Pacific Islands Fisheries Science Center Mariana Archipelago Cetacean Surveys: A review of available data and analyses through February 2018

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14. ABSTRACT
The PIFSC CRP has conducted research on cetaceans in the Mariana Archipelago since 2010. A cooperative effort with funding from U.S. Navy Pacific Feet and PIFSC has included summer and winter small-boat surveys off the southernmost islands (Saipan, Tinian, Aguijan, Rota, and Guam), development of photo-ID catalogs, analysis of collected tissue samples and satellite telemetry tag data, and shipboard visual and PAM surveys in portions of the EEZ in 2010 and 2015. PIFSC has maintained long-term PAM on moored recorders off Saipan and Tinian (since 2010) and off Pagan (since 2015) as part of the Pacific Islands Passive Acoustic Network (PIPAN). The goal of these efforts is to collect the data necessary to conduct population assessments for cetaceans within the Mariana Archipelago, including the determination of their occurrence, population structure and abundance, movements, distribution, and habitat use. The focus of this report is on PIFSC CRP projects, including the small-boat surveys conducted in partnership with the U.S. Navy (2010–February 2018), the shipboard survey conducted in 2015, and analysis of passive acoustic data. Photo-identification and cetacean encounter data collected during other surveys within the Mariana Archipelago were contributed by the U.S. Navy for incorporation into PIFSC CRP data sets for various species and are therefore also represented in the summary reported here.
Most tropical cetaceans have been observed. During small-boat surveys off the southern islands from 2010 to 2018, covering 22,488 km of on-effort trackline, 14 species of cetaceans were seen, including spinner, pantropical spotted, bottlenose, and rough-toothed dolphins; and short-finned pilot, false killer, melon-headed, pygmy killer, sperm, dwarf sperm, Blainville's beaked, Cuvier's beaked, Bryde's, and humpback whales. Risso's dolphin was observed during the

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2015 shipboard survey. PAM from PIPAN sites has provided occurrence data on additional species not yet visually observed, including an unknown species of beaked whale (referred to as the Cross Seamount beaked whale, or BWC), and blue, fin, and minke whales.

Although data are sparse for many species, the aggregate of all data collected to date do reveal insights into distribution and population structure for several species, and adequate data are available to assess abundance and movement patterns for others. Spinner dolphin genetic and photo-ID data analyzed to date suggest that there may be at least 2 populations within the Mariana Archipelago, and the existing photo-ID data are sufficient to conduct a mark-recapture analysis for abundance estimation. Spinner dolphin habitat preferences appear to be markedly different in the Mariana Archipelago than similar nearshore populations in Hawaii, with apparent preference for very nearshore areas with dynamic currents or otherwise rough seas. Characterization of spinner dolphin habitat use based on environmental and physical features of encounter locations may reveal habitat preferences and differences among the Mariana island areas, as well as provide context for examining exposure to human-caused threats in the nearshore environment.

Previous genetic analyses found that Mariana Archipelago bottlenose dolphins exhibited evidence of Fraser's dolphin ancestry, but there is no evidence of population structure within the analyzed samples from the southern islands. Further examination of genetic population structure is not feasible with the limited sample size, though examination for evidence of the presence of Indo-Pacific bottlenose dolphins would be valuable. The photo-ID catalog is small, but there are sufficient data to conduct a mark-recapture analysis to estimate abundance for the nearshore southern Mariana Archipelago. Additional satellite tagging, particularly with location-dive tags, is needed to provide sufficient sample size to examine spatial use and habitat of bottlenose dolphins in the region.

Population structure is unclear for pilot whales despite a robust collection of genetic, photo-ID, and satellite telemetry data. Additional samples and telemetry tags deployed in offshore areas and the islands north of Saipan may help clarify whether there is a southern archipelago island-associated population and a separate offshore or northern population(s). Analysis of the photo-ID data found a main social cluster within the southern islands that included 85% of the individuals within the catalog, and satellite telemetry data from individuals within the main social cluster demonstrated that the tagged whales primarily associate with nearshore waters. Adequate photo-ID data are available to conduct a mark-recapture analysis to estimate abundance within the southern archipelago. Based on increased use of intermediate dive depth at twilight and night, it was suggested tagged short-finned pilot whales were foraging while following the deep scattering layer as it migrated between the depth and surface. Additional analyses using data from location-dive satellite tags along with oceanographic data may reveal areas of importance for foraging whales.

There is no indication from genetic, photo-ID, or satellite telemetry data that there is population structure in melon-headed whales within the Mariana Archipelago. With the completion of the melon-headed whale photo-ID catalog, it may be possible to use the total catalog number as minimum population estimate since only 3 individuals have be re-sighted between encounters of hundreds of melon-headed whales over an 8-yr period.

Winter surveys targeting humpback whales have resulted in cataloging of at least 56 individuals using the waters near Saipan, including very small calves and competitive groups suggesting calving and breeding activity in the region. A small number of whales appear to use Saipan waters, though additional animals are added to the catalog each year. Analysis of PIPAN data from Saipan and Tinian reveal standard winter seasonality for a breeding and calving ground, with detection of humpback song from December to April. PIPAN recordings from Pagan, Saipan, and Tinian could be used to determine the relative abundance of humpback whales in the southern and northern archipelago and to evaluate the Mariana Archipelago humpback whale song relative to other regions in the North Pacific. Photo-ID and genetic data suggest that Mariana Archipelago humpback whales are part of the endangered western North Pacific distinct population segment. Additional data are necessary to better assess migratory routes and connectivity to other breeding and feeding grounds. Analysis of humpback whale song within PIPAN data and continued winter survey effort are among the highest priority for PIFSC.

For a few other species, existing PAM data could be used to investigate questions about distribution, seasonality, relative abundance, and regional population differences. Bryde's whale call types could be evaluated using existing species-confirmed recordings from towed array and sonobuoy data. Those call type descriptions could then be used in conjunction with autonomous datasets to evaluate the seasonality and distribution of Bryde's whales in the Mariana Archipelago. Continued analysis of passive acoustic datasets for beaked whales may provide a better assessment of distribution and habitat than a visual survey-based dataset. As well, the passive acoustic datasets are uniquely capable of providing insight into exposure of these species to Navy sonar in the region, an anthropogenic stressor that may increase as the U.S. military shifts it testing and training operations from Okinawa to Guam and the Mariana Archipelago.

15. SUBJECT TERMS

Monitoring, marine mammals, toothed whales, vessel visual survey, satellite tagging, photo-identification, biopsy sampling, genetic analyses, passive acoustic monitoring, Mariana Islands Range Complex

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Executive Summary

The Pacific Islands Fisheries Science Center (PIFSC) Cetacean Research Program (CRP) has conducted research on cetaceans in the Mariana Archipelago since 2010. A cooperative effort with funding from U.S. Navy Pacific Feet and PIFSC has included summer and winter small-boat surveys off the southernmost islands (Saipan, Tinian, Aguijan, Rota, and Guam), development of photo-identification catalogs, analysis of collected tissue samples and satellite telemetry tag data, and shipboard visual and passive acoustic surveys in portions of the EEZ in 2010 and 2015. PIFSC has also maintained long-term passive acoustic monitoring on moored recorders off Saipan and Tinian (since 2010) and off Pagan (since 2015) as part of the Pacific Islands Passive Acoustic Network (PIPAN). The goal of these efforts is to collect the data necessary to conduct population assessments for cetaceans within the Mariana Archipelago, including the determination of their occurrence, population structure and abundance, movements, distribution, and habitat use. In addition, these data may be used to evaluate the potential exposure of cetaceans to human-caused stressors within the waters surrounding the Mariana Archipelago including U.S. Navy operations (e.g., sonar, use of explosives), fisheries interactions, and dolphin tourism.

The purpose of this report is to summarize data collected by PIFSC CRP within the Mariana Archipelago since 2010, synthesize the findings of analyses conducted with those data, and evaluate the current state of the information in light of National Marine Fisheries Service population assessment and U.S. Navy monitoring plan goals. The focus of this report is on PIFSC CRP projects, including the small-boat surveys conducted in partnership with the U.S. Navy (2010–February 2018), the shipboard survey conducted in 2015, and analysis of passive acoustic data. Photo-identification and cetacean encounter data collected during other surveys within the Mariana Archipelago were contributed by the U.S. Navy for incorporation into PIFSC CRP data sets for various species and are therefore also represented in the summary reported here.

Most tropical cetaceans have been observed within the Mariana Archipelago. During small-boat surveys off the southern islands from 2010 to 2018, covering 22,488 km of on-effort trackline, 14 species of cetaceans were seen, including spinner dolphin (*Stenella longirostris*), pantropical spotted dolphin (*Stenella attenuata*), bottlenose dolphin (*Tursiops truncatus*), rough-toothed dolphin (*Steno bredanensis*), short-finned pilot whale (*Globicephala macrorhynchus*), false killer whale (*Pseudorca crassidens*), melon-headed whale (*Peponocephala electra*), pygmy killer whale (*Feresa attenuata*), sperm whale (*Physeter macrocephalus*), dwarf sperm whale (*Kogia sima*), Blainville's beaked whale (*Mesoplodon densirostris*), Cuvier's beaked whale (*Ziphius cavirostris*), Bryde's whale (*Balaenoptera edeni*), and humpback whale (*Megaptera novaeangliae*). Risso's dolphin (*Grampus griseus*) was observed during the 2015 shipboard survey. Passive acoustic monitoring from PIPAN sites has

provided occurrence data on additional species not yet visually observed, including an unknown species of beaked whale (referred to as the Cross Seamount beaked whale, or BWC), blue whale (*Balaenoptera musculus*), fin whale (*B. physalus*), and minke whale (*B. acutorostrata*).

Although data are sparse for many species, the aggregate of all data collected to date do reveal insights into distribution and population structure for several species, and adequate data are available to assess abundance and movement patterns for others. Spinner dolphin genetic and photo-identification data analyzed to date suggest that there may be at least 2 populations within the Mariana Archipelago, and the existing photo-identification data are sufficient to conduct a mark-recapture analysis for abundance estimation. Spinner dolphin habitat preferences appear to be markedly different in the Mariana Archipelago than similar nearshore populations in Hawaiʻi, with apparent preference for very nearshore areas with dynamic currents or otherwise rough seas. Characterization of spinner dolphin habitat use based on environmental and physical features of encounter locations may reveal habitat preferences and differences among the Mariana island areas, as well as provide context for examining exposure to human-caused threats in the nearshore environment.

Previous genetic analyses found that Mariana Archipelago bottlenose dolphins exhibited evidence of Fraser's dolphin ancestry (Martien *et al.* 2014), but there is no evidence of population structure within the analyzed samples from the southern islands. Further examination of genetic population structure is not feasible with the limited sample size, though examination for evidence of the presence of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) would be valuable. The photo-identification catalog is small, but there are sufficient data to conduct a mark-recapture analysis to estimate abundance for the nearshore southern Mariana Archipelago. Additional satellite tagging, particularly with location-dive tags, is needed to provide sufficient sample size to examine spatial use and habitat of bottlenose dolphins in the region.

Population structure is unclear for short-finned pilot whales despite a robust collection of genetic, photo-identification, and satellite telemetry data. Additional samples and telemetry tags deployed in offshore areas and the islands north of Saipan may help clarify whether there is a southern archipelago island-associated population and a separate offshore or northern population(s). Analysis of the photo-identification data found a main social cluster within the southern islands that included 85% of the individuals within the catalog, and satellite telemetry data from individuals within the main social cluster demonstrated that the tagged whales primarily associate with nearshore waters (Hill *et al.* 2018). Adequate photo-identification data are available to conduct a mark-recapture analysis to estimate abundance within the southern archipelago. Based on increased use of intermediate dive depth at twilight and night, Hill *et al.* (2018) suggested tagged short-finned pilot whales were foraging while following the deep scattering layer as it migrated between the depth and surface. Additional analyses using data from location-dive satellite tags along with oceanographic data may reveal areas of importance for foraging whales.

There is no indication from genetic, photo-identification, or satellite telemetry data that there is population structure in melon-headed whales within the Mariana Archipelago. With the completion of the melon-headed whale photo-identification catalog, it may be possible to use the total catalog number as minimum population estimate since only 3 individuals have be re-sighted between encounters of hundreds of melon-headed whales over an 8-yr period.

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For a few other species, existing passive acoustic data could be used to investigate questions about distribution, seasonality, relative abundance, and regional population differences. Bryde's whale call types could be evaluated using existing species-confirmed recordings from towed array and sonobuoy data. Those call type descriptions could then be used in conjunction with autonomous datasets to evaluate the seasonality and distribution of Bryde's whales in the Mariana Archipelago. Continued analysis of passive acoustic datasets for beaked whales may provide a better assessment of distribution and habitat than a visual survey-based dataset. As well, the passive acoustic datasets are uniquely capable of providing insight into exposure of these species to Navy sonar in the region, an anthropogenic stressor that may increase as the U.S. military shifts it testing and training operations from Okinawa to Guam and the Mariana Archipelago.

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Introduction

Study Area

The Mariana Archipelago is made up of 15 islands stretching approximately 890 km in a north-south arc from the northern-most island of Farallon de Pajaros (also known as Uracas) to the southernmost island of Guam (Figure 1). The region is most notably characterized by the Mariana Trench which parallels the archipelago about 148 km to the east, arcing westward to within 120 km south of Guam. The West Mariana Ridge is a series of seamounts paralleling the archipelago 145 to 170 km to the west. The Mariana Archipelago is composed of 2 U.S. jurisdictions: the territory of Guam, and the Commonwealth of the Northern Mariana Islands (CNMI). The CNMI includes all islands within the archipelago with the exception of Guam.

Background

Prior to 2010, little information existed on cetaceans in the Mariana Archipelago. Most of what was known at that time came from stranding records (Kami and Lujan 1976, Kami and Hosmer 1982, Donaldson 1983, Trianni and Kessler 2002, Trianni and Tenorio 2012), whaling records (Townsend 1935, Camba 1965, Masaki 1972), and publications of previously undocumented strandings and anecdotal sighting reports (Eldredge 1991, Eldredge 2003, Wiles 2005, Jefferson *et al*. 2006). A handful of scientific surveys, primarily focused on large whale distribution, were conducted throughout the lower latitude areas of the western North Pacific in the 1990s (Darling and Mori 1993, Yamaguchi 1995, Yamaguchi 1996, Shimada and Miyashita 2001, Ohizumi *et al*. 2002). These surveys met with low sighting rates in the vicinity of the Mariana Archipelago; however, each of these projects only spent a small amount of time in Mariana Archipelago waters[1].

Two scientific cetacean surveys dedicated to the Mariana region were conducted prior to 2010: the 2007 Mariana Islands Sea Turtle and Cetacean Survey (MISTCS), which was a large-ship line-transect survey that covered part of the U.S. exclusive economic zone (EEZ) around Guam and CNMI (Fulling *et al*. 2011) (Figure 1) and a 5-day aerial survey conducted in August 2007 (Mobley 2007). In 2010, a set of NOAA ship surveys were conducted (Oleson and Hill 2010, PIFSC 2010a, b, c). Two of these surveys were mammal-specific line-transect surveys conducted while in transit between Hawaiʻi and Guam (PIFSC 2010a, c), so little effort was actually spent surveying within Mariana Archipelago waters. Mammal observations were also

[1] Darling and Mori (1993) spent just 1 week on Saipan in February 1990; Shimada and Miyashita (2001) conducted "no effort within 12 nm [of] territorial waters" and only just a few days in the region across 3 survey years; and Ohizumi *et al*. (2002) spent just 1 day conducting a survey "about 5km off the coast of Pagan and Agrihan Islands in the Northern Mariana Islands." Yamaguchi (1995) spent 10 days surveying nearshore Mariana waters in March-April, 1995, but reported only 5 sightings (of any species). Although no information was given regarding weather, such a low sighting rate implies that poor sea conditions were likely a factor (No sighting data were reported from Yamaguchi 1996.).

conducted opportunistically during a NOAA offshore oceanographic survey within the EEZs of the CNMI, Guam, and Federated States of Micronesia (PIFSC 2010b).

While much information was known opportunistically or from systematic effort at reduced spatial or temporal scales prior to 2010, there had not been a consistent long-term effort aimed at assessing cetacean populations in the Mariana Archipelago. In an effort to further develop a record of the occurrence, abundance, and structure of cetacean populations in the Mariana Archipelago, the Pacific Islands Fisheries Science Center's (PIFSC) Cetacean Research Program (CRP) conducted surveys for cetaceans in the waters surrounding Guam and the CNMI during 2010–2018. Funding for these surveys was provided in partnership between the U.S. Navy (U.S. Pacific Fleet Environmental Readiness Division) and PIFSC. In addition to the PIFSC CRP small-boat effort, the U.S. Navy contracted HDR in 2011 and 2012 to conduct small-boat surveys around Guam and Saipan (HDR 2011, 2012). In 2013, TetraTech (Marine Corps contractor) conducted large-ship line-transect surveys off Pagan, Saipan, and Tinian that included small-boat non-systematic surveys in the nearshore waters of Pagan (TetraTech 2014). In 2015, the PIFSC CRP conducted a systematic line-transect shipboard survey of the Mariana Archipelago, which included small-boat non-systematic surveys in the nearshore waters of islands north of Farallon de Medinilla (FDM) (Oleson 2017).

For PIFSC, the goal of this research is to assess population status for each cetacean species in the Mariana Archipelago. Such assessment includes evaluating population structure, range, and habitat use from analyses of photo-identification, genetic, satellite telemetry, and acoustic datasets, as well as estimating population abundance using mark-recapture, line-transect, or other methods. In order to monitor for cetacean species in the Mariana Islands Training and Testing (MITT) area that also includes the Mariana Islands Range Complex (MIRC) (Figure 1), the Navy developed the following questions.

1. What species of marine mammals occur in the nearshore (within small-boat survey range) and offshore areas of the MITT study area?
2. What is the habitat use of cetaceans in the nearshore and offshore areas of the MITT study area?
3. What is the abundance and population structure of marine mammals in the MITT study area?
4. What is the seasonal occurrence and movements of baleen whales in the nearshore and offshore areas of the MITT study area?
5. What is the exposure of cetaceans and sea turtles to explosives and/or sonar in the MITT study area?
6. What is the baseline vocalization behavior of marine mammals in the MITT study area?

The purpose of this document is to summarize the existing data collected by PIFSC CRP within the Mariana Archipelago and to evaluate the current state of the data with respect to the U.S. Navy's questions, as well as the PIFSC's overall goal of cetacean population assessment. The focus of this report is on PIFSC CRP projects, including the small-boat surveys conducted in 2010–March 2018 and the shipboard survey conducted in 2015. Photo-identification, acoustic, and biopsy data from other surveys (2007 MISTCS, 2011–2012 HDR, 2013 TetraTech) were contributed by the U.S. Navy for incorporation into the PIFSC CRP data sets for various species and are therefore also represented in the summary reported here.

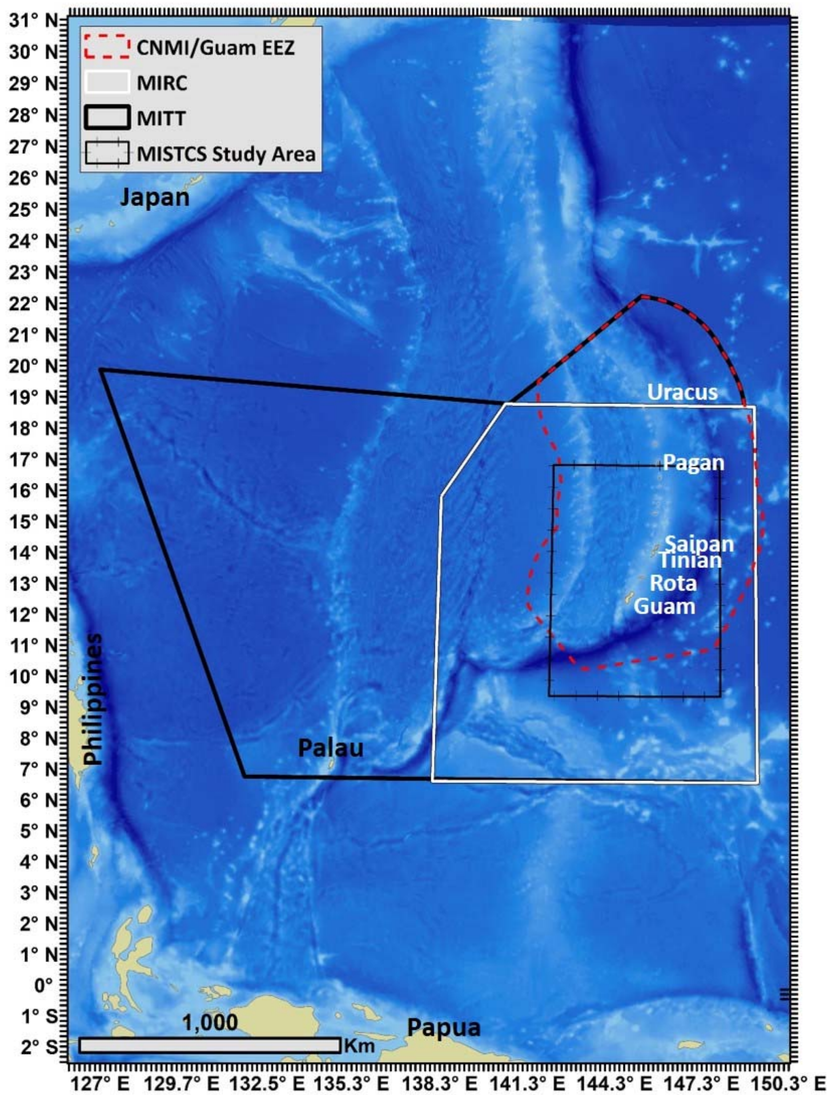

Figure 1: Guam and the Commonwealth of the Northern Mariana Islands (CNMI) Exclusive Economic Zone (EEZ), the Mariana Islands Range Complex (MIRC), and the Mariana Islands Training and Testing (MITT) area. The National Marine Fisheries Service is responsible for management of marine mammal stocks within the Guam and CNMI EEZ. The U.S. Navy is authorized to conduct training and testing activities within the MITT and is mandated by permits and Biological Opinions issued under the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA) to monitor cetacean presence because such activities have

the potential to harass or harm cetaceans. The MITT was expanded from the MIRC in 2015. The 2007 Mariana Islands Sea Turtle and Cetacean Survey (MISTCS) was a shipboard line-transect survey that covered part of the Guam and CNMI EEZ and the MIRC.

Surveys and Field Methods

Small-Boat Surveys

PIFSC CRP conducted non-systematic visual surveys for cetaceans in the waters off the southernmost islands of the Mariana Archipelago (Saipan, Tinian, Aguijan, Rota, and Guam) aboard small vessels (5.8–12.2 m) during 2010–February 2018. Vessel tracks were spread out from day to day to ensure broad survey coverage over a wide range of depths and were also dictated by weather and sea conditions. The survey vessels traveled at a speed of 15–26 km/h, depending on the size of the vessel and sea conditions. Between 4 and 6 observers scanned for marine mammals with unaided eye or, occasionally handheld binoculars, collectively searching 360-degrees around the vessel.

All cetacean groups encountered were approached for species confirmation, group size estimates, photo-identification, biopsy sampling/sloughed skin collection, and acoustic recording when possible. In 2013, satellite tagging was implemented to investigate movements and spatial use of individuals of some species. Additional data collected during each sighting included the location (latitude/longitude), behavior, and estimates of calf (neonates and young of the year) numbers. Survey conditions (e.g., Beaufort sea state, swell height) and effort status were recorded regularly as conditions changed. A handheld Global Positioning System (GPS) automatically recorded the vessel's track at 1-minute intervals.

Digital SLR cameras with telephoto zoom lenses were used for taking photographs. Photographic efforts were focused on dorsal fin and fluke images (for individual identification purposes) and images of the body and head (for assessments of health and scarring).

Biopsy sampling was conducted using a Barnett RX-150 crossbow and Ceta-Dart bolts with sterilized, stainless steel biopsy tips (25 mm long x 8 mm diameter for small to medium odontocetes and 40 mm long x 8 mm diameter for large odontocetes and baleen whales). Tissue samples were preserved in a cooler on ice while on the boat. Samples were split in half longitudinally at the end of each field day (with each subsample stored in a different vial) and stored in a standard refrigerator freezer until the end of the project. Samples were kept frozen during transport on board a commercial airline to Honolulu, HI. One vial of each sample was stored in a -80°C freezer at the PIFSC and the other (except for humpback whales; *Megaptera novaeangliae*) was submitted to the National Marine Mammal and Sea Turtle Research Collection at Southwest Fisheries Science Center (SWFSC) for tissue archiving and processing. The humpback whale samples, as well as the other halves of the stenellid dolphin samples were sent to the Marine Mammal Institute at Oregon State University (OSU).

Satellite tagging was conducted using a Dan Inject air rifle and deployment arrows designed by Wildlife Computers. Wildlife Computers location-only (SPOT5 and SPOT6) and location-depth (SPLASH10) tags were deployed in the Low Impact Minimally Percutaneous Electronic Transmitter (or LIMPET) configuration (Andrews *et al.* 2008). The tags were attached to the dorsal fin with 2 sterilized, titanium darts with backward facing petals. Two dart lengths were used depending on the species (4.5 cm for small to medium odontocetes or 6.5 cm for large odontocetes). Tag programming varied depending on the species and followed the specifications used by Cascadia Research Collective (CRC) based on the average number of respirations per hour, speed of surfacing, and the likelihood that a tag would remain attached for longer than a month, which were determined in previous tagging studies by CRC (Baird *et al.* 2013).

In 2011–2012, acoustic recordings were made during some PIFSC CRP encounters using a Fostex model FR-2 with a hydrophone suspended from 30 m of cable over the side of the survey vessel. The hydrophone was deployed once the boat was positioned (and turned off) within or in front of a group of interest, and recording continued until the group had left the area or the survey team was required to move on to pursue additional survey effort. The Fostex recorded 24-bit acoustic data sampled at 192 kHz to a Type II CompactFlash card. In 2016, acoustic recordings were made using a Compact Acoustic Recording Buoy (CARB, designed by Y. Barkley), a free-floating instrument deployed in the vicinity of animals, that includes an HTI-96-MIN hydrophone (High Tech, Inc., Long Beach, MS) suspended around 30 m depth and recording at 384 kHz on an SM2+ Song Meter (Wildlife Acoustics, Concord, Mariana Archipelago). Song Meter settings included pre-amplifier gain of +36 dB and a 1 kHz high pass filter.

In 2015, PIFSC CRP began conducting small-boat surveys targeting humpback whales off Saipan in February–March when the whales were expected to be present based known presence from December–April (Oleson *et al.* 2015). The field procedures were the same as described above; however shallow water (≤ 200 m) areas were targeted based on known humpback whale habitat preferences in other wintering areas (Herman and Antinoja 1977, Frankel *et al.* 1995).

