FINAL (VERSION 3)

MARINE MAMMAL SURVEY REPORT

in Support of the
Commonwealth of the Northern Mariana Islands Joint Military Training Environmental Impact Statement/Overseas Environmental Impact Statement

Department of the Navy
Naval Facilities Engineering Command, Pacific
258 Makalapa Drive, Suite 100
JBPHH, HI 96860-3134

April 2014

This page is intentionally left blank.

FINAL (VERSON 3)

MARINE MAMMAL SURVEY REPORT

in Support of the Commonwealth of the Northern Mariana Islands Joint Military Training Environmental Impact Statement/Overseas Environmental Impact Statement

Prepared for:

Department of the Navy

Naval Facilities Engineering Command, Pacific

258 Makalapa Drive, Suite 100

JBPHH, HI 96860-3134

Prepared by:

Tetra Tech, Inc.

1999 Harrison Street, Suite 500

Oakland, CA 94612

In association with:

Bio-Waves, Inc.

364 2nd Street, Suite #3

Encinitas, CA 92024

Clymene Enterprises, Inc.

13037 Yerba Valley Way

Lakeside, CA 92040

In collaboration with and under contract to:

Sea Engineering, Inc.

41-305 Kalanianaole Highway

Waimanalo, HI 96795

AECOM Technical Services, Inc.

1001 Bishop Street, Suite 1600

Honolulu, HI 96813

Under the:

TEC-AECOM Pacific Joint Venture

Contract: N62742-11-D-1801 Task Order: 0002

April 2014

This page is intentionally left blank.

EXECUTIVE SUMMARY

The purpose of this study was to conduct a marine resource survey at Pagan in the Commonwealth of the Northern Mariana Islands (CNMI) to collect data about the occurrence and distribution of marine mammals. It supports the development of the CNMI Joint Military Training Environmental Impact Statement/Overseas Environmental Impact Statement. Since no previous systematic marine mammal surveys have been done at Pagan, the goals of this field effort were to obtain information on marine mammal occurrence (including the potential of island-associated marine mammal populations) and distribution, visual sighting and acoustic encounter rates, individual presence, group size, group composition, diel (24-hour) patterns of vocalizations, and behavior.

The survey was conducted from August 7 to 24, 2013. Large vessel line transect surveys, rigid-hulled inflatable boat (RHIB) non-systematic surveys, photo-identification of individuals, and a variety of passive acoustic monitoring techniques were used. At the start of the survey, the team spent three days at Tinian conducting test surveys for technical preparation. The team then deployed to Pagan for the remainder of the survey. At Pagan, the team spent eleven days conducting research, of which four days were full line transects; line transect work also occurred on part of one other day.

Five marine mammal species were recorded at Pagan: common bottlenose dolphins (*Tursiops truncatus*), spinner dolphins (*Stenella longirostris*), Cuvier’s beaked whales (*Ziphius cavirostris*), Blainville’s beaked whales (*Mesoplodon densirostris*), and sperm whales (*Physeter macrocephalus*). Some dolphins could not be identified to species. Sighting rates for dolphin species at Pagan were 1.55 individual spinner dolphins/54 nautical miles (100 kilometers) and 0.31 individual bottlenose dolphin/54 nautical miles (100 kilometers) of line transect survey. The sighting rate for individual Cuvier’s beaked whales was 0.77 Cuvier's beaked whale/54 nautical miles (100 kilometers). The dolphin sighting rates are low relative to other island areas, but were based on extremely small sample sizes and limited line transect effort. No marine mammal sightings were made at Tinian.

There was one visual sighting and four acoustic encounters of beaked whales at Pagan. In general, beaked whales are infrequently detected (visually sighted or acoustically encountered) and are typically associated with water depths greater than 984 feet (300 meters). Of note is the moderately high detection rates of beaked whale species at Pagan (0.77 whale sighted per 54 nautical miles [100 kilometers] for Cuvier’s and 0.09 acoustic encounter per hour for Blainville’s). While unexpected, this finding may be explained by the deep-water habitat reasonably close to shore.

Sperm whales were detected on the acoustic recordings from nighttime moored sonobuoys, indicating their presence within 20 nautical miles (37 kilometers) of Pagan.

On 10 of the 11 research days at Pagan, dolphins were visually sighted or encountered acoustically within the study area. There is evidence of dolphins in the waters next to Blue/Red Beach and Green Beach, during both daytime (from visual surveys) and nighttime (from sonobuoy recordings). The survey team found preliminary indications that at least two species, bottlenose dolphins and spinner dolphins, are island-associated populations, similar to what has been documented for these two species at the main Hawaiian Islands. Group sizes for all species were relatively small, as would be expected for those that occur near islands. Analysis of photo-identification data yielded resightings of four individual spinner dolphins on subsequent days, on the east side of Pagan, which was consistent with residency patterns. Calves and juveniles were present off these beaches in groups of both spinner and bottlenose dolphins, suggesting that reproduction is occurring in or near the study area.

This page is intentionally left blank.

Marine Mammal Survey Report

Table of Contents

Page

List of Figures

List of Tables

List of Appendices

List of Acronyms and Abbreviations

CJMT	Commonwealth of the Northern Mariana Islands Joint Military Training
CNMI	Commonwealth of the Northern Mariana Islands
DoN	Department of the Navy
EIS	environmental impact statement
GPS	global positioning system
ID	identification
IPI	inter-pulse-interval
LTSA	long-term spectral average
MISTCS	Mariana Islands Sea Turtle and Cetacean Survey
NAVFAC	Naval Facilities Engineering Command
NTR	Navy Technical Representative
NOAA	National Oceanic and Atmospheric Administration
OEIS	Overseas Environmental Impact Statement
PAM	passive acoustic monitoring
RHIB	rigid-hulled inflatable boat
ROCCA	real-time odontocete call classification algorithm
VHF	very high frequency

This page is intentionally left blank.

CHAPTER 1 INTRODUCTION

1.1 PROJECT BACKGROUND

The proposed action is to establish a series of live-fire and maneuver ranges and training areas on two islands, Tinian and Pagan, within the Commonwealth of the Northern Mariana Islands (CNMI). The proposed action is needed to meet United States Pacific Command Service Components' unfilled unit level and combined level military training requirements in the Western Pacific. The U.S. Pacific Command designated the U.S. Marine Forces Pacific (a part of the Marine Corps) as executive agent to oversee development and implementation of the proposed action.

The purpose of this part of the marine resource survey in the CNMI is to collect data about the occurrence and distribution of marine mammals. Information from this report will be used to support the environmental impact analysis in the CNMI Joint Military Training (CJMT) Environmental Impact Statement (EIS)/Overseas Environmental Impact Statement (OEIS). The potential for island-associated populations of marine mammals was given particular attention since the CJMT is limited to nearshore activities and this information will fill a previous data gap. Information on the proposed action is available on the EIS/OEIS website (www.CNMIJointMilitaryTrainingEIS.com/). The actions with relevance to marine mammals are proposed coastal construction, landings of amphibious and small craft, and operation of marine vessels in nearshore waters. These actions are proposed for select beaches and the nearshore waters and coastal area on the islands of Tinian and Pagan. The principal types of potential impacts on marine mammals are physical disturbance, noise impacts, and strike stressors.

1.2 BRIEF REVIEW OF PREVIOUS MARIANA ISLANDS MARINE MAMMAL SURVEYS

The occurrence and abundance of marine mammals in and around the Mariana Islands (including the U.S. territory of Guam and the CNMI) are poorly known (Department of the Navy [DoN] 2013a). Historically, the Mariana Islands were a prominent whaling ground in the eighteenth century, with many catches of humpback whales (*Megaptera novaeangliae*) and a lesser number of sperm whales (*Physeter macrocephalus*; Townsend 1935). In the 1960s and 1970s, Japanese whaling companies conducted extensive tag (i.e., Discovery tags) and recovery programs for large commercially hunted whale species in the North Pacific, including the Mariana Islands (Masaki 1972; Ohsumi and Masaki 1975). Most of the marine mammal information from this island group before 2006 comes from infrequent strandings (Kami and Lujan 1976; Kami and Hosmer 1982; Donaldson 1983; Eldredge 1991, 2003; Trianni and Kessler 2002; Wiles 2005; Trianni and Tenorio 2012) and opportunistic sightings (Eldredge 1991, 2003; Miyashita et al. 1995; Wiles 2005; Jefferson et al. 2006).

Earlier marine mammal surveys were limited to large-scale surveys that passed through the Marianas briefly (Miyazaki and Wada 1978; Miyashita et al. 1996; Shimada and Miyashita 2002; Ohizumi et al. 2002). A few single-species surveys were directed primarily at humpback whales (Darling and Mori 1993; Yamaguchi 1995, 1996; Yamaguchi et al. 2002). Beginning in 2006, dedicated marine mammal surveys were conducted at some of the Mariana Islands; most of these covered only one or two islands (Mobley 2007; Oleson and Hill 2010; HDR 2011, 2012; Ligon et al. 2011; Hill et al. 2012, 2013). Also in 2006 there was a large-scale, 3-month, visual and acoustic line-transect survey of cetaceans and sea turtles (Mariana Islands Sea Turtle and Cetacean Survey [MISTCS]) conducted for the entire Mariana Islands Range Complex (DoN 2007). Analysis of some of the data from MISTCS was later published and has provided current density estimates for some cetaceans in waters surrounding the Mariana Islands (Fulling et al. 2011; Norris et al. 2012a). However, as most of the survey for MISTCS occurred in pelagic waters, it did not include nearshore (0 to 3 nautical miles [5.6 kilometers]) waters around Pagan.

Very little is known about the population structure, density, abundance, movement patterns, or behaviors of the various marine mammal species around the Mariana Islands. Basic information about marine mammal occurrence patterns in the nearshore areas around most of the Northern Mariana Islands is lacking. There is very little information about the distribution patterns of most species around individual islands, with the exception of some coastal species such as spinner dolphins (*Stenella longirostris*). Nearshore survey work conducted around Tinian includes DoN (2007), Oleson and Hill (2010), Fulling et al. (2011), Hill et al. (2012, 2013), and Trianni and Tenorio (2012). No systematic marine mammal survey work has been conducted around Pagan, which was not included in the 2006 MISTCS study area.

Based on a previous review of the available data, 33 species of marine mammals could occur in the CNMI (see Table 1-1, DoN 2013a). Sighting, stranding, or capture records confirm that four mysticete cetaceans, 15 odontocete (a suborder of the cetacea characterized by toothed dolphins and small whales) cetaceans, and one sirenian occur in the Mariana Islands. Based on expected distributions, four additional species of mysticetes and seven species of odontocetes are believed to occur. There are two species of pinnipeds that could occur in the area, but they are considered extralimital, meaning the area is on the edge of, or outside their usual range.

Darling and Mori (1993) conducted a limited acoustic monitoring for humpback whales off the nearshore waters of Saipan. Based on the limited information gathered, they concluded that humpback whales did not occur there regularly. However, local residents and a newspaper reported a group of three animals off Saipan in February 1991, which suggests that the humpback whales at least occasionally occur in this region. In February 2007, singing humpback whales were acoustically detected at night and eventually localized off the northwest coast of Saipan and a group of eight whales were sighted and photo-identified (DoN 2007; Fulling et al. 2011). These animals were engaged in conspicuous surface behaviors, such as breaching, chin slapping, and tail slapping. Singing and conspicuous surface behaviors are indicative of courtship and breeding activity for humpback whales in other subtropical regions (Clapham et al. 1992; Pack et al. 1998).

Analysis of passive acoustic data collected from autonomous recorders deployed at two deep-water locations on the seafloor 7 nautical miles (13 kilometers) east of Tinian and 22 nautical miles (41 kilometers) northwest of Saipan has documented the presence of Blainville's beaked whales (*Mesoplodon densirostris*), Cuvier's beaked whales (*Ziphius cavirostris*), and an unidentified species of beaked whale (suspected to be Deraniyagala's beaked whale, *M. hotaula*) (Baumann-Pickering et al. 2012).

Table 1-1. Marine Mammal Species with Possible Occurrence in the Mariana Islands Based on Known or Expected Range

Species	***Confirmed Sightings***	***Confirmed Acoustic Detections***	***Confirmed Strandings***	***Confirmed Captures***	***Occurrence in Mariana Islands (not legal status)***	***U.S. Legal Status (Endangered Species Act, MMPA Special Designation if any)***
North Pacific right whale (*Eubalaena japonica*)	None	None	None	None	Extralimital*	Endangered, Depleted
Blue whale (*Balaenoptera musculus*)	None	None	None	None	Rare	Endangered, Depleted
Fin whale (*B. physalus*)	None	None	None	None	Rare	Endangered, Depleted
Sei whale (*B. borealis*)	Masaki 1972; Ohsumi and Masaki 1975; Fulling et al. 2011	T. Norris, unpublished data	None	None	Regular	Endangered, Depleted
Bryde's whale (*B. brydei/edeni*)	Miyashita et al. 1996; Shimada and Miyashita 2002; Geo-Marine 2005; Mobley 2007; Fulling et al. 2011	None	Eldredge 2003; Trianni and Tenorio 2012	None	Regular	-
Omura's whale (*B. omurai*)	None	None	None	None	Unknown	-
Common minke whale (*B. acutorostrata*)	None	Norris et al. 2008, 2012b; Oleson and Hill 2010	None	None	Regular	-
Humpback whale (*Megaptera novaeangliae*)	Eldredge 1991, 2003; Darling and Mori 1993; Yamaguchi 1995; Fulling et al. 2011; M. Richlen pers. comm. 2014	Fulling et al. 2011; Morse et al. 2008	None	Townsend 1935	Regular	Endangered, Depleted
Sperm whale (*Physeter macrocephalus*)	Masaki 1972; Miyashita et al. 1996; Eldredge 2003; Oleson and Hill 2010; Ligon et al. 2011; Fulling et al. 2011	T. Norris, unpublished data	None	Townsend 1935	Regular	Endangered, Depleted
Pygmy sperm whale (*Kogia breviceps*)	None	None	Eldredge 1991, 2003; Trianni and Tenorio 2012	None	Regular	-
Dwarf sperm whale (*K. sima*)	Hill et al. 2012	None	Kami and Lujan 1976; Trianni and Tenorio 2012	None	Regular	-
Cuvier's beaked whale (*Ziphius cavirostris*)	Masaki 1972; Mobley 2007	None	None	None	Regular	-
Blainville's beaked whale (*Mesoplodon Densirostris*)	None	Baumann-Pickering et al. 2013	None	None	Regular	-
Deraniyagala's beaked whale (*M. hotaula*)	None	None	None	None	Unknown	-
Ginkgo-toothed beaked whale (*M. ginkgodens*)	None	None	None	None	Unknown	-
Longman's beaked whale (*Indopacetus pacificus*)	None	None	None	None	Regular	-
Killer whale (*Orcinus orca*)	Eldredge 1991; DoN 2013b	None	Kami and Hosmer 1982	None	Regular	-
Short-finned pilot whale (*Globicephala macrorhynchus*)	Eldredge 1991; Miyashita et al. 1996; Oleson and Hill 2010; Fulling et al. 2011; Hill et al. 2012	T. Norris, unpublished data	Kami and Hosmer 1982; Donaldson 1983	None	Regular	-
False killer whale (*Pseudorca crassidens*)	Fulling et al. 2011	T. Norris, unpublished data	Trianni and Tenorio 2012	None	Regular	-
Pygmy killer whale (*Feresa attenuate*)	Fulling et al. 2011; Hill et al. 2012	None	None	None	Regular	-
Melon-headed whale (*Peponocephala electra*)	Eldredge 1991; Jefferson et al. 2006; Oleson and Hill 2010; Fulling et al. 2011; HDR 2012	T. Norris, unpublished data	Kami and Hosmer 1982; Donaldson 1983	None	Regular	-
Rough-toothed dolphin (*Steno bredanensis*)	Jefferson et al. 2006; Mobley 2007; Fulling et al. 2011	T. Norris, unpublished data	None	None	Regular	-
Risso's dolphin (*Grampus griseus*)	Miyazaki and Wada 1978; Miyashita et al. 1996; Oleson and Hill 2010	None	None	None	Regular	-
Common bottlenose dolphin (*Tursiops truncatus*)	Trianni and Kessler 2002; Fulling et al. 2011; Hill et al. 2012	T. Norris, unpublished data	None	None	Regular	-

Species	***Confirmed Sightings***	***Confirmed Acoustic Detections***	***Confirmed Strandings***	***Confirmed Captures***	***Occurrence in Mariana Islands (not legal status)***	***U.S. Legal Status (Endangered Species Act, MMPA Special Designation if any)***
Indo-Pacific bottlenose dolphin (*Tursiops aduncus*)	None	None	None	None	Extralimital	-
Pantropical spotted dolphin (*Stenella attenuate*)	Trianni and Kessler 2002; Mobley 2007; Oleson and Hill 2010; Fulling et al. 2011; Ligon et al. 2011; Hill et al. 2012	T. Norris, unpublished data	None	None	Regular	-
Striped dolphin (*S. coeruleoalba*)	Ohizumi et al. 2002; Oleson and Hill 2010; Fulling et al. 2011	T. Norris, unpublished data	Eldredge 1991; Trianni and Tenorio 2012	None	Regular	-
Spinner dolphin (*S. longirostris*)	Eldredge 1991; Trianni and Kessler 2002; Wiles 2005; Oleson and Hill 2010; Fulling et al. 2011; Ligon et al. 2011; Hill et al. 2012	T. Norris, unpublished data	Trianni and Kessler 2002; Trianni and Tenorio 2012	None	Regular	-
Short-beaked common dolphin (*Delphinus delphis*)	None	None	None	None	Extralimital	-
Fraser's dolphin (*Lagenodelphis hosei*)	None	None	None	None	Regular	-
Hawaiian monk seal (*Monachus schauinslandi*)	None	None	None	None	Extralimital	Endangered, Depleted
Northern elephant seal (*Mirounga angustirostris*)	None	None	None	None	Extralimital	-
Dugong (*Dugong dugon*)	Randall et al. 1975; Eldredge 1991, 2003	None	None	None	Extralimital	Endangered, Depleted

Notes:
Bold = species with confirmed records
*The North Pacific right whale is listed as extralimital here following Navy precedent. This species was severely depleted before marine mammal surveys began; it is possible that the Mariana Islands were a part of its traditional geographic range.
All marine mammals are protected under MMPA; any species with extra MMPA status are delineated with special listing in the last column;
"-" = not listed under the U. S. Endangered Species Act.
Extralimital = a species in an area not considered part of its normal range
U.S. Legal Status – see Carretta et al. (2013) for more information on ESA and MMPA Depleted status.

1.3 ISLAND-ASSOCIATED ODONTOCETES

Island-associated populations of odontocetes are well known in some areas of the tropical Pacific Ocean. Many species of "small whale" (e.g., melon-headed whale, pygmy killer whale) are taxonomically dolphins. Dolphins, beaked whales, and sperm whales are all odontocetes, meaning they are toothed species (as opposed to baleen species). Individual dolphins and whales are considered island-associated if they are resighted regularly and occur less than approximately 20 nautical miles (37 kilometers) off shore (the exact distance varies for different populations). In addition to the goal of conducting a systematic survey at Pagan, another goal of the study was to determine if island-associated odontocetes were found in the study area (3 nautical miles [5.6 kilometers] around Pagan; see Section 2.1).

The large number of nearshore sightings, and the known occurrence of island-associated populations in areas of the Pacific Ocean with habitat similar to the Mariana Islands, make it highly likely that spinner dolphins occur around both Tinian and Pagan as island-associated populations (Norris and Dohl 1980; Norris et al. 1994; Trianni and Kessler 2002; Lammers 2004; Karczmarski et al. 2005). For example, in Hawaii the spinner dolphin is known to occur in island-associated populations (Norris et al. 1994; Andrews et al. 2006). Movements and genetic variability of other odontocete cetaceans around the main Hawaiian Islands suggest the existence of island-associated populations of several species, including Cuvier's beaked whale (McSweeney et al. 2007), Blainville's beaked whale (McSweeney et al. 2007), false killer whale (Chivers et al. 2007; Baird et al. 2008a), pygmy killer whale (Baird et al. 2011), melon-headed whale (Aschettino et al. 2012), rough-toothed dolphin (Baird et al. 2008b), and common bottlenose dolphin (Baird et al. 2009).

Seven odontocetes sighted within 3 nautical miles (5.6 kilometers) of the coast of Guam or Tinian appear to have a high probability for having island-associated populations: sperm whale, short-finned pilot whale, false killer whale, melon-headed whale, common bottlenose dolphin, pantropical spotted dolphin, and spinner dolphin (Oleson and Hill 2010; Fulling et al. 2011; Hill et al. 2012, 2013). Recent sightings of sperm whales in the nearshore waters off Guam (e.g., HDR 2012) suggest that sperm whales may frequent the area. Repeated sightings and occasional strandings of spinner dolphins in Saipan Lagoon also support the supposition of island-associated populations for the Mariana Islands (Trianni and Kessler 2002).

This page is intentionally left blank.

CHAPTER 2 METHODS

2.1 STUDY AREA AND SURVEY DATES

The study area selected for this survey was nearshore waters between 0 and 3 nautical miles (5.6 kilometers) from the coast of Pagan and Tinian. The DoN selected the nearshore study area because the nearshore environment is not included in previous National Environmental Policy Act analyses and could have impacts on marine mammals under the proposed action.

The study areas around Tinian and Pagan are displayed in Figures 2-2 and 2-3. Pagan is a remote island in the northern portion of the Mariana Islands, 200 nautical miles (320 kilometers) from Saipan (Figure 2-1). Tinian and Saipan are approximately 3 nautical miles (5.6 kilometers) apart and are not separated by deep water. Survey dates (inclusive of mobilization and demobilization) were August 3 to 29, 2013. Field personnel are listed in Appendix A.

At the start of the survey, field staff conducted test surveys around Tinian to check equipment and practice protocols before deploying to the more remote Pagan. These test surveys were conducted in nearshore waters (0 to 3 nautical miles [5.6 kilometers]) off the Tinian coastline. The nearshore waters of Saipan were surveyed opportunistically on a single day after the survey effort at Pagan was finished.

The *SS Thorfinn* (hereafter referred to as the *Thorfinn*), a 170-foot (52-meter) charter vessel, and its two smaller rigid-hulled inflatable boats (RHIB) were used to conduct the surveys. Further details about the survey methods are provided below.

This page is intentionally left blank.

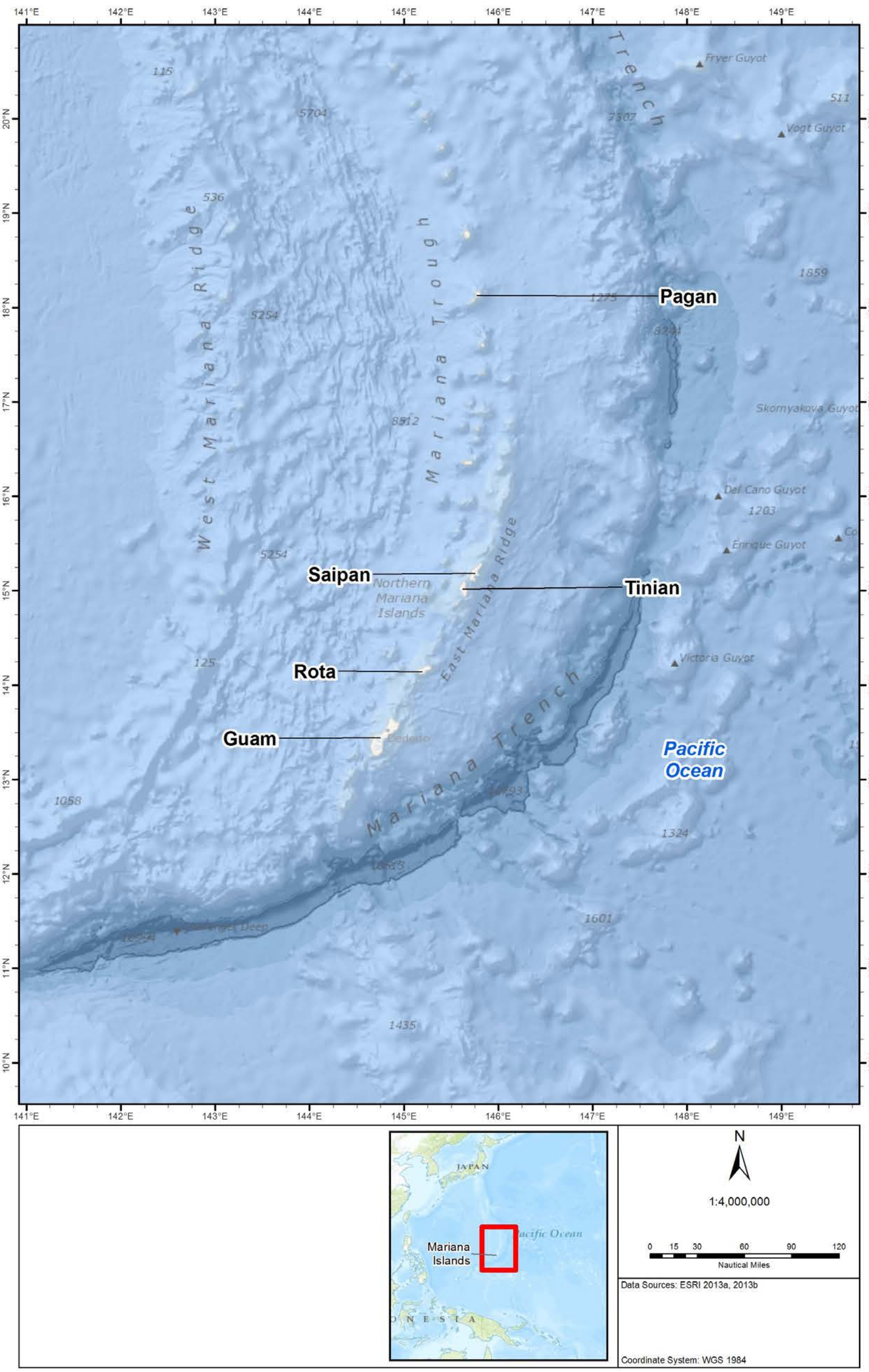


Figure 2-1. Geographical Context of the Study Area in the Mariana Islands

This page is intentionally left blank.

