Information Warfare Center (NIWC) Pacific Whale Acoustic Reconnaissance Project (WARP) Laboratory, which have also been preserved.

The goal of this task was to convert all the Alesis data to packet recorder format for storage on the M3R server, and to copy the PMRF data from hard drives to the server. Each Alesis recorder can record 12 channels of data, and thus a bank of Alesis recorders is needed to record all range hydrophones concurrently. At SOAR the Alesis setup consisted of eight recorders. Since only four recorders can be synched simultaneously, an Inter-Range Instrumentation Group (IRIG) timecode was included on one channel for each set of four recorders. These recorders stored acoustic data in a proprietary format that became outdated when Alesis stopped supporting the recorders. Additionally, Alesis stopped supporting the software tools used to extract the data from their proprietary format to other common file formats, such as wav files. At that time, the M3R program switched recording methods to the NUWC packet recorder, which records the raw packets of digitized data. In order to salvage the existing Alesis recordings, M3R replayed the broadband recordings through a simulated SOAR M3R signal processing cluster to convert them to packet recorder format by essentially re-recording the acoustic data in the current packet recorder format. This process preserved these historical broadband recordings for entry into the M3R multi-year database (Dolan et al., 2024).

2.1 SOAR

2.1.1 Methods

Data conversion and preservation methods used for the SOAR data are essentially the same as those used for the AUTEC Alesis Conversion/Data Preservation project outlined in the FY23 'Marine Mammal Monitoring on Navy Ranges (M3R) at the Atlantic Undersea Test and Evaluation Center (AUTEC), Bahamas, and the Jacksonville Shallow Water Testing Range (JSWTR)' annual monitoring report (Dolan et al., 2024).

2.1.2 Results

In total, 111 Alesis hard drives containing approximately 426 hours of acoustic data were converted into the packet recorder format. Table 1 outlines the number of hours of historical broadband acoustic data from 2006 through 2014 that were converted for SOAR. Of the drives that were converted, year 2008 encompassed most of the historical data, while 2006 contained the least number of recordings. Archive data created alongside the converted recordings during the conversion process were compared to the

archive data collected when the Alesis recordings were originally made (Figure 7). The converted archive data capture more of the clicks and whistles in the recordings than the original archive data.

Table 1. Hours of SOAR acoustic recordings successfully converted to packet recorder format, by year of original recording

	2006	2007	2008	2009 - 2014	Total
Hours Converted	61.0	101.9	176.5	86.4	~426

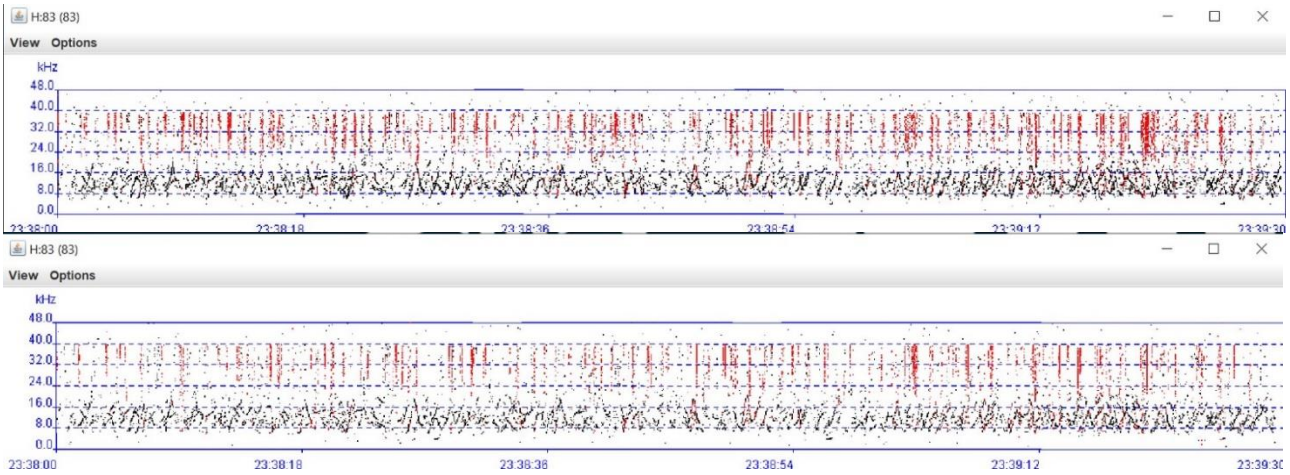


Figure 7. Comparison of MMAMMAL SPC-archive displays between re-recorded archive data (top) and original archive data (bottom) from hydrophone 83 during 2006

