Cetacean and Seabird Data Collected During the Mariana Archipelago Cetacean Survey (MACS), May–July 2021

Kymberly M. Yano, Marie C. Hill, Erin M. Oleson, Jennifer L.K. McCullough, and Annette E. Henry

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Pacific Islands Fisheries Science Center
NOAA Technical Memorandum NMFS-PIFSC-128

https://doi.org/10.25923/7pbh-zq68
June 2022

Cetacean and Seabird Data Collected During the Mariana Archipelago Cetacean Survey (MACS), May–July 2021

Kymberly M. Yano[1,2], Marie C. Hill[1,2], Erin M. Oleson[1], Jennifer L.K. McCullough[1], and Annette E. Henry[3]

[1] Pacific Islands Fisheries Science Center
National Marine Fisheries Service
1845 Wasp Boulevard
Honolulu, Hawaii 96818

[2] Joint Institute for Marine and Atmospheric Research
University of Hawaii
1000 Pope Road
Honolulu, Hawaii 96822

[3] Southwest Fisheries Science Center
National Marine Fisheries Service
8901 La Jolla Shores Drive
La Jolla, California 92037

NOAA Technical Memorandum NMFS-PIFSC128
June 2022

U.S. Department of Commerce
Gina Raimondo, Secretary

National Oceanic and Atmospheric Administration
Richard W. Spinrad, Ph.D., NOAA Administrator

National Marine Fisheries Service
Janet Coit, Assistant Administrator for Fisheries

About this report

The Pacific Islands Fisheries Science Center of NOAA's National Marine Fisheries Service uses the NOAA Technical Memorandum NMFS-PIFSC series to disseminate scientific and technical information that has been scientifically reviewed and edited. Documents within this series reflect sound professional work and may be referenced in the formal scientific and technical literature.

Recommended citation

Yano KM, Hill MC, Oleson EM, McCullough JLK, and Henry AE. 2022. Cetacean and seabird data collected during the Mariana Archipelago Cetacean Survey (MACS), May–July 2021. U.S. Department of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-128, 59 p. https://doi.org/10.25923/7pbh-zq68

Copies of this report are available from

Pacific Islands Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
1845 Wasp Boulevard, Building #176
Honolulu, Hawaii 96818

Or online at

https://repository.library.noaa.gov/

https://marinecadastre.gov/espis/#/

The content of this report, in part, fulfills the requirements of Interagency Agreements between the U.S. Navy and the National Marine Fisheries Service (Navy Agreement Number A2003-017-014-00274; NOAA Agreement Number NMFS-PIC-20-002).

Cover: An adult female sperm whale (*Physeter macrocephalus*) and her calf seen in the Mariana Archipelago. A remora fish is visible on the calf's dorsal fin. Photo courtesy of NOAA Fisheries/Mary Applegate (Permit 20311).

Table of Contents

List of Tables

List of Figures

Executive Summary

In summer 2021, the Pacific Islands Fisheries Science Center conducted a comprehensive line-transect survey for cetaceans and seabirds within the United States exclusive economic zones of Guam and the Commonwealth of the Northern Mariana Islands. The Mariana Archipelago Cetacean Survey (MACS) 2021 project was part of the multi-year Pacific Marine Assessment Program for Protected Species (PacMAPPS) plan to conduct surveys and estimate density for cetacean species in regions of joint NOAA Fisheries, Bureau of Ocean Energy Management, and U.S. Navy interest. MACS 2021 sailed for 59 days at sea aboard the NOAA Ship *Oscar Elton Sette* in May–July, 2021, and surveyed 8,711.7 km of trackline. The team conducted visual and passive acoustic surveys during daylight hours when weather permitted. There were 77 cetacean sightings of at least 12 species. The most frequently sighted species during the project were sperm whales (*Physeter macrocephalus*, 18 sightings), false killer whales (*Pseudorca crassidens*, 10 sightings), and pantropical spotted dolphins (*Stenella attenuata*, 8 sightings). Approximately 2,300 photos of 9 cetacean species were collected for individual or species identification during 20 cetacean sightings. Two biopsy samples were collected from false killer whales. During towed array surveys there were 245 acoustic detections of cetaceans, of which 47 were linked to visually sighted groups. Twenty-two Drifting Acoustic Spar Buoy Recorders were deployed and recovered throughout the survey area and will contribute additional information on beaked whale, *Kogia*, and baleen whale distribution and abundance. The seabird observers counted 3,266 individual birds in 1,605 seabird sightings among 29 species (plus 12 additional taxa). The most frequently sighted seabird species included the Sooty Tern (*Onychoprion fuscata*, 654 individuals), Short-tailed Shearwater (*Ardenna tenuirostris*, 547 individuals), and Red-footed Booby (*Sula sula*, 368 individuals). Sixty-eight feeding flocks were observed. Oceanographic sampling was conducted with twice daily CTD casts when conditions permitted, with a total of 79 casts throughout the survey area.

Project Overview

The Mariana Archipelago Cetacean Survey (MACS) 2021 project was a shipboard survey for cetaceans and seabirds around the Mariana Archipelago. MACS 2021 sailed aboard the NOAA Ship *Oscar Elton Sette,* hereafter referred to as the *Sette*, for 59 days at sea. The project was conducted during 2 survey "legs;" Leg 1 sailed 3–31 May and Leg 2 sailed 15 June−14 July.

This project implemented many of the same methods as previous projects conducted by the Pacific Islands Fisheries Science Center (PIFSC), most recently the Winter Hawaiian Islands Cetacean and Ecosystem Assessment Survey in 2020 (Winter HICEAS; Yano et al. 2020) and the Hawaiian Islands Cetacean and Ecosystem Assessment Survey in 2017 (HICEAS; Yano et al. 2018).

PacMAPPS

The MACS 2021 project was conducted as part of the Pacific Marine Assessment Program for Protected Species (PacMAPPS), a partnership between the NOAA Fisheries, Bureau of Ocean Energy Management, and the U.S. Navy. PacMAPPS includes rotational ship surveys in regions of joint interest throughout the Pacific designed to estimate the abundance of cetaceans and seabirds and to assess the ecosystems supporting these species. The previous PacMAPPS surveys include HICEAS 2017, California Current Ecosystem Survey 2018, and Winter HICEAS 2020. The HICEAS project was a collaborative effort between the PIFSC and the Southwest Fisheries Science Centers (SWFSC) and surveyed the U.S. waters surrounding the northwestern and main Hawaiian Islands from July through December 2017. The California Current Ecosystem Survey in 2018, led by the SWFSC, surveyed waters offshore from the U.S. West Coast from June through December (Henry et al. 2020). In 2020, the PIFSC led the Winter HICEAS project that surveyed waters offshore of the main Hawaiian Islands from January through March.

The MACS 2021 project represents the fourth PacMAPPS survey. The final component of the PacMAPPS partnership, led by the Alaska Fisheries Science Center occurred shortly following the completion of MACS 2021, and surveyed waters in the eastern Gulf of Alaska in August 2021 (Crance et al. 2022).

Survey Objectives

The primary goals of MACS 2021 were to collect data required to estimate the abundance and distribution, examine the population structure, and understand the habitat of cetaceans within the U.S. waters around the Mariana Archipelago. The following are 5 major research components to the project:

- Visual observations for cetaceans following a line-transect survey design;
- Passive acoustic monitoring for cetaceans using towed hydrophone arrays, sonobuoys, and autonomous drifting acoustic recorders;
- Collection of photographs and tissue samples for select cetacean groups;
- Visual observations for seabirds following a strip-transect survey design; and
- Ecosystem measurements for assessment of cetacean and seabird habitat.

The planning and execution of MACS 2021 was significantly challenged by the novel coronavirus SARS-CoV2 (COVID-19) global pandemic. COVID-19 mitigation protocols including testing and quarantine required agreement by all participating and supporting agencies and organizations, including NOAA's Office of Marine and Aviation Operations (OMAO), University of Hawaii (UH), Joint Institute for Marine and Atmospheric Research (JIMAR), Azura Consulting LLC, Guam Department of Health and Social Services, and U.S. Naval Base Guam. The scientific party that joined the *Sette* in Guam underwent a 14-day quarantine prior to the start of Leg 1, as required by UH and the Guam government. Staff were tested for COVID-19 on multiple occasions during quarantine, and all science personnel and ship's crew tested negative prior to sailing as required under OMAO's COVID-19 safety protocols. An extended inport between Legs 1 and 2 was necessary to accommodate the *Sette* crew's 6-day rest period (required after 40 or more consecutive days at sea) plus 7 days of required shelter-in-place prior to re-boarding the ship as a part of OMAO's COVID-19 safety protocols. All science party and ship's crew were tested prior to sailing on Leg 2.

The significant additional resources required to cover the cost of the extended quarantine, extended inport, and shelter-in-place were offset by a reduction in seagoing scientific staff and an associated reduction or elimination of some data collection activities. Specifically, unlike previous PacMAPPS surveys in the Pacific Islands, there were no satellite tagging capabilities during MACS 2021. Further, seabird survey effort was reduced by half, with only 1 seabird observer maintaining a periodic 2-hour watch during the survey.

Study Area

The MACS 2021 study area included the waters surrounding the Mariana Archipelago out to 200 nmi (370.4 km) from shore, which is the U.S. exclusive economic zone (EEZ) of Guam and the Commonwealth of the Northern Mariana Islands, hereafter referred to as the Marianas (Figure 1). The chain of 15 islands stretches in a latitudinal arc of approximately 800 km. Most of the human population live on the 4 southernmost islands (Guam, Rota, Tinian, and Saipan). The Mariana Trench Marine National Monument, established in 2009, is made up of the Islands Unit, Trench Unit, and the Volcanic Unit. The Islands Unit includes the waters and submerged islands of the three northernmost islands (Ascuncion, Maug, and Farallon de Pajaros (also known as Uracas)), the Trench Unit encompasses the submarine canyon and surrounding submerged lands extending through the entire Marianas, and the Volcanic Unit of Arc of Fire Refuge includes the submerged lands within 1 nmi of 21 designated volcanic sites.

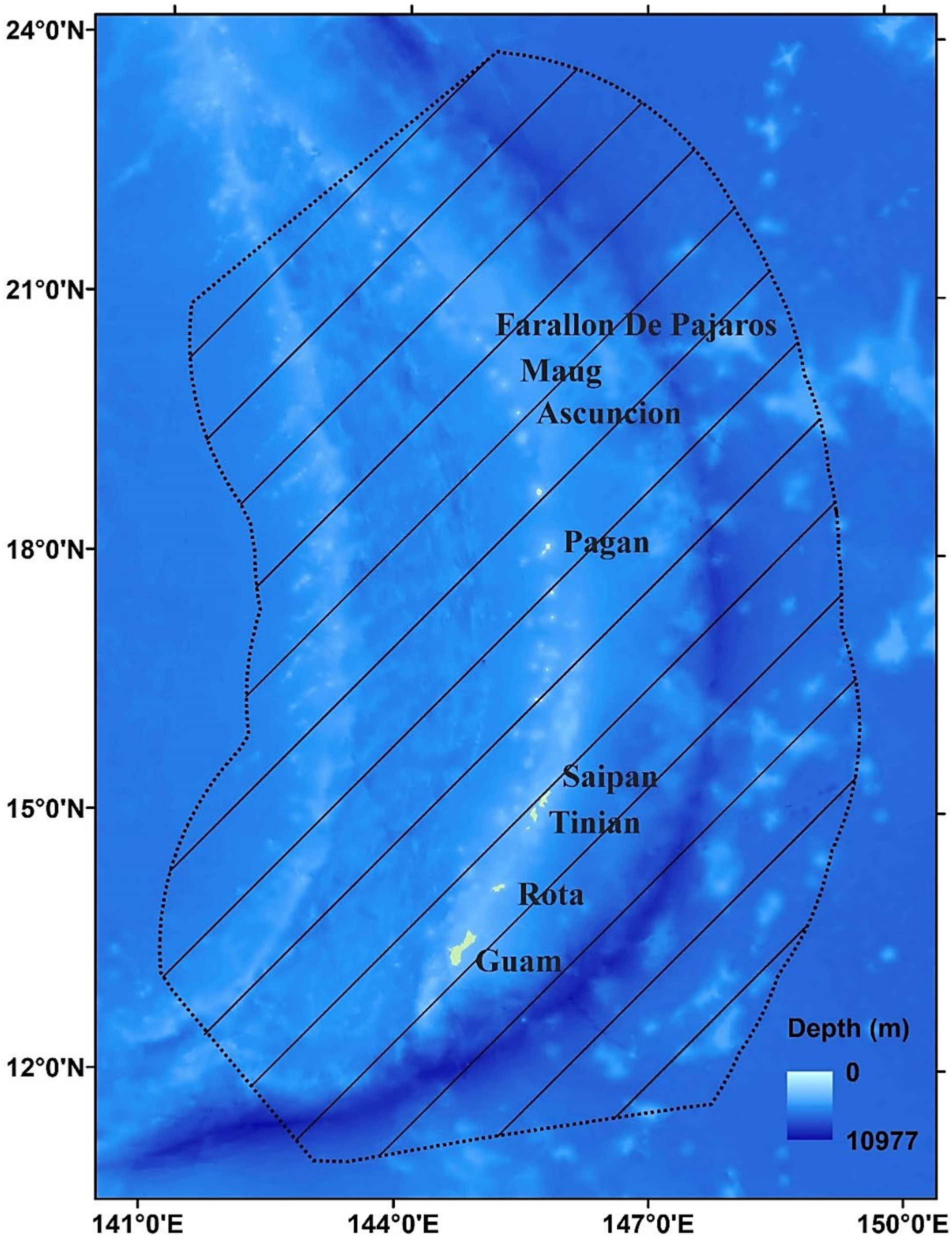

Figure 1. The MACS 2021 study area.

The study area was bounded by the Guam and Commonwealth of the Northern Mariana Islands EEZ (dashed black outline). The parallel transect lines (black lines) formed the basis for the line-transect survey effort.

Prior to MACS 2021, three shipboard visual and passive acoustic cetacean surveys were conducted in the Marianas, with the majority of the survey effort south of Pagan Island. The 2007 Mariana Islands Sea Turtle and Cetacean Survey (MISTCS), conducted by the U.S. Navy Pacific Fleet from January through April 2007, was the first shipboard cetacean survey in the region, and focused on the southern half of the archipelago as well as waters south of the EEZ (Fulling et al. 2011). The PIFSC conducted the MACS 2015 and MACS 2018 projects in May

2015 and July 2018, respectively (Hill et al. 2020). The MACS 2015 study area focused on waters within 50 nmi (93 km) of the entire island chain, whereas the MACS 2018 study area focused on the waters to the west of the islands (from Pagan south). In addition to shipboard surveys, the PIFSC has conducted non-systematic small-boat surveys (partially funded by the U.S. Navy) around the southernmost islands (from Guam to Saipan) during the summer and winter months in 2010–2019 (Hill et al. 2020).

Equipment and Methods

MACS 2021 consisted of visual surveys for cetaceans and seabirds with simultaneous passive acoustic monitoring during daylight hours and oceanographic sampling 1 hr before sunrise and 1 hr after sunset.

Cetacean Survey Operations

Ship-based visual and passive acoustic survey effort for cetaceans generally occurred along parallel transect lines (or tracklines), which were spaced 90 km apart and traversed the study area from WNW to ESE (Figure 1). The full span of an individual transect line required 2 or more days to survey. Nearshore waters around Farallon de Pajaros, Maug, Asunscion, Agrihan, Pagan, Alamagan, Anatahan, and Sarigan were non-systematically surveyed.

Visual Observations

The cetacean visual survey methods used during MACS 2021 have also been used by PIFSC during the HICEAS 2017 and the Winter HICEAS 2020 projects. These methods have been described in detail elsewhere (e.g., Kinzey et al. 2000), and so will be summarized here. A continuous watch for cetaceans was carried out by a team of 6 cetacean observers from the flying bridge of the *Sette* (approximately 15 m above the sea surface) during daylight hours (sunrise to sunset). The observer team rotated through 3 on-effort roles (port and starboard observers and a center observer/data recorder), searching for cetaceans ahead of the vessel from the starboard beam (90° right) to the port beam (90° left) using 25×150 mounted binoculars (port and starboard observers) and 7×50 handheld binoculars or unaided eyes (center observer). Each ship followed the survey tracklines at a speed of 10 kt (18.5 km/h). When glare, rain, or other environmental conditions obscured the view along the trackline, the observer team could request a change in course up to 20° from the established transect. If viewing conditions improved, or if this deviation led the ship to 5 nmi (9.3 km) away from the trackline, the ship was directed to turn back toward the trackline at an angle of 20° or less. During visual search effort, observers rotated every 40 min. At each rotation, the center observer recorded which observers were on watch in each position, as well as basic environmental data (e.g., Beaufort sea state, swell height, visibility). Survey effort was suspended if conditions were unworkable, including periods of heavy precipitation, swell greater than 13 ft (4.0 m) or greater than 10 ft (3.0 m) with a short wave period, or sea state of Beaufort 7 or higher. Each observer worked 2 hr on-effort followed by a 2-hr break.