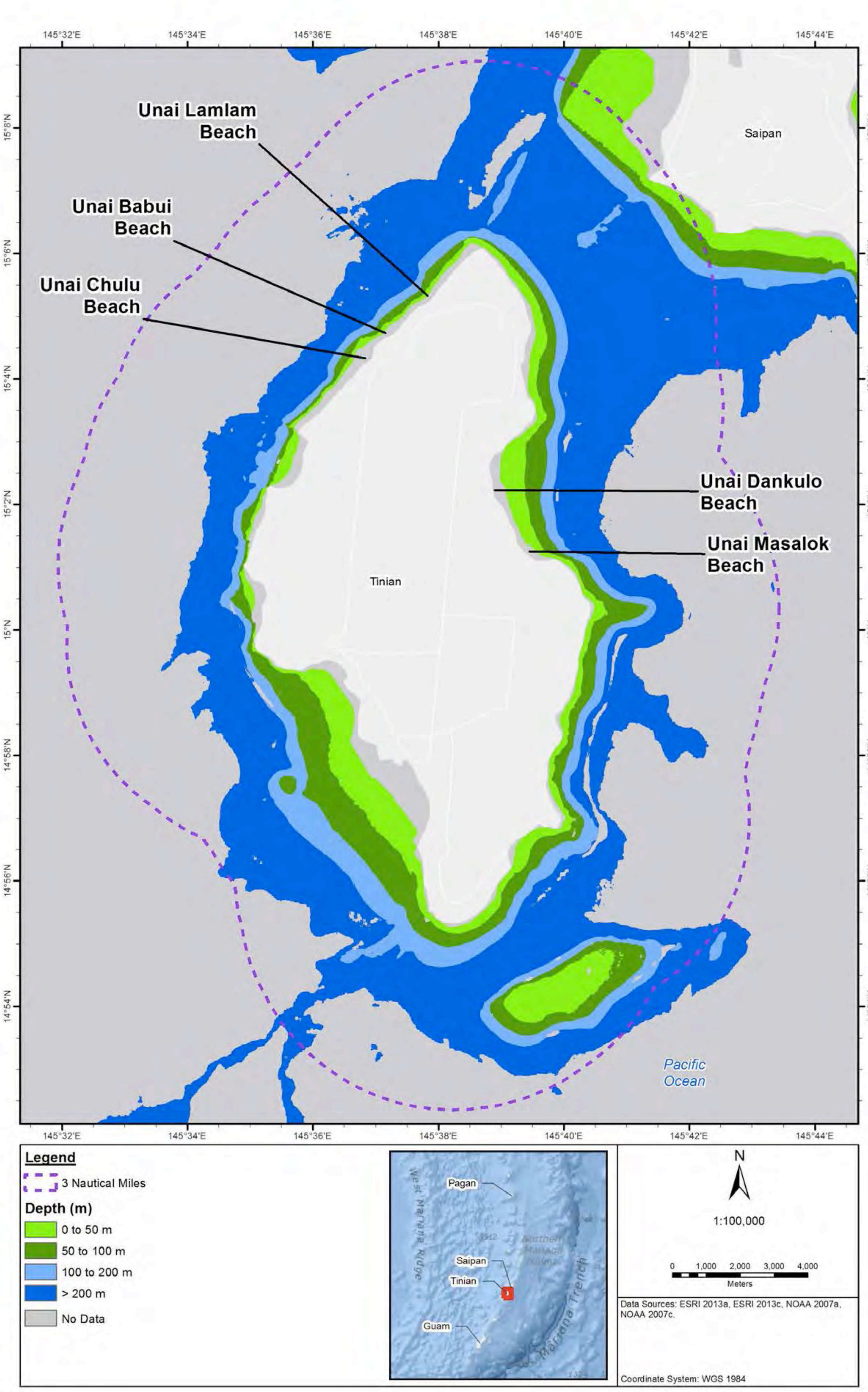


Figure 2-2. Study Area Around Tinian

This page is intentionally left blank.

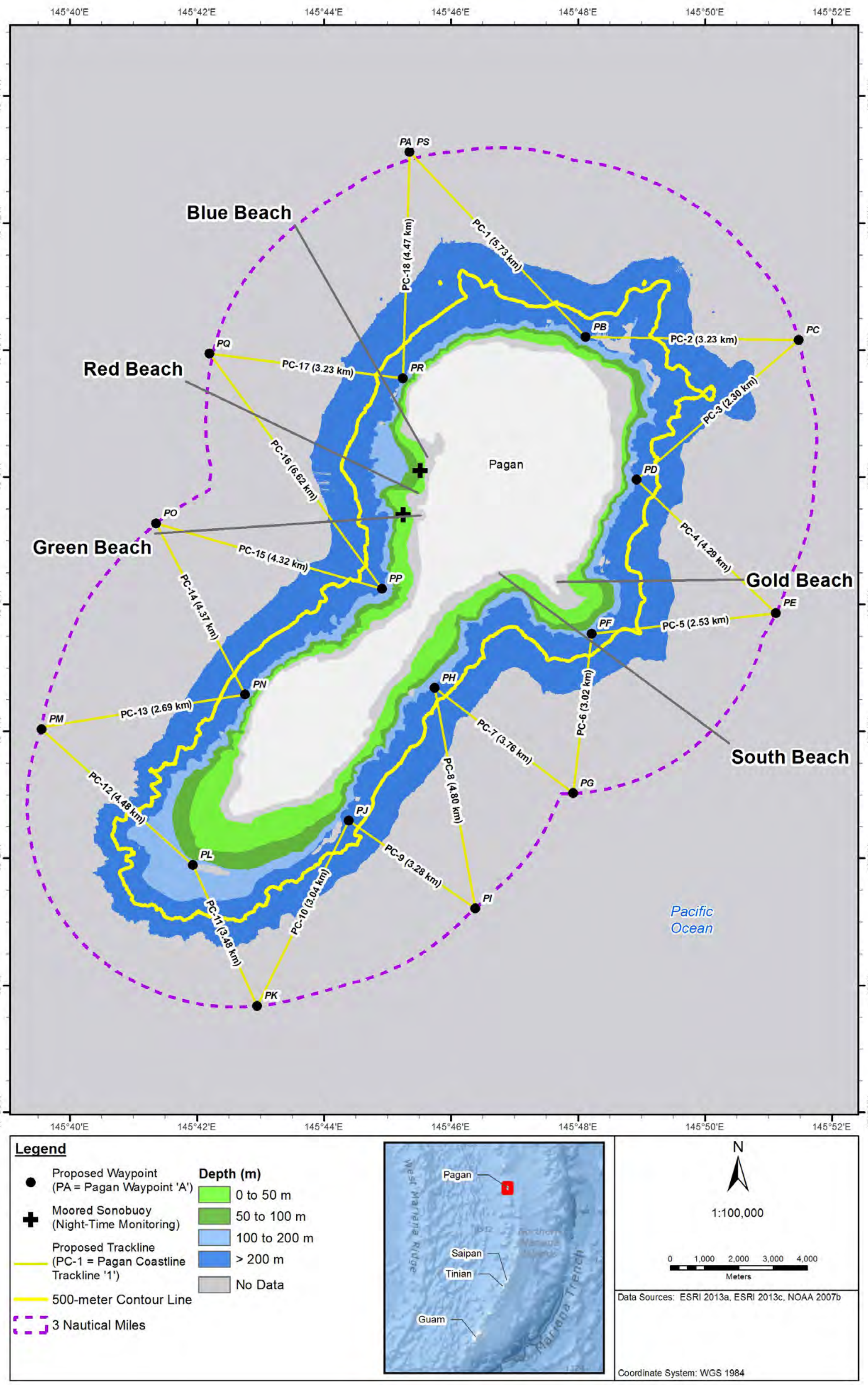


Figure 2-3. Study Area Around Pagan with Proposed Survey Lines

This page is intentionally left blank.

2013 SURVEY DATES

August 3	Advance Science Team arrived in Saipan and began mobilization
August 4	Remaining scientists arrived in Saipan and continued mobilization; *Thorfinn* arrived in Saipan port
August 5-6	Team continued mobilization
August 7	Conducted *Thorfinn* survey of Tinian (test survey)
August 8	Conducted RHIB survey of Tinian (test survey)
August 9	*Thorfinn* returned to Saipan; sonobuoys were loaded; personnel transferred from ship to Saipan (3 members of advance Science Team departed the ship before its transit to Pagan); remaining Science Team conducted RHIB survey of Tinian
August 10	Transited from Saipan to Pagan
August 11-21	Surveyed Pagan (11 days)
August 21-23	Transited from Pagan to Saipan
August 24	Conducted RHIB survey of Saipan
August 25-28	Team demobilized in Saipan
August 29	Scientists departed Saipan

2.1.1 Tinian Survey – August 7-9

On August 7, 8, and 9, surveys were conducted at Tinian to test field operations and equipment. On August 7, scientists aboard the *Thorfinn* completed a transect using both visual observations and acoustic towed array methods. On August 8, scientists aboard two RHIBs (for visual/photo-identification [ID] and acoustic operations) surveyed the leeward side of Tinian. On August 9, scientists aboard a single RHIB (for photo-ID) surveyed the leeward side of Tinian.

2.1.2 Pagan Survey – August 11-21

Pagan was the focal area of the survey, and most of the available survey time was spent working at this island.

August 11	*Thorfinn* arrived at Pagan 8:35 a.m.; conducted a RHIB survey
August 12	Conducted a 2-hour *Thorfinn* line transect survey; conducted RHIB survey
August 13	Conducted RHIB survey
August 14	Conducted RHIB survey
August 15	Conducted *Thorfinn* perimeter survey

August 16	Conducted RHIB survey
August 17	Conducted *Thorfinn* line transect survey
August 18	Conducted *Thorfinn* line transect survey
August 19	Conducted *Thorfinn* line transect survey and straight line survey
August 20	Conducted *Thorfinn* line transect survey
August 21	Conducted RHIB survey; *Thorfinn* departed from Pagan 7:45 p.m.

2.1.3 Saipan Survey – August 24

When the team returned from Pagan, they conducted opportunistic RHIB operations (visual/photo-ID and acoustic) on the leeward side of Saipan on August 24. On that date, the *Thorfinn* was unavailable. The Science Team had suspended research at Tinian until receiving direction on how to use the remaining marine mammal survey time (that is, if the ship would return to Pagan or some other location). The RHIBs were available, and permission was granted on this day to conduct an opportunistic survey of Saipan. Since these data were collected in nearshore habitat with similarities to Pagan and Tinian, they contribute to understanding the residency patterns of dolphins in these areas.

2.2 FIELD METHODS

The surveys were based from the *Thorfinn* which was fitted with two RHIBs that could be launched for additional activities (Figure 2-4). Data were collected using systematic line transect surveys designed for estimating the density and abundance of marine mammal species using well-developed statistical methods (Buckland et al. 2001). The visual and acoustic survey teams simultaneously collected line transect survey data, consisting of both visual sightings and acoustic encounters from the *Thorfinn*. The survey design for this project consisted of a sawtooth pattern of transect lines around the islands that provided efficient coverage in a small survey area. During the RHIB effort, non-systematic surveys were used to collect photographic data and acoustic recordings of dolphins. The recordings were used to ground-truth and augment the dolphin whistle classifier (see Section 2.3.3) used to identify acoustic recordings without associated visual observations. Acoustic recordings were also made from seafloor-moored sonobuoys located within a few hundred yards of shore at Pagan. (Detailed information on the planned study design is provided in the work plan [DoN 2013c].) Appendix B contains photographs taken in the field showing the various methods and the two most common dolphin species sighted around Pagan. Although this survey was focused on marine mammals, sea turtle sighting data were collected opportunistically (see Appendix C and the CJMT Sea Turtle Survey Report [DoN 2014]).

When a group of marine mammals was observed during the visual survey, the observation was termed a "sighting," and the time and position were recorded. Acoustic surveys resulted in an "encounter" of a group of marine mammals that were detected by their vocalizations. Note that in this document, the term "detection" refers to either a visual sighting or an acoustic encounter. Acoustic encounters may result in a sighting of the same group, and animals first observed in sightings may later be heard as encounters by the acoustics team. Both visual and acoustic methods were used to obtain the most complete data set possible.

Figure 2-4. Survey Vessels: The Two RHIBs (Left) and the *Thorfinn* (Right)

2.2.1 Visual Surveys

Visual data were collected using line transect surveys, RHIB non-systematic surveys, and opportunistic sightings.

2.2.1.1 Visual Line Transect Surveys

The marine mammal work plan (DoN 2013c) called for visual line transect surveys within 3 nautical miles (5.6 kilometers) of the coast of Pagan. There were no previous systematic surveys for marine mammals for this region. The work plan included a single day of line transect survey in waters around Tinian. The sampling design of line-transect surveys at Tinian was similar to that at Pagan to ensure data comparability (Figure 2-3). For all line transect surveys, the *Thorfinn* followed replicate transect lines (Figure 2-3) at approximately 9 knots (17 kilometers per hour). The path of the transect lines was determined during formulation of the survey design to provide representative coverage of the study area.

A three-person "on-effort" survey team conducted the visual line transect survey. On-effort refers to the visual team actively searching for marine mammals using a systematic effort. This effort included documenting sightings of marine mammals: the angle and distance to the sighting, species, group size, initial behavior, and the presence of calves. The survey team consisted of one observer recording data and two observers using Fujinon 7x50 binoculars (with reticles for distance measurements) mounted on stabilizing monopods (Figure 2-5). Less-experienced observers were paired with highly experienced observers to maximize accuracy.

One observer was stationed on the port bridge wing and one on the starboard bridge wing. Each observer searched continuously with binoculars, from 10° on the opposite side of the bow to 90° on the observer's side. This afforded 180° of coverage, with 20° of overlap at the bow. The team also used Nikon 16X image-stabilized binoculars to assist with field observations. The designated data recorder inside the bridge recorded all sighting data and searched with the naked eye. Any sightings made by the data recorder were treated the same as those made by the observers using binoculars. If a sighting was made by someone other than the on-effort three-person survey team, and the members of that team did not see this sighting, it was considered an off-effort sighting.

Figure 2-5. Three-Person Visual Team on Watch

Left binocular observer; center observer and data recorder; and right binocular observer.

The data recorder entered sighting data directly into a laptop computer using Mysticetus software, developed by David Steckler, Entiat Technologies, Washington. Mysticetus is a software tool that was designed specifically for marine mammal surveys and is a program which observers can use for recording, analysis, or reporting. It is designed to allow the scientists to record, analyze, map, and report marine observations. Mysticetus time-stamps all events and automatically records a global positioning system (GPS) position from a portable GPS receiver every 10 to 30 seconds. This allows for precise tracking of the vessel's course for recording sighting locations and later mapping. Observer positions, Beaufort sea state, swell height, and visibility conditions were recorded for each shift. Data were updated when conditions changed and at every observer shift change.

The team of six observers rotated through the three positions every 30 minutes. With three observers searching at any one time, no individual observer was on-effort continuously for more than 90 minutes. This rotation provided time for other duties (e.g., data sorting and processing photos) and helped prevent eye fatigue, which reduces an observer's effectiveness to sight animals over extended monitoring periods. The entire survey was done in "closing mode," meaning that the survey team could go off-effort from searching and leave the transect line to approach sighted groups of marine mammals to obtain additional data.

When a marine mammal group was sighted, the cruise leader or chief scientist aboard the vessel evaluated the sighting and used a predetermined set of decision criteria (described in Appendix D) to determine which data collection methods to use and for what duration. The cruise leader's or chief scientist's decisions ensured that the data collected met the study criteria and that environmental and sighting conditions were favorable and safe. Typically, the visual team would go off-effort to collect data on the sighted group of marine mammals, and the ship would leave the transect line while following the mammals. After collecting data on the sighted group, the ship would return to the transect line and the visual team would resume on-effort searching for marine mammals.

Observational data recorded for all sightings were:

- Location and time of sighting
- Species identification
- Number of calves, if present
- Number of individuals, group size or pod composition
- Duration of sighting
- Behavior, disposition and observed reaction/no reaction to vessel
- Direction of travel
- Photographs for verification of species and individual identification
- Environmental information associated with the sighting event
- Effort data

2.2.1.2 RHIB Non-Systematic Surveys and Photo-ID

Non-systematic surveys of the inshore waters (0 to 3 nautical miles [5.6 kilometers]) off of Tinian, Pagan, and Saipan were conducted using two 33-feet (10-meter) RHIBs (see Figure 2-4). One of the RHIBs was used for visual survey and photo-ID operations; the second RHIB was used in tandem with the first to obtain acoustic recordings of single species schools of dolphins. Photo-ID methods are described below; detailed methods for acoustic operations from the RHIB are described in Appendix E. Using two RHIBs simultaneously was also a safety measure since these vessels were out of sight of the *Thorfinn* for hours at a time. At Pagan, weather permitting, the RHIB operators circumnavigated the entire island of Pagan searching for marine mammals.

The RHIB conducted visual surveys at 8 to 10 knots (15 to 19 kilometers per hour), with five observers scanning the water (360° relative to the boat) using unaided eye and 7X binoculars, ensuring 360° coverage. The observers searched within 3 nautical miles (5.6 kilometers) of shore for dolphins and whales. Since the purpose of the RHIB surveys was to find as many marine mammal groups as possible, no set tracklines were followed. When a cue, such as a splash or a dorsal fin, was detected the Science Team boat operator would moderate speed and approach the marine mammal group slowly to minimize disturbance to the group. The Science Team data recorder would document the date, time, latitude, longitude, species, group size, group composition, and behaviors; the boat operator would follow the animals for photo-ID (Figure 2-6).

Photo-ID was accomplished using digital SLR cameras with zoom lenses varying in size between 100- and 400-millimeter focal length. The objective was to capture images of dolphin dorsal fins directly perpendicular to the camera to identify individuals. Scars, wounds, and other identifying features were also photographed.

Figure 2-6. Conducting Photo-ID of Dolphins from a RHIB

2.2.1.3 Opportunistic Visual Sightings

Opportunistic sightings were recorded when marine mammals were observed from the deck outside of transect or RHIB survey times, including mornings and evenings before and after the primary research of the day. Opportunistic sightings were also recorded if seen by the acoustic team in the RHIB during the daily replacement of the moored sonobuoys at Pagan. The date, time, latitude, longitude, species, group size, number of calves, and reaction to the vessel were documented. Any sea turtles observed opportunistically during these times were also recorded (see Appendix C).

Opportunistic sightings of marine mammals were also recorded during the July 2013 CJMT Coral and Sea Turtle Surveys (see Appendix G).

2.2.2 Passive Acoustic Monitoring

Passive acoustic monitoring (PAM) complemented visual methods during line transect and RHIB surveys and was used independently to monitor and record vocalizations of marine mammals in nearshore areas of Pagan at night. The PAM had three main components:

- A towed hydrophone array system, deployed and monitored from the *Thorfinn*
- A portable towed hydrophone array system, deployed and monitored from the RHIBs
- A sonobuoy system, with sonobuoys either deployed from the *Thorfinn* or moored on the sea floor; both types of sonobuoy deployments were monitored and recorded from the *Thorfinn*

The *Thorfinn*-towed hydrophone array was deployed initially during the only line transect survey at Tinian. *Thorfinn*-towed arrays were deployed within 3 nautical miles (5.6 kilometers) of Pagan during line transect surveys, during the perimeter survey (along the 3-nautical mile [5.6 kilometer] survey area boundary), and during the transits to and from Pagan. The portable hydrophone array was deployed from the RHIB to obtain recordings of single-species schools of dolphins sighted during RHIB surveys of the islands. (These recordings were needed to ground-truth and augment the dolphin whistle classifier used to identify acoustic recordings without associated visual observations; see Section 2.3.3.) Lastly, a sonobuoy system was used to monitor sonobuoys either deployed from the *Thorfinn* or moored at night at two nearshore sites on the west side of Pagan. The *Thorfinn*-towed array and sonobuoy systems are described in greater detail in Appendix H and I, respectively. The portable towed hydrophone array system is further described in Appendix E.

2.2.2.1 Thorfinn-Towed Hydrophone Array and Data Processing Systems

The hydrophone consisted of a four-element, oil-filled array, connected to a detachable tow cable deployed approximately 591 feet (180 meters) behind the aft deck of the *Thorfinn*, at an approximate depth of 40 feet (12 meters; Figure 2-7).

Figure 2-7. Deployment of the Towed Array from the Aft Deck of the *Thorfinn*

The acoustic processing system consisted of computers, GPS receivers, adjustable audio filters, and analog-to-digital signal converters (e.g., audio interface or digital acquisition board). These components were integrated to provide a system that allowed recordings to be made simultaneously with both semiautomated and manual detection and localization of marine mammal sounds.

A combination of software programs was used for localization, recording, data logging, and documentation. The primary software programs included Ishmael 2.0, Whaltrak 2.6, and PAMGuard v1.12.05. Ishmael is acoustic localization and digital recording software, developed by Dave Mellinger, Oregon State University Pacific Marine Environmental Laboratory, Newport, Oregon. Whaltrak is a data logging and mapping program, developed by Jay Barlow, National Oceanic and Atmospheric Administration (NOAA) Fisheries Southwest Fisheries Science Center, La Jolla, California, and designed to interface with Ishmael. PAMGuard is an open-source program developed for real-time acoustic monitoring and post-processing applications developed by Doug Gillespie, St. Andrews University, St. Andrews, Scotland, United Kingdom (Gillespie et al. 2008).

Once a bearing to the animal was estimated successfully using Ishmael, the bioacoustician sent it to Whaltrak, where it was plotted on a map of the survey area. PAMGuard was configured to automatically detect clicks. It also automatically calculated the bearings to clicks, plotted them on a map, and estimated the localization.

2.2.2.2 Acoustic Line Transect Surveys

Acoustic line-transect surveys were conducted simultaneously with visual line-transect surveys whenever possible. During line transect surveys, acoustic signals were continuously monitored from the towed hydrophone array in real time, both aurally (using stereo headphones) and visually (from a real-time scrolling spectrographic display with a time/bearing display of click detections). Bioacousticians manually recorded the monitoring, track line position, and observation status, using digital data entry forms in the PAMGuard database. Changes in effort status, vessel turns (e.g., when starting a new track line), and changes in acoustic monitoring status were also recorded in the database. While the acoustic effort generally was conducted simultaneously with visual effort, there were times when visual effort was not occurring (e.g., when weather or sea conditions were too poor) or vice versa (e.g., when the visual team was conducting a chase).

When both acoustics and visual teams were on-effort, the acoustics team did not report or provide information to the visual team about acoustic localizations or detections until it was confirmed that animals had passed the beam of the ship (> 90° horizontal bearing from the observers to the animal or school). This protocol prevented the acoustics team from cueing the visual observers and unintentionally biasing the visual search effort to look in a particular direction or area.

Independent acoustic encounters (i.e., any encounter considered to be separate from the previous or next encounter) of marine mammal groups were assigned an encounter number and classified to the lowest taxonomic level (species, if possible) in the field whenever feasible. (A visual sighting of the same group would have a different sighting number.) The bioacoustician on watch distinguished independent acoustic encounters using several criteria, including bearing angles, signal time-frequency characteristics, relative amplitude of the signals, and signal patterns.

The acoustic (PAMGuard) database was used to log the following acoustic encounter details:

- Acoustic detection number (acoustic ID)
- Visual sighting number (if the visual team sighted the same group as the acoustic team)
- Starting and ending date and time
- Initial latitude and longitude
- First angle
- First distance
- Perpendicular distance
- Beam time
- Detection distance
- Vocal type
- Detection type (acoustic, visual, or both)
- First detection (acoustic, visual, or both)
- Species

- Track line number
- Localization quality score (see below)

Sequential bearings to the sound source were plotted to estimate a localization to calls or clicks from an animal or group. This technique, known as target motion analysis, involves plotting several bearings to the target while steadily moving past it. When sufficient bearings converged, it was considered a localization. All acoustic localizations were assigned quality assessment scores. Localizations were designated high quality when 10 or more bearings formed a tight convergence of bearing lines. Localizations were designated low quality when there were five or fewer bearings in the localization, or the bearings formed a relatively loose convergence of bearing lines.

2.2.2.3 Perimeter Survey

On August 15, the entire island of Pagan was circumnavigated during the perimeter survey at an approximate distance of 3 nautical miles (5.6 kilometers) from shore (the perimeter of the study area) and at a speed of 4 to 5 knots (7 to 9 kilometers per hour) for 8 hours. Visual search was conducted concurrently to identify to species any marine mammals encountered acoustically and to collect data on group size, composition, and behavior.

The path of this survey followed the 3 nautical mile (5.6 kilometer) boundary of the survey area (Figure 2-3) to allow continuous monitoring and recording by the towed hydrophone array data without the extreme angle turns necessitated by the sawtooth pattern of the line transect surveys. Extreme angle turns can create problems for the towed hydrophone array such as excess noise, bending of the hydrophone array, and issues with estimating angles to sounds because the array is not in a straight line. The shallow curves of the perimeter survey provided an excellent opportunity for the continuous collection of acoustic data without the potential negative aspects of abrupt angled turns. The acoustic-focused perimeter survey was conducted because the *Thorfinn's* speed was limited to below 9 knots (17 kilometers per hour), which is less than the speed required for a visual line transect survey. The acoustic survey benefitted from the slower vessel speed due to reduced engine and flow noise.

2.2.2.4 Straight Line Survey

On August 19, after completing a full island-circumference line transect survey of Pagan, the remaining three hours of daylight were used to survey waters next to the study area. The survey focused on acoustic monitoring using the towed array to collect comparative acoustic data from the area just outside the study area, relative to data collected within the study area. The *Thorfinn* proceeded west in a straight line for 6 nautical miles (11 kilometers), then returned to anchorage off Green Beach. Additional details and a summary of this effort is provided in Appendix F. Because some of the survey effort was conducted outside of the study area, the data from this survey were not included in the data analysis or in the main body of this report.

2.2.2.5 Sonobuoy Acoustic System

The sonobuoy acoustic system consisted of three main components: the sonobuoys, the receiving system, and the signal processing and recording system. Underwater acoustic signals are received by the hydrophone in the sonobuoy and are transmitted in real time via very high frequency (VHF) radio signal (in the 136 to 173.5 megahertz band) to receivers on the monitoring platform. The receivers, signal processing, and recording system were located on the *Thorfinn*. Real-time monitoring of incoming signals was limited, so post-processing was required for some of the data. More details on the sonobuoy system are provided in Appendix I.