2.2 PMRF

2.2.1 Methods

Unlike historical SOAR acoustic recordings, Alesis recordings were not collected at PMRF. The M3R system was installed at PMRF in 2011, and the packet recorder was installed circa 2012 to make broadband recordings from the range hydrophones. However, M3R has copies of some historical recordings made by the NIWC WARP Laboratory using their recorder, which records in a DAT format. These recordings, located on external hard drives, were copied to the M3R server for preservation.

2.2.2 Results

Approximately 24 hard drives from 2005 to 2007 containing NIWC DAT files were transferred to and preserved on the M3R data server. Now that these data are preserved in a more accessible location and the 12-channel map associated with the data has been obtained, the MATLAB application Raven=X can be used to rapidly explore these data, as it has the capability to read in DAT files.

3 Real-Time Monitoring of On-Water Operations

3.1 SOAR

3.1.1 Field Work Summary

A total of 300 acoustic detections were logged using the M3R system during two field survey efforts that occurred between February 22 – 28th and November 22 – December 1st, 2024. Of the 300 acoustic detections, M3R directed the on-water team from the Marine Ecology and Telemetry Research (MarEcoTel) team to 46. Here 'directed' implies that the location of the acoustic detection was sent, and the field team decided to go to the location. MarEcoTel visually verified 23 of the acoustic detections which included the species goose-beaked whale (*Ziphius cavirostris*) (20 of the 23), fin whale (*Balaenoptera physalus*) (two), and Risso's dolphin (*Grampus griseus*) (one). Detailed information on the M3R real-time monitoring effort can be found in Schorr et al., 2025.

3.2 PMRF

3.2.1 Field Work

M3R personnel completed one field survey in 2024 in conjunction with Cascadia Research Collective (CRC), from February 11 – 19 2024. CRC personnel typically transit from Kikiaola Harbor at sunrise to locations provided by M3R personnel of marine mammals of interest on PMRF. Locations are derived using the M3R signal-processing cluster, the majority generated automatically by the 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 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. Communications are maintained via radio and phone. Upon finding animals, CRC personnel collect photo-ID and behavioral data, as well as biologicals samples such as biopsy or eDNA, and deploy tags on the animals, according to their research needs.

Table 2 lists the marine mammal species acoustically identified using the M3R system during the 2024 field survey, along with summary information extracted from the associated PMRF field logs.

One hundred twenty-eight acoustic detections (Figure 8) were logged in total, including 27 for dense-beaked whale, 18 for short-finned pilot whale, 11 for humpback whale, three for sperm whale, nine for bottlenose dolphin, and two for pantropical spotted dolphin. Additionally, a single acoustic detection was made for goose-beaked whale, false killer whale, melon-headed whale, rough toothed dolphin, spinner dolphin, and striped dolphin. Fifty-two acoustic detections could not be classified further than genus to specific species and remained defined as unidentified dolphin species (*delphinidae sp*.).

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 nine of these 128 sightings. CRC visually verified five of

these sightings, including three groups of short-finned pilot whales and one group each of dense-beaked whales and bottlenose dolphins. Additional details from the field team can be found in Baird et al. 2024.

Table 2. Species acoustically identified with the M3R system at PMRF in 2024. Data are extracted from field test logs in 2024.

Species			Acoustic Detections Logged	Acoustic Detections Directed	Acoustic Detections Visually Verified
ID	**Common Name**	**Scientific Name**			
Md	Dense-beaked whale	*Mesoplodon densirostris*	27	2	1
Zc	Goose-beaked whale	*Ziphius cavirostris*	1	0	0
Pm	Sperm whale	*Physeter macrocephalus*	3	0	0
Gm	Short-finned pilot whale	*Globicephala macrorhynchus*	18	3	3
Pe	Melon-headed whale	*Peponocephala electra*	1	0	0
Mn	Humpback whale	*Megaptera novaeangliae*	11	0	0
Sb	Rough-toothed dolphin	*Steno bredanensis*	1	0	0
Pc	False killer whale	*Pseudorca crassidens*	1	0	0
Sa	Pantropical spotted dolphin	*Stenella attenuata*	2	0	0
Sc	Striped dolphin	*Stenella coeruleoalba*	1	0	0
Sl	Spinner dolphin	*Stenella longirostris*	1	0	0
Tt	Bottlenose dolphin	*Tursiops truncatus*	9	3	1
UD	Unidentified dolphin	Delphinidae sp.	52	1	0
		Totals	128	9	5