In most cases, when a cetacean group was sighted within 3 nmi (5.6 km) of the trackline (perpendicular distance) by an on-effort observer, search effort was suspended, and the ship diverted from the trackline toward the sighting so that species identity, species composition (for mixed-species groups), and group size could be determined. If the species identity could not be determined for a sighting, the lowest possible taxonomic category was applied (e.g., unidentified beaked whale, unidentified small dolphin; Appendix B). At the conclusion of each sighting, the on-effort observers recorded their independent estimates of group size ("best," "high," and "low") in their observer logbooks. Estimates of group size were not discussed among observers at any time. Note that group-size estimation protocols varied for 2 species: false killer whales and sperm whales (see Species-specific Protocols). Following group-size estimation, some groups were pursued for additional data collection, including photo-identification or biopsy sampling from the ship's bow. Although a small boat launched from the ship has been used during prior surveys to collect photographs or tissue samples for some species, such operations were not feasible during the project due to limitations with the ship's crane that restricted launches to Beaufort 0–2 and swell height of 5 ft (1.5 m) or less.

Once scientific operations for a sighting were complete, the ship returned to the trackline either at or ahead of the previous sighting location, depending on the area covered by these operations, to avoid repeat survey effort of the same area. The start and end times and locations of transect effort were recorded so that total transect length could be calculated (as needed for density estimation) to accommodate these breaks in search effort.

Visual Effort

The visual team was considered to be on-effort once the 3-person observer team was on the flying bridge actively searching for cetaceans. Survey effort was divided into 2 on-effort categories: standard and non-standard. Standard survey effort occurred when the observer team surveyed for cetaceans along the established parallel transects for the MACS 2021 study area (Figure 1). Non-standard effort was carried out using the same visual survey protocols used during standard effort but did not occur along the standard transect lines. Non-standard effort was search effort that occurred while transiting to and from ports, between transects, or while circumnavigating islands. Any other effort configuration was recorded as off effort. A common off-effort configuration was when observers were on a "weather watch," which occurred when viewing conditions were unworkable (e.g., Beaufort 7 sea state or higher, swell height greater than 13 ft (4.0 m), visibility less than a mile, more than 50% of the horizon obscured), with only the center observer monitoring the weather for improved viewing conditions. Searching that continued during pursuit of a cetacean sighting or feature of interest was also considered to be off-effort.

Visual Survey Data

Data collection by the visual observers follows the same procedures as described in detail in Yano et al. (2018) so it is only briefly summarized here. Search effort, environmental conditions, and cetacean sightings were recorded using the software WinCruz, which also logged the time, latitude, and longitude for each event via connection to the ship's GPS. The program also automatically recorded the GPS location of the ship at a regular time interval (every 2 min). Environmental factors (e.g., sun height and angle, Beaufort sea state, swell height and direction), visibility, and the position of the observers were entered by the center observer at each observer rotation, when effort was resumed following a sighting, or when conditions changed. The bearing and binocular reticle for each sighting were used by WinCruz to calculate the perpendicular distance of the sighting location from the trackline.

For each cetacean sighting, additional sighting information was collected on electronic forms within a FileMaker database running on iPads. Individual iPads were networked to provide real-time access to observers working on the flying bridge, biopsy sampling from the ship's bow, or editing data in the lab. The sighting data form included a variety of data fields allowing cross-reference to the WinCruz record as well as descriptions of the encounter, group composition and behavior, photo details (if collected), and information required for reporting under applicable permits. A linked biopsy sampling form collected details about each biopsy attempt and provided a sample number for use during sample processing.

At the end of each day, the WinCruz data were first checked by the Senior Observers for errors or omissions and then by the Cruise Leader before being backed-up and archived nightly. All electronic sighting form entries were checked and compared to WinCruz data by the Senior Observers and Cruise Leader. At the end of the survey, the data were again reviewed for any errors or inconsistencies, e.g., reviewed observer logbooks to confirm the sighting number, species code, and group size estimates for visual observers, ensured photos and/or biopsy samples were collected and noted for the correct sighting number, double-checked mixed-species and species-specific protocol sightings data were properly formatted, verified survey effort type designations for areas of overlapping trackline, etc.

Photography and Biopsy Sampling

Digital SLR cameras with telephoto zoom lenses (100–400 mm and 70–200 mm) were used for taking photographs from the ship to aid in species identification, individual identification, and health and injury assessment.

Biopsy samples were collected using Barnett RX-150 crossbows and Ceta-Dart bolts with sterilized, stainless steel biopsy tips (25-mm long × 8-mm diameter for small-to-medium odontocetes and 40-mm long × 8-mm diameter for large cetaceans). Tissue samples were stored in separate cryovials and placed in a dewar of liquid nitrogen. At the end of the project, half of each sample was stored in a −80°C freezer at PIFSC for archiving and the other half of each sample was stored in a −80°C freezer at SWFSC for tissue archiving and processing.

Passive Acoustic Operations

Towed Hydrophone Array

Data collection by the acoustics team generally followed the same procedures as described in detail in Yano et al. (2018), so it will be briefly summarized here. A towed hydrophone array was deployed approximately 300 m behind the ship from sunrise to sunset during each day of survey. The array system was made up of a modular towed array (Rankin et al. 2013), SailDAQ soundcard, laptop computers, and PAMGuard software version 2.01.5 (Gillespie et al. 2008). The towed array contained an inline and an end array with a total of 6 HTI-96-min hydrophones and custom-built preamplifiers with combined average measured sensitivity of –144dB ± 5dB re 1V/µPa from 2–100 kHz and approximately linear roll-off to –156dB ± 2 dB re 1V/ µPa at 150 kHz. The hydrophones had strong high-pass filters at 1600 Hz to reduce low-frequency flow noise and ship noise, reducing sensitivity by 10 dB at 1000 Hz. The inline and end arrays also contained a Honeywell depth sensor, with depth recorded every second with a voltage MicroDAQ (max voltage ± 2V). The SailDAQ sampled all 6 channels simultaneously at 500 kHz sample rate and applied 6 dB of gain to the incoming signal from each hydrophone. Hydrophones were spaced 1-m apart within each array section. The inline and end array sections were separated by approximately 30 m of cable.

PAMGuard was set up on multiple laptops to manage data archiving and real-time monitoring of vocalizing cetaceans. PAMGuard interfaces with the SailDAQ to record incoming acoustic data and with the MicroDAQ to record depth data. The PAMGuard logger module was used to record all other real-time metadata about the array, effort type, sightings, and other information arising in the field. The real-time tracking system used a click classification design based on custom specifications (Keating and Barlow 2013) and the whistle and moan detector module to provide angles for tracking cetaceans. In addition, the acoustics team monitored the incoming towed array data for baleen whale calls that could be detected above 1 kHz, including humpback whale (*Megaptera novaeangliae*) calls, minke whale (*Balaenoptera acutorostrata*) "boings," and Bryde's whale (*Balaenoptera edeni*) "biotwangs" and other calls (e.g., "growls," Edds et al. 1993) during all daytime effort. Every 30 min, the presence (none, one animal, 2 or more animals) of each species calls was recorded.

Attribution of sounds to a specific species was generally limited to those acoustic detections with a concurrent visual sighting of the same group, with a few exceptions. Clicks produced by sperm whales are well described and were readily identifiable by the acoustics team and were identified to species in real-time. Species-specific upswept clicks commonly produced by beaked whale species were also identified in real-time and were assigned a species classification when they matched to a described type (Baumann-Pickering et al. 2014). During some encounters with other species, the acoustics team may have felt confident they were detecting a specific species, but without visual verification of species identity, those encounters were labeled following the same rubric used by the visual team (i.e., unidentified large dolphin includes false killer whales, short-finned pilot whales (*Globicephala macrorhynchus*), and killer whales (*Orcinus orca*); Appendix B). When available, species level attributions from the acousticians were recorded in the detailed metadata for the individual detection, but are not reflected as the official species determination.

Acoustic Effort

Two acousticians monitored incoming data during the day and were occasionally assisted by a third acoustician during acoustic detections of false killer whales. Each acoustician worked 3-hr on-effort followed by a 90-min break. During daytime effort, acoustic detections of vocal cetaceans were localized in real-time using PAMGuard. For most acoustic detections, the acoustics team did not provide information about detected species to the visual team to avoid cuing the visual observers to animal presence during on-effort search periods.

Sonobuoys

Directional Fixing and Ranging (DIFAR) type 53G sonobuoys provided by the U.S. Navy were deployed during baleen whale sightings when the ship approached the group within 1 nmi. The VHF signal from the sonobuoy was received at the ship using an omni-directional VHF antenna cabled into a WinRadio that was set to the VHF frequency specified for an individual sonobuoy. The signal from the WinRadio was digitized at a 48 kHz sample rate with an RME Fireface UC soundcard and fed into a Dell desktop computer where it was recorded for later analysis using PAMGuard v. 2.01.05. Only the low-frequency portion (0–3000 Hz) of the signal was monitored in real-time.

Species-specific Protocols

Modified data collection protocols were implemented for false killer whales and sperm whales because significant differences in their social or diving behavior, respectively, necessitated more detailed data-collection approaches. These data-collection protocols that were implemented are summarized as follows, with each protocol included in its entirety as an appendix to this report.

False Killer Whales

PIFSC has used a specific 2-phase data-collection protocol for false killer whales since 2011. The protocol is intended to align our assessment of false killer whale encounter rate with the tendency of this species to associate in small coordinated subgroups often spread over tens of miles. Individual subgroups are recorded as separate visual detections using the subgroup functionality within WinCruz.

In brief, Phase 1 focused on the detection of false killer whale subgroups. It was initiated when either the visual or acoustics teams detected false killer whales. During this phase, the ship continued along the trackline in passing mode until all false killer whale subgroups were beyond the beam of the ship. Primary observers recorded subgroup-size estimates if they felt they had a good look at an individual subgroup. Secondary (off-effort) observers assisted with collecting subgroup-size estimates during Phase 1. During Phase 2, the ship was directed to go back through the center of the group so that observers could determine sizes for as many subgroups as possible.

Recent examination of subgroup sizes collected during Phase 1 and Phase 2 from 2011 to 2017 PIFSC shipboard surveys indicated that these subgroup sizes were similar and that there was no bias in subgroup sizes reported during the passing mode in Phase 1 (Bradford et al. 2020). For this reason, if subgroup size estimates were collected during Phase 1 of a given sighting, Phase 2 was skipped.

For more detailed information on the False Killer Whale Protocol, see Appendix C.

Sperm Whales

Sperm whales can be spread over several miles and commonly contain smaller subgroups. Within a group, these subgroups commonly exhibit asynchronous dive behavior, with each subgroup diving for 20–60 min followed by an 8–12 min surface period. Extended group counts are necessary because of the asynchrony and long durations of these dives.

When a sperm whale group was sighted, the acoustics team was alerted. If the acoustics team reported that they had detected and localized the sighted group, then the visual team went off-effort and turned toward the sperm whale group to initiate the Sperm Whale Protocol, which involved an extended group-size count. If the acoustics team had not localized the sighted group, effort continued along the trackline until the sighted group was past the beam or until the acoustics team reported that they had localized the sighted group. If the visual team thought that the group contained only a single individual, they could request confirmation from the acoustics team. Upon such confirmation, the extended count was skipped. If the acoustics team detected more than 1 animal within 3 nmi (5.6 km) perpendicular distance from the trackline an extended group-size count was initiated after all animals passed the beam. In addition, for acoustic-only detections of a single sperm whale a minimum of a 20° turn was conducted to resolve left/right ambiguity for post-processing analyses.

From the time of the sighting, or when informed of the acoustic detection, the observer team recorded overall group size estimates at 3 intervals. The on-effort visual team independently recorded their group-size estimates after 10 min, at which time the fourth observer joined the team. After 60 min of observation with the 4-person team, observers independently recorded overall group size again. During this period, the team openly discussed the location, behavior, composition, and size of individual subgroups, and used that information to track individual subgroups through dive cycles. Finally, for the first sperm whale group sighting of each day, the observer team continued observation for another 30 min to record individual 90-min overall group size estimates. Extended counts were not conducted for all sperm whale sightings during MACS 2021 to ensure daily trackline progress. The collection of 60- and 90-min counts may be used to assess bias in group size estimates that may arise given long dive cycles for this species.

For more detailed information on the Sperm Whale Protocol, see Appendix D.

Seabird Observations

Seabird observers collected 2 separate data sets: (1) seabird distribution and abundance; and (2) seabird flock distribution, abundance, composition, and behavior.

Seabird Distribution and Abundance

Seabird distribution and abundance data were collected using strip-transect methods (Ballance 2007) and a default strip width of 300 m. The strip width was modified according to an “Observation Conditions” code. The seabird observer searched the forequarter, from directly in front of the ship to the beam on the side with best visibility conditions out to 300 m and recorded seabirds (and other animals or objects of interest) entering this area in real-time. The seabird observer used a hand-held binoculars ranging from 8× to 20× power to identify birds. Radial distance from the ship to individual birds entering the quadrant was estimated using a range-calibrating device based on Heinemann (1981).

Data were recorded in the form of strip transects, defined as a period of effort during which all observation conditions were constant and the ship sailed on the predetermined trackline. A transect ended each time conditions changed (e.g., change in seabird observer, ship’s course, sea state, side of ship), and a new transect would begin.

Weather permitting, data were collected between just after sunrise until just before sunset each day. This survey had 1 seabird observer who worked a 2-h rotating shift (on/off). In sea states above Beaufort 7, heavy fog, rain, or any other conditions that significantly impaired visibility, the seabird survey would be suspended until conditions improved. Seabird survey effort was also suspended when the ship closed on a cetacean sighting.

Data were collected from a station at the front of the *Sette*’s flying bridge and entered using SeeBird software. The software recorded date, time, and location of seabird sightings from the ship’s scientific computer system. Species identification, radial distance from the ship, flight direction, and behavior were entered manually by the seabird observer during the sighting. Environmental data (e.g., wind speed and direction) and factors affecting visibility were manually entered when conditions changed or the seabird observer resumed effort.

Distribution, Abundance, and Composition of Seabird Feeding Flocks

Flocks of seabirds operate over very large spatial scales, and because many of the species in them (as well as the fish and mammals that are often beneath the surface) actively avoid the ship, the 300-m strip transect method does not accurately survey for them. A separate strip-transect survey for flocks is conducted using the high-powered mounted binoculars and the mammal observers, who survey for flocks simultaneously with their survey for mammals. Data to quantify distribution, abundance, behavior, and composition of seabird flocks were collected using strip-transect methods and a strip width out to 1 reticle on either side of the ship was employed. Flock data were entered into the computer for any group containing 5 or more feeding birds (not commuting/traveling or sitting). The seabird observer then used mounted 25× power binoculars to quantify flock size and species composition. Effort data for seabird feeding flock data are matched to the cetacean effort data. Seabird flock data collected in SeeBird included time, angle, and radial distance to the flock, species identification, and flock behavior. If a feeding flock of birds entered the 300-m zone while on effort, the flock was entered in both the seabird strip transect and flock data programs.

Ecosystem Sampling

When weather and sea conditions permitted, 2 CTDs were conducted daily: 1 h before sunrise and another 1 h after sunset. Some CTD stations were omitted due to time constraints or proximity to the previous station. The CTD was cast to 1000 m (or to within 100 m of the seafloor if at depths shallower than 1000 m). The CTD sampled temperature, salinity, dissolved oxygen, and fluorescence from the ocean surface to depth. The CTD was equipped with a WetLab profiling and Seapoint flow-through fluorometer and redundant dissolved oxygen sensors. Cast descent rates were 30 m/min for the first 100 m of the cast and then 60 m/min after that, including the upcast. No water samples were collected during CTD casts.

Autonomous Drifting Acoustic Recorders

The Drifting Acoustic Spar Buoy Recorders (DASBRs) used during this survey were redesigned in 2018 and modified in 2020 by the PIFSC Science Operations Division's Advanced Tech program, now called the Marine and Applied Knowledge for Ecosystem Research Laboratory (MAKER Lab) (McCullough et al. 2021). The buoy included a PVC spar surface buoy housing a NAL Research Iridium transmitter. The spar buoy was constructed to survive vessel collisions and to pose no hazards to navigation. The Iridium transmitter provided real-time updates of the buoy location via email, allowing for both recovery of the buoy and GPS tracking of its drift. Each DASBR included 2 hydrophones, separated by 10 m, forming a short vertical array at ~150-m depth (Figure 2). The acoustic data were logged on an Ocean Instruments SoundTrap ST4300-HF recorder. The SoundTrap acoustic data were duty cycled, recording 2 of every 10 min, and were sampled at a rate of 384 kHz.