Two sonobuoys were deployed opportunistically from the *Thorfinn* during line-transect surveys, in deep water areas, as a supplement to the data being collected from the towed array. Location and time data were recorded for each deployment. Because the primary focus of the sonobuoy effort was for night-time monitoring (see Section 2.2.2.6), the use of sonobuoys during daytime vessel surveys was limited.

2.2.2.6 Moored Sonobuoy Deployments

Sonobuoys were deployed each night at two nearshore sites on the west side of Pagan to monitor and record acoustic signals from marine mammals (Figure 2-3). The sonobuoys were temporarily moored in water depths of approximately 98 feet (30 meters) using a sandbag attached to a small plastic float with a line length of approximately 131-164 feet (40-50 meters; Figure 2-8). A flag was inserted in the center of the float to allow it to be easily located. The float had a short 3.3 to 6.6 feet (1 to 2 meter) line with a metal clip, allowing the sonobuoy to be easily attached on deployment and detached on retrieval. The sonobuoys were set to the maximum 8-hour operating life and were monitored by the receiving system on the *Thorfinn* until they expired and sank in the early morning (around 3:00 to 5:00 a.m. local time, depending on the deployment time). The following evening they were retrieved and replacements were deployed.

Figure 2-8. Moored Sonobuoy with Float and Flag for Retrieval

The first sonobuoy mooring site was 0.2 nautical mile (0.4 kilometer) offshore of Red and Blue Beaches (Figure 2-3). These two beaches were close enough to each other that one sonobuoy could monitor both locations simultaneously. The second sonobuoy mooring site was 0.3 nautical mile (0.6 kilometer) offshore of Green Beach and 1.4 nautical miles (2.6 kilometers) southwest of the first sonobuoy location. These two mooring sites were intentionally chosen to simultaneously monitor the area around all three beaches from the receiver on the *Thorfinn*. Additionally, both sites were relatively protected from potential swell and wind and were in water depths shallow enough for easy deployment and retrieval using the RHIBs.

Incoming signals from sonobuoys were monitored only for the first 10-15 minutes of recordings following deployment to verify the system was working properly. After the initial post-deployment monitoring, they were monitored for 5 to 10 minutes at the top of each hour, and until the sonobuoy was scuttled (around 3:00 to 5:00 a.m., depending on initial deployment). Any obvious marine mammal vocalizations (usually dolphin whistles or clicks) were noted on a data sheet during the hourly system recording checks.

Eleven moored sonobuoys were deployed at each of the two monitoring sites at Pagan (Blue/Red Beach and Green Beach), for a total of 22 moored sonobuoy deployments. Two additional sonobuoys were deployed at these sites on the mornings of August 20 and 21, to allow monitoring to extend into the day. To standardize the analysis periods, these data were excluded from the diel analysis and summary because of the different periods they covered. One additional sonobuoy was deployed at South Beach to test if reception was possible from the west side of the island; however, reception was not possible due to a landmass blocking the line-of-sight transmission path required for VHF signal reception. These data were also excluded. No moored sonobuoys were deployed at Tinian.

2.3 ANALYSIS METHODS

2.3.1 Visual Survey Data

Species occurrence and distribution patterns were analyzed by examining maps showing the distribution of sightings relative to geographic and bathymetric features.

Due to the extremely small sample size of visual sightings during line transect surveys, calculating reliable estimates of density or abundance was not possible. Generally, sample sizes of at least 40 to 60 on-effort sightings are needed for reliable density and abundance estimation by line transect methods (see Buckland et al. 2001). Instead, visual detection rates were calculated as the number of sightings and the number of individuals per nautical mile (kilometer) of transect line completed.

Calf and juvenile age classes were classified based on field observations and the examination of photographs. Calves were defined as half the size of adults and swimming paired with an adult; neonates were identified based on evident fetal fold lines, short respiration intervals, a very small body, and awkward surfacing behavior. Juveniles were animals noticeably smaller than adults (two-thirds to three-quarters of adult size), often still swimming with an adult. Group composition was determined by calculating average group sizes for the different species and calculating the proportion of calves and juveniles in the groups. An understanding of group composition assists in determining if the animals observed are reproducing in the area.

Notes on the behavior of marine mammal groups were reviewed and categorized by senior marine mammal Science Team personnel. Behavior that indicated how groups in different areas appeared to be using the habitat (e.g., resting, feeding, and socializing) was of particular interest.

2.3.2 Photo-ID Data

Photographs of dolphins were examined during post-processing for unique natural markings, such as dorsal fin nicks, scars, and variation in pigmentation, and individuals were identified using methods described in Würsig and Jefferson (1990). Photographs of individual spinner dolphins at Pagan were compared to determine if any dolphins had been resighted on multiple days or had moved between groups. Resighting data provide information about group structure and residency of spinner dolphins around Pagan. Resighting data are also the first step in a capture-recapture (mark-capture) analysis to estimate population abundance.

Copies of all photo-ID data will be provided to the NOAA Pacific Islands Fisheries Science Center to fulfill a condition of the marine mammal permit.

2.3.3 Acoustic Data

The acoustic processing system and associated software (described in detail in Appendix E and H) was used to process real-time acoustic data collected by the towed hydrophone array during the survey. Recordings were always made during acoustic survey efforts.

Recordings of species that could not be reliably identified in real-time—acoustic encounters containing unidentified dolphin whistles and unidentified beaked whale clicks—were analyzed further during post-processing. Dolphin whistles that were recorded but did not have visual species confirmation were post-processed using the Real-time Odontocete Call Classification Algorithm (ROCCA) module in PAMGuard to determine species identity. Detailed methods for analyzing dolphin whistles and the ROCCA analysis are in Appendix J; methods for beaked whale click analysis are in Appendix K.

All sonobuoy data were post-processed and manually reviewed by experienced bioacousticians, who also logged all vocalization events. Detailed methods of review and analysis of sonobuoy data are provided in Appendix I.

CHAPTER 3
RESULTS

3.1 TINIAN

3.1.1 Tinian Visual Results

A total of 38.8 nautical miles (71.8 kilometers) of predetermined transect lines were completed at Tinian on August 7 (Figure 3-11, Table 3-2). No marine mammals were sighted. There were also no marine mammal sightings at Tinian during RHIB surveys on August 8 and 9, conducted in inshore waters on the leeward side of the island.

3.1.2 Tinian Acoustic Results

During the *Thorfinn*'s line transect survey around Tinian on August 7, 45 minutes of acoustic monitoring was conducted and two hours of recordings were made during 13.1 nautical miles (24.3 kilometers) of towing the hydrophone array (Figure 3-11). There were no acoustic encounters. The day was primarily intended to test equipment before the Pagan survey. Because of the tests, there were periods when the signals were not being monitored in real-time, or were not recorded. Therefore, acoustic data collected during this day were not reviewed further during post-processing.

RHIB operations with acoustic monitoring using the portable towed hydrophone array were tested on August 8. The portable RHIB array was successfully set up and tested, although no recordings were made. During the initial test deployment of the portable array, at approximately 12:00 p.m. local time, bioacousticians heard sperm whale clicks, but made no recordings.

A single sonobuoy was deployed to test reception methods and the VHF receivers. It was monitored briefly to ensure the receiving system was functioning properly, but recordings were not made.

3.2 PAGAN

3.2.1 Visual Species Occurrence and Distribution

Thirteen sightings of marine mammal groups were made at Pagan from the three visual methods: line transect survey (four sightings), RHIB survey (six sightings), and opportunistic sightings (three sightings; Table 3-1). Overall, four species were observed: spinner dolphins (seven groups), bottlenose dolphins (two groups), Cuvier's beaked whales (one group), and unidentified dolphins (three groups).

3.2.1.1 Dolphin Sightings

Spinner dolphins were observed seven times at Pagan. Five of the seven groups were observed on the exposed eastern (windward) side (Figure 3-1); the other two groups were observed on the west (leeward) side, < 0.5 nautical mile (0.93 kilometer) from Green Beach. All of the sightings were within 0.54 nautical mile (1 kilometer) of shore (Table 3-1), with an average distance from shore of 0.27 nautical mile (0.5 kilometer). Six of the seven groups were in shallow waters over the continental shelf, with an average water depth of 220 feet (67 meters).

Both groups of bottlenose dolphins were observed on the west (leeward) side of the island, although one sighting was near the northern tip (Figure 3-1). Both sightings were within 0.54 nautical mile (1 kilometer) of shore (Table 3-1) and one was 0.25 nautical mile (0.46 kilometer) from Blue Beach. This sighting was in relatively shallow water of 118 feet (36 meters), while the other was in moderately deep water of 1,535 feet (468 meters; Table 3-1).

The three groups of unidentified dolphins were observed on the west (leeward) side of the island, although one was near the southern tip. They were seen in a range of water depths, from 95 to 2,385 feet (29 to 727 meters) and at a range of distances from shore, 0.27 to 1.1 nautical miles (0.5 to 2 kilometers; Table 3-1). This range of depths is not unexpected, as these sightings were probably of different species. One of the unidentified groups was thought to be spinner dolphins, due to their slim profile. The other two groups were thought to be bottlenose dolphins, based on slightly robust bodies and pronounced dorsal fins. The body proportions of these dolphins was too short and not robust enough to be larger species, such as melon-headed whales or pygmy killer whales. Species identification could not be confirmed due to the low light at sunset and choppy water.

Table 3-1. Marine Mammal Sightings - August 2013

Date (2013)	*Local Time (GMT offset = +10)*	*Sighting Number**	*Species*	*Location*	*Latitude (°N)*	*Longitude (°E)*	*Platform/Method*	*Group Size*	*Behavior*	*Beaufort Sea State*	*Depth in Feet (Meters)*	*Distance to Land in Nautical Miles (Kilometers)*
August 13	8:03 a.m.	1	Bottlenose dolphin	Pagan	18.1392	145.7573	RHIB survey	9	Milling, slow travel, aerial	1	118 (36)	0.25 (0.46)
August 13	9:59 a.m.	2	Spinner dolphin	Pagan	18.1315	145.8119	RHIB survey	35	Milling, slow travel, aerial, bow riding	4	98 (30)	0.09 (0.17)
August 13	12:14 p.m.	3	Spinner dolphin	Pagan	18.0716	145.7497	RHIB survey	25	Milling, slow travel, aerial, bow riding	3	72 (22)	0.23 (0.43)
August 14	8:42 a.m.	1	Spinner dolphin	Pagan	18.1523	145.8105	RHIB survey	27	Milling, aerial, bow riding	2	33 (10)	0.19 (0.35)
August 14	10:52 a.m.	2	Spinner dolphin	Pagan	18.0669	145.7464	RHIB survey	25	Milling, bow riding	2	82 (25)	0.05 (0.09)
August 14	1:00 p.m.	3	Unidentified dolphin	Pagan	18.0456	145.7034	RHIB survey	4	Medium travel	3	95 (29)	0.27 (0.51)
August 14	6:16 p.m.	4	Unidentified dolphin	Pagan	18.1229	145.4514	*Thorfinn* opportunistic	2	Undetermined	2	217 (66)	0.29 (0.54)
August 15	6:49 p.m.	1	Spinner dolphin	Pagan	18.1203	145.4501	*Thorfinn* opportunistic	3	Undetermined	2	164 (50)	0.31 (0.58)
August 18	12:12 p.m.	1	Spinner dolphin	Pagan	18.0934	145.8035	*Thorfinn* line transect	10	Slow travel	3	394 (120)	0.53 (0.96)
August 18	4:37 p.m.	2	Unidentified dolphin	Pagan	18.1245	145.7362	*Thorfinn* line transect	5	Slow travel	2	2,385 (727)	1.13 (2.09)
August 19	2:22 p.m.	1	Bottlenose dolphin	Pagan	18.1664	145.7537	*Thorfinn* line transect	2	Medium travel	3	1,535 (468)	0.47 (0.87)
August 20	1:55 p.m.	1	Cuvier's beaked whale	Pagan	18.0479	145.6824	*Thorfinn* line transect	2	Slow travel	3	2,260 (689)	1.45 (2.70)
August 20	4:42 p.m.	2	Spinner dolphin	Pagan	18.1215	145.4501	*Thorfinn* opportunistic	2	Slow travel, aerial	1	696 (212)	0.49 (0.92)

Notes:
*The sighting number is a numerical identifier, and is not the same as the number of animals sighted. Each day, sighting numbers began with 1 for the first sighting of the day and continued sequentially throughout the day.
Milling = multidirectional slow movements; slow travel = unidirectional swimming < 6 knots (< 11 kilometers per hour); medium travel = unidirectional travel 6-8 knots (11-15 kilometers per hour);
aerial = breaching or spinning; bow riding = riding a vessel's bow wave.

This page is intentionally left blank.

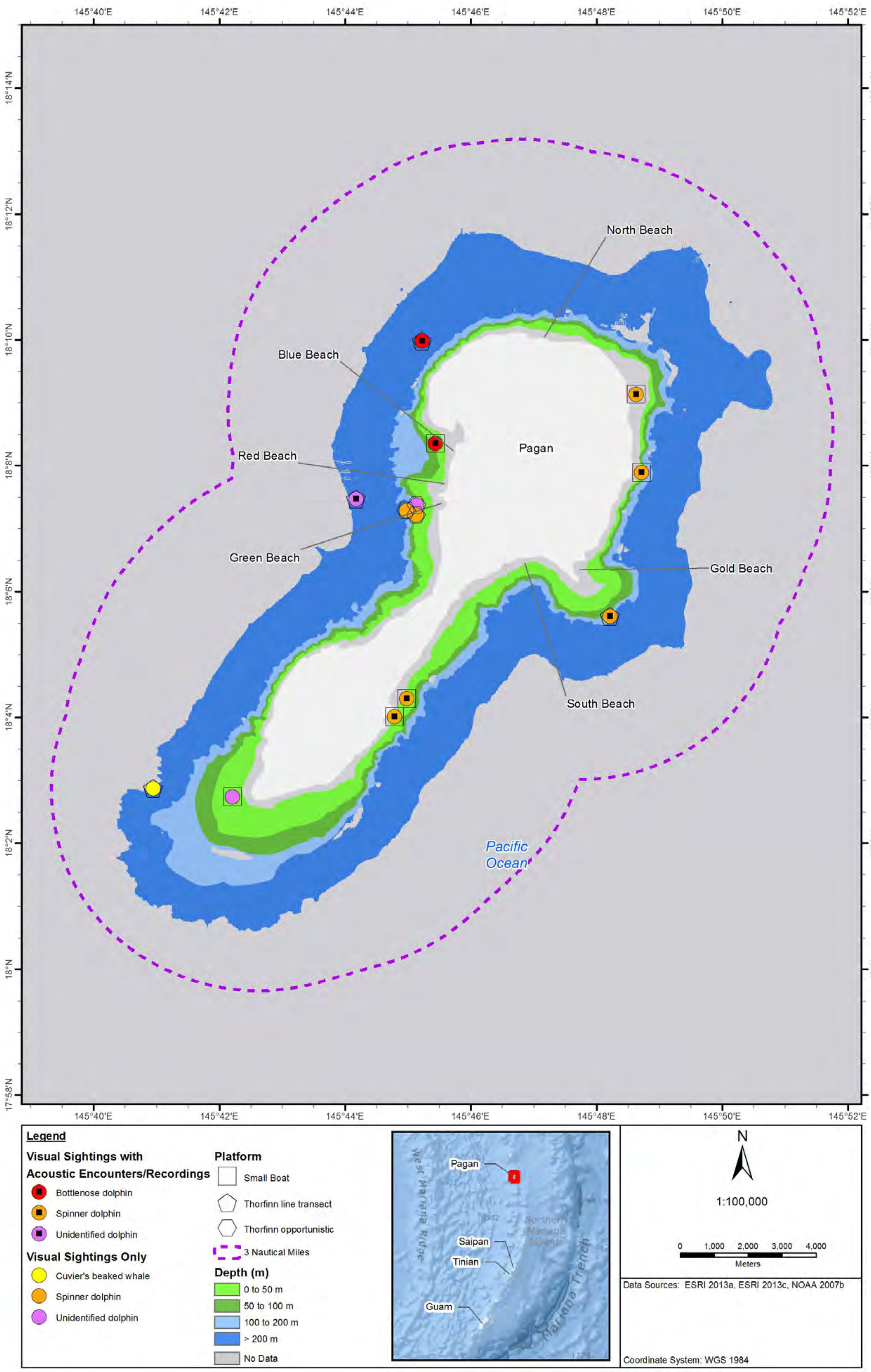


Figure 3-1. Pagan Sightings by Species and Platform

This page is intentionally left blank.

3.2.1.2 Cuvier's Beaked Whale Sighting

Cuvier's beaked whales were observed once off Pagan. A group of two Cuvier's beaked whales was observed at 1.46 nautical miles (2.7 kilometers) from shore in relatively deep water of 2,260 feet (689 meters; Figure 3-1, Table 3-1). Three surfacing sequences were observed over 37 minutes, at a distance of 656-1,312 feet (200-400 meters) from the *Thorfinn*. Due to the scarcity of nearshore sightings of beaked whales in this region, a transcript of the sighting notes is provided below for this sighting on August 20, 2013.

> *1:55 p.m. (local time)*—A dorsal fin was sighted 1,312 feet (400 meters) from the ship. The data recorder radioed the Science Team on the bridge deck, and the cruise leader instructed the ship to circle around the sighting location.
>
> *2:11 p.m.*—The whales were resighted in almost the same location as the first sighting, although the ship was closer to the whales this time, approximately 200 yards (183 meters) away. This surfacing provided the best views, and the animals were seen by five observers. Species identification was made at this time. There were two animals, an adult and a smaller individual, possibly a subadult, within a body length of one another. The adult was 21-24 feet (6.4-7.3 meters) in length with a robust body and a broadly triangular dorsal fin positioned 2/3-3/4 of the way down the back. The body color was medium brown with a hint of olive, except for the anterior portion of the back, behind the head, which was paler in color. There were many scratches and scars on the body. The animals were slowly surfacing (surfacing sequences were initiated head-first, followed by the rest of the body, tail stock last before a shallow dive), heading northwest. They were at the water surface for about a minute, surfacing 6-8 times. The last dive was at 2:12 p.m.
>
> *2:32 p.m.*—The whales were resighted approximately 984 feet (300 meters) northwest of the previous location. Only one observer saw this surfacing, consisting of a single surfacing, which the observer thought was the final dive. The Science Team searched for this group for another 25 minutes but the whales were not seen again.

Binoculars provided excellent views for species identification on this sighting. Nine photographs were taken of these whales, but they were too distant to use for individual identification.

There were no other biological sounds detected by the acoustics team in association with the sighting of Cuvier's beaked whales. However, beaked whales typically do not vocalize when at the surface (Johnson et al. 2004). Because beaked whales vocalize only at depth during deep foraging dives, which usually last one hour or more, the chance of sighting the same animal or animals concurrently with an acoustic encounter is low.

3.2.2 Visual Line Transect Effort and Sighting Rates

A total of 241.0 nautical miles (446.3 kilometers) were completed on predetermined transect lines at Pagan (Figure 3-2, Table 3-2) over five days (four full line transect days and one partial consisting of two hours of line transect work). Quantitative sighting rates were calculated for the species sighted from the line transect data, as Group Sighting Rate/54 nautical miles (100 kilometers), and as Individual Sighting Rate/54 nautical miles (100 kilometers; Table 3-3). Note that the sighting rates are based on extremely small sample sizes and therefore should be considered preliminary. Line transect analysis methods could not be applied to the survey data due to the small sample size; thus, density and abundance could not be calculated for this effort (sample sizes of on-effort sightings were below the minimum needed for robust line transect analysis; see Buckland et al. 2001).

Table 3-2. Visual Search Effort from the *Thorfinn*

Date (2013)	*Location*	*Area Surveyed in Nautical Miles (Kilometers)*
August 7	Tinian	38.77 (71.80)
August 10	Transit	52.68 (97.56)
August 11	Transit	4.79 (8.88)
August 12	Pagan	17.73 (32.84)
August 17	Pagan	33.10 (61.31)
August 18	Pagan	66.25 (122.70)
August 19	Pagan	57.73 (106.91)
August 20	Pagan	66.17 (122.54)
August 22	Transit	46.36 (85.85)
TOTAL		**425.66 (788.32)**

Table 3-3. Sighting Rates for Marine Mammal Species Observed On-Effort During the Line Transect Survey at Pagan

Species	*Number of Groups*	*Number of Individuals*	*Group Sighting Rate/54 Nautical Miles (100 Kilometers)*	*Individual Sighting Rate/54 Nautical Miles (100 Kilometers)*
Spinner dolphin	1	10	0.15	1.55
Bottlenose dolphin	1	2	0.15	0.31
Cuvier's beaked whale	1	2	0.15	0.31
Unidentified dolphin	1	5	0.15	0.77

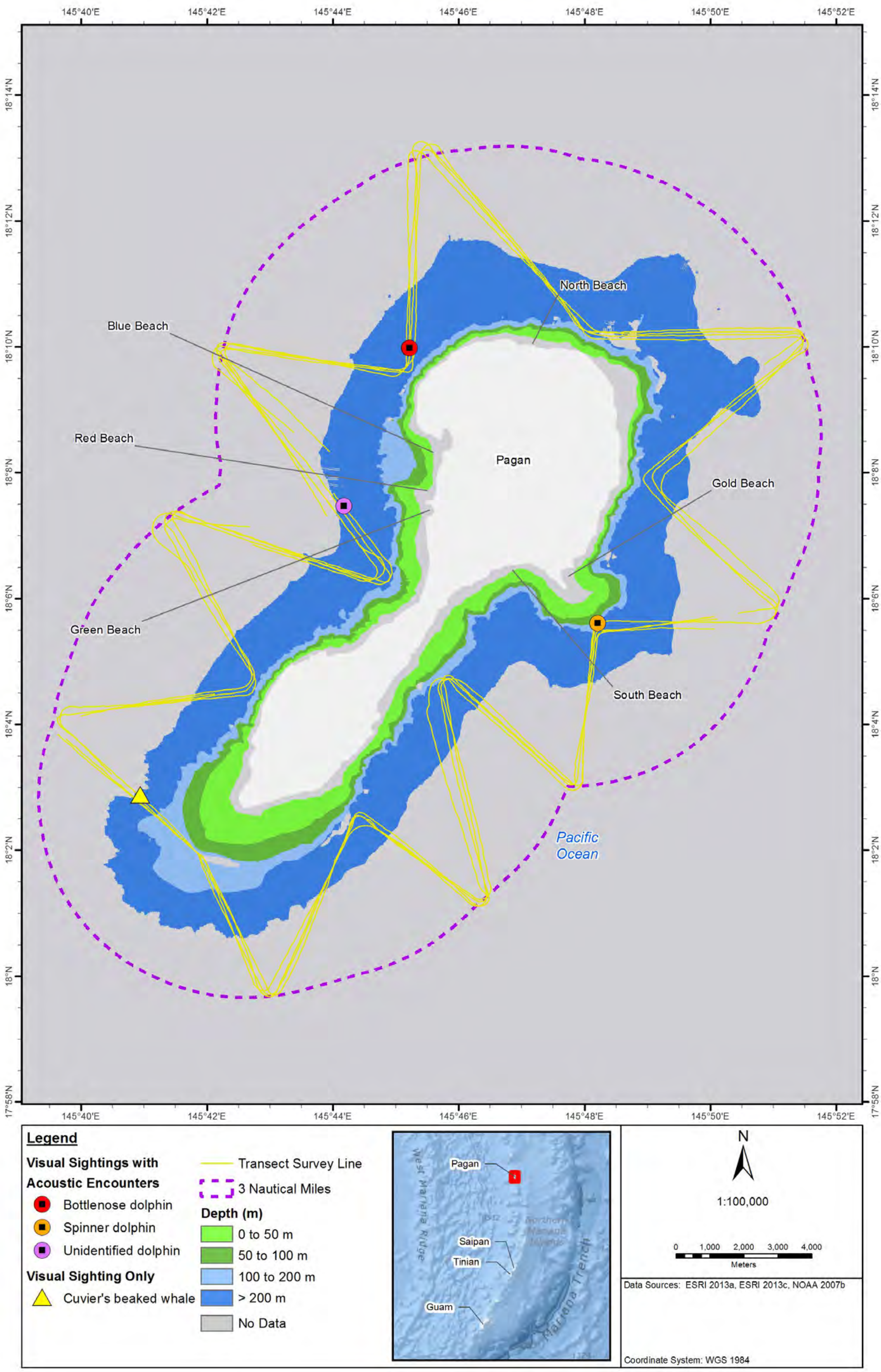


Figure 3-2. Transect Lines Surveyed and Locations of On-Effort Sightings at Pagan

Note that the sighting locations are the actual positions of the mammals, as calculated by the program Mysticetus.

This page is intentionally left blank.

3.2.3 Visual Data On Group Size and Composition

Four species of marine mammals were sighted at Pagan (from all three survey methods, Table 3-4): spinner dolphins, bottlenose dolphins, Cuvier's beaked whales, and unidentified dolphins. The species with the largest average group size was spinner dolphins, with an average of 18.1 individuals and group sizes ranging from 2 to 35 individuals. The other three species had smaller group sizes, ranging from 2 to 9 individuals per group.

Table 3-4. Pagan Sighting Summary by Species: Mean Group Size, Standard Deviation, and Range

Species Common Name	***Scientific Name***	***Number of Groups***	***Number of Individuals***	***Mean Group Size***	***Standard Deviation***	***Range***
Spinner dolphin	*Stenella longirostris*	7	127	18.1	12.99	2-35
Bottlenose dolphin	*Tursiops truncatus*	2	11	5.5	4.95	2-9
Cuvier's beaked whale	*Ziphius cavirostris*	1	2	2.0	NA	NA
Unidentified dolphin	Delphinid	3	11	3.7	1.53	2-5
Total number of groups: 13 Total number of estimated individuals: 151						

Group composition data, based on the minimum number of calves or juveniles in each group, was available from the dolphin groups sighted during the RHIB non-systematic surveys and from the sighting of Cuvier's beaked whales from the *Thorfinn* (Table 3-5). (Due to its maneuverability, the RHIB provided a better platform than the *Thorfinn* for following dolphin schools and gathering observational data on group composition.) Notably, the group of nine bottlenose dolphins sighted off Blue Beach on August 13 contained three calves, or 33% of the group. Two of the calves were neonates. Three of the four groups, or 75%, of spinner dolphins sighted from the RHIB included calves or juveniles, ranging from 3% to 8% per group.

