2019 U.S. Navy Annual Marine Species Monitoring Report for the Pacific:

A Multi-Range-Complex Monitoring Report for Hawaii-Southern California Training and Testing (HSTT), Mariana Islands Training and Testing (MITT), Northwest Training and Testing (NWTT), and the Gulf of Alaska Temporary Maritime Activities Area (GOA TMAA)

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National Marine Fisheries Service
Office of Protected Resources

Prepared By

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50 CFR §218.75(d), § 218.95(e), § 218.145(f), and § 218.155(f)

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Photograph Credit:
Cuvier's beaked whale (*Ziphius cavirostris*) photographed by Jordan Lerma/Cascadia Research Collective under NMFS Permit #20605 to Robin Baird.

Executive Summary

The United States (U.S.) Navy conducts training and testing activities in the Pacific study areas described in the following Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS) documents: Hawaii-Southern California Training and Testing (HSTT) (Department of the Navy [DoN] 2013, 2018a), Mariana Islands Training and Testing (MITT) (DoN 2015a, 2019a), Northwest Training and Testing (NWTT) (DoN 2015b, 2019b), and the Gulf of Alaska Navy Training Activities (DoN 2011a, 2016a). The U.S. Navy testing and training ranges covered by these documents include the Hawaii Range Complex (HRC), and the Southern California Range Complex (SOCAL), which are part of the HSTT Study Area; the Mariana Islands Range Complex (MIRC), which is part of the MITT Study Area; the Northwest Training Range Complex (NWTRC) including the Naval Sea Systems Command's Naval Undersea Warfare Center Keyport Range Complex (Keyport Range Complex), which are part of the NWTT Study Area, and the Gulf of Alaska Temporary Maritime Activities Area (GOA TMAA).

To authorize these actions, the National Marine Fisheries Service (NMFS) under the Marine Mammal Protection Act (MMPA) issued 5-year Final Rules for HSTT (NMFS 2013a, 2014b, 2018a), MITT (NMFS 2015a), NWTT (NMFS 2015e), and GOA TMAA (NMFS 2013d, 2017b); Letters of Authorization (LOA) under the MMPA to Commander, U.S. Pacific Fleet and Commander, Naval Sea Systems Command for HSTT (NMFS 2013b, 2013c, 2014c, 2014d, 2018c, 2018d), MITT (NMFS 2015b, 2016), NWTT (NMFS 2015f, 2015g), and GOA TMAA (NMFS 2017a); and Biological Opinions (BOs) under the Endangered Species Act for HSTT (NMFS 2013f, 2014a, 2015d, 2018b), MITT (NMFS 2015c, 2017d), NWTT (NMFS 2015h), and the GOA TMAA (NMFS 2013e, 2017c).

The U.S. Navy is required by the Final Rules, LOAs, and BOs above to implement marine species monitoring. The regulations issued with the Final Rules for HSTT, MITT, NWTT, and GOA TMAA require the U.S. Navy to submit an annual monitoring report, as specified at 50 Code of Federal Regulations § 218.75(d) (HSTT), § 218.95(e) (MITT), § 218.145(f) (NWTT), and § 218.155(f) (GOA TMAA).

This monitoring report was prepared in accordance with the annual monitoring reporting requirements for 2019, as described in these regulations. It presents NMFS and the public with results and progress made during the period of 1 January 2019 to 31 December 2019. The marine species monitoring described herein was conducted in accordance with project objectives listed on the U.S. Navy's Marine Species Monitoring website: http://www.navymarinespeciesmonitoring.us/regions/pacific/current-projects/.

These MMPA authorizations were issued for a period of 5 years. The MITT, NWTT, and GOA TMAA monitoring programs are currently within the second set of 5-year authorizations and environmental planning documentation for the U.S. Navy, and that of HSTT transitioned in December 2018 to the third set of authorizations (NMFS 2018a, 2018b, 2018c, 2018d). In August 2018, the MMPA was amended by the John S. McCain National Defense Authorization Act (NDAA) for Fiscal Year (FY) 2019 to allow for 7-year authorizations for military readiness activities, as compared to the previously allowed five years. In March 2019, the U.S. Navy submitted a request for extension of the regulations and LOA for HSTT through December 20, 2025 (DoN 2019d). To authorize these actions, NMFS issued a Proposed Rule in October 2019 for the 2-year extension (NMFS 2019). In February 2019, the U.S. Navy submitted a request for regulations and LOA for MITT from August 2020 through August 2027 (DoN 2019e) and in June 2019, a request for regulations and LOA was submitted for NWTT from November 2020 to November 2027 (DoN 2019f). These requests are still under review by NMFS.

In this report, monitoring goals for the HSTT, MITT, NWTT, and GOA TMAA study areas are framed in terms of progress made on question-based scientific objectives and programmatic Intermediate Scientific Objectives.

These objectives are considered within the conceptual framework that was developed in consultation with the project's Scientific Advisory Group (DoN 2011b). This conceptual framework is centered on gathering monitoring information within the categories of "*occurrence, exposure, response, and consequences*" as a progression of knowledge about marine species and their interaction with U.S. Navy training and testing activities.

Highlights of current scientific progress over the course of this reporting period include the following:

HSTT Hawaii Range Complex

- Seasonal and annual abundance and population trends of Blainville's beaked whales from 2015 to 2018 at Pacific Missile Range Facility (PMRF) were estimated using group vocal periods, and appear to be stable.
- For the first time, automated classification algorithms were successful in attributing acoustic tracks recorded at PMRF to Bryde's, fin, and sei whales. Automated algorithms were also successful in localizing blue whales and sperm whales at PMRF.
- Minke whales acoustically tracked from 2012 to 2017 at PMRF increased the source levels of their boing calls during periods with increased background noise. Animal source levels were also estimated for minke whale boings.
- Received sound levels were estimated for seven tagged odontocetes at PMRF (three short-finned pilot whales, two rough-toothed dolphins, and two melon-headed whales), during Submarine Command Course training events. Four individuals had maximum received levels (RLs) ranging from 133 to 148 decibels (dB), and one individual, a rough-toothed dolphin, had a maximum RL of 155.9 dB.
- Potential *response* of tagged odontocetes at PMRF was also assessed by analyzing animal tracks for any large-scale movements concurrent with mid-frequency active sonar (MFAS) exposure. When available, diving and surfacing behavior of tagged individuals was also analyzed before, during, and after MFAS use to assess potential reactions. Although two pilot whales exhibited changes in movements and diving behavior concurrent with MFAS exposure, these behavioral changes may have been due to other factors.

HSTT Southern California Range Complex

- Abundance trends for Cuvier's beaked whales at Southern California Offshore Antisubmarine Warfare Range (SOAR) from 2010 to 2019 were estimated using group vocal periods, and a significant annual increase was noted over this 10-year period. Analysis of 49,855 hours of acoustic data are part of this analysis. Mean monthly abundance varied from a high of 53 animals to a low of 4 animals with September continuing to be the month with lowest detections.
- Home ranges were estimated for Risso's dolphins tagged at SOAR from 2009 to 2019, and for Cuvier's beaked whales tagged from 2008 to 2017. Continued focus on photo-identification, biopsy sampling, and the movement and habitat use of Cuvier's beaked whales and fin whales will help elucidate population structure for these species.
- Measurements of intervals between deep (presumed foraging) dives for tagged Cuvier's beaked whales following sonar exposure indicate that it may take up to 10 dive cycles for individuals to return to "baseline" deep-diving patterns when exposed to sonar at a distance of 10 kilometers (km). The 10-dive cycle estimate is a conservative maximum based on available data. There is considerable variation depending on source type and distance.
- For the second year in a row, visual surveys of Guadalupe fur seals were conducted at Guadalupe Island and San Benito Archipelago during pupping season to better understand population trends of this species. In 2019, data from 35 Guadalupe fur seals instrumented in November 2018 with satellite-monitored tags were analyzed to characterize at-sea dive behavior and horizontal spatial use in relation to U.S. Navy training and testing areas.
- A comparison of fisheries and naval training explosions in the SOCAL range complex was conducted, revealing different signal characteristics. The characteristic difference between Navy missile explosions and seal bombs is that seal bombs included multiple bubble pulses following a primary pulse versus the Navy ordnance that consisted of only a primary pulse.
- Acoustic towed-array data collected during California Cooperative Oceanic Fisheries Investigations (CalCOFI) survey cruises from 2008 to 2019 were analyzed for beaked whale echolocation clicks and were only detected on one occasion. The low acoustic encounter rate of beaked whales in this dataset may be linked to the continuous use of shipboard echosounders during CalCOFI cruises.
- A planned summer 2019 wide area survey for beaked whales using an underwater glider with passive acoustic sensors was postponed due to an unforeseen equipment issue. While the issue has been resolved, it was decided to reschedule the survey for winter 2020.

NWTT

- Humpback whales were instrumented with satellite-monitored tags off the coast off Washington in September and October 2019, and off Hawaii in March 2019. Whales tagged off Washington were tracked from Vancouver Island, British Columbia to Seaside, Oregon, and whales tagged off Maui were tracked along the entire migratory route to the southwest coast of Baranof Island in Southeast Alaska, the northern Gulf of Alaska, Haida Gwaii, and the Aleutian Islands.

- Three species of salmonids were tagged with acoustic pinger tags along the Washington Coast. In 2019, 142 Chinook salmon, 35 coho salmon, and 17 bull trout were acoustically tagged to characterize the ocean distribution of salmonids and understand how salmon affect the distribution and effort expended by foraging Southern resident killer whales, thus affecting their survival. This is part of an internationally coordinated effort among scientists from Canada and the United States that has resulted in the deployment of over 107 stationary receivers along hundreds of miles of the Washington coast and collectively more than 400 salmon have been captured, tagged, and tracked. Fin clips were also obtained to perform genetic stock identification.

GOA

- Passive acoustic monitoring was conducted in the GOA TMAA in 2017-2019, resulting in analysis of the ambient soundscape and detections of blue, fin, humpback, killer, and sperm whales, as well as Cuvier's and presumably Stejneger's beaked whales. Anthropogenic signals of U.S. Navy MFAS, non-Navy low-frequency active sonar, and civilian explosions were also detected.

Several ongoing projects in the MITT and HSTT study areas resulted in peer-reviewed publications in 2019, including: Cetacean Monitoring in the Mariana Islands Range Complex; Blue and Fin Whale Tagging and Analysis in Support of Marine Mammal Monitoring across Multiple Navy Training Areas, and Marine Mammal Monitoring on PMRF (see Appendix D).

With regard to the conceptual framework categories, several projects in calendar year 2019 demonstrated progress beyond the category for *occurrence*—and estimated the *exposure* of animals to MFAS and explosives, assessed animals' *responses* to underwater noise generated by U.S. Navy training and testing activities, and made strides toward assessing any population *consequences* resulting from these activities by investigating population trends.

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Acronyms and Abbreviations

ADB	advanced dive behavior
AMR	Adaptive Management Review
ARS	Area Restricted Searching
ASW	anti-submarine warfare
BIA	Biologically Important Area(s)
BO	Biological Opinion
BW	beaked whale
CCAL	California Current Province
CalCOFI	California Cooperative Oceanic Fisheries Investigations
CFC	Conceptual Framework Category
CFR	Code of Federal Regulations
Chl-a	chlorophyll-*a*
CNMI	Commonwealth of the Northern Mariana Islands
CRC	Cascadia Research Collective
CRP	Cetacean Research Program
dB	decibel(s)
dB re 1µPa	decibel(s) referenced to 1 microPascal
DDG	guided missile destroyer
DEMVAL	Demonstration-Validation
DM	dive monitoring
DNA	deoxyribonucleic acid
DoN	Department of the Navy
DPS	Distinct Population Segment
DUR	dive duration monitoring
DUR+	dive duration monitoring plus
EAR	Ecological Acoustic Recorder(s)
EIS	Environmental Impact Statement
ESA	Endangered Species Act
FDM	Farallon de Medinilla
FM	frequency-modulated
FY	fiscal year
GOA	Gulf of Alaska
GPS	Global Positioning System
GVP	group vocal periods
HARP	High-frequency Acoustic Recording Package
hr	hour(s)
HRC	Hawaii Range Complex
hSSSM	hierarchical switching state-space models
HSTT	Hawaii-Southern California Training and Testing
Hz	Hertz
ICMP	Integrated Comprehensive Monitoring Program
IPI	interpulse intervals
ISO	Intermediate Scientific Objective
kHz	kilohertz
km	kilometer(s)
LIMPET	Low Impact Minimally Percutaneous Electronic Transmitter
LO	location-only
LOA	Letters of Authorization
LTSA	Long-Term Spectral Average(s)
m	meter(s)
MACS	Mariana Archipelago Cetacean Survey
M3R	Marine Mammal Monitoring on U.S. Navy Ranges
MarEcoTel	Marine Ecology and Telemetry Research
MFAS	mid-frequency active sonar
MIRC	Mariana Islands Range Complex
MISTCS	Mariana Islands Sea Turtle and Cetacean Survey
MITT	Mariana Islands Training and Testing
MMO	marine mammal observer
MMPA	Marine Mammal Protection Act
mtDNA	mitochondrial DNA
NDAA	National Defense Authorization Act
NIWC	Naval Information Warfare Center
NMFS	National Marine Fisheries Service
NPGO	North Pacific Gyre Oscillation
NUWC	Naval Undersea Warfare Center
NWTRC	Northwest Training Range Complex
NWTT	Northwest Training and Testing
NOAA	National Oceanic and Atmospheric Administration

OEIS	Overseas Environmental Impact Statement
ONI	Oceanic Niño Index
ONR	Office of Naval Research
OSU	Oregon State University
PAM	passive acoustic monitoring
PCoD	Population Consequences of Disturbance
PDO	Pacific Decadal Oscillation
photo-ID	photo-identification
PIFSC	Pacific Islands Fisheries Science Center
PMAR	Passive Miniature Acoustic Recorder
PMRF	Pacific Missile Range Facility
PT MUGU	Point Mugu Sea Range
RMS	root mean square
RPA	remotely piloted aircraft
RHIB	rigid-hulled inflatable boat
RL	received level(s)
s	second(s)
SCB	Southern California Bight
SCC	Submarine Command Course
SCORE	Southern California Offshore Range
SD	standard deviation
SIO	Scripps Institution of Oceanography
SOAR	Southern California Offshore Antisubmarine Warfare Range
SOCAL	Southern California Range Complex
SPL	sound pressure level
SPOT	smart position and temperature
SRKW	Southern Resident killer whale
SSC Pacific	Space and Naval Warfare Systems Center Pacific
SSSM	switching state-space model
SST	sea surface temperature
TMAA	Temporary Maritime Activities Area
U.S.	United States
W237	Warning Area 237

1. Introduction

The United States (U.S.) Navy conducts training and testing activities in the Pacific study areas described in the following Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS) documents: Hawaii-Southern California Training and Testing (HSTT) (Department of Navy [DoN] 2013, 2018a), Mariana Islands Training and Testing (MITT) (DoN 2015a, 2019a), Northwest Training and Testing (NWTT) (DoN 2015b, 2019b), and the Gulf of Alaska Navy Training Activities (DoN 2011a, 2016a). The U.S. Navy testing and training ranges covered by these documents include the Hawaii Range Complex (HRC), Southern California Range Complex (SOCAL), which are part of the HSTT Study Area; the Mariana Islands Range Complex (MIRC), which is part of the MITT Study Area; Northwest Training Range Complex (NWTRC) including the Naval Sea Systems Command's Naval Undersea Warfare Center Keyport Range Complex (Keyport Range Complex), which are part of the NWTT Study Area, and the Gulf of Alaska Temporary Maritime Activities Area (GOA TMAA).

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The regulations cited above associated with the authorizations for HSTT, MITT, NWTT, and GOA TMAA (i.e., 50 CFR § 218.75(d), § 218.95(e), § 218.145(f), and § 218.155(f), respectively) have in common an option for satisfying the monitoring report requirement with a multi-range-complex report. Therefore, monitoring results from all Pacific U.S. Navy ranges, (i.e., HSTT, MITT, NWTT, and GOA TMAA), are treated in this report in an integrated fashion in order to allow comparison across ranges and a cumulative view of progress made on monitoring goals across ranges. This report is the fifth such "multi-range"-complex annual monitoring report (see DoN 2016b, 2017, 2018b, 2019c).

1.1 Integrated Comprehensive Monitoring Program and Strategic Planning Process

Integrated Comprehensive Monitoring Program

The U.S. Navy's Integrated Comprehensive Monitoring Program (ICMP) (DoN 2010) provides the overarching framework for coordination of the U.S. Navy's marine species monitoring efforts and serves as a planning tool to focus U.S. Navy monitoring priorities pursuant to Endangered Species Act (ESA) and MMPA requirements. The purpose of the ICMP is to coordinate monitoring efforts across all regions and to allocate the most appropriate level and type of monitoring effort for each range complex based on a set of standardized objectives, regional expertise, and resource availability. Although the ICMP does not identify specific fieldwork or individual projects, it is designed to provide a flexible, scalable, and adaptable framework using adaptive-management and strategic-planning processes that periodically assess progress and reevaluate objectives.

Monitoring addresses the ICMP top-level goals through a collection of specific regional and ocean-basin studies based on scientific objectives, rather than objectives defined as a given quantity of monitoring effort. The reporting requirements and the adaptive-management process serve as the basis for evaluating performance and compliance, primarily considering the quality of the work and results produced, as well as peer review and publications, and public dissemination of information, reports, and data. Details of the current ICMP are available online at http://www.navymarinespeciesmonitoring.us/.

Adaptive Management Review

The ICMP is evaluated through the Adaptive Management Review (AMR) process to (1) assess progress, (2) provide a matrix of goals and objectives, and (3) make recommendations for refinement and analysis of monitoring and mitigation techniques. This process includes conducting an annual AMR meeting at which the U.S. Navy and NMFS jointly consider the prior-year goals, monitoring results, and related scientific advances to determine if monitoring plan modifications are warranted to more effectively address program goals. Modifications to the ICMP that result from annual AMR discussions are incorporated by an addendum or revision to the ICMP as needed.

Strategic Planning Process, Scientific Advisory Group, and the Conceptual Framework Categories

The Strategic Planning Process for Marine Species Monitoring (Chief of Naval Operations 2013) serves to guide the investment of resources to most efficiently address ICMP objectives and Intermediate Scientific Objectives (ISOs) developed through this process. The monitoring program has evolved and improved as a result of the AMR process through incorporation of the following changes:

- Developed a Conceptual Framework based on recommendations from the Scientific Advisory Group (DoN 2011b). The Conceptual Framework Categories (CFCs) are centered on gathering information within the categories of "*occurrence, exposure, response, and consequences"* as a progression of knowledge about marine species and their interaction with U.S. Navy training and testing activities.
- Shifted focus to projects based on scientific objectives that facilitate generation of statistically meaningful results upon which natural resources management decisions may be based (rather than objectives defined by level of effort).
- Focused on priority species or areas of interest as well as best opportunities to address specific monitoring objectives in order to maximize return on investment.
- Increased transparency of the program and management standards, improving collaboration among participating researchers, and improving accessibility to data and information resulting from monitoring activities.

Under the Strategic Planning Process, ISOs serve as the basis for developing and executing new monitoring projects across U.S. Navy training and testing areas in the Atlantic and Pacific Oceans. Implementation of the Strategic Planning Process involves coordination among fleets, system commands, Chief of Naval Operations Energy and Environmental Readiness Division, NMFS, and the Marine Mammal Commission with five primary steps:

- **Identify overarching ISOs.** Through the adaptive management process, the U.S. Navy coordinates with NMFS as well as the Marine Mammal Commission to review and revise the list of ISOs that are used to guide development of individual monitoring projects. (The current list of thirteen ISOs applied for this monitoring report is included in **Figure 1**, located in **Section 2.1**).
- **Develop individual monitoring project concepts.** Solicit input from the scientific community in terms of potential monitoring projects that address one or more of the ISOs. This can be accomplished through a variety of forums, including professional societies, regional scientific advisory groups, and contractor support.
- **Evaluate, prioritize, and select monitoring projects.** U.S. Navy technical experts and program managers review and evaluate all monitoring project concepts and develop a prioritized ranking. The goal is to establish a suite of monitoring projects that address a cross-section of ISOs spread over a variety of range complexes.
- **Execute and manage selected monitoring projects.** Individual projects are initiated through appropriate funding mechanisms and include clearly defined objectives and deliverables (e.g., data, reports, publications).
- **Report and evaluate progress and results.** Progress on individual monitoring projects is updated through the Navy Marine Species Monitoring Program website as well as annual monitoring reports submitted to NMFS. Both internal review and discussions with NMFS through the adaptive management process are used to evaluate progress toward addressing the primary objectives of the ICMP and serve to periodically recalibrate the focus of the monitoring program.

The collaborative framework of this process is designed to integrate various elements for developing, evaluating, and selecting monitoring projects across all areas where the U.S. Navy conducts training and testing activities.

These elements include the following:

- ICMP top-level goals;
- Scientific Advisory Group recommendations;
- Integration of regional scientific expert input;
- Ongoing AMR dialog between NMFS and the U.S. Navy;
- Lessons learned from past and future monitoring at U.S. Navy training and testing ranges; and
- Leveraging of research and lessons learned from other U.S. Navy-funded science programs.

The Strategic Planning Process will continue to shape the future of the U.S. Navy Marine Species Monitoring Program and serve as the primary decision-making tool for guiding investments.

1.2 Report Objectives

This document has been prepared in accordance with the reporting requirements of 50 CFR § 218.75(d), § 218.95(e), § 218.145(f), and § 218.155(f) for presenting NMFS and the public with results and progress made during the period of 1 January 2019 to 31 December 2019 in marine species monitoring in HSTT, MITT, NWTT, and GOA TMAA. Reviewers may review prior-year reports and associated publications that are available on the website at http://www.navymarinespeciesmonitoring.us/.

This report implements the option in these regulations to prepare a multi-Range-Complex report that describes progress of knowledge made with respect to monitoring plan study questions across multiple training and testing ranges, with similar study questions treated together so that progress on each topic may be summarized across multiple ranges (see DoN 2016b, 2017, 2018b, 2019c). These results are intended to iteratively inform future cycles of the ICMP AMR and Strategic Planning Processes and provide a comprehensive view of monitoring in the Pacific Ocean.

- Detailed technical reports for the individual monitoring projects are provided as supporting documents to this report (Baird et al. 2019b; DiMarzio et al. 2020; Gaos et al. 2020; Martin et al. 2020; Mate et al. 2019b, 2020; Norris and Elorriaga Verplancken 2019b, 2020; Palacios et al. 2020; Rice et al. 2019b, 2020a, 2020b; Schorr et al. 2020; Smith and Huff 2020; Trickey et al. 2020; Vars et al. 2019; Wiggins et al. 2020).
- Abstracts and executive summaries for these technical reports are in Appendix A.
- 2019 conference presentations from Navy-funded monitoring are listed in Appendix C by Range and project number.
- 2019 publications from Navy-funded monitoring are listed in Appendix D by author last name.

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2. Marine Species Monitoring in the Pacific

2.1 2019 Monitoring Goals and Implementation

The U.S. Navy training ranges in the Pacific are located in the HSTT Study Area, MITT Study Area, NWTT Study Area, and GOA TMAA. The ranges vary in terms of monitoring goals implemented for protected marine species including marine mammals and sea turtles, in support of each study area's MMPA and ESA requirements (NMFS 2013a, 2013b, 2013c, 2013d, 2013e, 2013f, 2014a, 2014b, 2014c, 2014d, 2015a, 2015b, 2015c, 2015d, 2015e, 2015f, 2015g, 2015h, 2016, 2017a, 2017b, 2017c, 2017d, 2018a, 2018b, 2018c, 2018d).

Figures 1 and 2 provide an overview of all monitoring projects and goals across all the Pacific ranges. **Figure 1** shows the distribution of monitoring questions and study objectives with respect to monitoring projects and CFCs (i.e., *occurrence, exposure, response, consequences*), as well as to illustrate which ISOs are addressed by each monitoring project. **Figure 2** illustrates the relative number of monitoring questions associated with each CFC, and how this varies by range. Although the CFC of *consequences* is considered a complex field of new science best supported by research and development efforts through the Office of Naval Research (ONR), rather than by MMPA compliance monitoring, one monitoring question each for HRC and SOCAL projects was related to population trends of species at range complexes. Because of their connection to population trends—although not comparable to the fully realized modeling of population consequences—these were tabulated in **Figure 2** under *consequences*.

Current monitoring goals are framed in terms of progress made on scientific monitoring questions and ISOs, and shown paired with cumulative accomplishments in **Table 1**.

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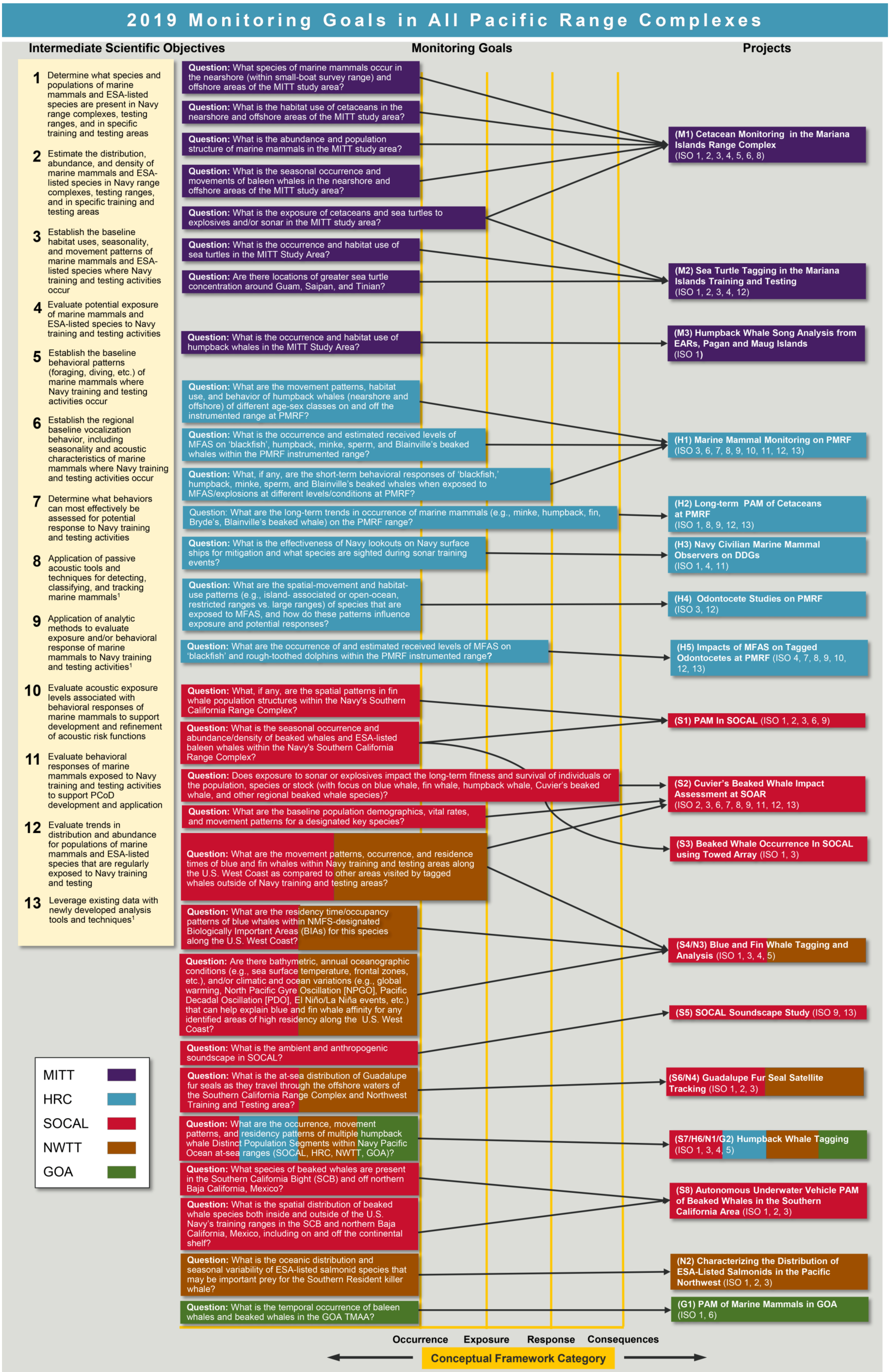

Figure 1. 2019 Monitoring goals in all Pacific range complexes. Primary research-and-development and demonstration-validation (DEMVAL) investments for tools and techniques supported by Office of Naval Research Marine Mammal and Biology and Living Marine Resource programs.