Tri-axial accelerometer and depth data were also logged using the SoundTrap's built-in accelerometer and a Lotek LAT time-depth recorder. The accelerometer data are used to calculate the tilt angle of the hydrophone array in the water, an essential measure for calculating the correct depth and distance of a vocalizing cetacean.

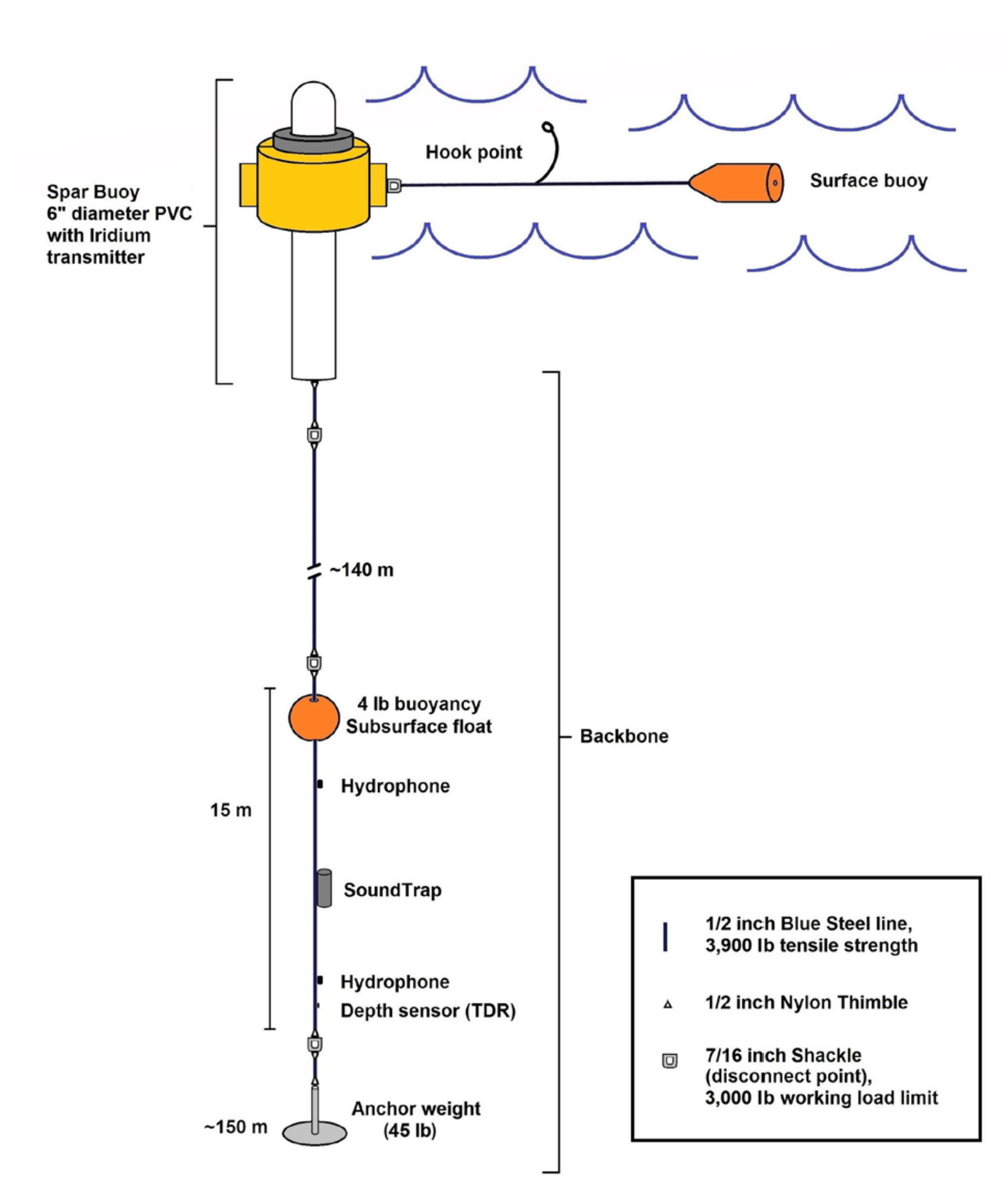

Figure 2. Schematic of the Drifting Acoustic Spar Buoy Recorder (DASBR) instrument used during MACS 2021.

DASBRs have several unique capabilities not available in the other acoustic systems; they were used to listen for cetaceans throughout the Marianas. DASBRs recorded across a broad frequency range, which enabled the detection of most cetacean species, from baleen whales to *Kogia*. DASBRs could more intensively survey an area after the ship left and could detect animals that may have avoided passing ships. The primary use for DASBRs was to augment cetacean encounter rates, primarily for deep-diving beaked whales and *Kogia* species, which are infrequently encountered during shipboard surveys (McCullough et al. 2021). These species are especially hard to see, particularly during marginal or poor weather, and are often difficult to approach for species identification when they are seen.

DASBR deployment locations were chosen with a goal of representatively sampling all regions of the study area while reducing disruption to daytime survey operations. Deployments primarily occurred prior to or after daytime effort, although recoveries could occur at any time of day depending on DASBR location.

Ancillary Projects

Several ancillary projects were conducted during this survey. Ancillary projects included opportunistic sampling or instrument servicing that could be accomplished while the ship was in a particular region or at specific times of interest during the course of the survey. Such ancillary projects included recovery and deployment of 2 High-Frequency Acoustic Recording Packages (HARPs) at offshore locations near Saipan and Pagan within the Pacific Islands Passive Acoustic Network. Ancillary projects are not discussed further in this report, as they are generally part of other larger sampling efforts or unique projects that will be described in partner reports or papers.

Results and Discussion

Cetacean Survey

Visual Effort and Sightings

Marine mammal surveys were conducted during all daylight hours on each day that weather and sea conditions permitted. During 56 of 59 days at sea, the *Sette* surveyed 8,711.7 km of on-effort trackline across all effort categories (Figure 3, Table 1).

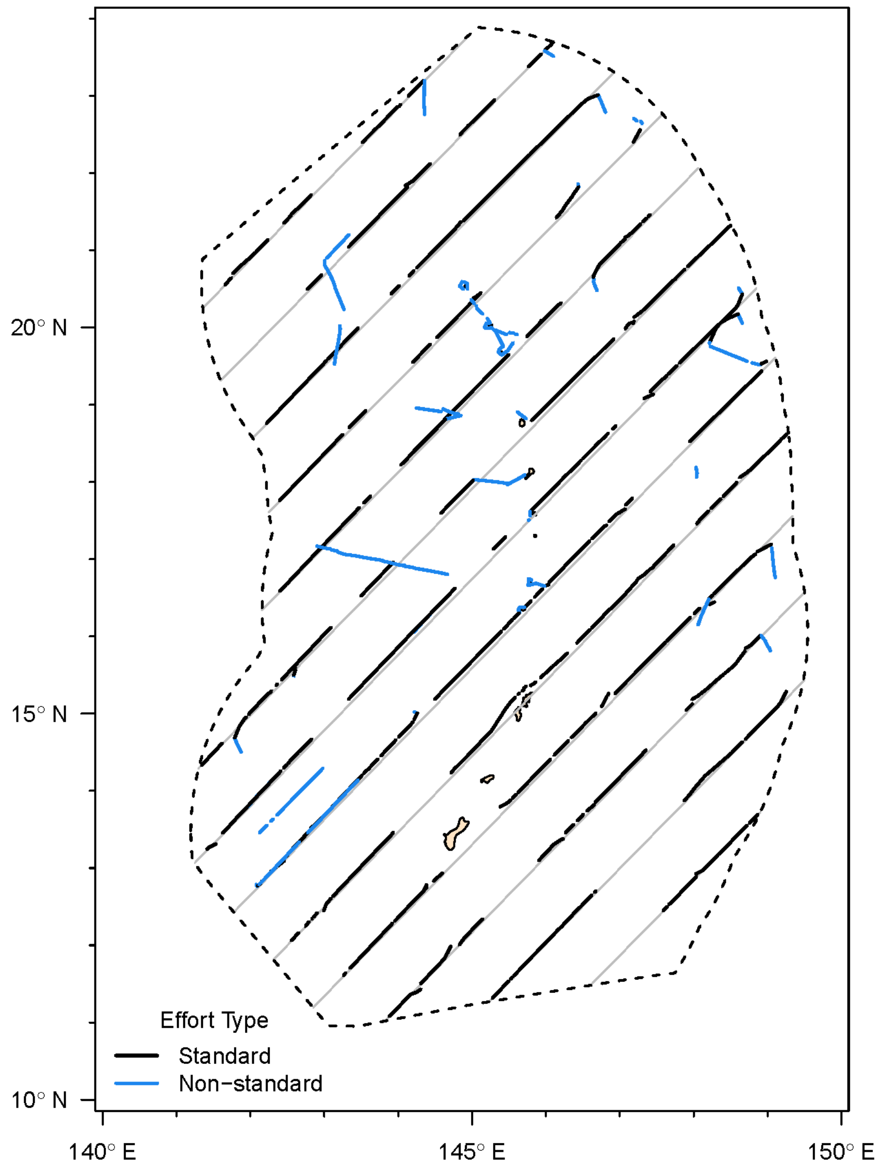

Figure 3. Daytime visual effort.

The visual effort (standard in black and non-standard in blue) overlays the established parallel transects (gray lines). Standard survey effort occurred when the observer team surveyed for cetaceans along predetermined tracklines (gray lines, also shown in Figure 1). Non-standard effort was carried out using the same visual survey protocols used during standard effort but did not occur along the standard transect lines. The Marianas study area is marked by the dashed black outline.

Table 1. Summary of survey effort (km) by Beaufort sea state.

Beaufort Sea State	Effort (km) Standard	Non-standard	TOTAL
1	20.2	0	20.2
2	163.6	0	163.6
3	838.2	90.5	928.7
4	1919.2	444.4	2363.6
5	2399.5	473.8	2873.3
6	1813.7	548.6	2362.3
TOTAL	**7154.4**	**1557.3**	**8711.7**

There were 77 cetacean sightings during MACS 2021, including at least 12 cetacean species (Table 2, Appendix A). The most frequently sighted species during the project were sperm whales (18 sightings), false killer whales (10 sightings), and pantropical spotted dolphins (8 sightings). There was 1 mixed-species sighting of pantropical spotted dolphins with striped dolphins (*Stenella coeruleoalba*). Weather and sea conditions likely contributed to the high number of sightings of "unidentified" species; observers sighted 3 groups of "unidentified *Mesoplodon* spp.," 5 groups of "unidentified rorquals," 10 groups of "unidentified whales," and 12 groups of "unidentified dolphins."

Approximately 2,300 photos of 9 cetacean species were collected during 20 sightings. Two tissue samples were collected during 2 sightings of false killer whales.

No small boats were launched from the *Sette*.

Table 2. Summary of cetacean species sighted across all effort types (standard, non-standard, and off).

The mixed species sighting (striped dolphins with pantropical spotted dolphins) are counted once for each species, such that the total number of sightings in this table does not match the total number of group sightings for the project (n=77).

Cetacean Species			**Effort**			**Total**
Code	Scientific Name	Common Name	Standard	Non-standard	Off	**Groups**
002	*Stenella attenuata*	pantropical spotted dolphin	5	2	1	8
013	*Stenella coeruleoalba*	striped dolphin	1	0	0	1
015	*Steno bredanensis*	rough-toothed dolphin	1	0	0	1
018	*Tursiops truncatus*	bottlenose dolphin	1	0	0	1
032	*Feresa attenuata*	pygmy killer whale	1	0	0	1
033	*Pseudorca crassidens*	false killer whale	4	2	4	10
036	*Globicephala macrorhynchus*	short-finned pilot whale	1	0	1	2
046	*Physeter macrocephalus*	sperm whale	9	6	3	18
048	*Kogia sima*	dwarf sperm whale	0	0	1	1
051	*Mesoplodon* sp.	unidentified *Mesoplodon*	1	1	1	3
061	*Ziphius cavirostris*	Cuvier's beaked whale	0	2	0	2
065	*Indopacetus pacificus*	Longman's beaked whale	1	0	0	1
070	*Balaenopterid* sp.	unidentified rorqual	3	0	0	3
077	----	unidentified dolphin	3	1	0	4
078	----	unidentified small whale	4	0	0	4
079	----	unidentified large whale	3	1	0	4
098	----	unidentified whale	0	1	1	2
102	*Stenella longirostris*	Gray's spinner dolphin	1	0	1	2
177	----	unidentified small delphinid	4	1	0	5
199	*Balaenoptera physalus/borealis/edeni*	fin/sei/Bryde's whale	1	1	0	2
277	----	unidentified medium delphinid	0	1	0	1
377	----	unidentified large delphinid	2	0	0	2
		TOTAL	**46**	**19**	**13**	**78**

Passive Acoustics

Towed array surveys were conducted during daylight hours on each day of the survey that weather and sea conditions permitted. During MACS 2021, there were 245 acoustic detections of separate cetacean groups during daytime monitoring of the towed hydrophone array (Figure 4). Of the 245 towed array detections, 47 were linked to visually sighted groups (Table 3). Paired visual sighting and acoustic detection data provided visual confirmation of species identification of detected sounds for 10 cetacean species. A humpback whale was detected on 4 May, the first day of survey effort near Anatahan. Minke whale “boings” and Bryde’s whale “biotwangs” were not detected during MACS 2021. Bryde’s whale “growl” calls were detected on 3 occasions during Leg 2.

Fifteen sonobuoys were deployed during the survey (Figure 5). All sonobuoys were deployed opportunistically during baleen whale sightings to assist the visual observers in species identification. Whale calls were detected on 6 sonobuoy deployments, including 5 with Bryde’s whale “growl” calls, and one with low-frequency sounds that could not be identified to species.

Twenty-two DASBRs were deployed and recovered during MACS 2021. One DASBR became detached from its anchor and drifted with the hydrophones near the surface. DASBR tracks are shown in Figure 6 and deployment and recovery details are provided in Appendix E. DASBR data will be processed for occurrence of a variety of vocal cetacean species.

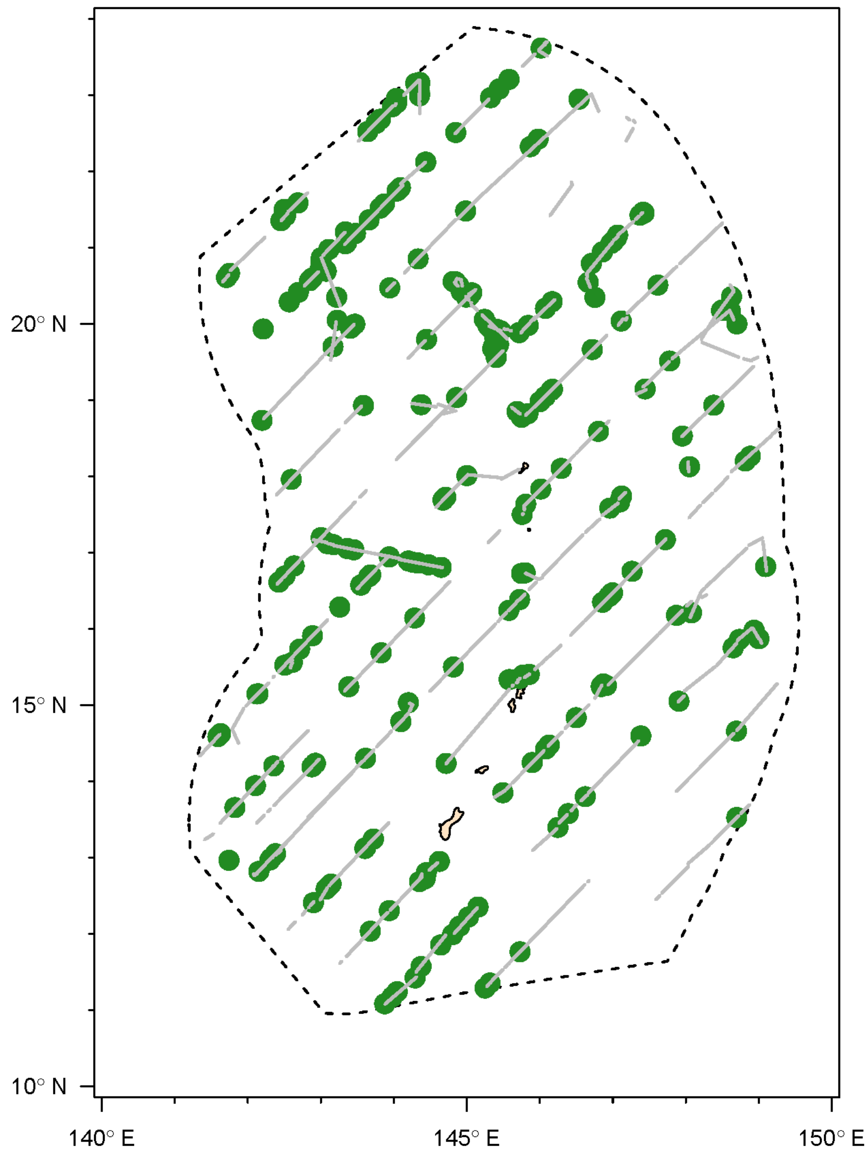

Figure 4. Locations of real-time acoustic detections of cetaceans on the towed array.