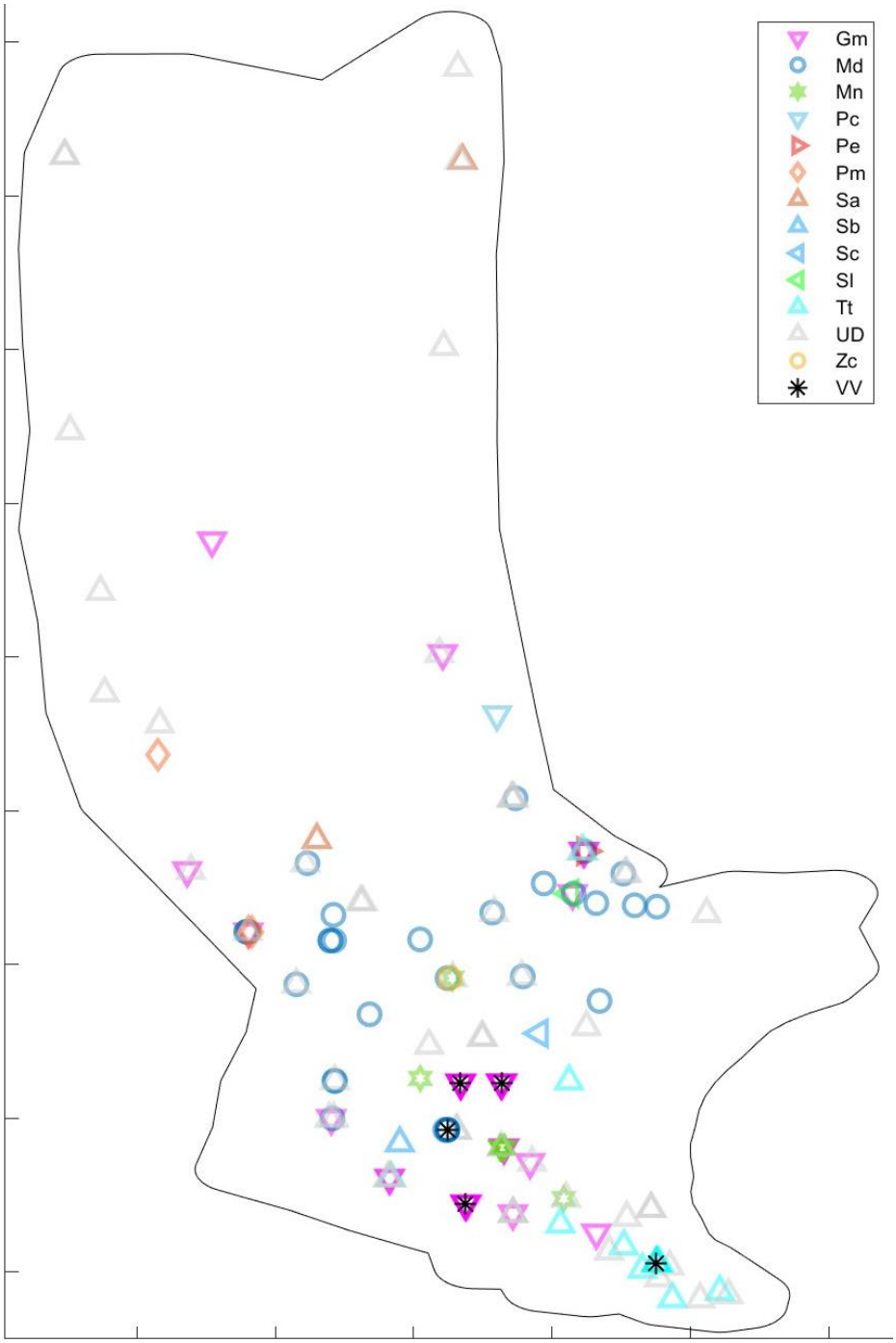


Figure 8. Acoustic detections at PMRF from February 11 - 19, 2024. Species included short-finned pilot whales (*Gm*), dense-beaked whales (*Md*), goose-beaked whales (*Zc*), humpback whales (*Mn*), false killer whales (*Pc*), melon-headed whales (*Pe*), sperm whales (*Pm*), pantropical spotted dolphins (*Sa*), rough-toothed dolphins (*Sb*), striped dolphins (*Sc*), spinner dolphins (*Sl*), bottlenose dolphins (*Tt*), and unknown delphinidae species (UD). Detections that were visually verified (VV) by CRC are overlaid with an asterisk.

4 SOAR Continuous Active Sonar (CAS) Behavioral Response Study (BRS)

4.1 CAS BRS Objective

Collaborative efforts between M3R and MarEcoTel at SOAR are focused on effects-centric analysis of the response of goose-beaked whales to active naval sonar events, shifting focus to Continuous Active Sonar (CAS) from Pulsed Active Sonar (PAS) events. The objective of this task was to examine the effects of CAS on goose-beaked whale foraging behavior by examining their Group Vocal Periods (GVPs) before, during, and after CAS events, using data collected on the range during the field studies with MarEcoTel and events pulled from the SPORTS database. Further details of this task can be found in Watwood et al. 2025.

4.2 Methods

The Sonar Positional Reporting System (SPORTS) database was queried to assess potential CAS events near SOAR for the years 2018-2023. Additionally, seven events were included in the dataset that were associated with times when MarEcoTel tags were on goose-beaked whales near SOAR and where a potential CAS-like signal was identified on the tag acoustics. After comparing the SPORTS query and CAS events identified on tag acoustics to available M3R SOAR archives, 52 potential CAS events were identified that might be found on range hydrophones. M3R personnel performed a manual review of the M3R archive data, looking for CAS signals on range hydrophones.

All fifty-two events were reviewed, for a total of almost 68 hours of data (Table 3).

Table 3. Results of archive manual review.