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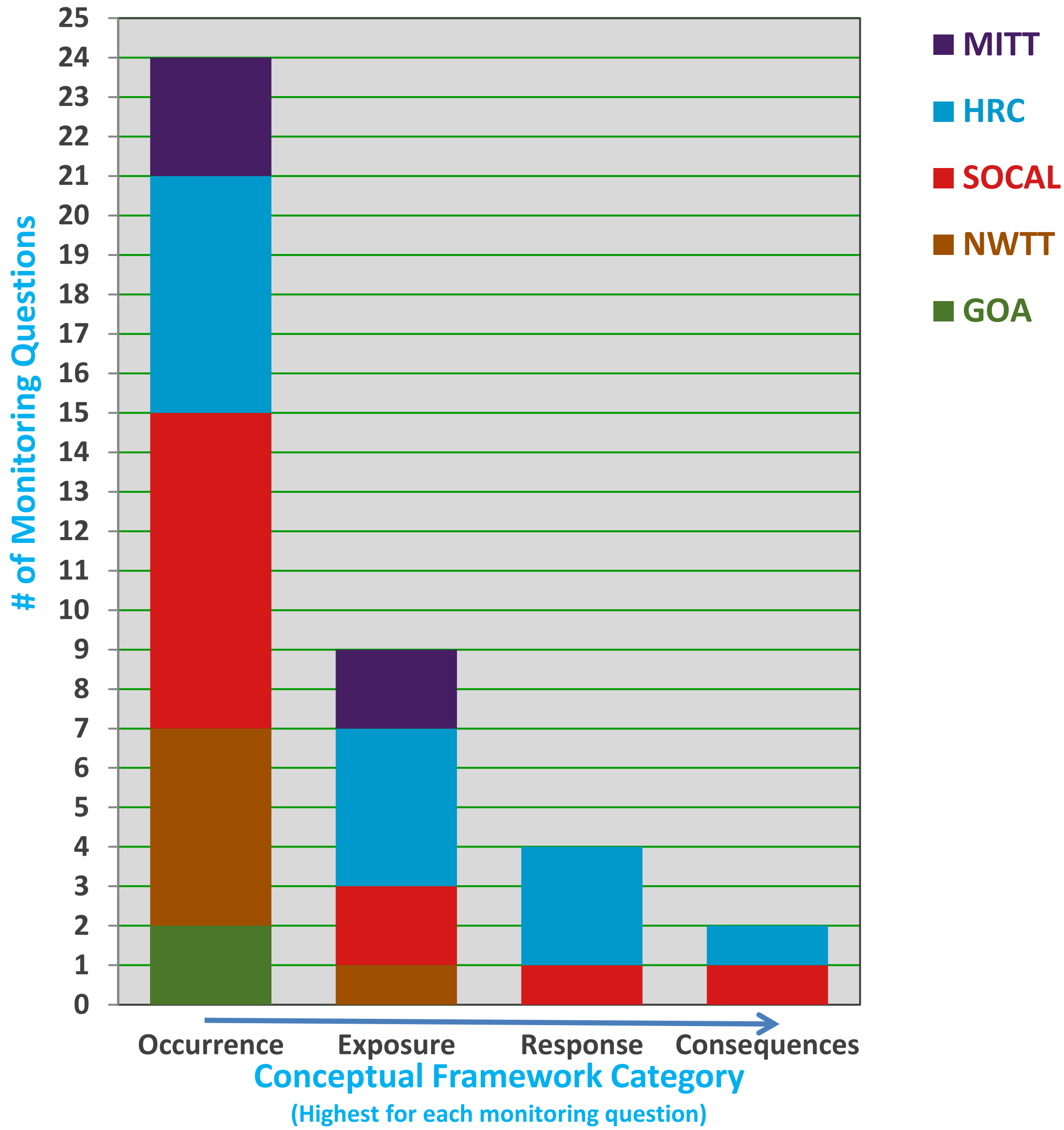

Figure 2. Numbers of monitoring questions and goals in all Pacific range complexes that address the four progressive Conceptual Framework Categories for monitoring knowledge outlined by the Scientific Advisory Group. Additional Navy-funded effort under *Response* (not represented here) has been conducted in SOCAL under the Office of Naval Research Marine Mammal and Biology and Living Marine Resource programs.

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Table 1. Monitoring goals and accomplishments for training ranges in second cycle of 5-year authorizations (MITT, NWTT, and GOA TMAA) and third cycle of 5-year authorizations (HSTT [HRC and SOCAL]).

Project (Technical report for 2019)	Conceptual Framework Category	Intermediate Scientific Objectives (Numbered as per Figure 1)	Monitoring Questions	Accomplishments[1]
MITT				
[M1] Cetacean Monitoring in the Mariana Islands Range Complex This project included “Small-Vessel Visual Surveys” and “Acoustic Analysis of High-frequency Acoustic Recording Package Data”.	Occurrence, Exposure	#1: Determine what species and populations of marine mammals and ESA-listed species are present in Navy range complexes, testing ranges, and in specific training and testing areas. #2: Estimate the distribution, abundance, and density of marine mammals and sea turtles in Navy range complexes, testing ranges, and in specific training and testing areas. #3: Establish the baseline habitat uses, seasonality, and movement patterns of marine mammals and ESA-listed species where Navy training and testing activities occur. #4: Evaluate potential exposure of marine mammals and ESA-listed species to Navy training and testing activities. #5: Establish the baseline behavioral patterns (foraging, diving, etc.) of marine mammals where Navy training and testing activities occur. #6: Establish the regional baseline vocalization behavior, including seasonality and acoustic characteristics) of marine mammals where Navy training and testing activities occur. #8: Application of passive acoustic tools and techniques for detecting, classifying, and tracking marine mammals[2].	• What species of marine mammals occur in the nearshore (within small-boat survey range) and offshore areas of the MITT study area? • What is the habitat use of cetaceans in the nearshore and offshore areas of the MITT study area? • What is the abundance and population structure of marine mammals in the MITT study area? • What is the seasonal occurrence and movements of baleen whales in the nearshore and offshore areas of the MITT study area? • What is the exposure of cetaceans and sea turtles to explosives and/or sonar in the MITT study area?	*In 2019:* • Published in Marine Mammal Science, “Short-finned pilot whales (*Globicephala macrorhynchus*) of the Mariana Archipelago: Individual affiliations, movements, and spatial use” (Hill et al. 2019a); Hill et al. (2020) was prepared and submitted to Endangered Species Research, “Found: a missing breeding ground for endangered western North Pacific humpback whales in the Mariana Archipelago”. *In 2018:* • Satellite-tag data suggest that short-finned pilot whales tagged off Guam and Rota had a home range that extended to the north beyond FDM and to the south beyond Guam to Santa Rosa Reef (Hill et al. 2018, 2019b). • Continued analysis: photo-ID and recapture analysis for abundance estimation in the southern Archipelago. • Published in Marine Mammal Science, “Clicks of dwarf sperm whales (*Kogia sima*)” (Merkens et al. 2018). • Evaluated population structure, range, and habitat use from analyses of photo-ID, genetic, satellite telemetry, and acoustic datasets for each cetacean species collected during small-boat surveys in the Mariana Archipelago from 2010 to 2018 (Hill et al. 2019c). *In 2017:* • The humpback whale catalog from winter surveys increased the number of individuals to 35 non-calves. Matches from 2017 included three resights, one from 2007, another from 2015, and the third seen in 2016 with calf. Genetic haplotype-based population analysis for this species from biopsied tissue samples ongoing. • For the first time in the month of May, a Bryde’s whale was encountered off the west side of Saipan. All other sightings have occurred during the months of August and September (Hill et al. 2016a, 2017). • Photo-ID and satellite tag data suggest that the population of short-finned pilot whales in the Marianas may include groups of individuals that are more island-associated within the southern portion of the archipelago, as well as those that are intermittent visitors to the nearshore waters of Guam, Rota, Saipan, and Tinian. • Acoustic analysis of beaked whale call variability from PIFSC-funded HARPs and kernel density estimates from tagging telemetry are ongoing 2016–2017. *In 2016:* • Began efforts to coordinate matching of individually-identifying fluke photographs from the winter survey effort in Saipan to various western Pacific catalogs. Initial matches made with: previous years (2015) in this survey series, Marpi Reef CNMI from 2007 MISTCS survey, two matches to Ogasawara (both in 2004), and two matches to the Commander Islands, one of which matches to Okinawa. Presented this work at the International Whaling Commission meeting, “Are humpback whales *(Megaptera novaeangliae)* breeding and calving in the Mariana Islands?*”* (Hill et al. 2016b). • Satellite tags deployed on two sperm whales and a pantropical spotted dolphin for the first time in the Marianas. Dwarf sperm whales encountered for the first time off Guam.

Project (Technical report for 2019)	Conceptual Framework Category	Intermediate Scientific Objectives (Numbered as per Figure 1)	Monitoring Questions	Accomplishments[1]
MITT (continued)				
[M2] Sea Turtle Tagging in the Mariana Islands Training and Testing Study Area (Gaos et al. 2020)	Occurrence, Exposure	#1: Determine what species and populations of marine mammals and ESA-listed species are present in Navy range complexes, testing ranges, and in specific training and testing areas. #2: Estimate the distribution, abundance, and density of marine mammals and ESA-listed species in Navy range complexes, testing ranges, and in specific training and testing areas. #3: Establish the baseline habitat uses, seasonality, and movement patterns of marine mammals and ESA-listed species where Navy training and testing activities occur. #4: Evaluate potential exposure of marine mammals and ESA-listed species to Navy training and testing activities. #12: Evaluate trends in distribution and abundance for populations of marine mammals and ESA-listed species that are regularly exposed to sonar and underwater explosives.	• What is the occurrence and habitat use of sea turtles in the MITT study area? • What is the exposure of sea turtles to explosives and/or sonar in the MITT study area? • Are there locations of greater sea turtle concentration in the MITT study area?	*In 2019:* • Surveyed and satellite-tagged sea turtles along the eastern coast of Saipan (Forbidden Island, Lao Lao, and Dandan) and the northern coast of Guam (Ritidian, Anderson Air Force Base, Tarague, and Pati Point) from 1 to 11 September 2019. • Prepared a manuscript, "Reef-dwelling turtles of the Mariana Archipelago: fine-scale habitat use revealed by multiple in-water surveys and GPS telemetry", slated for publication in FY21. *In 2018:* • Surveyed and satellite tagged turtles in previously unsurveyed areas along the northeast coast of Saipan, as well as the eastern and southern coasts of Guam (S.L. Martin et al. 2019). *In 2017:* • Satellite tagged juveniles and subadult sea turtles on the west Coast of Guam along the outer reef of Tumon Bay, and north and south of Tumon Bay; surveys or captures had not previously occurred at these sites. New areas surveyed off the western coast of Saipan include waters off Wing Beach, Pau Pau Beach, Aqua Hotel Reef, and outside of Mañagaha Island with successful tagging of sea turtles at each site (S.L. Martin and Jones 2018). • Published a second manuscript derived from this Navy/NOAA interagency agreement in Pacific Science "Demography of marine turtles in the near-shore environments of the Northern Mariana Islands" (Summers et al. 2017). *In 2016*: • Conducted sea turtle tagging surveys in nearshore and coastal waters of Guam, Saipan, and Tinian, including areas not previously surveyed—Tachungnya Bay in the southwest corner of Tinian, Tinian Harbor, Coral Ocean Point in southeast Saipan, and Agat Bay and Hagatna in Guam (S.L. Martin and Jones 2017). • Captured, satellite tagged, and took blood samples of an adult male green turtle on the west side of Tinian. • Deployed satellite (temperature-depth and temperature), Inconel, and passive integrated transponder tags on green and hawksbill turtles; 22 satellite tags were still transmitting as of November 2016, and performed preliminary analyses of habitat use and dive behavior. • Published first manuscript derived from this Navy/NOAA interagency agreement in Frontiers in Marine Science "Five decades of marine megafauna surveys from Micronesia" (S.L. Martin et al. 2016).
[M3] Humpback Whale Song Analysis from EARs, Pagan and Maug Islands (Munger and Lammers 2020)	Occurrence	#1: Determine what species and populations of marine mammals and ESA-listed species are present in Navy range complexes, testing ranges, and in specific training and testing areas.	• What is the occurrence and habitat use of humpback whales in the MITT study area?	*In 2019:* • Analyzed acoustic data from EARs deployed during 2009-2010 off the islands of Maug and Pagan. • Analyzed visually scanned spectrograms of each individual 30-s recording to detect humpback whales using the Matlab program *Triton.* • Detected humpback whale song at Pagan Island, humpback whale song was detected with high confidence on nearly one-third of the days in February 2010, but not in any other months. No evidence of humpback whale singing was detected at Maug in the months searched.

Project (Technical report for 2019)	Conceptual Framework Category	Intermediate Scientific Objectives (Numbered as per Figure 1)	Monitoring Questions	Accomplishments[1]
HRC				
[H1] Marine Mammal Monitoring on PMRF (Martin et al. 2020)	Occurrence, Exposure, Response	#3: Establish the baseline habitat uses, seasonality, and movement patterns of marine mammals and ESA-listed species where Navy training and testing activities occur. #6: Establish the regional baseline vocalization behavior, including seasonality and acoustic characteristics of marine mammals where Navy training and testing activities occur. #7: Determine what behaviors can most effectively be assessed for potential response to Navy training and testing activities. #8: Application of passive acoustic tools and techniques for detecting, classifying, and tracking marine mammals[2]. #9: Application of analytic methods to evaluate exposure and/or behavioral response of marine mammals to Navy training and testing activities #10: Evaluate acoustic exposure levels associated with behavioral responses of marine mammals to support development and refinement of acoustic risk functions #11: Evaluate behavioral responses of marine mammals exposed to Navy training and testing activities to support PCoD development and application. #12: Evaluate trends in distribution and abundance for populations of marine mammals and ESA-listed species that are regularly exposed to sonar and underwater explosives. #13: Leverage existing data with newly developed analysis tools and techniques[2].	• What is the occurrence and estimated received levels of MFAS on 'blackfish', humpback, minke, sperm, and Blainville's beaked whales within the PMRF instrumented range? • What, if any, are the short-term behavioral responses of 'blackfish,' humpback, minke, sperm, and Blainville's beaked whales when exposed to MFAS/explosions at different levels/conditions at PMRF? • What are the movement patterns, habitat use, and behavior of humpback whales (nearshore and offshore) of different age-sex classes on and off the instrumented range at PMRF?	*In 2019:* • Automated classification algorithms were successful in attributing acoustic tracks recorded at PMRF to Bryde's, fin, and sei whales (Martin et al. 2020). • Automated algorithms were also successful in localizing blue whales and sperm whales at PMRF. • Conducted disturbance analyses for minke whales utilizing tools developed under an ONR project titled Behavioral Response EValuation Employing (BREVE) robust baselines and actual U.S. Navy training. • Analyzed Blainville's beaked whale spatial distribution and dives for before, during, and after 16 SCCs. • Began analyzing whale acoustic tracks relative to environmental data to investigate how minke and other baleen whales respond to wind-wave events (E-BREVE). • Published two manuscripts in Aquatic Mammals, "Changes in the spatial distribution of acoustically derived minke whale (*Balaenoptera acutorostrata*) tracks in response to Navy training" (Harris et al. 2019) and "Quantifying the behavior of humpback whales (*Megaptera novaeangliae*) and potential responses to sonar" (Henderson et al. 2019). • Presented findings from this project at the World Marine Mammal Conference, Barcelona, Spain (See Appendix C). • Published two manuscripts in the Journal of the Acoustical Society of America, "Use of spatial context to increase acoustic classification accuracy" (Palmer et al. 2019) and "Deep whistle contour: recall-guided learning from synthesis" (Li et al. 2019). *In 2018:* • Refined detection and localization algorithms for sperm whales and Cuvier's beaked whales: first time results for Cuvier's beaked whales were presented as the number of unvalidated group dives per hour. • For the first time, researchers processed systematic results of all data from 2002 to 2006 to estimate long-term abundances for multiple species of marine mammals at PMRF (C.R. Martin et al. 2019). • Provided localization and tracking results for baleen whales (minke, humpback, and the low-frequency group [fin/sei/Bryde's] whales) and sperm whales. Odontocete groups were localized to the nearest hydrophone for the following species: Blainville's, Cuvier's, and Cross Seamount type beaked whales, and killer whales. • Performed disturbance analysis of four tracked minke whales. Whales tended to continue calling when exposed to cumulative sound exposure levels up to 168.1 dB re 1µPa2s (the highest recorded in this study). One animal made a heading change when exposed to MFAS from a ship 19.5 km away. Another animal did not react to a closest approach of 1 km to a ship not transmitting MFAS, and when that ship began transmitting 25 min later, this animal eased vocalizing (C.R. Martin et al. 2019). • Published manuscripts in the Journal of Acoustical Society of America "Estimating received levels for acoustically tracked whales from Navy mid-frequency active sonar" (C.R. Martin et al. 2018b) and "Identifying behavioral states and habitat use of acoustically tracked humpback whales in Hawaii" in Marine Mammal Science (Henderson et al. 2018b). • Presented results "Tracking the offshore and migratory movements of humpback whales in Hawaii" at the 22nd Biennial on the Biology of Marine Mammals 22–27 October 2017 in Halifax, Nova Scotia and the Southern California Marine Mammal Workshop 26–27 January 2018 in Newport Beach, California (Henderson et al. 2017, 2018a). • Prepared a manuscript "Quantifying the behavior of humpback whales and potential responses to sonar" to submit to Aquatic Mammals (Henderson et al. in review). *In 2017:* • Presented results of automated processing for all data collections throughout FY17 for relative abundance estimates for Blainville's and Cross Seamount-type beaked whale foraging dives and the number of vocalizing baleen whales for minke, humpback, and a combined category of low-frequency species. • Updated beaked whale detector to increase the automated detections of Blainville's beaked whale clicks and improve distinguishing these from Cuvier's beaked whale and Cross Seamount-type beaked whale clicks (C.R. Martin et al. 2018a). • Conducted disturbance analysis for the 31 minke whales tracked before and during the portion of the February SCC training event, resulting in a maximum estimated cumulative sound exposure. • Provided automated analyses of data collected between 2007 and 2011 using the new metric of numbers of individual whales present in each snapshot for minke and humpback whales. • Provided quick look analysis for species' abundances as the number of instantaneous snapshots taken every 10 minutes of the individual baleen species' tracks, an improvement from the number of localizations per hour. *In 2016:* • Estimated cumulative sound exposure level for three minke whales that were localized and tracked at PMRF

Project (Technical report for 2019)	Conceptual Framework Category	Intermediate Scientific Objectives (Numbered as per Figure 1)	Monitoring Questions	Accomplishments[1]
				during a training event using MFAS (C.R. Martin et al. 2017). • Analyzed beaked whale dives before, during, and after periods of MFAS activity at PMRF in order to identify any changes in foraging behavior. • Presented results of fully automated processing for all data collections throughout FY16 in terms of the beaked whale foraging dives per hour and the number of baleen whale and sperm whale passive acoustic localizations on and near the range. • Processed data automatically for 2007–2011 for beaked whales, humpback whales, and sperm whales, and presented plots of these. *In 2015:* • Used archived acoustic data collected by PMRF hydrophones in 2011–2013 to assess changes in Blainville's beaked whale dive counts correlated with periods of MFAS use (C.R. Martin et al. 2016a). • Developed and validated an automated beaked whale click detector. Discovered possible Cross Seamount-type beaked whale clicks during manual verification (confirmed in 2016 report). • Calculated number of beaked whale foraging dives relative to MFAS use. *In 2014:* • Estimated RLs during an ASW training event for humpback whales and short-finned pilot whales, ranged from 158 to 174 dB re 1 µPa. • Identified decrease in minke whale "boing" call counts in presence of MFAS. • Documented decrease in Blainville's beaked whale foraging dive rates during periods of MFAS transmission.
[H2] Long-term Passive Acoustic Monitoring of Cetaceans at PMRF (DiMarzio et al. 2020) This is a joint project with [S2] "Cuvier's Beaked Whale Impact Assessment at SOAR".	Occurrence, Exposure, Response, Consequences	#1: Determine what species and populations of marine mammals and ESA-listed species are present in Navy range complexes, testing ranges, and in specific training and testing areas. #8: Application of passive acoustic tools and techniques for detecting, classifying, and tracking marine mammals[2]. #9: Application of analytic methods to evaluate exposure and/or behavioral response of marine mammals to Navy training and testing activities. #12: Evaluate trends in distribution and abundance for populations of marine mammals and ESA-listed species that are regularly exposed to sonar and underwater explosives. #13: Leverage existing data with newly developed analysis tools and techniques[2].	• What are the long-term trends in occurrence of marine mammals (e.g., minke, humpback, fin, Bryde's, Blainville's) on the PMRF range?	*In 2019:* • Examined Blainville's beaked whale abundance and vocal behavior at PMRF from 2015 through 2018; data collected in 2019 are currently being analyzed. • Calculated yearly and monthly abundance, mean number of GVPs, mean length of the GVPs in minutes, and the mean number of clicks detected per beaked whale group, and examined seasonal changes in abundance and mean GVPs. • Presented findings from this project at the World Marine Mammal Conference, Barcelona, Spain (See Appendix C). • Published in Marine Mammal Science, "Acoustic observation of the reaction of rough-toothed dolphin (*Steno bredanensis*) to vocalizations, most likely from killer whales (*Orcinus orca*), off Kaua'i" (Jarvis et al. 2019). *In 2018:* • Configured the system to enable uninterrupted, continuous archiving of the M3R (DiMarzio et al. 2019). • Analyzed the first extended beaked whale detection achieved for PMRF from February 2017 through April 2018. • Abundance estimates for Blainville's beaked whale at PMRF: remained stable from 2015 to 2018. • Ongoing analysis of the extended archive covering the period April 2018 through January 2019, final report is expected during the FY19 reporting period. *In 2017:* • Obtained the first extended PAM data archive at PMRF: six months of continuous data were recorded and analyzed for Blainville's beaked whale abundance and added to previous estimates. • Incorporated automated sonar detector performing on streaming data into the M3R software at PMRF, and detection reports were integrated into the M3R data archives. • Archived automated time-tagged cetacean detections and localizations on streaming data at PMRF. • Determined no decline in beaked whale abundance at PMRF from 2010 to 2017. *In 2016*: • Compared beaked whale detection archives from both SSC Pacific and M3R algorithms and determined baseline abundance at PMRF. • Completed packet recorder interface and new disk-handling utilities; implemented sample rate decimation and undertaking testing. • Determined no change in the population trend line of beaked whales over the 5-year period, 2010–2014. *In 2015:* • Upgraded hardware/software for M3R Linux-based cluster signal processor at PMRF, which includes a full range of broadband recording and integrated data archives. • Conducted initial analysis of beaked whale detection archives to establish methods and baseline abundance at PMRF and SCORE.

Project (Technical report for 2019)	Conceptual Framework Category	Intermediate Scientific Objectives (Numbered as per Figure 1)	Monitoring Questions	Accomplishments[1]
HRC (continued)				
[H3] Navy Civilian Marine Mammal Observers on DDGs (Vars et al. 2019)	Occurrence, Exposure	#1: Determine what species and populations of marine mammals and ESA-listed species are present in Navy range complexes, testing ranges, and in specific training and testing areas. #4: Evaluate potential exposure of marine mammals and ESA-listed species to Navy training and testing activities. #11: Evaluate behavioral responses of marine mammals exposed to Navy training and testing activities to support PCoD development and application.	• What is the effectiveness of Navy lookouts on Navy surface ships for mitigation and what species are sighted during sonar training events?	*In 2019:* • Employed MMOs on the bridge wings of a U.S. DDG from 16 to 22 February 2019 during a SCC training event. • Recorded marine mammal and sea turtle sightings data to assess the effectiveness of the Navy lookout team and to characterize the possible exposure of marine species to sonar training events. *In 2018:* • Conducted MMO surveys 10–16 February 2018 to record marine species during a SCC training event (Oliveira et al. 2019). • Collected data to assess the effectiveness of the Navy lookout team and to characterize the possible exposure of marine species to MFAS. • Released formal Navy message to senior Navy commands requesting additional MMO opportunities. *In 2017:* • Embark was scheduled in February 2017 and MMO boarded the DDG but, due to emergent mechanical difficulties of the ship; the ship did not participate in the training event and the embark was cancelled. *In 2014–2016:* • Employed MMOs on U.S. Navy warships during a total of five training events: one SCC event in 2015 and one in 2016, and one Koa Kai and two SCC events in 2014 (Vars et al. 2016). • Recorded marine mammal and sea turtle sighting data to determine which species and populations are exposed to U.S. Navy training events.
[H4] Odontocete Studies on PMRF Tag telemetry data collected was also used in Project [H5]	Occurrence	#3: Establish the baseline habitat uses, seasonality, and movement patterns of marine mammals and ESA-listed species where Navy training and testing activities occur. #12: Evaluate trends in distribution and abundance for populations of marine mammals and ESA-listed species that are regularly exposed to sonar and underwater explosives.	• What are the spatial-movement and habitat-use patterns (e.g., island-associated or open-ocean, restricted ranges vs. large ranges) of species that are exposed to MFAS, and how do these patterns influence exposure and potential responses?	*In 2019:* • No survey was conducted in 2019 due to the August SCC event being canceled. • Presented a report to the Pacific Scientific Review Group providing insight on spotted dolphin habitat use in Hawaii based on data from individuals equipped with satellite tags, to better define stock boundaries (Baird and Webster 2019). *In 2018:* • A sighting of sperm whales cued by an acoustic detection by M3R was only the fourth sighting of sperm whales during CRC research effort off Kauai and Niihau; previous sightings occurred in June 2003 and October 2014. • Integration of tag and acoustic data revealed potential exposure to MFAS for one or more tagged individuals prior to the start of the SCC; exposure levels of those individuals will be calculated at a later time following similar methods to previous exposure analyses (Baird et al. 2017b, 2019a). • Confirmed the biopsy sample collected in FY17 from the possible hybrid between a melon-headed whale and a rough-toothed dolphin: the genotype expected for an F1 hybrid was between a female melon-headed whale and a male rough-toothed dolphin (Baird et al. 2019a). This is the first-known hybrid between these two species. • Published a manuscript in Behavioral Ecology and Sociobiology “Song of my people: Dialect differences among sympatric social groups of short-finned pilot whales in Hawaii” (Van Cise et al. 2018). • Continuing analyses: the final report is expected during the FY19 reporting period. *In 2017:* • Conducted small-vessel surveys prior to a SCC event in August 2017 on PMRF (Baird et al. 2018). • Sighted melon-headed whales on PMRF for the first time since 2008. • Observed two melon-headed whales associating with rough-toothed dolphins on two occasions. One of the two individuals in the pair appeared to be a hybrid between a melon-headed whale and a rough-toothed dolphin. Collected a biopsy sample from the hybrid. mtDNA analysis yielded melon-headed haplotype; nuclear DNA analysis in progress to confirm hybrid ancestry (see 2018). • Concluded that current data combined with previous year tag deployments on rough-toothed dolphins suggest tagged group was from resident, island-associated population (Baird et al. 2017b, 2019a). *In 2016:* • Sighted pantropical spotted dolphins on PMRF for the first time since 2003. • Determined that all tagged rough-toothed dolphins and the bottlenose dolphin (2015) remained associated with the island of Kauai and Niihau. Based on photo-ID, all were part of groups known to be resident to the islands. *In 2015:* • Conducted small-vessel surveys (non-random and non-systematic) prior to a SCC event. • Located animals using M3R detections; collected high-resolution photographs for individual photo-ID. • Deployed satellite tags on short-finned pilot whales, bottlenose dolphins, and rough-toothed dolphins. *In 2014:* • Collected data from a satellite-tag track for a Blainville’s beaked whale, which were the first detailed movement data available for this species around Kauai and Niihau. • Used M3R system to identify an acoustic detection of an encounter with false killer whales.