Acoustic detections of cetaceans are indicated by green circles. Gray lines are visual survey effort. The Marianas study area is marked by the dashed black outline.

Table 3. Comparison of cetacean species sighted and acoustically detected on the towed array during daylight hours.

For mixed species encounters, species sighting/detections are reported individually. The (-) in the Acoustics Only column indicate that the data have not been assessed for a particular species.

Code	Scientific Name	Common Name	Concurrent Visual & Acoustic	Visual Only	Acoustic Only
002	*Stenella attenuata*	pantropical spotted dolphin	7	1	-
013	*Stenella coeruleoalba*	striped dolphin	1	0	-
015	*Steno bredanensis*	rough-toothed dolphin	1	0	-
018	*Tursiops truncatus*	bottlenose dolphin	1	0	-
032	*Feresa attenuata*	pygmy killer whale	1	0	-
033	*Pseudorca crassidens*	false killer whale	9	1	-
036	*Globicephala macrorhynchus*	short-finned pilot whale	2	0	-
046	*Physeter macrocephalus*	sperm whale	16	3	60
048	*Kogia sima*	dwarf sperm whale	0	1	-
051	*Mesoplodon* sp.	Mesoplodon beaked whale	0	3	0
059	*Mesoplodon densirostris*	Blainville's beaked whale	0	0	19
061	*Ziphius cavirostris*	Cuvier's beaked whale	0	2	12
065	*Indopacetus pacificus*	Longman's beaked whale	1	0	1
070	*Balaenoptera* sp.	unidentified rorqual	0	3	-
077	----	unidentified dolphin	2	1	77
078	----	unidentified small whale	-	4	-
079	----	unidentified large whale	-	4	-
096	----	unidentified cetacean	0	0	1
098	----	unidentified whale	0	2	-
102	*Stenella longirostris*	spinner dolphin	2	0	-
177	----	unidentified small delphinid	1	4	7
199	*B. physalus/borealis/edeni*	fin/sei/Bryde's whale	0	2	-
277	----	unidentified medium delphinid	1	0	4
377	----	unidentified large delphinid	2	1	20
		TOTAL	**47**	**32**	**201**

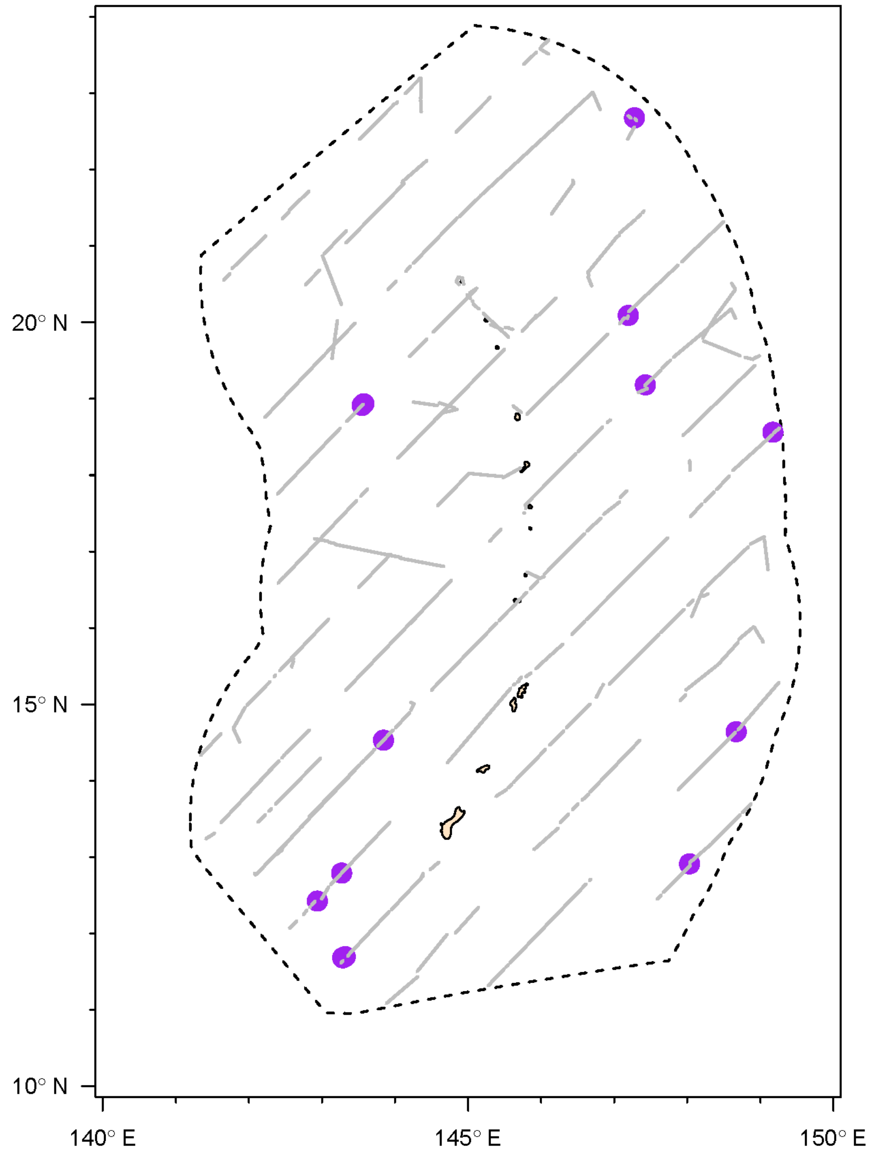

Figure 5. Locations of 15 sonobuoys deployed in the Marianas.

Sonobuoy deployments are indicated by purple circles. Gray lines are visual survey effort. The Marianas study area is marked by the dashed black outline.

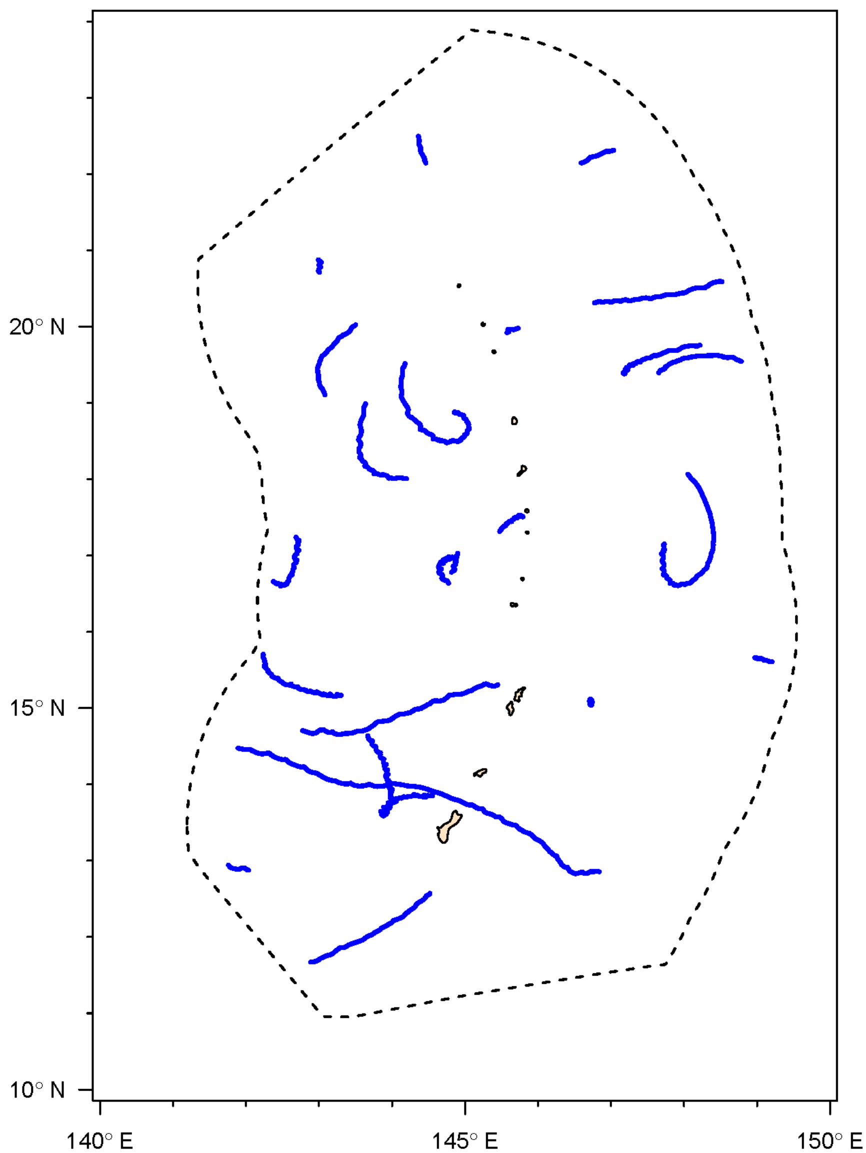

Figure 6. Tracklines of 22 DASBRs deployed in the Marianas.

DASBR tracks in dark blue represent the recording period for 22 deployed and retrieved units; deployment and recovery details are provided in Appendix E. The Marianas study area is marked by the dashed black outline.

Seabird Survey

During MACS 2021, the seabird observers counted 3,266 individual birds in 1,605 seabird detections among 29 species, plus 12 additional taxa (Table 4). All except 2 sightings were marine species: a Cattle Egret on Leg 1 and an unidentified hawk, characteristic of the genus *Buteo*, on Leg 2.

Nearly matching hours were spent on each leg conducting on-effort sightings. Leg 1 on-effort hours were 145.8 hr between 3 and 30 May and Leg 2 on-effort hours were 141.5 hr between 15 June and 13 July. On both legs, between 4 and 13 species were seen daily and the highest diversity occurred near islands, especially during the island circumnavigations on Leg 2. Twenty-four and 23 species were seen respectively on Legs 1 and 2.

The strip-transect seabird data collected on this survey documented changes in seabird distribution and abundance as the season progressed from late spring to mid-summer. Three species of birds made up almost half (48.1%) of all birds counted: Sooty Tern (20.0%), Short-tailed Shearwater (16.8%), and the Red-footed Booby (11.3%).

Sixty-eight seabird feeding flocks were observed during MACS 2021. The seabird observers counted 33 flocks on Leg 1 comprising 16 species and 35 flocks on Leg 2 comprising 14 species.

Sooty Tern were sighted throughout the survey, on 45 out of 56 survey days, however, the vast majority were seen during Leg 1 (83.0%). Short-tailed Shearwater were observed chiefly between 5 and 22 May although a few stragglers were seen as late as 1 July. Leg 1 coincided with one of the most remarkable of trans-equatorial bird migrations, the Short-tailed Shearwater. The population moves north to the Bering Sea, where the birds spend the boreal summer. The Red-footed Booby was sighted regularly throughout the survey but was more dominant on Leg 2 (69.6%). The seabird observer counted 106 Red-footed, 62 Masked, and 117 Brown booby birds on 11 July, making it an especially great day for booby species.

Several other species are worth noting. Bryan's Shearwater was seen twice, on 20 June for the first time and again on 2 July. A subspecies of the Brown Booby, *brewsteri*, was seen on both legs. The birds were very far west of their range in the eastern Tropical Pacific. On 7 July, Hutton's Shearwater was seen about 200 nmi (370 km) east of Asunción Island, about 3,000 nmi (5,556 km) from its range in Australia and New Zealand waters.

Table 4. Number of seabirds sighted within the 300-m strip transect.

Scientific Name	Common Name	Total Sightings	Total Birds Counted
Stercorarius maccormicki	South Polar Skua	1	1
Stercorarius pomarinus	Pomarine Jaeger	1	2
Stercorarius parasiticus	Parasitic Jaeger	3	3
Stercorarius longicaudus	Long-tailed Jaeger	1	1
Anous stolidus	Brown Noddy	52	348
Anous minutus	Black Noddy	22	143
Gygis alba	White Tern	163	244
Onychoprion fuscata	Sooty Tern	143	654
Onychoprion lunata	Gray-backed Tern	3	5
Onychoprion anaethetus	Bridled Tern	1	2
Sterna sumatrana	Black-naped Tern	1	1
Sterna (?) sp.	Unidentified tern	2	2
Phaethon lepturus	White-tailed Tropicbird	37	41
Phaethon rubricauda	Red-tailed Tropicbird	18	19
Phaethon sp.	Unidentified tropicbird	4	4
Oceanodroma matsudairae	Matsudaira's Storm-Petrel	52	54
Oceanodroma tristrami	Tristram's Storm-Petrel	1	1
Oceanodroma sp.	Unidentified storm-petrel	1	1
Pterodroma cervicalis	White-necked Petrel	8	9
Pterodroma hypoleuca	Bonin Petrel	1	1
Pterodroma sp.	Unidentified *Pterodroma*	1	1
Bulweria bulwerii	Bulwer's Petrel	61	63
Calonectris leucomelas	Streaked Shearwater	2	2
Ardenna pacificus	Wedge-tailed Shearwater (light morph)	161	283
Ardenna pacificus	Wedge-tailed Shearwater (intermediate morph)	2	2
Ardenna pacificus	Wedge-tailed Shearwater (dark morph)	34	77

Scientific Name	Common Name	Total Sightings	Total Birds Counted
Ardenna griseus	Sooty Shearwater	7	8
Ardenna tenuirostris	Short-tailed Shearwater	360	547
Ardenna griseus/A. tenuirostris	Sooty/Short-tailed Shearwater	3	3
Puffinus nativitatis	Christmas Shearwater	3	3
Puffinus huttoni	Hutton's Shearwater	1	1
Puffinus bryani	Bryan's Shearwater	2	2
Puffinus sp.	"Manx-Type" Shearwater	2	2
Puffinus sp.	Unidentified Shearwater	8	8
Fregata minor	Great Frigatebird	14	28
Fregata sp.	Unidentified frigatebird	1	1
Sula dactylatra	Masked Booby	63	96
Sula leucogaster	Brown Booby	116	226
Sula	Red-footed Booby	246	368
----	Shorebird	1	7
----	Unidentified bird (non-marine and non-passerine)	2	2
	TOTAL	**1,605**	**3,266**

Ecosystem Sampling

A total of 79 CTD casts were conducted during MACS 2021 (Figure 7).

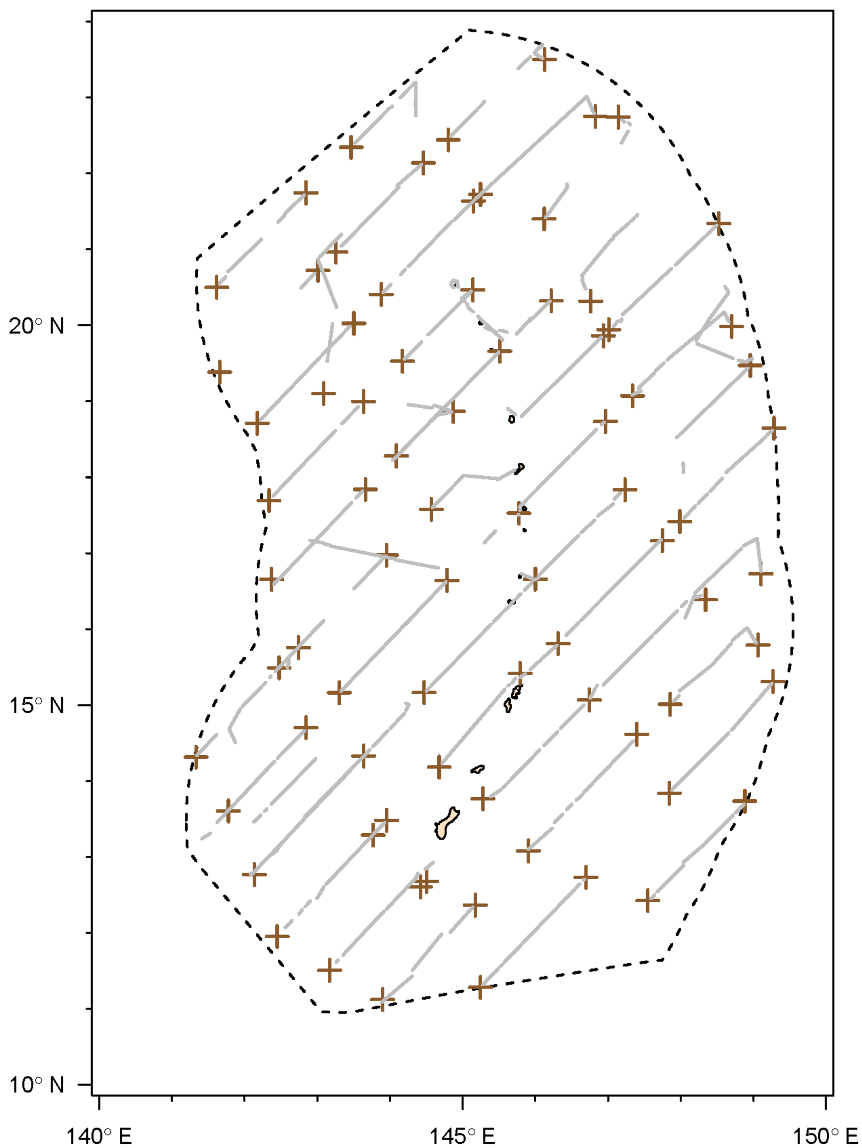

Figure 7. Locations of CTD casts conducted in the Marianas.