Across all summer and winter small vessel survey efforts, PIFSC CRP conducted 245 days of non-systematic surveys for cetaceans off the southernmost islands of the Mariana Archipelago (Saipan, Tinian, Aguijan, Rota, and Guam) between 2010 and February 2018 and completed 22,488 km of on-effort trackline (Table 1, Figure 2). A third of the total on-effort time was spent inside of the 200 m isobath (Figure 3). During the 2015–2018 winter (February–March) surveys, effort was targeted at humpback whales in shallow water (≤200 m) areas where they were expected to occur, which accounted for 23% (113 h) of the total effort in the 200 m depth bin. There were 330 groups (excluding within-day re-sights) identified to 14 species including (in order of frequency of occurrence) spinner dolphin (*Stenella longirostris*), pantropical spotted dolphin (*Stenella attenuata*), bottlenose dolphin (*Tursiops truncatus*), short-finned pilot whale (*Globicephala macrorhynchus*), rough-toothed dolphin (*Steno bredanensis*), false killer whale (*Pseudorca crassidens*), sperm whale (*Physeter macrocephalus*), dwarf sperm whale (*Kogia sima*), pygmy killer whale (*Feresa attenuata*), Bryde's whale (*Balaenoptera edeni*), melon-headed whale (*Peponocephala electra*), Blainville's beaked whale (*Mesoplodon densirostris*), and Cuvier's beaked whale (*Ziphius cavirostris*) (Table 2, Figure 2). Humpback whales were encountered in February–March 2015–2018 when targeted surveys were conducted off Saipan. Across all PIFSC CRP small-boat surveys, there were 17 mixed-species groups, each including 2–3 species. Some groups could not be identified to species, and are indicated as unidentified beaked whales, unidentified whales, and unidentified dolphins. A total of 122,871 photos and 402 biopsy samples were collected, 39 satellite tags were successfully deployed (Table 3), and 9 single-species acoustic recordings were made (Table 2). The cumulative number of species discovered during PIFSC small-boat surveys steadily increased before leveling out after a survey distance of 17,206 km (Figure 4).

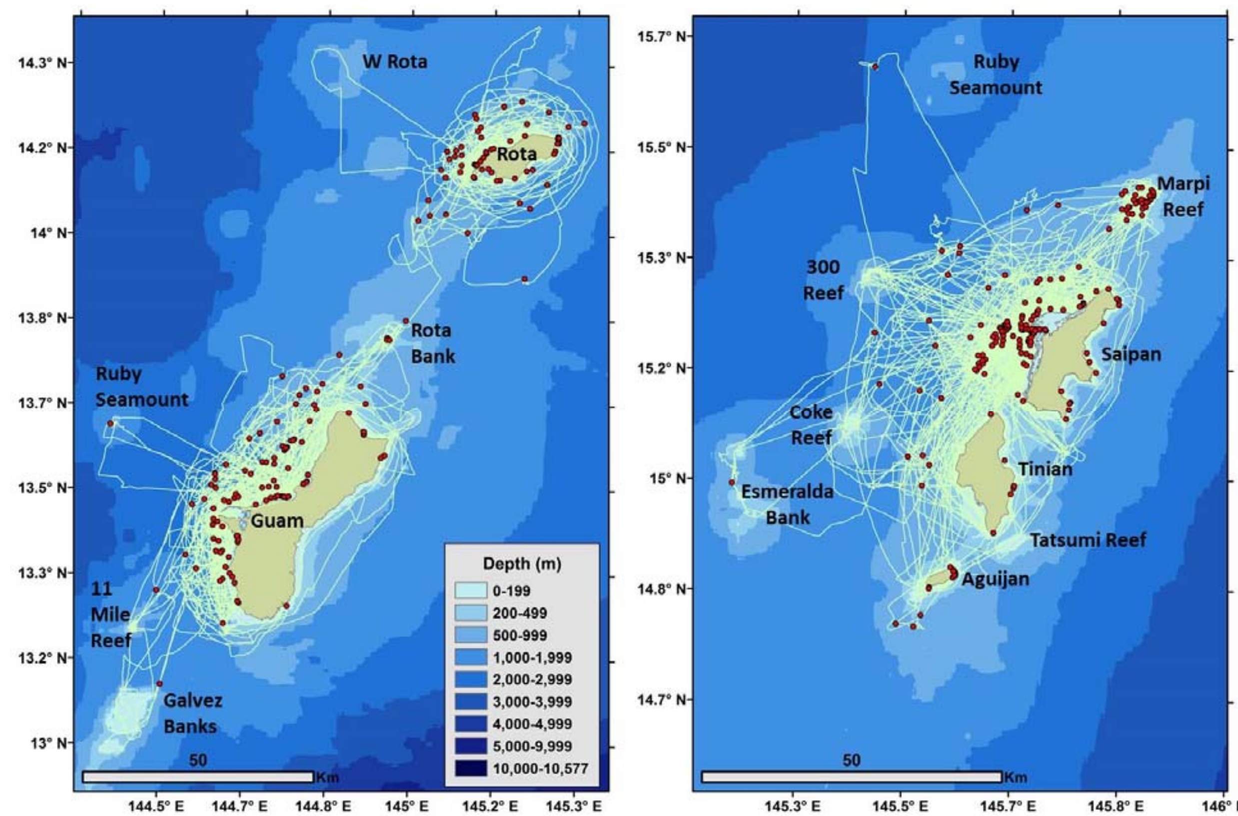

Figure 2: Tracks and cetacean encounter locations during the Pacific Islands Fisheries Science Center's Cetacean Research Program small-boat surveys of the southernmost Mariana Archipelago (2010–February 2018).

Table 1: Summary of small-boat surveys for cetaceans conducted by the Pacific Islands Fisheries Science Center's Cetacean Research Program off of the southernmost islands of the Mariana Archipelago including the months (Mo.) during which surveys were conducted, the number (No.) of survey days, and the distance (Dist.) of on-effort trackline (km). The 3-Islands refer to Saipan, Tinian, and Aguijan.

2010			2011			2012			2013			2014			2015			2016			2017			2018			Location Total	
Mo.	**No.**	**Dist. (km)**	**Mo.**	**No.**	**Dist. (km)**	**Mo.**	**No.**	**Dist. (km)**	**Mo.**	**No.**	**Dist. (km)**	**Mo.**	**No.**	**Dist. (km)**	**Mo.**	**No.**	**Dist. (km)**	**Mo.**	**No.**	**Dist. (km)**	**Mo.**	**No.**	**Dist. (km)**	**Mo.**	**No.**	**Dist. (km)**	**No.**	**Dist. (km)**
Feb-Mar	6	559	Aug	15	1,424	Jun	14	1,539	Jul	14	1,493	Apr; May-Jun	23	2,223	Feb-Mar	8	511	Mar; May	20	1,730	Feb; May	15	1,306	Feb	8	543	123	11,329
--	0	0	Sept	6	605	May-Jun	6	500	Jul	6	493	Jun	5	471	Aug-Sep	6.5*	668	May	5	304	---	0	0	---	0	0	35	3,042
Feb	10	681	Aug-Sep	9	949	May; Jul	11	1,292	Jun-Jul	10	1,062	Apr; May	17	1,363	Aug-Sep	14.5*	1,373	May-Jun	8	709	May	8	688				88	8,117
	16	1,240		30	2,978		31	3,331		30	3,048		45	4,058		29	2,552		33	2,744		23	1,994		8	543	**245**	**22,488**

*In September 2015, the CRP conducted 1 day of survey between Rota and Guam.

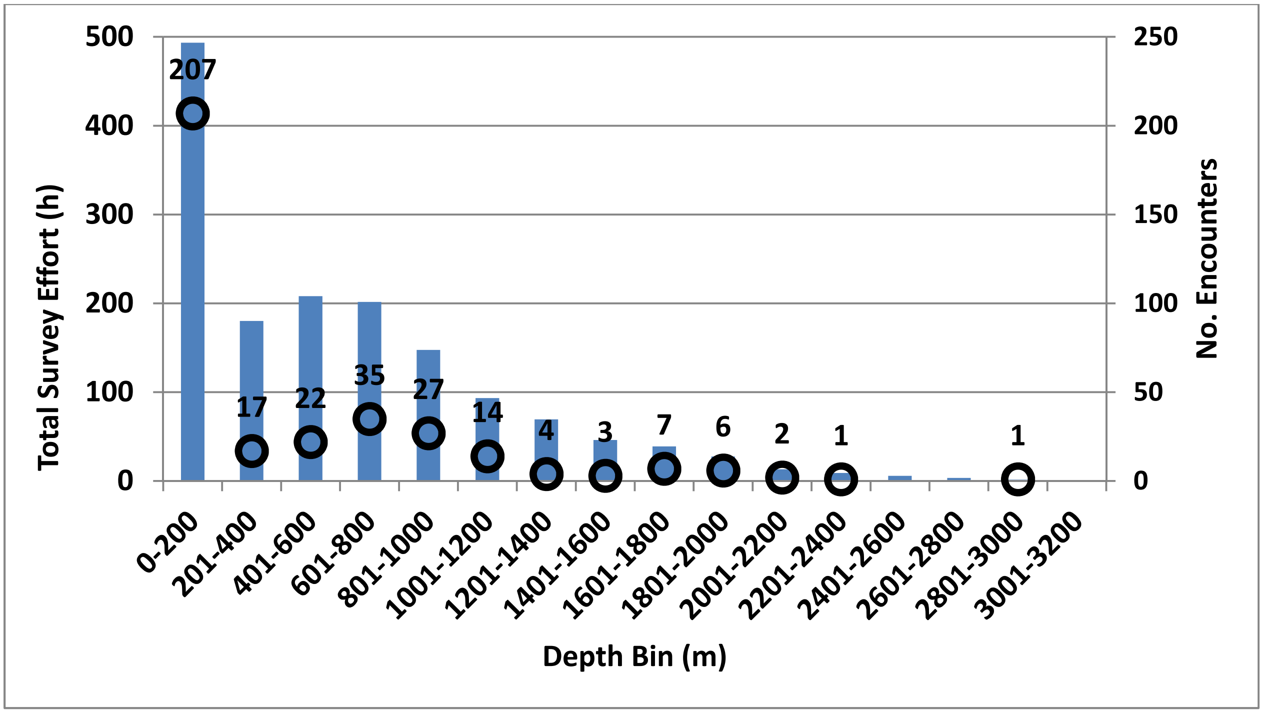

Figure 3: Survey effort (h) and the number of cetacean encounters (black circles with numbers) by depth during the Pacific Islands Fisheries Science Center's Cetacean Research Program 2010–2018 small-boat surveys off Saipan, Tinian, Aguijan, Rota, and Guam.

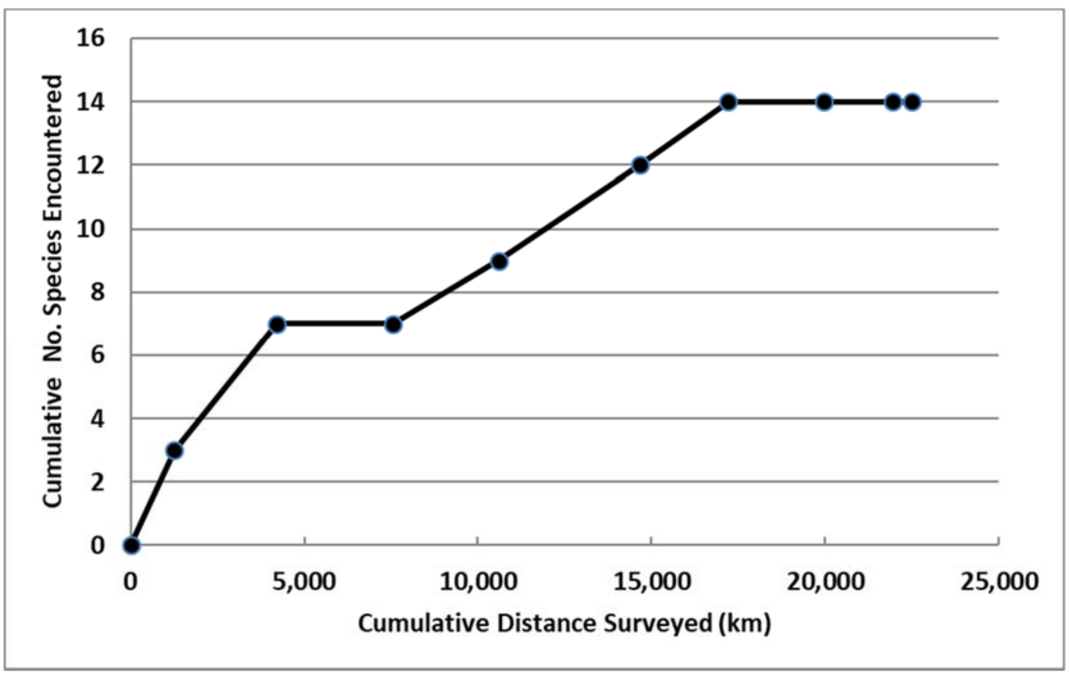

Figure 4: Cetacean species discovery curve (cumulative number (No.) species encountered over cumulative distance surveyed (km)) for Pacific Islands Fisheries Science Center's Cetacean Research Program small-boat surveys off the 3-Islands area, Rota, and Guam (2010–February 2018).

Table 2: Summary of cetacean encounters during 2010–February 2018 small-boat surveys conducted by the Pacific Islands Fisheries Science Center's Cetacean Research Program off the 3 -Islands area, Rota, and Guam including the number (No.) of encounters, the encounter rate (No. of encounters/100 km of on-effort trackline), the median (range) of the best group size estimates from the field, the No. of photos and biopsy samples collected, the number of satellite tags deployed, the median (range) encounter location depth (m), and the median (range) shore distance (km). Median values are not provided for species with fewer than 3 encounters. Species are listed in order of frequency of occurrence with the exception of humpback whales, which are listed last because they occur only seasonally in the Mariana Archipelago. For humpback whales, the encounter rate was calculated using the trackline distance (4,782 km) for "winter" (February–April) surveys when they are known to occur in the Mariana Archipelago. Groups that could not be identified to species are shown in gray boxes.

Species	No. Encounters	Encounter Rate (No./100 km)	Median (range) Best Grp. Size Est.	No. Photos	No. Biopsy Samples	No. Satellite Tags	No. Acoustic Recordings	Median (range) Depth (m)	Median (range) Shore Distance (km)
Spinner dolphin	148	0.66	31 (1–135)	43,143	95	0	2	41 (2–615)	0.6 (0.1–18.5)
Pantropical spotted dolphin	46	0.20	35 (4–145)	11,823	55	1	1	833 (333–3,000)	6.2 (1.7–52.8)
Bottlenose dolphin	36	0.16	7 (1–27)	7,913	35	6	1	122 (18–1,048)	4.9 (0.3–18.7)
Short-finned pilot whale	21	0.09	30 (4–48)	18,885	96	18	3	720 (51–1,443)	5.1 (0.5–36.3)
Rough-toothed dolphin	7	0.03	5 (1–24)	1,776	4	1	—	500 (66–808)	6.8 (0.4–14.3)
False killer whale	6	0.03	14 (2–25)	6,707	33	8	—	838 (88–2,107)	5.8 (0.7–8.4)
Sperm whale	6	0.03	9 (6–15)	2,627	14	2	—	1,385 (374–1,971)	15.2 (1.1–22)
Dwarf sperm whale	5	0.02	3 (1–4)	986	1	0	2	696 (642–870)	3.3 (1.6–16.7)
Pygmy killer whale	5	0.02	8 (6–11)	1,741	5	0	—	563 (38–1,978)	6.9 (1.1–10)
Bryde's whale	5	0.02	1	846	3	0	—	859 (487–1,918)	16.7 (12.4–23.9)
Melon-headed whale	3	0.01	325 (85–380)	7,502	31	3	—	1,014 (903–1,975)	6.5 (2.6–15.1)
Blainville's beaked whale	2	0.01	– (1–5)	468	1	0	—	– (678–1,200)	– (10.9–15.2)
Cuvier's beaked whale	1	0.004	4	230	0	0	—	1,706	18.8
Humpback whale	39	0.82	2 (1–8)	18,125	29	0	—	38 (12–307)	8.1 (1.2–18.1)
Mesoplodon beaked whale	5	0.02	1 (1–2)	71	0	0	—	1,078 (1,032–1,614)	20.3 (5.1–30.6)
Unid. beaked whale	3	0.01	2 (1–2)	0	0	0	—	1,352 (972–1,815)	7.0 (6.5–11.8)
Unid. medium dolphin	3	0.01	1 (1–5)	28	0	0	—	631 (464–702)	6.2 (2.8–12.6)
Unid. small dolphin	2	0.01	– (1–2)	0	0	0	—	– (26–1,515)	– (2.6–27.2)
Unid. small whale/whale	3	0.01	1	0	0	0	—	447 (343–568)	4.1 (1.3–21.3)
Total	**346**	**1.53**		**122,871**	**402**	**39**	**9**		

Table 3: Summary of satellite tags deployed during the Pacific Islands Fisheries Science Center's Cetacean Research Program small-boat surveys (2013–2017) and the MACS 2015 including the total number of tags deployed by species with the number of location-only (SPOT) and location-dive (SPLASH) tags, the years in which the tags were deployed, the deployment locations, and the median (range) of the tag transmission durations (d).

Species	No. Tags (SPOT/SPLASH)	Deployment Years	Deployment Locations	Median (range) Duration (d)
Short-finned pilot whale	18 (13/5)	2013, 2014, 2016	Guam, Rota, Marpi Reef	37.5 (6.8–234.7)
False killer whale	9 (7/2)	2013, 2014, 2015	Guam, Rota, Tinian, Asuncion	30.7 (4.0–198.3)
Bottlenose dolphin	6 (4/2)	2013–2015, 2017	Rota, Saipan, Tinian, Aguijan	9.6 (3.7–20.5)
Melon-headed whale	3 (3/0)	2014, 2017	Saipan, Guam	3.1 (1.8–15.9)
Sperm whale	2 (1/1)	2016	Saipan, Guam	25.8 (9.7–41.8)
Pantropical spotted dolphin	1 (1/0)	2016	Guam	11.4
Rough-toothed dolphin	1 (1/0)	2013	Aguijan	11.7

Shipboard Survey

From 8 May–5 June 2015, PIFSC CRP conducted the Mariana Archipelago Cetacean Survey (MACS), which was a ship-based survey around all islands in the Mariana Archipelago north of Farallon de Medinilla (FDM) and of waters out to 92.6 km (50 nmi) from shore. MACS 2015 consisted of both systematic line-transect effort from the ship and non-systematic offshore and nearshore tracks from the ship and small boat. During the systematic effort, most cetacean groups within a 5.6 km (3 nmi) perpendicular distance from the transect line were approached for group size estimation and, if time permitted, additional data collection including photo-identification and biopsy sampling from the ship. During some encounters, a small boat was launched for photo-identification, biopsy sampling, and satellite tagging. The sampling and tagging methods were the same as described above for small-boat surveys. In addition, at some of the northern islands, the small boat was launched to conduct an independent nearshore circumnavigation survey while the ship worked further offshore. Passive acoustic towed array surveys were conducted during all daylight hours. The towed array consisted of 2 array segments, including an inline array with 3 HTI 96-MIN hydrophones and an end array with 4 HTI 96-MIN hydrophones. The 2 array segments were separated by 30 m of cable. All incoming acoustic data, as well as depth data were sampled at 500 kHz using National Instruments A/D card and recorded to a computer hard drive. Data were monitored for the occurrence of dolphin whistles and echolocation clicks, and the vessel was directed toward detected groups if they were within 3 nmi of the trackline and passed the beam without being sighted by the visual team.

During MACS 2015, visual systematic effort was conducted along 1,996 km of trackline and offshore or nearshore non-systematic effort from the ship and small boat was conducted along 2,241 km of trackline (Figure 5). Three days were spent diverting from the area to avoid Typhoon Dolphin. There were 35 sightings of 9 species including spinner dolphin, rough-toothed dolphin, bottlenose dolphin, Risso's dolphin (*Grampus griseus*), melon-headed whale, false killer whale, sperm whale, Blainville's beaked whale, and Bryde's whale. Three encounters were mixed-species groups. During 2 encounters, bottlenose and rough-toothed dolphins were associated, and a third mixed-species encounter included Risso's dolphins and sperm whales. In addition, there were groups that could not be identified to species and included unidentified dolphins, whales, and beaked whales. A total of 6,616 photos and 51 biopsy samples were collected, and a single satellite tag was deployed on a false killer whale (Table 4). From the towed array there were single-species acoustic recordings during 21 visual encounters of identified species (Table 4), as well as of 3 groups of sperm whales, 1 group of beaked whales, and 12 groups of unidentified dolphins not observed by the visual survey team.

Long-term passive acoustic monitoring

In addition to opportunistic recordings obtained during small-boat surveys and towed array recordings collected during MACS 2015, PIFSC CRP has maintained 3 long-term passive acoustic monitoring sites within the Mariana Archipelago as part of the Pacific Islands Passive Acoustic Network (PIPAN). Monitoring sites at Saipan and Tinian have been occupied since 2010 and 2011, respectively. A site about 16 km (10 nmi) southwest of Pagan was monitored for 2 years from 2015 to 2017. High-Frequency Acoustic Recording Packages (HARPs) sampling at 200 kHz were deployed at each site annually and provided cetacean and noise data from 10 Hz to 100 kHz. All recordings were duty-cycled to maintain recording for the full year, though the length of the off-period of the duty cycle was reduced over time as battery life increased. Several analyses have been conducted with the PIPAN data including examination of baleen whale occurrence, beaked whale occurrence, and other species or time-specific analyses. Analysis methods for each species or call type have been described in detail in other reports and are not repeated here. Insights into species occurrence, distribution, and seasonality from the PIPAN data are incorporated into the species summaries below.

Table 4: Summary of cetacean encounters during the 2015 Mariana Archipelago Cetacean Survey conducted by the Pacific Islands Fisheries Science Center's Cetacean Research Program including the number (No.) of encounters (S=systematic effort; N=non-systematic effort), the median (range) of the best group size estimates from the field, the No. of photos and biopsy samples collected, the No. of satellite tags deployed, the No. of single-species acoustic recordings, the median (range) encounter location depth (m), and the median (range) shore distance (km). Median values are not provided for species with fewer than 3 encounters. Species are listed in order of frequency of occurrence. Groups not identified to species are shown in gray.

Species	No. Encounters (S/N)	Median (range) Best Grp. Size Est.	No. Photos	No. Biopsy Samples	No. Tags	No. Towed Array Acoustic Detections	No. Single Species Acoustic Recordings	Median (range) Depth (m)	Median (range) Shore Distance (km)
Spinner dolphin*	–/12	22 (6–47)	467	12	0	7	7	27 (14–416)	0.2 (0.1–0.8)
Melon-headed whale	2/2	167 (90–268)	2,462	27	0	4	4	2,500 (1,562–3,383)	40.1 (18.0–71.3)
Rough-toothed dolphin	1/3	16 (12–27)	1,072	6	0	2	2	559 (30–1,955)	2.1 (0.4–16.3)
Bottlenose dolphin	–/3	10 (9–20)	45	2	0	2	2	671 (98–961)	2.9 (1.1–35)
Bryde's whale	2/1	2 (1–4)	785	0	0	0	2†	3,198 (844–3,762)	45.9 (9.0–71.0)
Sperm whale	2/1	1 (1–9)	461	1	0	3	2	2,594 (1,578–2,975)	31.6 (14.3–75.1)
Blainville's beaked whale	1/1	– (3–4)	23	0	0	1	1	– (267–1,290)	– (0.5–3.5)
False killer whale	–/2	– (6–31)	1,285	3	1	1	1	– (2,457–2,461)	– (12.5–39.5)
Risso's dolphin	1/1	– (1–5)	8	0	0	2	1	– (2,594–4,398)	– (75.1–94.5)
Mesoplodon beaked whale	1/4	1	8	0	0	1	1	1,294 (914–1,699)	3.5 (0.8–12.7)
Unid. large whale	1/1	1	0	0	0	—	—	– (1,883–3,585)	– (6.7–72.6)
Unid. rorqual	1/–	1	0	0	0	—	—	2,047	79.7
Unid. dolphin	–/1	2	0	0	0	—	—	399	37.5
Unid. small dolphin	1/–	17	0	0	0	—	—	6,298	67.1
Total	**13/32**		**6,616**	**51**	**1**	**23**	**23**		

*Includes 4 small-boat only encounters

†Sonobuoys were deployed during 2 Bryde's whale encounters but the data have not been processed to determine if vocalizations were recorded.

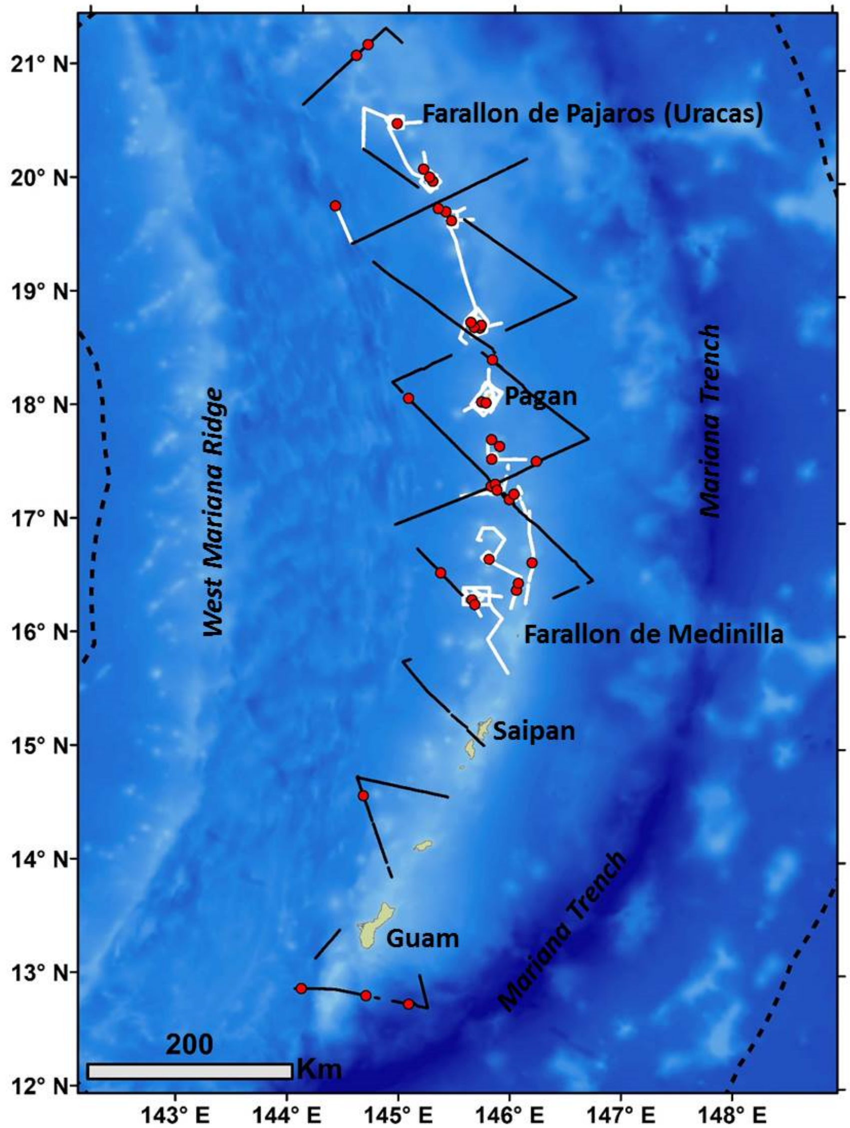

Figure 5: Systematic effort tracks (solid black lines), non-systematic effort tracks (white solid lines) and cetacean encounter locations (red dots) during Pacific Islands Fisheries Science Center Mariana Archipelago Cetacean Survey (8 May–5 June 2015). Dashed black line – Guam/Commonwealth of the Northern Mariana Islands exclusive economic zone.