Project (Technical report for 2019)	Conceptual Framework Category	Intermediate Scientific Objectives (Numbered as per Figure 1)	Monitoring Questions	Accomplishments[1]
HRC (continued)				
[H5] Impacts of MFAS on Tagged Odontocetes at PMRF (Baird et al. 2019b)	Occurrence, Exposure, Response	#4: Evaluate potential exposure of marine mammals and ESA-listed species to Navy training and testing activities. #7: Determine what behaviors can most effectively be assessed for potential response to Navy training and testing activities. #8: Application of passive acoustic tools and techniques for detecting, classifying, and tracking marine mammals[2]. #9: Application of analytic methods to evaluate exposure and/or behavioral response of marine mammals to Navy training and testing activities. #10: Evaluate acoustic exposure levels associated with behavioral responses of marine mammals to support development and refinement of acoustic risk functions. #12: Evaluate trends in distribution and abundance for populations of marine mammals and ESA-listed species that are regularly exposed to sonar and underwater explosives. #13: Leverage existing data with newly developed analysis tools and techniques[2].	• What is the occurrence and estimated received levels of MFAS on 'blackfish' and rough-toothed dolphins within the PMRF instrumented range?	*In 2019:* • In addition to estimating RLs for seven tagged odontocetes (three short-finned pilot whales, two rough-toothed dolphins, and two melon-headed whales) during SCC training events, potential responses of tagged animals were also assessed by analyzing animal tracks for any large-scale movements concurrent with sonar activity. When available, diving and surfacing behavior of tagged individuals was analyzed before, during, and after MFAS use to assess potential reactions. • To better assess variability in RL estimates, multiple metrics (mean, SD, minimum, maximum) of estimated RLs were calculated for each exposure event, both near the surface (10 m depth) and at depths meant to represent typical foraging depths for each species. *In 2018:* • Analyzed exposure and response of tagged whales on or around PMRF prior to SCCs in February 2016, August 2017, and August 2018 (Baird et al. 2019b). • Estimated MFAS exposure levels for satellite-tagged whales on PMRF. • Ongoing analyses: data from eight satellite tags deployed on odontocetes prior to the SCC events held in February 2016, August 2017, and August 2018. Analyses to estimate RLs are currently underway and a final report on these analyses will be available later in 2019. *In 2017:* • In August 2017, prior to the tagging field effort, a second Wildlife Mote receiving station was installed near the instrumented range at PMRF for enhancing the quantity of satellite-tag data. The new station was installed on Niihau, providing complementary coverage to the one previously installed February 2016 at Makaha Ridge in Kauai. • No cetaceans tagged off PMRF in summer 2017 prior to the August Navy training event remained in the area by the time event commenced. Analyses are deferred until after tagging off PMRF in summer 2018. *In 2016:* • Conducted vessel-based field efforts on three occasions between July 2013 and February 2015 that corresponded with MFAS use during SCCs (Baird et al. 2017a). • Estimated MFAS exposure levels for satellite-tagged individuals in February 2011, February 2012, and February 2013.
[H6/S7/N1/G2] Humpback Whale Tagging in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas in the Pacific Ocean (Mate et al. 2019b, 2020; Palacios et al. 2020) This project is also a component of SOCAL, NWTT, and GOA TMAA tagging, S7, N1, and G2.	*See project N1/H6/S7/G2 (below, in NWTT)*			

Project (Technical report for 2019)	Conceptual Framework Category	Intermediate Scientific Objectives (Numbered as per Figure 1)	Monitoring Questions	Accomplishments[1]
SOCAL				
[S1] Passive Acoustic Monitoring in SOCAL (Rice et al. 2020a)	Occurrence	#1: Determine what species and populations of marine mammals and ESA-listed species are present in Navy range complexes, testing ranges, and in specific training and testing areas. #2: Estimate the distribution, abundance, and density of marine mammals and ESA-listed species in Navy range complexes, testing ranges, and in specific training and testing areas. #3: Determine what species and populations of marine mammals and ESA-listed species are exposed to Navy training and testing activities. #6: Establish the regional baseline vocalization behavior, including seasonality and acoustic characteristics of marine mammals where Navy training and testing activities occur. #9: Application of analytic methods to evaluate exposure and/or behavioral response of marine mammals to Navy training and testing activities.	• What is the seasonal occurrence and abundance/density of beaked whales and ESA-listed baleen whales within the Navy's Southern California Range Complex? • What, if any, are the spatial patterns in fin whale population structures within the Navy's Southern California Range Complex?	*In 2019:* • Analyzed data recorded by HARPs deployed at sites E, H, and N from July 2018 to May 2019 (Rice et al. 2020a) for ambient sound levels, whale presence and relative abundance, and anthropogenic sound sources. • The beaked whale FM pulse type BW35 (newly described as of last year) was detected again at site E and H. • Overall detections were similar to previous years though some sound sources showed slight changes in number of detections at certain locations, suggesting possible shifts in activity. • Presented findings from this project at the OceanObs'19 Conference in Honolulu, Hawaii (See Appendix C). *In 2018:* • Deployed a new array of HARPs in the San Diego Trough during the summer and fall of 2017 (Rice et al. 2019a). • Analyzed data recorded by HARPs deployed at Sites E, H, N, and HP between March 2017 and July 2018 (Rice et al. 2019a). • Detected a new beaked whale FM pulse type, BW35, thought to be produced by Hubbs' beaked whale at site E and site H (Rice et al. 2019a). • Performed a comprehensive acoustic analysis of data collected between January 2013 and June 2017 at sites H, M, N, and P (Baumann-Pickering et al. 2018a). • Conducted analyses using automated detectors for whale sound sources across the five years (2013–2017) (Baumann-Pickering et al. 2018a). • Analyzed seasonal occurrence, interannual variability, and relative abundance of calls for fin whales, blue whales, and Cuvier's beaked whales that were consistently identified in the data over the 5-year period (2013–2017) (Baumann-Pickering et al. 2018a). • Presented this work at the 6th International Meeting on the Effects of Sounds in the Ocean on Marine Mammals, The Hague, The Netherlands "Impact of mid-frequency active sonar on beaked whale echolocation from long-term passive acoustic recordings" (Baumann-Pickering et al. 2018b). *In 2017:* • Analyzed fin whale song patterns from HARP data collected at four sites (Sites C, H, P, and Q) in the SCB between 2005 and 2014 (Širović et al. 2018). • Preliminary results indicated that the fin whale songs recorded between 2009 and 2010 across all four sites had the same doublet inter-pulse intervals corresponding to "short doublet" song likely attributed to resident population (Širović et al. 2018). • Conducted PAM from April 2016 to June 2017 to detect marine mammals and anthropogenic sounds using HARPs at three locations (Sites H, N and P) within SOCAL (Rice et al. 2018a). • Analyzed ambient noise and the presence of MFAS and explosions detected at all three sites (Rice et al. 2018a). • Performed data analysis using automated computer algorithms and detected blue whale call types B and D, and fin whale 20-Hz calls (Rice et al. 2018a). • Detected frequency-modulated echolocation pulses from Cuvier's beaked whales at sites H and N. Additional beaked whale-like frequency modulated pulse type, BW43, possibly produced by Perrin's beaked whale (Baumann-Pickering et al. 2014), was detected infrequently during winter at site N (Rice et al. 2018a). *In 2016:* • Conducted PAM from June 2015 to April 2016 to detect marine mammal and anthropogenic sounds using HARPs at three locations within SOCAL (Rice et al. 2017). • Described differences between recording sites in the occurrence of blue whale B calls and D calls, and fin whale 20-Hz calls. *In 2014–2016:* • Deployed HARPs at three locations in SOCAL to record marine mammal sounds and anthropogenic noise (Debich et al. 2015). • Continued refining understanding of fin whale population in SOCAL although analysis of fin whale song patterns identified songs from resident and "transient" (pan-Pacific) populations of fin whales. • Continued analysis of seasonal presence of fin, blue, and Cuvier's beaked whales, and the "BW43" beaked whale call (possibly Perrin's beaked whale). • Began new effort to characterize SOCAL regional Cuvier's beaked whale densities based on passive acoustic data.

Project (Technical report for 2019)	Conceptual Framework Category	Intermediate Scientific Objectives (Numbered as per Figure 1)	Monitoring Questions	Accomplishments[1]
SOCAL (continued)				
[S2] Cuvier's Beaked Whale Impact Assessment at SOAR (DiMarzio et al. 2020; Schorr et al. 2020) This is a joint project with [H2] "Long-term Passive Acoustic Monitoring of Cetaceans at PMRF".	Occurrence, Exposure, Response, Consequences	#2: Estimate the distribution, abundance, and density of marine mammals and ESA-listed species in Navy range complexes, testing ranges, and in specific training and testing areas. #3: Establish the baseline habitat uses, seasonality, and movement patterns of marine mammals and ESA-listed species where Navy training and testing activities occur. #6: Establish the regional baseline vocalization behavior, including seasonality and acoustic characteristics of marine mammals where Navy training and testing activities occur. #7: Determine what behaviors can most effectively be assessed for potential response to Navy training and testing activities. #8: Application of passive acoustic tools and techniques for detecting, classifying, and tracking marine mammals[2]. #9: Application of analytic methods to evaluate exposure and/or behavioral response of marine mammals to Navy training and testing activities. #11: Evaluate behavioral responses by marine mammals exposed to U.S. Navy training and testing activities to support PCoD development and application. #12: Evaluate trends in distribution and abundance for populations of marine mammals and ESA-listed species that are regularly exposed to sonar and underwater explosives. #13: Leverage existing data with newly developed analysis tools and techniques[2].	• What are the baseline population demographics, vital rates, and movement patterns for a designated key species in the SOCAL range complex? • Does exposure to sonar or explosives impact the long-term fitness and survival of individuals or the population, species or stock (with focus on blue whale, fin whale, humpback whale, Cuvier's beaked whale, and other regional beaked whale species)?	*In 2019:* • Deployed tags on a fin whale and Risso's dolphin (Schorr et al. 2020). • Analyzed home ranges for Risso's dolphins tagged from 2009 to 2019 and Cuvier's beaked whales tagged from 2008 to 2017 (Schorr et al. 2020). • To assess how long it takes Cuvier's beaked whales to return to "baseline" diving behavior following MFAS exposure, a general additive model was created using the *mgcv* package in R with Inter-deep dive interval as the response variable (Schorr et al. 2020). • Derived preliminary vital rates for Cuvier's beaked whales at SOAR (Schorr et al. 2020). • Submitted to the Journal of the Acoustical Society of America, "Foraging behavior of Cuvier's beaked whales (*Ziphius cavirostris*) during a 12 kHz multibeam ocean mapping survey off of southern California" (Varghese et al. in review. • Published in Frontiers in Marine Science, "Diel dive behavior of fin whales (*Balaenoptera physalus*) in the Southern California Bight" (Keen et al. 2019a),and in Aquatic Mammals, "Night and day: diel differences in ship strike risk for fin whales (*Balaenoptera physalus*) in the California Current System" (Keen et al. 2019b). • Presented findings from this project at the World Marine Mammal Conference, Barcelona, Spain (See Appendix C). • Examined changes in Cuvier's beaked whale abundance and vocal behavior (GVPs) at SOAR from August 2010 through October 2019 (DiMarzio et al. 2020). • Conducted five field efforts in 2019 at SOAR in conjunction with MarEcoTel to assist with visual verification of acoustic localizations and tag deployments (DiMarzio et al. 2020). • Presented findings from this project at the University of Rhode Island Biological Oceanography Poster Symposium (See Appendix C). *In 2018:* • Satellite tagging and photo-ID indicated high site fidelity within the SCB: Cuvier's beaked whales on SOAR and fin whales in the greater SCB (Schorr et al. 2019). • Cuvier's beaked whale photo-ID indicated that SOAR is home to a highly resident population segment (Schorr et al. 2019). • Manuscript detailing a mark-recapture assessment of abundance and survival rates of Cuvier's beaked whale is in preparation. • A project funded by ONR launched in 2018 at Isla Guadalupe, Mexico to assess diving behavior and demographics of beaked whales as a possible comparative site for the San Nicolas Basin. • Deployed tags on a Baird's beaked whale and Risso's dolphin (Schorr et al. 2019). • Analyzed extended beaked whale detection archives from August 2010 through July 2018 (DiMarzio et al. 2019). • Calculated monthly and yearly abundance estimates for Cuvier's beaked whale at SOAR between 2010 and 2018 (DiMarzio et al. 2019). • Determined that Cuvier's baked whale abundance for the SOAR range appears to be stable or increasing slightly from 2010 to 2018 (DiMarzio et al. 2019). *In 2017:* • Incorporated sightings of known reproductive Cuvier's beaked whale females with and without calves over time to provide critically needed calving and weaning rate data for PCoD models currently being developed for this species on SOAR (Schorr et al. 2018). • Updated Cuvier's beaked whale abundance estimates with data from 2015 through September 2017 (DiMarzio et al. 2018). • Incorporated automated sonar detector into the M3R software operating on streaming data at SOAR (DiMarzio et al. 2018). • Produced and archived time-tagged cetacean detections and localizations, and sonar detections made by automated system on streaming data at SOAR (DiMarzio et al. 2018). • Documented data show no decline in beaked whale abundance on SOAR from 2010 to 2017. *In 2016:* • Conducted survey effort for the first time during February, and doubled the previous amount of effort in April. • Updated hardware/software for M3R Linux-based cluster signal processor at SCORE, which includes a full range of broadband recording and integrated data archives; Update scheduled to be installed for the week of 5–10 March 2017. • Derived detection statistics (Probability of Detection and False Alarms) for M3Rs Auto-Grouper program and calculated correction factors from beaked whale detections at SOAR.
SOCAL (continued)				

Project (Technical report for 2019)	Conceptual Framework Category	Intermediate Scientific Objectives (Numbered as per Figure 1)	Monitoring Questions	Accomplishments[1]
				• Completed initial risk function for Cuvier's beaked whales. • Documented at SCORE that yearly abundance estimates showed no decline in population over the 5-year period, 2010–2014. *In 2015:* • Completed hardware/software upgrades for a M3R Linux-based cluster signal processor at SCORE, which includes a full range of broadband recording and integrated data archives. *In 2014–2015:* • Continued multi-year analysis of Cuvier's beaked and fin whale occurrence in SOCAL. Analyzed beaked whale detections from 2011 to 2014 to establish methods and baseline abundance. Beaked whale density estimation in progress. Collected sufficient sighting and photo-ID data for Cuvier's beaked whales to begin estimation of key population vital rates for impact analyses.
[S3] Marine Mammal Monitoring on California Cooperative Oceanic Fisheries Investigation (CalCOFI) Cruises [This project formerly titled "Beaked Whale Occurrence in SOCAL using Towed Array" in 2018 and "Marine Mammal Sightings during CalCOFI Cruises" from 2004-2017] (Trickey et al. 2020)	Occurrence	#1: Determine what species and populations of marine mammals and ESA-listed species are present in Navy range complexes, testing ranges, and in specific training and testing areas. #3: Establish the baseline habitat uses, seasonality, and movement patterns of marine mammals and ESA-listed species where Navy training and testing activities occur.	• What is the seasonal occurrence and abundance/density of beaked whales and ESA-listed baleen whales within the Navy's Southern California Range Complex?	*In 2019:* • Reported on visual monitoring for marine mammals aboard CalCOFI cruises from July 2016 to July 2019 (Trickey et al. 2020). • Analyzed towed-array data collected during CalCOFI cruises from 2008 to 2019 for beaked whale echolocation clicks. • Beaked whale clicks were detected on one occasion in the towed array recordings. *In 2018:* • Analyzed towed-array data collected four times per year during 52 CalCOFI survey cruises 2004–2018 (Frasier et al. 2019). • Implemented an unsupervised learning algorithm to distinguish between impulse signals associated with echosounders, vessel propeller cavitation, and beaked whale and dolphin echolocation clicks based on differences in their acoustic spectra (Frasier et al. 2019). • Screened towed–array data which contained acoustic detections of a variety of odontocete species' signals (Frasier et al. 2019). • Ongoing analysis: identification of beaked whale events from beaked whale signals (Frasier et al. 2019). *In 2017:* • Reported on visual and acoustic monitoring for marine mammals aboard CalCOFI cruises during July and November 2016, and January, April, and August 2017. • 20 species identified during on-effort observations. *In 2016:* • Performed visual and acoustic monitoring for cetaceans during 18 CalCOFI cruises from February 2012 to April 2016 in the SCB to collect distribution, abundance, and seasonal and inter-annual patterns of density. • 18 species identified and varied by season, 1,027 sonobuoy deployments, and 478 towed-array deployments during 334 days at sea and 2,034 observation hr on effort. *In 2015:* • Performed visual and acoustic monitoring for marine mammals aboard CalCOFI cruises in 2014 and 2015. • Platform provides an opportunity to assess the full range of marine mammal species present in SOCAL. • Habitat modeling underway to predict marine mammal presence in SOCAL. *In 2014:* • Gathered sufficient data for generation of species-specific seasonal densities and abundance trends at finer spatial and temporal scales than standard NMFS U.S. West Coast surveys, which are performed every 3 to 6 years.

Project (Technical report for 2019)	Conceptual Framework Category	Intermediate Scientific Objectives (Numbered as per Figure 1)	Monitoring Questions	Accomplishments[1]
SOCAL (continued)				
[S4/N3] Blue and Fin Whale Tagging and Analysis This project is also a component of NWTT tagging, N3.	Occurrence Exposure	#1: Determine what species and populations of marine mammals and ESA-listed species are present in Navy range complexes, testing ranges, and in specific training and testing areas. #3: Establish the baseline habitat uses, seasonality, and movement patterns of marine mammals and ESA-listed species where Navy training and testing activities occur. #4: Evaluate potential exposure of marine mammals and ESA-listed species to Navy training and testing activities. #5: Establish the baseline behavioral patterns (foraging, diving, etc.) of marine mammals where Navy training and testing activities occur.	• What are the movement patterns, occurrence, and residence times of blue and fin whales within Navy training and testing areas along the U.S. West Coast as compared to other areas visited by tagged whales outside of Navy training and testing areas? • What are the residency time/occupancy patterns of blue whales within NMFS-designated Biologically Important Areas (BIAs) for this species along the U.S. West Coast? • Are there bathymetric, annual oceanographic conditions (e.g., sea surface temperature, frontal zones, etc.), and/or climatic and ocean variations (e.g., global warming, North Pacific Gyre Oscillation [NPGO], Pacific Decadal Oscillation [PDO], El Niño/La Niña events, etc.) that can help explain blue and fin whale affinity for any identified areas of high residency along the U.S. West Coast?	*In 2019:* • Performed detailed analyses of existing tag data from blue and fin whales tagged in 2014–2017. Analyses included 1) fine-scale feeding behavior of tagged blue and fin whales; 2) assessment of Argos tag location accuracy; 3) site fidelity and residency patterns of tagged whales, and 4) the use of Navy training and testing areas and BIAs by tagged blue and fin whales. • Processed tag data collected in 2014–2017 for use in a future exposure analysis, comparing whale tracks to known Navy training events in SOCAL using MFAS. Tag data were filtered by location quality and include animal locations within a 20-km buffer zone of the SOCAL Range Complex. • Published the following papers: in Frontiers in Ecology and Evolution, "Scales of blue and fin whale feeding behavior off California, USA, with implications for prey patchiness" (Irvine et al. 2019); in Frontiers in Movement Ecology, "Ecological correlates of blue whale movement behavior and its predictability in the California Current Ecosystem during the summer-fall feeding season" (Palacios et al. 2019a); in Proceedings of the National Academy of Sciences, "Memory and resource tracking drive blue whale migrations" (Abrahms et al. 2019b); and in Diversity and Distributions Journal, "Dynamic ensemble models to predict distributions and anthropogenic risk exposure for highly mobile species" (Abrahms et al. 2019a). Submitted to Animal Telemetry, "An at-sea assessment of Argos location accuracy for three species of large whales, and the effect of deep-diving behavior on location error" (Irvine et al. in review). • Presented findings of this project at the World Marine Mammal Conference, Barcelona, Spain (See Appendix C). *In 2018:* • Conducted inter-annual comparisons of tracking results between 2014, 2015, 2016, and 2017 (Mate et al. 2018a). • Analyzed dive characteristic data obtained from DM tags used in 2016 and 2017 and compared to ADB data from 2014 and 2015 (Mate et al. 2018a). • Characterized whale tracking data in the context of environmental conditions (i.e., depth, slope, SST, and distance to shore) and a comparison among the four years 2014–2017). • Conducted genetic analysis of biopsy samples from all four years, including sex determination, individual identification, and species and stock identification, as well as results from the photo-ID of tagged and untagged whales. • Results indicated that blue and fin whales have distinct ecological optima that likely are reflections of different prey resource utilization in much of their range. Blue and fin whale range and movement patterns in CCAL are predicted to change, given that the euphausiid and pelagic schooling fish prey they forage upon respond strongly to decadal variability. • Examined whale movements in relation to three environmental indices (the ONI, the PDO index, and the NPGO index. • Results suggest that the anomalous warm-water events of 2014 and 2015 had different impacts on blue and fin whales: blue whale foraging effort was lowest in 2014 and 2015, while during the 2015–2016 El Niño fin whale foraging effort appeared worse. *In 2017:* • Conducted analyses on blue, fin, and humpback whale tracking results which included tag deployments from 2016 and tracking information through 8 April 2017. • Analyzed dive characteristic data obtained from DM tags used in 2016 and compared 2016 data to ADB data from 2014 and 2015. • Genetic analysis of biopsy samples to determine sex of individuals, individual identification, and species and stock identification was conducted for all three years (2014–2016). *In 2016:* • Analyzed genetic samples from blue whales and fin whales biopsied to determine sex of the individuals. • Used mtDNA sequences to define haplotypes for stock analysis and to confirm species identification. *In 2015:* • Analyzed genetic samples from blue whales and fin whales biopsied in 2014 and 2015 to determine sex of the individuals. • Used mtDNA sequences to define haplotypes for stock analysis and to confirm species identification. *In 2014:* • Analyzed data from ADB tags and identified strong and consistent diel feeding patterns in blue whales.

Project (Technical report for 2019)	Conceptual Framework Category	Intermediate Scientific Objectives (Numbered as per Figure 1)	Monitoring Questions	Accomplishments[1]
SOCAL (continued)				
[S5] SOCAL Soundscape Study (Rice et al. 2020a; Wiggins et al. 2020)	Occurrence	#9: Application of analytic methods to evaluate exposure and/or behavioral response of marine mammals to Navy training and testing activities. #13: Leverage existing data with newly developed analysis tools and techniques[2].	• What is the ambient and anthropogenic soundscape in SOCAL?	*In 2019:* • Examined underwater explosive sounds detected on HARPs to determine if different signal characteristics allow them to be classified as produced by fisheries-related seal bombs or Navy ordnance used during training exercises. *In 2018:* • Re-processed ambient soundscape SPLs, analyzed and displayed using new and improved techniques, including calculating long (multi-year) spectrograms, sound pressure spectrum level percentiles, and average SPLs over the five-year recording period (June 2012 to June 2017). • Detected MFAS throughout the five year period, with the highest cumulative sound exposure levels and number of packet detections at the site south of San Clemente Island (N) and the fewest at the shallow near-shore site (P). • Detected explosions at all three sites (H, N, and P) throughout the five-year period showed a general decrease in activity over time and with the highest number at the site (H) in the western San Nicolas Basin. *In 2017:* • Analyzed metrics characterizing the underwater soundscape in the SOCAL range, based on multi-year recordings by HARPs of ambient biological, abiotic, and anthropogenic sound.
[S6/N4] Guadalupe Fur Seal Satellite Tracking (Norris and Elorriaga Verplancken 2019b, 2020) This project is also a component of NWTT tagging, N4.	Occurrence	#1: Determine what species and populations of marine mammals and ESA-listed species are present in Navy range complexes, testing ranges, and in specific training and testing areas. #2: Estimate the distribution, abundance, and density of marine mammals and ESA-listed species in Navy range complexes, testing ranges, and in specific training and testing areas. #3: Establish the baseline habitat uses, seasonality, and movement patterns of marine mammals and ESA-listed species where Navy training and testing activities occur.	• What is the at-sea distribution of Guadalupe fur seals as they travel through the offshore waters of the Southern California Range Complex and Northwest Training and Testing area?	*In 2019:* • Conducted direct counts of Guadalupe fur seals by land- and vessel-based surveys at San Benito Archipelago from 23 to 29 July 2019 and a land- and vessel-based population survey was conducted at Guadalupe Island from 8 to 13 August 2019 (Norris and Elorriaga Verplancken 2020). • Used a RPA or drone to test the feasibility of aerial imagery to improve counts at Punta Sur, Guadalupe Island, to replace or supplement walk-through surveys that create a disturbance for mothers with <1 month-old pups (Norris and Elorriaga Verplancken 2020). • Conducted intermittent RPA surveys at both locations during boat-based surveys to develop substrate-specific correction factors to better account for animals missed from the boat (Norris and Elorriaga Verplancken 2020). • Analyzed dive-characteristic data for seals at Guadalupe Island (Norris and Elorriaga Verplancken 2019b). • Analyses are ongoing to further refine the dive bout definition and better quantify diving activity along Guadalupe fur seal tracks (Norris and Elorriaga Verplancken 2019b). *In 2018:* • Initiated one of the first studies of at-sea distribution and foraging behavior of Guadalupe fur seals; conducted land- and vessel-based population surveys at San Benito Archipelago, Mexico from 11 to 14 July 2018 and Guadalupe Island, Mexico from 30 July to 4 August 2018 (Norris and Elorriaga Verplancken 2019a). • Tracked satellite-tagged individuals in November 2018: 15 adult female, 10 juvenile female, and 10 juvenile male Guadalupe fur seals at Punta Sur, Guadalupe Island. • Analyzed Guadalupe fur seal densities, abundance estimates, dive-characteristic data, and distance traveled. • Preliminary analyses indicate adult and juvenile females exhibited more "resident" foraging behavior and remained close and returned to Guadalupe Island, while juvenile males dispersed away from the Island. • Performed analyses of dive characteristic data.
[S7/N1/G2/H6] Humpback Whale Tagging in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas in the Pacific Ocean (Mate et al. 2019b, 2020; Palacios et al. 2020) This project is also a component of HRC, NWTT, and GOA TMAA tagging, H6, N1, and G2.	*See project* N1/H6/S7/G2 *(below, in NWTT)*			

Project (Technical report for 2019)	Conceptual Framework Category	Intermediate Scientific Objectives (Numbered as per Figure 1)	Monitoring Questions	Accomplishments[1]
SOCAL (continued)				
[S8] Autonomous Underwater Vehicle PAM of Beaked Whales in the Southern California Area Field work for this project was delayed so a report has not yet been completed.	Occurrence	#1: Determine what species and populations of marine mammals and ESA-listed species are present in Navy range complexes, testing ranges, and in specific training and testing areas. #2: Estimate the distribution, abundance, and density of marine mammals and ESA-listed species in Navy range complexes, testing ranges, and in specific training and testing areas. #3: Establish the baseline habitat uses, seasonality, and movement patterns of marine mammals and ESA-listed species where Navy training and testing activities occur.	• What species of beaked whales are present in the Southern California Bight (SCB) and off northern Baja California, Mexico? • What is the spatial distribution of beaked whale species both inside and outside of the U.S. Navy's training ranges in the SCB and northern Baja California, Mexico, including on and off the continental shelf?	*In 2019:* • Deployments were originally scheduled for late summer 2019, but due to technical issues encountered with the glider firmware, work was rescheduled for winter/spring 2020. Deployed two Seagliders in February 2020 in the SCB to use PAM to characterize beaked whale occurrence and distribution in and around the Navy's training ranges in the SCB, both on and off the continental shelf. Gliders will be retrieved in March 2020 after a ~45 day deployment period. Results are expected to be available in fall 2020.
NWTT				
[N1/H6/S7/G2] Humpback Whale Tagging in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas in the Pacific Ocean (Mate et al. 2019b, 2020; Palacios et al. 2020) This project is also a component of SOCAL, HRC, and GOA TMAA tagging, S7, H6, and G2.	Occurrence	#1: Determine what species and populations of marine mammals and ESA-listed species are present in Navy range complexes, testing ranges, and in specific training and testing areas. #3: Establish the baseline habitat uses, seasonality, and movement patterns of marine mammals and ESA-listed species where Navy training and testing activities occur. #4: Evaluate potential exposure of marine mammals and ESA-listed species to Navy training and testing activities. #5: Establish the baseline behavioral patterns (foraging, diving, etc.) of marine mammals where Navy training and testing activities occur.	• What are the occurrence, movement patterns, and residency patterns of multiple humpback whale Distinct Population Segments within Navy Pacific Ocean at-sea ranges (SOCAL, HRC, NWTT, GOA)?	*In 2019:* • Tagged humpback whales off Washington in September and October 2019 (Mate et al. 2020) and off Hawaii in March 2019 (Mate et al. 2019b). • Observed killer whales and photographed on two occasions in 2019 (Mate et al. 2020). • Analyzed seven killer whale encounters from 2018 field efforts. Of 91 individual killer whales observed, 45 were matched to J, K, and L pods of the SRKW population. • Tracked humpback whales tagged off Washington from the northwest corner of Vancouver Island, British Columbia, Canada, to Seaside, Oregon (Mate et al. 2020). • Tracked humpback whales tagged off Maui along the entire migratory route to the southwest coast of Baranof Island in Southeast Alaska, the northern Gulf of Alaska, Haida Gwaii, and the Aleutian Islands (Mate et al. 2019b). • Determined sex and population/stock identification for humpback whales tagged off of Washington and Oregon in 2018; also analyzed dive characteristics (Palacios et al. 2020). • Submitted a technical report to Pacific Life Foundation, "Tracking North Pacific Humpback Whales To Unravel Their Basin-Wide Movements (Palacios et al. 2019b). • Presented findings from this project at the World Marine Mammal Conference, Barcelona, Spain (See Appendix C). • Ongoing analyses: genetic sex determination, population identity, individual identification, dive characteristic data, and species and stock identification. *In 2018:* • Tracked humpback whales tagged off Maui along entire migratory path to Prince of Wales Island in Southeast Alaska; Haida Gwaii, the northern Pacific coast of Canada and Queen Charlotte Sound; the Aleutian Island chain and Bering Sea (Mate et al. 2019c). • Tagged humpback whales off Hawaii in spring of 2018 (Mate et al. 2019c), and off California and Oregon in summer-fall of 2017 (Mate et al. 2018b). • Tagged humpback whales off Washington and Oregon in August and September 2018 (Mate et al. 2018c, 2019a), and a detailed analysis of these tag data will be available in a future report. • Applied SSSMs and hSSSMs to the Argos locations in order to examine home ranges, dive behavior, and ecological relationships. • Analyzed historical humpback whale tag data collected by OSU from 1997 to 2016 in California, Oregon, Southeast Alaska, and the Aleutian Islands in relation to U.S. Navy training and testing areas in the Pacific (Mate et al. 2018b). • Analysis of humpback whale mtDNA haplotypes showed significant differences between the tagging samples from California and Oregon, indicating a degree of differentiation between feeding areas. Oregon now shows a closer affinity with the Southern British Columbia/Washington feeding area (Mate et al. 2018b). • Tagged humpback whales had extended residencies in the Navy ranges: NWTT for Oregon whales, PT MUGU for California whales. • Ongoing analyses: genetic sex determination, population identity, individual identification, dive characteristic data, and species and stock identification. The final report is expected during the FY19 reporting period. *In 2017:* • Photo-ID and matching of photographs of tagged whales to existing photo-ID databases is ongoing. Continued genetic analysis of biopsy samples to determine sex of individuals, individual identification, and species and stock identification and will be presented in the final report (Mate et al. 2017b).