Table 3-5. Number of Calves and Juveniles per Group Sighted at Pagan

*Date (2013) and Sighting Number**	*Platform/Method*	*Species*	*Number of Calves*	*Number of Juveniles*	*Percent of Group*	*Number of Photographs*	*Number of Individuals Identified*
August 13 Sighting 1	RHIB survey	Bottlenose dolphin	3**	0	33	1,117	8
August 13 Sighting 2	RHIB survey	Spinner dolphin	1	0	3	420	24
August 13 Sighting 3	RHIB survey	Spinner dolphin	0	0	0	335	23
August 14 Sighting 1	RHIB survey	Spinner dolphin	2	0	7	480	20
August 14 Sighting 2	RHIB survey	Spinner dolphin	0	2	8	289	7
August 14 Sighting 3	RHIB survey	Unidentified dolphin	ND	ND	ND	0	0
August 14 Sighting 4	*Thorfinn* opportunistic	Unidentified dolphin	ND	ND	ND	2	0
August 15 Sighting 1	*Thorfinn* opportunistic	Spinner dolphin	ND	ND	ND	0	0
August 18 Sighting 1	*Thorfinn* line transect	Spinner dolphin	ND	ND	ND	0	0
August 18 Sighting 2	*Thorfinn* line transect	Unidentified dolphin	ND	ND	ND	0	0
August 19 Sighting 1	*Thorfinn* line transect	Bottlenose dolphin	ND	ND	ND	0	0
August 20 Sighting 1	*Thorfinn* line transect	Cuvier's beaked whale	0	0	0	9	0
August 20 Sighting 2	*Thorfinn* opportunistic	Spinner dolphin	ND	ND	ND	0	0

Notes:
*The sighting number is a numerical identifier, and is not the same as the number of animals sighted. Each day, sighting numbers began with 1 for the first sighting of the day and continued sequentially throughout the day.
**Includes two neonates.
ND = Not determined.

3.2.4 Visual Data On Behavior

Table 3-1 presents behaviors exhibited by marine mammals during sightings.

The seven groups of spinner dolphin sightings displayed a variety of behaviors. Four groups (57%) were milling (multidirectional, aimless, slow movements at the surface), with subsequent bow riding; four groups (57%) performed aerial activity, such as spinning and breaching; and two groups (29%) were engaged in slow travel.

Of the two groups of bottlenose dolphins observed at Pagan, one group (50%) was engaged in medium travel. The other group, off of Blue Beach and with the three calves, displayed milling, slow travel, and aerial (leaping) behaviors. This group did not bow ride and avoided the RHIB.

Of the three groups of unidentified dolphins, two groups were observed in travel; the behavior of the third group was undetermined. The single group of Cuvier's beaked whales sighted was engaged in slow travel and surfacing behavior.

3.2.5 Photo-ID And Individual Presence

A total of 2,652 data quality photographs were taken of marine mammals at Pagan (Table 3-5).

Of the seven groups of spinner dolphins observed at Pagan, four of the groups were photographed. From those four groups, 24, 23, 20, and 7 individuals were photo-identified (Table 3-5). A comparison of identification photos between groups showed that four dolphins photographed on August 13 were resighted on August 14 (Table 3-6; Figure 3-3). The marks used to recognize these individuals and confirm resightings were unique scars, nicks in the dorsal fin, and unique variations in pigmentation.

Table 3-6. Number of Spinner Dolphins Resighted on Two Days at Pagan

*August 13, 2013 Sighting Number**	*August 14, 2013 Sighting Number **	*Number of Dolphins Seen in Both Groups*
Sighting 2	Sighting 1	1
Sighting 2	Sighting 2	1
Sighting 3	Sighting 2	2

Note:
*The sighting number is a numerical identifier, and is not the same as the number of animals sighted. Each day, sighting numbers began with 1 for the first sighting of the day and continued sequentially throughout the day.

Figure 3-3. Identification Photos of Four Spinner Dolphins Resighted on Two Days at Pagan

The photos in the left column were taken on August 13, and those in the right column were taken on August 14.

The group of bottlenose dolphins sighted close to Blue Beach was photographed for individual identification (Table 3-4). Eight of the nine individuals from this group were identified, which means that almost the entire group was identified. No photos were obtained of the other bottlenose dolphin group sighted from the *Thorfinn* farther offshore.

Nine photos were taken of the group of Cuvier's beaked whales sighted at Pagan. These provided confirmation to species level however photos were too distant to identify specific individuals via markings.

3.2.6 Thorfinn Towed Hydrophone Array

Monitoring effort was characterized according to three types:

- Line transect (standard)
- Nonstandard or without line transect (i.e., visual chase periods, when the survey vessel left the transect line to approach marine mammals)
- Perimeter survey (also nonstandard and without line transect)

All three monitoring types of monitoring effort were conducted within the 3 nautical mile (5.6 kilometer) survey area. Table 3-7 presents the acoustic monitoring results. Line transect monitoring time totaled 23 hours of acoustic monitoring over 189.7 nautical miles (351 kilometers). The perimeter survey was conducted on August 15, with 7.5 hours of acoustic monitoring, covering 40.3 nautical miles (74.6 kilometers). Figure 3-5 maps the acoustic encounters during these surveys. Table 3-8 summarizes mid-frequency and high-frequency recordings resulting in just over 33 hours and 250 nautical miles (463 kilometers) for each type of recording effort.

Table 3-7. Summary of *Thorfinn* Towed Hydrophone Array Monitoring

Date (2013)	*Monitoring Standard (Hours: Minutes: Seconds)*	*Monitoring Standard in Nautical Miles (Kilometers)*	*Monitoring Nonstandard (Hours: Minutes: Seconds)*	*Monitoring Nonstandard in Nautical Miles (Kilometers)*	*Monitoring Visual Chase (Hours: Minutes: Seconds)*	*Monitoring Visual Chase in Nautical Miles (Kilometers)*
August 15*	-	-	7:39:58	40.3 (74.6)	-	-
August 17	1:48:02	12.9 (23.8)	1:01:24	6.6 (12.3)	-	-
August 18	6:56:00	57.9 (107.3)	-	-	0:47:00	5.8 (10.7)
August 19	6:41:58	56.0 (103.7)	-	-	0:14:04	2.0 (3.7)
August 20	7:38:01	62.9 (116.5)	-	-	1:02:00	8.4 (15.6)
TOTAL	**23:04:01**	**189.7 (351.3)**	**8:41:22**	**46.9 (86.9)**	**2:03:04**	**16.2 (30.0)**

Notes:
Monitoring effort is reported for each day of survey within 3 nautical miles (5.6 kilometers) of Pagan.
*Perimeter survey was conducted.
"-" = no data.

Table 3-8. Summary of *Thorfinn* Towed Hydrophone Array Recordings

Date (2013)	*Mid-Frequency Recording Effort (Hours: Minutes: Seconds)*	*Mid-Frequency Recording Effort Nautical Miles (Kilometers)*	*High-Frequency Recording Effort (Hours: Minutes: Seconds)*	*High-Frequency Recording Effort Nautical Miles (Kilometers)*
August 15*	7:39:58	40.3 (74.6)	7:39:58	40.3 (74.6)
August 17	2:49:26	19.5 (36.1)	2:49:26	19.5 (36.1)
August 18	7:43:00	63.7 (118.0)	7:29:56	61.9 (114.7)
August 19	6:56:02	58.0 (107.4)	6:56:02	58.0 (107.4)
August 20	8:40:01	71.3 (132.1)	8:40:01	71.3 (132.1)
TOTAL	**33:48:27**	**252.8 (468.2)**	**33:35:23**	**251.0 (464.9)**

Notes:
Recording for all mid-frequency (96 kilohertz bandwidth) and high-frequency (250 kilohertz bandwidth) recordings made within 3 nautical miles (5.6 kilometers) of Pagan.
*Perimeter survey was conducted.

There were 14 acoustic encounters (Table 3-9, Figure 3-4) during surveys conducted within 3 nautical miles (5.6 kilometers) of Pagan. The acoustic encounters were identified as the following species (number of encounters in parentheses): bottlenose dolphin (1), spinner dolphin (1), Blainville's beaked whale (3), Cuvier's beaked whale (1), and unidentified dolphin (8). Of this total, 11 were acoustic-only encounters, and 3 were combined visual and acoustic encounters (Table 3-10, Figure 3-4). Four of the eleven acoustic encounters were localized in real time (Table 3-10). Localization ranges (estimated as the perpendicular distance from the track line) were 0.2 and 0.4 nautical mile (0.3 and 0.7 kilometer) for the two unidentified dolphin encounters and 0.76 nautical mile (1.4 kilometers) and 1.03 nautical miles (1.9 kilometers) for the two Blainville's beaked whale encounters.

The acoustic encounter rate for all standard line transect monitoring was 0.48 encounters per hour. Acoustic encounter rates for dolphins (all dolphin groups, both identified and unidentified) was 0.35 per hour. Blainville's beaked whales were encountered at a rate of 0.09 per hour. There were insufficient numbers of independent acoustic encounters to calculate reliable density or abundance estimates using the towed hydrophone array data (usually 40-50 acoustic encounters are considered the minimum number needed per species specifically for acoustic line transect methods; see DoN 2013b).

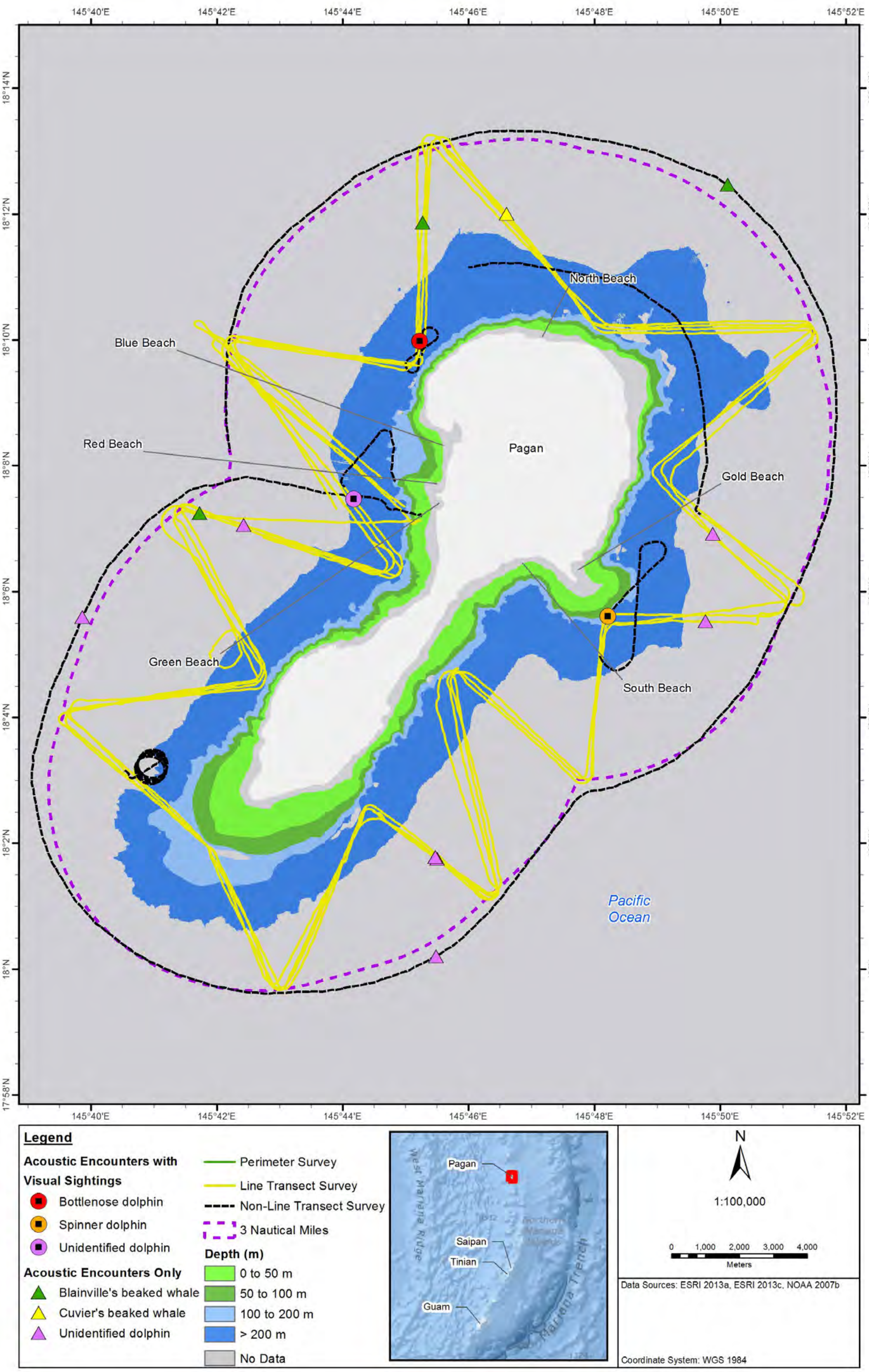


Figure 3-4. Acoustic Encounters of Marine Mammals During Line Transect and Perimeter Surveys at Pagan

Note that all the acoustic encounters were plotted at the point *on the track line* where the detection initially occurred, not at the exact location of the animal or animal group. Therefore, there may be errors or biases associated with these locations. Non-line transect survey included time following visually sighted dolphins and whales or transit time of the *Thorfinn* returning to anchor.

This page is intentionally left blank.

Table 3-9. Summary of Acoustic Encounters for Surveys within 3 Nautical Miles (5.6 Kilometers) of Pagan

Local Date and Time (2013) (GMT offset = +10)	***Survey Type***	***Acoustic Detection Number****	***Visual Sighting Number****	***Latitude (°N)***	***Longitude (°E)***	***Perpendicular Distance in Nautical Miles (Kilometers)***	***Greatest Detection Distance in Nautical Miles (Kilometers)***	***Species ID***
August 15 9:28 a.m.	Perimeter	7	-	18.0932	145.6644	ND	ND	Unidentified dolphin
August 15 11:27 a.m.	Perimeter	8	-	18.0034	145.7581	ND	ND	Unidentified dolphin
August 15 2:14 p.m.	Perimeter	9	-	18.2078	145.8354	ND	ND	Blainville’s beaked whale
August 17 12:16 p.m.	Line transect	10	-	18.1208	145.6954	1.0 (1.9)	1.0 (1.9)	Blainville’s beaked whale
August 18 10:03 a.m.	Line transect	11	-	18.1978	145.7545	0.8 (1.5)	0.8 (1.5)	Blainville’s beaked whale
August 18 10:26 a.m.	Line transect	12	-	18.2001	145.7768	ND	ND	Cuvier’s beaked whale
August 18 12:14 p.m.	Line transect	13	1	18.0941	145.8101	ND	ND	Spinner dolphin
August 18 2:04 p.m.	Line transect	14	-	18.0292	145.7584	ND	ND	Unidentified dolphin
August 18 4:08 p.m.	Line transect	15	-	18.1176	145.7071	0.2 (0.4)	1.0 (1.9)	Unidentified dolphin
August 18 4:43 p.m.	Line transect	16	2	18.1354	145.7373	ND	ND	Unidentified dolphin
August 19 10:56 a.m.	Line transect	17	-	18.0297	145.7579	ND	ND	Unidentified dolphin
August 19 2:22 p.m.	Line transect	18	1	18.1667	145.7536	ND	ND	Bottlenose dolphin
August 20 11:02 a.m.	Line transect	20	-	18.1153	145.8314	0.4 (0.7)	0.9 (1.7)	Unidentified dolphin
August 20 11:30 a.m.	Line transect	21	-	18.0921	145.8295	ND	ND	Unidentified dolphin

Notes:
*The sighting number is a numerical identifier, and is not the same as the number of animals sighted. Acoustic detection numbers were sequential throughout the cruise. Visual sighting numbers began each day with 1 for the first sighting of the day and continued sequentially through the day.
“-” = no sighting number; ND = no data

This page is intentionally left blank.

Table 3-10. Acoustic Encounter Summary of Species within 3 Nautical Miles (5.6 Kilometers) of Pagan

Species	***Thorfinn Towed Array***		
	Acoustic Only	***Acoustic and Visual***	***Number Localized***
Bottlenose dolphin	0	1	0
Spinner dolphin	0	1	0
Cuvier's beaked whale	1	0	0
Blainville's beaked whale	3	0	2
Unidentified dolphin	7	1	2
TOTAL	**11**	**3**	**4**

Note:
Acoustic encounters are reported by species for acoustic only and combined visual and acoustic encounters for all survey efforts within 3 nautical miles (5.6 kilometers; line transect and perimeter surveys). The number of acoustically localized encounters is also reported in the last column.

3.2.7 Dolphin Acoustic Encounters and ROCCA Species Classifications

There were ten dolphin acoustic encounters during the line transect surveys. These were initially not identified to species but were clearly from the dolphin family (family Delphinidae) because of their whistle vocalizations. Of these ten groups, two were seen and the visual observers were able to identify their species. One group was spinner dolphins, and the other was bottlenose dolphins. Three groups were identified as either spinner or striped dolphins using the ROCCA classifier (see Appendix J).

The remaining five encounters were omitted from the classification analysis.. Four encounters were omitted because they were less than 3 nautical miles (5.6 kilometers) from other visual or acoustic dolphin detections. Dolphin whistles are relatively high frequency and attenuate as they travel through water. Consequently, whistles produced more than 3 nautical miles (5.6 kilometers) from the hydrophones were assumed undetectable or too faint to affect the analysis. Restricting whistles to those occurring at least 3 nautical miles from each other reduces the likelihood of including whistles produced by a species other than those in the intended encounter. The fifth encounter was omitted because the recording contained only pulsed sounds, which cannot be identified using the whistle classifier. There were no whistles in this recording.

Table 3-11 presents the final results of the classification analysis. The three detections included in the classification analysis were classified as spinner/striped dolphins. Although it is ideal to identify encounters to the species level, whistles produced by spinner and striped dolphins have similar time-frequency characteristics; for this reason, the classifier performed better when these two species were combined. Most likely, the encounters classified as spinner/striped dolphins were all spinner dolphins for two reasons. First, spinner dolphins were the most commonly sighted dolphin species (7 of 9 dolphin groups identified to species) in the nearshore waters surrounding Pagan; second, striped dolphins are found in offshore waters (Au and Perryman 1985; Carretta et al. 2013), making it unlikely that whistles produced in offshore waters would be detected by hydrophones in nearshore waters.

All of the acoustic encounters of delphinids occurred in water depths between 394 feet (120 meters) and 5,837 feet (1,779 meters; Figure 3-4).

Table 3-11. Classification Results for Acoustic Encounters That Did Not Have Associated Visual Observations

Local Date and Time (2013)	***Acoustic ID***	***Number of Whistles Analyzed***	***Identified As***	***Reason Omitted from Classification Analysis***
August 15 9:28 a.m.	7	NA	NA	no whistles
August 15 11:27 a.m.	8	8	Spinner dolphin/striped dolphin	NA
August 18 2:04 p.m.	14	50	Spinner dolphin/striped dolphin	NA
August 18 4:08 p.m.	15	NA	NA	Within 3 nautical miles of another dolphin detection
August 18 4:43 p.m.	16	NA	NA	Within 3 nautical miles of another dolphin detection
August 19 10:56 a.m.	17	15	Spinner dolphin/striped dolphin	NA
August 20 11:02 a.m.	20	NA	NA	Within 3 nautical miles of another dolphin detection
August 20 11:30 a.m.	21	NA	NA	Within 3 nautical miles of another dolphin detection

Note:
NA = not applicable

3.2.8 Beaked Whale Acoustic Encounters

There were four acoustic encounters with beaked whales at Pagan. Three of these occurred during the line transect survey, and one occurred during the perimeter survey (Figure 3-4). These encounters could not be classified to genus or species in real-time and therefore were classified as unidentified beaked whales during the surveys. Post-processing of the recorded acoustic data following the surveys resulted in classifying three of these encounters as Blainville's beaked whales and one as Cuvier's beaked whale (Table 3-12). The differences in click characteristics between species are small but distinct, as exemplified in Figure 3-5. (A detailed review of beaked whale click characteristics is provided in Appendix K.) Median peak frequencies for Blainville's beaked whale encounters ranged from 34.48 to 35.32 kilohertz, and median inter-pulse-interval (IPI) values ranged from 0.27 to 0.35 millisecond (Table 3-12; Figure 3-5). The median peak frequency of clicks for the encounter classified as Cuvier's beaked whale was 38.10 kilohertz, and the median IPI was 0.41 millisecond (Table 3-12; Figure 3-5).

Table 3-12. Summary of Descriptive Statistics for Clicks from Unidentified Beaked Whale Encounters

Acoustic Sighting ID	*Peak Frequency in Kilohertz (10th, 90th Percentiles)*	*IPI in Seconds (10th, 90th Percentiles)*	*Number of Animals*	*Species ID*
A9	34.48 (34.03, 35.82)	0.35 (0.30, 0.37)	1	Blainville's beaked whale
A10	34.80 (32.32, 35.75)	0.32 (0.25, 0.37)	3	Blainville's beaked whale
A11	35.32 (34.39, 36.25)	0.27 (0.23, 0.32)	1	Blainville's beaked whale
A12	38.10 (36.25, 39.03)	0.41 (0.37, 0.55)	1	Cuvier's beaked whale

Note:
Peak frequency and IPI of click values were used to classify clicks to species. Medians and 10th and 90th percentile values were calculated for peak frequency and IPI measurements. This was because these data typically exhibit a non-normal distribution. Species identifications were based on the values for these two click variables.

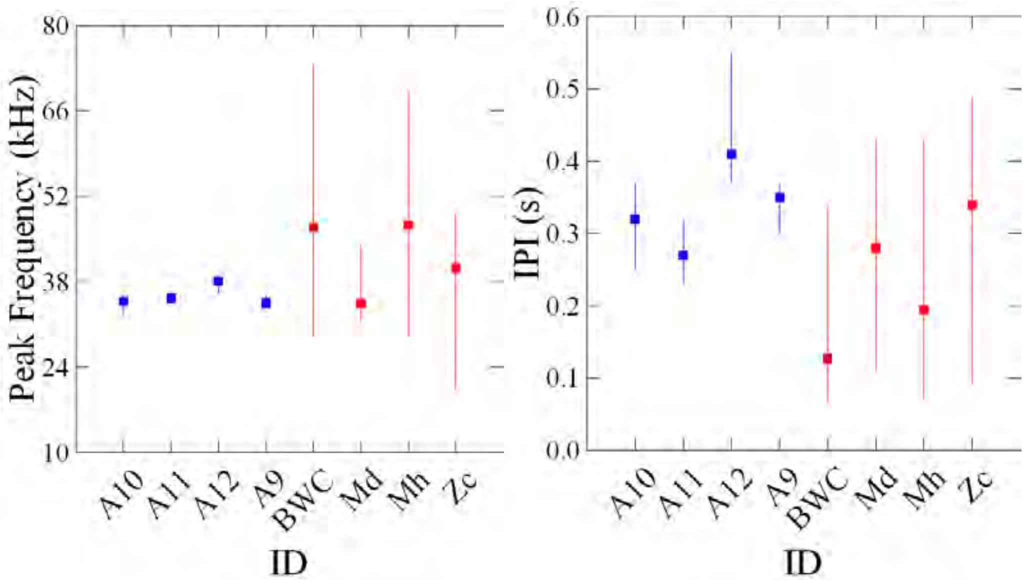


Figure 3-5. Comparative Boxplot Showing Median Values and 10th to 90th Percentile Ranges for Peak Frequency and IPI for All Beaked Whale Acoustic Encounters and Published Values

Median values are shown as squares; 10th to 90th percentile ranges are shown as lines. Beaked whale acoustic encounters from this study are shown in blue, and published values are shown in red for Cuvier's (Zc), Blainville's (Md), Deraniyagala's (Mh) beaked whales, and an unidentified beaked whale click type from the tropical Pacific (BWC) from Baumann-Pickering et al. (2013).

The Blainville's beaked whales were encountered on the northern and western sides of Pagan, and the Cuvier's beaked whale was encountered on the northwest side of Pagan (Figure 3-4). The groups were encountered in water depths of between 2,953 feet (900 meters) and 5,249 feet (1,600 meters). Three of the beaked whale acoustic encounters were single animals, and one encounter of Blainville's was a group with at least three animals.

There were no sounds detected from the Cuvier's beaked whale visually sighted off the southwest end of Pagan. Detailed analysis of beaked whale clicks is provided in Appendix K.

3.2.9 *Thorfinn* Line Transect Sonobuoy Deployments

Two sonobuoys were deployed from the *Thorfinn* during the line transect surveys; both during an offshore turn, on the east side of the island in deeper waters. One sonobuoy failed for unknown reasons.

The recordings collected from the second sonobuoy were reviewed during post-processing; however, the signal quality was too poor to determine if any vocalizations were detected.

Twenty-two moored sonobuoys were deployed during the project at the two sites (Blue/Red Beach and Green Beach). On the last night (August 20), two sonobuoys were deployed approximately three hours later than the previous nine nighttime deployments. On the next morning (August 21), two sonobuoys were deployed at approximately 6:00 a.m. and were recorded during the daytime at each of the two sites. Sonobuoys were located so that they were acoustically isolated relative to animals in the study area.

These four sonobuoys were deployed to conduct 24-hour monitoring during the last day of the survey effort. However, to maintain consistency in the analysis, data from all four of these sonobuoy deployments were excluded from the diel analysis summaries. The reason for this exclusion was because the different periods or locations that the sonobuoys covered would have resulted in a potential bias in the results. Table 3-13 is a summary of the moored sonobuoy deployments analyzed in this study. A total of 66.65 hours of overnight recordings were made at Blue/Red Beach, for an average recording duration of 7.4 hours per night. A total of 67.56 hours of overnight recordings were made at Green Beach, for an average recording duration of 7.5 hours per night. Most dolphin vocalizations occurred between 1:00 a.m. and 3:00 a.m. (Figure 3-6). Recordings were obtained of dolphins and sperm whales.