Species Summaries

The following species summaries are listed in order of frequency of species occurrence during the PIFSC CRP small-boat surveys in the southernmost islands of the Mariana Archipelago (2010–February 2018) (Table 2), however information is also included on species encountered during MACS 2015 (Table 4) and other vessel surveys since 2010 funded by the U.S. Department of Defense (

Table 5). A special case is the humpback whale, which is listed last because it occurs only seasonally in the Mariana Archipelago during "winter" months (December–April).

Available data are summarized by the 15 encountered species (with the 2 encountered beaked whale species combined into 1 section) to address questions important to both PIFSC CRP and the U.S. Navy. The U.S. Navy's questions (listed above) are framed with reference to the MITT (Figure 1), while the PIFSC CRP survey area is more archipelago or island focused (Figure 2, Figure 5). These summaries include a discussion of what is known or what could be assessed relative to population structure, abundance, distribution and habitat use, and exposure to human stressors. Population structure may be assessed for certain species using genetic, as well as photo-identification and satellite telemetry data. Abundance estimates may be possible for some species using mark-recapture analysis of photo-identification data. Distribution and habitat use may be assessed using encounter and satellite telemetry data and incorporating physical attributes of the locations (e.g., bathymetry, bottom type) and available environmental variables (e.g., wind, currents). Potential human stressors include activities by the U.S. Navy (e.g., sonar, underwater explosives detonations), fisheries interactions, and dolphin-directed tourism. Assessing the exposure of cetaceans to sonar is difficult in the Mariana Archipelago because exact locations where the operations occur are unknown, but certain species (e.g., beaked whales) are known to be sensitive to sonar. Occurrence of sonar use can be assessed using recording from the HARPs. There are 3 nearshore U.S. Navy training areas off Guam where underwater detonations and explosive ordnance use occur. These include the Piti Mine Neutralization Area (depth=750 m), the Agat Bay Underwater Detonation (UNDET) Area (depth=1,750 m), and the Outer Apra Harbor UNDET Area (depth=38 m) (Figure 6). The U.S. Navy-provided a schedule of operations for the 3 sites listing the dates, as well as the range of hours for potential exercises and underwater detonations as 0800–1800 local time. Potential exposure to underwater detonations can be assessed using encounter location and satellite telemetry data for certain cetacean species. Evidence of fisheries interactions can be assessed using photos to look for injuries and scarring patterns characteristic of fishing line entanglement (Baird & Gorgone 2005, Baird *et al.* 2015). Dolphin–directed tourism activities have been observed off Guam, particularly within and just outside of bays along the west coast (e.g., Tumon, Piti, Hagatna, Agat).

Except in cases where passive acoustic data have already provided insights into species occurrence, distribution, or seasonality, the U.S. Navy's question about vocal behavior will be addressed separately after the species summaries.

Table 5: Summary of data contributed by the U.S. Navy from other survey efforts in the Mariana Archipelago. MISTCS – Mariana Islands Sea Turtle and Cetacean Survey in 2007 (Fulling *et al.* 2011); HDR – small-boat surveys conducted off Saipan and Guam in 2011 and 2012 (HDR 2011, 2012); TetraTech – ship and small-boat survey off Pagan, Saipan, and Tinian in 2013 (TetraTech 2014). All biopsy samples were collected under the Pacific Islands Fisheries Science Center's Cetacean Research Program permit. TBD - to be determined.

	MISTCS		**HDR**			**TetraTech**		
Species	**Encounters for Photo Analysis**	**No. Photos**	**Encounters for Photo Analysis**	**No. Photos**	**No. Biopsy Samples**	**Encounters for Photo Analysis**	**No. Photos**	**No. Biopsy Samples**
Spinner dolphin	1	22	7	1,786	—	4	TBD	5
Pantropical spotted dolphin	1	55	1	TBD	4	—	—	—
Bottlenose dolphin	2	24	2	222	—	1	1,094	—
Short-finned pilot whale	4	196	2	1,232	3	—	—	—
False killer whale	6	175	—	—	—	—	—	—
Sperm whale	6	327	1	—	—	—	—	—
Bryde's whale	10	589	—	—	—	—	—	—
Melon-headed whale	2	202	1	543	2	—	—	—
Humpback whale	1	199	—	—	—	—	—	—
Total	**33**	**1,789**	**12**	**3,489**	**9**	**5**	**1,094**	**5**

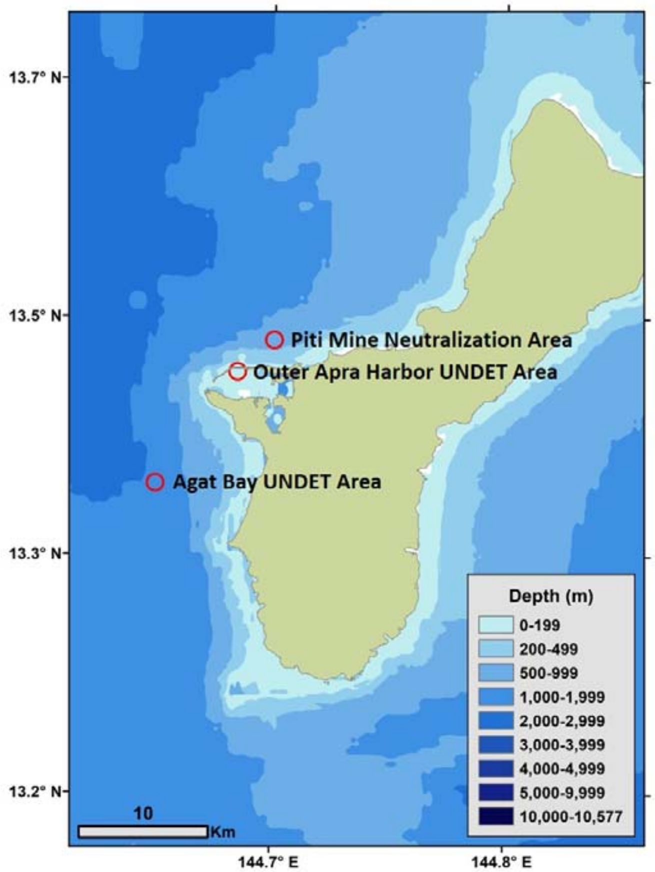

Figure 6: U.S. Navy underwater explosive operation sites off Guam. Circles represent the 640 m exclusion zones. Piti Mine Neutralization Area = 750 m depth, 1.9 km shore distance; Outer Apra Harbor UNDET Area = 38 m depth, 0.3 km shore distance; Agat Bay UNDET Area = 1,750 m depth, 6.7 km shore distance.

Spinner Dolphin

Spinner dolphins were the most frequently sighted species during PIFSC CRP small-boat surveys (*n*=148; 0.66 encounters/100 km) (Table 2). On 3 occasions they were encountered with other species including bottlenose dolphins, rough-toothed dolphins, and humpback whales. Spinner dolphins were encountered in all months during which surveys occurred and at all of the southern islands, as well as at some offshore reefs (e.g., Rota Bank, Chalan Kanoa (CK) Reef, Marpi Reef) (Figure 7a-b). They were consistently seen in locations with water depths <100 m (median=41 m), and spinner dolphins accounted for 70% (*n*=144) of all cetacean encounters in depths less than 200 m (Figure 3). With the exception of encounters at offshore reefs, most of the spinner dolphin encounter locations were within 1 km from shore (median=0.6 km). Group sizes ranged from 1 to 135 individuals (median=31 individuals). A total of 43,143 photos and 95 biopsy samples have been collected during PIFSC CRP small-boat surveys. Acoustic recordings were made during 2 encounters with spinner dolphins off Guam in 2012 (Table 2).

During MACS 2015, spinner dolphins were also seen more often than any other species and accounted for a third (*n*=12) of all encounters (Table 4). Spinner dolphins were encountered at all islands within the northern Mariana Archipelago except Anatahan and Alamagan (Figure 7c). No surveys were conducted at FDM. The median (22) and maximum (47) group size estimates were smaller than those observed in the southern islands during small-boat surveys. The median depth of spinner dolphin encounter locations was 27 m (range=14–416 m) and the median shore distance was 0.2 km (range=0.1–0.8 km) (Table 4). A total of 467 photos and 12 biopsy samples were collected during MACS 2015. Spinner dolphins were acoustically detected on the towed hydrophone array and recorded during 7 encounters (Table 4).

The current spinner dolphin photo-identification catalog includes encounters from 2010 to 2013 and contains 307 individuals from 84 PIFSC CRP encounters off Saipan, Tinian, Aguijan, Rota, and Guam and 7 HDR encounters off Guam. Forty-three percent of individuals have been seen in more than 1 year. To date, there are no matches between Guam and the other islands, but there are photo matches between Rota and the 3-Islands area. All of the remaining photos collected since 2013 have gone through initial processing, matching, and checking. The photos from 15 encounters have undergone distinctiveness and quality rating and need only to be added to the catalog. The remaining 30 encounters during which photos were taken await the grading process. Through 2013, the cumulative number of individuals sighted in each year is still increasing relative to the cumulative number of distinctive individuals (Figure 8), indicating that the photo-identification catalog is still growing steadily.

To date, all 95 biopsy samples collected during small-boat surveys off Saipan (*n*=43), Tinian (*n*=6), Aguijan (*n*=8), Rota (*n*=11), and Guam (*n*=27) have been genetically sexed and sequenced at the mitochondrial control region by SWFSC (Martien *et al.* 2014a). These samples represent 41 females, 53 males, and 1 dolphin of unknown sex. Twenty-four haplotypes were identified from 93 samples. Eleven haplotypes were identical to ones found in the Central Pacific (Oremus *et al.* 2007, Andrews *et al.* 2010). Martien *et al.* (2014) found that Mariana Archipelago spinner dolphins are not evolutionarily distinct from other Pacific populations and concluded that a larger sample size, sampling from the northern islands, or microsatellites may reveal genetic population structure. OSU conducted an analysis of 18 microsatellite loci from 76 spinner dolphin samples and found weak but significant differentiation between Guam and the 3-Islands area. There are 17 biopsy samples from the northern Mariana Archipelago (12 MACS and 5 TetraTech) that have not been genetically processed by either lab (Table 4 - Table 5).

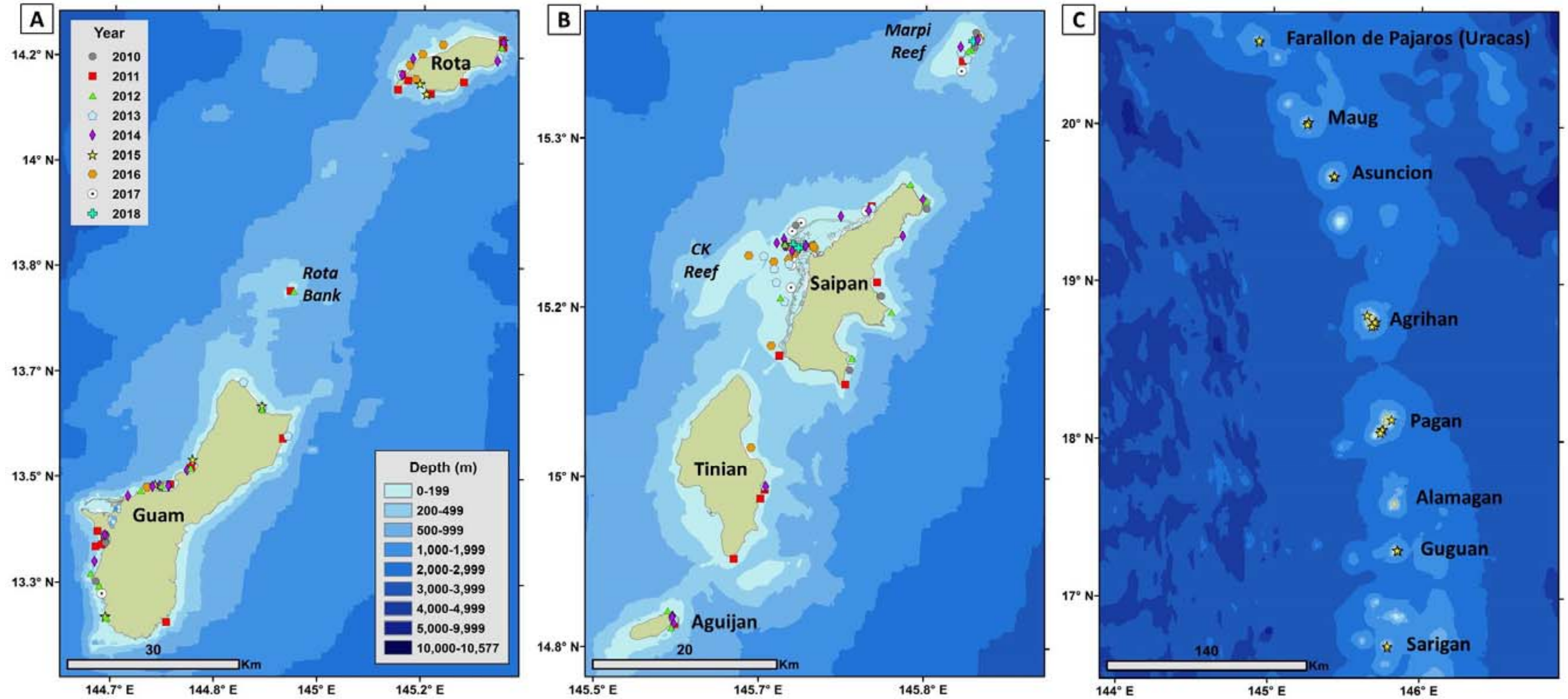

Figure 7: Spinner dolphin encounter locations by year. Panel A and B – encounters during 2010–2018 Pacific Islands Fisheries Science Center's Cetacean Research Program small-boat surveys. Panel C – encounters during the 2015 Mariana Archipelago Cetacean Survey.

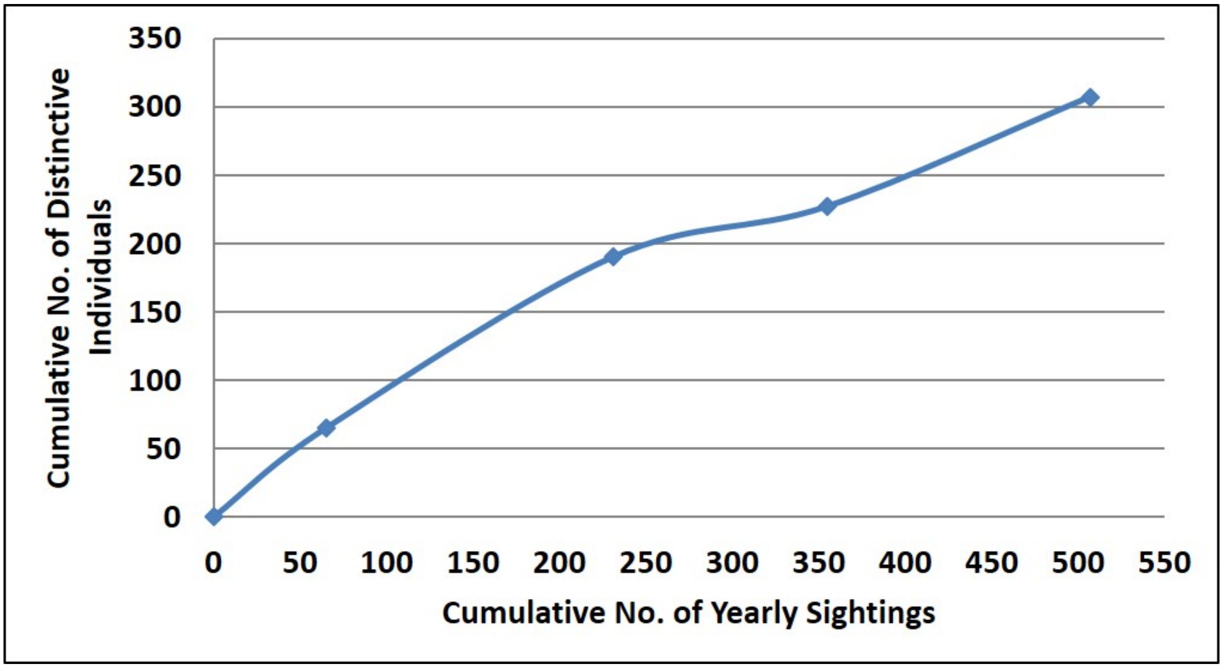

Figure 8: The cumulative number of individual spinner dolphins sighted in each year (2010–2013) versus the cumulative number of distinctive individuals.

Population Structure

The photo-identification and genetic data together appear to support designation of 2 demographically-independent populations, 1 that includes the 3-Islands area and Rota and the other around Guam, though photo-identification cataloging of the remaining photos since 2014 should be concluded before such a designation is finalized. Although the sample size of biopsy samples from the northern Mariana Archipelago is small, if there is a significant difference between the northern and southern islands, it may be possible to detect additional population structure. Additional biopsy sampling off Guam and the northern islands is recommended due to the smaller number of existing samples from those areas.

Abundance

Given the high percentage (43%) of photo-identified individuals that have been seen in more than 1 year, mark-recapture abundance estimation is promising. Before proceeding, photo cataloging through 2018 should be completed and population structure within the southern islands resolved. Fulling *et al.* (2011) estimated an abundance of 1,803 individuals (CV=0.96) from 1 sighting of spinner dolphins during the 2007 MISTCS.

Distribution and Habitat Use

Martin *et al.* (2016) examined the nearshore distribution of "small cetacean" sightings around Guam from 1963 to 2012 based on aerial surveys conducted semimonthly by the Guam Department of Agriculture Division of Aquatic and Wildlife Resources (DAWR). Based on notes provided by the survey teams and discussion with the surveyors, the authors suggested that the vast majority of the small cetacean sightings were spinner dolphins. The highest density of small cetacean sightings was along the southwestern coast from Facpi Pt. to the west edge of Cocos Lagoon and on the east side from Pago Bay to Pati Pt., though dolphins were seen in all 12 geographic zones except inside of Cocos Lagoon, on the east side from Talofofo Bay to Pago Bay, and on the west side inside of Agana Bay and Apra Harbor (see Figure 4 in Martin *et al.* 2016). There was 1 sighting of spinner dolphins during MISTCS approximately 3 km off the north end of Saipan (Fulling *et al.* 2011).

The geographic distribution, depth and distance from shore of all spinner dolphin groups sighted during PIFSC surveys have been assessed. Of particular interest is the repeated use of areas by spinner dolphins that are atypical from what is observed in other locations around the tropical Pacific. Spinner dolphins in Hawaiʻi and French Polynesia are found in calm, sheltered locations (typically bays) during the day (Norris *et al.* 1994, Poole 1995). While some spinner dolphins do follow this pattern off Guam and the west side of Saipan, others are regularly encountered at Marpi Reef, 18 km north of Saipan and fully exposed to wind and swell. Spinner dolphins occur at Marpi Reef in the winter and summer. Spinners also use areas where currents and swell backwash off cliff faces create extremely dynamic conditions, as was seen at all northern islands during MACS 2015.

Exposure to human-caused stressors

All spinner dolphin encounters were more than 4 km from any of the U.S. Navy underwater detonation sites off Guam; however, photo-identification matches between encounters demonstrate that individuals move between northern and southern locations along the west side of Guam and could pass through underwater detonation areas, particularly at the Piti Mine Neutralization Area (Figure 6). In addition, movements of spinner dolphins between coastal locations and offshore feeding areas that pass through the Piti site or Agat Bay UNDET Area could expose them to the U.S. Navy activities. The morning and evening operation hours coincide with movements of spinner dolphins between coastal and offshore locations observed in Hawaiʻi (Norris *et al.* 1994, Benoit-Bird and Au 2003), and it is likely that Guam spinner dolphins display similar patterns of movement.

The regular occurrence of spinner dolphins in the coastal waters and bays off Guam make them easy targets for the tourism industry. Such activities have the potential to affect spinner dolphins by displacing them from preferred habitat, leading to shorter resting periods as has been observed in Hawaiian waters (Delfour 2007, Ostman-Lind 2008, Courbis and Timmel 2009). The long-term effects of such disturbance could be a reduction in the overall health and abundance of individuals in the population (Tyne *et al.* 2014).

Pantropical Spotted Dolphin

Pantropical spotted dolphins were the second most frequently sighted species (*n*=46; 0.20 encounters/100 km) during PIFSC CRP small-boat surveys (Table 2, Figure 9). They were seen mixed with bottlenose dolphins during 2 encounters. Pantropical spotted dolphins were primarily encountered off Guam and Rota but were seen within the 3-Islands area 4 times (Figure 9). The median depth of pantropical spotted dolphin encounter locations was 833 m (range=333–3,000 m) and the median shore distance was 6.2 km (range=1.7–52.8 km). Best estimates for group sizes ranged 4 to 145 animals (median=35). A total of 11,823 photos, 55 biopsy samples, and 1 acoustic recording have been collected and 1 satellite tag was deployed (Table 2). No pantropical spotted dolphins were observed during MACS 2015.

Pantropical spotted dolphin photos collected off Guam (2010–2014) were analyzed to assess whether it would be worthwhile to undertake the creation of a photo-identification catalog for the ultimate purpose of mark-recapture abundance estimation. Twelve group encounters from Guam were evaluated. On average, only 30% of discernible individuals in a group had usable (of sufficient quality) fins and within that subset, only about 30% were adequately marked to be included in a photo-identification catalog. The combination of spotted dolphin behavior (moving rapidly and creating water spray) coupled with poor sea conditions during many encounters result in poor quality photos with dorsal fins being partially obscured by water. The likelihood of re-sighting marked individuals was assessed by comparing 21 very distinctive fins across encounters with the assumption that all individuals (very distinctive and less distinctive) would have the same re-sight potential. Of that group, 2 individuals were re-sighted. Given the combination of poor photo quality, low proportion marked, and low re-sight potential, the creation of a photo-identification catalog for pantropical spotted dolphins was not pursued.

In addition to the 55 biopsy samples collected from pantropical spotted dolphins during small-boat surveys off Saipan (*n*=6), Rota (*n*=21), and Guam (*n*=28), there were 4 samples collected during an HDR encounter off Guam in 2012 (

Table 5). At OSU, the 55 PIFSC samples were sequenced and genotyped at 12 microsatellite loci, and both data sets showed significant differentiation between Guam and Rota. No differentiation was found between Saipan and the other islands, which may have been related to sample size. Pantropical spotted dolphins from the Mariana Archipelago are significantly differentiated from those in Hawaiʻi, the Marquesas, and the Solomon Islands (the only other areas of significant sample size) (Baker 2015).

A single location-only satellite tag (SPOT) was deployed on a pantropical spotted dolphin off Guam during PIFSC CRP small-boat surveys in June 2016 (Table 3, Figure 10). The tag transmitted for 11.4 d during which the dolphin spent most of the time off the west side of the island.

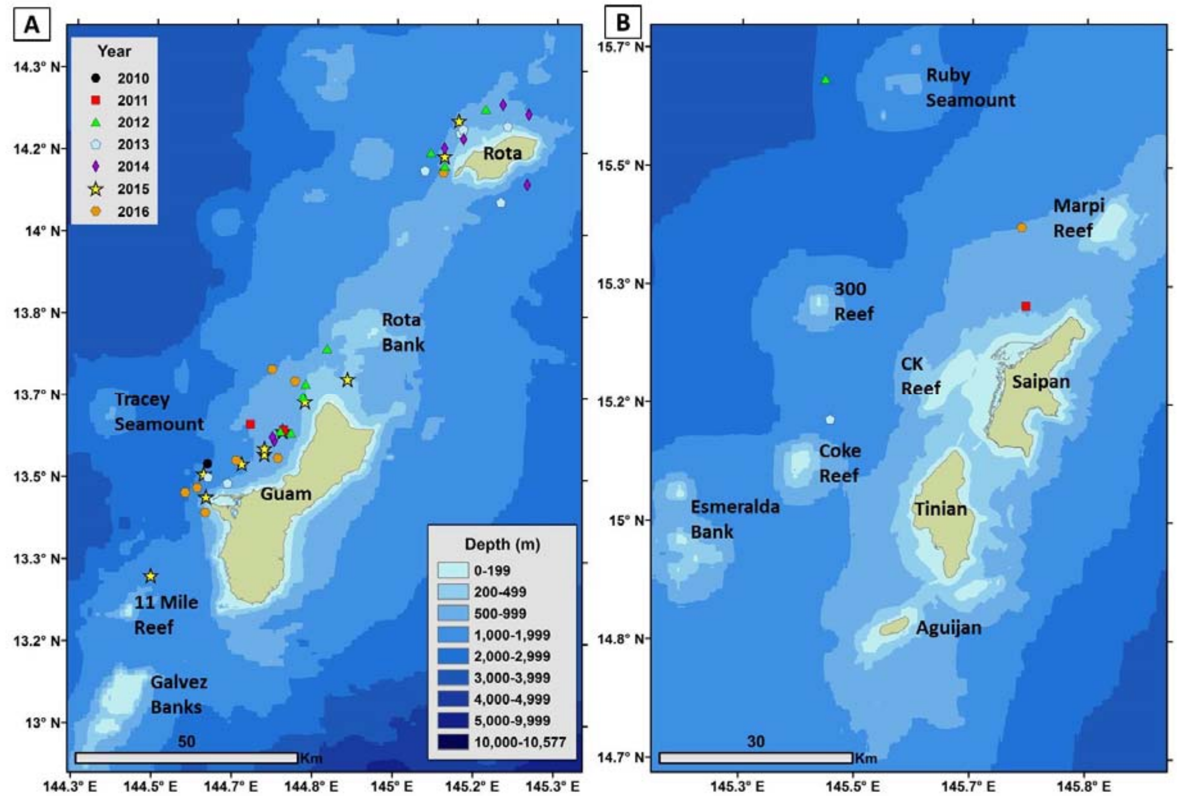

Figure 9: Pantropical spotted dolphin encounter locations by year during 2010–2018 Pacific Islands Fisheries Science Center's Cetacean Research Program small-boat surveys. Panel A – encounters off Guam and Rota. Panel B – encounters in the 3-Islands area.

Population Structure

There is not enough data on pantropical spotted dolphin genetics or movements to assess population structure at this time. Significant differentiation in the mtDNA sequences and microsatellite loci between Guam and Rota do suggest there may be structure within the archipelago, though larger genetic sample sizes or corroborating data from another line of evidence (e.g., photo-ID or movement data) are needed to confirm that spotted dolphins at these 2 islands represent separate demographically independent populations.