Total events reviewed	Total duration of events reviewed (hours)	Mean duration of reviewed events (hours)	Min range to reviewed events (nm)*	Max range to reviewed events (nm)*	Total with PAS detected on Range	Total with CAS detected on Range	Total with CAS+PAS detected on Range	Mean range to CAS events (nm)*
52	67.9	1.3	22.9	120.7	23	13	6	53.8

*range calculated to Hydrophone 505 in center of SOAR range

None of the identified events occurred on or close to the range. Based on the reported SPORTS locations, the events ranged approximately 22-120 nautical miles (nm) from the center of the SOAR range. After manual review of the archives, CAS signals on SOAR range hydrophones were only detected in 13 of the 52 events. PAS signals were detected in 23 events, and eight events included both CAS and PAS.

Several of the initial individual CAS events occurred within three hours of each other, and therefore were grouped together for additional analysis. This led to a total of eight separate CAS events for final analysis, six of which also included PAS.

For comparative analysis, eight events were included that were relatively similar in distance to the CAS and CAS+PAS events, but only included PAS, and eight events with no sonar reported or detected on range were also included. This resulted in a total of 24 events that were used in the analysis:

- eight with CAS or CAS+PAS,
- eight with PAS only, and
- eight with no sonar

Each of these 24 events was composed of a before, during, and after period, in which the during period included instances of either CAS, PAS, or CAS+PAS (except for the cases with no sonar). The total duration of each event varied between 6.5 and 27 hours, and the events were divided into 30-minute windows (starting on the hour).

Each of the 30-minute windows was designated as falling within a before, during, or after period. For some events, there were breaks of longer than 30 minutes between sonar bouts; however, all time windows from the start of the first sonar bout to the end of the last sonar bout were included in the during period. The length of the before and after periods were matched as closely as possible but were set to a minimum of 2.5 hours. This provided a minimum of five-time windows to establish a baseline of goose-beaked whale foraging before and after the event.