The location of CTD casts are marked with a brown plus symbol (+) and typically mark the start and end of a survey day's visual effort (gray lines). The Marianas study area is marked by the black dash outline.

Acknowledgments

MACS 2021 was executed with funding from PIFSC and PacMAPPS partner, the U.S. Navy Pacific Fleet Environmental Readiness Division (IAA NMFS-PIC-20-002). Additional funding required for COVID-19 mitigation (staff quarantines, testing, etc.) was provided by the NMFS Office of Science and Technology. Ship time aboard the *Sette* was provided by PIFSC. The Chief Scientist was Marie Hill, the Cruise Leaders were Marie Hill (Leg 1) and Erin Oleson (Leg 2), the Seabird Coordinator was Annette Henry, and the MACS Survey Coordinator was Kym Yano. Many observers, acousticians, and the officers and crew of the *Sette* made the survey possible and a success during unprecedented circumstances. Significant appreciation is also extended to PIFSC administrative and Science Operations Division staff (including Stephanie Garnett, Andrew Choy, Nori Shoji, Kyle Koyanagi, Sujuan Situ, Tanya Ochoa, Eric Cruz, and Jeremy Taylor) for ensuring MACS 2021 success through their assistance with funding agreements, contracts, permits, technical support, and ship and logistic coordination. In addition, the Guam Department of Public Health and Social Services (Nicole Tydingco, Kane Agan, and the on-site nurses) and the Guam National Guard deserve immense gratitude for organizing, managing, and operating the 2-week quarantine and COVID-19 testing on Guam prior to the start of MACS 2021 Leg 1. Thank you to Julie Rivers, Jessica Chen, and Chip Johnson for their insightful suggestions and editorial comments. Cetaceans were approached and sampled under NMFS MMPA-ESA take permit 20311. All seabird research was conducted under U.S. Fish and Wildlife Service Migratory Bird permit 033305-0.

Literature Cited

Ballance LT. 2007. Understanding seabirds at sea: why and how? Marine Ornithology 35:127-135.

Baumann-Pickering S, Roch MA, Brownell RL Jr, Simonis AE, McDonald MA, Solsona-Berga A, Oleson EM, Wiggins SM, Hildebrand JA. 2014. Spatio-temporal patterns of beaked whale echolocation signals in the North Pacific. PLoS ONE 9(1): e86072. https://doi.org/10.1371/journal.pone.0086072

Bradford AL, Becker EA, Oleson EM, Forney KA, Moore JE, Barlow J. 2020. Abundance estimates of false killer whales in Hawaiian waters and the broader central Pacific. U.S. Department of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-104, 78 p. https://doi.org/10.25923/2jjg-p807

Crance JL, KT Goetz, RP Angliss. 2022. Report for the Pacific Marine Assessment Program for Protected Species (PacMAPPS) 2021 field survey. Submitted to the U.S. Navy Marine Species Monitoring Program, MIPR No. N00070-21-MP-0E115. Prepared by Alaska Fisheries Science Center, Seattle, Washington. February 2022. 21 p.

Edds P, Odell PK, Tershy BR. 1993. Vocalizations of a captive juvenile and free-ranging adult-calf pairs of Bryde's whales, *Balaenoptera edeni*. Mar. Mamm. Sci. 9(3):269-284. https://doi.org/10.1111/j.1748-7692.1993.tb00455.x

Fulling GL, Thorson PH, Rivers J. 2011. Distribution and Abundance Estimates for Cetaceans in the Waters off Guam and the Commonwealth of the Northern Mariana Islands. Pacific Science 65(3):321–343. https://doi.org/10.2984/65.3.321

Gillespie D, Gordon J, McHugh R, McLaren D, Mellinger DK, Redmond P, Thode A, Trinder P, Deng XY. 2008. PAMGUARD: Semi-automated, open source software for real-time acoustic detection and localisation of cetaceans. Proc. Inst. Acoust. 30(5), 9 p. https://doi.org/10.1121/1.4808713

Heinemann D. 1981. A range finder for pelagic bird censusing. J. Wildl Manage. 45(2): 489–493.

Henry AE, Moore JE, Barlow JP, Calambokis J, Ballance LT, Rojas-Bracho L, Urbán-Ramírez J. 2020. Report on the California Current Ecosystem Survey (CCES): Cetacean and Seabird Data Collection Efforts, June 26 – December 4, 2018. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-636. 36 p. https://doi.org/10.25923/0wyw-s486

Hill MC, Oleson EM, Bradford AL, Martien KK, Steel D, Baker S. 2020. Assessing cetacean populations in the Mariana Archipelago: A summary of data and analyses arising from Pacific Islands Fisheries Science Center surveys from 2010 to 2019. U.S. Department of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-108, 98 p. https://doi.org/10.25923/wrye-6h14

Keating JL, Barlow J. 2013. Summary of PAMGUARD beaked whale click detectors and classifiers used during the 2012 Southern California Behavioral Response Study. U.S. Department of Commerce, NOAA Technical Memorandum, NOAA-TM-NMFS-SWFSC-517, 17 p. https://repository.library.noaa.gov/view/noaa/4535

Kinzey D, Olson P, Gerrodette T. 2000. Marine mammal data collection procedures on research ship line-transect surveys by the Southwest Fisheries Science Center. U.S. Department of Commerce, Administrative Report LJ-00-08, 32 p.

McCullough JLK, Wren JLK, Oleson EM, Allen AN, Siders ZA, Norris ZA. 2021. An acoustic survey of beaked whales and Kogia spp. in the Mariana Archipelago using drifting recorders. Front. Mar. Sci. 8:664292. https://doi.org/10.3389/fmars.2021.664292

Rankin S, Barlow J, Barkley Y, Valtierra R. 2013. A guide to constructing hydrophone arrays for passive acoustic data collection during NMFS shipboard cetacean surveys. U.S. Department of Commerce, NOAA Technical Memorandum. NOAA-TM-NMFS-SWFSC-511, 33 p. https://repository.library.noaa.gov/view/noaa/4443

Yano KM, Oleson EM, Keating JL, Ballance LT, Hill MC, Bradford AL, Allen AN, Joyce TW, Moore JE, Henry A. 2018. Cetacean and seabird data collected during the Hawaiian Islands Cetacean and Ecosystem Assessment Survey (HICEAS), July–December 2017. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-PIFSC-72, 110 p. https://doi.org/10.25923/7avn-gw82

Yano KM, Oleson EM, McCullough JLK, Hill MC, and Henry AE. 2020. Cetacean and seabird data collected during the Winter Hawaiian Islands Cetacean and Ecosystem Assessment Survey (Winter HICEAS), January–March 2020. U.S. Department of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-111, 72 p. https://doi.org/10.25923/ehfg-dp78

Appendix A—Cetacean Distribution Maps

Sightings and Acoustic Detections on the Towed Array of Delphinids (Figure A1–Figure A2)

Concurrent sightings and acoustic detections are shown as blue diamonds. Sightings without concurrent acoustic detection are shown as red asterisks. All sightings are shown, independent of visual effort type (gray lines). The Marianas study area is marked by the dashed black outline. Acoustic detections of delphinid groups that did not have associated visual species confirmation are classified at this time as unidentified dolphin and are shown in Figure A6.

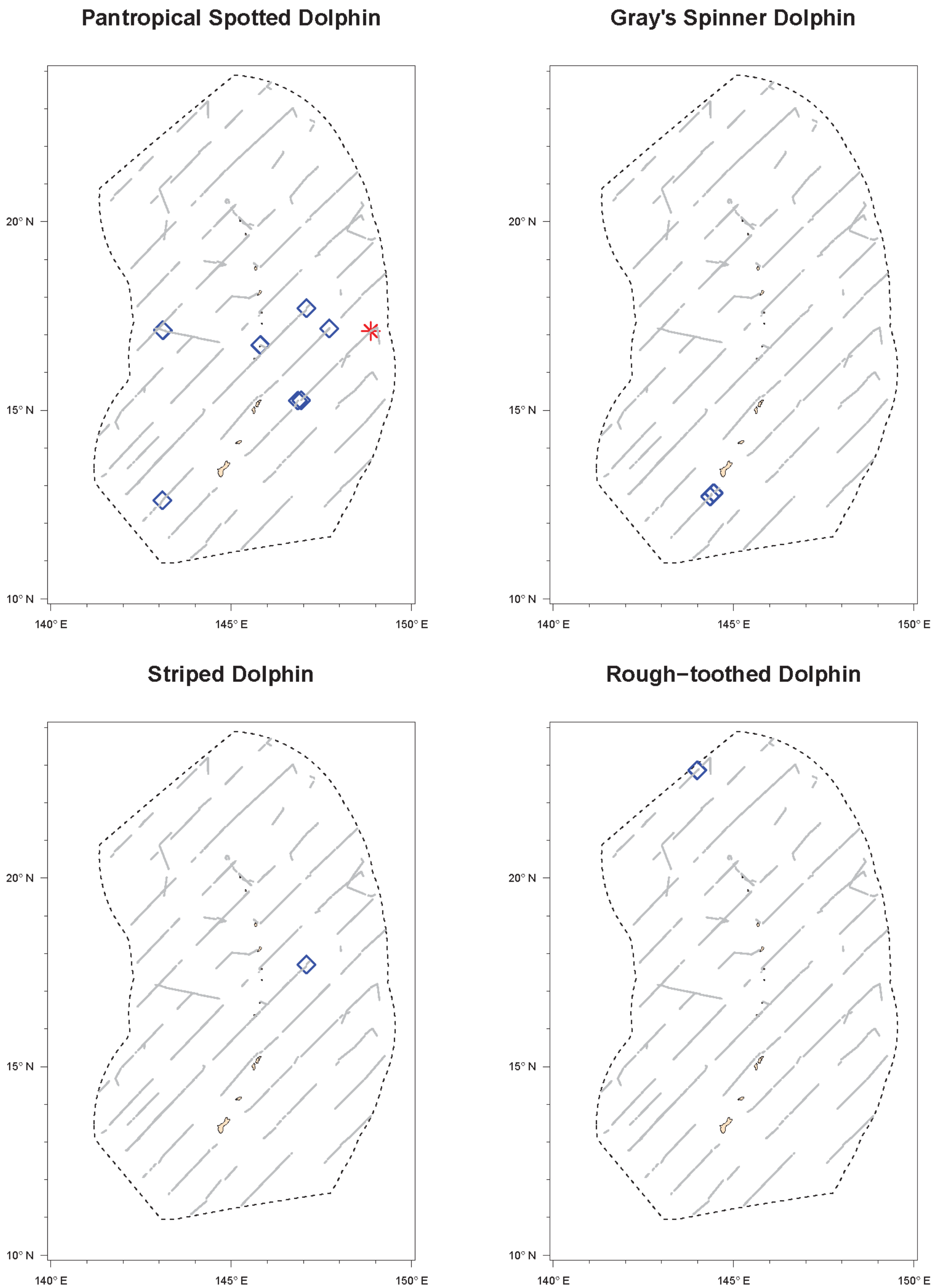

Figure A1. Sightings and acoustic detections of pantropical spotted, Gray's spinner, striped, and rough-toothed dolphins.

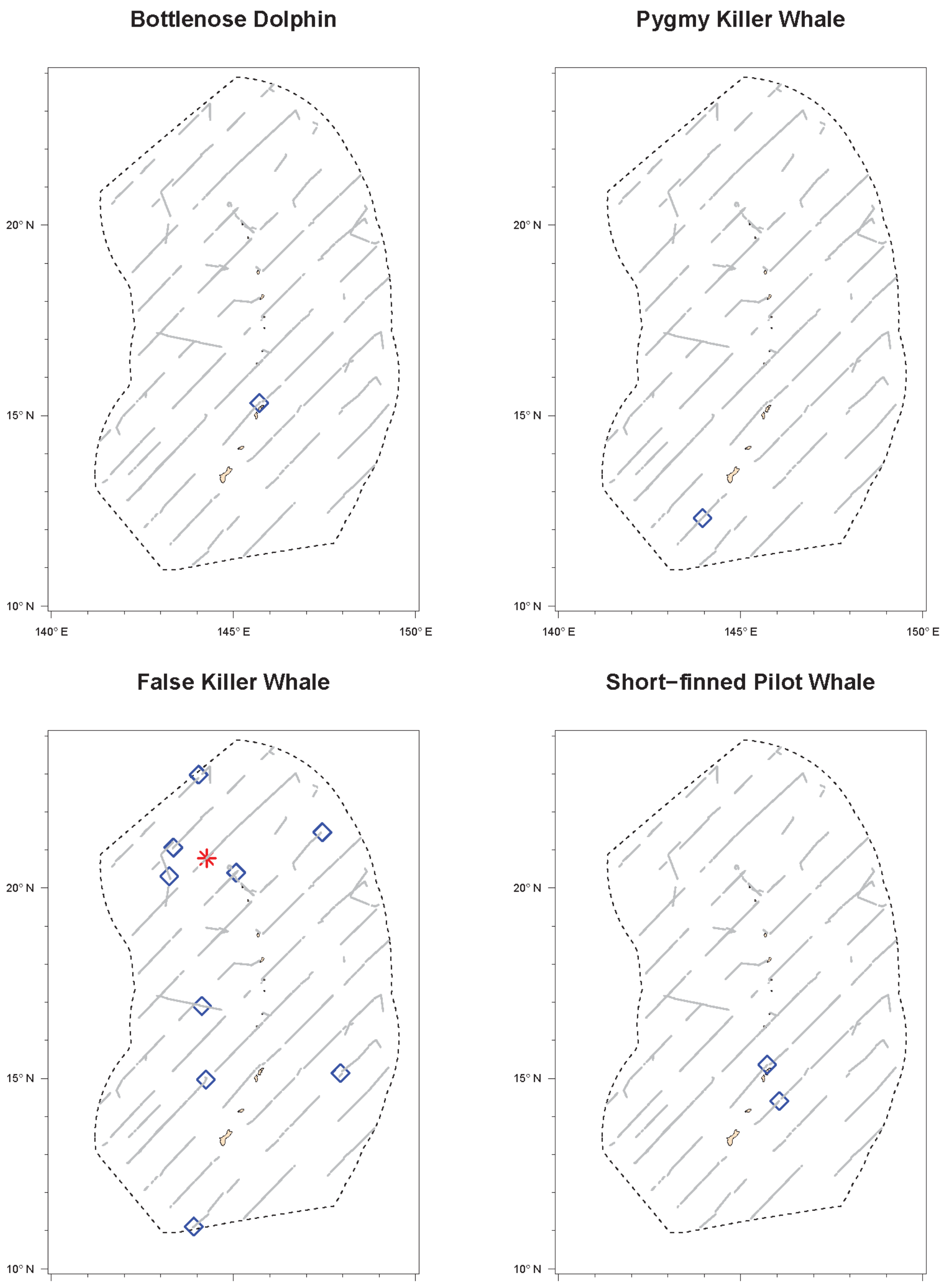

Figure A2. Sighting and acoustic detections of bottlenose dolphin, pygmy killer, false killer, and short-finned pilot whales.

Sightings and Acoustic Detections on the Towed Array of Sperm and Beaked Whales (Figure A3–Figure A4)

Concurrent sightings and acoustic detections are shown as blue diamonds. Sightings without concurrent acoustic detection are shown as red asterisks. Acoustic detections without a concurrent visual sighting are shown as green circles. All sightings are shown, independent of visual effort type (gray lines). The Marianas study area is marked by the dashed black outline.