Abundance

Because there is no photo-identification catalog for pantropical spotted dolphins, mark-recapture for abundance estimation is not possible using photo data; however, mark-recapture using biopsy data may be considered, but will require more samples across all locations particularly in northern and offshore areas. Pantropical spotted dolphin abundance will likely be better assessed using larger-scale line-transect surveys that can provide assessment of the broader distribution of spotted dolphins and their archipelago-wide abundance. Using data from 11 encounters during the 2007 MISTCS survey, Fulling *et al.* (2011) estimated an abundance of 12,981 (CV = 0.70) pantropical spotted dolphins.

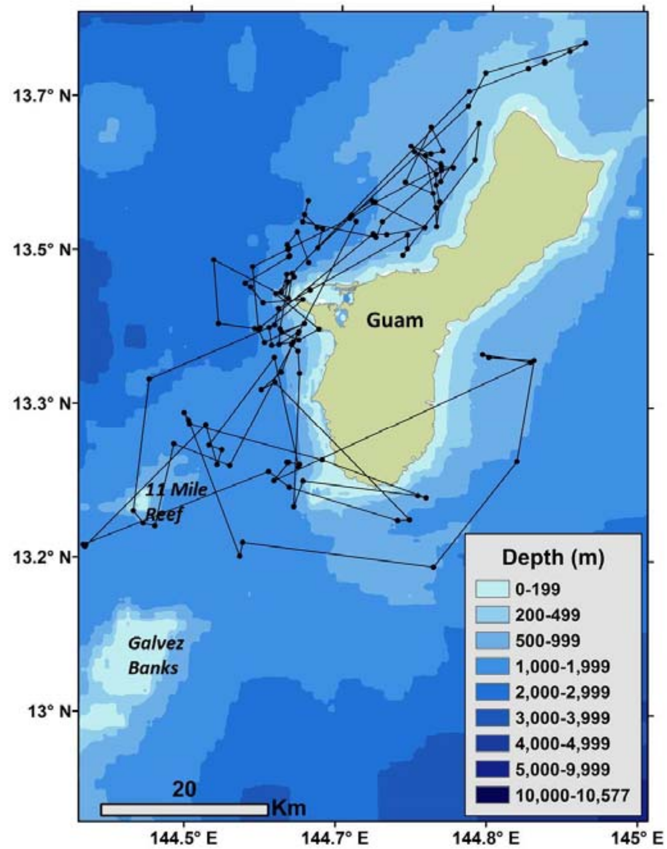

Figure 10: Locations and track from a satellite tag deployed on a pantropical spotted dolphin off Guam during the June 2016 Pacific Islands Fisheries Science Center's Cetacean Research Program small-boat survey. The tag transmitted for 11.4 d.

Distribution and Habitat Use

Encounter data demonstrate that pantropical spotted dolphins are distributed in offshore and nearshore areas. Pantropical spotted dolphins were the most frequently sighted small dolphin during the 2007 MISTCS (Fulling *et al.* 2011), with 15 of 17 encounters in offshore areas (6 outside of the EEZ) and few encounters associated with significant bathymetric features (3 over the west Mariana Ridge and 1 over the Mariana Trench). They were the second most frequently sighted species during PIFSC CRP small-boat surveys and all of the encounters were within 52.8 km from shore (median = 6.2 km).

Fulling *et al.* (2011) reported a broad range of depths (114–5,672 m) for pantropical spotted dolphin encounter locations, which overlap with the range of encounter depths during the PIFSC CRP small-boat encounters (333–3,000 m). The single location-only tag deployed off Guam (Figure 10) may offer some additional information on nearshore spatial use but is limited because of the short tag duration.

Exposure to human-caused stressors

Pantropical spotted dolphins have been encountered within 1.0 km from the Piti Floating Mine Neutralization Area (Figure 6). Locations from a satellite tagged pantropical spotted dolphin were close to the Agat Bay UNDET Area (from 0.6 km to 1.2 km), and the Outer Apra Harbor UNDET Area (from 0.3 km to 1.6 km). The proposed schedule of operations in 2016 did not coincide with the times that the tagged dolphin passed through the detonation areas.

Off the west side of Guam, pantropical spotted dolphins were encountered repeatedly near fish aggregating devices (FADs); specifically, FAD-1 and FAD-2. When assessing the Mariana Archipelago spotted dolphin photos for suitability for photo-identification, some dolphins were found to have signs of fisheries interactions, with dorsal fin or peduncle scarring that is characteristic of fishing line entanglement (Baird & Gorgone 2005, Baird *et al.* 2015). To estimate the proportion of individuals with entanglement scars, a full assessment of the existing pantropical spotted dolphin photos would be necessary. Additional photos of pantropical spotted dolphins taken during a 2007 MISTCS and a 2012 HDR encounter (

Table 5) could be used for this assessment.

Bottlenose Dolphin

There were 36 bottlenose dolphin encounters (0.16 encounters/100 km) during the PIFSC CRP small-boat surveys (Table 2, Figure 11a). Bottlenose dolphins were encountered multiple times in mixed-species groups and were seen with short-finned pilot whales (*n*=4), false killer whales (*n*=3), rough-toothed dolphins (*n*=2), pantropical spotted dolphins (*n*=2), spinner dolphins (*n*=2), and humpback whales (*n*=1). Bottlenose dolphins were encountered in each year 2011–2018 and were seen off all of the southernmost islands and at some offshore reefs (Figure 11a). The median depth of bottlenose dolphin encounter locations was 122 m (range=18–1,048 m) and the median shore distance was 4.9 km (range=0.3–18.7 km). Best estimates of group sizes ranged from 1–27 individuals (median=7 individuals). A total of 7,913 photos and 35 biopsy samples were collected, and 6 satellite tags were deployed during bottlenose dolphin encounters. In 2011, an acoustic recording was made during a PIFSC CRP bottlenose dolphin encounter off Saipan (Table 2).

During MACS 2015, there were 3 bottlenose dolphin encounters (Table 4, Figure 11b), 2 of which were with rough-toothed dolphins. The 2 mixed-species encounters were off Agrihan while the third bottlenose dolphin encounter was east of Anatahan. The median depth of bottlenose dolphin encounter locations was 671 m (range=98–961 m) and the median shore distance was 2.9 km (range=1.1–35.0 km). Best estimates of group sizes ranged 9–20 individuals (median=10 individuals). Only 45 photos and 2 biopsy samples were collected during MACS. Bottlenose dolphins were acoustically detected on the towed hydrophone array and recorded during 2 encounters (Table 4).

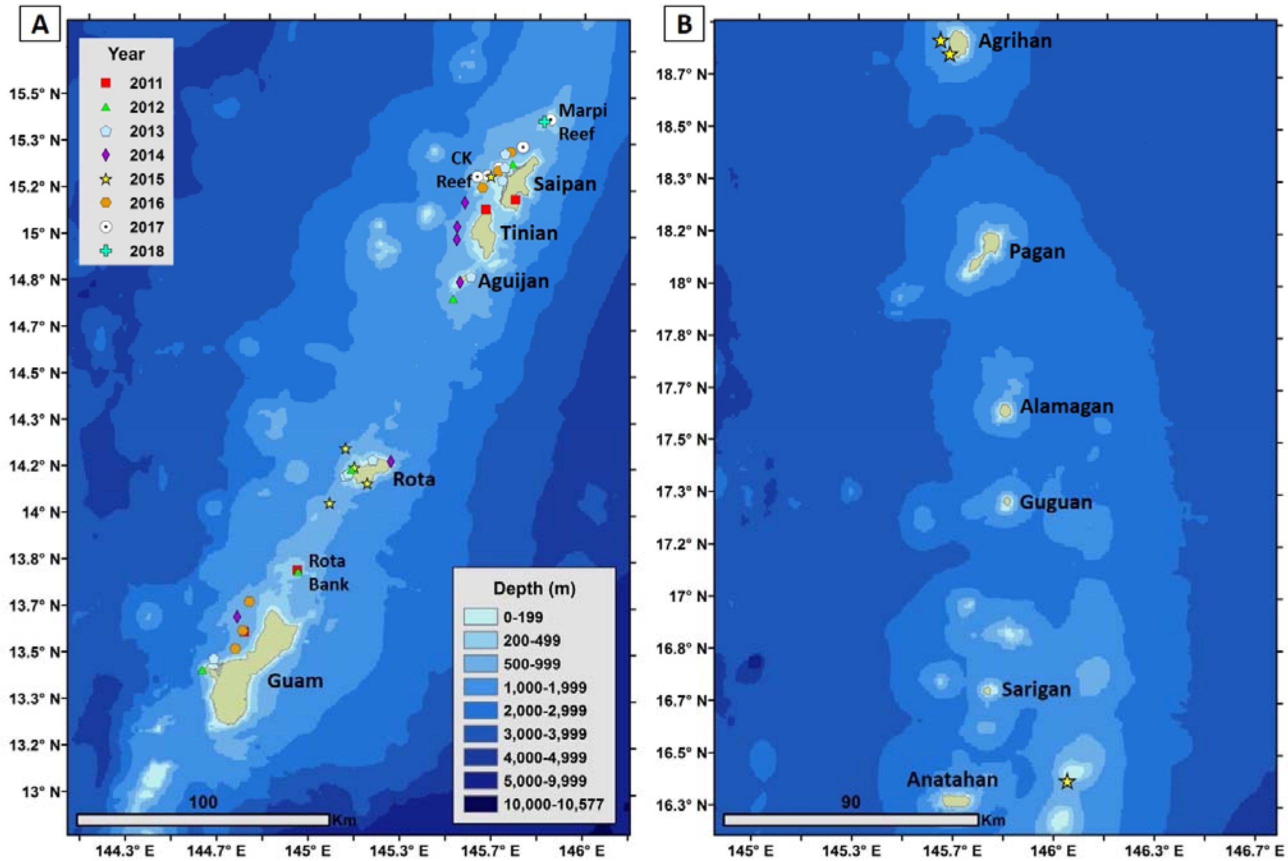

Figure 11: Bottlenose dolphin encounter locations by year. Panel A – encounters during 2010–2018 Pacific Islands Fisheries Science Center's Cetacean Research Program small-boat surveys. Panel B – encounters during the 2015 Mariana Archipelago Cetacean Survey.

The bottlenose dolphin photo-identification catalog currently includes photos collected from 2010 through 2016 and contains 61 individuals from 30 encounters off Saipan, Tinian, Aguijan, Rota, and Guam (Table 2) and 2 encounters off Guam and Saipan by HDR in 2011 and 2012 (

Table 5). Sixty-two percent (62%) of the individuals were seen in more than 1 year, 41% were seen in 3 or more years, and there are matches among all islands. Photos from MACS 2015 and PIFSC CRP small-boat surveys in 2017 and 2018 have undergone initial processing and matching, but individuals are not yet cataloged. The U.S. Navy contributed photos from 2 encounters outside of the Guam and CNMI EEZ during the 2007 MISTCS and from 1 encounter off Pagan during the 2013 TetraTech survey. Although there were a handful of very distinctive fins, no matches were found in the existing catalog, and none of the individuals were added to the catalog because the associated photos did not meet the quality criteria. Through 2016, the cumulative number of individuals sighted each year versus the cumulative number of distinctive individuals is leveling off, suggesting that we have encountered a large portion of the population within our survey area (Figure 12).

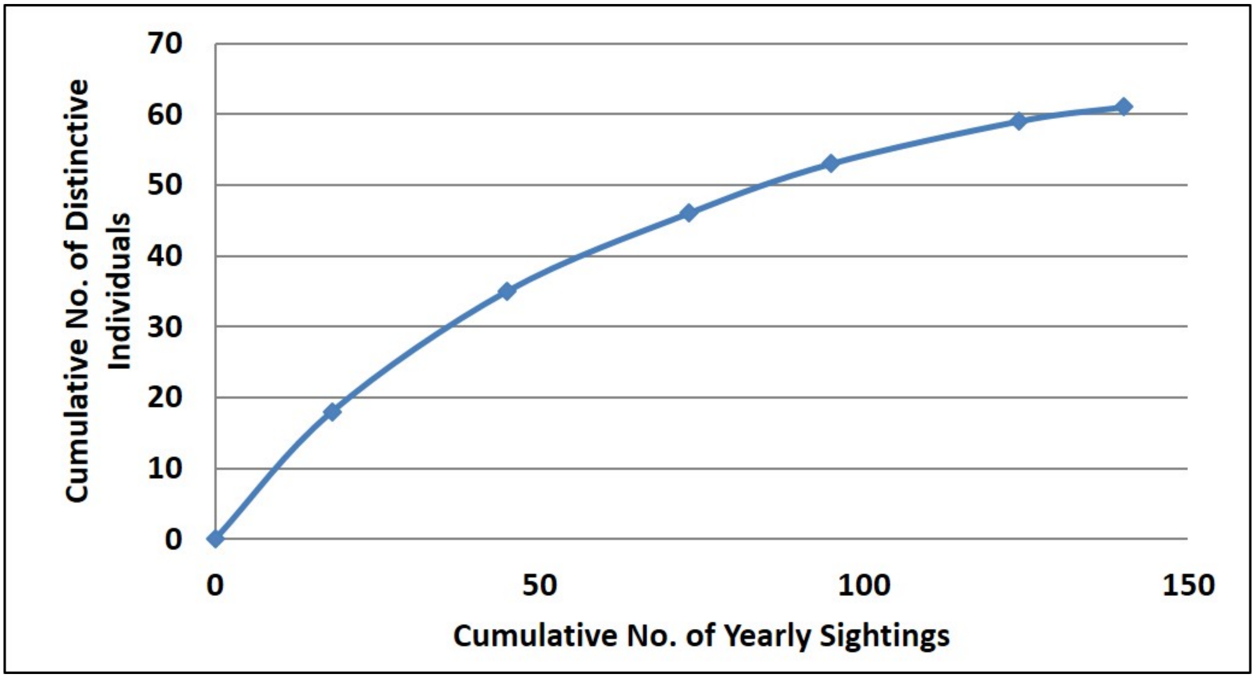

Figure 12: The cumulative number of individual bottlenose dolphins sighted in each year (2011–2016) versus the cumulative number of distinctive individuals.

Fifteen biopsy samples collected from bottlenose dolphins during PIFSC CRP small-boat surveys off Saipan (*n*=7), Tinian (*n*=1), Aguijan (*n*=1), Rota (*n*=3), and Guam (*n*=3) from 2011 to 2013 were genetically sexed and sequenced at the mitochondrial control region (Martien *et al.* 2014a). The remaining 20 biopsy samples collected during PIFSC CRP small-boat surveys, as well as the 2 samples collected from Agrihan and offshore of Anatahan during MACS 2015, have not been genetically processed.

Of the 15 bottlenose dolphin biopsy samples that have been processed, there were 10 males, 4 females, and 1 dolphin of unknown sex. Four haplotypes were identified, including the Lh1 haplotype that most closely matches a haplotype from Fraser's dolphins sampled in the Philippines (Martien *et al.* 2014a). Comparing the nuclear microsatellite genotypes of the Mariana Archipelago samples to those of 'pure' bottlenose dolphins and Fraser's dolphins revealed that all 15 Mariana Archipelago samples exhibited evidence of Fraser's dolphin ancestry, with individuals deriving on average 14% of their nuclear ancestry from Fraser's dolphins. The fact that every Mariana Archipelago sample showed evidence of nuclear introgression, combined with the fact that those exhibiting mitochondrial introgression all share the same Fraser's dolphin haplotype, suggests that there was a single hybridization event far enough in the past to allow Fraser's dolphin nuclear DNA to permeate the population. The Mariana Archipelago samples exhibited low genetic diversity compared to other bottlenose dolphin populations, suggesting that they represent a small, demographically independent population.

Satellite tags were deployed on 6 bottlenose dolphins (4 SPOT, 2 SPLASH) during PIFSC CRP small-boat surveys (2013–2015, 2017) (Table 3, Figure 13). Tag durations ranged from 3.7–20.5 d. Five of 6 satellite tags were deployed within the 3-Islands area and the dolphins primarily stayed within the area, however 2 went north to East Diamante Seamount and a third individual went almost as far north as Sarigan. A single tag was deployed on a bottlenose dolphin off Rota. During the 10.4 d duration of the tag, the dolphin traveled between Rota and Guam.

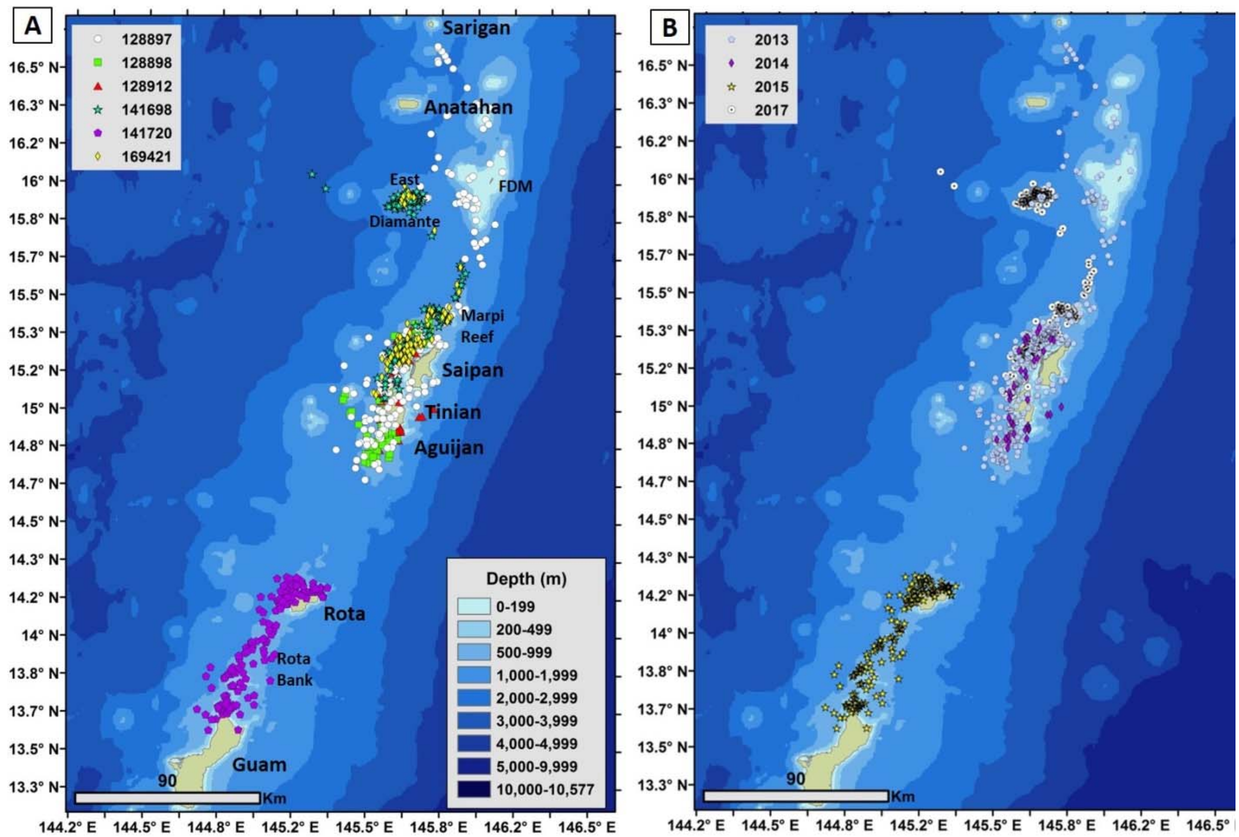

Figure 13: Locations from satellite tags deployed on bottlenose dolphins during the Pacific Islands Fisheries Science Center's Cetacean Research Program small-boat surveys (2013–2017). Tag durations ranged 3.7–20.5 d. Panel A – Locations shown by tag ID. Panel B – Locations shown by year.

Population Structure

There is no population structure within the southern Mariana Archipelago evident from the genetic analyses and photo-identification results available to date. It is unlikely that sequencing the remaining 20 biopsy samples from the southern islands alone would contribute significant new information toward examination of population structure. Collection and analysis of additional samples from dolphins in the northern islands and offshore, including the 2 biopsy samples collected off Agrihan and Anatahan, would be valuable for assessing structure more broadly within the region.

It is possible that Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) could occur within the Mariana Archipelago. None have been identified from the 15 processed samples to date; however, all samples should be sequenced to determine if any of the dolphins are Indo-Pacific bottlenose dolphins.

Abundance

Abundance estimation using mark-recapture methods may be feasible. Although the bottlenose dolphin photo-identification catalog is small (*n*=61 individuals), 62% of the individuals were seen in more than 1 year and 41% were seen in 3 or more years. Such an estimate would apply to the southern islands only. Fulling *et al.* (2011) estimated an abundance of 122 (CV=0.99) bottlenose dolphins from 3 offshore encounters in 2007. Bottlenose dolphin abundance throughout the archipelago may be better assessed using line-transect methods from a ship-based survey of the broader area.

Distribution and Habitat Use

The geographic distribution, depth, and distance from shore for PIFSC CRP bottlenose dolphin encounters have been characterized. All encounters were within 35 km from shore and in water depth less than 1,048 m. All 5 of the 2007 MISTCS encounters were offshore, with 2 outside of the EEZ boundary (Fulling *et al.* 2011) and had an average depth of 4,554 m (SE=162.7), much deeper than those found by PIFSC CRP during nearshore surveys. Data from the satellite tags could be used to more fully characterize habitat use, including associations with islands, bathymetric features, and oceanographic conditions. Such an analysis would benefit from additional tag data, given the few number of tags (*n*=6) and relatively short tag durations for those deployments. One bottlenose dolphin has been tagged twice in 2 different years, such that patterns or changes in the dolphin's space use between years may be informative. Two of the satellite tags deployed on bottlenose dolphins were SPLASH tags and could be used to look at the dive behavior of the individuals, including geographic variation in dive depth.

Exposure to human-caused stressors

It is possible that bottlenose dolphins could be exposed to underwater detonations off Guam. In 2013, we encountered a group of bottlenose dolphins approximately 1.2 km from the Piti Floating Mine Neutralization Area (Figure 6). As well, the depth of this location falls within the range of the observed bottlenose dolphin encounter locations.

Short-finned Pilot Whale

The encounter rate for short-finned pilot whales was 0.09 encounters/100 km (*n*=21) during PIFSC CRP small-boat surveys (Table 2, Figure 14). Short-finned pilot whales were encountered each year except 2010 and 2015 and were seen off each of the southernmost islands and at offshore locations including Marpi Reef and Esmeralda Bank. They were found in mixed-species groups during a third of the encounters, including with bottlenose dolphins (*n*=4), rough-toothed dolphins (*n*=2), pantropical spotted dolphins (*n*=1), and humpback whales (*n*=1). The median depth of short-finned pilot whale encounter locations was 720 m (range=51–1,443 m) and the median shore distance was 5.1 km (range=0.5–36.3 km). Best estimates of group sizes ranged from 4–48 individuals (median=30 individuals). A total of 18,885 photos and 96 biopsy samples were collected, and 18 satellite tags were deployed during short-finned pilot whale encounters. Acoustic recordings were made during 3 PIFSC CRP small-boat encounters in 2011–2012 (Table 2). There were no sightings of short-finned pilot whales during MACS 2015 except for a brief view of a group just outside of Apra Harbor (Guam) as the ship left the harbor. The visual team was not yet on-effort, and it was not possible to respond to the group.

The photo-identification catalog for short-finned pilot whales includes all encounters through 2017 and contains 206 individuals from 23 encounters off Saipan, Tinian, Aguijan, Rota and Guam (Table 2) including 2 encounters in 2011 and 2012 by HDR and 1 encounter off Guam during the 2007 MISTCS (

Table 5). The U.S. Navy contributed photos from 3 additional encounters during MISTCS. Although there were a handful of very distinctive fins, no matches were found in the existing catalog, and none of the individuals were added to the catalog because the photos did not meet the quality criteria. The cumulative number of individuals sighted each year versus the cumulative number of distinctive individuals appears to be leveling off (Figure 15), with the exception of the most recent encounter in winter 2017, during which several new whales were identified and only 3 individuals were associated with a group that had been seen once before.

Biopsy samples (*n*=96) were collected from 81 individuals; 78 individuals sampled during the PIFSC CRP small-boat surveys and 3 individuals sampled in 2012 by HDR operating under the PIFSC permit. These samples represent 43 females, 34 males, and 4 whales of unknown sex (Hill *et al.* 2018). Five haplotypes (A1, A2, C, 17, 18) were found, 2 of which are unique to the Mariana Archipelago (17 and 18) (Martien *et al.* 2014a, Hill *et al.* in press). Haplotype A1 and A2 were identified based on use of longer sequences (962 bp versus 345 bp) and when truncated were identical to haplotype A identified by Oremus *et al.* (2009).

Between 2013 and 2017, 18 satellite tags (13 SPOT, 5 SPLASH) were deployed on short-finned pilot whales during PIFSC CRP small-boat surveys (Table 3, Figure 16). Most of the tag deployment locations were off Guam and Rota, but in 2017 a satellite tag was deployed on a short-finned pilot whale at Marpi Reef. Tag durations ranged from 6.8–234.7 d.

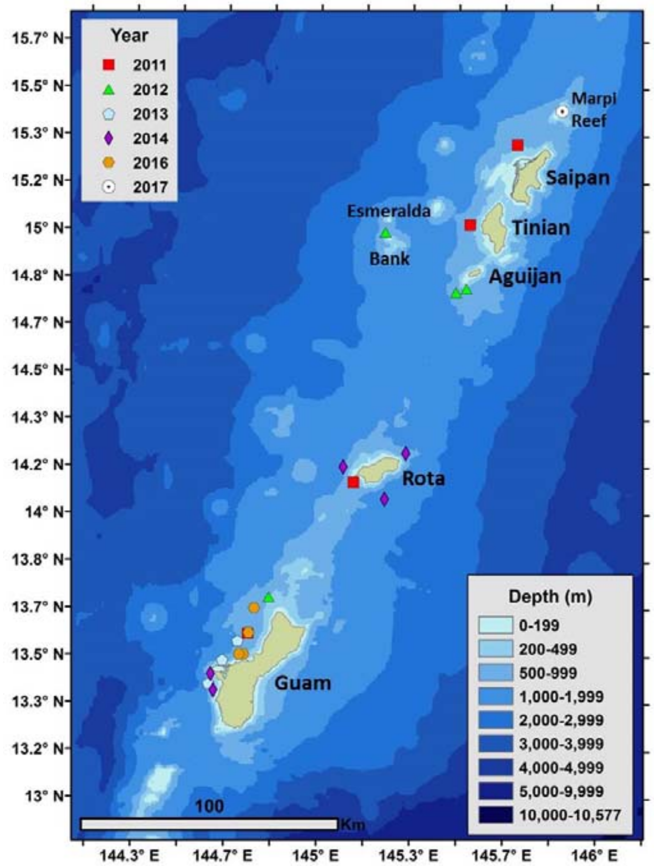

Figure 14: Short-finned pilot whale encounter locations by year during 2011–2017 Pacific Islands Fisheries Science Center's Cetacean Research Program's small-boat surveys.