Project (Technical report for 2019)	Conceptual Framework Category	Intermediate Scientific Objectives (Numbered as per Figure 1)	Monitoring Questions	Accomplishments[1]
NWTT (continued)				
[N2] Characterizing the Distribution of ESA-Listed Salmonids in the Pacific Northwest (Smith and Huff 2020)	Occurrence	#1: Determine what species and populations of marine mammals and ESA-listed species are present in Navy range complexes, testing ranges, and in specific training and testing areas. #2: Estimate the distribution, abundance, and density of marine mammals and ESA-listed species in Navy range complexes, testing ranges, and in specific training and testing areas. #3: Establish the baseline habitat uses, seasonality, and movement patterns of marine mammals and ESA-listed species where Navy training and testing activities occur.	• What is the oceanic distribution and seasonal variability of ESA-listed salmonid species that may be important prey for the Southern Resident killer whale?	*In 2019:* • Purchased and programmed 195 acoustic tags, 100 temperature tags, and 5 satellite-monitored tags. • Deployed tags on Bull trout (17), Chinook salmon (142), and Coho salmon (35). • Detected tagged Chinook salmon (123) (87%) 50,533 times on 103 acoustic receivers. • Deployed 107 stationary receivers from 14 to 16 May 2019 (98 within the NWTT) and downloaded/redeployed between 31 August and 4 September 2019. • Analyzed detection history, residence times, and movement characteristics of tagged fish in order to build a species distribution model to determine suitable habitat for each species, how this may influence killer whale populations, and how this overlaps with the NWTT. *In 2018:* • Conducted a pilot study to demonstrate the feasibility of capturing, tagging, and releasing salmonids at sea; captured, weighed, measured, and tagged two species of salmonids in June and August 2018 at various depths along the coastal shelf of Washington in the vicinity of NWTT. Successful capture of 45 salmonids of appropriate size for tagging was demonstrated, with lessons learned that are expected to increase catch rate in 2019 (Huff and Smith 2019).
[N3/S4] Blue and Fin Whale Tagging and Genetics This project is also a component of SOCAL tagging, S4.	*See project S4/N3 (above, in SOCAL)*			
[N4/S6] Guadalupe Fur Seal Satellite Tracking (Norris and Elorriaga Verplancken 2019b, 2020) This project is also a component of SOCAL tagging, S6.	*See project S6/N4 (above, in SOCAL)*			

Project (Technical report for 2019)	Conceptual Framework Category	Intermediate Scientific Objectives (Numbered as per Figure 1)	Monitoring Questions	Accomplishments[1]
GOA TMAA				
[G1] PAM of Marine Mammals in the Gulf of Alaska Temporary Maritime Activities Area using Bottom-Mounted Devices (Rice et al. 2019b, 2020b)	Occurrence	#1: Determine what species and populations of marine mammals and ESA-listed species are present in Navy range complexes, testing ranges, and in specific training and testing areas. #6: Establish the regional baseline vocalization behavior, including seasonality and acoustic characteristics of marine mammals where Navy training and testing activities occur.	• What is the temporal occurrence of baleen whales and beaked whales in the GOA TMAA?	*In 2019:* • Collected passive acoustic data using two HARPs deployed in the GOA and completed analysis 1) characterizing the low-frequency ambient soundscape, and 2) detecting marine mammal and anthropogenic sounds during times of naval exercises in the area. • Recorded a total of 14,060 hours of acoustic data over 585 days from 2017-2019. • Mid-frequency sonar was detected in conjunction with a U.S. Navy exercise where sonar was known to be used. Low-frequency sonar was detected just prior to the exercise but confirmed by U.S. Navy that the signal was not from a U.S. Navy source. Explosives detected were from civilian sources (i.e., seal bombs) and not U.S. Navy. *In 2017:* • Recorded signals from three known odontocete species: sperm whales, Cuvier's beaked whales, and presumed Stejneger's beaked whales; four baleen whale species were also recorded: blue, fin, gray, and humpback whales. Blue and fin whales were the most commonly detected baleen whales and no North Pacific right whale upcalls were noted. Sperm whale and Stejneger's beaked whales occurred throughout the summer at all sites, while Cuvier's beaked whales were detected mainly at one site during early summer (Rice et al. 2018b). • Analyzed PAM data from 3 HARP deployments April–September 2017 for anthropogenic sound, beaked whales and ESA-listed baleen whales. • Tracked a pair of fin whales from their 40-Hz calls recorded on an array of PAM instruments in May 2015.This is the first report of tracked 40-Hz fin whale calls, and the animals were shown to be moving while producing calls. • Measured call and swimming parameters (depth, location, recording duration, swim speed, source levels) for localized 40-Hz calls from whales A and B. *In 2016:* • Ambient soundscape sound pressure levels were re-processed using new and improved techniques, including calculating long (multi-year) spectrograms, sound pressure spectrum level percentiles, and average sound pressure spectrum levels.
[G2/N1/S7/H6] Humpback Whale Tagging in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas in the Pacific Ocean (Mate et al. 2019b, 2020; Palacios et al. 2020) This project is also a component of SOCAL, HRC, and NWTT tagging, S7, H6, and N1.	*See project S7/N1/G2/H6 (above, in NWTT)*			

[1] As per the regulations implementing monitoring reporting requirements (described in Section 1. Introduction), accomplishments from monitoring in the second and third cycle of 5-year authorizations are reported in a cumulative fashion.

[2] Primary Research & Development and Demonstration-Validation (DEMVAL) investments for tools and techniques supported by the Office of Naval Research Marine Mammal and Biology and the Living Marine Resource programs.

Key: ADB = advanced dive behavior; Argos = Advanced Research and Global Observation Satellite; ASW = anti-submarine warfare; BW = beaked whale; CalCOFI = California Cooperative Oceanic Fisheries Investigations; CCAL = California Current Province; Chl-a = Chlorophyll a; dB re 1 µPa = decibels referenced to 1 micro Pascal; DDG= guided missile destroyer; DM = Dive Monitoring; DNA = deoxyribonucleic acid; DoN = Department of the Navy; E-BREVE = Environmentally-influenced Behavioral Response Evaluations; EAR = Ecological Acoustic Recorder; ESA = Endangered Species Act; FDM = Farallon de Medinilla; FM = frequency-modulated; FY = Fiscal Year; GOA TMAA = Gulf of Alaska Temporary Maritime Activities Area; *g*(0) = trackline detection probability; GPS = Global Positioning System; GVP = group vocal periods; HARP = High-frequency Acoustic Recording Package; hr = hour(s); HRC = Hawaii Range Complex; hSSSM = hierarchical switching state-space model; HSTT = Hawaii Southern California Training and Testing; Hz = Hertz; kHz = kilohertz; km = kilometer; LIMPET = Low Impact Minimally Percutaneous Electronic Transmitter; m = meter; LTSA = Long-Term Spectral Average; M3R = marine mammal monitoring on U.S. Navy ranges; MFAS = mid-frequency active sonar; MISTCS = Mariana Islands Sea Turtle and Cetacean Survey; MITT = Mariana Islands Training and Testing; MMO = marine mammal observer; mtDNA = mitochondrial DNA; NMFS = National Marine Fisheries Service; NOAA = National Oceanic and Atmospheric Administration; NPGO = North Pacific Gyre Oscillation; NWTT = Northwest Testing and Training; ONI = Oceanic Niño Index; ONR = Office of Naval Research; OSU = Oregon State University; PAM = passive acoustic monitoring; PCoD = Population Consequences of Disturbance; PDO = Pacific Decadal Oscillation; photo-ID = photo-identification; PIFSC = Pacific Islands Fisheries Science Center; PMRF = Pacific Missile Range Facility; PT MUGU = Point Mugu Sea Range; RPA = remotely piloted aircraft; s = second(s); SCB = Southern California Bight; SCC = Submarine Command Course; SCORE = Southern California Offshore Range; SD = standard deviation: SPOT = smart position and temperature; SOAR = Southern California Offshore Antisubmarine Warfare Range; SOCAL = Southern California Range Complex; SPL = sound pressure level; SRKW = Southern Resident killer whale; SSC Pacific = Space and Naval Warfare Systems Pacific; SSSM = switching state-space model; SST = sea surface temperature; U.S. = United States.

2.2 Timeline of Monitoring Efforts

In this sub-section, a graphical timeline of monitoring projects is presented for each range, covering the 2019 monitoring year. The timelines include monitoring projects as well as notable items (e.g., results and outcomes). Each timeline graphic is followed by a description of each monitoring project's methods; the corresponding monitoring project in the timeline can be identified by the numbered code at the beginning of the project title, which begins with a one-letter abbreviation of the range/study area (e.g., M = MITT; H = HRC; S = SOCAL; N = NWTT; G = GOA TMAA). Project results can be found in the Supporting Technical Reports section at the Navy's MSM website: https://www.navymarinespeciesmonitoring.us/reporting/pacific/

2.2.1 MITT

A timeline of all U.S. Pacific Fleet-funded monitoring tasks implemented in the MITT in 2019 is illustrated in **Figure 3**. Detailed project summaries follow below.

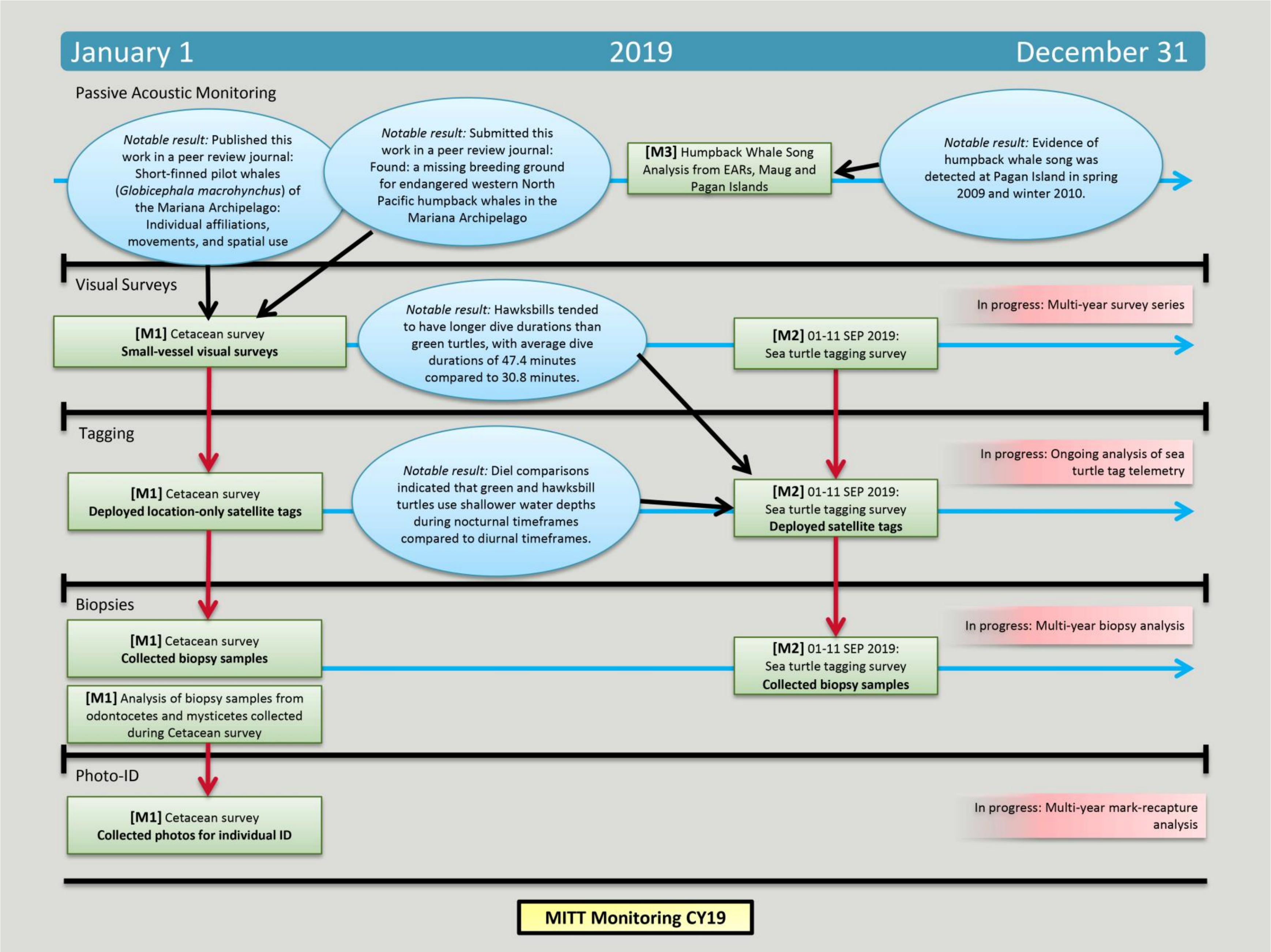

Figure 3. Timeline of 2019 projects in the Mariana Islands Training and Testing Study Area.

[M1] Cetacean Monitoring in the Mariana Islands Range Complex

In an effort to develop baseline information of the occurrence, abundance, and structure of cetacean populations in the Mariana Archipelago, the Pacific Islands Fisheries Science Center's (PIFSC's) Cetacean Research Program (CRP) conducted visual surveys for cetaceans in the waters surrounding Guam and the southernmost islands of the Commonwealth of the Northern Mariana Islands (CNMI) (Saipan, Tinian, Aguijan, and Rota) during 2010–2018. These non-systematic visual surveys were conducted aboard small boats, and satellite tagging and biopsy collection for genetic analysis was performed. No field work was conducted in 2019. Hill et al. (2019c) summarized the 2010 to 2018 data by evaluating population structure, range, and habitat use from analyses of photo-identification (photo-ID), genetic, satellite telemetry, and acoustic datasets, including bottom-moored High- frequency Acoustic Recording Packages (HARPs) and the 2015 Mariana Archipelago Cetacean Survey (MACS), a large-ship survey around all islands in the Mariana Archipelago north of Farallon de Medinilla (FDM). In 2019, CRP conducted more detailed analyses of existing genetic and satellite-tag data, and photo-ID, including individual affiliations, movements, dive behavior, and spatial use for short-finned pilot whales (*Globicephala macrorhynchus*) within the Mariana Archipelago and published this work in a peer-reviewed journal (Hill et al. 2019a). Also in 2019, population identity analyses were conducted from data collected during small-boat photo-ID and biopsy sampling surveys on humpback whales (*Megaptera novaeangliae*) in the southern portion of the archipelago during February and March 2015−2018 (Hill et al. 2020).

[M2] Sea Turtle Tagging in the Mariana Islands Training and Testing [Gaos et al. 2020]

In September 2019, tagging surveys were conducted for green sea turtles (*Chelonia mydas*) and hawksbill sea turtles (*Eretmochelys imbricata*) in the nearshore and coastal waters of Guam and Saipan. These surveys are part of an ongoing study to better understand the distribution and habitat use of sea turtles in the MITT. Turtles were captured, weighed, measured, biopsied, and tagged [i.e., flipper, passive integrated transponder (PIT), and satellite-monitored tags], and blood samples were also collected. In 2018, survey efforts were conducted in areas never before surveyed, including the northeast coast of Saipan, and the eastern and southern coasts of Guam. In 2019, efforts were conducted in similarly isolated areas; however, the northern coastal waters of Guam (Ritidian, Anderson Air Force Base, Tarague and Pati Point) and the eastern coast of Saipan (Forbidden Island, Lao Lao and Dandan) were surveyed. This research was conducted by PIFSC Marine Turtle Biology and Assessment Program in a collaborative effort with the U.S. Pacific Fleet Environmental Readiness Office, Naval Base Guam, University of Guam/Sea Grant, United States Fish and Wildlife Service, Guam Division of Aquatic and Wildlife Resources, and CNMI Department of Lands and Natural Resources.

[M3] Humpback Whale Song Analysis from Ecological Acoustic Recorder (EAR) data from Pagan and Maug Islands [Munger and Lammers 2020]

In 2019, archived acoustic data were analyzed for the presence of baleen whales at Pagan and Maug Islands. Acoustic data were recorded using bottom-mounted Ecological Acoustic Recorders (EARs) deployed off the islands of Maug and Pagan in the northern portion of the CNMI by the PIFSC's Coral Reef Ecosystem Division from 2009 to 2010 **(Figure 4)**. The EARs were deployed at depths between 10 and 20 meters (m) and sampled at 40 kilohertz (kHz) for an effective bandwidth of 20 kHz, and recorded data for 30 seconds (s) on at 15 minute intervals (3.3% duty cycle).

The Maug EAR recorded from 29 April 2009 to 17 October 2010, and the Pagan EAR recorded from 23 April 2009 to 23 February 2010. Data were searched manually by visually scanning spectrograms of each individual 30-s recording using the Matlab program *Triton* (Wiggins 2003) by Oceanwide Science Institute. The search effort focused on winter months (January to March) when humpback whales were most likely to be detected, as well as adjacent months in late autumn and early spring when data were available. Two recording periods were analyzed from the Maug Island EAR: late April 2009 to May 2009, and November 2009 to May 2010. The entire Pagan Island dataset was analyzed, from late April 2009 through late February 2010.

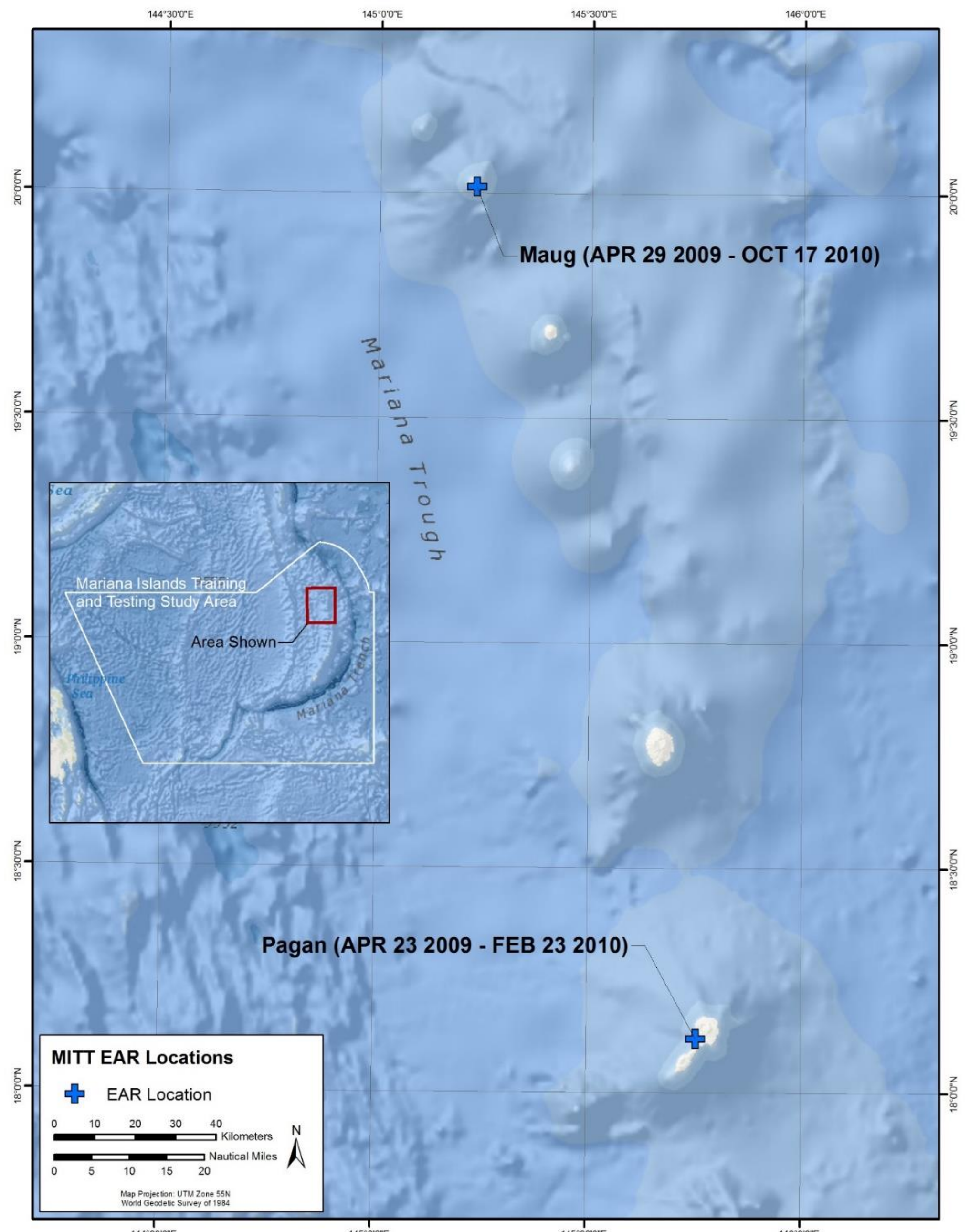

Figure 4. Ecological Acoustic Recorders deployment locations in the Mariana Islands Training and Testing Study Area [Project M3]

2.2.2 HSTT

Monitoring in HRC and SOCAL is presented individually in the following sections.

2.2.2.1 HRC

A timeline of all U.S. Pacific Fleet-funded monitoring tasks implemented in the HRC in 2019 is illustrated in **Figure 5**. Detailed project summaries follow.

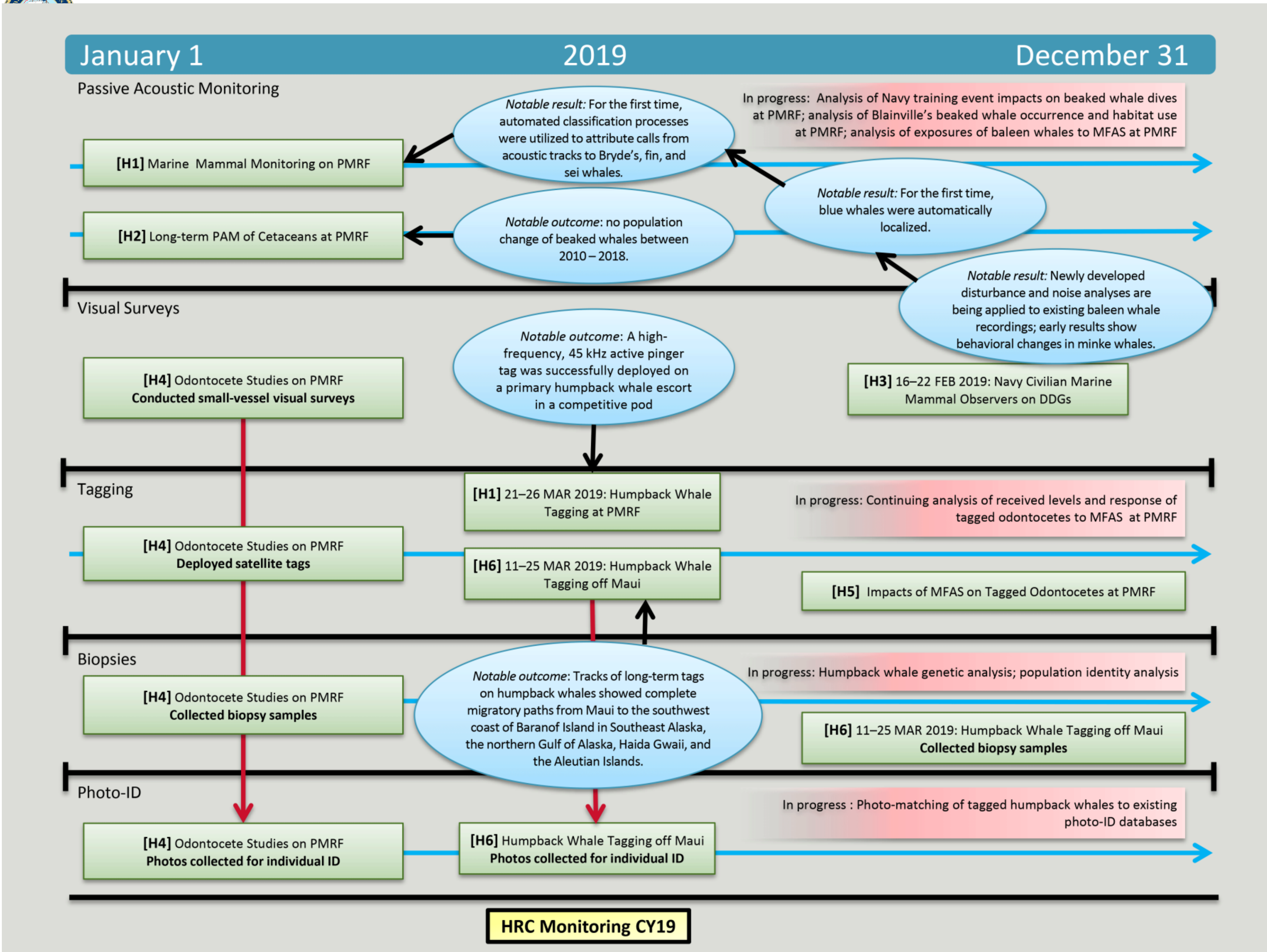

Figure 5. Timeline of 2019 projects in the Hawaii Range Complex.

[H1] Marine Mammal Monitoring on PMRF [Martin et al. 2020]

Biological and anthropogenic sounds recorded by range hydrophones at PMRF were analyzed to identify and localize marine mammals that use the range, as well as MFAS activity. Multiple algorithms were used to process acoustic data, including a custom C++ for beaked whales (Blainville's, *Mesplodon densirostris*; Cross Seamount [CSM], *Mesoplodon* sp.; and Cuvier's, *Ziphius cavirostris*), killer whales (*Orcinus orca*), sperm whales (*Physeter macrocephalus*), baleen whales (minke whales, *Balaenoptera acutorostrata*; and low-frequency baleen whales [Bryde's, *B.edeni*; sei, *B. borealis*; fin, *B. physalus*; and blue, *B. musculus*, whales] as a single group not identified to species), and MFAS transmissions. A custom Matlab algorithm separately processed humpback whale song detections and localizations and incorporated new tools that classify low-frequency baleen whale calls to species. Methods now exist for classifying calls attributed to Bryde's, fin, sei, fin and/or sei, and blue whales. In addition, a "nearest conspecific" tool was used for the first time in 2019 to examine minke whale bimodal call rates as a function of distance between conspecifics to investigate potential interactions between species (C.R. Martin et al. 2019).

The number of acoustic tracks and group dives were used to estimate minimum densities and abundances of vocalizing individuals over short- and long-term scales. A semi-automated Matlab localization association tracker was used to track automated localizations from baleen and sperm whales (C.R. Martin et al. 2018b). A Matlab "noise analysis" tool was also used to identify periods when noise levels deviated from expected natural variations. Noise analysis processes can be implemented to: 1) identify suspicious "unnatural" noise that can impact recordings, 2) look at changes in ambient noise over time, 3) understand natural and anthropogenic changes in background noise, 4) better understand the limitations of detecting calls based on different noise environments, and 5) look for biological relationships between marine mammal activity and noise. This tool was tested and partially validated on all the decimated data thus far.

[H2] Long-term Passive Acoustic Monitoring of Cetaceans at PMRF and SOAR [DiMarzio et al. 2020]

Abundance patterns and vocal behavior of beaked whales (Blainville's beaked whale at PMRF, and Cuvier's beaked whale at SOAR) were examined using a dive-counting method and passive acoustic data (DiMarzio et al. 2020). PAM data collected from range hydrophones at PMRF during 2015–2018, and at Southern California Offshore Antisubmarine Warfare Range (SOAR) during 2010–2019, were examined to study abundance patterns and vocal behavior of these beaked whale species. Field efforts at SOAR were conducted in conjunction with Marine Ecology and Telemetry Research (MarEcoTel) (see **Project S2**). Yearly and monthly abundance, mean number of group vocal periods (GVPs), mean length of the GVPs, and the mean number of clicks detected per beaked whale group were calculated. Potential impacts on these metrics by MFAS events at SOAR in 2018 and 2019 were also analyzed.

Naval Undersea Warfare Center (NUWC) Division Newport maintains the Marine Mammal Monitoring on U.S. Navy Ranges (M3R) system, which can be run with minimal operator intervention to collect and archive passive acoustic detection data on a nearly continuous basis (see also **Project S2**). M3R personnel use both a real-time review of binary spectrograms and output from the Class-Specific Support Vector Machine classifier and Fast

Fourier Transform detector via a click train viewer display in order to identify relevant species. The archive files provide an electronic record of marine mammal acoustic activity, sonar activity, and marine mammal localization data from multiple algorithms.

[H3] Navy Civilian Marine Mammal Observers on DDGs [Vars et al. 2019]

In order to assess the effectiveness of Navy lookouts in locating and identifying marine mammals, marine mammal observers (MMOs) are placed on U.S. Navy guided missile destroyer (DDG) warships during Submarine Command Course (SCC) training events (in February 2014, 2015, 2016, 2018, and 2019), and Koa Kai events (January 2014) (Dickenson et al. 2014; Shoemaker et al. 2014; Vars et al. 2016, 2019; Watwood et al. 2016; Oliveira et al. 2019). During these embarks, MMOs follow a systematic protocol to collect data (sighting and weather information) that are pooled with other embarks for analysis of the effectiveness of U.S. Navy lookouts observing from the pilot house or the bridge wings of the DDG. In 2019, an embark was conducted from 16 to 22 February during one SCC event.

[H4] Odontocete Studies on the Pacific Missile Range Facility: Satellite-tagging, Photo-identification, and Passive Acoustic Monitoring

Cascadia Research Collective (CRC) has been conducting this long-term marine mammal monitoring project each year since 2011, adding to prior, independent surveys extending back to 2003. Surveys are conducted in conjunction with the M3R PAM system streaming from the instrumented PMRF Range (Moretti 2017; DiMarzio et al. 2018, 2019, 2020). M3R detections are used to direct the CRC boat to animals of interest for satellite-tag deployment, biopsy sampling, and photo-ID in addition to providing visual validations of species for the acoustic detections. Animals instrumented with satellite tags can provide information on spatial movements and habitat-use patterns of cetaceans that are exposed to MFAS on and around PMRF before, during, and after the SCC (see Baird et al. 2019a, 2019b). Tagged animals that overlap in space and time with training events can be utilized for MFAS exposure analysis (Project [**H5**], below.). Because the August 2019 SCC training event at PMRF was cancelled, CRC tagging activities were postponed until February 2020.