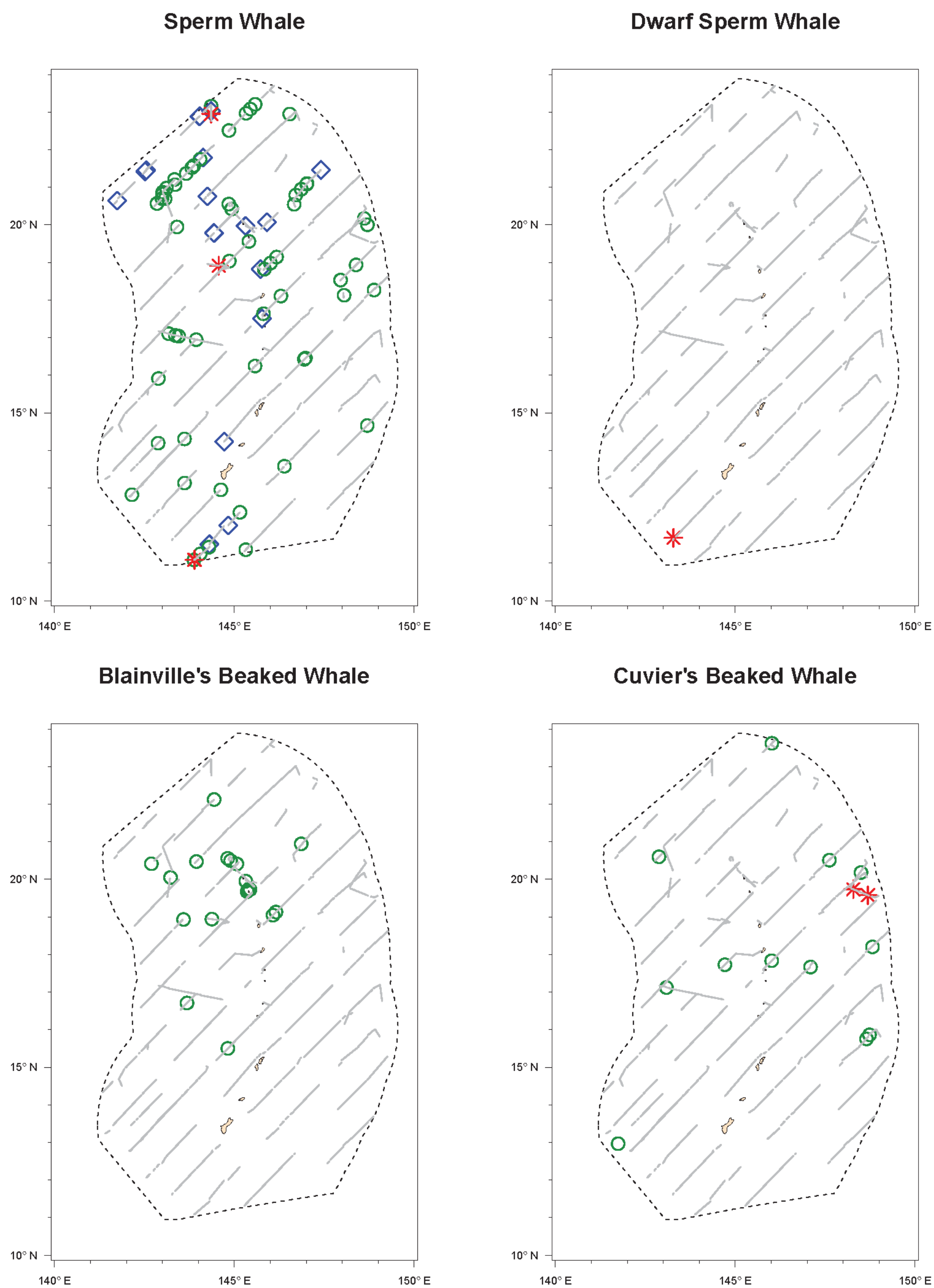

Figure A3. Sightings and acoustic detections of sperm, dwarf sperm, Blainville's beaked, and Cuvier's beaked whales.

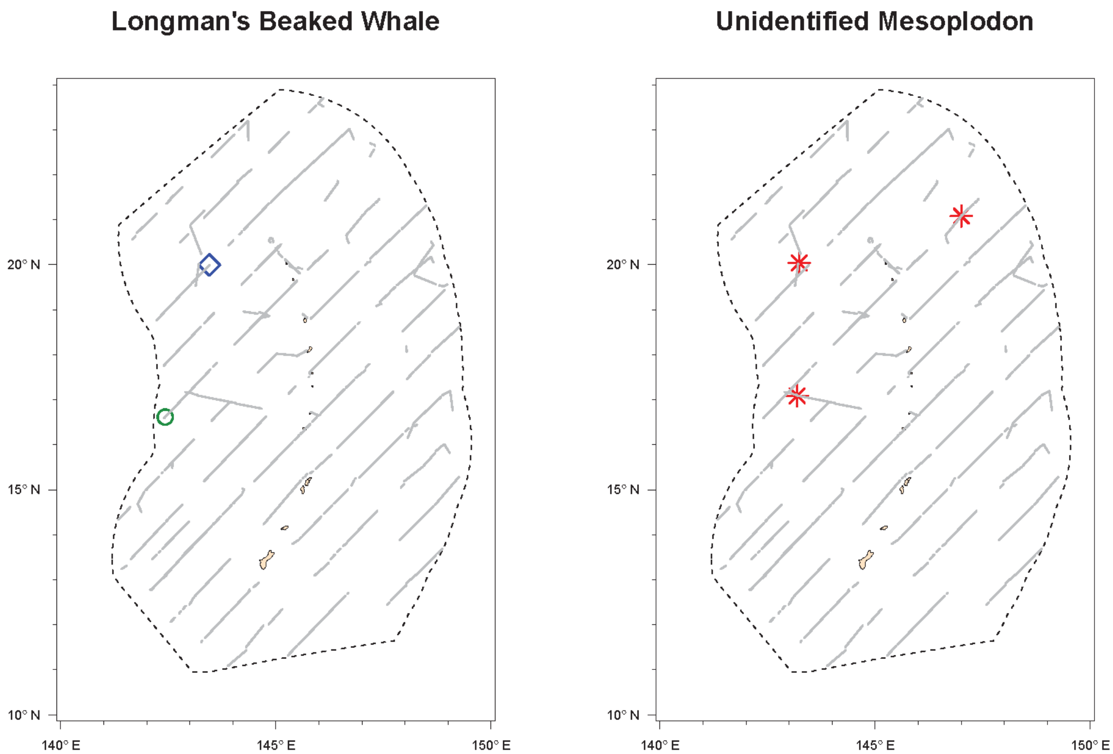

Figure A4. Sightings and acoustic detections of Longman's beaked whale and unidentified *Mesoplodon* sp.

Sightings and Acoustic Detections on the Towed Array of Baleen Whales (Figure A5)

Sightings without concurrent acoustic detection are shown as red asterisks. Acoustic detections without a concurrent visual sighting are shown as green circles. All sightings are shown, independent of visual effort type (gray lines). The Marianas study area is marked by the dashed black outline.

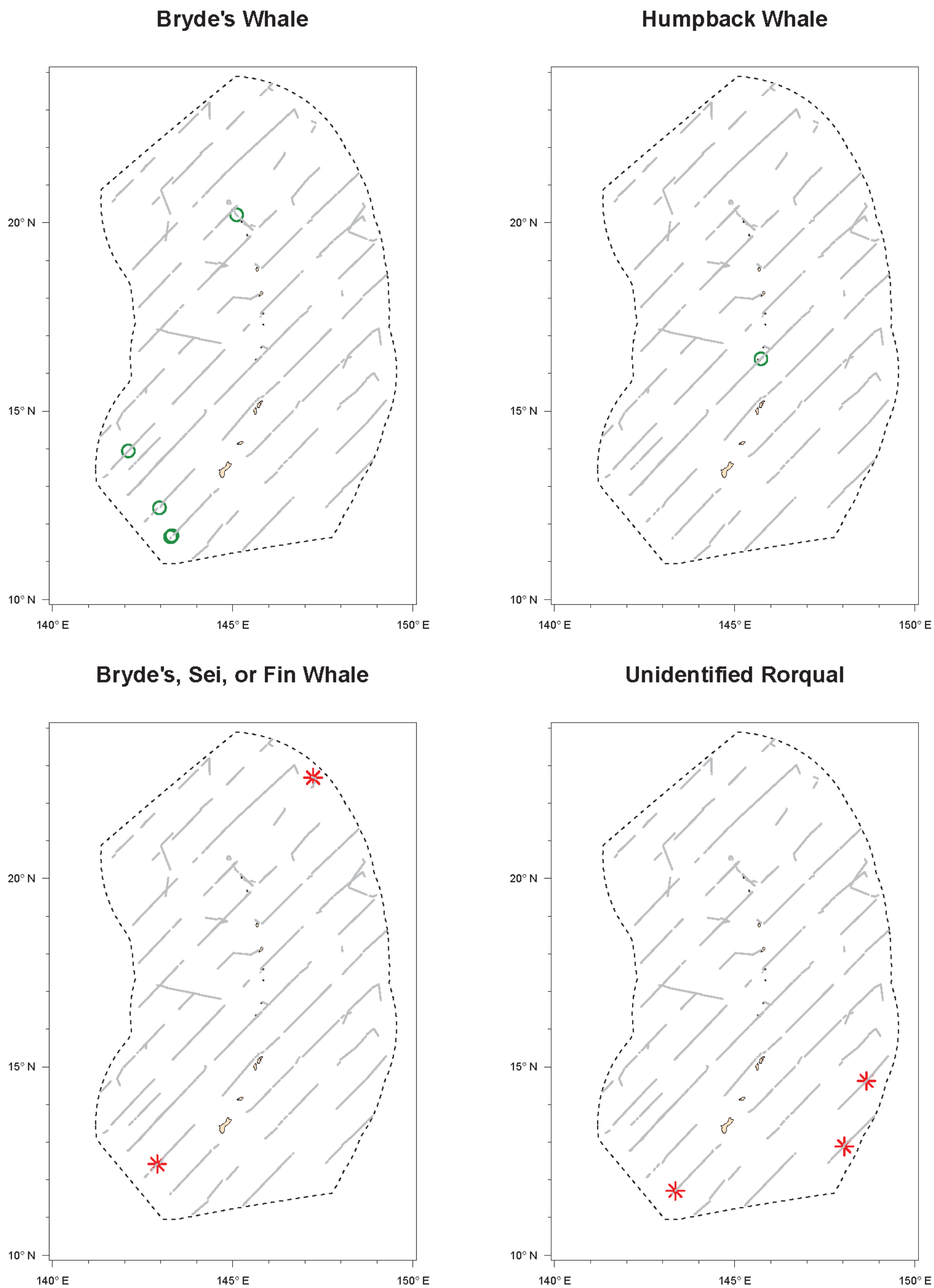

Figure A5. Sightings and acoustic detections of Bryde’s whale, humpback whale, unidentified Bryde’s, sei, or fin whale, and unidentified rorqual.

Sightings and Acoustic Detections on the Towed Array of Unidentified Species (Figure A6–Figure A7)

Concurrent sightings and acoustic detections are shown as blue diamonds. Sightings without concurrent acoustic detection are shown as red asterisks. Acoustic detections without a concurrent visual sighting are shown as green circles. All sightings are shown, independent of visual effort type (gray lines). The Marianas study area is marked by the dashed black outline.

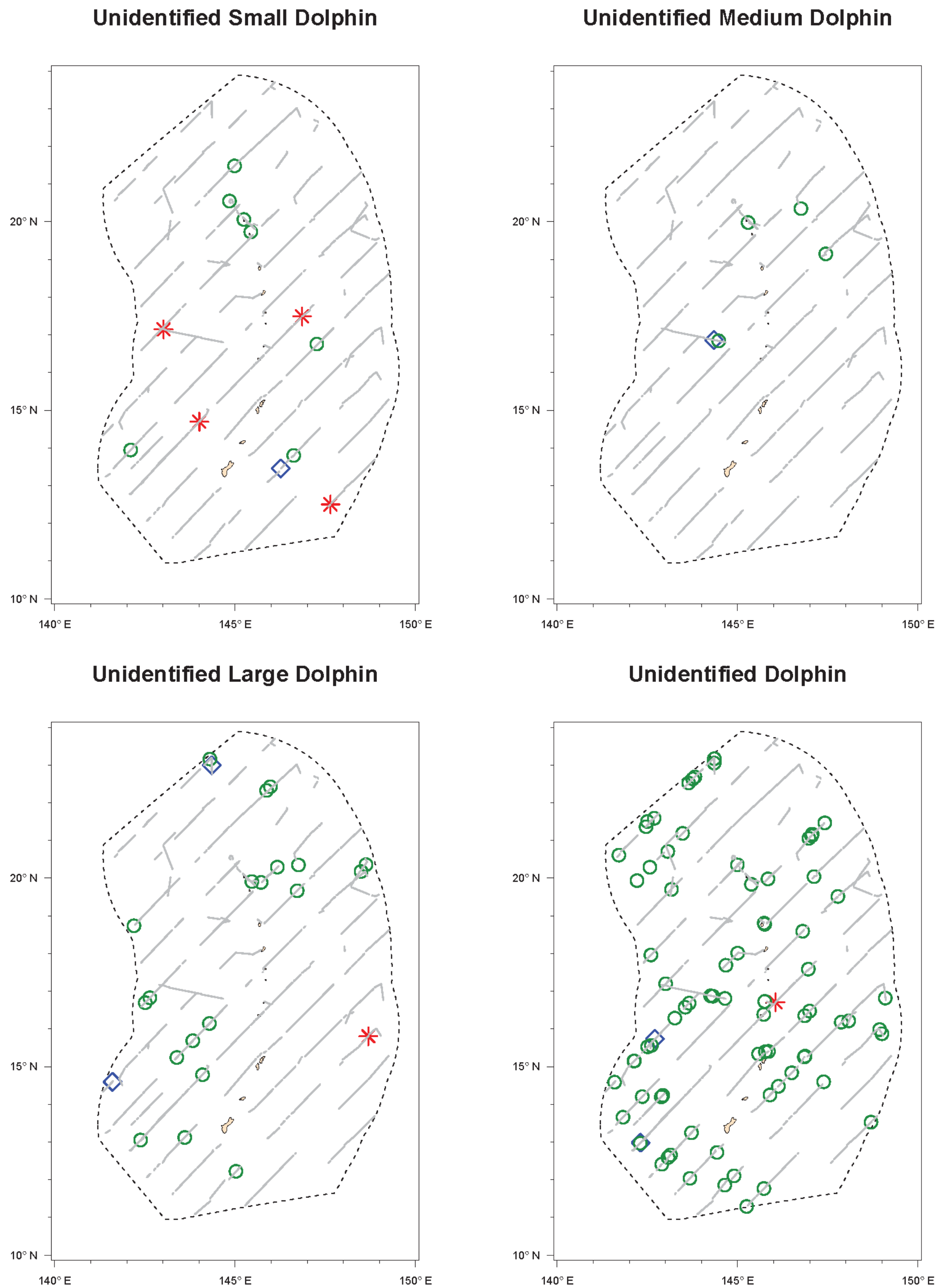

Figure A6. Sightings and acoustic detections of unidentified dolphins of various sizes.