At the Blue/Red Beach site, 66% of the nighttime sonobuoy deployments contained dolphin vocalizations (Figure 3-7). There were 11 dolphin vocalizations in the overnight recordings (Figure 3-7). These were relatively infrequent and short in duration, with vocalization events occurring for only 3% of total time recorded (1 hour 57 minutes out of 66 hours 39 minutes). The average vocalization duration was 10.7 minutes. Two sperm whale vocalizations were detected at Blue/Red Beach, representing 2.4 minutes of vocalizations in the recordings (0.06% of the total recordings; Figure 3-8).

At the Green Beach site, 66% of the nighttime sonobuoy deployments contained dolphin vocalization events (Figure 3-9). Twenty-two dolphin vocalizations were recorded (Figure 3-9). Nighttime dolphin vocalization events were relatively infrequent, and short in duration, with only 3% of the total time recorded containing vocalization events (1 hour 58 minutes out of 67 hours 34 minutes), with an average duration of 5.3 minutes per vocalization event. At Green Beach, two sperm whale vocalizations were detected, resulting in 1.48 hours of vocalizations in the recordings (2.2% of the total; Figure 3-10).

Table 3-13. Sonobuoy Deployments for the Blue/Red and Green Beach Mooring Sites

Location	***Dates (2013)***	***Buoy Number***	***Recording Duration (Hours: Minutes: Seconds)***	***Dolphin Vocalizations Present***	***Sperm Whale Vocalizations Present***
Blue/Red Beach	August 11-12	2	4:14:00	Yes	No
Blue/Red Beach	August 12-13	4	7:27:00	Yes	No
Blue/Red Beach	August 13-14	6	7:45:00	No	No
Blue/Red Beach	August 14-15	8	7:41:00	Yes	No
Blue/Red Beach	August 15-16	10	7:55:00	Yes	No
Blue/Red Beach	August 16-17	12	8:05:00	Yes	No
Blue/Red Beach	August 17-18	14	8:03:00	No	No
Blue/Red Beach	August 18-19	17	7:26:00	Yes	No
Blue/Red Beach	August 19-20	20	8:03:00	No	Yes
Total	**9 nights**	**9 sonobuoys**	**66:39:00**	**6**	**1**
Green Beach	August 11-12	3	4:35:00	Yes	No
Green Beach	August 12-13	5	7:35:00	Yes	No
Green Beach	August 13-14	7	7:58:00	No	No
Green Beach	August 14-15	9	7:47:00	Yes	No
Green Beach	August 15-16	11	8:04:00	Yes	No
Green Beach	August 16-17	13	8:02:00	Yes	No
Green Beach	August 17-18	15	8:02:00	No	No
Green Beach	August 18-19	18	7:37:00	No	No
Green Beach	August 19-20	21	7:54:00	Yes	Yes
Total	**9 nights**	**9 sonobuoys**	**67:34:00**	**6**	**1**

Note:
The Blue/Red Beach mooring site was latitude 18.1351 and longitude 145.7586; the Green Beach mooring site was latitude 18.1235 and longitude 145.7541.

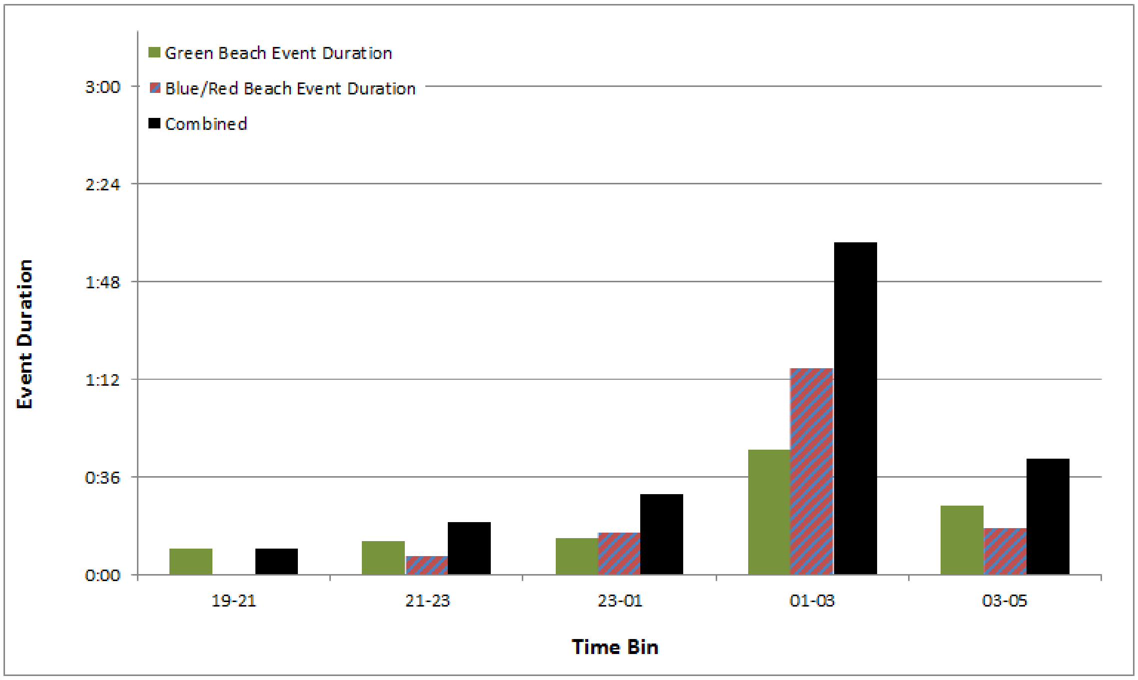


Figure 3-6. Cumulative Durations of Dolphin Vocalization Events in 3-Hour Bins

Event duration (y axis) represents cumulative time of vocalizations per bin. Time bins (x axis) are two-hour bins starting at a point between 7:00 and 9:00 p.m. local-time and ending at between 3:00 and 5:00 a.m. the next morning. The bin with the greatest time with vocalizations is 1:00 to 3:00 a.m.

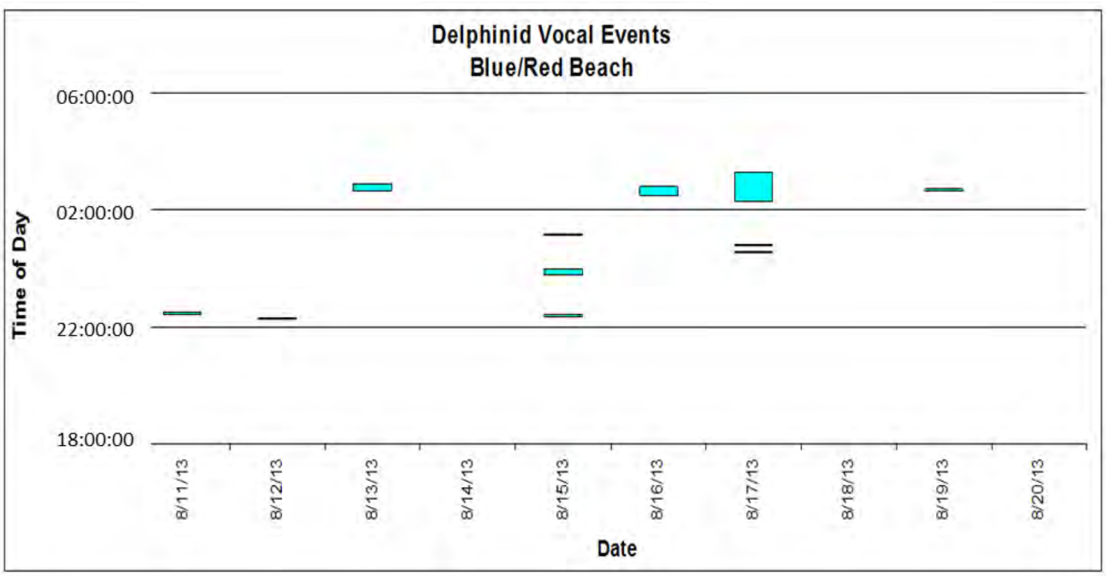


Figure 3-7. Plots of Dolphin Vocalizations During Nighttime Sonobuoy Deployments at Blue/Red Beach

The date is plotted on the x axis, and the time (7:00 p.m. on each day to 6:00 a.m. the next morning) is plotted along the y axis. In general, sonobuoys were deployed between approximately 7:00 p.m. and 9:00 p.m., and the recording was ended between 3:00 a.m. and 5:00 a.m. the next morning. This is because the sonobuoys were programmed to scuttle after eight hours of operation. This type of graph is useful to visually detect diel patterns in activity.

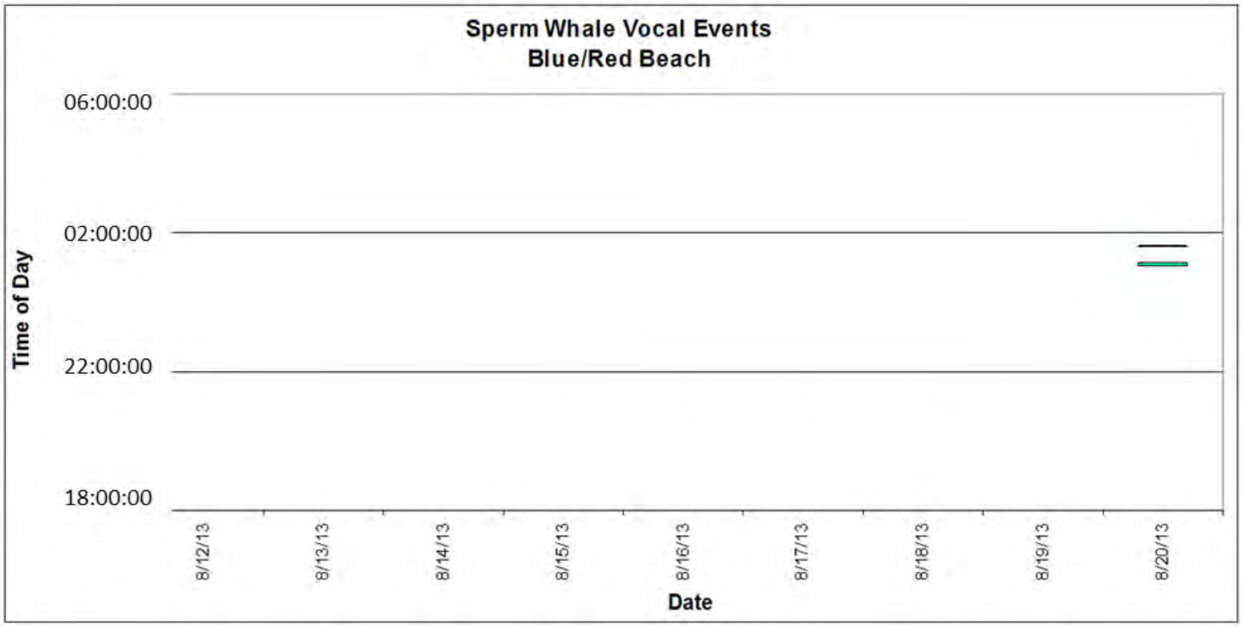


Figure 3-8. Plots of Sperm Whale Vocalizations During Nighttime Sonobuoy Deployments at Blue/Red Beach

The date is plotted on the x axis and the time (7:00 p.m. on each day to 6:00 a.m. the next morning) is plotted along the y axis. In general, sonobuoys were deployed between 7:00 and 9:00 p.m., and recording ended between 3:00 and 5:00 a.m. the next morning. This is because the sonobuoys were programmed to scuttle after eight hours of operation. This type of graph is useful to visually detect diel patterns in activity.

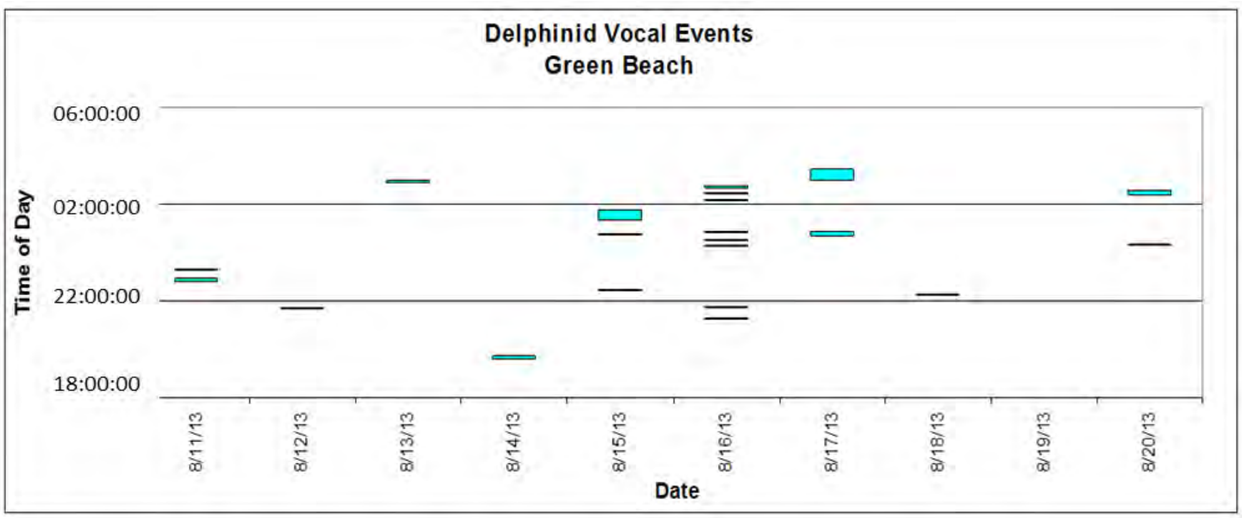


Figure 3-9. Plots of Dolphin Vocalizations Recorded During Nighttime Sonobuoy Deployments at Green Beach

The date is plotted on the x axis, and time (7:00 p.m. on each day to 6:00 a.m. the next morning) is plotted along the y axis. In general, sonobuoys were deployed between approximately 7:00 p.m. and 9:00 p.m., and recording was ended between 3:00 a.m. and 5:00 a.m. the next morning. This is because the sonobuoys were programmed to scuttle (sink) after eight hours of operation. This type of graph is useful to visually detect diel patterns in activity.

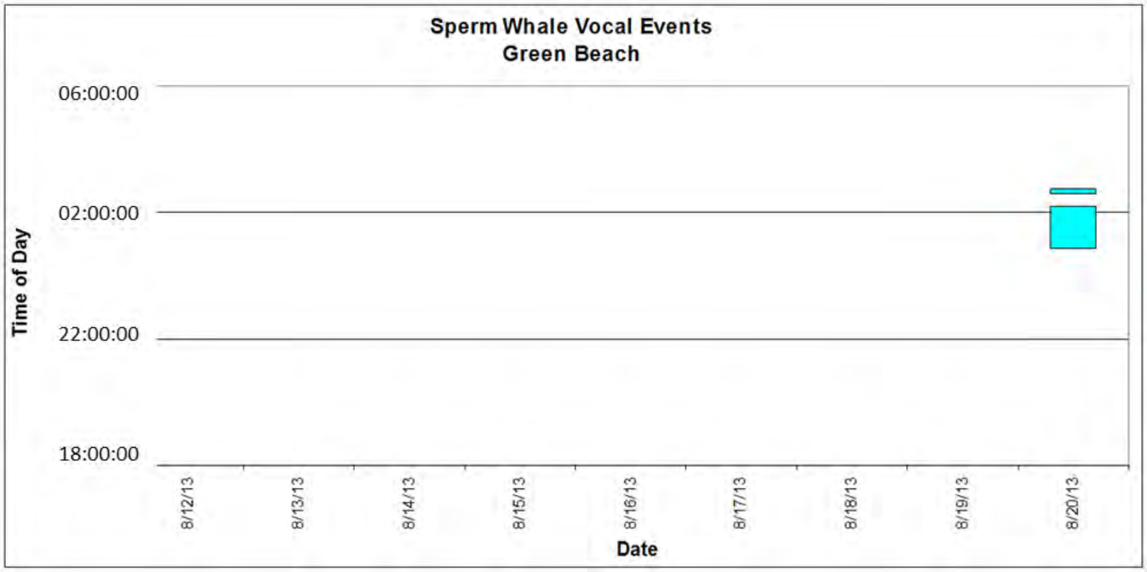


Figure 3-10. Plots of Sperm Whale Vocalizations During Nighttime Sonobuoy Deployments at Green Beach

The date is plotted on the x axis and the time (7:00 p.m. on each day to 6:00 a.m. the next morning) is plotted along the y axis. In general, sonobuoys were deployed between 7:00 and 9:00 p.m., and recording ended between 3:00 and 5:00 a.m. the next morning. This is because the sonobuoys were programmed to scuttle after eight hours of operation. This type of graph is useful to visually detect diel patterns in activity.

3.3 SAIPAN

3.3.1 Saipan Visual Results

One RHIB survey of the leeward side of Saipan was conducted on August 24. One sighting of spinner dolphins was made at 3:20 pm local time at 15.864°N and 148.8294°E. This was near the northern tip of the island, close to shore (Figure 3-11). One juvenile was observed in the group of 28 (4% of the group). The dolphins engaged in milling, bow riding, spinning, and other aerial behaviors. Four individuals were photo-identified.

3.3.2 Saipan Acoustic Results

Ten minutes of acoustic recordings were obtained of this group (Appendix E).

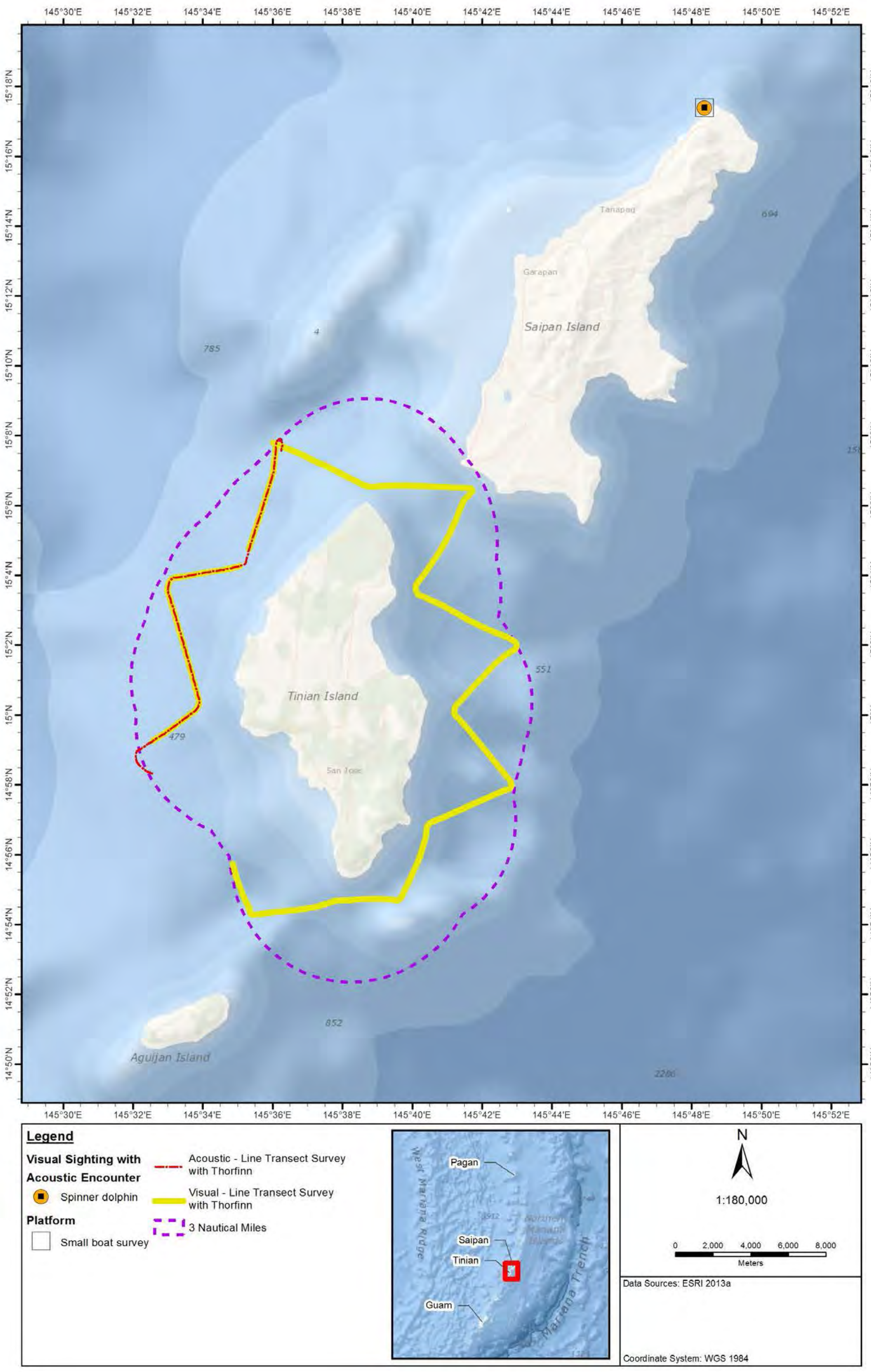


Figure 3-11. Transect Line Surveyed around Tinian and the Location of the Sighting near Saipan

The transect lines around Tinian were surveyed on August 7. The opportunistic survey around Saipan was conducted on August 24. There were no systematic survey lines around Saipan. A "visual sighting with acoustic encounter" means the animal was detected both visually and acoustically.

This page is intentionally left blank.

CHAPTER 4 DISCUSSION

4.1 LINE TRANSECT SURVEYS AT PAGAN

The marine mammal line transect survey findings were improved because of a larger data set resulting from combining the methods and results of the visual and acoustic data collection. Generally, acoustic methods resulted in higher detection rates, but the visual methods provided important data on species identity, group size, composition, and surface behavior. The visual data also aided in interpreting the acoustic data. The combined data, yielding twelve groups of marine mammals detected (Table 4-1), are more informative than when examined by separate methods.

Table 4-1. Visual Sightings and Acoustic Encounters During Line Transect Surveys

Species	**Thorfinn** ***Line Transect Visual Sightings and Acoustic Encounters***			
	Acoustic and Visual	***Acoustic Only***	***Visual Only***	***Total Sightings and Encounters***
Bottlenose dolphin	1	0	0	1
Spinner dolphin	1	0	0	1
Cuvier's beaked whale	0	1	1	2
Blainville's beaked whale	0	2	0	2
Unidentified dolphin	1	5	0	6
TOTAL	**3**	**8**	**1**	**12**

These data provide important preliminary detection rates for the more common species of marine mammals at Pagan. The visual and acoustic detection rates from this survey for marine mammal groups are relatively low (Table 3-3, Section 3.2.6), except for beaked whales (see Section 4.3) suggesting low densities of marine mammals at Pagan. However, caution is recommended in overinterpreting this result and the low sighting and encounter rates should not be equated to low abundance or absence of marine mammals. The low total number of sightings and encounters most likely reflects the limited data obtained as a result of the reduced number of line transects accomplished (full line transect survey effort occurred on four days and on a fifth day there was 2-hours of effort, due to vessel constraints).

These surveys reveal important information about the distribution and occurrence of several marine mammal species. In particular, beaked whales and sperm whales were not expected to occur in these types of nearshore habitats.

These data were collected during a single month, August; therefore, seasonal variation in distribution or the presence of winter/spring migratory species, such as baleen whales, is undetermined without further surveys. Notably, humpback whales are known to occur in the CNMI waters during winter (Darling and Mori 1993; Morse et al. 2008; Fulling et al. 2011).

4.2 ISLAND-ASSOCIATED DOLPHINS

The potential of island-associated populations of dolphins was considered important to assess in this project because the CJMT is limited to nearshore activities, and this information will fill a previous data gap. On 10 of the 11 research days at Pagan, dolphins were sighted or encountered acoustically within the study area (Tables 3-1, 3-8, and 3-12). Sightings and encounters occurred in both shallow and deeper waters and at locations all around the island (Figures 3-1 and 3-5).

There is evidence of both daytime (from visual surveys) and nighttime (from sonobuoy recordings) presence of dolphins in the waters next to Blue Beach, Red Beach, and Green Beach. Bottlenose dolphins were sighted off Blue Beach on August 13, spinner dolphins off Green Beach on August 15 and 20, and unidentified dolphins off Green Beach on August 14. Analysis of the acoustic data from the moored sonobuoys next to the beaches showed that vocalizations, most likely spinner or bottlenose dolphins (see below), were detected almost every night. They were most concentrated around the 1:00 a.m. to 3:00 a.m. period (Figures 3-7, 3-8, and 3-10). The sonobuoys usually stopped working between 3:00 a.m. and 5:00 a.m., so it is possible that the last period would have had more vocalizations if the sonobuoy transmissions were not truncated by the eight-hour scuttle setting.

Noise from snapping shrimp resulted in poor signal-to-noise ratio in the moored sonobuoy recordings; consequently, it was not possible to identify the vocalizations to the species level using ROCCA. Based on sightings made during the daytime, it is likely that the nighttime unidentified dolphin vocalizations were produced by spinner dolphins, bottlenose dolphins, or both species.

In general, the vocalization activity patterns correspond with what would be expected if the dolphins moved offshore at night to feed. This has been demonstrated to occur for both spinner and bottlenose dolphins in the main Hawaiian Islands (Norris and Dohl 1980; Norris et al. 1994; Benoit-Bird and Au 2003; Lammers 2004). In these studies, researchers described resting and foraging patterns by spinner dolphins at Hawaii and Oahu. They found that animals rested in shallow nearshore water during the day, became more active toward the afternoon and evening, and eventually moved offshore at night to feed. The data analyzed by Norris et al. (1994) indicated that the dolphins were less active acoustically during the daytime, especially while resting. Norris et al. (1994) noted that the dolphins were more active acoustically at dusk before departing offshore to forage and at night when they were presumed to be foraging. Lammers (2004) also described spinner dolphin behaviors off Oahu, in which schools moved toward the 100-fathom (183-meter) contour in the late afternoon. Often they were joined by aggregations of bottlenose and pantropical spotted dolphins, with which they made extended dives in coordinated groups, presumably to forage.

These findings suggest that using moored passive acoustic monitoring during the day, night, and especially in the late afternoon could provide information about 24-hour vocalization patterns. More information is needed on species identity of vocalizations, more precise animal locations, and movement patterns at night to better understand the distribution and behaviors of dolphins associated with Pagan Island.