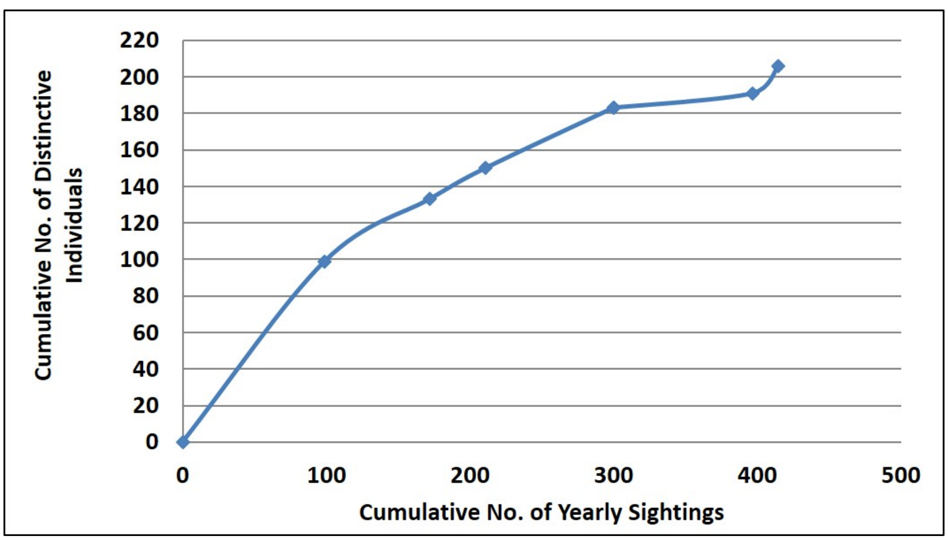

Figure 15: The cumulative number of individual short-finned pilot whales sighted in each year (2011–2017) versus the cumulative number of distinctive individuals.

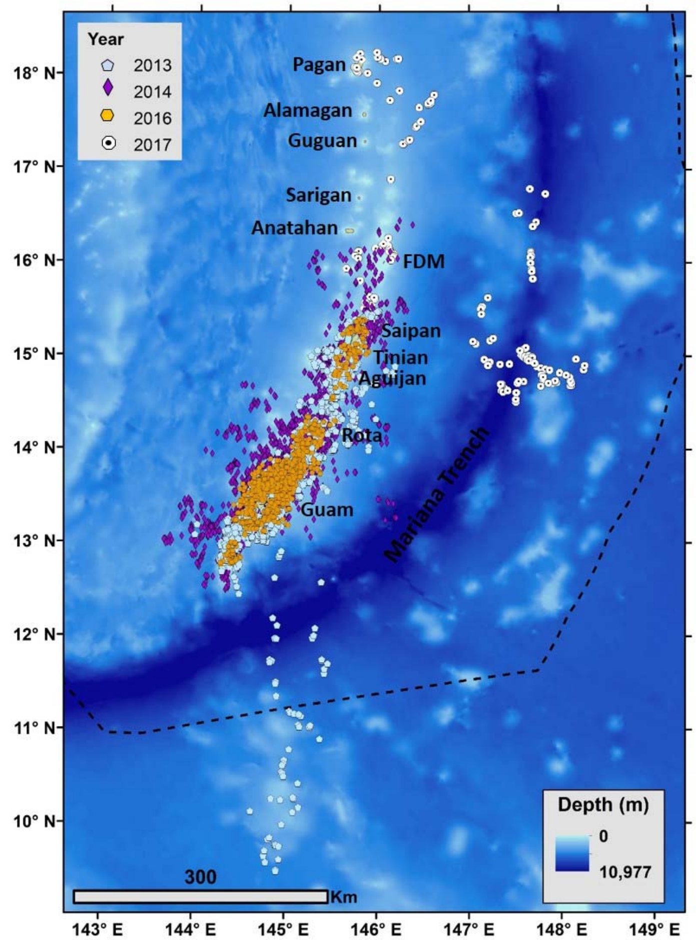

Figure 16: Locations from satellite tags deployed on short-finned pilot whales during the Pacific Islands Fisheries Science Center's Cetacean Research Program small-boat surveys (2013–2017). Tags were deployed off Guam and Rota in May–June 2013–2016, and a single tag was deployed at Marpi Reef in February 2017. Tag durations ranged 6.8–234.7 d.

Population Structure

Photo-identification, satellite tag, and genetic data provide a complicated picture of potential population structure in Mariana Archipelago short-finned pilot whales. Photo-identification data through 2016 were used by Hill *et al.* (2018) to create a preliminary social network diagram for 196 individuals. The network diagram demonstrated that most of the photo-identified individuals were part of 1 main social cluster, while 3 other groups had been observed only once and were not connected. Satellite tag data from the main social cluster also indicate a restricted home range extending from south of Santa Rosa Reef and north of FDM. Hill *et al.* (2018) suggested the Mariana Archipelago short-finned pilot whales may be similar to other archipelagic populations in which some individuals are resident and island-associated within the southernmost Mariana Archipelago, while others may be occasional visitors and have more northern or offshore distributions. A satellite tag was deployed on a short-finned pilot whale during a 2017 encounter at Marpi Reef, and that whale's movements were different than all other tagged whales (Figure 16). Over the 27 d duration of the tag, the whale traveled north to Pagan and then moved out over the Mariana Trench where it spent twelve days before the tag stopped transmitting. None of the whales at Marpi Reef were connected to the main social cluster, although 3 individuals had been observed in 1 of the single-encounter groups.

Genetic analyses have focused primarily on a broader question of the relatedness of Mariana Archipelago short-finned pilot whales to those in other parts of the Pacific. Three mitochondrial haplotypes identified in Mariana Archipelago short-finned pilot whales are distributed broadly in the South Pacific, southeast Asia, the Indian Ocean, the western North Atlantic, and the Caribbean (Oremus *et al.* 2009, Téllez *et al.* 2014, Van Cise *et al.* 2016, Morin *et al.* 2015), while 2 haplotypes appear to be unique to the region (Martien *et al.* 2014a), indicating that the Mariana Archipelago is an area of unusually high diversity. Within samples collected in the Mariana Archipelago, Martien *et al.* (2015) found strong mitochondrial differentiation between short-finned pilot whales encountered in the waters off the 3-Islands area and those encountered off Rota and Guam, suggesting a lack of female-mediated gene flow between these island groups, although the differentiation between the areas may reflect familial or social structure rather than population differentiation (Martien *et al.* 2014a). No significant nuclear differentiation has yet been found between island groups in the Mariana Archipelago, suggesting that there is male-mediated gene flow between among sampled individuals, though lack of differentiation could be due to small sample size (Van Cise *et al.* 2015). In order to better assess the population structure of short-finned pilot whales in the Mariana Archipelago, samples from new groups and new areas (offshore and northern islands) are needed.

Abundance

Photo-identification data from the main social cluster are adequate to conduct a mark-recapture analysis for an abundance estimation of short-finned pilot whales within the southern Mariana Archipelago. Of the 206 individuals in the photo-identification catalog, 128 (62%) were seen in more than 1 year and 55 (27%) were seen in 3 or more years. Fulling *et al.* (2011) calculated an abundance of 909 (CV=0.68) individuals from 4 encounters during the 2007 MISTCS.

Distribution and Habitat Use

Short-finned pilot whales are found in nearshore and offshore areas of the Mariana Archipelago. All of the PIFSC CRP small-boat encounters were within 36.3 km from shore, while all but 1 of the 5 2007 MISTCS encounters were offshore; including 1 that was south of Guam and outside of the EEZ boundary (Fulling *et al.* 2011).

Hill *et al.* (2018) used satellite telemetry data from short-finned pilot whales tagged off Guam and Rota to determine the home range, core area, and highest use area of the whales in summer months (June–August). They found that the highest use area was off the northwest side of Guam and extended north toward Rota. The home range of the whales spanned an area south of Santa Rosa Reef and north of FDM, and the core area centered on Guam and Rota, extending south to Santa Rosa Reef and north beyond Rota (see Fig. 3 in Hill *et al*. 2018). The telemetry data also demonstrated that the tagged whales primarily associated with nearshore waters and had a median distance from shore of 13.4 km (Hill *et al.* 2018). Individual whales made occasional longer distance trips away from the islands, including 1 that traveled 417 km south of Guam before returning to the Mariana Archipelago.

Five of the satellite tags collected dive data as well as locations, and Hill *et al.* (2018) found that the tagged whales were primarily diving to intermediate depths (101–499 m) at night and suggested that they may follow the deep scattering layer to feed.

Exposure to human stressors

The locations of encounters during PIFSC CRP small-boat surveys and the telemetry data from satellite tags deployed on short-finned pilot whales, suggest that exposure to underwater explosive events may occur at all 3 U.S. Navy sites off Guam (Figure 6). Numerous locations from short-finned pilot whale tags were near the UNDET exclusion zones, some of which were on days of scheduled operations. Other satellite tag locations fell within the exclusion zones but did not coincide with scheduled operations.

Some Mariana Archipelago short-finned pilot whales have signs of fisheries interactions, with dorsal fin scarring or mutilation or peduncle scarring that is characteristic of fishing line entanglement (Baird & Gorgone 2005, Baird *et al.* 2015).

While the dolphin-directed tourism off Guam is primarily focused on spinner dolphins, tour vessels have been observed during short-finned pilot whale encounters outside of Agat Bay.

Rough-toothed Dolphin

There have been 7 rough-toothed dolphin encounters (0.03 encounters/100 km) during PIFSC CRP small-boat surveys (Table 2, Figure 17a). Rough-toothed dolphins were encountered off Saipan, Aguijan, and Guam and were found in mixed-species groups with bottlenose dolphins (*n*=3), spinner dolphins (*n*=1), and short-finned pilot whales (*n*=2). The median depth of rough-toothed dolphin encounter locations was 500 m (range=66–808 m) and the median shore distance was 6.8 km (range=0.4–14.3 km). Best estimates of group sizes ranged from 1–

24 individuals (median=5 individuals). A total of 1,776 photos and 4 biopsy samples were collected, and 1 satellite tag was deployed during rough-toothed dolphin encounters.

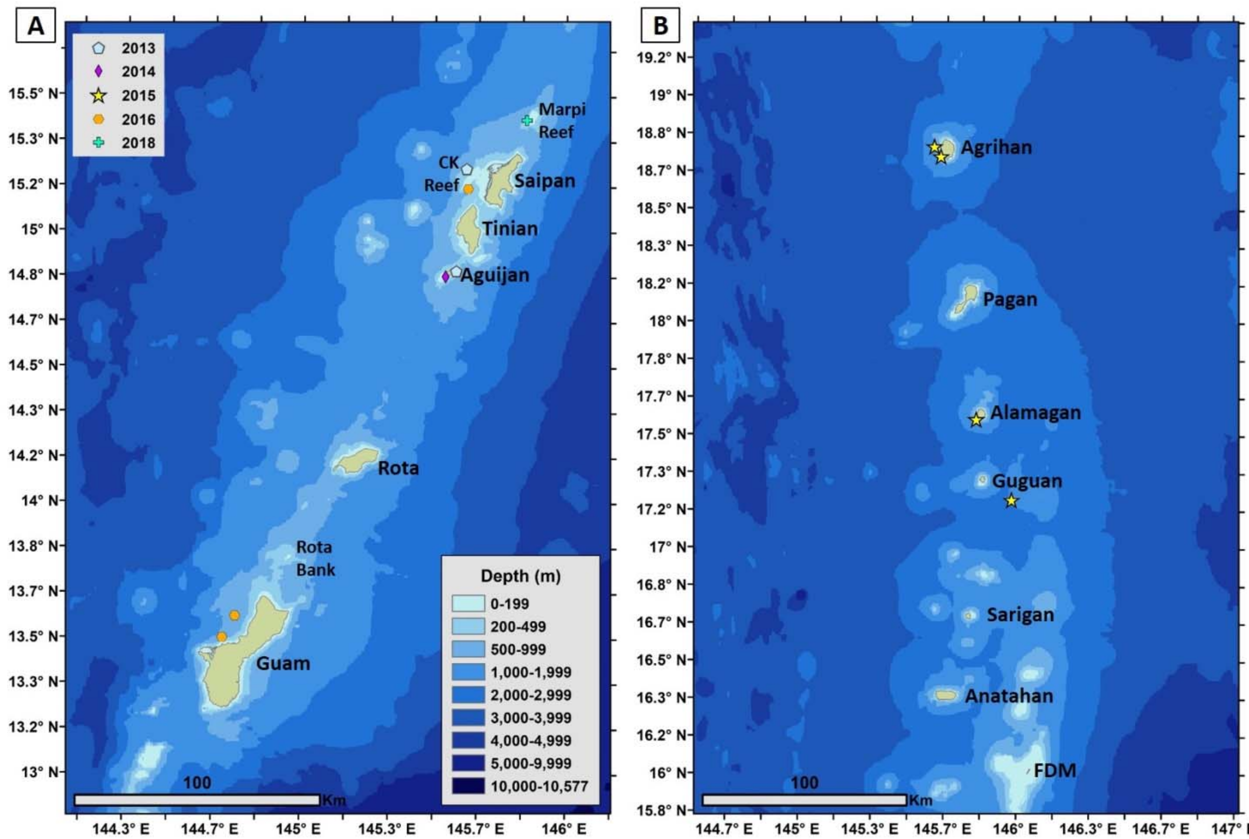

Figure 17: Rough-toothed dolphin encounter locations by year. Panel A – encounters during 2010–2018 Pacific Islands Fisheries Science Center's Cetacean Research Program small-boat surveys. Panel B – encounters during the 2015 Mariana Archipelago Cetacean Survey.

During MACS 2015, there were 4 rough-toothed dolphin encounters, 2 of which were with bottlenose dolphins at Agrihan (Table 4, Figure 17b). The other 2 encounters were off Guguan and Alamagan. The median depth of rough-toothed dolphin encounter locations during MACS was 559 m (range=30–1,955 m) and the median shore distance was 2.1 km (range=0.4–16.3 km). Best estimates of group sizes ranged from 12–27 individuals (median=16 individuals). A total of 1,072 photos and 6 biopsy samples were collected during MACS. Rough-toothed dolphins were acoustically detected on the towed hydrophone array and recorded during 2 encounters (Table 4).

The current rough-toothed dolphin photo-identification catalog contains 7 individuals from 4 encounters off Saipan and Aguijan during PIFSC CRP small-boat surveys. A very distinctive (D-1) individual was photographed in 2016 off Guam that did not match to the existing catalog and was not added to the catalog because the photo quality did not meet the criteria. Photos taken during a MACS 2015 encounter at Guguan have undergone all steps of photo processing, matching, and checking. There were 7 D-1 or distinctive (D-2) individuals, none of which matched to the photo-identification catalog from the southern islands. None were added to the photo-identification catalog because they did not meet the photo quality criteria. Photos from the other 3 MACS encounters and a 2018 encounter at Marpi Reef have undergone initial processing and matching.

A total of 10 biopsy samples were collected from rough-toothed dolphins. Two of these samples have been processed and were both female with the same haplotype (KA_01), a haplotype common in animals sampled off Kauaʻi in the Hawaiian Archipelago. These samples were also included in an analysis of the worldwide phylogeography study of rough-toothed dolphins conducted at OSU (Albertson *et al.* in prep). The analysis included both full mitochondrial genomes and nuclear introns to examine structure from the species level to the population level. The Mariana Archipelago samples were included in a western Pacific/Indian Ocean stratum. Albertson *et al.* (in prep) found significant differences in the metagenomes of the western Pacific/Indian Ocean stratum versus the central/eastern Pacific and Atlantic, but did not find significant nuclear differentiation. They did not examine structure within the Mariana Archipelago. The remaining 11 Mariana Archipelago samples have not been genetically processed.

A single location-only satellite tag was deployed on a rough-toothed dolphin off Aguijan in 2013. The tag transmitted for 11.7 d, during which the dolphin remained off the west sides of Saipan, Tinian, and Aguijan (Table 3, Figure 18).

Population Structure

Only 2 of the 10 rough-toothed dolphin biopsy samples have been genetically processed to date; however, processing the remaining 8 samples is unlikely to be informative. Assuming levels of differentiation similar to that found among stocks of rough-toothed dolphins in Hawaiʻi (Albertson *et al.* 2017), a minimum of 20 to 40 samples per stratum would likely be necessary to detect structure within the Mariana Archipelago, if it exists. More identification photos, biopsy samples, and movement data are needed to determine if there is structure at any scale.

Abundance

Although a photo-identification catalog exists, there are too few individuals to conduct a mark-recapture analysis for abundance estimation. More encounters will be required before mark-recapture analyses can be pursued. Fulling *et al.* (2011) used 1 encounter during MISTCS in 2007 to estimate an abundance of 166 (CV=0.89) rough-toothed dolphins.

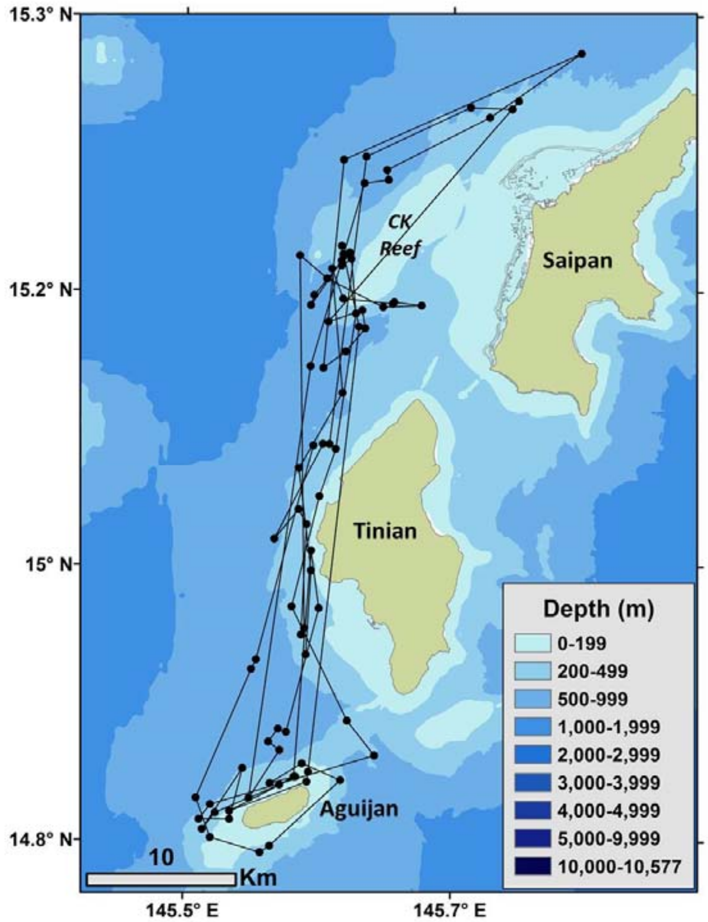

Figure 18: Locations and track from a satellite tag deployed on a rough-toothed off Aguijan during the Pacific Islands Fisheries Science Center's Cetacean Research Program small-boat surveys (2013). The tag transmitted for 11.7 d.

Distribution and Habitat Use

Rough-toothed dolphins occur in both nearshore and offshore waters of the Mariana Archipelago. During PIFSC CRP small-boat surveys, rough-toothed dolphin encounters were within 16.3 km from shore and inside of the 2,000 m isobath (Table 2, Table 4, Figure 17, Figure 18). There were 3 rough-toothed dolphin encounters during the 2007 MISTCS (Fulling *et al.* 2011). One was south of Guam and outside of the EEZ boundary. One was nearshore of Guguan, and the third was a mixed-species encounter with bottlenose dolphins offshore of Saipan. The MISTCS encounter locations were in a range of depths 1,019–4,490 m. In addition to the encounter location data, telemetry data from a tag deployed on a rough-toothed dolphin in 2013 (Figure 18) could be used to characterize habitat use.

Exposure to human stressors

It is possible that rough-toothed dolphins could be exposed to underwater detonations at the Piti Floating Mine Neutralization Area or at the Agat Bay UNDET Area where the depths fall within the range used by rough-toothed dolphins (Figure 6).

False Killer Whale

There have been 6 false killer whale encounters (0.03 encounters/100 km) during PIFSC CRP small-boat surveys off Tinian, Rota, and Guam (Table 2, Figure 19a). During half of these encounters, the false killer whales were accompanied by bottlenose dolphins. The median depth of false killer whale encounter locations was 838 m (range=88–2,107 m), and the median shore distance was 5.8 km (range=0.7–8.4 km). Best estimates of group sizes ranged from 2–25 individuals (median=14 individuals). A total of 6,707 photos and 33 biopsy samples were collected, and 8 satellite tags were deployed during false killer whale encounters.

During MACS 2015, there were 2 false killer whale encounters: 1 off Asuncion and the other off Alamagan (Table 4, Figure 19b). The depths of false killer whale encounter locations during MACS were 2,457 m and 2,461 m and the shore distances were 12.5 km and 39.5 km. Best estimates of group sizes were 6 and 31 individuals. A total of 1,285 photos and 3 biopsy samples were collected, and 1 satellite tag was deployed during MACS. False killer whales were acoustically detected on the towed hydrophone array during 1 MACS 2015 encounter (Table 4).

The current false killer whale photo-identification catalog contains 57 individuals from all 6 PIFSC CRP small-boat encounters. Nine of these individuals were seen in 2 different years. One additional cataloged individual comes from a 2007 offshore encounter during MISTCS. Six other very distinctive individuals were photographed during MISTCS encounters, but no matches were found in the existing catalog and the individuals were not added to the catalog because the photos did not meet the quality criteria. Photos from the 2 false killer whale encounters during MACS 2015 have undergone all stages of processing, matching, and checking, and no matches were found in the existing catalog. New individuals will be added to the catalog once the quality grading is complete.

Sixteen false killer whale biopsy samples that were collected off Rota in 2013 were genetically sexed and sequenced at the mitochondrial control region by SWFSC. They represent 12 females and 4 males. Nine have haplotypes that are also found in the central and eastern Pacific (haplotypes 7 and 9), while 7 have a haplotype that has only been found in the Mariana Archipelago (haplotype 34), but is similar to other pelagic haplotypes. There are 20 additional samples from false killer whales that have not been genetically processed.

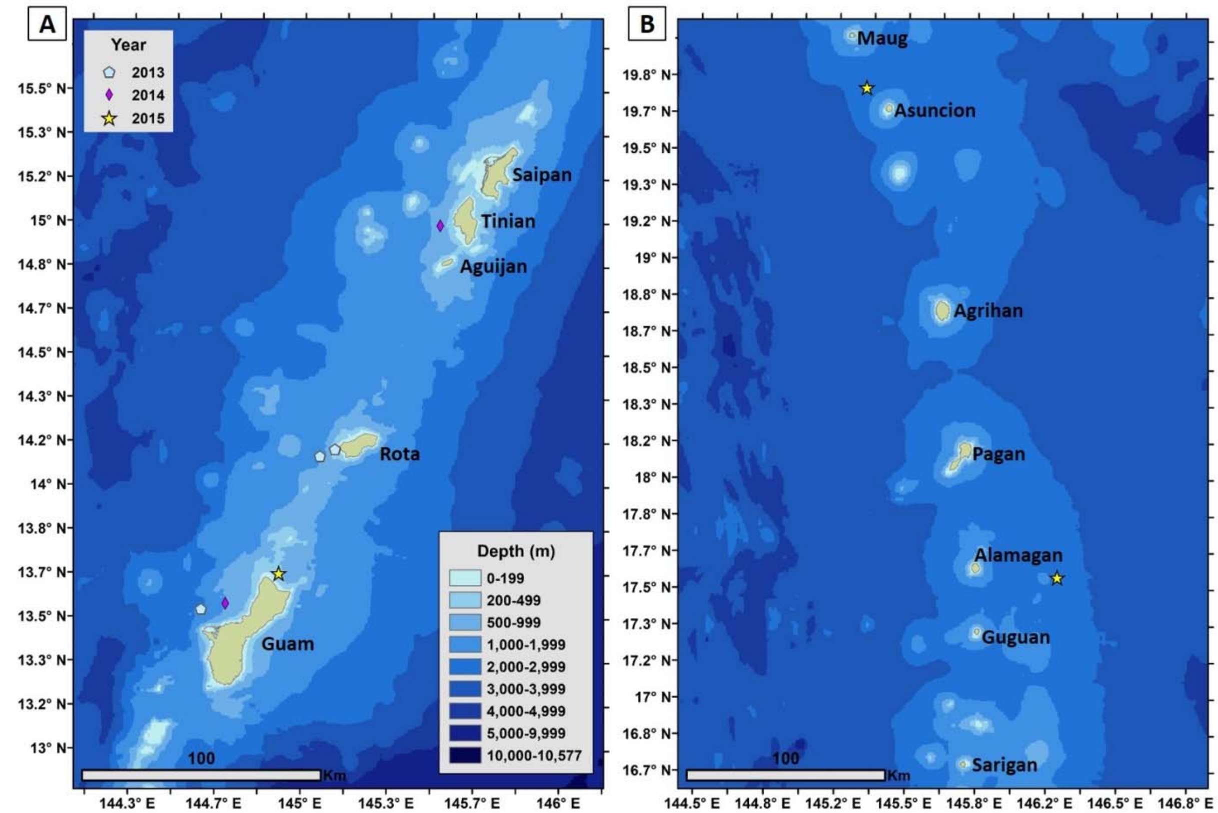

Figure 19: False killer whale encounter locations by year. Panel A – encounters during 2013–2015 Pacific Islands Fisheries Science Center's Cetacean Research Program small-boat surveys. Panel B – encounters during the 2015 Mariana Archipelago Cetacean Survey.

A total of 9 satellite tags (7 SPOT, 2 SPLASH) were deployed on false killer whales in the Mariana Archipelago between 2013 and 2015 (Table 3, Figure 20). The tag durations ranged 4.0–198.3 d. With the exception of 2 individuals, most of the tagged false killer whales remained within the Guam and CNMI EEZ boundary. The individual tagged off Asuncion during MACS 2015 traveled more than 1,500 km west of the EEZ to the boundary of the MITT before turning back east (Figure 20b).

Population Structure

Population structure of Mariana Archipelago false killer whales remains uncertain given the genetic, photo-identification, and movement data available to date. Although 1 of the haplotypes (34) found in the biopsy samples collected from false killer whales off Rota has only been found in the Mariana Archipelago, it is not very different from other pelagic false killer whale haplotypes. It would be worthwhile to sequence the remaining 20 biopsy samples, 3 of which were collected from individuals off Asuncion, at the northern end of the island chain. Nine individuals have been re-sighted over a 3-year period, and satellite telemetry data from most tagged animals suggest affinity to the islands. Tag records show long excursions away from the island chain, but repeated returning to the islands over the course of several weeks to months. Additional genetic samples and satellite tags will likely be required to resolve false killer whale population structure in this region.