A custom MATLAB-based Autogrouper algorithm was used to estimate the number of goose-beaked whales foraging groups starting a foraging bout on range within a given time window (referred to as a GVP), based on automatic detection and classification of goose-beaked whale echolocation clicks from a class-specific support-vector machine (CS-SVM) classifier (Jarvis et al. 2008). Groups were divided into those that had clicks that were detected only on hydrophones on the edge of the SOAR range (indicating they may be located off range – 'edge-only groups') and those that were detected on at least one non-edge hydrophone ('non-edge groups'). A custom java algorithm was used to estimate the maximum received level (RL) in decibels (dB re 1 µPa) on any hydrophone on the range in a given time window in the frequency band of interest for CAS sonar.

A generalized additive model (gam function from the R package mcgv) was used to test if there was a significant effect on the number of non-edge group GVPs from either the before, during, after period (B, D, or A) or the type of event (CPC=CAS and CAS+PAS, P=PAS only, or N=No Sonar). The following function call was used, with the Tweedie distribution and a log link function:

NEGVP_BDA_Type_gam2 = gam(events2_NEGVP ~ events2_BDA + events2_Type,family=tw())

4.3 Results

The distance to sonar (and therefore received level) varied across events within event categories. Figure 9 shows the mean max RL across before, during, and after time windows for each of the event categories. Higher received levels were seen in the during period of CAS, CAS+PAS, and PAS events, but not for all events in those categories. Received levels were low for during periods of No Sonar events. Figure 10 and Figure 11 show the mean number of non-edge groups starting a foraging bout (on range foraging groups) in a 30-minute time window before, during, and after the event. Figure 12 shows that there was not a strong relationship between RL and the during event period within each event type, as described above.

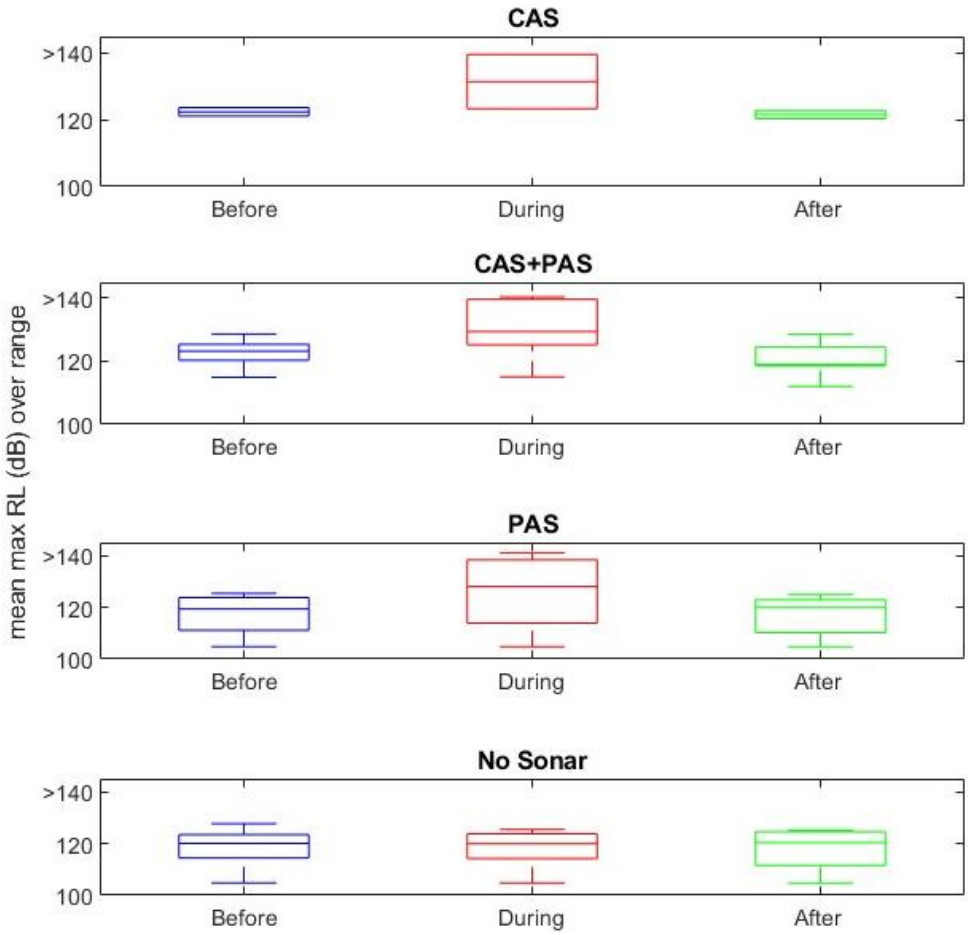


Figure 9. Mean maximum received level (in dB) over period time windows. One each box, the central line is the median, the edges of the box are 25th and 75th percentiles, and whiskers extend to the extreme datapoints not considered outliers.