Results of the photo-ID analyses indicate that spinner dolphins identified at Pagan on August 13 were resighted on August 14. These resighting data are limited, but do suggest residency. Individuals moved between groups on the two days; not all four dolphins that were resighted were seen with the same associates the following day. This is consistent with a fission/fusion society, which is characterized by primarily short-term social bonds. Fission/fusion societies have been documented for island-associated spinner dolphin populations around the main Hawaiian Islands (Würsig et al. 1994; Lammers 2004).

An actively breeding and possibly resident population of bottlenose dolphins is likely present at Pagan, based on the presence of three calves (including neonates) in a group sighted at Blue Beach. Bottlenose dolphin mothers need easy access to prey while nursing, which would be provided in the relatively more productive nearshore waters surrounding a volcanic island, compared to the less productive offshore waters. Pagan's isolated setting in oligotrophic (less productive) waters is comparable to the situation in the Hawaiian Islands, where bottlenose dolphins are highly associated with islands (Baird et al. 2009). Baird postulated that the productive waters of the islands encourage the development of island-associated populations. If so, this same situation may hold true for Pagan, as well as some of the other Mariana Islands.

The data collected during this effort indicate that the spinner dolphins and bottlenose dolphins detected were closely associated with nearshore island habitat around Pagan. While all the evidence suggests that these are island-associated dolphins, it is also possible that dolphins from an offshore population may occasionally occur in Pagan's nearshore waters. More information about the occurrence and identity (via photographs) of animals from both nearshore *and* offshore regions is needed to determine if there is significant overlap between animals in nearshore and offshore areas.

4.3 BEAKED WHALES

Beaked whale distribution and abundance is poorly known for the Northern Mariana Islands (Geo-Marine 2005; DoN 2007, 2013a; Fulling et al. 2011; Baumann-Pickering et al. 2012). Before this study, there was no information on beaked whales near Pagan; therefore, the sighting and acoustic encounters of beaked whales within 3 nautical miles (5.6 kilometers) of Pagan is considered significant.

A total of five beaked whale groups were detected during the survey at Pagan, all in deep water (> 984 feet [> 300 meters]) and close to shore. Research around the main Hawaiian Islands indicate Blainville's Beaked Whale prefer deep water where they are found typically in water depths of 2,297- 3,281 feet (700–1000 meters), usually well offshore. However, around the Canary Islands, Blainville's Beaked Whales have been sighted regularly in shallower waters (mean depth 1,050 feet [320 meters]) and relatively close to shore (mean distance 14,436 feet [4.4 kilometers]; Ritter and Brederlau 1999).

The unidentified beaked whales acoustically encountered during the survey were identified to species after post-processing the echolocation clicks (Table 3-11; Figure 3-6). Based on the documented or expected geographic distribution of beaked whales, there are several additional species that could occur in waters around Pagan that must also be considered (Table 1-1): Deraniyagala's beaked whale (*M. hotaula*), ginkgo-toothed beaked whale (*M. ginkgodens*), and Longman's beaked whale (*Indopacetus pacificus*; DoN 2013a). We are confident that the unidentified beaked whales clicks detected during the survey were produced by Cuvier's and Blainville's beaked whales. This is based on an expert bioacoustician's review of the information extracted from the clicks recorded during this study and a comparison of recorded click characteristics from these other species and from descriptions in the scientific literature.

Although both Cuvier's and Blainville's beaked whales are expected to occur in the Mariana Islands area (Geo-Marine 2005), there are few documented sightings of Cuvier's beaked whales (Mobley 2007) and none of Blainville's beaked whales (Table 1-1; DoN 2013a). However, a recent analysis of acoustic data documented the presence of Blainville's beaked whales, Cuvier's beaked whales, and an unidentified species of beaked whale (Baumann-Pickering et al. 2012). These data were collected from autonomous recorders deployed at two deep-water locations on the seafloor, 7 nautical miles (13 kilometers) northeast of Tinian and 22 nautical miles (40.7 kilometers) northwest of Saipan. Based on expert classification of clicks, Blainville's beaked whales were determined to be the most frequently detected species of beaked whale at both locations (S. Baumann-Pickering, personal communication, November 6, 2013).

It is interesting that both of these species occurred within 3 nautical miles (5.6 kilometers) of shore. Based on satellite tagging data of Blainville's beaked whales around the islands of Hawaii, Schorr et al. (2009) calculated a mean distance from shore of 10.5 miles (17 kilometers; range 0.04 to 47 kilometers) and a mean depth of 3,793 feet (1,156 meters), with a depth range of 46 to 11,253 feet (14 to 3,430 meters). However, many of the satellite tag derived locations were quite close to shore (< 3 miles [5 kilometers]), especially along the south side of the island, where the slope is very steep.

Around the western Canary Island of La Gomera, Blainville's beaked whales have been sighted regularly in shallower waters (mean depth = 1,050 feet [320 meters]) and relatively close to shore (mean distance = 2.4 nautical miles [4.4 kilometers], standard deviation = 1.0 nautical mile [1.85 kilometers]; Ritter and Brederlau 1999). Both of these islands are of volcanic origin, with steep slopes close to shore, similar to the marine environment off Pagan. Further research would be needed to clarify the distribution and abundance of these typically deep-water species in the waters around Pagan.

Blainville's beaked whales may be common in the Pagan study area. This is indicated by the relatively high encounter rates for beaked whales in the acoustic data collected during the towed hydrophone array surveys. Cuvier's beaked whales may also be common, based on the fact that they were encountered independently on two occasions, once visually and once acoustically. The acoustic data collected during this effort may indicate that the beaked whales (particularly Blainville's beaked whales) may forage in this area or that both Blainville's and Cuvier's beaked whales may be closely associated with nearshore island habitat around Pagan. At the Hawaiian Islands, island-associated Blainville's and Cuvier's beaked whales are present in all seasons, suggesting residency (Baird et al 2013; McSweeney et al 2007).

4.4 SPERM WHALES

A brief series of vocalizations attributed to sperm whales was detected at both moored sonobuoy deployment sites between 12:00 a.m. and 3:00 a.m. on August 20. Based on well-known habitat preferences for sperm whales, the animals were presumed to have been located in deep water offshore (> 1,640 feet [> 500 meters]; Jaquet and Whitehead 1996; Table 3-12). A similar but more obvious pattern of sperm whale vocalizations that peaked during the night was evident in a recent analysis of data from seafloor recorders. These were deployed in deep waters just off the continental slope near Jacksonville, Florida (Norris et al. 2012c).

The detection of sperm whale clicks from sonobuoys for this study, which were deployed in only 98-feet (30-meter) waters, suggests that it is possible to acoustically detect marine mammals in deeper waters offshore (> 1,640 feet [> 500 meters]). Generally, acoustic detection ranges for sperm whale clicks are much greater—up to tens of miles (Barlow and Taylow 2005; Norris et al. 2012a)—than whistles produced by dolphins (Rankin et al. 2008). The 1,640 feet (500-meter) depth isopleth occurs close to shore around Pagan (Figure 2-3); therefore, sperm whales can occur within 20 nautical miles (37 kilometers) of Pagan, yet still be in deep water. However, with the sonobuoy methods used in this study, it was not possible to estimate the locations of vocalizing animals. Additional sampling over more days, in more locations, and using localization methods would help to answer these questions.

4.5 CONCLUSIONS

The marine mammal survey collected new information on the marine mammal fauna in nearshore waters at Pagan. Good sea conditions during the survey, combined with an experienced and efficient field survey team, contributed to this success. Before this survey, virtually nothing was known about the biology of marine mammals at Pagan.

The survey included both visual and passive acoustic methods. Five species of marine mammals were documented in the study area: common bottlenose dolphins, spinner dolphins, Cuvier's beaked whales, Blainville's beaked whales, and sperm whales.

On 10 of the 11 research days at Pagan, dolphins were visually sighted or acoustically encountered in the study area. Dolphins were documented in the waters next to Blue Beach, Red Beach, and Green Beach during both daytime (from visual surveys) and nighttime (from sonobuoy recordings). Based on survey results, there are preliminary indications that at least two species, bottlenose and spinner dolphins, are presumably island-associated populations, similar to what has been documented for these two species off the main Hawaiian Islands. Results of the photo-ID analyses indicate that spinner dolphins identified at Pagan on August 13 were also present on August 14; these resighting data are limited but suggest residency. A breeding and possibly resident population of bottlenose dolphins was documented at Pagan based on the presence of three calves (including neonates) in a group sighted at Blue Beach.

Unexpectedly, three of the species detected at Pagan—Cuvier's beaked whales, Blainville's beaked whales, and sperm whales—are considered deep-water species (e.g., they are typically observed at depths > 984 to 1,640 feet [> 300 to 500 meters]), and not expected to occur regularly nearshore. The moderately high detection rates of beaked whale species in nearshore waters off Pagan was unexpected, but may be explained by the existence of deep-water habitat very close to shore due to the steep slopes of the volcanic island. Sperm whale vocalizations were detected on sonobuoys deployed within 0.25 miles of shore; however, these could not be localized, so their distance from shore remains uncertain.

Visual and acoustic detection rates were calculated for the four most common species identified at Pagan: spinner dolphins, bottlenose dolphins, Cuvier's beaked whales, and Blainville's beaked whales. These data provide important preliminary detection rates for marine mammals at Pagan. The visual and acoustic detection rates for spinner and bottlenose dolphins were relatively low. Caution should be used in interpreting any of the detection rate results due to the small sample size.

The density or abundance of marine mammals in the study area could not be estimated because the sample sizes were too low, which in turn would make density or abundance calculations unreliable (i.e., they would have a high degree of uncertainty). If future surveys are conducted, using similar methods and platform heights, the line transect survey data can be pooled with future data collected to estimate density and abundance.

Basic group composition and behavior data were collected and presented in Chapter 3, characterizing the groups found at Pagan and providing baseline data for future studies. Photo-ID data, information on movements, and individual mammal's use of the area, will be added to existing photo-ID catalogs and databases held by the Pacific Islands Fisheries Science Center (NOAA). These data can be used in future analysis of potential movements of dolphins identified near Pagan to other islands in the Marianas. The photo-ID data also can be used in any future capture-recapture analysis to determine population size for these dolphins.

In summary, the August 2013 marine mammal survey provided important new information and contributed significantly to the understanding of marine mammals at Pagan and the Northern Mariana Islands.

CHAPTER 5
LIST OF REFERENCES

Andrews, K. R., L. Karczmarski, W. W. L. Au, S. H. Rickards, C. A. Vanderlip, C.A., and R. J. Toonen. 2006. "Patterns of diversity of the Hawaiian spinner dolphin (*Stenella longirostris*)." Atoll Research Bulletin 543:65-73.

Aschettino, J. M., R. W. Baird, D. J. McSweeney, D. L. Webster, G. S. Schorr, J. L. Huggins, K. K. Martien, and S. Mahaffy. 2011. Population structure of melon-headed whales (*Peponocephala electra*) in the Hawaiian Archipelago: Evidence of multiple populations based on photo-identification. Marine Mammal Science DOI: 10.1111/j.1748-7692.2011.00517.x

Au, D. W. K., and W. L. Perryman. 1985. "Dolphin habitats in the eastern tropical Pacific." Fishery Bulletin 83:623-643.

Baird, R. W., A. M. Gorgone, D. J. McSweeney, A. D. Ligon, M. H. Deakos, D. L. Webster, G. S. Schorr, et al. 2009. "Population structure of island-associated dolphins: evidence from photo-identification of common bottlenose dolphins (*Tursiops truncatus*) in the main Hawaiian Islands." Marine Mammal Science 25:251-274.

Baird, R.W., A. M. Gorgone, D. J. McSweeney, D. L. Webster, D. R. Salden, M. H. Deakos, A. D. Ligon, G. S. Schorr, J. Barlow, and S. D. Mahaffy. 2008a. False killer whales (*Pseudorca crassidens*) around the main Hawaiian Islands: long-term site fidelity, inter-island movements, and association patterns. Marine Mammal Science 24: 591-612.

Baird, R. W., G. S. Schorr, D. L. Webster, J. McSweeney, B. Hanson, and R. D. Andrews. 2011. Movements of two satellite-tagged pygmy killer whales (*Feresa attenuata*) off the island of Hawai'i. Marine Mammal Science DOI: 10.1111/j.1748-7692.2010.00458.x

Baird, R. W., D. L. Webster, J. M. Aschettino, G. S. Schorr, and D. J. McSweeney. 2013. "Odontocete cetaceans around the Main Hawaiian Islands: Habitat use and relative abundance from small-boat sighting surveys." Aquatic Mammals 39(3): 253-269.

Baird, R. W., D. L. Webster, S. B. Mahaffy, D. J. McSweeney, G. S. Schorr, and A.L. Ligon. 2008b. Site fidelity and association patterns in a deep-water dolphin: Rough-toothed dolphins (*Steno bredanensis*) in the Hawaiian Archipelago. Marine Mammal Science 24: 535-553.

Barkley, Y., J. N. Oswald, J. V. Carretta, S. Rankin, A. Rudd, and M. O. Lammers. 2011. Comparison of real-time and post-cruise acoustic species identification of dolphin whistles using ROCCA (Real-time Odontocete Call Classification Algorithm). NOAA technical memorandum NOAA-TM-NMFS-SWFSC-473. National Marine Fisheries Service, La Jolla, California.

Barlow, J., and B. L. Taylor. 2005. "Estimates of sperm whale abundance in the northeastern temperate Pacific from a combined acoustic and visual survey." Marine Mammal Science 21(3):429-445.

Baron, S. C., A. Martinez, L. P. Garrison, and E. O. Keith. 2008. "Differences in acoustic signals from delphinids in the western North Atlantic and northern Gulf of Mexico." Marine Mammal Science 24:42-56.

Baumann-Pickering, S, M. A. McDonald, A. E. Simonis, A. Solsona-Berga, K. P. B. Merkens, E. M. Oleson, M. A. Roch, et al. 2013. “Species-specific beaked whale echolocation signals.” The Journal of the Acoustical Society of America 134:2293-2301.

Baumann-Pickering, S., A. E. Simonis, M. A. Roch, M. A. McDonald, A. Solsona-Berga, E. M. Oleson, S. M. Wiggins, et al. 2012. “Spatio-temporal patterns of beaked whale echolocation signals in the North Pacific.” International Whaling Commission, Panamá, Panamá.

Benoit-Bird, K. J., and W. W. L. Au. 2003. “Prey dynamics affect foraging by a pelagic predator (*Stenella longirostris*) over a range of spatial and temporal scales.” Behavioral Ecology and Sociobiology 53:364-373.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. *Introduction to Distance Sampling: Estimating Abundance of Biological Populations*. Oxford University Press.

Carretta, J. V. et al. 2013. U.S. Pacific marine mammal stock assessments: 2012. NOAA Technical Memorandum NMFS-SWFSC 504.

Chivers, S. J., R. W. Baird, D. J. McSweeney, D. L. Webster, N. M. Hedrick, and J. C. Salinas. 2007. Genetic variation and evidence for population structure in eastern North Pacific false killer whales (*Pseudorca crassidens*). Canadian Journal of Zoology 85: 783-794.

Cox, T. M., T. J. Ragen, A. J. Read, E. Vos, R. W. Baird, K. Balcomb, J. Barlow, et al. 2006. “Understanding the impacts of anthropogenic sound on beaked whales.” Journal of Cetacean Research and Management 7(3):177-187.

Darling, J. D., and K. Mori. 1993. “Recent observations of humpback whales (*Megaptera novaeangliae*) in Japanese waters off Ogasawara and Okinawa.” Canadian Journal of Zoology 71:325-333.

Ding, W., B. Würsig, and W. E. Evans. 1995. Whistles of bottlenose dolphins: comparisons among populations. Aquatic Mammals 21: 65-77.

DoN (Department of the Navy). 2007. Marine Mammal and Sea Turtle Survey and Density Estimates for Guam and the Commonwealth of the Northern Mariana Islands. Final Report Contract No. N68711-02-D-8043. Prepared for U.S. Navy, NAVFAC Pacific, by SRS-Parsons Joint Venture, Geo-Marine, Inc., and Bio-Waves, Inc. MISTCS Survey Report. http://www.nmfs.noaa.gov/pr/pdfs/permits/mirc_mistcs_report.pdf. August 2007.

_____. 2013a. Mariana Islands Marine Mammal Data Gap Analysis, p. 27. Prepared for U.S. Navy, NAVFAC Pacific by Tetra Tech, Oakland, in association with Bio-Waves, Inc., and Clymene Enterprises, Inc., under contract to SEI and AECOM-TEC/JV. March 2013.

_____. 2013b. Mariana Islands Training and Testing (MITT) Activities Draft Environmental Impact Statement/Overseas Environmental Impact Statement. Prepared for U.S. Navy NAVFAC Pacific. http://mitt-eis.com/DocumentsandReferences/EISDocuments/DraftEISOEIS.aspx. September 2013.

_____. 2013c. Final CJMT Marine Mammal Work Plan. Prepared for U.S. Navy NAVFAC Pacific by Tetra Tech, in association with Bio-Waves, Inc., and Clymene Enterprises, Inc., under contract to SEI and AECOM-TEC/JV. September 2013.

_____. 2014. Final CJMT Sea Turtle Survey Report. Prepared by Tetra Tech, Oakland, under contract to SEI and AECOM-TEC/JV, for U.S. Navy, NAVFAC Pacific. March 2014.

Donaldson, T. J. 1983. "Further investigations of the whales *Peponocephala electra* and *Globicephala macrorhynchus* reported from Guam." Micronesica 19:173-181.

Eldredge, L. G. 1991. "Annotated checklist of marine mammals of Micronesia." Micronesica 24:217-230.

_____. 2003. "The marine reptiles and mammals of Guam." Micronesica 35, 36:653-660.

ESRI. 2013a. Ocean basemap. Geospatial data. Contributors: ESRI, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames. org, et al. http://www.arcgis.com/features/maps/basemaps.html. March 2013.

_____. 2013b: Topographic basemap. Geospatial data. Contributors: ESRI, DeLorme, HERE, TomTom, Intermap, Increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, ESRI Japan, METI, ESRI China (Hong Kong), swisstopo, MapmyIndia, and the GIS User Community. http://www.arcgis.com/features/maps/basemaps.html. December 2013.

_____. 2013c: Light gray canvas basemap. Geospatial data. Contributors: ESRI, DeLorme, and NAVTEQ. http://www.arcgis.com/features/maps/basemaps.html.

Fulling, G. L., P. H. Thorson, and J. Rivers. 2011. "Distribution and Abundance Estimates for Cetaceans in the Waters off Guam and the Commonwealth of the Northern Mariana Islands." Pacific Science 65(3):321-343.

Geo-Marine, Inc. 2005. Marine Resources Assessment for the Marianas Operating Area: Final Report. Department of the Navy. Unpublished contract report.

Gillespie, D. M., J. Gordon, R. McHugh, D. McLaren, D. Mellinger, P. Redmond, A. Thode, et al. 2008. "PAMGUARD: Semiautomated, open source software for real-time acoustic detection and localisation of cetaceans." Proceedings of the Institute of Acoustics, 30, Part 5.

HDR. 2011. Guam Marine Species Monitoring Survey: Vessel-Based Monitoring Surveys Winter 2011. Unpublished contract report.

_____. 2012. Guam and Saipan Marine Species Monitoring: Winter-Spring Survey 15-29 March. Unpublished contract report.

Hill, M., A. Ligon, M. H. Deakos, A. U, E. Norris, and E. Oleson. 2012. Cetacean surveys of Guam and CNMI waters: August - September, 2011. Pacific Islands Fisheries Science Center Data Report DR-12-002.

Hill, M., A. Ligon, M. H. Deakos, A. U, A. Milette-Winfree, and E. Oleson. 2013. Cetacean surveys of Guam and CNMI waters: May-July, 2012. Pacific Islands Fisheries Science Center Data Report DR-13-001.

Jaquet, N., and H. Whitehead. 1996. "Scale-dependent correlation of sperm whale distribution with environmental features and productivity in the South Pacific." Marine ecology progress series. Oldendorf, 135(1):1-9.

Jefferson, T. A., D. Fertl, M. Michael, and T. D. Fagin. 2006. "An unusual encounter with a mixed school of melon-headed whales (*Peponocephala electra*) and rough-toothed dolphins (*Steno bredanensis*) at Rota, Northern Mariana Islands." Micronesica 38:239-244.

Johnson, M., P. T. Madsen, W. M. X. Zimmer, N. Aguilar de Soto, and P. L. Tyack. 2004. "Beaked whales echolocate on prey." Proceedings of the Royal Society, London, Series B, Supplement 6 271:383-386.

Kami, H. T., and A. J. Hosmer. 1982. "Recent beachings of whales on Guam." Micronesica 18:133-135.

Kami, H. T., and R. J. Lujan. 1976. "Records of the dwarf sperm whale *Kogia simus* from Guam." Micronesica 12:327-332.

Karczmarski, L., B. Wursig, G. Gailey, K. W. Larson, and C. Vanderlip. 2005. "Spinner dolphins in a remote Hawaiian atoll: Social grouping and population structure." Behavioral Ecology 16:675-685.

Lammers, M. O. 2004. "Occurrence and behavior of Hawaiian spinner dolphins (*Stenella longirostris*) along Oahu's leeward and south shores." Aquatic Mammals 30:237-250.

Ligon, A. D., M. H. Deakos, and A. D. U. 2011. Small-boat cetacean surveys off Guam and Saipan, Mariana Islands, February - March 2010. Unpublished contract report.

Marques, T. A, L. Thomas, S. W. Martin, D. K. Mellinger, J. A. Ward, D. J. Moretti, D. Harris, and P. L. Tyack. 2013. "Estimating animal population density using passive acoustics." Biological Reviews, 88:287-309.

Masaki, Y. 1972. "Tagging investigations of whales in Ogasawara and Mariana Islands." Geiken-Tsushin 249:35-42.

McSweeney, D. J., R. W. Baird, and S. D. Mahaffy. 2007. "Site fidelity, associations, and movements of Cuvier's (*Ziphius cavirostris*) and Blainville's (*Mesoplodon densirostris*) beaked whales off the Island of Hawaiʻi." Marine Mammal Science 23:666-687.

Miyashita, T., H. Kato, and T. Kasuya. 1995. Worldwide Map of Cetacean Distribution Based on Japanese Sighting Data. National Research Institute of Far Seas Fisheries.

Miyashita, T., T. Kishiro, N. Higashi, F. Sato, K. Mori, and H. Kato. 1996. "Winter distribution of cetaceans in the western North Pacific inferred from sighting cruises 1993-1995." Reports of the International Whaling Commission 46:437-442. Shimizu, Japan.

Miyazaki, N., and S. Wada. 1978. "Observation of Cetacea during whale marking cruise in the western tropical Pacific, 1976." Scientific Reports of the Whales Research Institute 30:179-195.

Mobley, J. R. 2007. Marine mammal monitoring surveys in support of "Valiant Shield" training exercises (August 13-17, 2007). Final report.

Morse, L., T. Norris, A. Azzara, and A. Pack. 2008. "First recordings of humpback whale songs in the northern Mariana Islands." Second International Conference on Acoustic Communication by Animals, pp. 151-152. Oregon State University, Corvallis. Extended abstract. August 12-15, 2008.

Morisaka, T., M. Shinohara, F. Nakahara, and T. Akamatsu. 2005. "Geographic variations in the whistles among three Indo-Pacific bottlenose dolphin *Tursiops aduncus* populations in Japan." Fisheries Science 71:568-576.

NOAA (National Oceanic and Atmospheric Administration). 2007a. Gridded multibeam bathymetry of Tinian and Aguijan Islands and Tatsumi Bank, Commonwealth of the Northern Mariana Islands. Pacific Island Fisheries Science Center, Coral Reef Ecosystem Division, Pacific Islands Benthic Habitat Mapping Center. http://www.soest.hawaii.edu/pibhmc. Geospatial data. November 2007.

_____. 2007b. Gridded multibeam bathymetry of Pagan Island, Commonwealth of the Northern Mariana Islands. Pacific Island Fisheries Science Center, Coral Reef Ecosystem, Division Pacific Islands Benthic Habitat Mapping Center. http://www.soest.hawaii.edu/pibhmc. Geospatial data. November 2007.

Norris, K. S., and T. P. Dohl. 1980. "Behavior of the Hawaiian spinner dolphin, *Stenella longirostris*." Fishery Bulletin 77:821-849.

Norris, K. S., B. Würsig, R. S. Wells, and M. Würsig. 1994. *The Hawaiian Spinner Dolphin*. University of California Press, Berkeley.

Norris, T., L. Morse, A. Azzara, and T. Yack. 2008. "Acoustic detections of minke whale 'boings' during a winter-spring survey indicate distribution, occurrence, population structure and possible reproductive behaviors of minke whales in the Northern Mariana Islands in the western North Pacific Ocean." Second International Conference on Acoustic Communication by Animals. Pp.167-168. Oregon State University, Corvallis. Extended abstract. August 12-15, 2008.

Norris, T.F., J. Oswald, T. Yack, E. Ferguson, C. Hom-Weaver, K. Dunleavy, S. Coates and T. Dominello. 2012a. An Analysis of Acoustic Data from the Mariana Islands Sea Turtle and Cetacean Survey (MISTCS). Prepared for Commander, Pacific Fleet, Pearl Harbor, Hawaii. Submitted to Naval Facilities Engineering Command Pacific (NAVFAC), EV2 Environmental Planning, Pearl Harbor, Hawaii, under Contract No. N62470-10D-3011 CTO KB08, Task Order #002 issued to HDR, Inc. Submitted by Bio-Waves Inc., Encinitas, California.

Norris, T., S. Martin, L. Thomas, T. Yack, J. N. Oswald, E. M. Nosal, and V. M. Janik. 2012b. Acoustic ecology and behavior of minke whales in the Hawaiian and Mariana Islands: Localization, abundance estimation, and characterization of minke whale boings. *In:* A. N. Popper and A. Hawkings (editors), The Effects of Noise on Aquatic Life, pp. 149-153. New York, New York: Springer Science.

Norris, T. F., J. O. Oswald, T. M. Yack, and E. L. Ferguson. 2012c. An Analysis of Marine Acoustic Recording Unit (MARU) Data Collected off Jacksonville, Florida in Fall 2009 and Winter 2009-2010. Final Report. Submitted to Naval Facilities Engineering Command (NAVFAC) Atlantic, Norfolk, Virginia, under Contract No. N62470-10-D-3011, Task Order 021, issued to HDR Inc., Norfolk, Virginia. Prepared by Bio-Waves Inc., Encinitas, California.