[H5] Impacts of MFAS on Tagged Odontocetes at PMRF [Baird et al. 2019b]

Since 2011, researchers have estimated the received level of exposure (RL) of satellite-tagged odontocetes during Navy training events at PMRF by comparing tracks of tagged animals with localized sonar activity recorded from the PMRF range hydrophones (Baird et al. 2014, 2017a). In 2019, in addition to RL estimation using these methods, potential *responses* of odontocetes to MFAS were assessed by analyzing animal tracks for any large-scale movements concurrent with sonar activity. Diving and surfacing behavior of tagged individuals was analyzed before, during, and after MFAS exposure to calculate RLs and assess potential responses for seven tagged animals: three short-finned pilot whales (one from the resident population and two from a non-resident population); two rough-toothed dolphins (*Steno bredanensis*, both from the resident population), and two melon-headed whales (*Peponocephala electra*, both from an offshore population). To better assess variability in RL estimates, multiple metrics (mean, standard deviation [SD], minimum, maximum) of estimated RLs (measured as dB re: 1μPa root mean square [RMS]) were calculated for each exposure event, both near the surface (10 m depth) and at depths representative of typical foraging depths for each species.

[H6] Humpback Whale Tagging in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas in the Pacific Ocean [Mate et al. 2019b, 2020; Palacios et al. 2020]

Researchers from the Oregon State University (OSU) Marine Mammal Institute instrumented humpback whales in California, Oregon, Washington, and Hawaii with long-duration satellite-tracked dive monitoring (DM) tags, collected images for photo-ID, and conducted genetic analyses on tissue collected during tag placement. The objective of this project is to track humpback whale movements and elucidate what portion of each humpback whale distinct population segment (DPS) used Navy at-sea ranges in the North Pacific, as well as the proportion of time the humpback whales spent in these areas. In addition, dive duration, breeding-season home range, core areas of utilization, migration to the feeding areas, habitat use, and ecological/oceanographic characteristics were also analyzed. Data from tagged whales provide valuable information on dive duration, activity levels, and other behavioral characteristics over periods spanning weeks to months. Humpback whales were tagged off Hawaii in spring of 2019 (Mate et al. 2020), off Oregon in the fall of 2018 (Palacios et al. 2020), and off Washington in the fall of 2018 (Palacios et al. 2020) and 2019 (Mate et al. 2019b).

This is the same project conducted for SOCAL, NWTT, and GOA TMAA **[S7, N1, and G2]**.

2.2.2.2 SOCAL

A timeline of all U.S. Pacific Fleet-funded monitoring tasks implemented in SOCAL in 2019 is illustrated in **Figure 6**. Detailed project summaries follow.

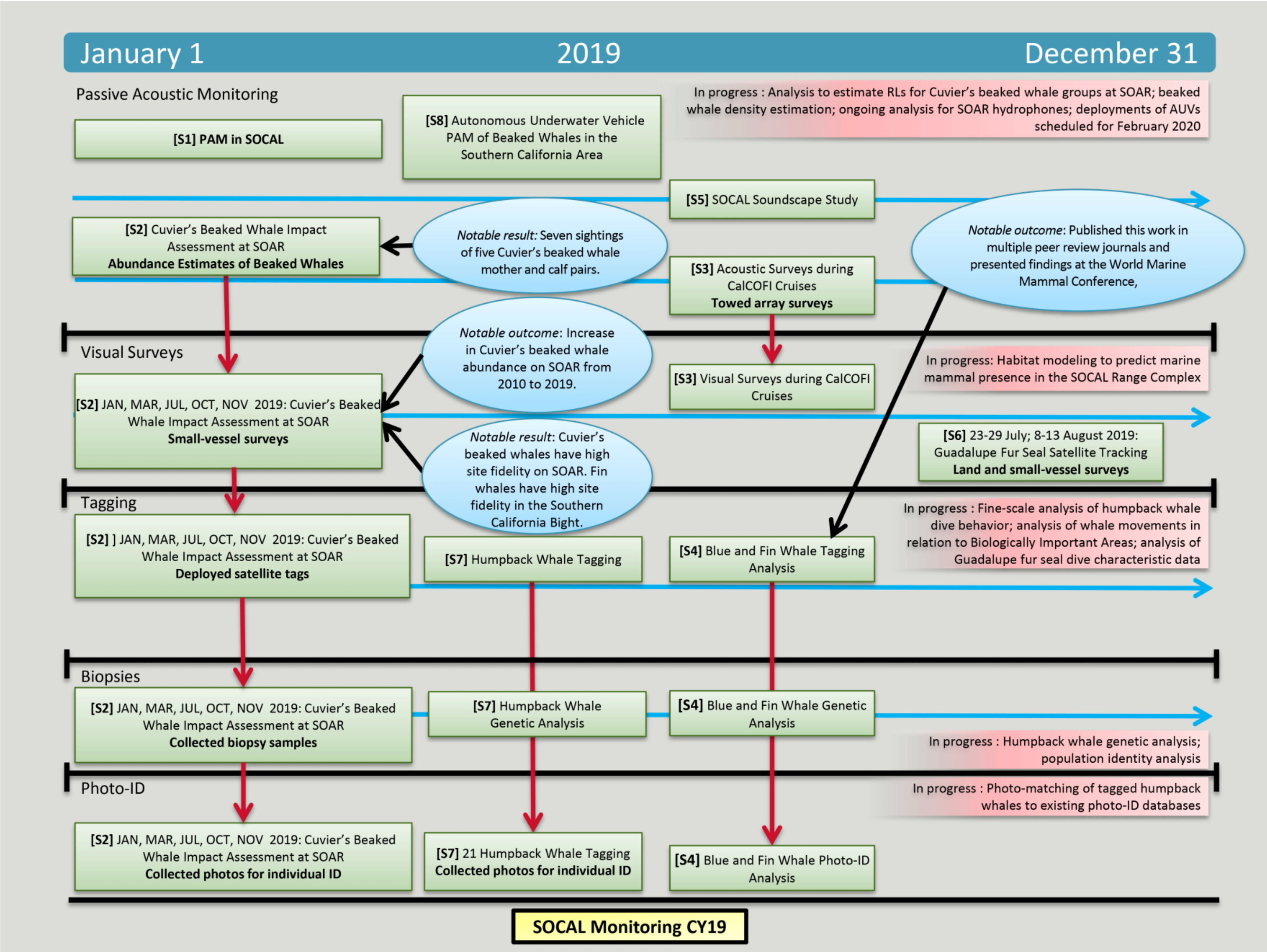

Figure 6. Timeline of 2019 projects in the Southern California Range Complex.

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[S1] Passive Acoustic Monitoring in SOCAL [Rice et al. 2020a]

The University of California San Diego's Scripps Institution of Oceanography (SIO) studies marine mammal presence and acoustic behavior near naval training areas. The range of work includes analyses of whale calls and echolocation clicks (of particular interest are blue whales [*Balaenoptera musculus*], fin whales, and all species of beaked whales); collection of anthropogenic signals (including sonar, shipping noise, etc.); impact of MFAS on whale calling behavior; beaked whale population density; and fin whale population structure.

Broadband PAM data have been collected in the southern California region since 2006 using HARPs.

Rice et al. (2020a) analyzed data collected July 2018 through May 2019 from HARPs deployed at three locations near San Clemente Island: one to the northwest (Site E), one to the west (Site H), and one to the southwest (Site N) (**Figure 7**). A sub-set of species was analyzed, which included blue whales, fin whales, and beaked whales. Based on discussion during the Navy-NMFS Adaptive Management meeting in 2019, future analysis effort will be limited to beaked whales only. The low-frequency ambient soundscape was characterized and the data were analyzed for anthropogenic sounds (sonar and explosions).

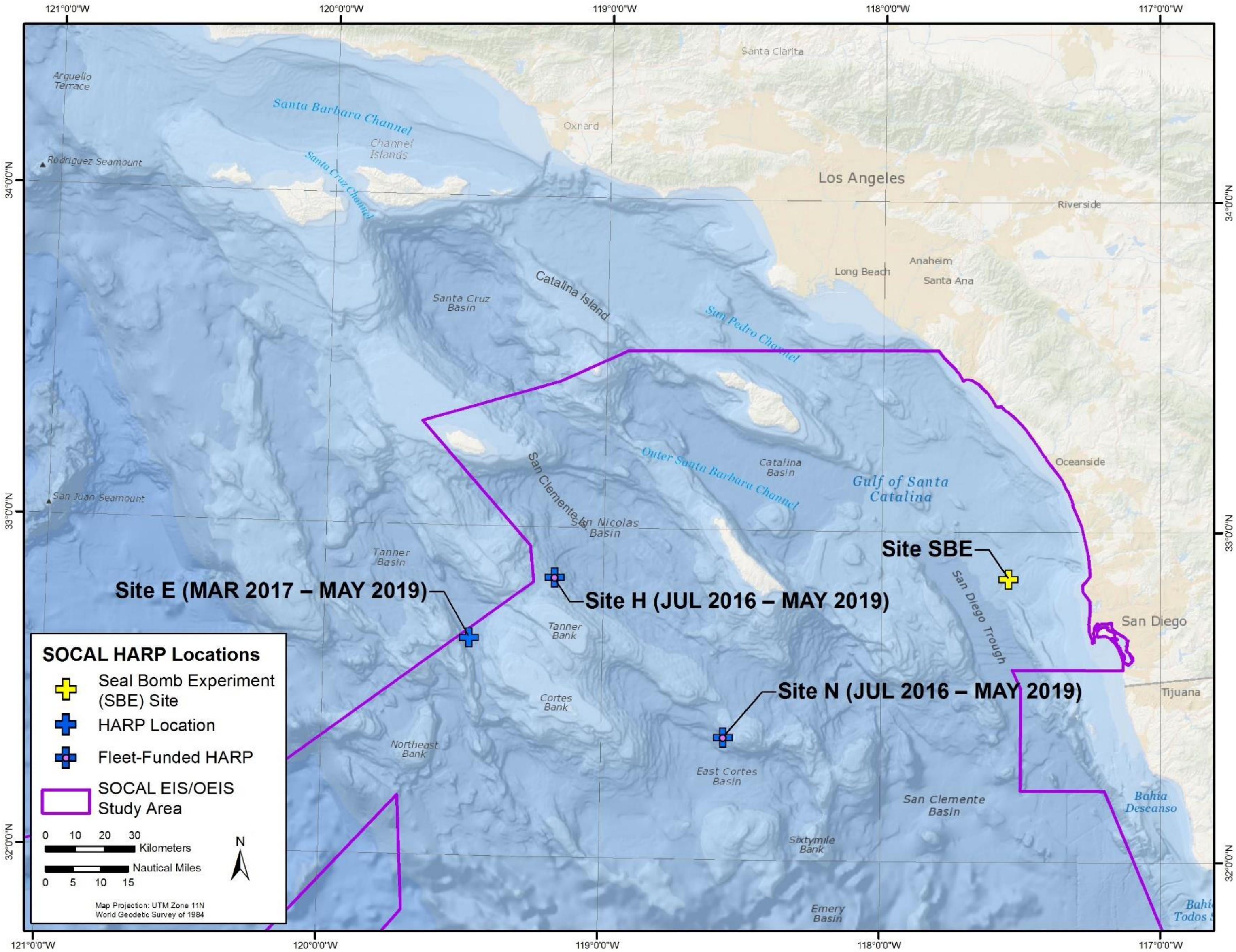

Figure 7. High-frequency Acoustic Recording Package locations in the Southern California Range Complex [Projects S1 and S5]

[S2] Cuvier's Beaked Whale Impact Assessment at the Southern California Offshore Antisubmarine Warfare Range (SOAR) [Schorr et al. 2020; DiMarzio et al. 2020]

Small-vessel surveys were performed by MarEcoTel at SOAR in 2019 as part of an ongoing, long-term study to elucidate distribution and demographics of beaked whales and fin whales that use the Range, using tagging, biopsy sampling, and photo-ID techniques. Group sizes of Cuvier's beaked whales were recorded for use in abundance and density estimation on SOAR (DiMarzio et al. 2020; see **Project H2**). In 2019, dive-reporting satellite tags (Low Impact Minimally Percutaneous Electronic Transmitter [LIMPET]) MK10-A and smart position and temperature [SPOT5] tags, see **Appendix B**) were deployed on fin whales and other odontocete species in order to study their distribution and diving behavior, and to assess any behavioral changes associated with MFAS use. Staff from the NUWC M3R program monitored SOAR hydrophones to assist with visual verification of acoustic localizations and tag deployments and directed the MarEcoTel rigid-hulled inflatable boats (RHIBs) into areas where marine mammal vocalizations were detected. NUWC continued an ongoing project to develop estimates of abundance of Cuvier's beaked whales at SOAR, including investigating seasonal changes in abundance and mean group vocal periods, and vocal behaviors (see **Project H2**).

[S3] Marine Mammal Monitoring on CalCOFI Cruises (formerly Beaked Whale Occurrence in SOCAL From Towed Passive Acoustic Data and Marine Mammal Surveys on CalCOFI Cruises) [Trickey et al. 2020]

The California Cooperative Oceanic Fisheries Investigations (CalCOFI) cruises, a joint agency field effort, have been conducted off southern California since the 1950's, and represent the only continuous, seasonal marine mammal information available for southern California. More information on the overall history of the CalCOFI program is available at: http://www.calcofi.net/. Beginning in 2004, the Chief of Naval Operations Environmental Readiness Division funded the collection of marine mammal visual and passive acoustic data during regularly scheduled CalCOFI cruises, which occur four times per year. For the marine species monitoring program, U.S. Pacific Fleet specifically funded visual and acoustic marine mammal data collection from 2013 to 2018 (Campbell et al. 2014, 2015; Debich et al. 2017; Hildebrand et al. 2018). Each CalCOFI cruise consists of sampling the same survey tracklines including coverage offshore (>185 km). Visual and acoustic data are used to characterize spatial and temporal distribution and habitat use patterns, seasonal and inter-annual patterns of density, and abundance of cetaceans in the Southern California Bight (SCB). In 2018, this project transitioned from focus on visual data to a focus on beaked whale detections from towed array data. The goal is to qualitatively assess beaked whale occurrence across the entire CalCOFI survey area based on location and season. In 2019, towed array data from 2008 to 2019 was analyzed for beaked whale echolocation clicks (Trickey et al. 2020). Visual survey data was also analyzed for surveys conducted from July 2016 to July 2019.

[S4] Blue and Fin Whale Tagging and Analysis in Support of Marine Mammal Monitoring across Multiple Navy Training Areas

From 2014 to 2017, OSU's Marine Mammal Institute conducted a four-year tagging and tracking study on eastern North Pacific blue and fin whales in the offshore areas of southern California (Mate et al. 2015, 2016, 2017a, 2018b). The purpose of this study was to characterize the movement patterns, occurrence, and residence times of these whales within U.S. Navy training and testing areas, as well as Biologically Important Areas (BIAs), along the U.S. West Coast. Three types of Argos (satellite-monitored) tags were deployed: location-only (LO) tags, DM tags; and pop-off Advanced Dive Behavior (ADB) tags (see **Appendix B**). In 2019, OSU performed more detailed analyses of existing tag data, including fine-scale feeding behavior of tagged blue and fin whales; assessment of Argos tag location accuracy; site fidelity and residency patterns of tagged whales, and the use of Navy training and testing areas and BIAs by tagged blue and fin whales. In 2019 OSU also began processing tag data collected from 2014–2017 for use in an exposure analysis, comparing whale tracks to known Navy training events in SOCAL using MFAS. Tag data were filtered by location quality and include animal locations within a 20-km buffer zone of the SOCAL Range Complex.

This is the same project conducted for NWTT **[N3]**.

[S5] SOCAL Soundscape Study [Rice et al. 2020a, Wiggins et al. 2020]

In 2019 this project shifted focus to examine explosions recorded on existing passive acoustic data collected from U.S. Navy funded HARP deployments (Sites E, H, and N; **Figure 7**). The signal characteristics of seal bombs (Site SBE; **Figure 7**) and Navy missile explosions were examined based on signals which were attributable with high certainty to the source. The signal characteristics were compared to determine if the two types of explosions can be distinguished from each other. The underwater soundscape is characterized and presented for July 2018 to May 2019 in Rice et al. 2020a).

[S6] Guadalupe Fur Seal Satellite Tracking [Norris and Elorriaga Verplancken 2019b, 2020]

This is the second year of this project, which aims to assess population size and at-sea movements of Guadalupe fur seals (*Arctocephalus townsendi* or *A. philippii townsendi*). Visual surveys of Guadalupe fur seals were conducted at the San Benito Archipelago, Mexico, from 23 to 29 July 2019, and at Guadalupe Island, Mexico from 08 to 13 August 2019. Surveys were timed to follow peak pupping season and to coincide as closely as possible with the timing of visual surveys performed in summer 2018. Surveys were conducted on foot and from a small vessel. During the August 2019 surveys at Guadalupe Island, a remotely piloted aircraft (RPA, or drone) was also employed to test the feasibility of using aerial imagery to replace or supplement walk-through surveys, and to develop substrate-specific correction factors to better account for animals missed from the small vessel. All adults, juveniles, and pups were counted, and juveniles were assigned to demographic groups by experienced observers. Also in 2019, data from 35 Guadalupe fur seals instrumented in November 2018 with satellite-monitored tags (SPLASH10-F, Wildlife Computers; see **Appendix B**) were analyzed to characterize at-sea dive behavior and horizontal spatial use in relation to U.S. Navy training and testing areas. In March 2020, additional satellite-monitored tags are planned for deployment on seals at Guadalupe Island.

This is the same project conducted for NWTT [**N4**].

[S7] Humpback Whale Tagging in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas in the Pacific Ocean [Mate et al. 2019b, 2020; Palacios et al. 2020]

This is the same project conducted for HRC, NWTT, and GOA TMAA, refer to Project **H6**.

[S8] Autonomous Underwater Vehicle (AUV) PAM of Beaked Whales in the Southern California Area

The goal of this project is to characterize beaked whale occurrence and distribution in and around the U.S. Navy's training ranges in the SCB, both on and off the continental shelf. Surveys will be designed to complement other Fleet-funded acoustic monitoring projects in the region. Target species include Cuvier's, Baird's (*Berardius bairdii*), Blainville's, Stejneger's (*Mesoplodon stejnegeri*), Hubbs' (*M. carlhubbsi*), Perrin's (*M. perrini)*, and Ginkgo-toothed (*M. ginkgodens*) beaked whales. The gliders are capable of diving to 1000 m. The acoustic recording system on the gliders (Passive Miniature Acoustic Recorder -XL, Hydroid Inc., Lynnwood, Washington, U.S.) can record frequencies up to 85 kHz, and will be duty-cycled to accomplish the 45-day mission. The pilot will remotely control the gliders' programmed path, dive depth, and speed. The glider will also collect basic oceanographic data, including temperature and salinity, during each dive. Data analysis will be performed using the software packages *Triton* and *Ishmael* and additional MATLAB-based tools to classify recorded vocalizations to the lowest taxon possible. Results from these deployments are expected to be reported in fall 2020.

2.2.3 NWTT

A timeline of all U.S. Pacific Fleet-funded monitoring tasks implemented in the NWTT in 2019 is illustrated in **Figure 8**. See below for detailed project summaries.

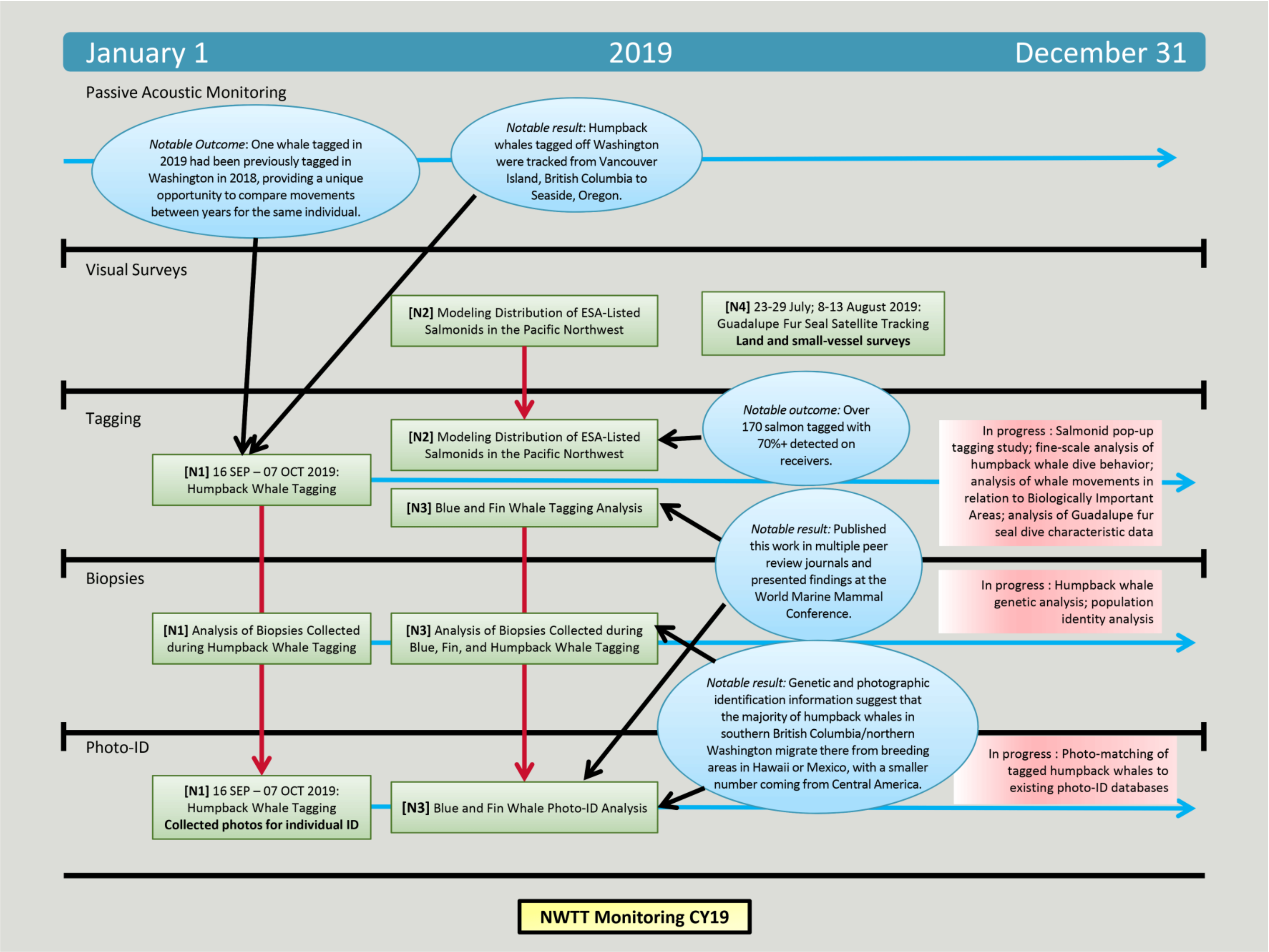

Figure 8. **Timeline of 2019 projects in the Northwest Training and Testing Study Area.**

[N1] Humpback Whale Tagging in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas in the Pacific Ocean [Mate et al. 2019b, 2020; Palacios et al. 2020]

This is the same project conducted for HRC, SOCAL, and GOA TMAA, refer to **Project H6**.

[N2] Characterizing the Distribution of ESA-Listed Salmonids in the Pacific Northwest [Smith and Huff 2020]

An international team of researchers, including scientists from NOAA Northwest Fisheries Science Center, the Canadian Department of Fisheries and Oceans, the University of Washington, and OSU, examined salmonid distribution in relation to naval training and testing activities using an acoustic receiver array off the Washington Coast. The goal of this study is to use a combination of acoustic, temperature and pop-up satellite tagging technology on Chinook salmon (*Oncorhynchus tshawytscha*), Coho salmon (*O. kisutch*), and Bull trout (*Salvelinus confluentus*) to provide critical information on spatial and temporal distribution of salmonids to inform salmon management, U.S. Navy training activities, and Southern Resident killer whale conservation. Tags were programmed with a random ping rate between 60 s and 120 s with a mean of 90 s. The expected detection range of tags was between 200 m and 500 m. Tag battery life ranged from 172 to 651 days, depending on the tag.

[N3] Blue and Fin Whale Tagging and Analysis in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas

This is the same project conducted for SOCAL, refer to **Project S4**.

[N4] Guadalupe Fur Seal Satellite Tracking [Norris and Elorriaga Verplancken 2019b, 2020]

This is the same project conducted for SOCAL, refer to **Project S6**.

2.2.4 GOA TMAA

A timeline of all U.S. Pacific Fleet-funded monitoring tasks implemented in the GOA TMAA in 2019 is illustrated in **Figure 9**. See below for detailed project summaries.

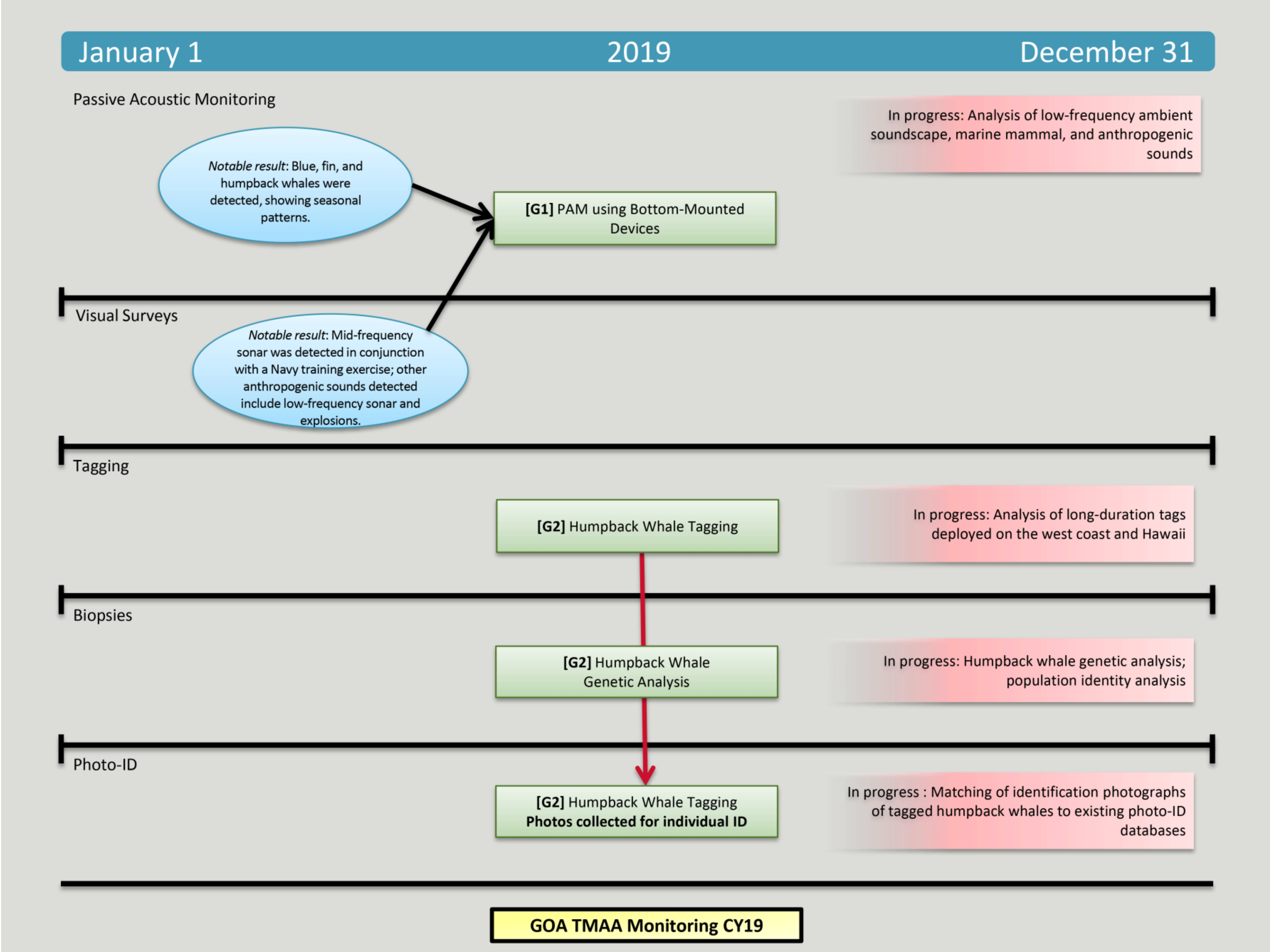

Figure 9. Timeline of 2019 Gulf of Alaska Temporary Maritime Activities Area monitoring projects.

[G1] Passive Acoustic Monitoring of Marine Mammals in GOA TMAA using Bottom-Mounted Devices [Rice et al. 2019b, 2020b]

U.S. Navy has funded PAM in the GOA TMAA since 2011, using two to five HARPs deployed and maintained by SIO (Baumann-Pickering et al. 2012; Debich et al. 2013, 2014; Wiggins et al. 2017; Wiggins and Hildebrand 2018; Rice et al. 2015, 2018b, 2019b, 2020b). In 2019, passive acoustic data were collected by two HARPs in the GOA (**Figure 10**) in order to characterize the low-frequency ambient soundscape and detect marine mammal and anthropogenic sounds during times of naval exercises in the area. Site CB is located in the continental slope in deep water (900 m), and site KOA is in deep water off Kodiak Island (1000 m, **Figure 10**). The two HARPs were deployed in a seafloor mooring configuration with hydrophones suspended at least 10 m above the seafloor. Sounds were recorded over a broad frequency range of 10 Hz–100 kHz to allow monitoring of the low-frequency ambient soundscape, and detection of baleen whales (mysticetes), toothed whales (odontocetes), and anthropogenic sounds. Data from site CB were analyzed for the recording period September 2017 to September 2019, and data from site KOA were analyzed for the recording period April 2019 to September 2019.Data were analyzed by visually scanning Long-Term Spectral Averages (LTSAs) in source-specific frequency bands and, when appropriate, using automatic detection algorithms.

[G2] Humpback Whale Tagging in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas in the Pacific Ocean [Mate et al. 2019b, 2020; Palacios et al. 2020]

This is the same project conducted for HRC, SOCAL, and NWTT, refer to **Project H6**.