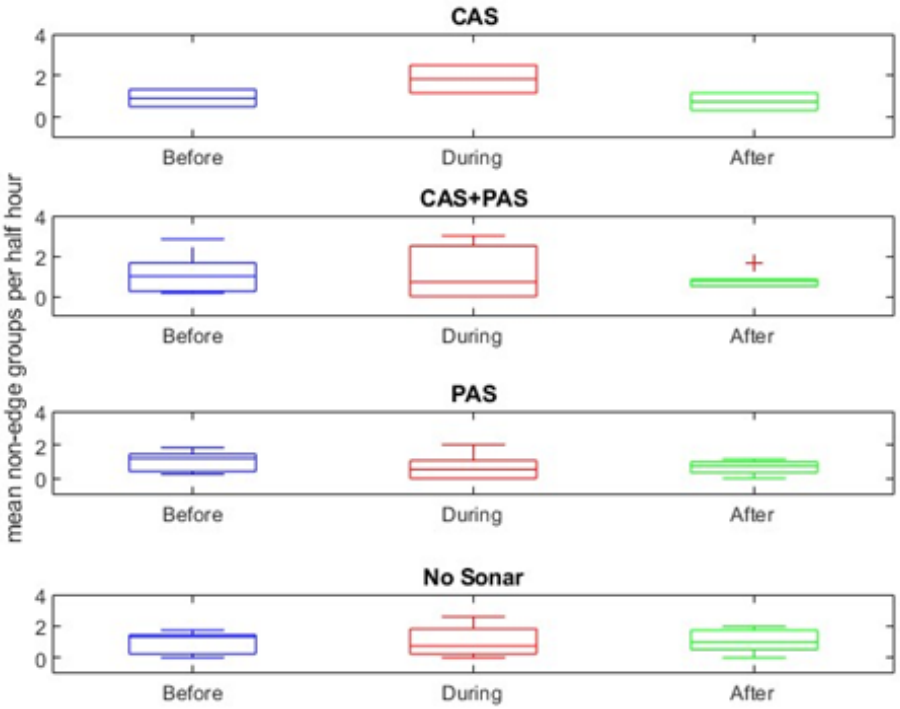


Figure 10. Mean number of goose-beaked whale foraging groups starting a foraging bout (GVP) per 30-minute time window before, during, and after the sonar event. Boxplot parameters are as described in Figure 9.