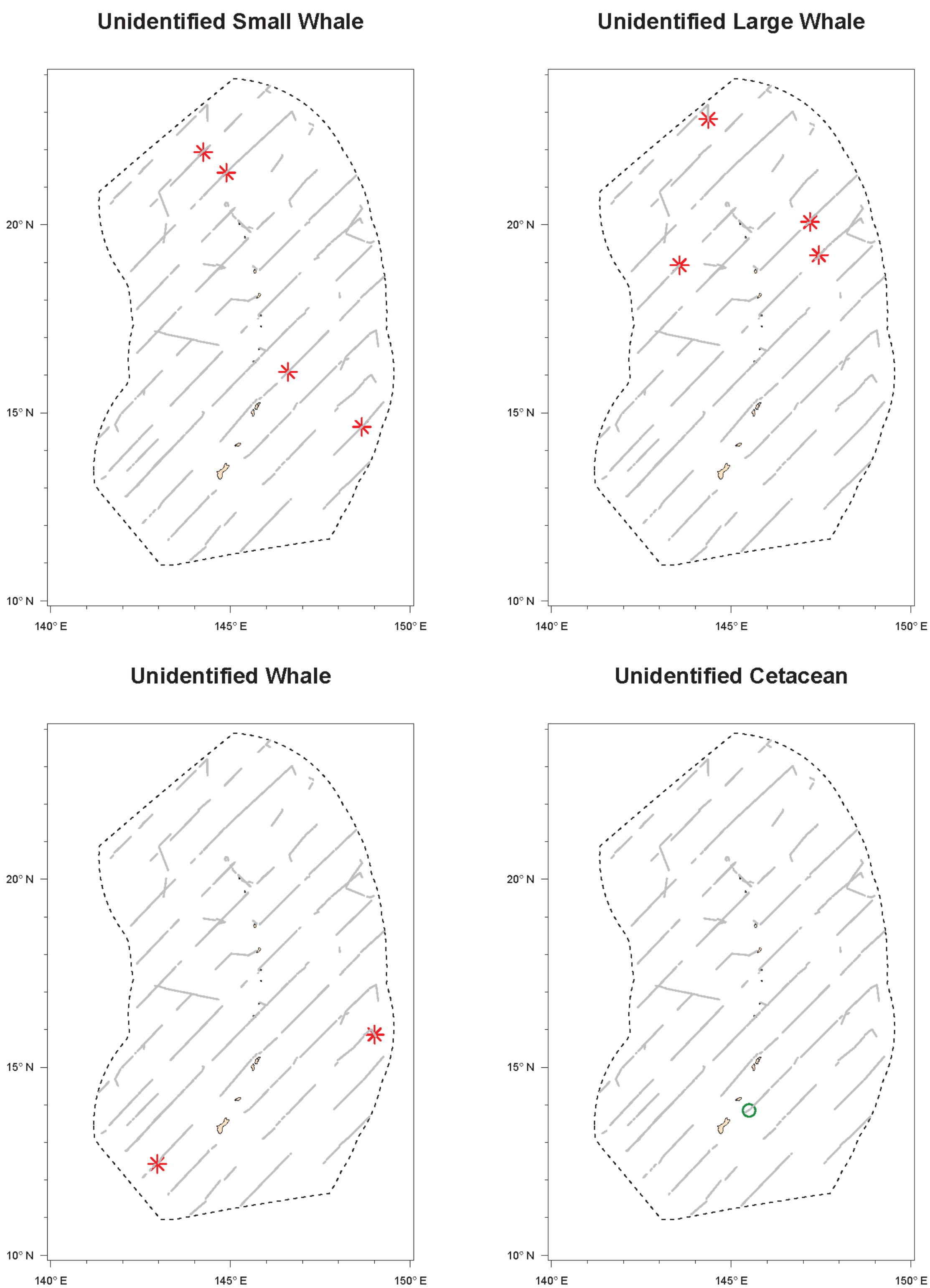

Figure A7. Sightings and acoustic detections of unidentified whales of various sizes and unidentified cetacean.

Appendix B—Cetacean Sighting Codes when Species is Unknown

177 Unidentified small dolphin
A cetacean < 12 ft in length that is likely of the genus *Delphinus*, *Lagenodelphis*, or *Stenella*.

277 Unidentified medium dolphin
A cetacean < 12 ft in length that is likely of the genus *Feresa*, *Grampus*, *Peponocephala*, *Steno*, or *Tursiops*.

377 Unidentified large dolphin
A cetacean < 12 ft in length that is likely of the genus *Pseudorca*, *Orcinus*, or *Globicephala*.

077 Unidentified dolphin
A cetacean < 12 ft in length that cannot be placed in one of the three unidentified dolphin size categories. An animal that cannot be positively identified but is thought to be a dolphin is coded 077 although it may exceed 12 ft in length.

051 Unidentified *Mesoplodon*
Mesoplodon sp. not positively identified to species.

049 Unidentified beaked whale
A beaked whale (*Ziphiidae*) not positively identified to a more specific category.

080 Unidentified *Kogia*
Kogia sp. not positively identified as either dwarf or pygmy sperm whale. If suspected to be *Kogia* but unsure, then use code 078 (unidentified small whale).

078 Unidentified small whale
A cetacean 12–30 ft in length not positively identified to a more specific category.

099 Rorqual identified as a sei or Bryde's whale
A rorqual that is clearly either a sei or Bryde's whale, but the head was not seen to confirm.

199 Rorqual identified as a sei, Bryde's, or fin whale
A rorqual that is either a sei, Bryde's, or fin whale, but the head was not seen to confirm.

070 Unidentified rorqual
A large whale > 30 ft in length with tall columnar spouts, two-part blows, or distinctive falcate dorsal fin located in the latter third of the body (*Balaenoptera* sp.). An animal that cannot be positively identified but is thought to be a minke whale may be coded as 070 although it does not exceed 30 ft in length.

079 Unidentified large whale
A cetacean > 30 ft in length not positively identified to a more specific category.

098 Unidentified whale
A cetacean > 12 ft in length not positively identified to a more specific category.

096 Unidentified cetacean
A cetacean that cannot be placed in a more specific category.

Appendix C—False Killer Whale Protocol

False Killer Whale Protocol for Visual Observers

False killer whales, *Pseudorca crassidens* (PC), usually travel in multiple subgroups of a few individuals that are part of a larger group of tens of individuals. Previous studies of PC have found that 1) subgroups are the best unit of detection for line-transect analysis, and 2) visual-only searches tend to miss a large proportion of subgroups that can be acoustically detected. Therefore, a two-phase PC protocol was developed to combine visual and acoustic detection methods so that more precise subgroup and group size estimates can be made, while adhering to line-transect assumptions.

PHASE 1. On-effort trackline passing mode

Remain on current trackline so that the visual observers can obtain accurate subgroup distances and bearings (for line-transect analysis) and passing mode estimates of subgroup size.

PHASE 2. Off-effort acoustic-directed passing mode

Pass through the center of the overall group so that the visual observers can obtain size estimates for as many subgroups as possible and a sense of overall group size and behavior.

The following provides general information and key points relevant to all personnel. Please see individual protocols for responsibilities of the cruise leader, visual observers, and acousticians.

PHASE 1: Phase 1 is initiated when a possible PC detection is made within 3 nmi of the trackline while the visual observers are on-effort, regardless of how the animals were detected. During this phase, the ship should continue along the trackline at 10 kt with both the visual and acoustic teams independently localizing and naming subgroups. Visual and acoustic detections of other species should be noted as usual, but the ship should not turn. The only circumstance where a turn might be warranted is if the visual team sights possible PC and, following consultation with acoustics, a brief turn would aid in PC identification. As soon as such a sighting has been established as PC, the ship should immediately return to the trackline at a 20 degree angle and continue the passing mode detection of PC subgroups. Continue Phase 1 until there are no additional visual or acoustic detections ahead of the beam of the ship and, based on characteristics of the group (behavior, dispersion of subgroups), it is judged by the visual and acoustics teams that all animals are past the beam. Phase 2 should be initiated as soon as possible after Phase 1 is complete to maximize the likelihood of relocating the animals. If the visual team is notified they are in Phase 1 (by Acoustics or the Bridge) prior to detection, they should indicate that in WinCruz with a Comment.

PHASE 2: Once the cruise leader initiates Phase 2, the ship should slow to a speed of 5–6 kt and the acoustics team should direct the ship toward what appears to be the center of the overall group to maximize subgroup detections. Note that a new acoustics-led naming system should be initiated, and that the Phase 2 subgroup detections do not need to be linked to those from Phase 1. Continue Phase 2 until there are no additional visual or acoustic detections ahead of the beam of the ship or the cruise leader determines that operations should change or end.

CRUISE LEADER

Your overall responsibility is to coordinate the PC protocol, which will require active direction, guidance, and decision-making on the flying bridge.

Actions

1. Go to the flying bridge to monitor operations once notified by the visual team of a possible PC sighting within 3 nmi. If first alerted by acoustics of possible PC (at any distance), wait at the acoustic team station until the visual team makes a Phase 1 sighting or until the animals from the acoustic detection are past the beam.
2. Call the off-effort visual observers to the flying bridge and assign them to positions once a PC sighting has been made by the on-effort visual observers during Phase 1 or, if no Phase 1 sightings were made, when you initiate Phase 2.
3. Serve as the flying bridge communicator and/or runner or assign an off-effort visual observer to cover one or both of these positions.
   - *Communicator*: responsible for radio communications with acoustics and for ensuring that the primary and backup visual observers are adequately communicating.
   - *Runner*: writes down the subgroup information on a white-board (time, observer, subgroup letter, bearing, and distance) and supplemental data form (observer, subgroup letter, closest distance, size, and response), ensuring that necessary information is relayed to the center observer and communicator.
   - *Note that PIFSC cruise leaders have gravitated toward serving in both of these roles, but this approach is not necessary.*
4. If the visual team is notified they are in Phase 1 prior to visual sighting (i.e., by bridge, or acoustics), ensure a WinCruz Comment is entered regarding the sighting bias.
5. Make real-time decisions, see next.

Real-time Decisions

- If the visual team made a species ID <u>and</u> adequate subgroup estimates, then skip Phase 2.
- If a PC detection is made beyond 3 nmi of the trackline, convene with the team(s) who made the detection. Once it is established that all subgroups are past the beam (i.e., there is no chance of initiating Phase 1) either:
  a. Bypass the detection,
  b. Initiate an unpaired Phase 2 of the PC protocol, or
  c. Approach the group for photo/biopsy sampling from ship or small boat.
- After 30 min of Phase 2, evaluate if the acoustics team has been able to localize and differentiate subgroups and if the visual observers have been able to detect and estimate the size of subgroups (i.e., *is Phase 2 working?*):
  a. If not, end Phase 2.
  b. If yes, continue Phase 2 until there are no detections ahead of the beam or for 30 min more, when the success of Phase 2 will be reevaluated.
- Once both phases of the protocol are completed, convene with the visual team and either:
  a. Approach the group for photo/biopsy sampling from ship or small boat, or
  b. Resume on-effort survey.

ON-EFFORT (PRIMARY) VISUAL OBSERVER—PHASE 1

Your overall responsibility is to search for and record data on subgroups while maintaining your normal observer roles and rotation. Delays to the rotation may be needed during active periods.

1. Immediately notify the cruise leader and acoustics team of a possible or confirmed PC sighting at any distance from the trackline. A sighting within 3 nmi will prompt the cruise leader to summon the off-effort observers to the flying bridge for Phase 1 operations.
2. *Big-eye observers*: search for subgroups ahead of the ship. Once a new subgroup is detected, hand it off to the off-effort backup observers for tracking and subgroup size estimation and resume general searching ahead of the ship for new subgroups as soon as possible. If the primary observer had an adequate look at a given subgroup, discreetly give the runner a Best/High/Low estimate and closest observed distance from the subgroup.
3. *Center observer*: use the subgroup functionality in WinCruz to record and map subgroups, which should be named alphabetically with each new subgroup assigned a new, consecutive letter (i.e., A, B, C, D, etc.)
    a. If uncertain whether a visual sighting is an existing or new subgroup, assign a new letter.
    b. If the subgroup is later determined to be an existing subgroup, note this in the WinCruz record (i.e., with the Comment "Subgroup C=F").
    c. Although the characteristics of each subgroup (bearing, distance, size) at its initial detection are most important for subsequent analyses, the joining of subgroups and other behavioral observations should also be noted (e.g., "Now Subgroup C=C+D").
4. Share each new visual subgroup detection, letter designation, and GPS location/time information (hover over subgroup on WinCruz map) with the acoustics team as soon as possible. Re-sightings of subgroups should also be recorded in WinCruz and relayed to the acoustics team.

OFF-EFFORT (BACKUP) VISUAL OBSERVER—PHASE 1

Your overall responsibility is to search for and estimate the size of subgroups that have been detected by the primary visual observers and to serve as the communicator and/or runner.

1. When paged, report to the flying bridge in support of subgroup localization and size estimation. The cruise leader will assign you to a position, which you should maintain throughout the protocol. However, if enough time passes and it would not be disruptive, you can rotate into your next on-effort shift.
2. Search for subgroups using the aft big-eyes until the primary observer passes you one or more subgroups for tracking and size estimation. As you are tracking these subgroups, relay resighting information to the center observer.
3. Track each subgroup until it passes the beam. At that time, discreetly give the runner a Best/High/Low estimate and closest observed distance from the subgroup.
4. If you sight a subgroup not seen by the primary observer, do <u>not</u> communicate the sighting to the primary observer. Wait until the subgroup passes the beam and then announce the detection so it can be recorded on the supplemental data form. Starting in 2020, code "different" (i.e., Independent Observer, >90 degree, birder or other source) sightings made while the primary observers were on-effort as ON effort in WinCruz (to no longer break up the effort stream when the sighting occurs).

ALL VISUAL OBSERVERS—PHASE 2

Your overall responsibility is to search for and estimate the size of subgroups that have been detected by the acoustic or visual team.

5. Once the cruise leader initiates Phase 2, the center observer should go off-effort in WinCruz. All observers (primary and backup) should attempt to locate each acoustically-detected subgroup and estimate subgroup sizes. You will not be in on-effort search mode but should search specifically for acoustically-detected subgroups, while also noting visually-detected subgroups.
6. As the acoustic team relays acoustically-detected subgroup information (i.e., estimated location and subgroup name SA, SB, SC, SD, etc.), at least one observer will be assigned to visually scan that area in an attempt to locate the subgroup and obtain subgroup size estimates.
    a. If there are fewer acoustically-detected subgroups than observers at a given time, observers not focused on a subgroup should scan for other subgroups.
    b. If there are more acoustically-detected subgroups than observers at a given time, first priority should go to subgroups closer to the transect line or at greater bearing angles (if the distance is unknown).
7. Once a subgroup is sighted, relay the subgroup's sighting information (GPS location/time from WinCruz map) to the acoustics team, who must decide if the subgroup is a match to one of their subgroups or a new subgroup that has not yet been acoustically detected.
    a. The center observer should input into WinCruz the subgroup name provided by the acoustics team, noting if a "new" subgroup is subsequently determined to be an existing subgroup.
    b. Remain with the sighted subgroup while reporting re-sighting locations until either acoustics confirms a match with an acoustic detection or the subgroup passes the beam of the ship.
    c. At that time, discreetly give the runner a Best/High/Low estimate and closest observed distance from the subgroup. Note that in most cases, subgroup size estimates will be made by only one observer.
8. Although acoustics will be directing the ship, the visual team may make turn suggestions to acoustics to improve the approach distance for subgroup size estimation. The acoustic team will determine when and how such recommended course changes will be made.
9. Up to 2 personnel (1 port, 1 starboard) can also take identification photographs if a subgroup(s) is in close enough proximity to the ship. Photo-identification efforts at this time should be restricted to the flying bridge and should stop when additional subgroups are acoustically detected.
10. Upon conclusion of the PC protocol, observers who were able to get a good sense of total group size (i.e., accounting for all subgroups) are encouraged to record a Best/High/Low estimate in their green book. Subgroup size estimates will be recorded on a supplemental data form and do not need to be included in the green book.

Edited December 2020

False Killer Whale Protocol for Passive Acoustics

False killer whales, *Pseudorca crassidens* (PC), usually travel in multiple subgroups of a few individuals that are part of a larger group of tens of individuals. Previous studies of false killer whales have found that visual-only searches tend to miss a large proportion of subgroups that can be acoustically detected. Therefore, a two-phase PC Protocol was developed to combine visual and acoustics methods, allowing more precise subgroup and group size estimates to be made.

PASSIVE ACOUSTICS—PHASE 1

Your goal is to detect and localize all false killer whale whistles and clicks, organize those detections into subgroups, and track those subgroups for pairing with visual sightings.

1. Immediately notify Cruise Leader of false killer whale detections that occur within or near 3 nmi of the trackline. Very distant groups should still be tracked, but the PC protocol will not begin until subgroups are located within 3 nmi.
2. Using the telephone, call the ship's bridge and let them know that we are in the PC protocol and that they should not make any unscheduled turns or change speed. Do not communicate with the visual team.
3. Using the timing, signal type, and bearing angle information from the PAMGUARD detector output for both clicks and whistles, create a subgroup IDs starting with AA.
4. Continue to monitor incoming signals and assign new subgroups until there are no more detections ahead of the beam of the ship. The visual team may call in subgroup sightings. To the extent feasible, pair up visual sighting locations with acoustic detections locations and link visual subgroup sightings in the Acoustics notes.
5. Continue for 0.5 nmi past the last acoustic detection, and then notify the Cruise Leader that the Acoustic Phase 1 is complete.

PASSIVE ACOUSTICS—PHASE 2

During Phase 2, Acoustics attempts to direct the ship through the subgroups as efficiently (i.e., without lots of extra turning) as possible. You may request that the ship reduce its speed if it is helpful for localizing subgroups. Use the collection of Phase 1 detections, as well as information from the visual team (viewing conditions, etc.) to decide how to reposition the ship to begin Phase 2.