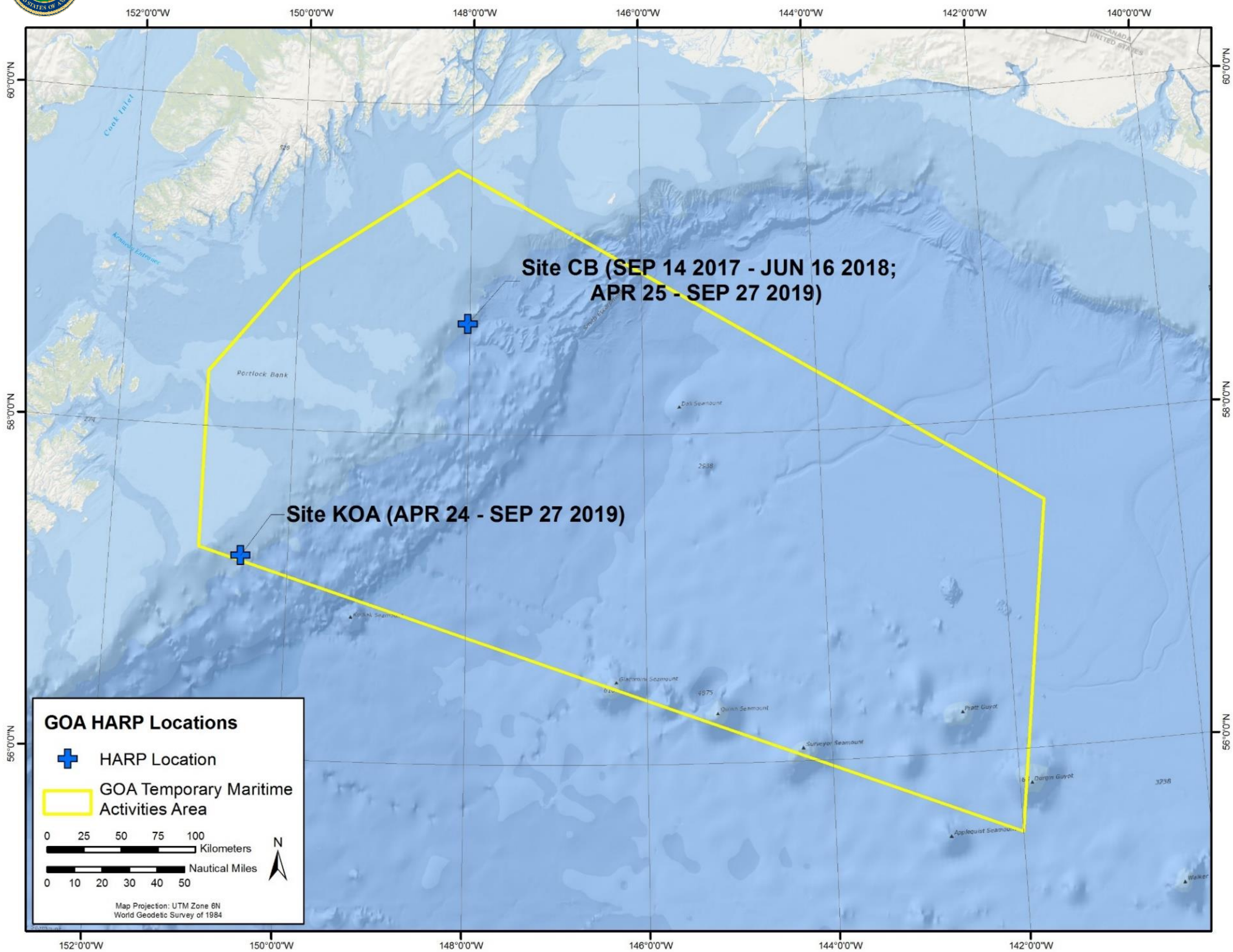

Figure 10. High-frequency Acoustic Recording Package locations in the Gulf of Alaska Temporary Maritime Activities Area. [Project G1]

3. Adaptive Management and Yearly Monitoring Goals

The Strategic Planning process is used to set ISOs, identify potential species of interest at a regional scale, and evaluate and select specific monitoring projects to fund or continue supporting for a given FY. Continuing or new monitoring projects for calendar year 2020 are listed in **Table 2** and are also listed on the U.S. Navy's Marine Species Monitoring website:

http://www.navymarinespeciesmonitoring.us/regions/pacific/current-projects/

Table 2. 2020 Monitoring projects for Pacific Navy Ranges: HSTT (HRC and SOCAL), MITT, NWTT, GOA TMAA.

Project Description	Monitoring Questions	Intermediate Scientific Objectives (numbered as per Figure 12)	Continuing or Proposed New Start
Location: Hawaii Range Complex (HRC)			
Title: Long-Term Acoustic Monitoring utilizing the instrumented range at PMRF **Methods:** Analysis of archived PMRF hydrophone recordings **Performer:** SSC Pacific and NUWC Division Newport	• What are the long-term trends in occurrence of marine mammals (e.g., minke, humpback, fin, Bryde's, Blainville's beaked whales) on the PMRF range?	#1: Determine what species and populations of marine mammals and ESA-listed species are present in Navy range complexes and testing ranges. #8: Application of passive acoustic tools and techniques for detecting, classifying, and tracking marine mammals[1]. #9: Application of analytic methods to evaluate exposure and/or behavioral response of marine mammals to Navy training and testing activities. #12: Evaluate trends in distribution and abundance for populations of protected species that are regularly exposed to sonar and underwater explosives. #13: Assess existing data sets which could be utilized to address the current objectives[1].	Continuing from 2015

Project Description	Monitoring Questions	Intermediate Scientific Objectives (numbered as per Figure 1)	Continuing or Proposed New Start
Title: Estimation of Received Levels of MFAS and Behavioral Response of Marine Mammals at PMRF **Methods:** PAM (PMRF), tagging (GPS LIMPET tags if available), photo-ID, biopsy, visual survey. **Performer:** SSC Pacific; Cascadia Research Collective, and HDR	• What is the occurrence and estimated received levels of MFAS on 'blackfish,' humpback, minke, sperm and Blainville's beaked whales within the PMRF instrumented range? • What are the spatial-movement and habitat-use patterns of species that are exposed to MFAS, and how do these patterns influence exposure and potential responses? • What, if any, are the short-term behavioral responses of 'blackfish' and humpback, minke, sperm, and Blainville's beaked whales when exposed to MFAS/explosions at different levels/conditions at PMRF?	#3: Establish the baseline habitat uses, seasonality, and movement patterns of marine mammals and ESA-listed species where Navy training and testing activities occur. #6: Establish the regional baseline vocalization behavior, including seasonality and acoustic characteristics) of marine mammals where Navy training and testing activities occur. #7: Determine what behaviors can most effectively be assessed for potential response to Navy training and testing activities. #8: Application of passive acoustic tools and techniques for detecting, classifying, and tracking marine mammals[1]. #9: Application of analytic methods to evaluate exposure and/or behavioral response of marine mammals to Navy training and testing activities. #10: Evaluate acoustic exposure levels associated with behavioral responses of marine mammals to support development and refinement of acoustic risk functions. #12: Evaluate trends in distribution and abundance for populations of protected species that are regularly exposed to sonar and underwater explosives. #13: Assess existing data sets which could be utilized to address the current objectives[1].	Continuing from 2015
Location: Hawaii Range Complex (HRC) (continued)			
Title: Navy Civilian Marine Mammal Observers on DDGs **Methods:** Visual survey embarked on DDG during training exercise **Performer:** U.S. Navy and HDR, Inc.	• What is the effectiveness of Navy lookouts on Navy surface ships for mitigation and what species are sighted during sonar training events? (This project spans all Navy at-sea ranges.)	#1: Determine what species and populations of marine mammals and ESA-listed species are present in Navy range complexes, testing range, and in specific training and testing area. #4: Evaluate potential exposure of marine mammals and ESA-listed species to Navy training and testing activities. #11: Evaluate behavioral responses of marine mammals exposed to Navy training and testing activities to support PCoD development and application.	Continuing from 2010

Project Description	Monitoring Questions	Intermediate Scientific Objectives (numbered as per Figure 12)	Continuing or Proposed New Start
Location: Southern California Range Complex (SOCAL)			
Title: Cuvier's Beaked Whale and Fin Whale Population Dynamics and Impact Assessment at the Southern California Offshore Antisubmarine Warfare Range (SOAR) **Methods:** PAM, satellite tagging, photo-ID, visual survey **Performer:** Naval Undersea Warfare Center Newport and Marine Ecology & Telemetry Research	• What are the baseline population demographics, vital rates, and movement patterns for a designated key species in the SOCAL Range Complex? • What, if any, are the short-term behavioral and/or vocal responses when exposed to sonar or explosions at different levels or conditions? • Does exposure to sonar or explosives impact the long-term fitness and survival of individuals or the population, species or stock (with initial focus on Cuvier's beaked whales)?	#2: Estimate the distribution, abundance, and density of marine mammals and sea turtles in Navy range complexes, testing ranges, and in specific training and testing areas. #3: Establish the baseline habitat uses, seasonality, and movement patterns of marine mammals and ESA-listed species where Navy training and testing activities occur. #6: Establish the regional baseline vocalization behavior, including seasonality and acoustic characteristics) of marine mammals where Navy training and testing activities occur. #7: Determine what behaviors can most effectively be assessed for potential response to Navy training and testing activities. #8: Application of passive acoustic tools and techniques for detecting, classifying, and tracking marine mammals[1]. #9: Application of analytic methods to evaluate exposure and/or behavioral response of marine mammals to Navy training and testing activities. #11: Evaluate behavioral responses of marine mammals exposed to Navy training and testing activities to support PCoD development and application. #12: Evaluate trends in distribution and abundance for populations of marine mammals and ESA-listed species that are regularly exposed to sonar and underwater explosives. #13: Assess existing data sets which could be utilized to address the current objectives[1].	Continuing from 2016
Title: Navy Civilian Marine Mammal Observers On DDGs	*(see this project under HRC, above)*	*(see this project under HRC, above)*	*(see this project under HRC, above)*

Project Description	Monitoring Questions	Intermediate Scientific Objectives (numbered as per Figure 12)	Continuing or Proposed New Start
Location: Southern California Range Complex (SOCAL) (continued)			
Title: Southern California Beaked Whale Distribution **Methods:** PAM (moored, glider, towed-array, drifting buoys), visual survey **Performer:** Scripps Institution of Oceanography (University of California San Diego), Oregon State University	• What is the distribution of beaked whale occurrence in the waters within and outside the Southern California Range Complex?	#1: Determine what species and populations of marine mammals and ESA-listed species are present in Navy range complexes, testing ranges, and in specific training and testing areas. #3: Establish the baseline habitat uses, seasonality, and movement patterns of marine mammals and ESA-listed species where Navy training and testing activities occur. #6: Establish the regional baseline vocalization behavior, including seasonality and acoustic characteristics) of marine mammals where Navy training and testing activities occur #8: Application of passive acoustic tools and techniques for detecting, classifying, locating, and tracking marine mammals.	Continuing from 2010 with 2020 focus specially on beaked whales
Title: Guadalupe Fur Seal Population Census and Satellite Tracking **Methods:** Tagging, visual survey (land census) **Performer:** The Marine Mammal Center, Sausalito, California	• What is the at-sea distribution of Guadalupe fur seals as the travel through the offshore waters of the Southern California Range Complex and Northwest Training and Testing area?	#1: Determine what species and populations of marine mammals and ESA-listed species are present in Navy range complexes, testing ranges, and in specific training and testing areas. #2: Estimate the distribution, abundance, and density of marine mammals and sea turtles in Navy range complexes, testing ranges, and in specific training and testing areas. #3: Establish the baseline habitat uses, seasonality, and movement patterns of marine mammals and ESA-listed species where Navy training and testing activities occur.	Continuing from 2018
Location: Mariana Islands Training and Testing (MITT)			
Title: Humpback Whale Survey at FDM **Methods**: Visual, photo-ID **Performer:** HDR, Inc.	• What is the winter occurrence of humpback whales at Farallon de Medinilla?	#1: Determine what species and populations of marine mammals and ESA-listed species are present in Navy range complexes, testing ranges, and in specific training and testing areas.	New start: 2020 Jan-Feb survey

Project Description	Monitoring Questions	Intermediate Scientific Objectives (numbered as per Figure 12)	Continuing or Proposed New Start
Location: Northwest Training and Testing (NWTT)			
Title: Distribution of Southern Resident Killer Whales and their Prey in the Pacific Northwest **Methods:** PAM, model development, visual survey, satellite tagging, analysis of archival data, acoustic pinger tagging glider and stationary receivers. **Performer**: NMFS Northwest Fisheries Science Center, University of Washington (School of Aquatic and Fisheries Sciences), Naval Undersea Warfare Center Keyport, Oregon State University	• What are the seasonal and annual occurrence patterns of Southern Resident killer whales relative to offshore Navy training ranges? • What is the oceanic distribution and seasonal variability of ESA-listed salmonid species that may be important prey for the Southern Resident killer whale?	#1: Determine what species and populations of marine mammals and ESA-listed species are present in Navy range complexes, testing ranges, and in specific training and testing areas. #2: Estimate the distribution, abundance, and density of marine mammals and sea turtles in Navy range complexes, testing ranges, and in specific training and testing areas. #3: Establish the baseline habitat uses, seasonality, and movement patterns of marine mammals and ESA-listed species where Navy training and testing activities occur. #6: Establish the regional baseline vocalization behavior, including seasonality and acoustic characteristics) of marine mammals where Navy training and testing activities occur.	Continuing from 2014 with 2020 focus on salmonids
Title: Humpback Whale Tagging in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas in the Pacific Ocean **Methods:** Satellite tagging, photo-ID, biopsy, visual survey **Performer**: Oregon State University	• What are the occurrence, movement patterns, and residency patterns of multiple humpback whale DPSs within Navy Pacific Ocean at-sea ranges (SOCAL, HRC, NWTT, GOA)?	#1: Determine what species and populations of marine mammals and ESA-listed species are present in Navy range complexes, testing ranges, and in specific training and testing areas. #3: Establish the baseline habitat uses, seasonality, and movement patterns of marine mammals and ESA-listed species where Navy training and testing activities occur.	Continuing from 2016

Title: Guadalupe Fur Seal Population Census and Satellite Tracking	*(see this project under SOCAL, above)*	*(see this project under SOCAL, above)*	*(see this project under SOCAL, above)*

Project Description	Monitoring Questions	Intermediate Scientific Objectives (numbered as per Figure 12)	Continuing or Proposed New Start
Location: Gulf of Alaska Temporary Maritime Activities Area (GOA TMAA)			
Title: Telemetry and Genetic Diversity of Chinook Salmon in Alaska **Methods:** acoustic tagging, satellite tagging **Performer:** University of Alaska Fairbanks, NMFS Northwest Fisheries Science Center	• What is the distribution, seasonal variability, migratory pattern, habitat use, and population identity of Chinook salmon that may be important prey for the Southern Resident killer whale?	#1: Determine what species and populations of marine mammals and ESA-listed species are present in Navy range complexes, testing ranges, and in specific training and testing areas. #3: Establish the baseline habitat uses, seasonality, and movement patterns of marine mammals and ESA-listed species where Navy training and testing activities occur.	New start summer 2020

[1] Primary Research & Development and Demonstration Validation (DEMVAL) investments for tools and techniques supported by Office of Naval Research Marine Mammal & Biology and Living Marine Resource programs.

[2] Though as continuing from 2018, this project is conceptually a refinement and continuation of 2017 Project [N3], "Modeling the Offshore Distribution of Chinook Salmon in the Pacific Northwest." The updated project retains substantially the same monitoring questions

Key: DDG = guided missile destroyer; ESA = Endangered Species Act; FY = Fiscal Year; GOA = Gulf of Alaska; GPS = Global Positioning System; HRC = Hawaii Range Complex; LIMPET = Low Impact Minimally Percutaneous Electronic Transmitter; MFAS = Mid-frequency active sonar; MITT = Mariana Islands Training and Testing; NMFS = National Marine Fisheries Service; NOAA = National Oceanic and Atmospheric Administration; NWTT = Northwest Testing and Training; PAM = Passive Acoustic Monitoring; PCoD = Population Consequences of Disturbance; photo-ID = photo identification; PMRF = Pacific Missile Range Facility; SOAR = Southern California Offshore Antisubmarine Warfare Range; SOCAL = Southern California; SSC = Space and Naval Warfare Systems Center; TBD= to be determined; TMAA = Temporary Maritime Activities Area.

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Abstracts/Executive Summaries from the 2019 Technical Reports

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[M2] Sea Turtle Tagging in the Mariana Islands Training and Testing

Gaos, A.R., Martin, S.L., and T.T. Jones. 2020

Understanding the spatio-temporal movements of animals is an integral component of wildlife conservation and management. Marine turtles are species of conservation concern and satellite telemetry is a primary research tool used to study their movements, providing high accuracy location data in near "real time", thus facilitating rapid identification of movements and key habitats. Although it has been recognized that both green (*Chelonia mydas*) and hawksbill (*Eretmochelys imbricata*) turtles inhabit the waters around Guam and the Commonwealth of the Northern Mariana Islands (collectively referred to as the Mariana Archipelago), their distribution and habitat use in the region has remained unclear. Under an inter-agency agreement between the United States Navy and the National Oceanic and Atmospheric Administration (NOAA), in 2013 NOAA began conducting in-water surveys to record and quantify observations of marine turtles around the Mariana Archipelago. When observed, attempts were made to hand-capture turtles and equip them with satellite tags in an effort to better understand their spatial ecology. Between 2013 and 2019 (the project is still underway), researchers encountered a total of 517 turtles, 111 of which were captured and equipped with satellite tags, including 97 green turtles and 14 hawksbill turtles. Movements and habitat use were highly neritic for the overwhelming majority of turtles, with home range estimates revealing limited movements for both species and 94 (89.5%) of the tracked turtles remaining within a 1-3 km2 area for the entire life of their tag (average tag retention time = 191 days), demonstrating limited movements and high foraging site fidelity. Notwithstanding this perspective, there were three more vagile movement patterns observed, including shifts in intra-island foraging areas (n = 7), transitions between inter-island foraging areas (n = 2) and a long-range migration departure out the Mariana Archipelago (n = 1). Dive patterns suggest that both green and hawksbill turtles spend most of their time in waters shallower than 25 meters. However, it is possible that habitat partitioning may exist between the two species, with hawksbill turtles spending more time in deeper waters than green turtles, using average depths of 15.3 meters and 10.5 meters, respectively. Spatial analysis of satellite tags has demonstrated limited direct overlap of turtles with Navy detonation sites (i.e., Agat Bay Mine Neutralization Site, Piti Point Mine Neutralization Site, and Outer Apra Harbor Underwater Detonation Site). However, turtles are spending significant amounts of time in and moving through areas within 1-2 km of these sites and additional analyses are needed to better evaluate potential overlap. The research detailed in this report provide important insights into the movement ecology of green and hawksbill turtles around the Mariana Archipelago and represents the most rigorous individual satellite tracking study on these species in the world.

[M3] Humpback Whale Song from Ecological Acoustic Recorder (EAR) data from Pagan and Maug Islands

Munger, L., and M. Lammers. 2020

Since 2007, visual and acoustic cetacean monitoring efforts in the Mariana Islands have documented the occurrence of humpback whales (*Megaptera novaeangliae*) during winter months. However, these efforts have focused mainly around the southern portion of the archipelago, in particular Saipan and Tinian. This report presents an analysis of passive acoustic data for humpback whale song near the islands of Maug and Pagan in the northern portion of the archipelago. Data were recorded using Ecological Acoustic Recorders (EARs) from April 2009 through February 2010 (Pagan) or October 2010 (Maug). EARs sampled for 30 seconds at 15-minute intervals with an effective recording bandwidth of 0 - 20 kHz. Analysts visually browsed spectrograms from the entire Pagan dataset and from the winter months (Nov-May) at Maug. Potential humpback whale detections were reviewed aurally and visually by experienced researchers. Humpback whale song was detected at Pagan on 8 days in February 2010, prior to the cessation of recording in late February. No humpback whale song was detected in any recordings from Maug. The lack of detections at Maug was likely due to the location of the EAR inside the perimeter of the Maug islands, which acoustically shielded it from the open ocean. The occurrence of humpback whales at Pagan in February is consistent with the timing of occurrence at other islands in the Mariana archipelago; future monitoring effort for humpback whales (and other migratory baleen whales) should consider placement of instruments, duty cycle, and seasonality of recording in order to maximize the likelihood of detection.

[H1] SSC Pacific FY19 Annual Report on PMRF Marine Mammal Monitoring

Martin, C.R., E.E. Henderson, S.W. Martin, T.A. Helble, R.A. Manzano-Roth, B.M. Matsuyama, G.C. Alongi, and R.A. Guazzo. 2020.

This report documents Naval Information Warfare Center Pacific (NIWC Pacific) marine mammal monitoring efforts in fiscal year (FY) 2019 for Commander, Pacific Fleet (COMPACFLT) at the Pacific Missile Range Facility (PMRF), Kauai, Hawaii. The following list highlights tasks completed in FY19 in support of COMPACFLT monitoring goals:

1) Raw acoustic data from 62 bottom-mounted hydrophones at PMRF were recorded at the full bandwidth sample rate of 96 kHz and at a decimated sample rate of 6 kHz. This report updates last year's report with inclusion of 2,509 hours of new data collected between August 21, 2018 and August 24, 2019. Due to a recording conflict (see Section **Error! Reference source not found.**) and a change in Submarine Command Courses (SCC) venue, no classified SCC recordings were collected in February and August 2019.
2) Abundance results for baleen whales from August 21, 2018 to August 24, 2019 indicated that a maximum of four minke whales occurred in a 10-minute snapshot during a month in December 2018, compared to a maximum of two humpback whales in April 2019. There was a maximum of three tracks from the low-frequency baleen whale group that occurred in a 10-minute snapshot in November and December 2018, and February 2019. For the first time, spectral correlation call templates were utilized to attribute calls from acoustic tracks to Bryde's, fin, and sei whales. All available data collected on hydrophones with sufficient frequency response (January 11, 2011 to August 24, 2019) were processed and preliminary results include 110 Bryde's whale tracks, 325 fin whale tracks, 334 fin and/or sei whale tracks, and 138 sei whale tracks (note these total tracks do not equate to total number of individuals as single individuals can be counted multiple times). Investigation of classifier performance indicates automatically classified Bryde's whale tracks concur with previously documented Bryde's whale presence (Martin and Matsuyama, 2014; Helble et al., 2016; Martin et al., 2019). For the first time, blue whales were automatically localized from January 11, 2011 to August 24, 2019; these localizations were manually reviewed, and confirmed blue whale calls occurred in February 2012; December 2012 and 2017; January and December 2018; and February 2019.

3) Abundance results for odontocetes from August 21, 2018 to August 24, 2019 included Blainville's, Cross Seamount (CSM), and Cuvier's beaked whales, sperm whales, and killer whales. The number of FY19 Blainville's beaked whale dives were corrected based on FY19 sample validation and had a monthly maximum of 2.59 dives per hour (December 2018) and a maximum count of 10.53 dives that occurred in a one-hour time bin (August 2019). The number of fully validated FY19 CSM beaked whale dives had a strong diel trend at night and occurred far less frequently than Blainville's beaked whale dives, resulting in a monthly maximum of 0.18 dives per hour (October 2018) and a maximum count of two dives that occurred in a one-hour time bin (multiple times during FY19). The number of fully validated FY19 Cuvier's beaked whale dives had a slightly higher number of group foraging dives per hour than CSM beaked whales, with a monthly maximum of 0.24 dives per hour (February 2019), and a maximum count of two dives that occurred in a one-hour time bin (multiple times from November 2018 to April 2019). The number of fully validated FY19 killer whale high-frequency modulated (HFM) calling groups occurred infrequently and had a low abundance with a monthly maximum of 0.022 groups per hour (May and June 2019), and a maximum count of one killer whale HFM calling group detected in a one-hour time bin (multiple times from November 2018 to Jun 2019). Individual/group tracking of the improved sperm whale detection and localization processing was performed for the first-time on all non-decimated data between Feb 6, 2002 and Aug 24, 2019. The maximum number of automatically generated sperm whale tracks in a 10-minute snapshot during a month typically varied from zero to four whales with a maximum of eight in May 2016.
4) Disturbance analyses conducted at PMRF:
    a) Disturbance analyses were conducted for minke whales utilizing tools developed under an Office of Naval Research project titled Behavioral Response EValuation Employing robust baselines and actual United States (U.S.) Navy training (BREVE). A clear change in the spatial distribution of minke whale acoustic presence and absence related to mid-frequency active sonar (MFAS) was observed in recordings from February 2014 and January and February of 2017. Preliminary analyses also indicate that whale speeds were higher and headings were more directed during periods of MFAS compared to periods without MFAS. Periods of time after sonar retained lower probabilities of presence, suggesting the return to baseline conditions may take more than five days.
    b) The spatial distribution and number of validated Blainville's beaked whale dives were analyzed before, during and after 16 SCCs. A Generalized Additive Model (GAM) of the spatial distribution of foraging dives found no change in the spatial distribution of dives during the first, non-MFAS phase of the SCC, but did find a 58% reduction in the number of foraging dives in that phase. Both a spatial change to the distribution of dives and a further reduction in the number of dives was observed during the subsequent MFAS Phase of the SCC.
    c) Validated CSM beaked whale dives from February and August 2011 to 2018 exhibited a statistically significant reduction in the number of dives during SCCs compared to baseline periods. The average dive rate was 0.1 dives/hour during SCCs and 0.14 dives/hour during baseline periods. CSM detections during SCCs were on hydrophones located closer to shore and installed at depths < 1000 m, which shows a spatial redistribution compared to baseline periods, when they are found in depths up to 1,526 m.
    d) For the first time, preliminary disturbance analyses were performed for three minke whale tracks and one suspected fin whale track in the presence of opportunistically recorded explosive impulse sounds. As a general observation, all three minke whales exhibited slightly increased call rates, all whales seemed to make some heading adjustments, and two whales slightly increased their swim speeds.

5) In March 2019 LIMPET-configured SPLASH10 tags enabled with FastLoc GPS (Wildlife Computers, Inc) recorded positional and dive information for six humpback whales. These tags add to the now three-year dataset of humpback whale movements near PMRF and where the animals go when they travel beyond Kauai. Over the three years, most animals continued west to Niihau, and several of those animals continued on northwest to additional islands and seamounts that make up the Hawaiian archipelago. Results indicate that humpback whales generally move northwest through the Hawaiian Islands during the breeding season, and that whales found off Kauai are likely near the end of their time on the breeding grounds, although some whales did travel east from Kauai to the other main Hawaiian Islands.
6) The minke whale bimodal call rate was characterized with data collected between February 2002 and May 2018 and had peak call rate distributions at 27.52 seconds and 345.5 seconds. Validated minke whale acoustic tracks from January 2016 to May 2017 were utilized to investigate call rate as a function of distance between calling conspecifics for the first time. Results showed typical distances between individuals > 10 km regardless of call rate, while tracks at the high call rate (nominally every 30 seconds) were as close as 4-5 km to a conspecific while tracks at the low call rate (nominally > 5 minutes) were at least 7-8 km from a conspecific.
7) Application of noise analyses at PMRF:
   a) Minke whales acoustically tracked from 2012 to 2017 increased the source levels of their boing calls during periods with increased background noise. Animal source levels were estimated by adding transmission loss estimates to measured received levels of 42,159 individual minke whale boings. Results suggest minke whales increase their RMS source level by an average of 0.24 dB per 1 dB increase in background noise level in the 1,250 -1,600 Hz band for the full range of noise encountered from 65-90 dB, and a maximum source level increase of 0.34 dB per 1 dB increase in background noise level in the 1,250-1,600 Hz band when the noise was 82 dB.
   b) A current ONR project titled Environmentally-influenced Behavioral Response EValuations (E-BREVE) has started investigating how minke and other baleen whales respond to wind-wave events by analyzing whale acoustic tracks relative to environmental data. Recent analysis of results from January 2017 supports prior findings from Martin et al., 2019a and Helble et al., 2020 that minke whales decrease calling during periods of high wind-wave events. The behavioral response of whales to naturally occurring events at PMRF is a helpful step towards contextualizing the response to U.S. Navy activity.

[H2] Long-term Passive Acoustic Monitoring of Cetaceans at PMRF and SOAR

Dimarzio N., K. Dolan, S. Watwood, Y. Luna, S. Vaccarro, L. Sparks, B. Bartley, and A. O'Neil. 2020.

Beaked whale abundance and vocal behavior were examined at two different U. S. Navy training ranges: for Cuvier's beaked whale (*Ziphius cavirostris*) at the Southern California Anti-Submarine Warfare Range (SOAR) between August 2010 through October 2019, and for Blainville's beaked whales (*Mesoplodon densirostris*) at the Pacific Missile Range Facility (PMRF) between 2015 and 2018. The yearly and monthly abundance, mean number of group vocal periods (GVPs), mean duration of the GVPs in minutes, and the mean number of clicks detected per beaked whale group were calculated.

At SOAR, 49,691 hours of data were processed. The Cuvier's beaked whale abundance has increased significantly over the 10-year period from 2010 to 2019, as has the mean number of GVPs per hour on the range. Cuvier's beaked whale abundance peaks in January and reaches its lowest point in September, with another smaller dip in March. The Cuvier's beaked whale monthly mean number of

GVPs per hour is highest in May and lowest in September. A total of 14,068 hours of data were processed at PMRF. At PMRF the Blainville's beaked whale abundance peaks in May and is lowest in February, while the mean number of GVPs per hour is highest in June and lowest in February. Aside from the lower abundance in 2016, the mean abundance per year between 2015 and 2018 has remained fairly constant. At both SOAR and PMRF the mean duration of the GVPs and the mean number of clicks per group follows a similar, but less pronounced, seasonal pattern as the abundance.