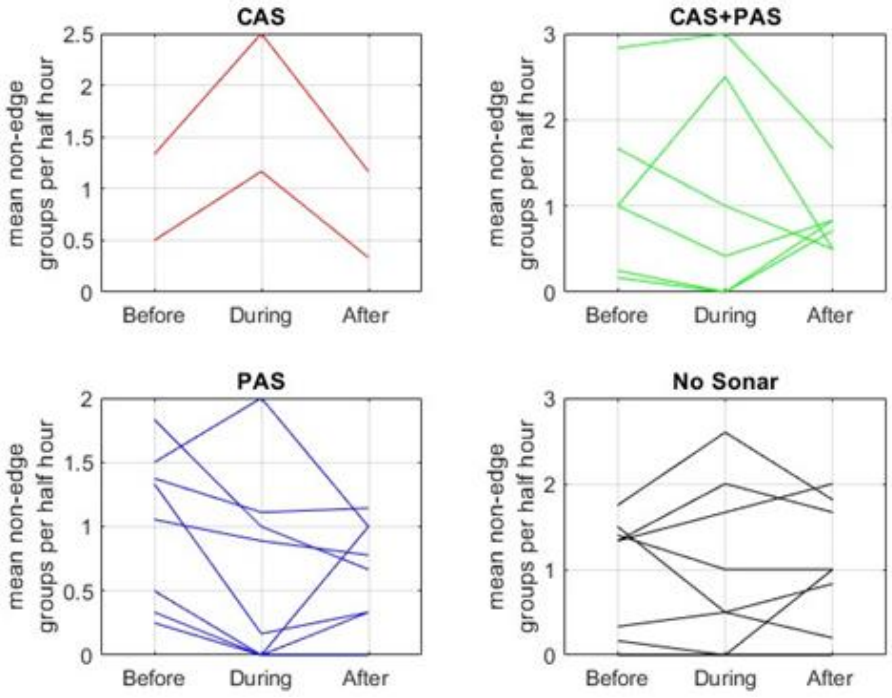


Figure 11. Mean number of goose-beaked whale foraging groups starting a foraging bout (GVP) per 30-minute time window on range before, during, and after the sonar event. Each event is represented with a single line connecting event periods to show trends, and events are separated into event categories to show CAS only (upper-left, n=2), CAS+PAS (upper-right, n=6), PAS only (lower-left, n=8), and No Sonar (lower-right, n=8).

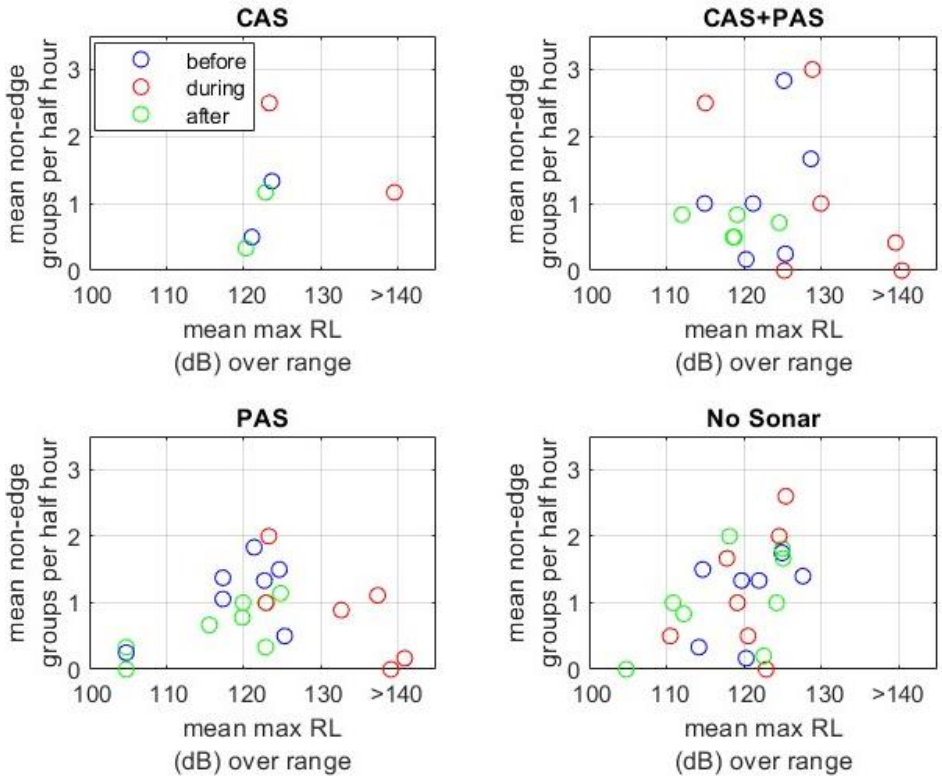


Figure 12. Mean number of goose-beaked whale foraging groups starting a foraging bout (GVP) per 30-minute time window on range before, during, and after the sonar event versus the mean maximum received level (in dB) in a half hour period. Received level as described in Figure 9**.**

Results of the gam (Table 4) indicate that with these data there was no significant effect on the number of non-edge GVPs from the Before-During-After period, and there was only a small significant effect on the number of non-edge GVPs from the data that had No Sonar. However, the adjusted R^2 value for this model is only 0.0219, with only 2.93% of the deviance explained, indicating this model is not explaining much of the variation in the number of non-edge GVPs.

Table 4. GAM results for the response Non-edge GVPs as a function of predictors BDA period and event Type.