Ohizumi, H., T. Matsuishi, and H. Kishino. 2002. "Winter sightings of humpback and Bryde's whales in tropical waters of the western and central North Pacific." Aquatic Mammals 28:73-77.

Ohsumi, S., and Y. Masaki. 1975. "Japanese whale marking in the North Pacific, 1963-1972." Bulletin of the Far Seas Fisheries Research Laboratory 12:171-219.

Oleson, E. M., and M. C. Hill. 2010. 2010 Report to PACFLT: Report of Cetacean Surveys in Guam, CNMI, and the High-seas and Follow up on 2009 Main Hawaiian Islands Cetacean Survey. Unpublished contract report.

Oswald, J. N., S. Rankin, J. Barlow, and M. O. Lammers. 2007. "A tool for real-time acoustic species identification of delphinid whistles." Journal of the Acoustical Society of America 122:587-595.

Oswald, J. N., S. Rankin, J. Barlow, M. Oswald, and M. O. Lammers. 2013. Real-time Call Classification Algorithm (ROCCA): software for species identification of delphinid whistles. Pp. 245-266. *In:* O. Adam and F. Samaran (editors). Detection, Classification and Localization of Marine Mammals using Passive Acoustics, 2003-2013: 10 years of International Research. DIRAC NGO, Paris, France.

Randall, R. H., R. T. Tsuda, R. S. Jones, M. J. Gawel, J. A. Chase, and R. Rechebei. 1975. Marine biological survey of the Cocos Barrier Reefs and enclosed lagoon. University of Guam Marine Laboratory Technical Report 17.

Rankin, S., J. N. Oswald, and J. Barlow. 2008. "Acoustic behavior of dolphins in the Pacific Ocean: Implications for using passive acoustic methods for population studies." Canadian Acoustics, 36(1):88-92.

Rendell, L. E., J. N. Matthews, A. Gill, J. C. D. Gordon, and D. W. MacDonald. 1999. "Quantitative analysis of tonal calls from five odontocete species, examining interspecific and intraspecific variation." Journal of Zoology 249:403-410.

Ritter, F., and B. Brederlau. 1999. Behavioural observations of dense beaked whales *(Mesoplodon densirostris)* off La Gomera, Canary Islands (1995-1997). *Aquatic Mammals*. 25 (2):55-61.

Schorr G. S., R. W. Baird, M. B. Hanson, D. L. Webster, D. J. McSweeney, and R. D. Andrews. 2009. "Movements of the satellite tagged Blainville's beaked whales off the island of Hawai'i." Endangered Species 10:203-213.

Shimada, H., and T. Miyashita. 2001. Report of the sighting surveys for winter distribution of large cetaceans in the low latitudinal waters of the western North Pacific, 1999-2001. International Whaling Commission/SC/RMP 10.

Soto, N. H., M. Johnson, P. T. Madsen, P. L. Tyack, and A. Bocconcelli. 2006. "Does intense ship noise disrupt foraging in deep-diving Cuvier's beaked whales (*Ziphius cavirostris*)?" Marine Mammal Science 22(3):690-699.

Townsend, C. H. 1935. "The distribution of certain whales as shown by logbook records of American whaleships." Zoologica 19:3-50.

Trianni, M. S., and C. C. Kessler. 2002. "Incidence and strandings of the spinner dolphin, *Stenella longirostris*, in Saipan Lagoon." Micronesica 34:249-260.

Trianni, M. S., and M. C. Tenorio. 2012. "Summary of recorded cetacean strandings in the Commonwealth of the Northern Mariana Islands." Micronesica 43:1-13.

Tyack P. L., W. M. X. Zimmer, D. Moretti, B. L. Southall, D. E. Claridge, J. W. Durban, C. W. Clark, et al. 2011. "Beaked whales respond to simulated and actual Navy sonar." PLoS ONE 6(3):e17009. doi:10.1371/journal.pone.0017009.

Wiggins, S. 2007. Triton (Version 1.80; acoustic processing software). Scripps Institution of Oceanography, University of California San Diego, La Jolla. www.cetus.ucsd.edu.

Wiles, G. J. 2005. "A checklist of the birds and mammals of Micronesia." Micronesica 38:141-189.

Würsig, B., and T. A. Jefferson. 1990. "Methods of photo-identification for small cetaceans." Reports of the International Whaling Commission (Special Issue) 12:43-52.

Würsig, B., R. S. Wells, M. Würsig, and K. S. Norris. 1994. "Population structure." *In: The Hawaiian Spinner Dolphin*, 1st edition. K. S. Norris, B. Würsig, R. S. Wells, M. Würsig, S. M. Brownlee, C. M. Johnson, and J. Solow (editors). University of California Press, Berkeley. Pp. 122-140.

Yack, T. M. 2013. "The development of automated detection techniques for passive acoustic monitoring as a tool for studying beaked whale distribution and habitat preferences in the California current ecosystem." University of California Davis. PhD dissertation.

Yack, T. M., J. Barlow, J. Calambokidis, B. Southall, and S. Coates. 2013. "Identification of previously unknown beaked whale habitat in the Southern California Bight using a towed hydrophone array." The Journal of the Acoustical Society of America 134(3):2589-2595.

Yamaguchi, M. 1995. The study of humpback whales in the northern Mariana Islands, Annual Report 1995. Submitted to the Commonwealth of the Northern Mariana Islands, Division of Fish and Wildlife, Department of Natural Resources. Unpublished manuscript.

_______. 1996. The study of humpback whales in the Mariana Islands, Annual Report 1996. Submitted to the Commonwealth of the Northern Mariana Islands, Division of Fish and Wildlife, Department of Natural Resources. Unpublished manuscript.

Yamaguchi, M., J. M. Acebes, and Y. Miyamura. 2002. The breeding ground distribution of the humpback whale (*Megaptera novaeangliae*) in the western North Pacific and their trans-movements among the Ogasawara Islands, the Ryukyu Islands and the Babuyan Islands, Philippines. Unpublished abstract.

This page is intentionally left blank.

APPENDIX A

List of Preparers and
Biosketches of Key Marine Mammal Field Survey Personnel

This page is intentionally left blank.

List of Preparers

Name	*Affiliation*	*Contact*	*Role*
Ann Zoidis	Tetra Tech, Inc.	ann.zoidis@tetratech.com	Project manager/author/ quality control
Emmy Andrews	Tetra Tech, Inc.	emmy.andrews@tetratech.com	Deputy project manager/quality control
Paula Olson	Tetra Tech, Inc.	paula.olson@tetratech.com	Lead author
Thomas A. Jefferson	Clymene Enterprises	sclymene@aol.com	Author of line transect sections
Thomas Norris	Bio-Waves, Inc.	thomas.f.norris@bio-waves.net	Author of acoustic sections
Tina Yack	Bio-Waves, Inc.	tina.yack@bio-waves.net	Author of acoustic sections
Julie Oswald	Bio-Waves, Inc.	julie.oswald@bio-waves.net	Author of acoustic sections
Ann Roseberry Lincoln	Tetra Tech, Inc.	ann.lincoln@tetratech.com	Author/quality control
Joel Peters	Tetra Tech, Inc.	joel.peters@tetratech.com	GIS/Figures
Kate Lomac-MacNair	Tetra Tech, Inc.	kate.MacNair@tetratech.com	Author/quality control
Shannon Coates	Bio-Waves, Inc.	shannon.coates@bio-waves.net	Author of acoustic sections
Elizabeth Ferguson	Bio-Waves, Inc.	eferguson@bio-waves.net	Author of acoustic sections

Marine Mammal Survey Personnel

Role	*Survey Staff*
Project Manager, Marine Mammal Observer	Ann Zoidis
Chief Scientist, Marine Mammal Observer	Thomas A. Jefferson
Acoustic Lead	Thomas Norris
Cruise Leader, Marine Mammal Observer	Paula Olson
Cruise Manager, Marine Mammal Observer, Tetra Tech Site Safety Coordinator	Kate Lomac-MacNair
Marine Mammal Observer	Mark Cotter
Marine Mammal Observer, Acoustic Support	Maren Anderson
Marine Mammal Observer	Tom Kieckhefer
Marine Mammal Observer	Allan Ligon
Marine Mammal Observer	Morgane Lauf
Acoustic Observer	Jeff Jacobson
Acoustic Observer	Shannon Coates
AECOM Representative	Andrea Von Burg Hall
SEI Representative, EMT	Kamalu Souza

Biosketches of Marine Mammal Field Survey Personnel

Ann Zoidis

Ms. Zoidis has been an environmental consultant at Tetra Tech for eighteen years and has over thirty years of scientific experience as a wildlife biologist specializing in marine mammal research and impact assessment. She has designed and managed field projects or surveys all over the United States and the world, many in remote areas. She is a trained marine mammal observer and has worked from a variety of platforms (vessel, aerial, and shore stations). She also is a NMFS Office of Protected Resources permit holder for marine mammal research, and is the principal investigator for a long-term underwater study of acoustic calls and behaviors of the humpback whale. As one of Tetra Tech's senior biologists and project managers, she brings extensive biological and regulatory knowledge to her projects, along with considerable experience managing complicated field projects. Much of Ms. Zoidis' scientific work has focused on biological monitoring, behavioral research, and acoustic studies of many different cetacean species, bird species, and various terrestrial mammal species. The emphasis of her work has been on the effects of ecosystem disturbance on animal behavior, especially anthropogenic disturbance, and assessing related impacts. During her years with Tetra Tech, she has managed numerous projects for NAVFAC Pacific, the U.S. Coast Guard, NOAA, the U.S. Army Corps of Engineers, the Bureau of Reclamation, the Ports of San Francisco and Oakland, the U.S. EPA, and other agencies. Ms. Zoidis recently managed numerous large biological assessments for different agencies. She has an extensive professional background that includes first or co-authorship on peer-reviewed marine mammal publications, as well as project management, public involvement, and public speaking. She is also a skilled technical editor and leads the company-wide Tetra Tech marine mammal team. She is a Principle Investigator with her own National Marine Fisheries Service Office of Protected Research marine mammal research permit and has led many marine mammal studies, including her ongoing studies of Hawaiian humpback whales dating from 1996. Her degrees include a Master of Science from San Francisco State University in physiology and behavioral biology and a BA from Smith College in Geology.

Dr. Thomas A. Jefferson

Dr. Jefferson has been studying marine mammals since 1983 as an undergraduate. His main interests are the development of marine mammal identification aids and the systematics and population ecology of the more poorly known species of dolphins and porpoises. Essentially all of his work for the past 30 years has been on conservation and management of marine mammals threatened by human activities. Since 1995, he has worked in Southeast Asia and has traveled widely in the region. His current primary research focuses on the conservation biology of Indo-Pacific humpback dolphin (*Sousa chinensis*) and finless porpoise (*Neophocaena phocaenoides*) populations in Hong Kong and surrounding waters. Dr. Jefferson is also working on other projects, looking at the systematics and ecology of these species throughout their ranges. In addition, he is involved in the conservation of the critically endangered vaquita (*Phocoena sinus*) and on the taxonomy and population ecology of common dolphins (*Delphinus* spp.). With co-authors Marc Webber and Robert Pitman, he published a comprehensive identification guide to the marine mammals of the world (Academic Press, 2008). He has worked with Tetra Tech on marine mammal projects since 2008 under his affiliation of director of Clymene Enterprises. His degrees include a Ph.D. from Texas A&M, a Master of Science from Moss Landing Marine Labs, San Jose State University and BA from UC Santa Cruz.

Paula A. Olson

Ms. Olson is a cetacean biologist with over 25 years of experience studying whale and dolphin populations in all of the world's oceans. She is an expert in field taxonomy and in field surveys, especially in remote area marine research. With a research focus on population abundance and structure, Ms. Olson has worked on projects for the International Whaling Commission, the International Union for the Conservation of Nature, the National Marine Fisheries Service, and other international, national, and private research organizations. She has co-authored over 40 scientific papers, among them six papers focused on the distribution of dolphin species in the eastern tropical Pacific. Ms. Olson has previously led six shipboard field teams in the tropical Pacific, including a survey in 2010 in the waters of the southern Mariana Islands. She is a lead on the Tetra Tech marine mammal team. Her degrees include a Master of Marine Affairs from the University of Rhode Island and a BA from the University of Maine.

Thomas R. Kieckhefer

Mr. Kieckhefer received his Master's degree in Marine Science through Moss Landing Marine Laboratories/San Jose State University in 1992. His thesis was titled "The Feeding Ecology of Humpback Whales in Continental Shelf Waters near Cordell Bank, California, 1988-1990." He also has his BA in zoology from University of Hawaii, Manoa. He has over 30 years of research and education experience in the marine mammal field. His research includes several marine species, from humpback whales, killer whales, bottlenose dolphins, Dall's and vaquita porpoises, elephant seals, and sea otters to schooling fish and krill. His special skills are RHIB outfitting, handling, and navigation; marine mammal aerial/boat-based surveys, photo ID, and dissections; scuba; underwater marine environmental survey techniques; and outreach education, program development, and website design and management. His special interests include the study of marine ecology, bioacoustics, communication, diving physiology, predator-prey relationships, and educating the public about marine mammals, their environment, and preservation. He is a lead on the Tetra Tech marine mammal team.

Kate Lomac-MacNair

Ms. Lomac-MacNair's education and work history has focused on marine biology with an emphasis on marine mammal resources. Previously, Ms. Lomac-MacNair has been project manager of several Alaska-based marine mammal surveys and is adept in all aspects of planning and execution of marine surveys. While working at Tetra Tech, Ms. Lomac-MacNair has gained experience implementing the National Environmental Policy Act. She has also worked on EISs, Biological Assessments, IHAs, and other marine resource assessments, including those for NAVFAC Pacific. She is a lead on the Tetra Tech marine mammal team and has been working on Tetra Tech marine mammal projects since 2008. She is an experienced marine mammal observer and has worked on marine mammal surveys from various platforms, including aerial, shore, and vessel-based studies. She is also an AAUS-certified research scuba diver. She is currently acquiring her Master's degree from John Hopkins University.

Maren Anderson

Ms. Anderson has training and experience pertinent to the environmental field, with an emphasis in ecology, evolutionary biology, and marine biology. She has obtained research and writing skills through higher education and work experience in the fields of biology and conservation. Her education and previous work have focused on mountain and stream biology and marine biology, with an emphasis on coral reef ecology and marine mammal resources. Throughout her career and education, Ms. Anderson has gained valuable experience working with marine mammals in a variety of capacities, including rescue and rehabilitation of pinnipeds and cetaceans in California, Florida, and Hawaii, and cognitive research with cetaceans in Florida. She is a trained marine mammal observer and has worked on surveys from various platforms, including aerial, shore, and vessel-based studies. Ms. Anderson has gained experience implementing the National Environmental Policy Act and the California Environmental Quality Act, and has worked on several large EIS's, biological assessments, EAs, and marine resource assessment projects.

She is a member of the Tetra Tech marine mammal team and has been working on Tetra Tech marine mammal projects since 2005. Ms. Anderson is a trained coral reef research and rescue scuba diver. She has a BA in ecology and evolutionary biology.

Andrea Von Burg Hall

Ms. Von Burg Hall is an experienced technician and project manager for AECOM and has conducted human health and ecological risk assessments for a wide range of environmental pollutants. In addition, she is experienced in marine ecology and is an AAUS-certified research scuba diver. This has enabled her to conduct underwater surveys of coral reefs for the DoN and other institutions. Ms. Hall acted as AECOM's corporate representative for the CJMT marine mammal survey. Her degrees include a Master of Science in risk assessment and regulatory toxicology from Tulane University and a Bachelor of Science in marine biology from Fairleigh Dickinson University.

Mark Cotter

Mr. Cotter is a marine mammal biologist, with an educational background in biology and oceanography. His primary research focuses on the social ecology and population dynamics of cetaceans. He is an experienced marine species observer, having worked on numerous surveys from multiple ocean platforms, including both small and large vessels. He is also an experienced aerial survey observer. Mr. Cotter is an experienced RHIB operator and photo-identification specialist, in addition to planning and executing cetacean RHIB survey logistics. Mark is a member of the Tetra Tech marine mammal team and has been working on Tetra Tech marine mammal projects since 2013. His degrees include a BS in biological sciences from the University of Amherst and he is currently in the process of acquiring his Ph.D. from University of Massachusetts in Marine Science.

Allan Ligon

Mr. Ligon is an accomplished field biologist with 16 years experience conducting photo-ID, biopsy sampling, and satellite tagging for a variety of marine mammal research projects. He is a skilled RHIB operator. His background also includes work as an observer for line transect surveys aboard large oceanographic research vessels. In recent years his research focus has been on the population assessment, distribution, and diving behavior of cetaceans in the Central and Western tropical Pacific, including the Mariana Islands. Allan is a member of the Tetra Tech marine mammal team and has been working on Tetra Tech marine mammal projects since 2013. He is a co-author on four papers about dolphins in the Hawaiian and Mariana Islands.

Morgane Lauf

Ms. Lauf has a BS in biology and experience in field research, ecology, genetics, and veterinary medicine. She gained experience in field work in Argentina as a boat-based marine mammal observer, photographer, and naturalist. Most recently an intern for Clymene Enterprises, she has just been hired by the Genetics Department at Southwest Fisheries Science Center as a member of the marine mammal genetics group.

Thomas Norris

Mr. Norris is the founder and president of Bio-Waves, Inc. He has over 20 years of research experience in the marine and biological sciences, with a focus on marine bioacoustics and the effects of noise on living marine resources. Mr. Norris has served as the principal investigator on over 15 research projects. He has developed and implemented a variety of new technologies to study large marine vertebrates, including passive and active acoustic technologies. Mr. Norris has conducted research for a variety of organizations, including the U.S. government (e.g., NOAA, U.S. Navy, and the U.S. Coast Guard), universities (UCSD, UCSC, Columbia University, Texas A&M, Oregon State University), and the private sector. Most recently Mr. Norris has led projects investigating the acoustic ecology and behavior of minke whales in the Pacific Islands (sponsored by DoN/ONR) and analyzing data from autonomous recorder arrays off the Atlantic coast (sponsored by DoN/NavFac Atlantic). He has authored and co-authored numerous scientific reports and publications. Mr. Norris holds a Masters in Science from San Jose State University's Moss Landing Marine Laboratory, and a BA in Zoology (aquatic science emphasis) from UC Santa Barbara.

Shannon Coates

Ms. Coates has been working at Bio-Waves since 2010, where she works as a data-analyst and field bioacoustician. She earned a BS from San Diego State University in 2011. Ms. Coates started working with marine mammal bioacoustics when she interned with NOAA's Southwest Fisheries Science Center, where she characterized high-frequency echolocation clicks recorded from Dall's porpoise. Currently, Ms. Coates studies dolphin whistles from the Atlantic and Hawaiian regions. In addition to data analysis work, Ms. Coates has participated in numerous vessel-based visual and acoustic surveys of marine mammals, in such areas as the Gulf of Mexico, the Pacific Northwest, the South Pacific, and the California coast. She has served as a bioacoustician on several field projects. Ms. Coates also has worked as a marine mammal observer on both small and large vessels.

Jeff Jacobsen

Mr. Jacobsen has over 30 years of experience as a biologist working on marine mammal and bird field projects around the North Pacific. For the past 20 years Mr. Jacobsen has dedicated himself to a long-term multifaceted study of the breeding behavior of humpback whales around the Mexican Revillagigedo Islands in the Pacific Ocean. This study included research on humpback whale bioacoustics, population dynamics, and genetics. Mr. Jacobsen designs and fabricates acoustic monitoring technologies and has been instrumental in towed array design and development for Bio-Waves, Inc. Mr. Jacobsen holds a BS in Oceanography and an Masters in Biology from Humboldt State University.

Michael Souza

Mr. Souza is an EMT and marine technician with Sea Engineering and an active member of the Honolulu Fire Department. He has 15 years of field experience as a medical/emergency first responder. From 1998 to 2005, he served first as a lifeguard/water safety instructor for the City and County of Honolulu, and then as an Ocean Safety Officer for the Emergency Services/Ocean Safety Division. From 2005 through the present, Mr. Souza has been a firefighter and is currently serving as Firefighter II for the Honolulu Fire Department. He has worked and performed hazardous rescues at many of Oahu's famous big wave beaches. He has responded to hundreds of emergency situations, including drownings, car accidents, gunshots, water rescues, mountain rescues, helicopter operations, fire suppression, and hazardous material response. Mr. Souza is also a skilled RHIB operator and diver.

This page is intentionally left blank.

APPENDIX B

Photolog

This page is intentionally left blank.

Spinner dolphin (*Stenella longirostris*) in the air, mid-spin

Spinner dolphin exhibiting characteristic long beak and tripartite color pattern

A pair of spinner dolphins

Three spinner dolphins

A pair of bottlenose dolphins (*Tursiops truncatus*); note the characteristic stout beak

A mother/calf pair of bottlenose dolphins

Observers aboard a RHIB, photographing dolphins

Dolphins and a RHIB, with observers, off Pagan

A dolphin off Red Beach (Pagan) with the *Thorfinn* in the background

Observer on watch, searching for marine mammals

Observer on watch, searching for marine mammals

Bio-Waves' primary acoustic array, towed from behind the *Thorfinn*

Retrieving the towed acoustic array back aboard the *Thorfinn*

Setting up the towed acoustic array on the *Thorfinn*

The acoustic monitoring station aboard the *Thorfinn*

Preparing the sonobuoys for nighttime deployment at the moored sites

Preparing for lid removal of the sonobuoys for nighttime deployment at the moored sites

Preparing the sonobuoy assembly for nighttime deployment at the moored sites

Removing the cap of the sonobuoys in preparation for nighttime deployment at the moored sites

APPENDIX C

Sea Turtle Observations

This page is intentionally left blank.

Sighting data (date, time, position, species, group size, and behavior) were recorded whenever sea turtles were observed opportunistically in the course of marine mammal research. Sea turtles were observed in Saipan Harbor and also off Green and Red Beaches at Pagan (Table C-1). These sighting data are included in an appendix in the CMJT Sea Turtle Survey Report (DoN [Department of the Navy] 2014. Final CJMT Sea Turtle Survey Report. Prepared by Tetra Tech, Oakland, under contract to SEI and AECOM-TEC/JV, for U.S. Navy, NAVFAC Pacific).

Table C-1. Sea Turtle Observations

Date (2013)	*Time*	*Sighting Number*	*Species*	*Location*	*Position*	*Platform*	*Observed During Line Transect?*	*Beaufort Sea State*	*Grou p Size*	*Behavior*
August 9	3:16 p.m.	1	Unidentified hardshell	Saipan	15.2314N, 1457278E	*Thorfinn*	No	2	1	Swimming
August 13	4:34 p.m.	1	Green (*Chelonia mydas*)	Pagan	18.1188N, 145.7633E	*Thorfinn*	No	1	1	ND
August 18	6:20 p.m.	1	Hawksbill (*Eretmochelys imbricata*)	Pagan	18.1333N, 145.0333E	RHIB	No	1	1	ND
August 18	6:24 p.m.	2	Hawksbill (*E. imbricata*)	Pagan	18.1333N, 145.0333E	RHIB	No	1	1	ND

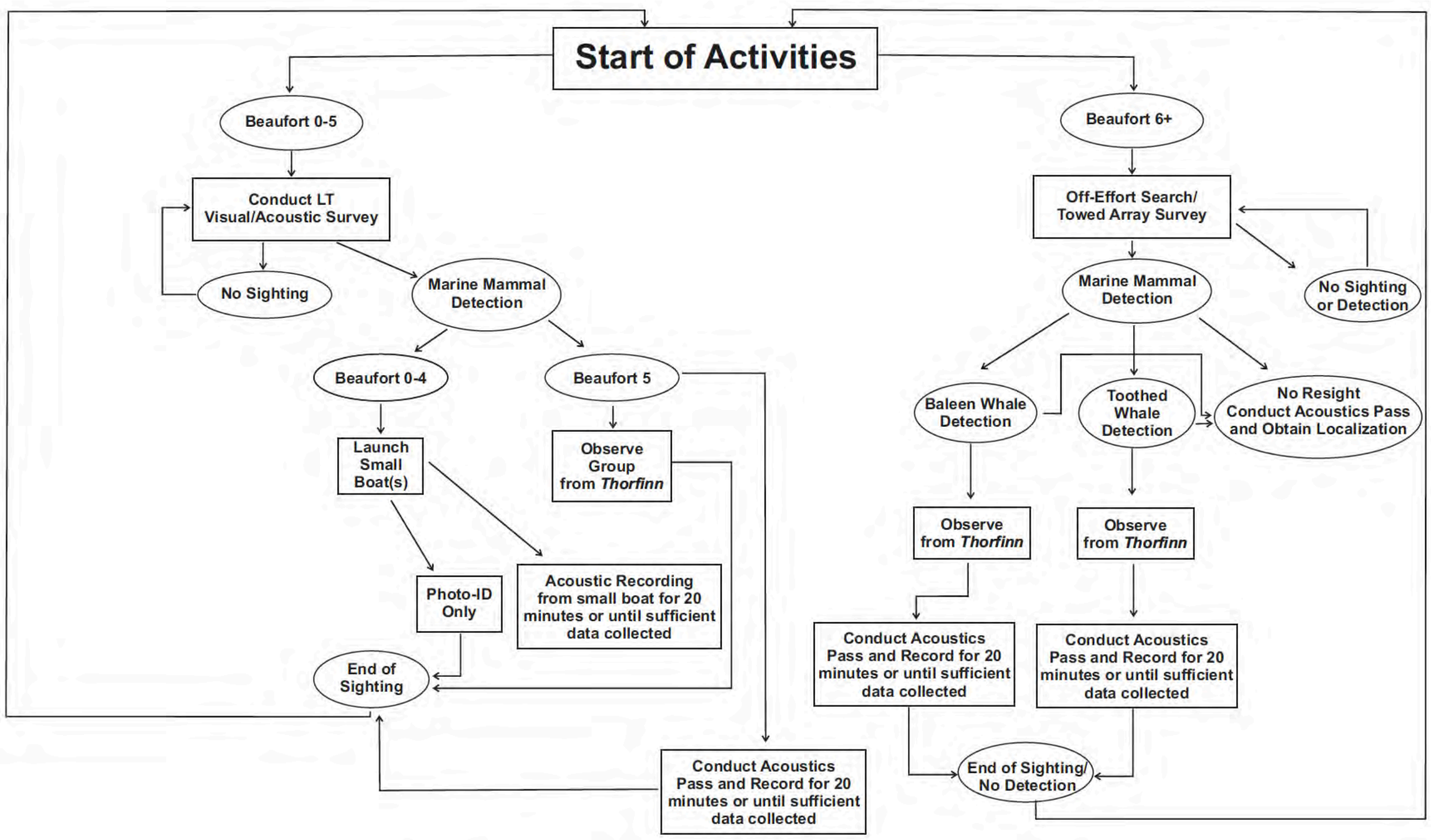
Notes:
This is a numerical identifier; that is, the sighting number is not the same as the number of animals sighted. Each day, sighting numbers began with 1 for the first sighting of the day and continued sequentially throughout the day.
ND = not determined

This page is intentionally left blank

APPENDIX D

Flow Chart for Prioritizing Research Activities

This page is intentionally left blank


Start of Activities
Beaufort 0-5
Beaufort 6+
Conduct LT Visual/Acoustic Survey
Off-Effort Search/ Towed Array Survey
No Sighting
Marine Mammal Detection
Marine Mammal Detection
No Sighting or Detection
Beaufort 0-4
Beaufort 5
Baleen Whale Detection
Toothed Whale Detection
No Resight Conduct Acoustics Pass and Obtain Localization
Launch Small Boat(s)
Observe Group from *Thorfinn*
Observe from *Thorfinn*
Observe from *Thorfinn*
Photo-ID Only
Acoustic Recording from small boat for 20 minutes or until sufficient data collected
Conduct Acoustics Pass and Record for 20 minutes or until sufficient data collected
Conduct Acoustics Pass and Record for 20 minutes or until sufficient data collected
End of Sighting
End of Sighting/ No Detection
Conduct Acoustics Pass and Record for 20 minutes or until sufficient data collected

This page is intentionally left blank

APPENDIX E

Rigid-Hulled Inflatable Boat Acoustics

This page is intentionally left blank

Rigid-Hulled Inflatable Boat (RHIB) Acoustic Methods

RHIB Portable Towed Hydrophone Array

A portable hydrophone array system was deployed from a RHIB (the Passive Acoustic Monitoring [PAM] boat) to obtain high-quality recordings of single species schools of dolphins. The portable array consisted of three hydrophone elements: one mid-frequency (APC) and two high-frequency Reson (R) hydrophones separated by 3.3 feet (1 meter; Table E-1, Figure E-1). The hydrophone array was attached to cable and typically towed at a distance of 131 to 262 feet (40 to 80 meters); however, it could extend to 492 feet (150 meters) behind the PAM boat (Figures E-1 and E-2).