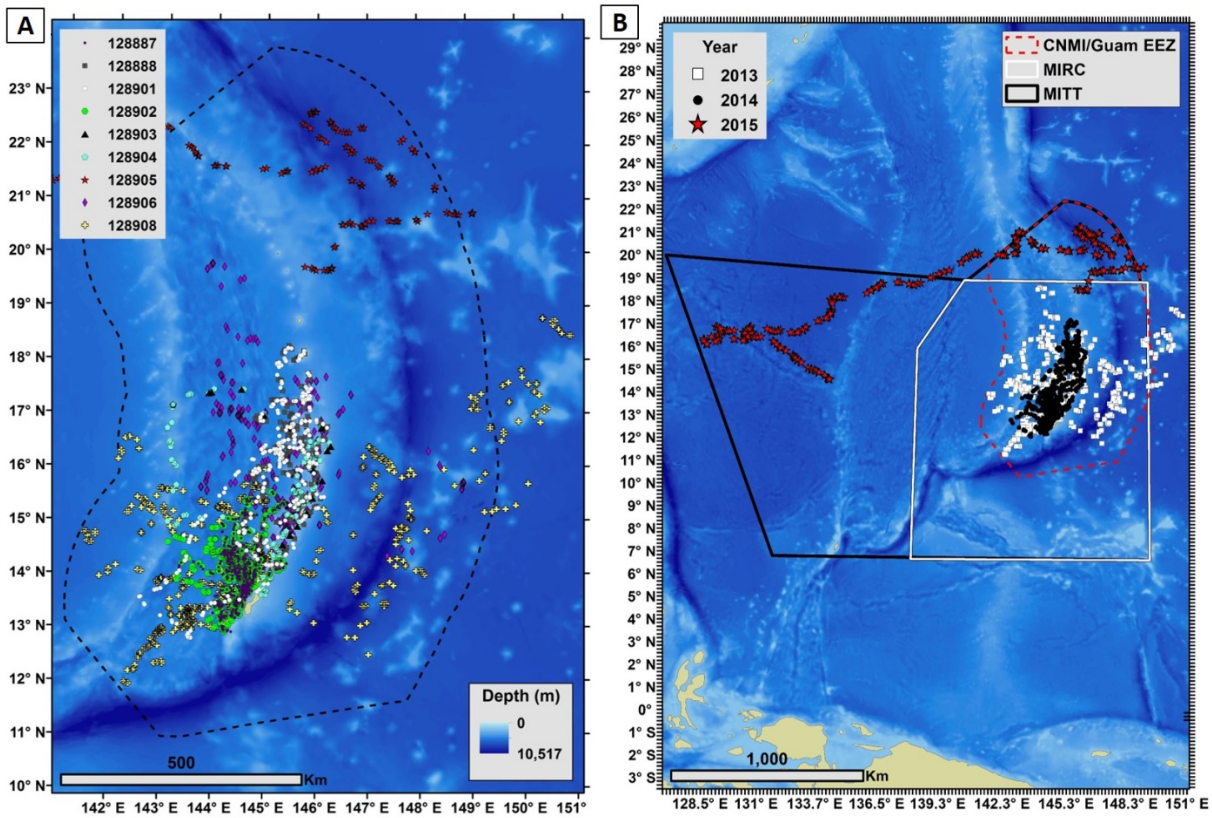

Figure 20: Locations of satellite tags deployed on false killer whales in the Mariana Archipelago. Eight of 9 tags were deployed during 2013–2014 Pacific Islands Fisheries Science Center's Cetacean Research Program small-boat surveys off Guam, Rota, and Tinian. The ninth tag was deployed on a false killer whale during the 2015 Mariana Archipelago Cetacean Survey off Asuncion. Tag durations ranged 4–198 d. Panel A – Satellite tag locations shown by individual tag ID. Panel B – Tag locations shown by year. Dotted line – Guam and Commonwealth of the Northern Mariana Islands exclusive economic zone boundary (EEZ). White line – Mariana Islands Range Complex (MIRC) boundary. Black solid line – Mariana Islands Training and Test (MITT) area.

Abundance

Nine of 58 individuals within the false killer whale photo-identification catalog have been seen in more than 1 year. Given the small catalog size and low re-sight rate, it is unlikely that a mark-recapture analysis would provide a robust assessment of population size. Additional encounter and photo-identification effort is needed, particularly within the northern islands and offshore waters. Fulling *et al.* (2011) estimated an abundance of 637 (CV = 0.74) false killer whales from 5 encounters during MISTCS 2007.

Distribution and Habitat Use

All available encounter and satellite telemetry data on false killer whales demonstrate that the whales occur in both nearshore and offshore waters of the Mariana Archipelago (Figure 19–Figure 20). Eight of 9 encounters during the MISTCS were offshore (Fulling *et al.* 2011). Kernel density estimates of home range, core area, and highest use area could be pursued using the satellite tag data. The encounter location and satellite tag data could be used to look at false killer whale associations with islands, bathymetric features, and oceanographic conditions. Two of the satellite tags were SPLASH tags, which could provide information on the dive behavior of the tagged false killer whales.

Exposure to human stressors

Based on their occurrence in the waters off the west side of Guam and the depth at false killer whale encounters during PIFSC CRP small-boat surveys, it is possible that the whales may be exposed to underwater detonations at the Piti Floating Mine Neutralization Area and at the Agat Bay UNDET Area (Figure 6). In addition, there were multiple satellite tag locations from false killer whales in and around the exclusion zones of these sites. There were tag locations within 10 km from the Agat site on a scheduled day of the U.S. Navy operations in 2014.

Sperm Whale

There have been 6 sperm whale encounters (0.03 encounters/100 km) off Saipan and Guam in 2010, 2013, and 2016 during PIFSC CRP small-boat surveys (Table 2, Figure 21a). The median depth of sperm whale encounter locations was 1,385 m (range=374–1,971 m) and the median shore distance was 15.2 km (range=1.1–22.0 km). Best estimates of group sizes ranged from 6–15 individuals (median=9 individuals). A total of 2,627 photos, 14 biopsy samples, and 8 sloughed skin samples were collected, and 2 satellite tags were deployed during sperm whale encounters.

There were 3 sperm whale encounters during MACS 2015 (Table 4, Figure 21b). One of the encounters included a single Risso's dolphin. The median depth of the MACS sperm whale encounter locations was 2,594 m (range=1,578–2,975 m), and the median shore distance was 31.6 km (range=14.3–75.1 km). Best estimates of group sizes ranged from 1–9 individuals. A total of 461 photos and 1 biopsy sample were collected during MACS sperm whale encounters. Single-species recordings of sperm whales were collected on the towed hydrophone array during 2 MACS 2015 visual encounters (Table 4). In addition, there was 1 mixed-species visual-acoustic encounter and 3 acoustic-only detections of sperm whales.

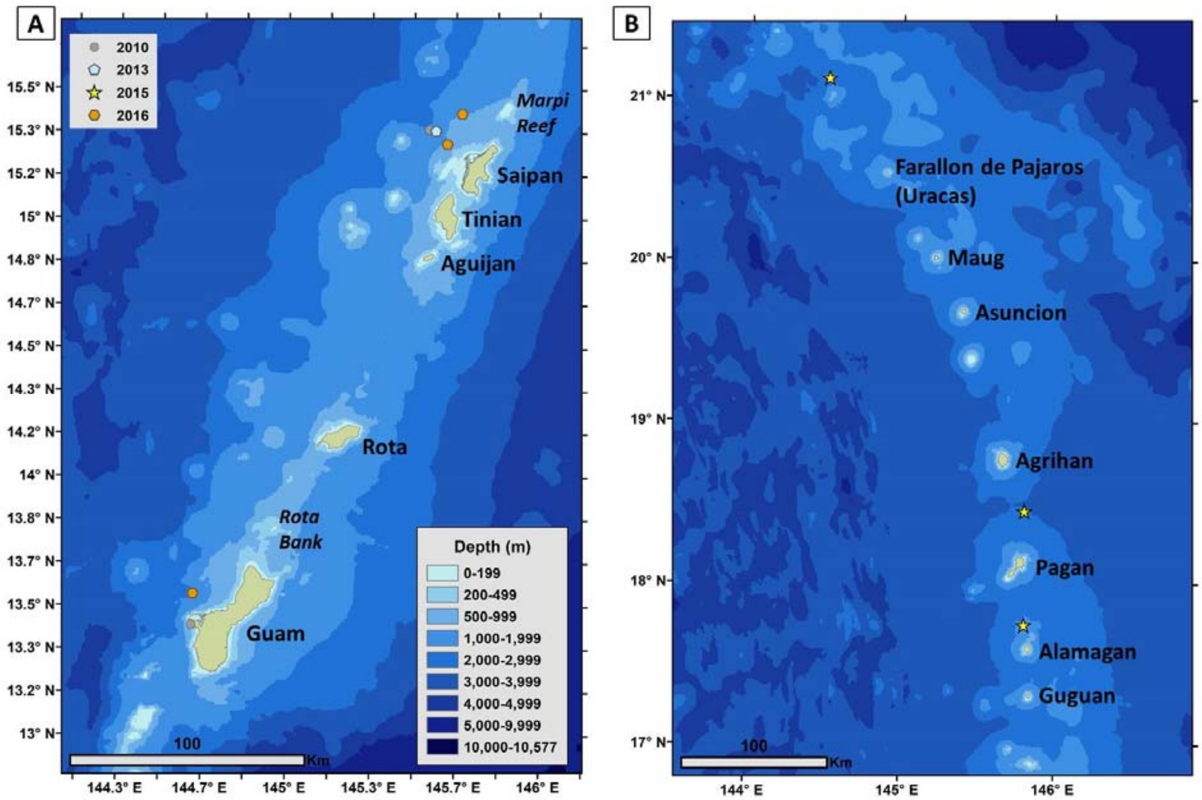

Figure 21: Sperm whale encounter locations by year. Panel A – encounters during 2010, 2013, and 2016 Pacific Islands Fisheries Science Center's Cetacean Research Program small-boat surveys. Panel B – encounters during the 2015 Mariana Archipelago Cetacean Survey.

Photos from all PIFSC sperm whales encounters have been processed, matched, and cataloged, and the sperm whale catalog contains 11 individuals with full fluke images. Two individuals have been encountered twice, first off Guam in 2010 and then in 2016 off Saipan. There are photos from 6 encounters with sperm whales during the 2007 MISTCS which have not been processed.

A total of 15 biopsy samples and 8 sloughed skin samples were collected from sperm whales in the Mariana Archipelago. Five samples (1 biopsy and 4 skin) collected during a 2013 encounter off Saipan were sequenced by SWFSC for a global phylogeography study of sperm whales using mitogenome haplotypes (Morin *et al.* 2018). All of the samples had the same mitogenome haplotype (mtGen08) and sex (female). The remaining 14 biopsy samples and 4 sloughed skin samples have not been processed.

Two satellite tags (1 SPOT/1 SPLASH) were deployed on sperm whales during small-boat surveys off Saipan and Guam in 2016 (Table 3, Figure 22). The tags transmitted for 41.8 d and 9.6 d, respectively. The individual tagged off Saipan traveled north almost as far as Guguan, while the individual tagged off Guam moved offshore and went north as far as Tinian during the life of the tag.

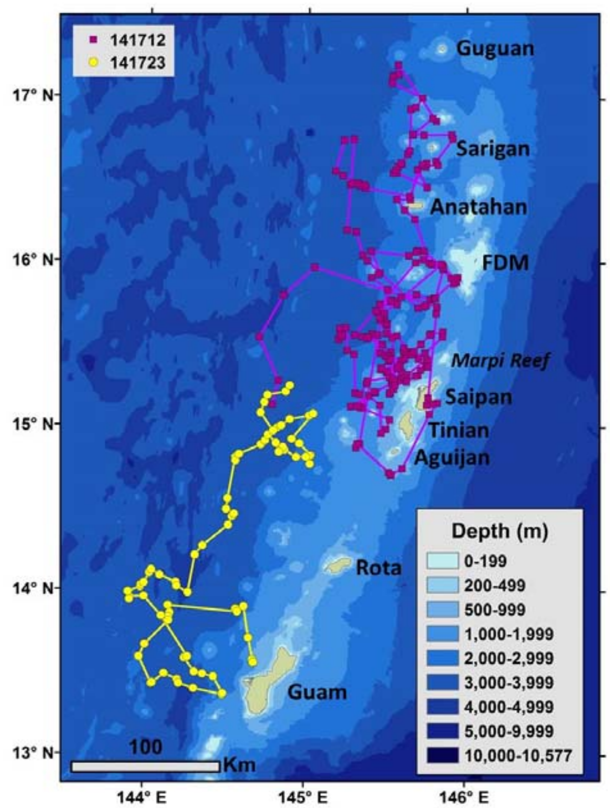

Figure 22: Locations from satellite tags deployed on 2 sperm whales off Saipan and Guam during the Pacific Islands Fisheries Science Center's Cetacean Research Program small-boat surveys (2016). The tags transmitted for 41.8 d and 9.6 d, respectively.

Population Structure

Globally, sperm whales have a low mitochondrial DNA diversity, and the Morin *et al.* (2018) global phylogeography study concluded that existing sperm whales descended from a reduced population of whales in the Pacific, suggesting that genetic selection and hitchhiking are not solely responsible for the low mtDNA diversity in sperm whales. Based on the existing data, no conclusions can be made about the population structure of sperm whales in the Mariana Archipelago. At this time, it would not be worthwhile to sequence the remaining 14 biopsy samples. In order to assess the relation of Mariana Archipelago sperm whales to other locations in the Pacific, more than 25 samples are needed. In order to assess population structure within the Mariana Archipelago, more than 50 samples are needed and due to the extremely low haplotype diversity, single nucleotide polymorphisms (SNPs) analysis would be required. All but 2 of the Mariana Archipelago sperm whale biopsy samples are from the southern islands. More samples are needed from the northern islands and offshore areas.

Abundance

The sperm whale photo-identification catalog is too small conduct a mark-recapture analysis for abundance estimation. Sperm whales were the most frequently sighted species during the 2007 MISTCS, and using 11 encounters Fulling *et al.* (2011) estimated an abundance of 705 (CV = 0.60) individuals. Sperm whale abundance in the Mariana Archipelago will be better assessed using a large-scale line-transect survey of the broader region.

Distribution and Habitat Use

All available sperm whale encounter and satellite telemetry data demonstrate that sperm whales are distributed in both offshore and nearshore locations within the Mariana Archipelago. The PIFSC CRP encounter locations were as close as 1.1 km and as far as 75.1 km from shore. The PIFSC CRP encounter location depths ranged from 374–2,975 m compared to the MISTCS encounter locations that ranged from 809–9,874 m. The encounter and satellite telemetry data could be used to characterize the habitat use of sperm whales in the Mariana Archipelago, including associations with islands, bathymetric features, and oceanographic conditions.

Sperm whales were the most common large whale detected within the PIPAN dataset from Saipan and Tinian. At the Saipan site, they were heard during all months with recording effort with the exception of April 2011, when only 4 days of recording effort occurred during that month (Oleson *et al.* 2015). PIFSC CRP has undertaken a large-scale assessment of temporal and geographic patterns in the occurrence of sperm whales based on the PIPAN sensors throughout the central and western Pacific, including the sites at Saipan and Tinian. A regional Northern Mariana Island model produced as part of this analysis suggests that sperm whales peak in occurrence in spring and fall and are detected less often in summer (Merkens *et al.* in review). Examination of the Pagan data may provide greater insight into movements north and south within the archipelago and on the relative occurrence of whales further to the north.

Exposure to human stressors

Based on the depths of the locations of sperm whale encounters during the PIFSC CRP small-boat surveys, particularly those encounters off Guam, it is possible that sperm whales may be exposed to underwater detonations at the Piti Floating Mine Neutralization Area or at the Agat Bay UNDET Area (Figure 6).

Dwarf Sperm Whale

There were 5 dwarf sperm whale encounters (0.02 encounters/100 km) during PIFSC CRP small-boat surveys (Table 2, Figure 23). Dwarf sperm whales were encountered at Marpi Reef in 2011 and off Guam in 2016. Two encounters off Guam included the same 2 mom-calf pairs. The median depth of dwarf sperm whale encounter locations was 696 m (range=642–870 m) and the median shore distance was 3.3 km (range=1.6–16.7 km). Best estimates of group sizes ranged from 1–4 individuals (median=3 individuals). A total of 986 photos and 1 biopsy sample were collected during dwarf sperm whale encounters. Passive acoustic recordings were made using a CARB during 2 encounters with 2 mom-calf pairs that were seen together (Merkens *et al.* 2018). There were no dwarf sperm whale encounters during MACS 2015.

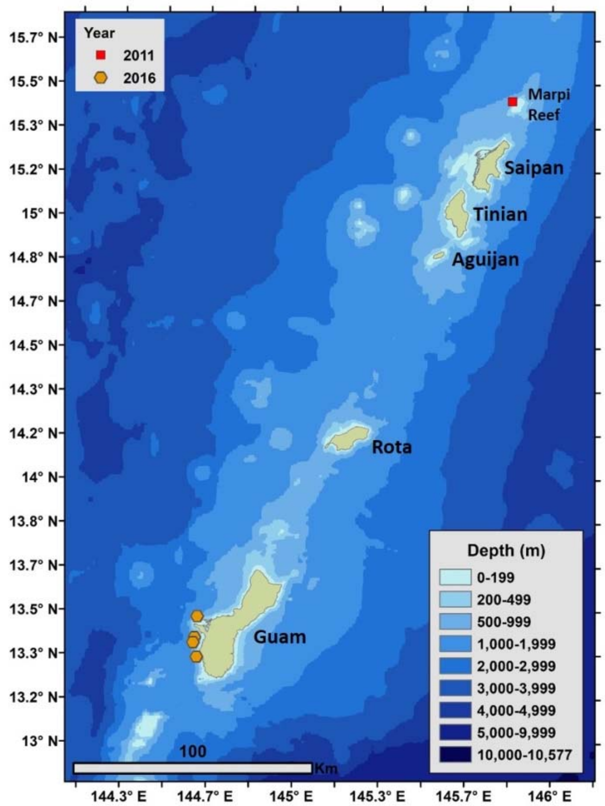

Figure 23: Dwarf sperm whale encounter locations by year during 2011 and 2016 Pacific Islands Fisheries Science Center's Cetacean Research Program small-boat surveys.

There is no photo-identification catalog for dwarf sperm whales, as photos are generally of low quality and dorsal fins are not distinctive.

Population Structure

It is not possible to assess population structure of dwarf sperm whales with the available data.

Abundance

There is no photo-identification catalog for dwarf sperm whales in the Mariana Archipelago, precluding mark-recapture abundance estimation. Abundance of this species in the Mariana Archipelago would be better assessed using large-scale ship-based surveys or passive acoustic surveys using drifting buoys (e.g., Griffiths and Barlow 2016), such as Drifting

Acoustic Spar Buoy Recorders (DASBRs). Such recorders have been incorporated into PIFSC CRP ship surveys.

Distribution and Habitat Use

Within the Mariana Archipelago, dwarf sperm whales have only been observed in nearshore waters and the low number of sightings is limiting for an assessment of habitat use.

Exposure to human stressors

It is possible that dwarf sperm whales may be exposed to underwater detonations off Guam. The 2 encounters with mom-calf dwarf sperm whales were 2.8 km and 3.6 km from the Agat Bay UNDET Area (Figure 6). An encounter with another dwarf sperm whale was 3.5 km from the Piti Mine Neutralization Area and the depths of the dwarf sperm whale encounter locations off Guam were similar to the depth at the Piti site.

Vocal Behavior

The passive acoustic recordings of dwarf sperm whales collected during the mom-calf pair encounters were only the second confirmed-species recordings in the wild (Merkens *et al.* 2018). These recordings were used to characterize dwarf sperm whale clicks and make comparisons to other dwarf sperm whale acoustic recordings and previously described clicks of pygmy sperm whales (*Kogia breviceps*) (Merkens *et al.* 2018). The authors concluded that although dwarf sperm whale clicks cannot yet be distinguished from those of pygmy sperm whales, the detailed description of the clicks will provide genus identification and the ability to monitor these cryptic species using passive acoustics.

Pygmy Killer Whale

Pygmy killer whales were encountered 5 times (0.02 encounters/100 km) during PIFSC CRP small-boat surveys off Saipan and Guam (Table 2, Figure 24). During 1 encounter, pygmy killer whales were seen interacting with humpback whales. A single group of individuals was encountered off Guam each year from 2013 to 2015, and included new calves in 2014 and 2015. The median depth of pygmy killer whale encounter locations was 563 m (range=38–1,978 m) and the median shore distance was 6.9 km (range=1.1–10.0 km). Best estimates of group sizes ranged from 6–11 individuals (median=8 individuals). A total of 1,741 photos and 5 biopsy samples were collected during pygmy killer whale encounters. No pygmy killer whales were encountered during MACS 2015.

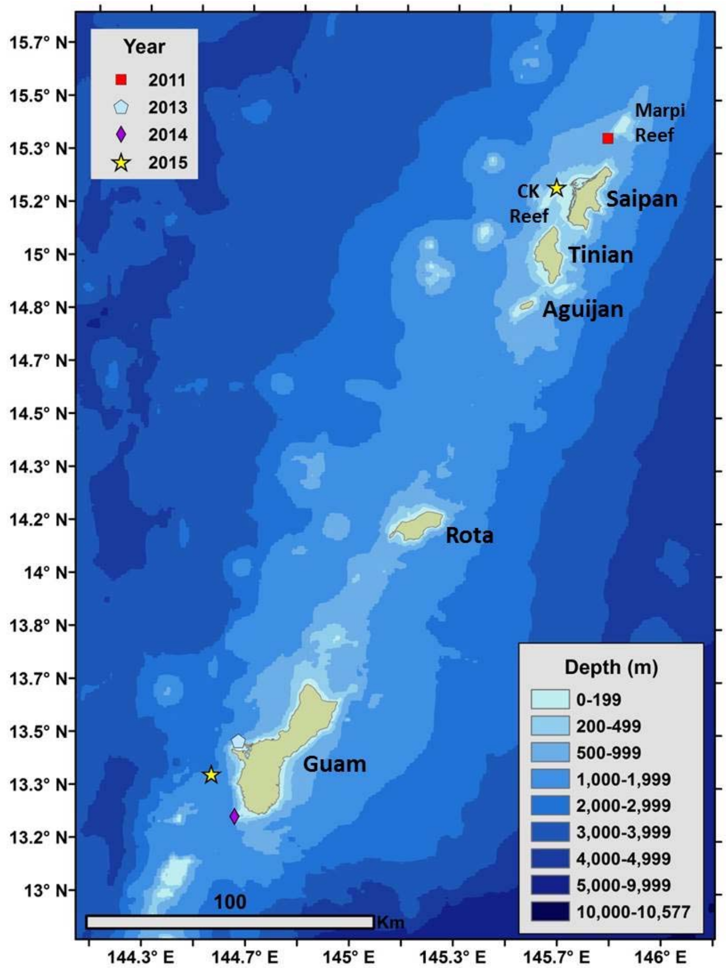

Figure 24: Pygmy killer whale encounter locations by year during 2011, 2013–2015 Pacific Islands Fisheries Science Center's Cetacean Research Program small-boat surveys.

All photographs of pygmy killer whales have been processed and the photo-identification catalog contains 8 individuals. All 8 individuals were part of the same group seen off Guam in 3 consecutive years. Six of the individuals were seen in all 3 years. The other 2 were added to the catalog in 2015.

The 5 biopsy samples have not been genetically processed, but photos collected during the sampling events show that 2 individuals were each sampled twice resulting in a total of 3 sampled pygmy killer whales.

Population structure

Repeated encounters of the same group of individuals off Guam during suggest that some pygmy killer whales may be island-associated. Satellite telemetry data would be useful in determining the range of individuals in this group. Other than this single group with apparent fidelity to Guam, there is insufficient data to assess population structure for pygmy killer whales in the Mariana Archipelago. With only 3 sampled individuals, there is little value in processing the biopsy samples from pygmy killer whales at this time.

Abundance

With only 8 individuals in the photo-identification catalog, a mark-recapture analysis for abundance estimation is not possible. This species may be better assessed using a large-scale ship-based survey of the broader archipelago.

Distribution and Habitat Use

Pygmy killer whales were encountered in both nearshore and offshore waters and across a broad range of depths. During PIFSC CRP small-boat surveys, the median shore distance was 6.9 km and the farthest encounter location was 10 km north of Saipan (Table 2, Figure 24). There was a single encounter of pygmy killer whales during the 2007 MISTCS, which was south of Guam and just north of the Mariana Trench (Fulling *et al.* 2011). An assessment of habitat use is limited by the low number of sightings.

Exposure to human stressors

Pygmy killer whales were encountered 2.5 km from the Piti Floating Mine Neutralization Area and 3 km from the Agat Bay UNDET Area (Figure 6). Given their use of a wide range of depths, it is possible that they could be exposed to underwater explosive detonations at either the Piti or Agat site.

Bryde's Whale

Bryde's whales were encountered for the first time during PIFSC CRP small-boat surveys in 2015 and were seen 4 times that year off Rota and Guam (Table 2, Figure a). A Bryde's whale was also encountered off Saipan in 2017. The overall encounter rate for Bryde's whales during small-boat surveys was 0.02 encounters/100 km. The median depth of Bryde's whale encounter locations was 859 m (range=487–1,918 m) and the median shore distance was 16.7 km (range=12.4–23.9 km). All encounters were with single individuals. A total of 846 photos and 3 biopsy samples were collected during Bryde's whale encounters.

During MACS 2015, Bryde's whales were seen 3 times (Table 4, Figure b). Two of the 3 encounters were in the central portion of the Mariana Archipelago (off Pagan and Alamagan), while the third was south of Guam. The median depth of Bryde's whale encounter locations during MACS was 3,198 m (range=844–3,762 m) and the median shore distance was 45.9 km (range=9.0–71.0 km). Best estimates of group sizes ranged from 1–4 individuals (median=2 individuals). A total of 785 photos were collected during MACS. No biopsy samples were collected. Sonobuoys were deployed during 2 Bryde's whale encounters but the data have not been processed to determine if vocalizations were recorded (Table 4).