Parametric coefficients:				
	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.1498	0.1078	-1.389	0.165
events2_BDAB	0.1645	0.109	1.509	0.132
events2_BDAD	0.1778	0.1223	1.454	0.147
events2_TypeN	0.2804	0.1137	2.466	0.014 *
events2_TypeP	-0.1906	0.1215	-1.569	0.117
Signif. Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				
R=sqr. (adj) = 0.0219 Deviance explained = 2.93%				

4.4 Discussion

In the two cases with only CAS the number of GVPs was higher in the during period than before or after the CAS, while the six cases with both CAS and PAS had mixed results; in some cases the number of GVPs was higher in the during period than the before and after, while in others it was lower, and in one case the number of GVPs dropped through the whole event. This might indicate that the addition of PAS may decrease the number of GVPs, but with such a small sample size these conclusions cannot be reliably drawn.

During both the PAS only events and those with No sonar there were a mix of cases in which the number of GVPs increased in the during period or decreased. There were also cases in PAS only in which the number of GVPs decreased throughout the event, and cases in which the number increased throughout the No sonar events. The gam did not indicate a significant effect of BDA period on the number of non-edge GVPs, and there was only a relatively weakly significant effect on the number of GVPs from the No sonar cases. The model, however, did not explain much of the variation in the number of GVPs detected.

Overall, the paucity of CAS data makes it difficult to draw conclusions from this dataset on the effect of CAS on goose-beaked whale foraging at SOAR. However, when additional data is collected that include CAS, this analysis could be revisited. CAS exposure data collection and analysis will be ongoing in 2025 and 2026.

5 DICASS Sonobuoy Receiver Adaptation

5.1 Background

Directional Command Activated Sonobuoy System (DICASS) sonobuoys are capable of emitting active sonar signals in order to aid in localization of submarines and other subsurface targets. These devices can be used as sources as part of ongoing efforts to quantify the effects of anthropogenic sound on marine mammals. Efforts are underway to adapt a sonobuoy receiver to enable MarEcoTel to activate these sonobuoys from Rigid-Hulled Inflatable Boat (RHIB) boats. This will facilitate the addition of controlled exposure events of DICASS on tagged marine mammals to enable behavioral effects analysis.

5.2 Sonobuoy Receiver Adaptation Work Summary

The DICASS sonobuoys need to be commanded into an active mode. This is done via a Radio Frequency (RF) command transmission from a sonobuoy commander device. The M3R program has procured a LCSR (Low Cost Sonobuoy Receiver) (Figure 13a) from Ultra Electronics which includes an integrated sonobuoy commander.

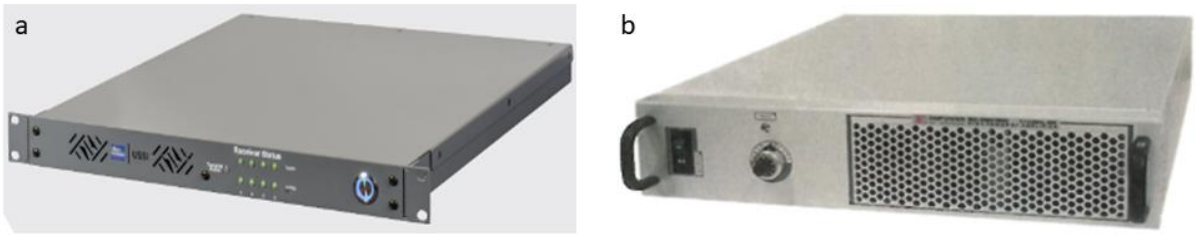


Figure 13. a) Low Cost Sonobuoy Receiver (LCSR), b) LCSR RF Amplifier

Concept of Operations- The LCSR is paired with a RF Amplifier (Figure 13b) to provide the command capability. The RF amplifier is connected to the LCSR output jack and is in turn connected to the antenna selected as the transmit antenna. The RF amplifier is separately powered from the LCSR.

As designed, the LCSR and the accompanying RF amplifier are intended for rack mounting in either a shore-based facility or a large ship. For mounting on the RHIB envisioned as the primary study platform, the LCSR has been packaged in a waterproof case along with the RF amplifier.

A smaller RF amplifier was chosen to reduce both power and space requirements on the RHIB. The concept of operations calls for the ship to deploy the DICASS sonobuoy and standoff within visual range of both the animals and the sonobuoy. The ship then initiates transmission from the buoy using the LCSR to transmit the command to the buoy. A smaller amplifier can therefore be employed as the required transmission distance is small. Note that acoustic data reception from the buoy is not required for this mode of operation, although it would potentially be helpful during analysis. The sound pressure level (SPL) at the animal is computed from an acoustic tag attached to the animal in advance.

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