Cuvier's beaked whales forage primarily on the western and southwestern parts of the SOAR range. There are a significantly higher mean number of GVPs per hydrophone per year, averaged from 2010 to 2019, for the cool season (winter and spring) than for the warm season (summer and fall). This may be due to an increase in the availability of beaked whale prey from upwelling in the cool season.

At SOAR the number of days of Mid-Frequency Active Sonar (MFAS) and number of GVPs detected per effort month were calculated for 2019, for the year with the maximum number of days of MFAS, and for the mean from 2010 through 2019. There is weak evidence that the percentage of the effort month with sonar was significantly lower in 2019 than in the year with the maximum sonar, and that the number of GVPs per effort month was significantly higher.

The number of GVPs were examined before, during, and after a series of MFAS events at SOAR in 2018 and 2019. Most events were under ten hours in length, and the majority showed either a decrease in number during MFAS and increase after, or a decreasing number throughout the event and post-event period. For the 2018 data the Before-During and Before-After periods had a significantly different mean number of GVPs, whereas the During-After periods did not. There were no significant differences between time periods for the 2019 data. The time periods examined before and after the events were the same length as the events. Since these were mostly short periods, the recovery time examined afterwards may not have been sufficiently long in all cases to show a recovery to pre-event numbers of GVPs. This indicates that the recovery times are longer than on the order of several hours. A similar analysis was carried out at PMRF, with no significant differences found among the Before, During, and After periods. However, only eleven short events met the criteria laid out, and the low sample size may have been insufficient to show patterns between the time periods.

Field efforts are carried out at SOAR in conjunction with Marine Ecology and Telemetry Research (MarEcoTel) and at PMRF with the Cascadia Research Collective (CRC). Five field efforts were conducted in 2019 at SOAR, and though none occurred in 2019 at PMRF, there was one field test at PMRF in 2018. During these field efforts M3R personnel use the M3R monitoring tools to find animals on the range, and direct on-water researchers in RHIBs to these animals, where photo-IDs, behavioral data and/or biopsy data are collected, and satellite tags may be placed on animals. The methods used and typical species acoustically detected are presented.

[H3] Navy Civilian Marine Mammal Observers on DDGs

Vars, T., M. Bejder, C. Hotchkin, and T. Jefferson. 2019.

To comply with the Endangered Species Act and the Marine Mammal Protection Act, the Navy is required to determine the effectiveness of the monitoring and mitigation techniques used during at-sea activities. As part of this compliance, a Marine Species Monitoring & Lookout Effectiveness Study evaluated the effectiveness of the Navy lookout team in sighting marine mammals and sea turtles by establishing "trials" in which trained Marine Mammal Observers (MMO) record a sighting of an animal or group before the lookout (LO) team. If the lookout team later observes the same animal(s), the trial is considered a successful trial. Similarly, if the LO observes an animal simultaneously as the MMO, the trial is also considered successful. If the LO does not detect the animal(s), the trial is considered unsuccessful. In this study, the MMO recorded 24 independent, marine mammal sightings, while the LO recorded 1 independent sighting. Four sightings were made by both teams. A second goal of this study was to obtain data to characterize the possible exposure of marine species to mid-frequency active sonar (MFAS). By collecting bearing and distance of the animal(s) to the vessel, the sound level to which a marine mammal may be exposed during an MFAS event can be determined. This study documented 10 sightings and 10 trials during periods with MFAS. In total, humpback whales and short-finned pilot whales comprised 60% of sightings, and the highest sighting rate occurred in the channel between the islands of Kauai and Niihau. This study documents the 19th event aboard a guided missile destroyer, and the data will be combined with future monitoring efforts to determine the effectiveness of Navy lookouts as a whole, rather than specific to each vessel.

[**H5] Impacts of MFAS on Tagged Odontocetes at PMRF**

Baird, R.W., E.E. Henderson, S.W. Martin, and B.L. Southall. 2019.

A number of species of resident and non-resident odontocetes use the waters of the Kaulakahi Channel between Kaua'i and Ni'ihau, overlapping with the Pacific Missile Range Facility (PMRF). Submarine Command Courses (SCCs) held at PMRF provide an opportunity to assess exposure and measure odontocete reactions to mid-frequency active sonar (MFAS) being used in realistic training scenarios. The primary goal of this assessment was to estimate MFAS received levels (RLs) for satellite tagged odontocetes and determine whether any large-scale movements occurred in response to hull-mounted surface ship MFAS exposure. Two prior reports have used odontocete satellite tag data and information on MFAS use to estimate RLs for animals tagged in 2011 through 2015.

This study continues and extends the earlier efforts using data from three species of odontocetes satellite tagged prior to SCCs in August 2016, February 2017, and August 2018. Methods in the current analyses were consistent with prior methods to allow for comparison, using filtered satellite tag data, the locations of ships transmitting MFAS, and the times of sonar transmissions from PMRF range hydrophones. However, several key improvements were made in data collection and the ability to quantify received noise exposure and describe various sources of error. One (in 2016) or two (in 2017 and 2018) land-based Argos receiving stations were used to supplement satellite tag data received through the Argos satellite system. RLs were estimated at the nominal location of tagged individuals and variability in RL estimates were assessed using information on the accuracy of locations, for locations received within one hour of MFAS transmissions. For each exposure, multiple metrics (mean, SD, minimum, maximum) of estimated RLs (measured as dB re: 1μPa RMS) were calculated, both near the surface (10 m depth) and at depths meant to represent typical foraging depths for each species. When available, information on diving and surfacing behavior of tagged individuals before, during and after MFAS use was also compared to assess potential reactions to MFAS.

From the 2016-2018 SCCs data for estimating RLs and examining potential responses were available for three short-finned pilot whales, *Globicephala macrorhynchus* (one from the resident population and two from a non-resident population), two rough-toothed dolphins, *Steno bredanensis* (both from the resident population), and two melon-headed whales, *Peponocephala electra* (both from an offshore population). The three short-finned pilot whales (in two different groups) were exposed to MFAS at estimated distances of 27.2 km to 145.5 km, with estimated mean RLs ranging from 122.6 to 145.0 dB at 10-m depth. Estimated RLs at 500 m depth for these individuals were typically 10-20 dB lower. The two pilot whales in the same group were traveling together before, during and after the August 2016 SCC, and were thought to be from a non-resident population. Prior to the start of surface ship MFAS use the two individuals had moved off PMRF. After the start of MFAS use these individuals moved away from the source for approximately 24 hours (to approximately 127 km from the source), then moved back towards PMRF to approximately 44 km from the source, moving from an area with estimated RLs of approximately 122 dB to 145 dB. Changes in diving behavior over the three sonar exposure periods (before, during, after the SCC) were documented for both individuals, but the patterns were not consistent between them, suggesting that some factor other than MFAS exposure may have been influencing the diving behavior of one or both individuals. The other individual, tagged prior to the August 2018 SCC, was a member of the resident population. At the start of surface ship MFAS use this individual was 32.9 km from the MFAS source in an area with an estimated median RL of 133.3 dB, and over the next six hours moved to 52.4 km from the MFAS source into an area with an estimated median RL of 130.6 dB.

Two rough-toothed dolphins were tagged in the same group prior to the February 2016 SCC, but had separated prior to the start of the SCC. Both individuals moved south of PMRF prior to the start of surface ship MFAS use. At the start of MFAS exposures the individuals were in areas with estimated median RLs of 143.4 and 147.3 dB. Some movements away from the MFAS source were documented for both individuals, although by the end of the SCC the individuals were in areas with estimated median RLs of 146.3 and 151.4 dB, respectively. Night-time dive depths and durations did differ significantly among the three sonar exposure periods for both individuals, but not in a consistent way, suggesting that some factor other than MFAS exposure may have been influencing the diving behavior of one or both individuals.

Two melon-headed whales tagged in the same group prior to the August 2017 SCC appeared to remain associated throughout the SCC. Both individuals moved off PMRF prior to the start of surface-ship MFAS use, and were almost 100 km from the MFAS source at the start of exposure, continuing to move away during the sonar exposure period. Only a few Argos locations were obtained within one hour of MFAS use for these individuals, so we undertook a preliminary exploration of a continuous-time animal movement model (a Bayesian switching state space model, SSSM) to generate locations at regular (one-hour) time intervals during the period of MFAS exposure. Using the modeled location data, estimated median RLs were in the range of approximately 75 to 105 dB. While we are confident in the magnitude of exposure for these individuals (i.e., that they were exposed at low RLs), further refinements and assessments of continuous-time movement models are needed for this type of application. Overall these analyses provide additional case studies of exposure and responses of three species of odontocetes to hull-mounted surface ship MFAS use, including individuals both from resident (rough-toothed dolphins, short-finned pilot whale) and non-resident populations (melon-headed whales, short-finned pilot whales). Six of the seven individuals had moved off PMRF prior to the start of surface ship MFAS use; the one individual which had not moved off PMRF prior was a short-finned pilot whale from the resident population. It is unknown whether or not such movements off PMRF may have been in response to surface or sub-surface Navy activities on the range prior to the start of surface-ship MFAS use. For the two pilot whales from the non-resident population, initial movements away from the MFAS source may have been a large-scale movement response to exposure. Movements back towards areas with higher RLs starting approximately 24 hours after the beginning of MFAS exposure may have indicated an increased tolerance of MFAS exposure. Alternatively, the exposure levels could have been too low to elicit a large-scale movement response and movements documented were in response to some other factor (e.g., prey patterns).

[H6/S7/N1/G2] Humpback Whale Tagging in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas in the Pacific Ocean

Mate, B.R., D.M. Palacios, C.S. Baker, B.A. Lagerquist, L.M. Irvine, T.M. Follett, D. Steel, and C.E. Hayslip. 2019.

Between 11 and 25 March 2019, Oregon State University (OSU) conducted a field study involving satellite telemetry, genetics, and photo-identification (photo-ID) of humpback whales (*Megaptera novaeangliae*) in waters of Maui, Hawaii. This work is in support of marine species monitoring activities by the United States (US) Navy in its training and testing range complexes in the Pacific Ocean. Specifically, the study seeks to help delineate humpback whale Distinct Population Segments found off the US West Coast, as well as to describe their feeding-season home range, migration to the breeding areas, diving behavior, habitat use, and ecological characteristics. This Preliminary Summary provides an overview of field survey methodologies as well as initial summaries of the data collected through 1 July 2019. Twenty-five tags were deployed and Argos satellite locations were received from 24 of them. For the period covered by this report, tracking durations ranged from 0.1 to 81.3 days (mean = 21.4 days, standard deviation = 20.2 days), while minimum distance traveled averaged 1,978 km (standard deviation = 2,073 km, maximum = 8,062 km). Locations for humpback whales tagged off Maui ranged from the south coast of Maui to the southwest coast of Baranof Island in Southeast Alaska. While in Hawaiian waters, the majority of locations were in the Maui Nui region. Penguin Bank was another area heavily frequented by the tagged whales, while a few animals ranged into waters of the Papahanaumokuakea Marine National Monument, mostly near Middle Bank. Residence time in Hawaii ranged from 3.6 to 36.5 days. Of the twelve whales that began their northbound migration, three reached the high-latitude feeding area off British Columbia, Canada. Other possible destinations based on the trajectories of partial tracks included the northern Gulf of Alaska and the Aleutian Islands.

[S1] Passive Acoustic Monitoring for Marine Mammals in the SOCAL Range Complex July 2018-May 2019

Rice, A.C., S. Baumann-Pickering, J.A. Hildebrand, M. Rafter, J.S Trickey, and S.M. Wiggins. 2020

Passive acoustic monitoring was conducted in the Navy's Southern California Range Complex from July 2018 to May 2019 to detect marine mammal and anthropogenic sounds. High-frequency Acoustic Recording Packages (HARPs) recorded sounds between 10 Hz and 100 kHz at three locations: two west of San Clemente Island (1,300 m depth, site E and 1,000 m depth, site H) and one southwest of San

Clemente Island (1,250 m depth, site N).

While a typical southern California marine mammal assemblage is consistently detected in these recordings (Hildebrand et al. 2012), only a sub-set of species including blue and fin whales, and beaked whales were analyzed for this report. The low-frequency ambient soundscape and the presence of Mid-Frequency Active (MFA) sonar and explosions are also reported.

Ambient sound levels were highest for frequencies greater than ~200 Hz at site E and lowest at site H, likely related to local wind. Peaks in sound levels at sites E, H, and N during the fall and winter are related to the seasonally increased presence of blue whales and fin whales, respectively.

For marine mammal and anthropogenic sounds, data analysis was performed using automated computer algorithms. Calls of two baleen whale species were detected: blue whale B calls and D calls, and fin whale 20 Hz calls. Both species were present at all sites: blue whale B and D calls occurred in high numbers at all sites and the fin whale acoustic index, representative of 20 Hz calls, was high at sites E and H. Blue whale B call detections peaked in September 2018 and again in October and November 2018 at all sites. Very few blue whale B calls were detected after January 2019. Blue whale D calls peaked in August 2018 at site E and in July 2018 at sites H and N. The fin whale acoustic index was highest from October 2018 to February 2019.

Frequency modulated (FM) echolocation pulses from Cuvier's beaked whales were regularly detected at all sites, but were detected in much higher numbers at sites E and H. At both site E and H, detections were lowest in late summer/early fall 2018. At site E, detections were highest in late fall 2018, while at site H they peaked in spring 2019. A new beaked whale FM pulse type, BW35, thought to be produced by Hubbs' beaked whale (Griffiths et al. 2018), was detected only in January 2019, on multiple occasions at site E and on only one day at site H. The FM pulse type, BW43, thought to be produced by Perrin's beaked whale (Baumann-Pickering et al*.* 2014), was detected only in July 2018 at site E and intermittently throughout the recording period at site N. No other beaked whale signal types were detected.

Two anthropogenic pulsed signals were detected: MFA sonar and explosions. MFA sonar was detected at all sites with a peak in August and September 2018. Site N had the most MFA sonar packet detections normalized per year and the highest cumulative sound exposure levels, including events concurrent with a major naval exercise during August 2018. Site E had the lowest number of sonar packet detections, as well as the lowest cumulative sound exposure level.

Explosions were detected at all sites, but were highest in August 2018 and January 2019 at site H. Temporal and spectral parameters suggest primarily association with fishing, specifically with the use of seal bombs.

[S2] Cuvier's Beaked Whale Impact Assessment at the Southern California Offshore Antisubmarine Warfare Range (SOAR)

Schorr, G.S., B.K. Rone, E.A. Falcone, E.L. Keene, and D.A. Sweeney. 2020.

The Southern California Range Complex (SOCAL) is one of the United States (US) Navy's most active training areas, particularly concerning the use of mid-frequency active sonar (MFAS). Much of SOCAL lies within the Southern California Bight, a productive oceanographic region that hosts a wide variety of marine species. As part of an ongoing study of the distribution and demographics of several marine mammal species within SOCAL, we conducted 28 days of survey effort from 2 January 2019 to 17 November 2019, specifically focusing on the Southern California Anti-submarine Warfare Range (SOAR). The primary goal of these surveys was sighting, photographing, and collecting biopsy samples from Cuvier's beaked whales and fin whales. With combined effort from ancillary projects funded by the US Navy's Living Marine Resources (LMR) program, we had 224 sightings of cetaceans, including 39 sightings of 95 Cuvier's beaked whales and 23 sightings of 41 fin whales. Reconciliation of identification photographs revealed 56 unique individual Cuvier's beaked whales were sighted on an average of 1.6 days each in 2019; 27 of these whales were previously identified in SOCAL, with sighting histories of up to 12 years. There were seven sightings of five Cuvier's beaked whale mother and calf pairs. Thirteen genetic samples were collected, including five from Cuvier's beaked whales, seven from fin whales, and one from a minke whale. There were forty-six environmental DNA (eDNA) samples collected for an ancillary project funded by the Office of Naval Research, but which will provide key data for monitoring efforts. Two tags were deployed under this project– one Spot5 on a fin whale and one MK10A on a Risso's dolphin. Data analyses was completed on these, plus previous tag deployments in the region. Home range analyses indicated that Risso's dolphins utilize the entire Southern California Bight, and Cuvier's beaked whales have a preference for the west sides of Catalina Basin and the San Nicolas Basin within SOAR, with both species spending the majority of their time within one or more of the training ranges.

Following on previous findings that Cuvier's extend their time between deep (presumed foraging) dives in response to Navy sonar exposure, we analyzed previously collected tag data with overlapping sonar data to assess how much time it takes for Cuvier's to return to a 'baseline' deep dive rate after exposure. Initial results indicate that foraging dive cycle time returns to at, or just below, average immediately following the exposed dive cycle, but the rate is much more constrained in variability than data collected further away from sonar and the implications of this are not yet understood. Continued focus on photo-identification, biopsy sampling, and the movement and habitat use of Cuvier's beaked whales and fin whales will help elucidate population structure for these species, an important element of any management and mitigation strategies.

[S3] Marine Mammal Monitoring on California Cooperative Oceanic Fisheries Investigation (CalCOFI) Cruises (formerly Beaked Whale Occurrence in SOCAL From Towed Passive Acoustic Data and Marine Mammal Surveys on CalCOFI Cruises)

Trickey, J.S., B.J. Thayre, K. Whitaker, A. Giddings, K.E. Frasier, S. Baumann-Pickering, and J.A. Hildebrand. 2020

Cetacean distribution, density, and abundance in the Southern California Bight were assessed through visual and acoustic surveys during thirteen California Cooperative Oceanic Fisheries Investigations (CalCOFI) cruises from July 2016 – July 2019. Visual monitoring incorporated standard line-transect protocol during all daylight transits, while acoustic monitoring employed a towed hydrophone array during transits and sonobuoys deployed at oceanographic sampling stations. Visual effort included 1,010 observation hours covering 19,295 kilometers. A total of 913 sightings were made, which included 13 different cetacean species. Acoustic effort included 682 sonobuoy deployments and 329 towed array deployments.

Blue whales, fin whales, and humpback whales were the most frequently sighted mysticetes. Blue whales were primarily observed during summer, while fin whales and humpback whales were observed year-round. Gray whale sightings only occurred during winter and spring, and minke whales were only sighted in summer.

Short-beaked and long-beaked common dolphins were the most frequently encountered odontocetes, while Risso's dolphins, Pacific white-sided dolphins, and bottlenose dolphins were also observed somewhat regularly. Seasonally, short-beaked common dolphins were most abundant in winter and spring, whereas long-beaked common dolphins were most abundant in summer and fall. Sightings of Pacific white-sided dolphins peaked in the spring, whereas Risso's dolphins were never encountered during spring cruises.

Beaked whale echolocation clicks were only detected on one occasion in towed array recordings collected between 2008 and 2019. The low acoustic encounter rate of beaked whales in this dataset may be linked to the continuous use of shipboard echosounders during CalCOFI cruises.

The CalCOFI marine mammal monitoring program examines seasonal and inter-annual patterns in density, abundance, and distribution on a longer continuous time scale and with a higher rate of sampling than previous cetacean surveys off the California coast, particularly for the winter and spring periods, for which there are currently few data available.

[S6/N4] Guadalupe Fur Seal Satellite Tracking

Norris, T.A., and F.R. Elorriaga Verplancken. 2019.

Guadalupe fur seals (*Arctocephalus townsendi*) were thought to be extinct in the early 1900s. The population has been increasing since rediscovery of this species in 1949 but is currently approximately 80% less than the pre-exploitation level. As the population continues to recover, Guadalupe fur seals are increasingly common in their historical range extending from central México to Washington State. However, relatively little is known about this species compared with other more abundant pinnipeds that also use the California Current System. Accurate and current population estimates are lacking because censuses at the only rookery have been sparse and sporadic, and there is a paucity of data on the at-sea movements of this species because few individuals have been tracked using telemetry instruments. The goal of this project, therefore, is to better understand Guadalupe fur seal abundance, behavior, distribution, and habitat use and determine the degree to which this recovering population uses U.S. Navy training and testing ranges in the North East Pacific. In 2018, censuses were performed at both the main rookery (Guadalupe Island, México) and the primary recolonization site (San Benito Archipelago, México) during the breeding season, and satellite tags were deployed on adult females (n = 15) and juveniles (n = 20) at Guadalupe Island during the non-breeding season. In 2018, the number of fur seals observed at Guadalupe Island almost doubled compared to the last census in 2010, but at San Benito Archipelago, fewer fur seals were counted than any other year during the breeding season since 2007. From November 2018-April 2019, Guadalupe fur seals broadly used the California Current System (20-42°N, 112-130°W), primarily north of Guadalupe Island and offshore of the continental shelf break, but remained <800 km from the west coast of North America with mostly nocturnal diving to depths <60 m. Adult females were distributed farther offshore and had greater spatial segregation among individuals. Juvenile animals intensely used three areas: (1) 50-250 km offshore of central California, extending from Point Conception to San Francisco Bay (both sexes), (2) up to 300 km south-southeast of Guadalupe Island (females only), and (3) ~100 km offshore of Magdalena Bay, Baja California Sur. One adult female used the U.S. Navy Northwest Training and Testing (NWTT) Area (3% overlap), whereas there was 42% overlap between the area used by all 35 fur seals and the Southern California (SOCAL) Range Complex (10% of this within the nearshore portion of the range with water depths <2,000 m). Guadalupe fur seals had greater use of the Southern California Anti-submarine Warfare Range (SOAR; 87% overlap) and the Point Mugu Sea Range (PMSR), both the overall area (99% overlap) and the nearshore portion of the range with water depths <2,000 m (38% overlap). This species, listed as threatened under the U.S. Endangered Species Act (ESA), appeared to primarily use the SOCAL Range as a transit corridor between Guadalupe Island and foraging grounds farther to the north, but there was significant juvenile seal use of the PMSR (water depths >2,000 m) that appeared to be linked to foraging activity. As the first year in a multiyear study, these 2018-2019 results improve our understanding of Guadalupe fur seal abundance, behavior, and use of U.S. Navy training and testing ranges in the North East Pacific, and additional census and telemetry data collected in subsequent years will further elucidate population trends and interannual and seasonal variability in habitat use and movement patterns.

[S5] SOCAL Soundscape Study

Wiggins, S.M., M. Rafter, L.M. Dorman, S. Baumann-Pickering, and J.A. Hildebrand. 2020

Over the past decade, underwater explosive sounds have been recorded in the U.S. Navy's Southern California Range Complex. The majority of these events are related to the use of seal bombs by the fishing industry as a deterrent to depredation. In addition, a smaller number of explosions are from Navy ordnance use during training exercises, especially in the Southern California Anti-submarine Warfare (ASW) Range (SOAR).

Navy-supplied periods of missile ordnance use on SOAR reveal explosions with different signal characteristics than those measured for seal bombs. The characteristic difference between Navy missile explosions and seal bombs is that seal bombs included multiple bubble pulses following a primary pulse versus the Navy ordnances that consisted of only a primary pulse. These differences suggest a straightforward approach for separation of these two types of explosions based on the presence or absence of multiple bubble pulses. However, further investigation revealed that acoustic propagation can greatly alter recorded waveforms such that signal type differentiation is difficult and may need more sophisticated methods than visual examination by a trained analyst.

[S6/N4] Guadalupe Fur Seal Satellite Tracking

Norris, T.A., and F.R. Elorriaga Verplancken. 2019.

Guadalupe fur seals are listed as threatened under the U.S. Endangered Species Act and endangered under Mexican law. However, prior to the first year of this study in 2018, the last full census for this species was in 2010, making it difficult to develop current and accurate population estimates and trends. To determine the degree to which this recovering population uses U.S. Navy training and testing ranges in the North Pacific, updated population information for Guadalupe fur seals is needed in addition to tracking at-sea movement patterns using satellite transmitters. Similar to 2018, during the 2019 summer breeding season, direct counts of Guadalupe fur seals were conducted at Guadalupe Island and San Benito Archipelago, México. At San Benito Archipelago, twice as many animals were counted in 2019 (1,113 individuals) relative to 2018 (539 individuals), but only approximately 20 mom-pup pairs were observed at this site during both years. In contrast, at Guadalupe Island, approximately the same number of animals were observed in 2018 (26,217 individuals) and 2019 (26,369 individuals), but there were ~3,000 more adult females and ~2,500 fewer pups in 2019 compared with 2018. During the 2019 surveys at Guadalupe Island, we also used a remotely piloted aircraft to collect >12,000 visual and thermal still images as well as 4K video to test the feasibility of using aerial imagery to improve our population estimates and reduce animal disturbance. These images currently are being processed using various tools and techniques. With only two consecutive years of Guadalupe fur seal population monitoring, it is unknown if these 2018-2019 census data reflect interannual fluctuations or longer term abundance trends, and therefore, ongoing annual censuses for this species are needed.

[N1/S7/G2/H6] Humpback Whale Tagging in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas in the Pacific Ocean

Mate, B.R., D.M. Palacios, C.S. Baker, B.A. Lagerquist, L.M. Irvine, T.M. Follett, D. Steel, and C.E. Hayslip. 2020.

Between 16 September and 7 October 2019, Oregon State University (OSU) conducted a field study involving satellite telemetry, genetics, and photo-identification (photo-ID) of humpback whales (*Megaptera novaeangliae*) in waters of the Strait of Juan de Fuca, Washington. This work is in support of marine species monitoring activities by the United States (US) Navy in its training and testing range complexes in the Pacific Ocean. Specifically, the study seeks to help delineate humpback whale Distinct

Population Segments found off the US West Coast, as well as to describe their feeding-season home range, migration to the breeding areas, diving behavior, habitat use, and ecological characteristics. This Preliminary Summary provides an overview of field survey methodologies as well as initial summaries of the data collected through 18 November 2019. Twenty-four tags were deployed and Argos satellite locations were received from 22 of them. For the period covered by this report, tracking durations ranged from 4.2 to 59.3 days (mean = 35.6 days, standard deviation = 15.9 days), while minimum distance traveled ranged from 171 to 3,186 km (mean = 1,669 km, standard deviation = 925.3 km). Locations for humpback whales tagged off Washington ranged from the northwest corner of Vancouver Island, British Columbia, Canada, to Seaside, Oregon. The densest area of locations occurred over Swiftsure Bank, approximately 16 km northwest of Cape Flattery, while a smaller cluster of locations occurred approximately 45 to 65 km offshore of Grays Harbor, southern Washington. One whale tagged in 2019 had been previously tagged by OSU in Washington in 2018, providing a unique opportunity to compare movements between years for the same individual. Killer whales (Orcinus orca) were observed and photographed opportunistically on two occasions in 2019. Information is also presented for seven encounters with killer whales made during the 2018 field effort. Of the estimated 91 individual killer whales encountered, 45 were matched to the J, K, and L pods of the Southern Resident killer whale population.

[N1/S7/G2/H6] Humpback Whale Tagging in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas in the Pacific Ocean

Palacios, D.M., B.R. Mate, C.S. Baker, B.A. Lagerquist, L.M. Irvine, T.M. Follett, M.H. Winsor, C.E. Hayslip, and D. Steel. 2020.

Three of the 14 Distinct Population Segments (DPSs) of humpback whales (*Megaptera novaeangliae*) recently designated by the National Marine Fisheries Service (NMFS) for listing under the Endangered Species Act (ESA) based on their winter breeding grounds ("Hawaii", "Mexico", and "Central America"), can be found along the western coast of North America during the feeding season. The mixing of whales from these DPSs in the feeding areas in different proportions complicates unequivocal assignment of individuals to breeding stock for management purposes without further information. As a result, there is an urgent need for data on occurrence and habitat use by these different DPSs throughout their range, as well as on their overlap with shipping traffic, fishing grounds, and areas of military operation, in order to prioritize management actions and to mitigate the impacts from these activities.

In 2018, Oregon State University (OSU) conducted a tagging and tracking study on Eastern North Pacific humpback whales to determine their movement patterns, occurrence, and residence times within United States (US) Navy training and testing areas along the US West Coast. This work was performed under a Cooperative Ecosystem Studies Unit (CESU) agreement in support of the Navy's efforts to meet regulatory requirements for marine mammal monitoring under the ESA and the US Marine Mammal Protection Act (MMPA). This report presents detailed results from the tagging, biopsy sampling, and photo-identification efforts conducted off the coast of northern Washington and central Oregon in summer 2018, as well as results from previous OSU studies of humpback whales in Oregon in 2016 and 2017. Whale use of Navy training and testing areas as well as their use of NMFS-identified Biologically Important Areas (BIAs) is examined and assignment to various DPSs (based on tracking, genetic, and photographic information) is discussed. Comparisons are made to tracking results from humpback whales tagged by OSU in California in 2004, 2005, and 2017 (presented in Mate et al. 2018a). For the 2018 data, this report also presents detailed dive behavior analyses and ecological relationships between whale locations and oceanographic conditions.