Clear the map of Phase 1 detections to eliminate confusion, as it is not necessary to match Phase 1 and Phase 2 detections. When new subgroups are localized:

6. As the PAMGUARD detectors provide new information on detected clicks and whistles, create subgroups and assign IDs sequentially starting with SA (i.e., SA, SB, SC, etc.)
7. Relay the subgroup ID and location to the visual team. Continue to provide position updates until they sight the subgroup or until it passes the beam of the ship (> 90°).
8. If the visual team sights a subgroup that does not match an acoustic subgroup, assign it the next subgroup ID.
9. Keep track of which subgroups are sighted by the visual team.

Edited January 2020

Appendix D—Sperm Whale Protocol

Sperm Whale Protocol for Visual Observers

Sperm whales groups can be spread over several miles and commonly contain smaller subgroups (also called clusters) of 1–10 tightly associated individuals. Within a group, these subgroups commonly exhibit asynchronous dive behavior, with each cluster diving for 20–60 min followed by an 8–12 min surface period. Given the asynchronicity and long durations of these dives, the standard line-transect group size estimation approach results in underestimating sperm whale group size. Thus, extended group counts are needed. Sperm whale clusters will be documented using the Subgroup functionality within WinCruz.

Sperm whale group counts during Pacific Islands Fisheries Science Center surveys have typically lasted 60 minutes. However, comparisons of 60-min and 90-min sperm whale counts from Southwest Fisheries Science Center surveys have suggested that 60-min counts may still lead to underestimates of group size. Given that sperm whales are one of the most frequently sighted species during ship surveys in Hawaiian (or Pacific Islands Region) waters, 90-min counts for all sightings might impede trackline progress. However, to assess if 60-min counts are underestimating sperm whale group size, a sample of 90-min counts will be made for comparison.

Specifically, a 90-min count will be made for the first sperm whale detection of the day regardless of detection source (visual or acoustic team), as long as the detection is within 3 nmi of the trackline.

VISUAL OBSERVER

The following points outline the steps visual observer should take for visual or acoustic sperm whale detections within 3 nmi of the trackline.

1. Once a visual sighting of sperm whales (or likely sperm whales) is made and entered into WinCruz, inform Acoustics and the Bridge following standard protocols. Ask Acoustics to confirm that a localization of any subgroup has been made.
    a. If so, go off-effort and close on group for group size estimation.
    b. If not, continue on-effort in passing mode until Acoustics has a localization, or the visual sighting is past the beam, then close on group.
    c. If Acoustics can confirm that the sighting is of a single male, forego group size estimation and remain on trackline unless instructed otherwise by cruise leader.
    d. For acoustic detections that were not sighted, the acoustics team will notify the visual team of the detection when all animals are past the beam. If the detection is a single animal, the visual team will go off-effort while the acoustics team directs the ship to turn in order to resolve the left/right ambiguity. If the detection is of a group of animals, the acoustic team will initiate an Acoustics Chase to help the visual team locate the animals for group size estimation.
2. Once closing has begun, call the next on-effort observer to the flying bridge, while scanning 360 degrees for all visible subgroups. See Count Details section below.
    a. After 10 min, the initial three on-effort observers should record independent Best/High/Low group size estimates in their green book.

   b. After an additional 60 min (and again at 90 min, if first detection of the day), all four observers should record independent Best/High/Low group size estimates in their green book.
   c. All sperm whale clusters should be entered into WinCruz using the Subgroup functionality, as is used for false killer whales. Subgroup names should start with A and continue with new subgroups until the end of the 60/90-min period. If groups join or if there is uncertainty on group ID, enter a new group and notate the uncertainty with a Comment in WinCruz.
3. Off-effort sperm whale detections should be treated like off-effort detections of other species (i.e., the sperm whale protocol is not required) unless they were encountered on-effort by the acoustics team.
4. When filling out the sighting form on the iPad, note that the supplemental sighting portion of the form contains a few additional fields that are different than for other species.
   a. There will be a field for the number of males in the group.
   b. Observers will enter calf and neonate estimates as numbers, not percentages.
   c. Although not required, if you have a good sense of the number of subadults in the group, record the estimate in the comments section.
5. Once the 60/90-min count is complete, consult with the Cruise Leader and initiate photo/biopsy sampling as advised. The remaining two observers should be prepared to help with either photo/biopsy sampling or with finding animals for the ship or small boat.

Count Details

- While group-size estimates are made independently, observers can talk freely about the size of individual subgroups since a given observer may not see all subgroups.
- Observers can make notes about subgroup sizes in their green book to aid in estimating total group size at the end of the count.
- Brief the next on-effort observer joining the count on the number and size of subgroups sighted in the first 10 min.
- Each new sighted subgroup should be entered into WinCruz as a Subgroup (DO NOT use Object) with the subgroup letter designation (e.g., A, B, C, D, etc.) in the "ID Label" field.
    - The Subgroup function in WinCruz should be used for tracking and recording sperm whales, noting that this functionality works best if initiated at the beginning of the sighting (i.e., in the initial F2 window).
    - If a subgroup surfaces during the 60/90-min count that cannot readily be linked to a subgroup that surfaced previously, assign it a new subgroup letter, but the center observer should record a comment that it may be the same as a previous subgroup (e.g., Subgroup I is possibly B).
    - Use external clues to link subgroups that were previously sighted (e.g., resight location, subgroup size, presence of calves or distinctive individuals, dive time) to avoid double-counting subgroups.
- After an observer sees a subgroup dive, inform the other observers of the subgroup letter, size, and age composition so they can make a note in their green book. If the center observer made a comment that the subgroup was possibly seen previously, this information should be relayed again for all observers to note.
- Use the WinCruz map to maintain a good position of the ship to sight subgroups once they surface after diving. If the ship is traveling slowly or holding a position, check the box to

hold the course on the WinCruz map to prevent it from losing a useful orientation. It is best to do this before the map begins to struggle.

- Note that communication is open between the Visual and Acoustics team during the count. Acoustics can call up subgroup detections that the visual team may not have seen and can notify observers of subgroups that have stopped vocalizing and may be coming to the surface.

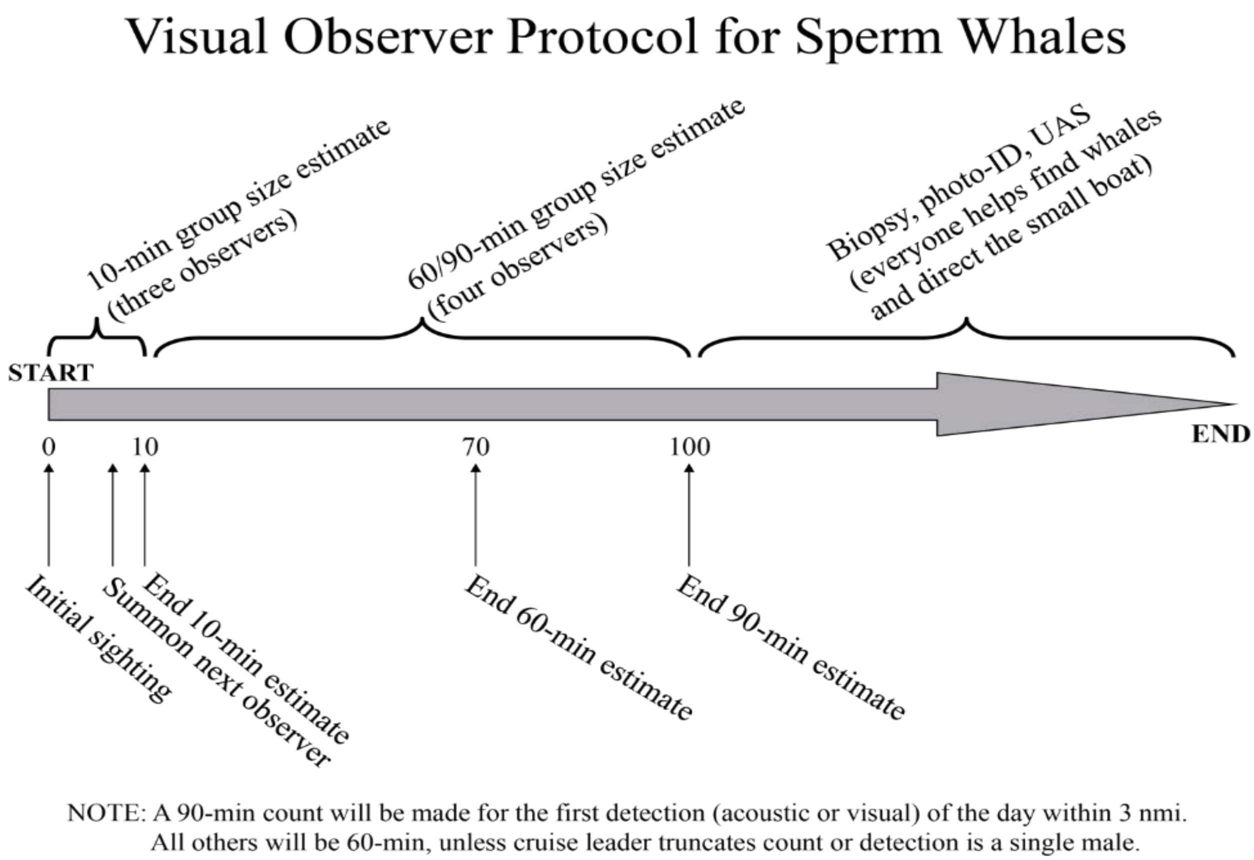

Figure D1. Sperm Whale Protocol diagram for visual observers.

Edited December 2020

Sperm Whale Protocol for Passive Acoustics

ACOUSTICIAN

There are four types of detection scenarios, additional details below:

1. The initial detection is made by the visual team ahead of the beam (detection angle < 90°)
2. The initial detection is made by the acoustic team ahead of the beam
3. The detection may be made by the acoustic team aft of the beam (detection angle > 90°)
4. The detection may be made by the acoustic team aft of the beam (detection angle > 90° and > 3 nmi)

1. VISUAL team sights animals < 90°

When Visuals has an ON-effort sighting (< 90°) they will start the "Group Size Protocol." During the "Group Size Protocol," Visuals directs the ship- they can turn the ship and change the speed at any point. At this point communication between Visual and Acoustic teams is open and Acoustics will assist Visuals in tracking animals. If Acoustics is certain that the detection is of a single whale, this information should be relayed the Visual team to avoid a lengthy group count.

2. ACOUSTIC team detects animals < 90°

When Acoustic team has a detection ahead of the beam (< 90°) they will localize ALL animals, but NOT communicate with Visual team about the detection. Communication is not allowed at this point to avoid biasing the Visual search effort (the visual team has until the animals pass 90° to potentially detect the animals). If the Visual team sights the animals before they pass the beam, then the crews proceed as above (see VISUAL team sights animals < 90°).

3. ACOUSTIC team detects animals > 90°

If the Acoustic team either makes the initial detection of a sperm whale group that is aft of the beam, or if a group initially heard ahead of the beam becomes aft of the beam without having been detected by the Visual team, then the ship may divert from the trackline to close on this group IF the Acoustic team is certain that ALL animals have passed the beam (> 90°) and they are within 3 nmi (perpendicular to trackline). In this situation, Acoustic team contacts the Visual team (communications is now open) and starts an Acoustic Chase. During an Acoustics Chase, directions to the Bridge come from Acoustics. If sperm whales are sighted, the Visual team takes control of directing the ship and Acoustics continues to assist in tracking animals. If it is a single animal, Acoustic team will conduct an Acoustics Chase until the left/right ambiguity is resolved for the localization.

4. ACOUSTIC team detects animals (single or group) > 90° & > 3 nmi

If the Acoustic team either makes the initial detection of a sperm whale group that is aft of the beam, or if a group initially heard ahead of the beam becomes aft of the beam without having been detected by the Visual team, AND the animal(s) are farther than 3 nmi (perpendicular to trackline), then the ship may divert from the trackline to resolve the left/right ambiguity of the localization IF the Acoustic team is certain that ALL animals have passed the beam (> 90°).

Edited March 2021

Appendix E—DASBR Deployment and Retrieval Details

Table E1. Details of the 22 Drifting Acoustic Spar Buoy Recorders (DASBRs) deployed.

DASBR deployment and retrieval details include the identification number (ID), deployment and retrieval location (latitude, longitude), deployment and retrieval time, and total duration of deployment.

	Deployment			Retrieval			Duration
ID	LAT (°N)	LON (°E)	Time (UTC)	LAT (°N)	LON (°E)	Time (UTC)	(days)
DS1	13.8528	144.5607	5/3/2021 08:47	14.6686	143.6686	5/28/2021 12:00	12
DS2	15.3127	145.4504	5/4/2021 01:03	14.7051	142.7758	5/14/2021 06:42	10
DS3	17.3127	145.4731	5/6/2021 08:43	17.5167	145.7878	5/11/2021 06:41	5
DS4	19.5333	144.1782	5/8/2021 19:56	18.8703	144.8602	5/25/2021 00:47	16
DS5	16.6355	144.7805	5/11/2021 20:04	16.7814	144.8167	5/25/2021 18:52	14
DS6	15.1689	143.3083	5/12/2021 10:20	15.7067	142.2360	5/26/2021 21:32	14
DS7	16.6605	142.3782	5/16/2021 10:24	17.2437	142.6847	5/26/2021 10:31	10
DS8	18.9939	143.6397	5/17/2021 09:45	18.0076	144.1994	5/25/2021 10:46	8
DS9	20.0269	143.5051	5/18/2021 10:53	19.1082	143.0796	5/24/2021 11:41	6
DS10	22.1430	144.4668	5/19/2021 10:09	22.4945	144.3610	5/23/2021 10:34	4
DS11	20.7102	143.0064	5/20/2021 19:47	20.8771	142.9926	5/23/2021 23:08	3
DS12	12.8751	142.0426	5/27/2021 19:39	12.9426	141.7599	5/29/2021 08:21	2
DS13	12.5734	144.5193	6/15/2021 11:26	11.6722	142.8869	6/24/2021 11:35	9
DS14	12.8548	146.8378	6/17/2021 11:04	14.4781	141.8862	7/11/2021 20:11	24
DS15	15.6660	148.9711	6/19/2021 12:30	15.6064	149.2061	6/21/2021 11:11	2
DS16	15.0667	146.7421	6/20/2021 09:59	15.0533	146.7392	6/26/2021 08:46	6
DS17	17.1530	147.7314	6/27/2021 09:53	18.0714	148.0499	7/8/2021 08:33	11
DS18	19.3868	147.6505	6/29/2021 05:03	19.5462	148.7849	7/7/2021 06:54	8
DS19	19.3874	147.1540	6/29/2021 12:01	19.7579	148.2199	7/7/2021 02:56	8
DS20	20.3132	146.7730	6/29/2021 19:46	20.5864	148.5208	7/6/2021 18:51	7
DS21	22.3135	147.0409	6/30/2021 15:16	22.1462	146.5891	7/3/2021 03:23	3
DS22	19.9216	145.5739	7/4/2021 02:32	19.9783	145.7285	7/5/2021 11:06	1

Appendix F—Science Personnel

Table F1. MACS 2021 scientific personnel.

Pacific Islands Fisheries Science Center, NMFS, NOAA (PIFSC); Joint Institute for Marine and Atmospheric Research*, University of Hawaiʻi at Manoā (JIMAR); Azura Consulting LLC (Azura); Southwest Fisheries Science Center, NMFS, NOAA (SWFSC); Northeast Fisheries Science Center, NMFS, NOAA (NEFSC)

Name	Role	Affiliation	Sailed
Marie Hill	Chief Scientist, Project Lead	JIMAR	Leg 1
Erin Oleson	Project Lead	PIFSC	Leg 2
Suzanne Yin	Visual Survey Lead	Azura	Legs 1, 2
Dawn Breese	Visual Survey Lead, Seabird Survey	Azura	Legs 1, 2
Jennifer McCullough	Acoustic Survey Lead	PIFSC	Legs 1, 2
Lisa Barry	Visual Survey	Azura	Legs 1, 2
Taylor Sullivan	Visual Survey	Azura	Legs 1, 2
Alexa Gonzalez	Acoustic Survey	PIFSC	Legs 1, 2
Erik Norris	Acoustic Survey	JIMAR	Leg 1
Nicholas Metheny	Seabird Survey	Azura	Leg 1
Paul Nagelkirk	Visual Survey	Azura	Leg 1
Mary Applegate	Visual Survey	Azura	Leg 1
Allan Ligon	Visual Survey Lead	Contractor	Leg 2
Jim Gilpatrick	Visual Survey	SWFSC	Leg 2
Peter Duley	Visual Survey	NEFSC	Leg 2
Alexandra Carroll	Acoustic Survey	Azura	Leg 2
Laura McCue	Visiting Scientist	PIFSC	Leg 2

*Joint Institute for Marine and Atmospheric Research (JIMAR) officially changed their name to Cooperative Institute for Marine and Atmospheric Research (CIMAR) in October 2021.