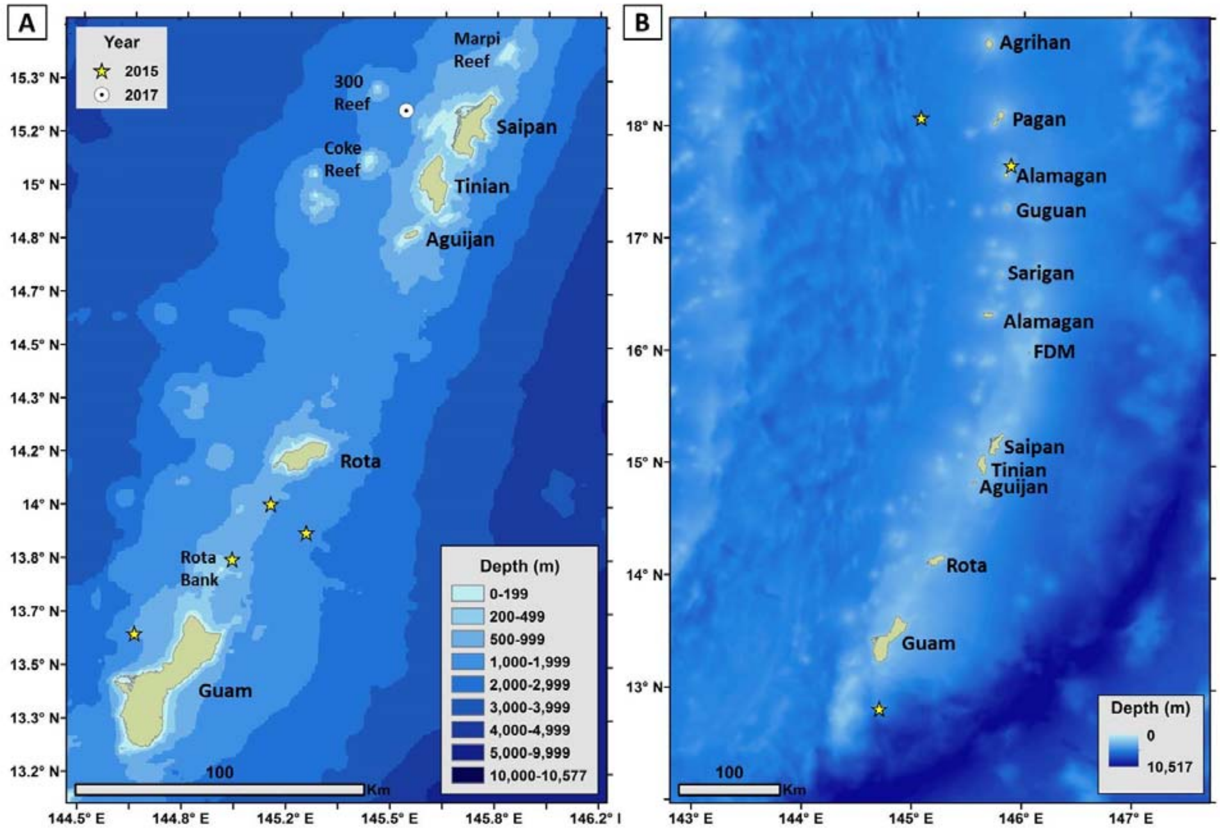

Figure 25: Bryde's whale encounter locations by year. Panel A – encounters during 2015 and 2017 Pacific Islands Fisheries Science Center's Cetacean Research Program small-boat surveys. Panel B – encounters during the 2015 Mariana Archipelago Cetacean Survey.

A photo-identification catalog has not been created for Bryde's whales due to poor photo quality and lack of distinctive dorsal fins in the PIFSC CRP photos. Photos collected during 10 encounters of MISTCS have not been processed (

Table 5).

The 3 biopsy samples collected from Bryde's whales were genetically determined by SWFSC to be males. Mitochondrial sequences from the biopsies were compared to data from a genetic study of Bryde's whales in the western Pacific and Indian Ocean (Kanda *et al.* 2007). All 3 had haplotypes that were also detected in the earlier study.

Population structure

Though not detected among the 3 biopsy samples collected during this study, it is possible that the recently-described Omura's whales (*Balaenoptera omurai*) may occur in the Mariana Archipelago, as its range is not yet fully described. Identification of Bryde's whale call types in this region may provide an opportunity to assess the distribution of these whales in other regions, including within PIPAN sites at Hawaiʻi and Wake Atoll, and long-term acoustic monitoring from other parts of the western Pacific.

Abundance

Mark-recapture abundance estimation of Bryde's whales is not possible because there is no photo-identification catalog. Fulling *et al.* (2011) estimated an abundance of 233 (CV=0.45) individuals using 10 encounters during the MISTCS in 2007. Population size of Bryde's whales will be better assessed using a large-scale ship-based survey of the broader region.

Distribution and Habitat Use

All available encounter data with Bryde's whales demonstrate that the whales use both nearshore and offshore waters. Eight of 18 MISTCS encounters were south of the Mariana Trench and outside off the EEZ (Fulling *et al.* 2011). Eight of the remaining 10 MISTCS encounters that were within the EEZ boundary were far offshore. The PIFSC CRP small-boat encounter locations were all within 24 km of shore, while the MACS 2015 encounter locations ranged 9–71 km from shore.

The MISTCS encounters with Bryde's whales generally occurred in areas of steep bathymetric relief including the West Mariana Ridge and the Mariana Trench (Fulling *et al.* 2011). Bryde's whales were encountered in locations with depths that ranged from 2,549–7,373 m during the MISTCS and from 487–3,762 m during PIFSC CRP small boat surveys and MACS. During a small-boat encounter at Rota Bank, a Bryde's whale was visibly skim feeding, but its prey is unknown.

It is likely that Bryde's whales are in the Mariana Archipelago year-round. They were seen in all months of the January–April MISTCS survey (Fulling *et al.* 2011), in May during MACS 2015, and in August–September during small-boat surveys.

Exposure to human stressors

Bryde's whale have not been seen near the U.S. Navy underwater detonation areas off Guam, but the depths of the Piti Floating Mine Neutralization Area and the Agat Bay UNDET sites (Figure 6) fall within the range of depths recorded at the PIFSC CRP encounter locations (Figure 25).

Melon-headed Whale

Melon-headed whales have been encountered 3 times (0.01 encounters/100 km) during PIFSC CRP small-boat surveys (Table 2, Figure 26). The median depth of melon-headed whale encounter locations was 1,014 m (range=903–1,975 m) and the median shore distance was 6.5 km (range=2.6–15.1 km). Best estimates of group sizes ranged from 85–380 individuals (median=325 individuals). A total of 7,502 photos and 31 biopsy samples were collected, and 3 satellite tags were successfully deployed during melon-headed whale encounters.

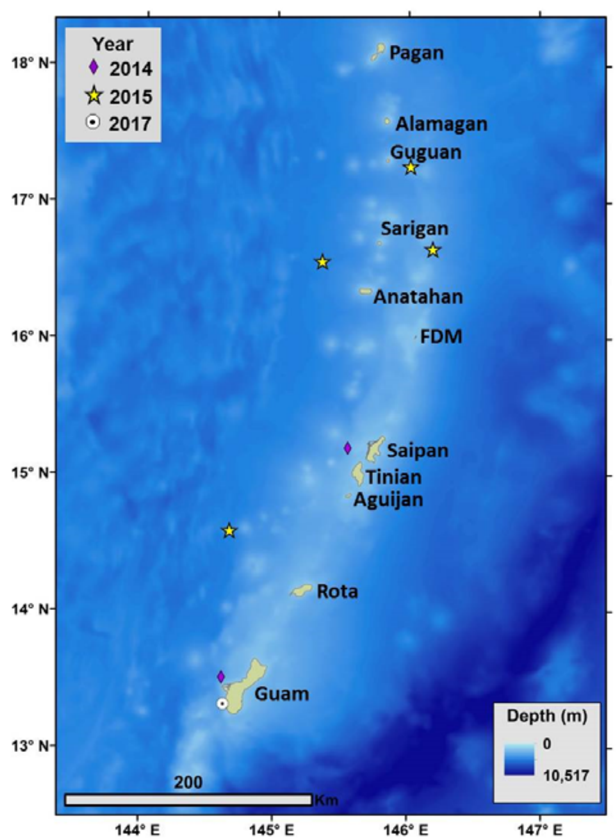

Figure 26: Melon-headed whale encounter locations by year during 2014 and 2017 Pacific Islands Fisheries Science Center's Cetacean Research Program small-boat surveys and the 2015 Mariana Archipelago Cetacean Survey.

Melon-headed whales were the second most frequently sighted species during MACS 2015 (*n*=4) and were seen offshore of Rota and in the central portion of the Mariana Archipelago (Table 4, Figure 26). The median depth of melon-headed whale encounter locations during MACS was 2,500 m (range=1,562–3,383 m) and the median shore distance was 40.1 km (range=18.0–71.3 km) (Table 4). Best estimates of group sizes ranged from 90–268 individuals (median=167 individuals). A total of 2,462 photos and 27 biopsy samples were collected during MACS, and acoustic recordings were collected during all 4 visual encounters (Table 4).

The current melon-headed whale photo-identification catalog contains 146 individuals from a single 2014 encounter off Saipan. All remaining photos from PIFSC CRP small boat surveys, MACS 2015, a 2012 HDR encounter off Guam, and 2 MISTCS encounters have undergone all aspects of processing, matching, checking, and grading and only need for new IDs to be assigned. Comparisons between all sightings resulted in only 3 matches. Those 3 melon-headed whales were photographed off Sarigan during MACS 2015. One of the whales was matched to an individual photographed during a MISTCS encounter approximately 100 km north of Challenger Deep (Mariana Trench), and the other 2 individuals were matched to melon-headed whales photographed off Saipan in 2014.

Three location-only satellite tags have been deployed on melon-headed whales (Table 3, Figure 27). Two were deployed off Saipan in 2014, and the third was deployed off Guam in 2017. Tag durations ranged from 1.8–15.9 d. The individual with the longest duration tag primarily stayed within the 3-Islands area, but moved as far south as Rota and as far north as East Diamante Seamount, west of FDM (Figure 26).

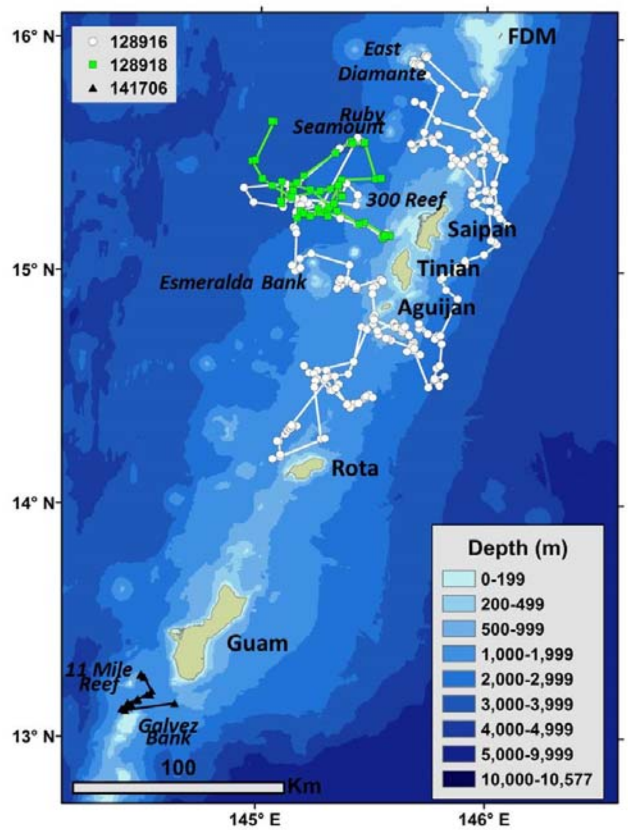

Figure 27: Locations from satellite tags deployed on 2 melon-headed whales off Saipan in 2014 and 1 off Guam in 2017 during the Pacific Islands Fisheries Science Center's Cetacean Research Program small-boat surveys. The tags transmitted for 3.1 d, 15.9 d, and 1.8 d, respectively.

Population structure

Martien *et al.* (2017) found only moderate genetic differentiation between melon-headed populations within and between ocean basins and suggested that connectivity between island-associated populations may be maintained through occasional long-distance dispersal or gene flow with larger pelagic populations. Two Mariana Archipelago melon-headed whale samples collected by HDR off Guam (

Table 5) were used in the Martien *et al.* (2017) study. Detecting population structure within Mariana Archipelago melon-headed whales using genetic data would require analysis of both mitochondrial and nuclear data and sample sizes in excess of 20 samples per stratum, assuming levels of genetic differentiation between populations comparable to that found by Martien *et al*. (2017). Photo-identification and movement data are insufficient to delineate any population structure, though it is clear that some animals remain or return to the area over a several year period, evidenced by the re-sights of 3 individuals between 2007, 2014, and 2015.

Abundance

Given that only 3 individuals of several hundred within the working photo-identification catalog have been re-sighted, a mark-recapture analysis for abundance is not possible. The final photo-identification catalog number may be used as a proxy for the minimum abundance of melon-headed whales in the Mariana Archipelago. Fulling *et al.* (2011) estimated an abundance of 2,455 (CV = 0.702) individuals from 2 encounters during the MISTCS in 2007. Melon-headed whales may be better assessed using a large-scale ship-based survey of the broader region.

Distribution and Habitat Use

Melon-headed whales have been encountered in both nearshore and offshore locations in the Mariana Archipelago. The PIFSC CRP small-boat encounters were all within 15.2 km from shore, while MACS 2015 encounters were 18.0–71.3 km from shore (Table 2, Table 4, Figure 26). During the 2007 MISTCS, 1 melon-headed whale encounter was nearshore to Guam, while the other was close to the Mariana Trench and the EEZ boundary (Fulling *et al.* 2011). The photo data suggest that individuals roam over large areas within the Mariana Archipelago. One individual was seen during the MISTCS near the southwestern portion of the Mariana Trench and was then observed more than 600 km away off Sarigan during MACS 2015. Two other individuals photographed off Sarigan were observed approximately 170 km away during a PIFSC CRP encounter off Saipan the previous year.

Encounter and tag locations of melon-headed whales could be used to characterize the melon-headed whale habitat use. The PIFSC CRP encounter locations had water depths that ranged from 903–3,383 m (Table 2, Table 4), and the MISTCS encounter locations had water depths that range from 3,224–3,935 m (Fulling *et al.* 2011). The locations from satellite tags deployed on melon-headed whales indicate some associations with submerged reefs and seamounts (Figure 27).

Exposure to human stressors

Based on their occurrence in the waters off the west side of Guam and the depths of the locations of melon-headed whale encounters during small-boat surveys, it is possible that the whales may be exposed to underwater detonations at the Agat Bay UNDET Area (Figure 6).

Beaked Whales

Two confirmed species of beaked whales were encountered during PIFSC CRP small-boat surveys in 2014–2015 and included Blainville's beaked whales (*n*=2) and Cuvier's beaked whales (*n*=1) (Table 2, Figure 28a). There were several other beaked whale sightings that were recorded as *Mesoplodon* beaked whales or ziphiid whales. Blainville's beaked whale encounter locations were 678 m and 1,200 m deep, and were 10.9 km and 15.2 km from shore. Best estimates of group sizes of Blainville's beaked whales were 1 and 5 individuals. A total of 468 photos and 1 biopsy sample were collected during Blainville's beaked whale encounters. The depth of the Cuvier's beaked whale encounter location was 1,706 m and the shore distance was 18.8 km. The best estimate for the group size was 4 individuals. A total of 230 photos were collected during the Cuvier's beaked whale encounter. No biopsy samples were collected.

During MACS 2015, there were 7 beaked whale sightings, 2 of which were identified as Blainville's beaked whales (Table 4, Figure 28b). The remaining sightings were identified as *Mesoplodon* beaked whales. The depth of Blainville's beaked whale encounter locations were 267 m and 1,290 m, and the shore distances were 0.5 km and 3.5 km. Best estimates of group sizes were 3 and 4 individuals. A total of 23 photos and 1 acoustic recording were collected during Blainville's beaked whale encounters. Mesoplodon beaked whales were acoustically detected on the towed hydrophone array during a visual encounter (Table 4). This acoustic detection could be classified to the species level with additional analysis.

A photo-identification catalog has not been created for beaked whales due to poor photo quality and lack of distinctive dorsal fins.

The only biopsy sample collected from a Blainville's beaked whale encountered off Rota in 2015 has not been genetically processed.

PIPAN data from Saipan and Tinian, as well as from other sites in the central and western Pacific network have been partially analyzed for beaked whale occurrence. Blainville's beaked whales are most commonly detected, though Cuvier's and the unidentified beaked whale currently known as the Cross Seamount beaked whale (BWC) have also been heard sporadically at both monitoring sites (Baumann-Pickering *et al.* 2014, Oleson *et al.* 2015, Hill *et al.* 2015). There is no clear seasonality in the occurrence of any beaked whale species within the acoustic data, with detections of each species occurring year-round. Blainville's beaked whales are detected on 42% of all recording days at the Saipan site, and 26% at the Tinian site. Cuvier's beaked whales are detected on 30% and less than 1% of days respectively, and BWC on 12% and 5% of days at the 2 sites (Baumann-Pickering *et al.* 2018).

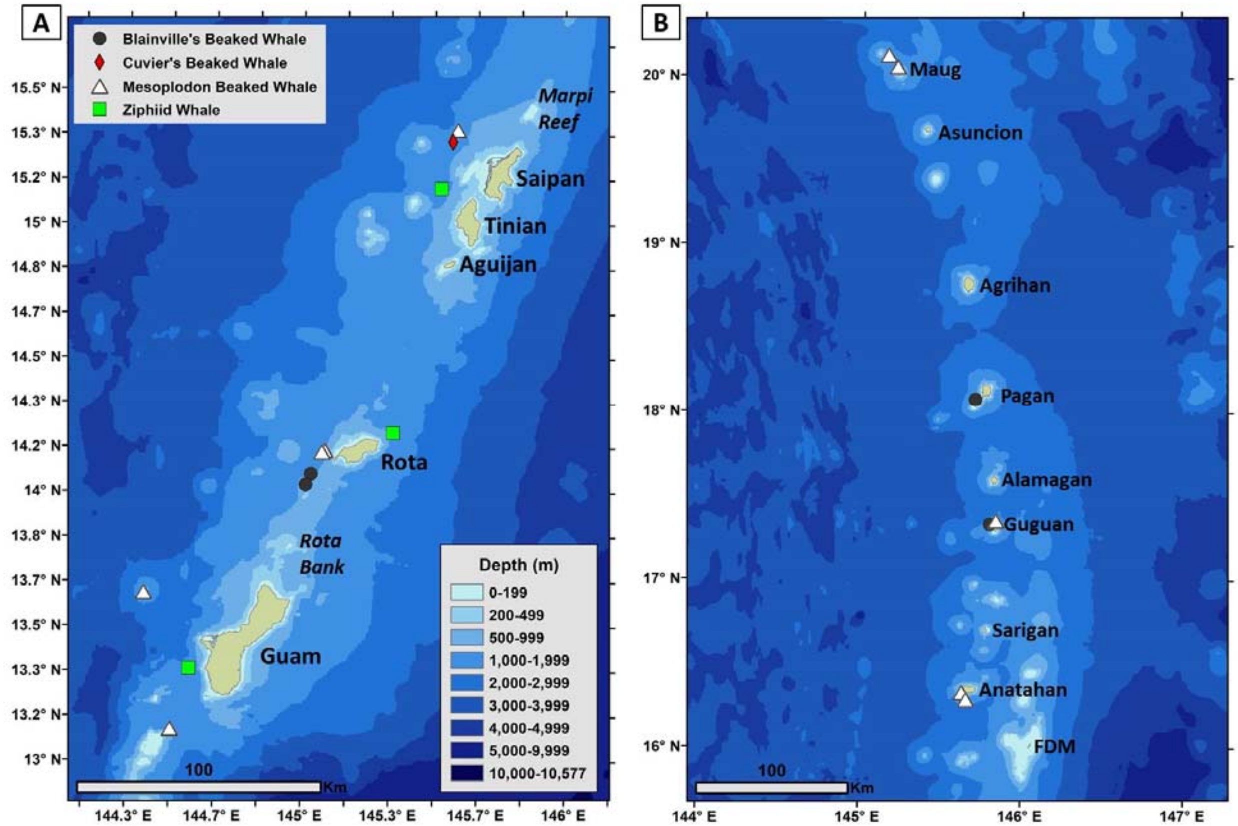

Figure 28: Beaked whale encounter locations. Panel A – encounters during 2012–2017 Pacific Islands Fisheries Science Center's Cetacean Research Program small-boat surveys. Panel B – encounters during the 2015 Mariana Archipelago Cetacean Survey.

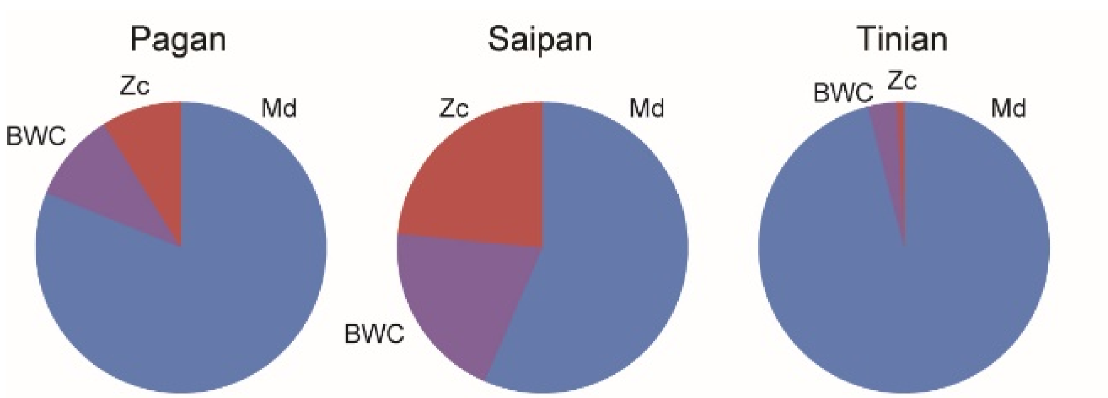

Figure 29: Relative frequency of occurrence of beaked whale species in the passive acoustic data form PIFSC monitored PIPAN sites from 2010 through 2017. BWC - Cross Seamount beaked whale; Zc - Cuvier's beaked whale; Md - Blainville's beaked whale.

Population structure

It is not possible to assess population structure of either Blainville's or Cuvier's beaked whales in the Mariana Archipelago with the available tissue samples or photographic data. Acoustic analysis of geographic variation in Blainville's beaked whale echolocation click characteristics suggests that while characters such as center frequency and inter-click interval (ICI) are fairly stable across the species range, geographic variation in peak frequency is evident (Baumann-Pickering *et al.* 2018), though it is not yet clear if this variability is correlated with population boundaries or other ecological or behavioral factors, such as differences in prey choice or prey size.

Abundance

Given the lack of a photo-identification catalog, a mark-recapture analysis of abundance is not possible. Beaked whale abundance may be best assessed acoustically using a combination of towed array and drifting acoustic sensors. Towed array data from MACS 2015 have not been processed to classify beaked whale encounters to species. Future work with DASBRs in this region may provide greatest insight into distribution and abundance.

Distribution and Habitat Use

All of the PIFSC beaked whale encounters were nearshore and within 30.6 km from shore. During the 2007 MISTCS, there were 2 *Mesoplodon* beaked whale encounters that were on or near the West Mariana Ridge, and 1 ziphiid whale encounter that was close to Alamagan (Fulling *et al.* 2011). The depths of the MISTCS encounters ranged from 2,122–3,984 m, which were deeper than all of the PIFSC beaked whale encounters. Some of the PIFSC beaked whale encounter locations were on or near an underwater feature or near an island (Figure 28).

Exposure to human stressors

Based on the depths of the locations of beaked whale encounters during the PIFSC CRP small-boat surveys, it is possible that they may be exposed to underwater detonations at the Piti Floating Mine Neutralization Area or the Agat Bay UNDET Area (Figure 6).

Beaked whales are known to be sensitive to military sonar (e.g., Filadelpho *et al.* 2009, Tyack *et al.* 2011, DeRuiter *et al.* 2013), other high intensity anthropogenic sounds, including air guns and oceanographic echosounders (Cholewiak *et al.* 2017), and other sources (e.g., Carretta and Barlow 2011) in certain circumstances. Cuvier's beaked whales have stranded on Saipan and Guam within a few days of Naval training exercises that included mid-frequency active sonar (Simonis *et al. in prep*), though assessment of a link between sonar activities and the strandings is still ongoing.

Risso's Dolphin

Risso's dolphins were not encountered during PIFSC CRP small-boat surveys but were seen twice during MACS 2015 (Table 4, Figure 30). During the encounter north of Uracus, a single Risso's dolphin was associated with 2 sperm whales. The depths of the Risso's dolphin encounter locations were 2,594 m and 4,398 m and the shore distances were 75.1 km and 94.5 km. A total of 8 photos were collected and acoustic recordings were made during 1 encounter (Table 4). No biopsy samples were collected, and there is no photo-identification catalog.

Population structure

There are no genetic, photographic, or movement data with which to assess population structure for Risso's dolphins in the Mariana Archipelago. An acoustic analysis of geographic variation in Risso's dolphin echolocation clicks in the central and eastern North Pacific and the western Atlantic revealed potential patterns in the spectral peaks and troughs that may be indicative of population structure (Soldevilla *et al.* 2017), though additional examination will be required to determine whether that variation is tied to prey preference or other factors rather than population structure. Acoustic recordings of Risso's dolphins in the Mariana Archipelago may provide additional information about the utility of acoustic data for assessing population structure and the similarity between Risso's dolphins echolocation clicks here versus elsewhere in the central Pacific.

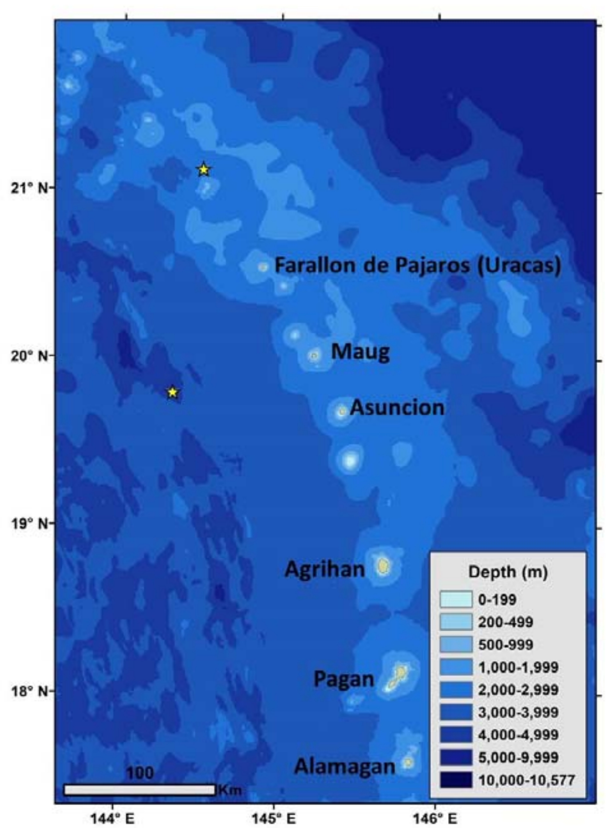

Figure 30: Risso's dolphin encounter locations during the 2015 Mariana Archipelago Cetacean Survey.

Abundance

There are inadequate data to assess Risso's dolphin abundance in the Mariana Archipelago. A large-scale ship-based survey will likely be the best approach for determining Risso's dolphin abundance in the region.

Distribution and Habitat Use

Both Risso's dolphin sightings during MACS 2015 were in offshore waters in depths greater than 2,500 m. Passive acoustic data from PIPAN and other autonomous recorders may provide additional information about Risso's dolphin occurrence in the region, as the species does produce distinctive species-specific clicks (Soldevilla *et al.* 2008, 2017).