Four types of non-recoverable, fully implantable tags were used in this study, all providing long-term tracking information via the Argos satellite system: Wildlife Computers SPOT6 Location-Only (LO) tags, Telonics Duration Monitoring (DUR) tags, providing locations and dive duration information, Telonics Duration Monitoring Plus (DUR+) tags, providing locations, dive duration, and number of feeding lunges, and Telonics Dive Monitoring (DM) tags, providing locations, dive duration, number of feeding lunges, and depth. Additionally, one Wildlife Computers MK-10 Advanced Dive Behavior (ADB) tag, a partially implantable, recoverable tag, was used in 2018, providing tracking over multiple weeks while recording high-resolution dive profile information (dive duration, depth, and accelerometer and magnetometer data). Twenty humpback whales (10 DUR+ tags, 9 DM tags, 1 ADB tag) were tagged in Washington in August 2018 and five humpback whales (5 DUR+ tags) were tagged in Oregon in September 2018. Additionally, one fin whale was tagged (1 LO tag) opportunistically in Oregon in September 2018 during humpback whale field efforts. Argos locations were received from all 24 non-recoverable tags on humpback whales, with tracking periods ranging from 6.7 to 110.6 days (d) (mean = 31.0 d, standard deviation [SD] = 24.2 d). The ADB tag transmitted for 12.5 d but was not recovered. The fin whale was tracked for 35.9 d. Seven humpback whales were tagged previously in Oregon; two in 2016 and five in 2017. Locations were received for six of these tags, with tracking periods ranging from 7.3 to 150.4 d (mean = 45.6 d, SD = 52.3 d). Hierarchical switching state-space models (hSSSM) were applied to the Argos locations from the tags for the purpose of generating regularly spaced tracks with annotated movement behavior for use in several analyses including home range, dive behavior, and ecological relationships.

The distribution of tracked humpback whales supported humpback whale affinity for continental shelf and shelf-edge habitat, and also documented extensive use of the western portion of the Salish Sea (Strait of Juan de Fuca, Strait of Georgia, and Puget Sound). The latitudinal range of whales during the feeding season was similar for humpbacks tagged in Washington in 2018 (5 degrees) and those tagged in Oregon from 2016 to 2018 (4 to 7 degrees), as was the total distance traveled by individual whales (1,884 km for Washington whales and 1,610 to 2,944 km for Oregon whales). Locations extended from the north coast of Vancouver Island to the north Oregon coast, for whales tagged in Washington, and from Barkley Sound on the central west coast of Vancouver Island to Point Arena, central California, for whales tagged in Oregon. Feeding-area home ranges and core areas did not differ significantly in size between whales tagged in Washington and those tagged in Oregon. Areas of highest use (where core areas overlapped for multiple whales) for whales tagged in Washington occurred at the western end of the Strait of Juan de Fuca out to Swiftsure Bank off the northwest corner of Washington, and off the Columbia River mouth and Trinidad Head, northern California, for whales tagged in Oregon. When compared with previous tracking results of humpback whales tagged in California, both the overall latitudinal ranges in feeding areas and the home ranges showed overlap in the distribution of whales tagged in Oregon and Washington, and between whales tagged in Oregon and California, but not between whales tagged in Washington and California.

The Navy areas considered in this report were: the Southern California Range Complex (SOCAL), the Southern California Anti-submarine warfare Offshore Range subarea (SOAR), the Point Mugu Range Complex (PT MUGU), the Northwest Training and Testing Study Area (NWTT), the Warning Area-237 (W237) within the NWTT, and the Gulf of Alaska Temporary Maritime Activities Area (GOA). Sixty-one percent of all humpback whales tagged by OSU in Washington and Oregon from 2016 to 2018 (19 of 31) were instrumented within the NWTT training range, and all 31 tagged whales had locations within NWTT, with a maximum residency of 86.5 d. Ninety-five percent (19 of 20) of whales tagged in Washington in 2018 had locations within area W237 of the NWTT (maximum residency of 16.8 d), compared to 17 percent (1 of 6) of whales tagged in Oregon in 2016 and 2017 (residency in W237 of 14.3 d). No whales tagged in Oregon in 2018 had locations in area W237. Humpback whale locations occurred in the NWTT and area W237 from August through December. With the exception of one migrating whale (tagged in Oregon in 2017) transiting through SOCAL in January, no whales from Oregon or Washington spent time in southern California training ranges. It is worth noting here that no other whales tagged in the Pacific Northwest began their southbound migrations during their tracking periods. Presumably, humpback whales migrating to and from breeding areas in Mexico or Central America would pass briefly through SOCAL in winter and spring, as the range extends approximately 1,200 km offshore, but otherwise we have no evidence of Oregon or Washington whales spending extended periods of time in the southern ranges. No tagged humpback whales were located in the GOA training range in any of the years covered in this report (2016 to 2018).

The occupancy of US West Coast feeding BIAs also suggests spatial separation of humpback whales throughout feeding areas, as no humpbacks tagged in Washington spent time in BIAs south of Washington, and only one whale tagged in California was found in a BIA north of California, spending less than one day in the Stonewall BIA in Oregon. As noted above, none of the whales tagged in Washington were tracked on their southbound migration, however, and all tagging took place in mid-late summer. Longer tracking durations and deployments at other times of year may yield different results in terms of BIA use by Washington whales. Spatial separation was not as clear for whales tagged in Oregon, with one Oregon whale spending time in the Northern Washington (NWA) BIA and the Olympic Coast National Marine Sanctuary (OCNMS) in northern Washington, and others spending time in the Point St. George, Fort Bragg to Point Arena, and the Gulf of the Farallones-Monterey Bay BIAs in California. The extensive use of the NWA BIA and the OCNMS by whales tagged in Washington reflects not only the location of tag deployments in Washington, within or very close to the BIA and/or sanctuary, but also speaks to the whales' affinity for the regions, as evidenced by the substantial residency (average 18.3 d in NWA and 23.1 d in OCNMS) and the seasonal extent (August through October) of locations there. Large proportions of humpback locations occurred east of the western boundary of the NWA BIA and north of the US/Canada maritime border, suggesting Canadian waters at the southwestern tip of Vancouver Island also represent important habitat such as those used to designate BIAs in the US.

The fin whale tagged off Oregon in 2018 was tracked for 35.9 d between the central coasts of Oregon and British Columbia. The areas of highest use for this whale were between Newport and Cascade Head on the central Oregon coast, out to 120 km offshore, and over deep oceanic waters approximately 150 to 300 km west of Queen Charlotte Sound, British Columbia. This whale spent an estimated 14.4 d within the NWTT training range and 3.9 d within area W237 within the NWTT. The time spent in area W237 was estimated from interpolated locations during a 10-d gap in transmissions for the tag. The fin whale was not tracked within any other Navy training area.

Humpback whale dives reported through Argos summarized a mean of 72.7 percent of the tracking durations. Dive behavior was similar for tagged whales off Washington and Oregon with dive durations primarily ranging from 2-7 min and dive depths generally less than 100 m for DM-tagged whales off Washington. Feeding effort was evenly distributed across the areas occupied by tagged whales. Longer duration and deeper daytime dives suggest whales were feeding on krill throughout the study area, although dive depths occurring on Swiftsure Bank off Washington were limited by shallow bottom topography. Tagged whales spent a mean of 53.0 percent of their reported time at ≤ 30 m depth, which is within the zone of possible impact for deep-drafted vessels that transit the Strait of Juan de Fuca. Thus, the high occupancy by tagged whales of the Strait of Juan de Fuca, and the shallower waters of Swiftsure Bank immediately west of the Strait likely place them at an elevated risk for vessel collision.

The output of the state-space models applied to 56 humpback whale Argos tracks, representing a combination of the 2016-2018 data collected under CESU agreements together with earlier data collected by OSU off the US West Coast during tagging efforts in 2004 and 2005, produced a total of 1,893 daily locations with annotated behavioral mode available for ecological characterization. Of these, 82.0 percent were classified as area-restricted searching (ARS; an indication of foraging behavior), 12.0 percent as uncertain, and 6.0 percent as transiting. These locations occurred across 16.6 degrees of latitude, spanning much of US West Coast from the Strait of Juan de Fuca, Washington, in the north to Point Conception, California, in the south. Ecological characterization of these data indicated that tracked humpback whales moved at speeds ranging from a median of 0.61 km/h while engaging in ARS to 2.74 km/h while transiting. While in ARS, whales occurred at a median depth of 146.0 m, over southwest-facing seafloor with median slope of 0.55°, and at median distances of 4.6 km from the shelf break and 21.8 km from shore. In contrast, while in transiting activities, whales were found at a median depth of 376.0 m, over seafloor slopes that faced west-southwest with a steeper median slope of 0.74°, and at median distances of 13.5 km from the shelf break and 39.2 km from shore. There were no apparent behavioral mode differences with respect to sea surface temperature or sea surface temperature gradient (a measure of frontal activity), although tracked whales occurred in waters with higher phytoplankton chlorophyll-*a* content while engaged in ARS compared to transiting (median = 1.42 versus 0.93 mg/m^3). Thus, while occupying waters off the US West Coast during the feeding season, tracked humpback whales spent the majority of their time foraging over relatively shallow continental shelf waters, and spent a small proportion of their time in deeper, more offshore waters beyond the shelf break during transiting.

Analysis of the data by latitudinal 2-degree blocks revealed an apparent pattern in the proportion of locations in ARS behavior across blocks, being lowest (below 62 percent) off the northern Oregon, southern Oregon, and northern California blocks, implying that whales spent less time foraging there compared to the other blocks where the proportion of ARS locations was higher (above 75 percent). Locations occurring in the northernmost block, encompassing locations in the Strait of Juan de Fuca and adjacent waters, were characterized by a more southerly (or even easterly) aspect of the seafloor slope and by smaller median distances to the shelf break and to shore than for the other blocks, reflecting the semi-enclosed and distinct physiographic conditions imposed by the Strait of Juan de Fuca. For the other blocks, median distance to shore gradually decreased from north to south while median distance to the shelf break remained relatively constant, reflecting the narrowing width of the continental shelf along the US West Coast, and the preference for humpbacks to forage over the continental shelf. Other than a strong trend in sea surface temperature across blocks, being lowest in the north and highest in the south and reflecting the well-known global latitudinal temperature gradient, there were no other apparent latitudinal trends in the environmental variables examined. From this analysis we conclude that while other results in this study suggest spatial separation (or at least limited exchange) between BIAs and areas of whale aggregation along the US West Coast, the movement characteristics and environmental conditions associated with the tracking data do not suggest that these areas, or the humpback whale

DPSs they support, have different habitat requirements.

The wide-ranging movements of the single tracked fin whale in this study were in contrast with the more coastal habits of the tracked humpback whales. This track had a high proportion of locations classified as ARS (80.8 percent) and no locations were classified as transiting (although the 10-d gap occurred during this whale's movement between the coastal and oceanic environment, when transiting behavior would likely have been recorded). The overall speed between location pairs was higher for this fin whale's track than for the humpbacks (0.80 km/h versus 0.72 km/h). Although the sample size was very small, this result is supported by previous results from 28 fin whales tagged in the Eastern North Pacific (see Mate et al. 2018b) that point at inter-species differences in movement speed. Similarly, deeper depths (median = 2378.0 m versus 153.0 m) and larger distances to the shelf break (median = 74.9 km versus 5.1 km) and to shore (median = 94.3 km versus 23.7 km) for the fin whale locations compared to the humpbacks' reflect the more oceanic habits of the species.

Biopsy samples were collected from 18 of the 20 tagged humpback whales in Washington in 2018 (plus seven untagged whales) and from all five of the tagged humpback whales in Oregon in 2018 (plus one untagged whale). A biopsy sample was also collected from the fin whale tagged off Oregon. Mitochondrial deoxyribonucleic acid (mtDNA) sequences of the 31 humpback whale samples resolved eight control region haplotypes for a consensus sequence of 500 bp for the Washington samples and four haplotypes for the Oregon samples. All mtDNA haplotypes have been described previously for North Pacific humpback whales and confirmed species identity of the field observations. The mtDNA sequence of the single fin whale sample has also been described previously for North Pacific fin whales. All humpback whale samples were represented by a unique multi-locus genotype of at least 14 loci, confirming individual identity and documenting one genotype recapture between two samples collected from an untagged whale in Washington. Sex-specific molecular markers showed that the 24 Washington individuals represented six females and 18 males, while the six Oregon individuals were all males. The mtDNA haplotypes, multi-locus genotypes, and sex markers together provided a standard "DNA profile" for each of the 30 individual humpback whales sampled in 2018. These profiles were compared to a reference database of 1,805 individuals sampled previously in the North Pacific by the ocean-wide survey referred to as the "Structure of Populations, Levels of Abundance, and Status of Humpbacks" program (SPLASH), and to the 23 individuals sampled during previous tagging off the California and Oregon coasts in 2016 and 2017 under previous CESU agreements (Mate et al. 2018a). This comparison detected one recapture of an individual sampled in Washington during the 2018 tagging effort and sampled previously in Washington during SPLASH in 2005. For population analyses, data from the six individuals sampled during 2018 off Oregon were combined with data from the nine individuals collected in 2016 and 2017, for a total of 15 individuals representing the Oregon feeding area. The fin whale sample was represented by a unique multi-locus genotype of 17 loci. A comparison to a reference dataset of 20 previously tagged fin whales (Mate et al. 2018b) found no recaptures.

Differences in mtDNA haplotype frequencies were used to investigate the influence of maternal fidelity to both feeding aggregations and breeding grounds, including tagging samples collected previously and the SPLASH reference database. A comparison of haplotype frequencies from the California and Oregon samples suggested some degree of differentiation between these feeding aggregations, with Oregon whales appearing more similar to the Southern British Columbia/Washington aggregation. This differentiation between California and Oregon feeding aggregations had not been recognized previously in the limited sampling of the Oregon coast during SPLASH, but was noted in the results of previous tagging efforts, based on smaller sample sizes, under previous CESU agreements in 2016 and 2017 (Mate et al. 2018a). Further, comparisons to the breeding areas defined by SPLASH indicated that the haplotype frequencies of California whales were most similar to Central America, while the haplotype frequencies of Oregon whales were most similar to those found off Mexico. The haplotype frequencies of the Washington sample did not differ significantly from the Southern British Columbia/Washington stratum in SPLASH and showed the greatest affinity with the Hawaii DPS.

The DNA profiles of humpback whale sampled on the feeding grounds were used to calculate the relative likelihood of individual membership in each of the four recognized DPSs in the North Pacific, based on a Bayesian assignment procedure and the SPLASH reference database. The 24 individuals sampled in Washington showed the highest likelihood of assignment to the Hawaii DPS for 13 individuals, to the Mexico DPS for five individuals, to the Central America DPS for four individuals, and to the Western North Pacific DPS for one individual. Two individuals were assigned with nearly equal likelihood to both Mexico and Hawaii. For the six Oregon samples, the individual assignment showed the highest likelihood of assignment to the Hawaii DPS for two individuals, to the Mexico DPS for two individuals, and to the Central America DPS for one individual. One individual was assigned with similar likelihood to Hawaii and Mexico. Assignments to the Hawaii or the Western North Pacific DPS could suggest changes in the migratory destinations, since some of these whales were tracked and/or photographed in Mexico. In interpreting the results of genetic assignment, however, it is important to keep in mind that accuracy is dependent on the quality of the reference dataset (which is limited to a relatively small sample size for the Central America DPS), and that assignments reflect genetic ancestry, including recent reproductive exchange between breeding areas.

[N2] Characterizing the Distribution of ESA-Listed Salmonids in the Pacific Northwest

Smith, J.M., and D.D. Huff. 2020.

The Northwest Fisheries Science Center is conducting a study to characterize the distribution of salmon within the Northwest Training and Testing (NWTT) area. In May 2019, we deployed 107 stationary receivers in a grid pattern along the coast of Washington State. From May to August 2019 we tagged 142 Chinook salmon and 35 coho salmon along the coast of Washington State. We collected fin clips to perform genetic stock identification. We retrieved, downloaded, and redeployed stationary receivers in September 2019. We detected 87% of tagged Chinook salmon and 71% of tagged coho salmon between May and September 2019. The projected battery life of the tags is two years. We will retrieve, download, re-battery, and redeploy receivers in March 2020. Further analyses examining the distribution of salmon will be completed once the complete detection history of each fish is obtained.

[G1] Passive Acoustic Monitoring of Marine Mammals in GOA TMAA using Bottom-Mounted Devices

Rice, A.C., N. Posdaljian, M. Rafter, J.S. Trickey, S.M. Wiggins, S. Baumann-Pickering, and J.A. Hildebrand. 2020.

Passive acoustic monitoring was conducted in the Gulf of Alaska Temporary Maritime Activities Area (GATMAA) from September 2017 to June 2018 and from April to September 2019 to record the low-frequency ambient soundscape and detect marine mammal and anthropogenic sounds during times of naval exercises in the area. High-frequency Acoustic Recording Packages (HARPs) recorded sounds between 10 Hz and 100 kHz at two locations: a continental slope site in deep water (~900–1,000 m depth, site CB) and a deep-water site off Kodiak Island (~1,000 m depth, site KOA).

The low-frequency ambient soundscape showed spectrum level peaks at both sites during winter and fall, related to the seasonally increased presence of blue and fin whales.

For marine mammal and anthropogenic sounds, data analysis consisted of detecting sounds by analyst visual scans of long-term spectral averages (LTSAs) and spectrograms, and by automated computer algorithm detection when possible. The data were divided into three frequency bands (low, mid, and high frequency) and each band was analyzed for marine mammal and anthropogenic sounds.
Three baleen whale species were recorded: blue, fin, and humpback whales. No gray whale M3 calls or North Pacific right whale up calls were noted. Blue whales and fin whales were the most commonly detected baleen whales in these recordings. Blue whale B calls were the most common blue whale call type detected and peaked during the fall at both sites. Blue whale D calls were highest during the spring and summer. Central Pacific tonal calls were the least common blue whale call type but were detected at both sites, peaking in August. The fin whale acoustic index (representative of 20 Hz calls) was low throughout the summer and began to increase in August at all sites. Meanwhile, fin whale 40 Hz calls were seen throughout the recordings at all sites, with highest calling at site CB. Humpback whales were detected only at site CB during the winter and early spring.

Signals from four known odontocete species are reported: killer whales, sperm whales, Cuvier's beaked whales, and presumable Stejneger's beaked whales. Killer whale pulsed calls occurred throughout the recordings at both sites but were highest at site CB during the summer. Sperm whale clicks occurred throughout the recordings at both sites but were highest at site CB during summer and fall. Cuvier's beaked whales were detected only at site CB in the winter. Stejneger's beaked whales were detected at both sites but were more common at site CB.

Three anthropogenic signals were detected: mid-frequency active (MFA) sonar, low-frequency active (LFA) sonar, and explosions. MFA sonar was detected only in May 2019 at both sites which overlapped with a known naval training exercise (13-24 May 2019). Site CB had the most MFA sonar packet detections normalized per year in 2019 and had the highest cumulative sound exposure levels. LFA sonar was detected only at site CB in April and May 2019. The Navy confirmed that no LF sources from the Navy were used during this time.

Explosions were detected in high numbers at site KOA and peaked in August. The Navy confirmed that no at-sea explosives were used by the Navy during the 13-24 May 2019 training exercise.

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B

Animal Telemetry Tag Types

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Table B-1. Summary of Animal Tracking Tag Types Used on Navy-Funded Monitoring Projects

Tag Name	Acronym/ Model	Project #	Use[1]
Acoustic Coded Transmitters	VEMCO/ V7-2L V7-4L V8-4L V9-6L V9-1L V9-2L	N2	Tracks the behavior patterns of small and juvenile fish. These tags are particularly suited for seamless monitoring of salmon smolt migrations. Coded pingers send acoustic pulse trains that include a unique ID number which permits identification of the specific tag. These tags can be equipped with sensors to encode temperature, depth, or both. The expected detection ranges of tags are between 200 m and 500 m, and the tags have an expected battery life of 172 to 651 days, depending on the battery size and power output (V7 = 136 dB, V8 = 144 dB, V9 = 145 dB) of the tag.
Advanced Dive Behavior	ADB	H6, S7, N1, G2	Provides short-term, fine-scale dive profile information and Global Positioning System (GPS)-quality locations.
Dive Monitoring	DM	H6, S7, N1, G2	Provides intermediate duration Advanced Research and Global Observation Satellite (Argos) tracking and data on dive behavior (duration, depth, and number of feeding lunges per dive).
Dive Duration Monitoring	DUR, DUR+	H6, S7, N1, G2	Provides data on longer-term movements and dive durations. DUR+ satellite tags are also equipped with accelerometers and lunge-detection software to monitor movement behavior.
Flipper	-	M2	The most common tag used on sea turtles. Made from metal or plastic and attached by piercing through the skin of flipper. The tags usually have a unique number on one side, and a return address on the other (in case someone finds the turtle far away from where the turtle was tagged). This tag does not transmit data.
Location-Only	LO	H5	Provides long-term tracking information via the Argos satellite system such as derived location, depth, temperature, light level, and wet/dry sensor. SPLASH and SPOT are specific types of location-only tags (see below).
Passive Integrated Transponder	PIT	M2	Tracks individual organisms (in this report, sea turtles) using electromagnetically-coded glass-encased microchips (i.e., reliable lifetime 'barcode' for an individual animal). Animal has to be caught and scanned; data are not transmitted.
Pinger	-	H1	Active high-frequency pinger tags assist in the detection of the locations, movement patterns, and vocalization rates of whales for assessment. The tag creates a repeated high-frequency ping outside the range of the whale's hearing that can be detected on hydrophones and used to track whales when they are not vocalizing. Attaches temporarily using suction cups, so the tag can fall off within minutes to hours.
Smart Position and Temperature	SPOT, SPOT311A SPOT5 SPOT6	S2, H5, M2	Provides data on a variety of measurements, such as temperature, salinity, and depth.

Tag Name	Acronym/ Model	Project #	Use[1]
SPLASH	SPLASH, SPLASH10, SPLASH10-F SPLASH10-F-297 SPLASH10-F-238 SPLASH297A MK10-A	M2, H1, H5, S2, S6	Provides horizontal movement and additional information such as vertical behavior (depth). The SPLASH10 tag includes sensors to measure depth, temperature, light level, and wet/dry periods (to determine surfacing). During the deployment, depth and temperature data are collected, analyzed, summarized, and compressed for transmission through the Argos satellites. The SPLASH10 tag is configured with 1 GB of non-volatile memory available for the archived data. The SPLASH10 tag must be recovered in order to retrieve the entire raw archived data set. The Low Impact Minimally Percutaneous Electronic Transmitter (LIMPET) configuration is sometimes mentioned in reference to SPLASH tag. The tag's small size allows for deployment high on the dorsal fin to enable frequent transmissions to Argos satellites. SPLASH10-F tags are also equipped with a Fastloc-GPS receiver that provides locations approaching the quality of those obtained from traditional GPS receivers, and can do so even when the tag is only at the surface for a very short period of time.

[1]References: Hill et al. 2018a; Martin and Jones 2018; Mate et al. 2017a, b; Smith and Huff 2020; https://wildlifecomputers.com

C

2019 Conference Presentations from Navy-Funded Monitoring

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2019 CONFERENCE PRESENTATIONS from Navy-Funded Monitoring (in alphabetical order by Range and Project)

HRC

Project H1

Alongi, G.C., E.E. Henderson, S.W Martin, C.R. Martin, T.A. Helble, and B.M. Matsuyama. 2018. Baleen whale response to broadband explosive noise in Kauai. 5th International Meeting on the Effects of Noise on Aquatic Life. 7-12 July 2019, Den Haag, the Netherlands.

Helble, T.A., and the DCLDTE Lab. 2019. Developing tools for acoustic-only BRS studies at Navy instrumented ranges. Living Marine Resources Program Review Meeting. 5 November 2019, Point Hueneme, California.

Helble, T.A., S.W. Martin, C.R. Martin, E.E. Henderson, G.C. Alongi, R.A. Manzano-Roth., and R. Guazzo. 2019. PMRF Noise Analysis. US Navy Marine Species Monitoring Program Annual Meeting. 13-14 May 2019. Seattle, Washington.

Helble, T.A., C.R. Martin, S.W. Martin, E.E. Henderson, G.C. Alongi, and R. Guazzo. 2019. Minke whales exhibit Lombard effect during natural changes in ocean noises conditions. 5th International Meeting on the Effects of Noise on Aquatic Life. 7-12 July 2019, Den Haag, the Netherlands.

Henderson, E.E., and DCLDTE Lab. 2019. Long-term odontocete occurrence and abundance at PMRF and Humpback whale satellite tagging. US Navy Marine Species Monitoring Program Annual Meeting. 13-14 May 2019. Seattle, Washington.

Henderson, E.E., J. Aschettino, M. Deakos, G. Alongi, and T. Leota. 2019. Habitat use and behavior of satellite tagged humpback whales off Kauai. World Marine Mammal Conference, 9-12 December 2019, Barcelona, Spain.

Henderson, E.E., J. Aschettino, M. Deakos, G. Alongi, and T. Leota. 2019. Blainville's beaked whales reduced foraging dives prior to the onset of hull-mounted MFAS sonar during Navy training events. 5th International Conference on Effects of Aquatic Noise on Marine Life, 7-12 July 2019, Den Haag, the Netherlands.

Jacobson, E., E.E. Henderson, C. Oedekoven, S. Watwood, D. Moretti, and L. Thomas. 2019. Quantifying the response of Blainville's beaked whales to Naval sonar exercises in Hawaii. Speedtalk, World Marine Mammal Conference. 9-14 December 2019, Barcelona, Spain.

Manzano-Roth, R., E.E. Henderson, G. Alongi, S.W. Martin, and B. Matsuyama. 2019. Long-term foraging dive characteristics of Cross Seamount beaked whales at the Pacific Missile Range Facility. Talk, 178th Meeting of the Acoustical Society of America. 2-6 December 2019. San Diego, California.

Project H2

Watwood, S., E. Jacobson, C. Oedekoven, N. DiMarzio, K. Dolan, J. Fayton, P. Hulton, L. Thomas, and D. Moretti. 2019. Behavioral response function for Cuvier's beaked whales on a Navy training range. Speedtalk, World Marine Mammal Conference. 9-14 December 2019, Barcelona, Spain.

Project H6

Irvine, L.M., D.M. Palacios, B.A. Lagerquist, T.M. Follett, C.E. Hayslip, M.H. Winsor, and B.R. Mate. 2019a. A Synopsis of Hawaiian humpback whale movements, including migration routes to foraging destinations, from satellite-monitored tracking between 1995 and 2018. Poster, World Marine Mammal Conference. 9-14 December 2019, Barcelona, Spain.

SOCAL

Project S1

Baumann-Pickering, S., J.S. Trickey, A. Rice, A. Širović, U. Send, J. Renfree, and D. Demer, 2019. Season response of large mobile predators to oceanographic and prey conditions at an offshore pelagic environment; OceanObs '19 Conference, 15-20 September 2019, Honolulu, Hawaii.

Giddings, A., E. Snyder, J.S. Tricky, D. Demer, P. Franks, and S. Baumann-Pickering. 2019. Deep sea prey layer in Cuvier's beaked whale foraging habitat modulated by ocean Poster, World Marine Mammal Conference, 9-14 December 2019, Barcelona, Spain.

Solsona Berga, A., J.S. Trickey, A. Rice, A. Širović, M.A. Roch, C.G. Paxton, C.S. Oedekoven, S.M. Wiggins, J. Hildebrand, L. Thomas, and S. Baumann-Pickering. 2019. Potential impact of mid-frequency active sonar on whales from passive acoustic monitoring data. 178th Meeting of the Acoustical Society of America. 2-6 December 2019. San Diego, California.

Project S2

Curtis, K.A., E. Falcone, G. Schorr, J. Moore, J. Barlow, D. Moretti, and E. Keene. 2019. Bayesian mark-recapture assessment of Cuvier's beaked whales on a navy sonar range. 2019. Talk, World Marine Mammal Conference. 9-14 December 2019, Barcelona, Spain.

DiMarzio, N. 2019. Chl-a levels in relation to Cuvier's beaked whale foraging group data on the Southern California Anti-submarine Warfare Range (SOAR). University of Rhode Island OCG561 Biological Oceanography Poster Symposium, 10 December 2019, Narragansett, Rhode Island.

Falcone, E., E. Keene, G. Schorr, B. Rone, S. Watwood, and D Moretti. 2019. Preliminary estimates of vital rates from Cuvier's beaked whales on a military training range. Poster, World Marine Mammal Conference. 9-14 December 2019, Barcelona, Spain.

Schorr, G., B. Rone, E. Falcone, S. DeRuiter, R. Andrews, and S. Watwood. 2019. Cuvier's beaked whales in high fidelity: Medium-term archival tags allow for detailed behavioral studies. Talk, World Marine Mammal Conference. 9-14 December 2019, Barcelona, Spain.

Project S3

Frasier, K.E., A. Solsona Berga, J. Hildebrand, R. Cohen, S.M. Wiggins, L. Garrison, D. Cholewiak, and M. Soldevilla. 2019. An interactive machine learning toolkit for classifying impulsive signals in passive acoustic recordings. 178th Meeting of the Acoustical Society of America. 2-6 December 2019. San Diego, California

Rafter, M., K.E. Frasier, J.S. Trickey, S.M. Wiggins, and J. Hildebrand. 2019. Fine-scale classification of odontocete echolocation clicks using deep learning. 178th Meeting of the Acoustical Society of America. 2-6 December 2019. San Diego, California.

Project S4

Palacios, D.M., L.M. Irvine, T.M. Follett, B.A. Lagerquist, and B.R. Mate. 2019. Applications of a new satellite-linked tag for long-term monitoring of large whale movements, diving, and feeding behavior. Talk, World Marine Mammal Conference. 9-14 December 2019, Barcelona, Spain.

Project S5

Wiggins, S.M., A. Krumpel, M. Rafter, L. Dorman, J. Hildebrand, and S. Baumann-Pickering. 2019. Explosions recorded underwater offshore of southern California. 178th Meeting of the Acoustical Society of America. 2-6 December 2019. San Diego, California.

GOA TMAA

Project G1

Rice, A., A. Širović, J. Trickey, J. Hildebrand and S. Baumann-Pickering. 2019. Marine mammal distribution in the Gulf of Alaska from long-term passive acoustic monitoring. 178th Meeting of the Acoustical Society of America. 2-6 December 2019. San Diego, California.

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D

2019 Publications from Navy-Funded Monitoring

2019 Publications From Navy-Funded Monitoring 2019 Through February 2020

(Beaked whale references from other geographical areas included)

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