Exposure to human stressors

Risso's dolphins have not been encountered near the U.S. Navy underwater detonation sites off Guam and the depths of the encounter locations during MACS 2015 were deeper than the operation sites.

Humpback Whale

Between 2015 and 2018 PIFSC CRP conducted targeted humpback whale surveys off the 3-Islands area. There were 39 encounters with humpback whales during which photos were collected (Table 2, Figure 31). The encounter rate for humpback whales, based on only the trackline distance during "winter" surveys (4,782 km), was 0.82 encounters/100 km. Small-boat surveys in February–March 2010 and April 2014 off the 3-Islands area and Guam did not target humpback whales but did include survey effort in waters ≤200 m (32% of on-effort time) including some offshore reefs (Figure 32), however no humpback whales were observed.

All of the humpback whale encounters were off Saipan in 2015–2018 and most were on either CK Reef or Marpi Reef. Humpback whales accounted for 17% (*n*=36) of the encounters within the 200 m depth bin (Figure 3). The median depth of humpback whale encounter locations was 38 m (range=12–307 m) and the median shore distance was 8.1 m (range=1.2–18.1 m). Best estimates of group sizes ranged from 1–8 individuals (median=2 individuals). Mother-calf pairs were seen in all years, and there were a total of 14 pairs across years. A total of 18,125 photos and 29 biopsy samples were collected during humpback whale encounters.

The humpback whale photo-identification catalog includes all available data collected to date. The catalog includes 43 non-calf individuals including 4 animals photographed at Marpi Reef during the 2007 MISTCS. There are full fluke images for 29 individuals. Seven individuals were encountered in more than 1 year, and the cumulative number of individuals sighted each year is still increasing relative to the cumulative number of distinctive individuals (Figure 33), indicating that the photo-identification catalog is still growing.

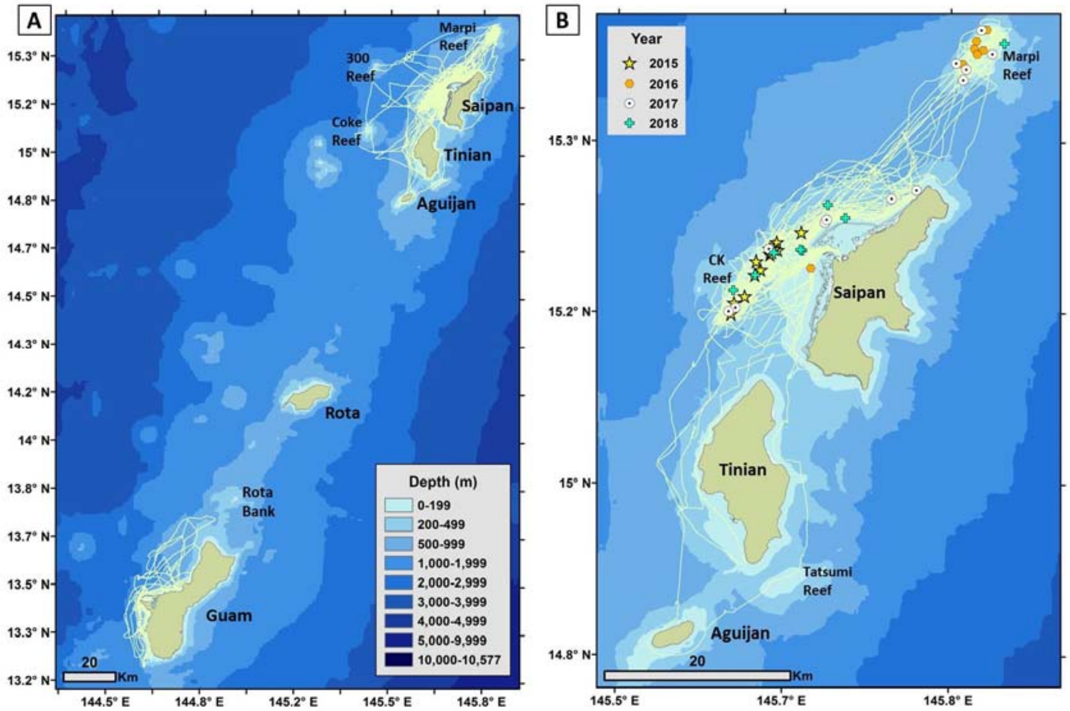

Figure 31: Panel A – Survey tracklines (4,782 km) during Pacific Islands Fisheries Science Center's Cetacean Research Program small-boat surveys (2010, 2014–2018) in "winter" months (February–April) when humpback whales are known to occur in the Mariana Archipelago. Panel B – Tracklines and humpback whale encounter locations by year during 2015–2018 PIFSC small-boat "winter" (February–March) humpback whale surveys.

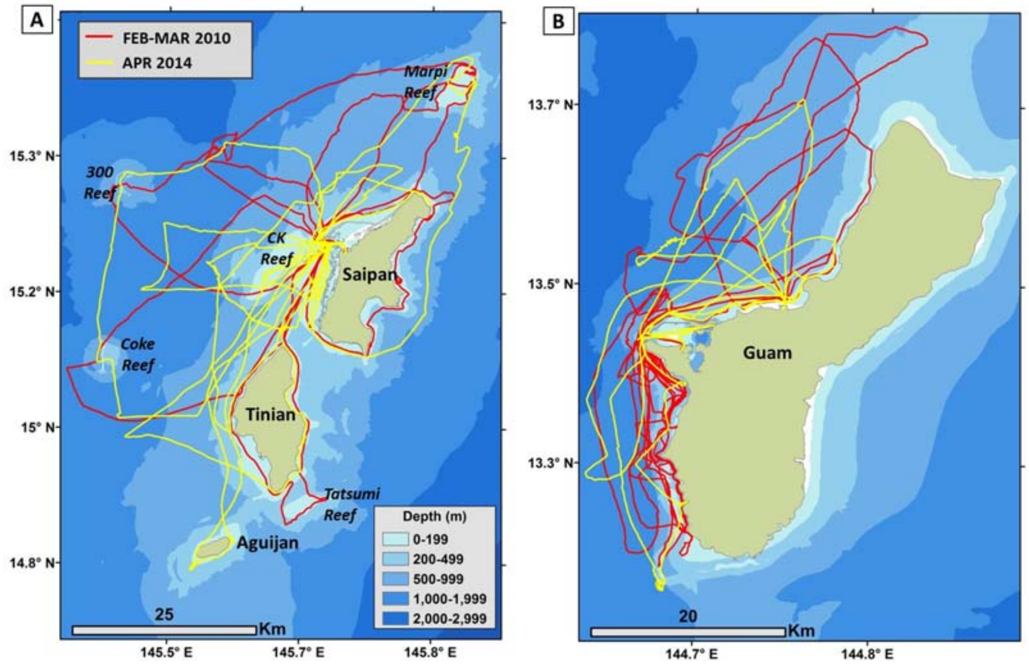

Figure 32: Pacific Islands Fisheries Science Center's Cetacean Research Program survey tracklines in February–March 2010 and April 2014. Panel A - 3-Islands area of Saipan, Tinian, and Aguijan. Panel B - Guam. No humpback whales were observed.

Population structure

Five of the haplotypes (A-, A+, A3, E1, F2) found in the Mariana Archipelago humpback whale samples are common throughout the North Pacific. Two haplotypes (E5, E6) are more localized to the western North Pacific but are also present in the eastern and central North Pacific. Comparisons of mitochondrial DNA from Mariana Archipelago humpback whale samples to those collected during the 2004–2006 North Pacific study of humpbacks (SPLASH, Baker *et al.* 2013) showed the greatest identity with the Ogasawara breeding ground and the Commander Islands feeding ground in the WNP (Hill *et al*. in prep).

Matching of fluke images from the Mariana Archipelago photo-identification catalog to existing catalogs from the Philippines, Japan, and Russia revealed connectivity to all locations (Hill *et al.* in prep). The current catalog and biopsy sample size from the Mariana Archipelago are small, and additional data are necessary to better assess migratory routes and connectivity to other breeding and feeding grounds.

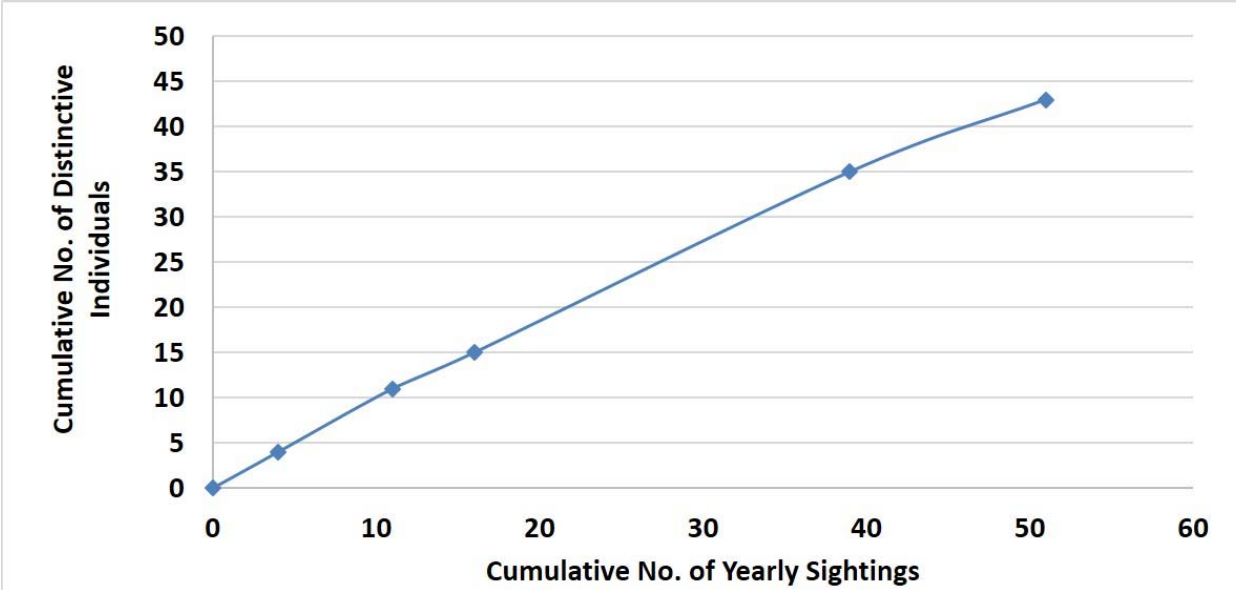

Figure 33: The cumulative number of individual non-calf humpback whales sighted in each year (2007, 2015–2018) versus the cumulative number of distinctive individuals.

Abundance

Additional data collection and a better assessment of the connectivity of Mariana Archipelago humpback whales to other breeding and feeding areas is recommended before pursuing mark-recapture abundance estimation.

Distribution and Habitat Use

The occurrence of humpback whales in the Mariana Archipelago was evident from whaling records (Townsend 1935), opportunistic sightings (Eldredge 1991, 2003, Darling and Mori 1993, Yamaguchi *et al.* 2002, Uyeyama 2014), and passive acoustic records (DoN 2007, Oleson *et al.* 2015), but it was not clear whether this area served as a migratory corridor or a winter breeding ground. The 2015–2018 small-boat surveys that targeted humpback whales confirmed that the whales are using the Mariana Archipelago as a breeding ground (Hill *et al.* in prep). Multiple mother-calf pairs (including a neonate and very small calves) and competitive groups were encountered off Saipan. In addition, several individuals were re-sighted between years, including females with different calves in different years, demonstrating individual site fidelity to the Mariana Archipelago as a wintering area.

Humpback whales were acoustically detected within the PIPAN data from Saipan and Tinian in December–April in all years analyzed to date (2010–2013) (Oleson *et al.* 2015). More recent recordings (since 2013) and new data from Pagan in the northern portion of the archipelago could be assessed to evaluate relative occurrence geographically and any trends in the number of singers present in the region since recording effort began in 2010. Mariana

Archipelago humpback whale song may also be characterized annually for comparison to other humpback whale breeding areas.

Studies on humpback whales around the world demonstrate that on breeding grounds the whales use warm, shallow water areas (< 200 m) that are typically close to shore (Whitehead & Moore 1982, Martins *et al.* 2001, Ersts and Rosenbaum 2003, Rasmussen *et al.* 2007, Félix and Botero-Acosta 2011), and the 2015–2018 small-boat and the 2007 MISTCS (Fulling *et al.* 2011) encounters reflected the finding. The median depth of the PIFSC encounter locations was 38 m and all of the humpback whale encounters were within 18 km from shore. Semimonthly aerial surveys conducted by the Guam DAWR did not report humpback whales from 1963 to 2012 (Martin *et al.* 2016), suggesting humpback whales are not common in the nearshore waters around Guam. In addition, small-boat surveys conducted off Guam by PIFSC CRP in February 2010 and April 2014 did not result in any humpback whale encounters.

A study of humpback whales in New Caledonia found that the whales used offshore seamounts intensively within the breeding season and during their migration away from the breeding area (Garrigue *et al.* 2015). There are numerous seamounts and submerged reefs within the Mariana Archipelago. In March 2018, the PIFSC partnered with the U.S. Coast Guard Sector Guam to survey 2 offshore locations for humpback whales. Neither Santa Rosa Reef (60 km south of Guam) nor Galvez Banks (30 km south of Guam) is accessible with a small-boat in winter. During the single-day survey, no humpback whales were observed in those areas.

Visual surveys or use of passive acoustic devices at other shallow water locations and seamounts in the Mariana Archipelago may reveal additional humpback whale wintering locations. Examination of 2 years of PIPAN data from Pagan may be particularly enlightening with regard to whether humpbacks are distributed further north into the archipelago and whether the timing of their occurrence there suggests migratory movements along the archipelago.

Exposure to human threats

Humpback whales are not commonly reported off Guam, and have not been reported within or near the U.S. Navy underwater detonation areas (Figure 6).

Other Baleen Whales

No baleen whales other than humpback and Bryde's whales have been observed in the Mariana Archipelago during PIFSC surveys, though several are known to occur across the western Pacific, including blue (*B. musculus*), fin (*B. physalus*), sei (*B. borealis*), and minke (*B. acutorostrata*) whales. PIFSC PIPAN acoustic datasets have been analyzed to annotate occurrence of sounds consistent with those known or likely to be produced by these species.

Blue and fin whale calls were rarely detected in the Saipan and Tinian datasets, and minke whales boings were detected on a few occasions off Saipan only.

Blue whale 20 Hz tonal calls produced by central Pacific blue whales and downswept D calls, produced by all blue whale populations and not identifiable to population, were each detected on less than 1% of monitoring days. Blue whale 20 Hz calls were heard only in fall and winter (September, November–January) and downswept D calls were heard only in summer (May, June, and August). Other calls similar to those produced by blue whales elsewhere in the world (i.e., long duration, very low frequency, tonal calls) have also been detected at the Mariana Archipelago PIPAN sites, though to date cannot be confirmed as being produced by blue whales.

Fin whale 20 Hz calls were detected on 4 days off Saipan (April 2010 – 2 days; May 2011 – 2 days) and 2 days in April 2011 off Tinian. Minke whale boings were detected during 6 days in March and April 2010 off Saipan.

Priority Analyses and Data Collection Needs

Large-scale visual and passive acoustic survey

It is clear from the data collected and analyses conducted to date that there are inadequate data to assess population structure, abundance, or distribution for many species throughout the Guam and CNMI EEZs, in both nearshore and offshore waters of the archipelago. The greatest research need for most cetacean species in the Mariana Archipelago is a new large-scale ship-based abundance survey. The full suite of available data, including small-boat and shipboard visual surveys, as well as towed and autonomous passive acoustic monitoring data should be used to develop a robust stratified survey design capable of providing adequate data for assessing abundance, as well as adequate time for collecting additional tissue samples in offshore and northern island waters and deployment of satellite tags. Both autonomous and towed passive acoustics will be a necessary component of the survey effort in order to accumulate adequate data to assess any beaked whale or *Kogia* species.

The Pacific Marine Assessment Program for Protected Species (PacMAPPS) includes a Mariana Archipelago survey within the 5-year rotation. The Mariana survey is currently scheduled for 2021 or 2022.

Analyses of Existing Survey Data and Continuation of Data Collection Efforts

Although data are sparse for many species, there are high priority analyses that could be conducted with the data currently available or with a modest amount of additional data collection. We attempt to summarize here, by species, what analyses could be pursued given staff and resources to dedicate to examining these questions. We also include potential analyses of passive acoustic datasets that may be particularly valuable for examining structure, abundance, or distribution of Mariana Archipelago cetaceans. Analyses are considered high priority if 1 or more of the following criteria apply:

- they will directly inform NMFS assessments under MMPA or ESA
- they are relatively low cost and may provide focus or direction to future analyses or data collection efforts
- they will inform current Navy monitoring plan questions or consideration of future directions for future Navy monitoring efforts in the region

High priority analyses or data collection are not identified for all species observed in the region. Analyses and data collection needs by species are listed in the same order as the species summaries. Within each species, analyses are listed in priority order, though many analyses can or should occur concurrently.

Spinner dolphins

- **Photo-identification matching and cataloging for 2014–2018 encounters**. Photo-identification matching provides for examining connectivity and movements of individuals between island areas. Completing the processing and matching of photos from the southern and northern islands will provide needed insight into the extent of animal movement and therefore population range.
- **Generate mark-recapture estimates of abundance for Guam and for Rota/3-Islands area**. Once photo-identification processing and matching is complete and population structure within the southern islands resolved, spinner dolphin abundance within the 2 southern island regions is feasible.
- **Genetic analyses of samples collected in the northern islands**. Although the number of samples available from the northern islands is relatively few compared to the southern islands, processing those samples for haplotype and microsatellites may reveal the northern extent of the population occurring around Rota and the 3-Islands. This population includes animals that have been identified outside of traditional shallow water daytime spinner dolphin habitat, such as at Marpi Reef, potentially suggesting these animals have the potential to roam further north along the island chain. Such analyses may also inform the extent of future sampling efforts in the northern islands.
- **Characterize spinner dolphin habitat use based on environmental and physical features.** Spinner dolphins in the Mariana Archipelago north of Guam appear to occupy unique habitat compared with those in Hawaiʻi and other island archipelagos. Such characterization may reveal habitat preferences and provide context for examining exposure to human-caused threats in the nearshore environment.

Bottlenose dolphins

- **Generate mark-recapture abundance estimation for the southern islands**. The available photo-identification catalog includes a large proportion of re-sighted individuals, enabling pursuit of mark-recapture estimates. Such estimates would apply to the nearshore areas of the southern islands only.
- **Genetic analysis to determine occurrence of Indo-Pacific bottlenose dolphins**. *Tursiops aduncus* could occur within the Mariana Archipelago, and examination of genetic sequence data for all remaining unprocessed samples would prove valuable for assessing which species occur in the region.
- **Deploy additional location-only and location-dive tags to assess movements and habitat association**. A modest number of additional location-only tags deployed in the southern islands could provide insight into population boundaries for a population occurring within the southern islands. Additional location-dive tags could provide insight into variability in foraging behavior throughout the day and in association with other environmental features, including bathymetry and satellite-sensed variables.

Short-finned pilot whales

- **Additional tissue sample collection and satellite tagging off the 3-Islands area and northern islands.** Available genetic and photo-identification data provide a complex picture of population structure for this species. Some groups encountered in the 3-Islands area appear not to be connected to the main social cluster encountered near Guam and Rota. Additional samples may help resolve structure between the northern and southern islands, and provide focus for future efforts aiming to examine the potential impact of Navy activities, fisheries interactions, or other human impacts to short-finned pilot whales.
- **Generate mark-recapture estimate for the southern islands main social cluster.** Photo-identification data are adequate to carry out mark-recapture estimation for the main social cluster found in the southern islands.

False killer whales

- **Sequence remaining genetic samples**. This processing would allow us to better assess occurrence of unique haplotypes and evaluate differences between northern and southern animals, particularly those with broader offshore movements.
- **Examine movements and habitat preferences using satellite telemetry data.** Telemetry data from 9 whales are currently available and relatively long duration deployments provide information over 6–9 month timeframes for some individuals. The apparent affinity for the island archipelago may be better assessed in relation to various habitat variables.

Melon-headed whales

- **Complete photo cataloging and evaluate use of catalog size as minimum population size.** Only 3 re-sights between groups over 8 years suggest catalog size may be a reasonable proxy for minimum population size.

Humpback whales

- **Continue winter surveys off Saipan** including collection of identification photographs and tissue samples, to examine number of animals using this breeding ground and their connections to other North Pacific breeding and feeding grounds. Additional data from the Mariana Archipelago may provide valuable insight into the structure of WNP humpback whales.

Analysis of Passive Acoustic Datasets

Available passive acoustic datasets, including long-term fixed site monitoring within PIPAN and towed array data from shipboard surveys, may be useful for evaluating questions of population structure, abundance, distribution and habitat, and exposure to human-stressors. The same criteria were applied to determine analyses that were highest priority. Analyses are listed in order of species occurrence within the Species Summaries.

False killer whales & short-finned pilot whales

- **Examine all visually-verified or satellite tag-concurrent acoustic detections to assess vocal characteristics of false killer whales and short-finned pilot whales** in the region relative to those from Hawaiʻi or other areas. Validation of current false killer whales and short-finned pilot whale acoustic classifiers for the Mariana Archipelago would provide opportunity for assessing occurrence and movements from PIPAN and DASBR data, and potential for acoustic abundance estimates from future systematic acoustic surveys.

Bryde's whales

- **Describe species-specific call types** using available sonobuoy and array data concurrent with sightings of Bryde's whales.
- **Examine seasonality and distribution** of Bryde's whales within PIPAN datasets using call type descriptions from sonobuoy data. Seek datasets from other monitoring networks in the western Pacific to better assess the range of the Bryde's whale population.

Beaked whales

- **Re-process towed array data from MACS 2015** to assess distribution of beaked whale species in the northern Mariana Archipelago. Such analyses should aid in design of future large-scale ship-based or autonomous drifting recorder surveys in the region.

Humpback whales

- **Assess occurrence of humpback whale song and structure** in Pagan datasets and unprocessed Saipan and Tinian datasets to evaluate relative abundance in the northern versus southern portion of the archipelago, possible migratory routes, and relatedness to humpback song in other regions of the western North Pacific and Aleutians.

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Appendix – Data Analyses

Bathymetry Data

For visualization and analysis of spatial data, bathymetric datasets of varying resolutions were used, which included high-resolution multibeam color-shaded bathymetry for nearshore waters from the Pacific Islands Benthic Habitat Mapping Center[2]. A Global Multi-Resolution Topography (GMRT)[3] custom bathymetric grid encompassing the U.S. EEZs of CNMI and Guam was referenced for offshore areas not covered by the other datasets. All bathymetry datasets were processed using ArcCatalog 10.3 (ESRI, Redlands, CA). The ASCII files were first converted into raster grids, projected in the World Geodetic System (WGS) 1984 Universal Trans Mercator (UTM) Zone 55N coordinate system and imported into ArcMap 10.3.

Surveys and Encounters

Vessel GPS tracks and encounter locations were processed in ArcCatalog 10.3, projected in the WGS 1984 UTM Zone 55N coordinate system, and then overlaid onto the bathymetric datasets within ArcMap 10.3. Depths of the encounter and on-effort trackline locations were determined by extracting the depth values from each relevant bathymetric raster dataset. The search effort was then summarized in depth bins of 200 m intervals. In addition, the distances from the closest shoreline for each encounter location were determined. Tracklines were created from point location files and on-effort trackline distances were calculated.

Photo-Identification

Photo-identification catalogs were created using photos collected during small-boat surveys from 2010 to 2018, and MACS 2015. Additional photos were contributed by the U.S. Navy from the 2007 MISTCS, the 2011 and 2012 HDR, and the 2013 TetraTech surveys (

[2] School of Ocean and Earth Science and Technology (University of Hawaiʻi at Manoa) http://www.soest.hawaii.edu/pibhmc/pibhmc_cnmi.htm

[3] Ryan *et al.* 2009; Marine Geoscience Data System http://www.marine-geo.org/portals/gmrt

Table 5). Initial matches of individuals were made within each sighting by a photo-identification analyst and were then checked by a second analyst. Individually identified fins were also compared with all others within the sighting to look for missed matches. Marks along the leading and trailing edges of the dorsal fins were used as the primary identifiers. Marks or scars on the body, dorsal fin surface, and peduncle; and coloration patterns on the body and dorsal fin were used as secondary identifiers. Each individual fin in each photo was rated for quality based on numeric scores within 4 categories (focus/clarity, contrast/lighting, angle, extent visible) and was assigned an overall quality rating (Q-1 = high, Q-2 = moderate, Q-3 = poor). Distinctiveness ratings were assigned to each individual based on the number, size, and shape of the features located on the leading and trailing edges of the dorsal fin (D-1 = high, D-2 = moderate, D-3 = low, D-4 = clean fin and no marks on the peduncle directly behind the dorsal fin). After the completion of matching and rating within sightings, identified individuals were compared between sightings by both analysts. Only those fins with a distinctiveness of D-1 or D-2 and a quality rating of Q-1 or Q-2 were initially entered into the catalog. Images of D-1 and D-2 individuals that did not meet the quality criteria for the catalog were kept for future comparisons.

Tissue Sample Analysis

Sample Analysis at SWFSC

DNA was extracted from biopsy samples and used for genetic sex determination, mitochondrial control region sequencing, and microsatellite genotyping using standard laboratory methods. Methods used for control region sequencing and sex determination were as described in Martien *et al.* (2012, 2014b). Microsatellite genotyping methods for bottlenose dolphins are as described in Martien *et al.* (2012). Full mitochondrial genome sequencing methods for sperm whales are described in Morin *et al.* (2018).

Sample Analysis at OSU

Total genomic DNA was extracted following methods described in Olavarria *et al.* (2007). For humpback whales, spinner dolphins, and spotted dolphins a genetic profile was created for each sample which contained sex, mitochondrial DNA (mtDNA) control region haplotype and 12 to 18 previously published microsatellite loci depending on species. Replicate samples were identified with the program CERVUS (Marshall *et al.* 1998) requiring a minimum of 8 matching microsatellite loci, supported by sex and control region haplotype where available. All replicate samples were removed before population level analyses.

Satellite Telemetry

Argos Doppler locations of the satellite-tagged cetaceans were determined by the Argos system using Kalman filtering (Lopez and Malardé 2011). The Argos raw DIAG files were uploaded to Movebank where the Douglas Argos Filter (DAF) was run on the satellite tag locations, using the distance angle rate filtering method (Douglas *et al.* 2012). The DAF was set to automatically retain location classes (LC) of LC2 and LC3, and LC1, LC0, LCA, LCB, and LCZ locations were retained if they met certain criteria. Locations of those classes had to be separated from the next location by less than a maximum redundant distance of 3 km. The maximum sustainable rate of movement was set to 15 km/h for short-finned pilot whales, melon-headed whales, and sperm whales and 20 kph for false killer whales, bottlenose dolphins, rough-toothed dolphins, and spotted dolphins based on maximum travel speeds noted during observations in Hawaiʻi (Baird *et al.* 2013, Baird pers. comm.). The filtered satellite tag locations were plotted in ArcMap 10.3.

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