Table E-1. RHIB (Portable) Towed Hydrophone Array Components and Specifications

Hydrophone (Number)	*Manufacturer and Model*	*Spacing (Meters)*	*Usable Frequency Range*
Mid-frequency Hydrophone (1)	APC 42-1021	3.0	250 to 35,000 hertz
High-Frequency Hydrophones (2) and (3)	Reson TC4013	1.0	1,600 to 170,000 hertz

Note:
Hydrophone usable frequency range was estimated from the hydrophone and preamplifier frequency response curves.

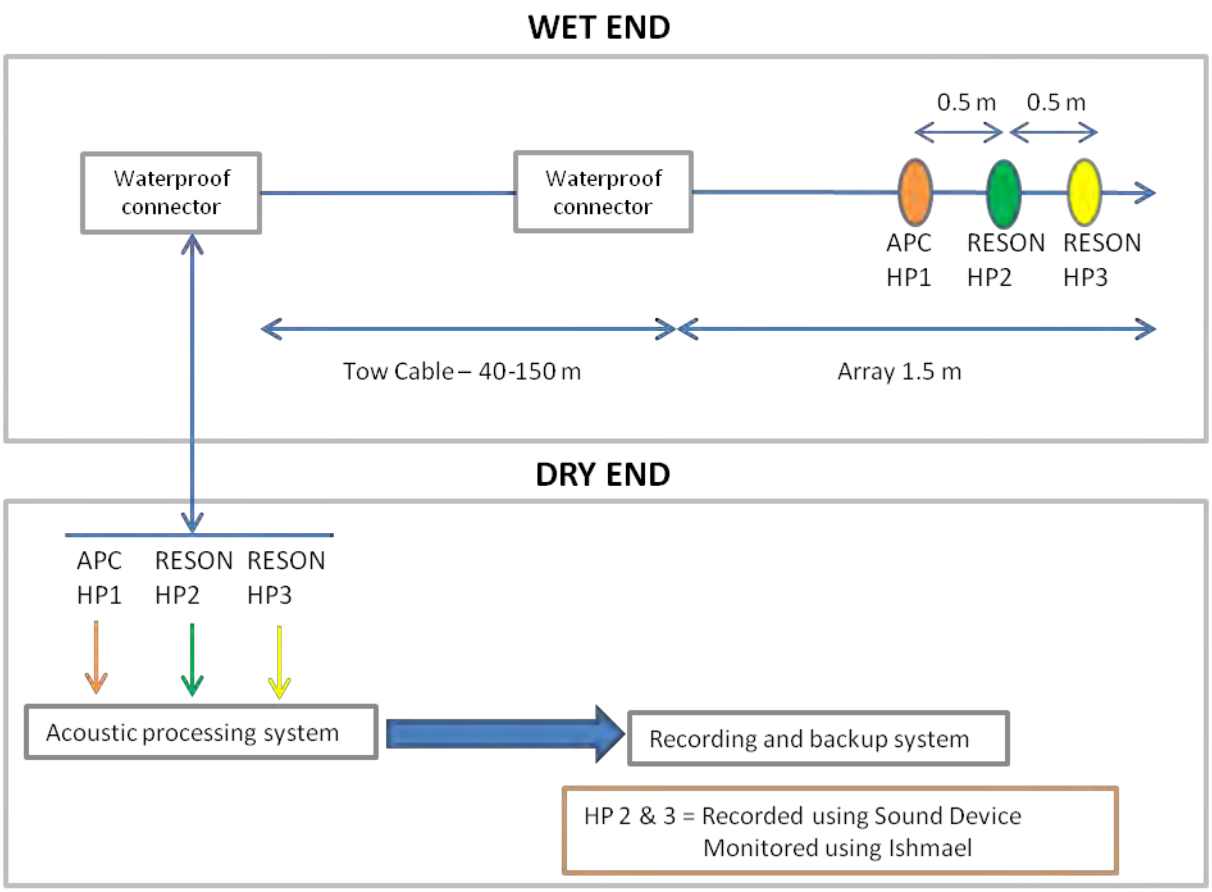


Figure E-1. Schematic of Portable Towed Hydrophone Array System Used on the PAM RHIB

Figure E-2. RHIB Portable Array Deployment and Monitoring

RHIB Portable Hydrophone Array Recording and Monitoring System

Hydrophone signals from the portable array that was deployed from one of the RHIBs (the PAM boat) were monitored both aurally with a headset and visually, as needed, with the software program Ishmael. This program was run on a sunlight-viewable netbook field computer (SOL NetBook; Figures E-2 and E-3). The computer provided a means of visually monitoring high-frequency signals that are above the range of human hearing. Recordings from the portable array were made using a portable digital audio recorder (Sound Devices 744T) at a sample rate of 192 kilohertz. A portable sound card (Babyface RME) was used to digitize the signal (at a sample rate of 192 kilohertz) and interface with the Ishmael software for real-time monitoring. Recordings of visually confirmed, single-species dolphin schools were made for whistle classification (Figure E-3).

Marine mammal observers and photographers onboard another RHIB (the photo-ID boat) visually searched for dolphins along the coast. During this procedure, the PAM boat followed offshore at a distance of up to 0.54 nautical mile (1 kilometer) to minimize any disturbance to marine mammals and to reduce interference with visual operations. When a dolphin group was located, the observers on the photo-ID boat identified the species, estimated group size, recorded observational data, and photographed individuals for identification. The portable array monitored and recorded any detected whistles during these operations. If the whistling group of marine mammals was a single-species school, the whistles were recorded for at least 20 minutes or until the recording quality was considered too poor to be used in post-processing. These recordings provided ground-truthing and augmented the dolphin whistle classifier program, ROCCA. In some cases, the PAM boat approached the dolphin group to obtain better recordings. Recordings from the portable array were copied to a hard drive onboard the *Thorfinn* and archived for later post-processing and analysis.

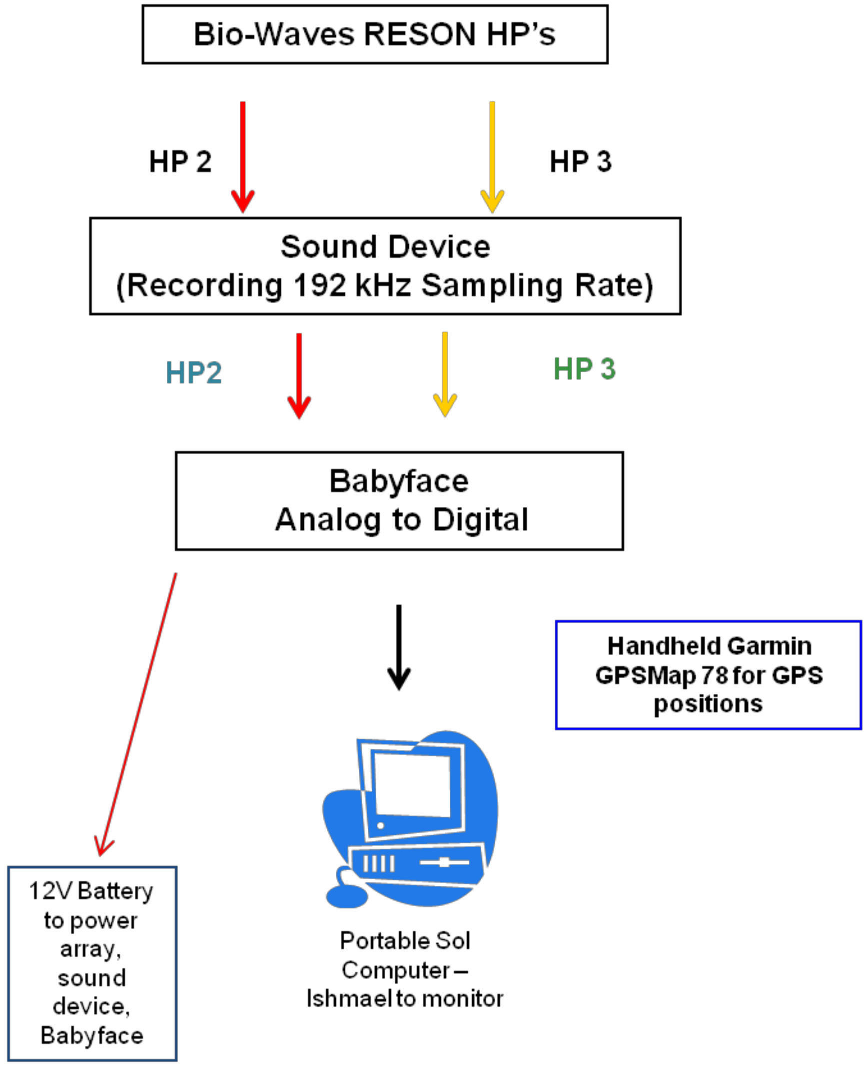


Figure E-3. Portable Hydrophone (HP) Array Monitoring and Recording System

RHIB Passive Acoustic Results

The portable towed hydrophone array proved to be effective in making recordings from the RHIB, even while the boat was motoring to keep up with moving schools of dolphin. Noise from snapping shrimp was problematic because it occasionally obscured possible dolphin vocalizations, but this issue was circumvented by moving into deeper water where snapping shrimp are less common.

Recordings of single-species dolphin schools were made for one school of bottlenose dolphins and five schools of spinner dolphins (Table E-1). The bottlenose dolphin school and four of the spinner schools were encountered at Pagan, and one spinner school was encountered at Saipan.

Table E-2. Species and Number of Whistles Included in the Classifier Training Dataset

Date (2013)	***Location***	***Start Time (Local)***	***Recording Effort (Hours: Minutes: Seconds)***	***Start Latitude (North)***	***Start Longitude (East)***	***Species Encountered***
August 11	Pagan	11:25 a.m.	1:02:00	18.1218	145.7420	None
August 11	Pagan	3:59 p.m.	0:02:00	18.1356	145.7215	None
August 12	Pagan	4:16 p.m.	1:05:00	18.0412	145.6838	None
August 13	Pagan	8:06 a.m.	1:32:00	18.1369	145.7552	Bottlenose dolphins
August 13	Pagan	10:22 a.m.	0:49:00	18.1156	145.8063	Spinner dolphins
August 13	Pagan	12:24 p.m.	0:44:00	18.0716	145.7497	Spinner dolphins
August 14	Pagan	8:46 a.m.	1:10:00	18.1785	145.8243	Spinner dolphins
August 14	Pagan	10:29 a.m.	0:10:00	18.0902	145.8026	None
August 14	Pagan	11:44 a.m.	0:48:00	18.0776	145.7597	Spinner dolphins
August 14	Pagan	1:07 p.m.	0:23:00	18.0456	145.7034	None
August 21	Pagan	8:50 a.m.	2:16:00	18.1170	145.7322	None
August 24	Saipan	3:04 p.m.	0:10:00	15.2598	145.7153	Spinner dolphins

Separate single-species recordings of visually validated bottlenose dolphins (1.53 hours) and spinner dolphins (3.35 hours) were made on five occasions over two days at Pagan. Whistles in the recordings from Pagan were used to validate and improve the ROCCA whistle classifier (Appendix J). Ten minutes of recordings of spinner dolphins at Saipan were not used in the whistle classifier.

Table E-3 presents descriptive statistics for data recorded for the visually confirmed recordings of bottlenose and spinner dolphins. Small sample sizes prohibit statistical comparisons, but qualitatively, starting frequency was higher for bottlenose dolphins and ending frequency was lower for bottlenose dolphins.

Table E-3. Descriptive Statistics for Whistles from Visually-Validated Recordings of Spinner and Bottlenose Dolphins

Species	***n***	***Mean or SD***	***Frequency (kilohertz)***				***Duration (seconds)***	***Number of Steps***	***Number of Inflection Points***
			Max	***Min***	***Beg***	***End***			
Spinner dolphins	100	Mean	17.4	9.6	12.6	15.3	0.68	0.06	2.2
		SD	2.9	2.4	4.4	3.8	0.37	0.24	2.2
Bottlenose dolphins	27	Mean	20.4	10	17.7	11	0.7	0.04	2.7
		SD	3.5	2.1	3.9	3.4	0.39	0.19	3.4

Note:
n = number of whistles; SD = standard deviation; Max = maximum; Min = minimum; Beg = Beginning

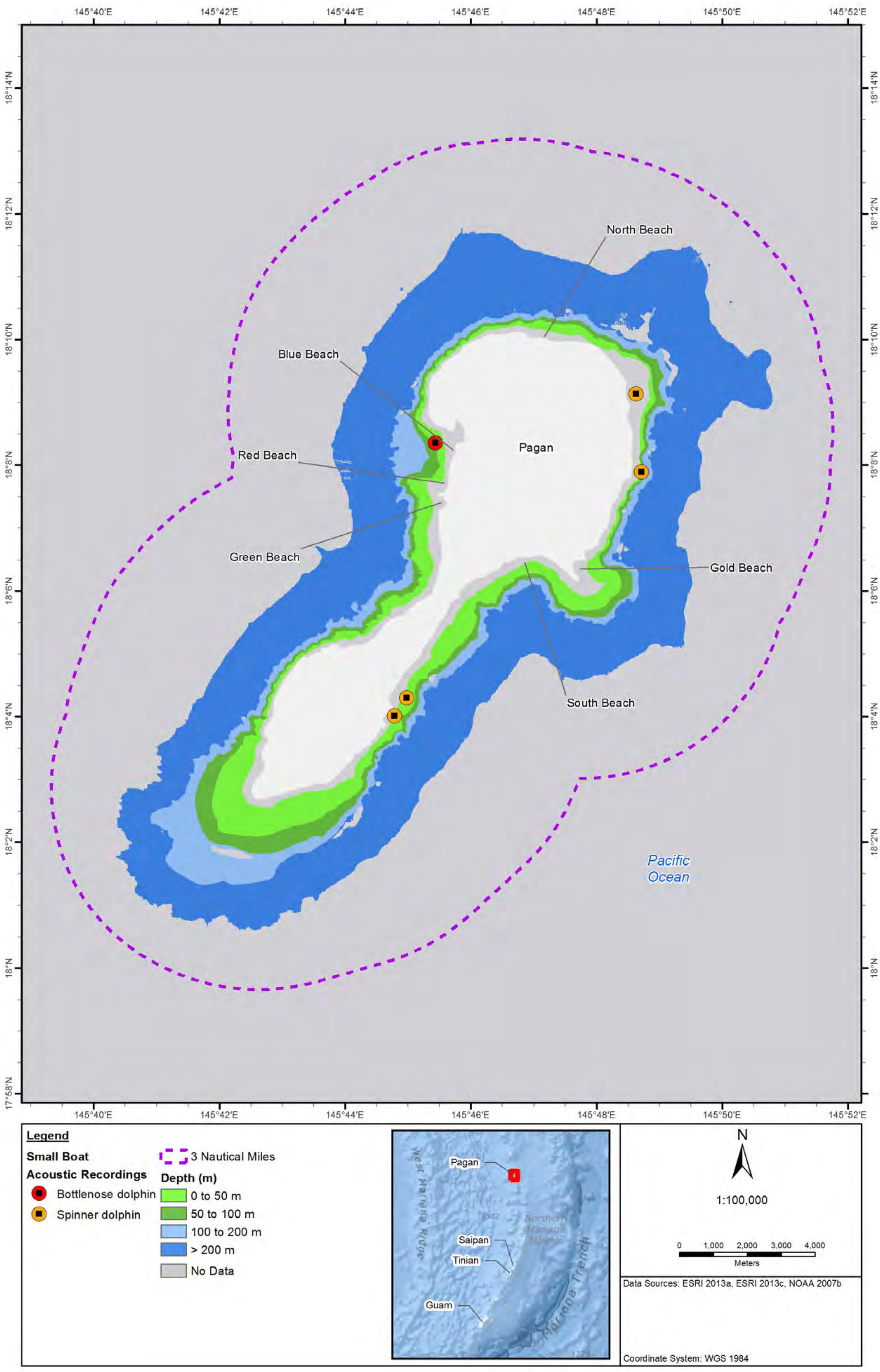


Figure E-4. Acoustic Recordings of Marine Mammal Encounters during RHIB Operations

This page is intentionally left blank

APPENDIX F

Summary of Straight Line Survey at Pagan

This page is intentionally left blank

Summary of Straight Line Survey at Pagan

On August 19, after a full island-circumference line transect survey of Pagan, the remaining three hours of daylight were used to survey waters not previously surveyed. The intention was to provide additional information about the occurrence and distribution of marine mammals in the study area and the waters immediately adjacent, since dolphins may move back and forth between the study area and the waters just outside the 3 nautical mile (5.6 kilometer) circumference line around Pagan. The survey focused on acoustic monitoring using the towed array. The visual team remained on deck to assist with species identifications, should the acoustic team detect any cetaceans.

The *Thorfinn* proceeded offshore in a straight line, from the point where the line transect survey was completed, for approximately 6 nautical miles (11 kilometers) before returning to anchor at Green Beach (Figure F-1). The team surveyed 11.82 nautical miles (21.9 kilometers), of which 3.52 nautical miles (6.52 kilometers) were within 3 nautical miles (5.6 kilometers) of the Pagan coastline, and 8.28 nautical miles (15.33 kilometers) were beyond 3 nautical miles (5.6 kilometers). One group of unidentified dolphins was detected acoustically outside of 3 nautical miles (5.6 kilometers). This group was not visually detected and there were no other sightings. The acoustic encounter rate was 0.56 encounter/hour during the straight line survey.

This page is intentionally left blank

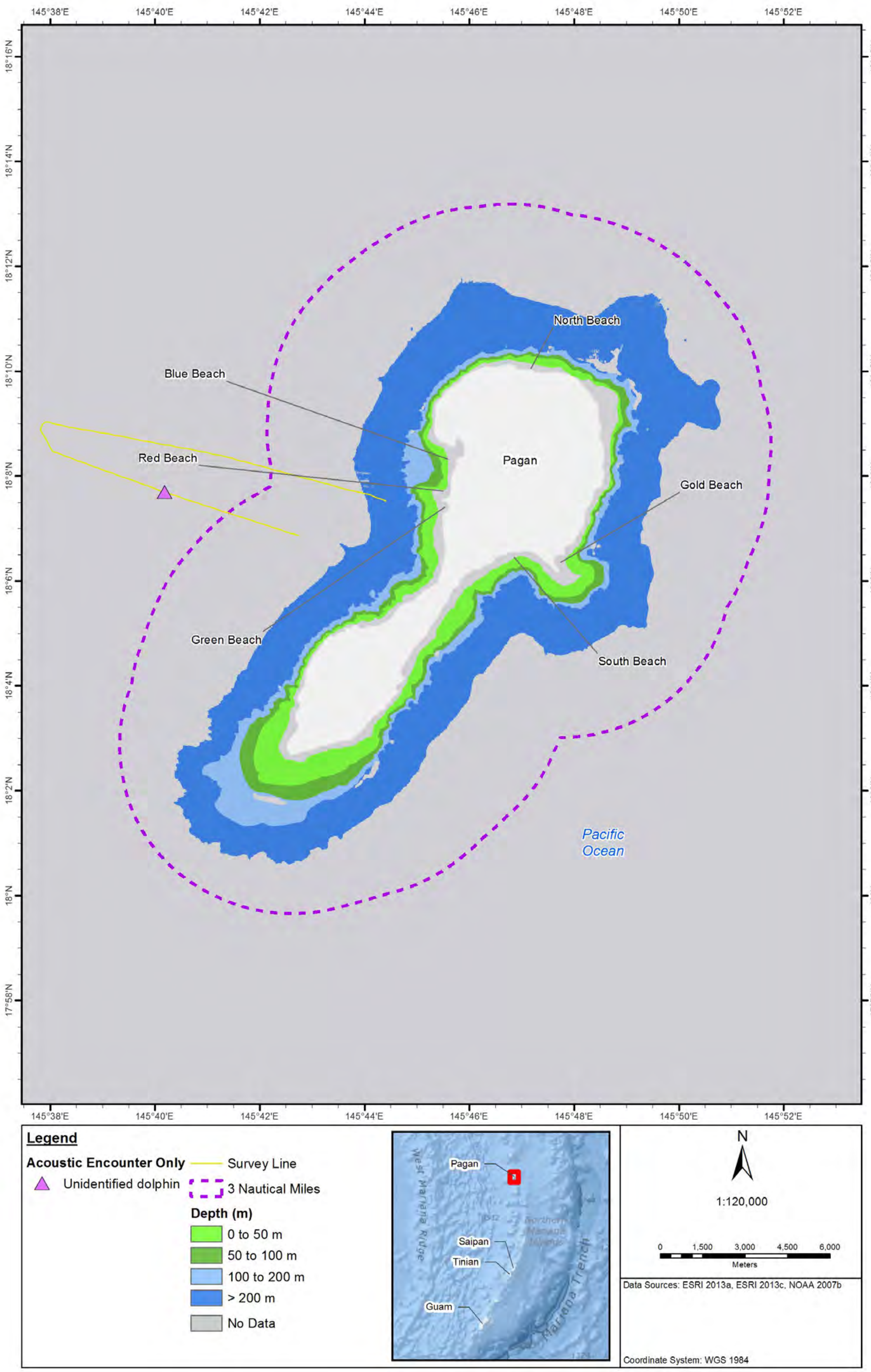


Figure F-1. Survey Line and Acoustic Detection on the Afternoon of August 19 Post-Line Transect Survey

This page is intentionally left blank

APPENDIX G

Marine Mammal Sightings During the July 2013 CJMT Coral and Sea Turtle Survey

This page is intentionally left blank

Opportunistic Sightings of Marine Mammals During the July 2013
CJMT Coral and Sea Turtle Survey

Tinian

During approximately 128 hours of informal watch in the nearshore waters of Tinian (approximately 8-hour days over 8 days using 2 boats), there were no sightings of marine mammals.

Pagan

With approximately 128 hours of informal watch in the nearshore waters of Pagan (approximately 8-hour days over 8 days using 2 boats), there were 4 sightings of marine mammals. All were small groups, tentatively identified as Pacific spinner dolphins (*Stenella longirostris*).

Land-based teams advised that dolphins were regularly sighted within an hour of sunrise inside Bandera Bay, in the waters off of Green Beach. (Because the dawn light is not intense enough for high-quality observations of the seafloor, the coral team was not on the water at the right time to make these sightings.)

This page is intentionally left blank

APPENDIX H

Thorfinn-Towed Hydrophone Array and Data Processing Systems

This page is intentionally left blank

***Thorfinn*-Towed Hydrophone Array and Data Processing Systems**

The *Thorfinn*-towed hydrophone array consisted of a four-element, oil-filled, towed hydrophone array. The components consisted of two high-frequency Reson hydrophones (Reson #2 and #3), separated by 3.3 feet (1 meter), and two mid-frequency APC hydrophones (APC #1 and #4), separated by 9.8 feet (3 meters; Table H-1, Figure H-1). The Reson hydrophone pair monitored higher frequency signals (1,500 to 170,000 hertz) and the APC hydrophone pair monitored low- and mid-frequency signals (250 to 35,000 hertz). The array depth was determined using a pressure sensor located inside the array (Figure H-1). The hydrophone array was connected to a detachable tow cable and was deployed approximately 591 feet (180 meters) behind the aft deck of the *Thorfinn*, at an approximate depth of 40 feet (12 meters). The usable frequency range for hydrophones was estimated from the hydrophone and preamplifier frequency response curves.

Table H-1. *Thorfinn*-Towed Hydrophone Array Components and Specifications

Array Components	*Manufacturer and Model*	*Spacing in Feet (Meters)*	*Usable Range*
Mid-frequency Hydrophones (2)	APC 42-1021	9.8 (3.0)	250 to 35,000 hertz
High frequency Hydrophones (2)	Reson TC4013	3.3 (1.0)	1,500 to 170,000 hertz
Depth sensor	Keller 7se	Not applicable	0 to 656 feet (0 to 200 meters)

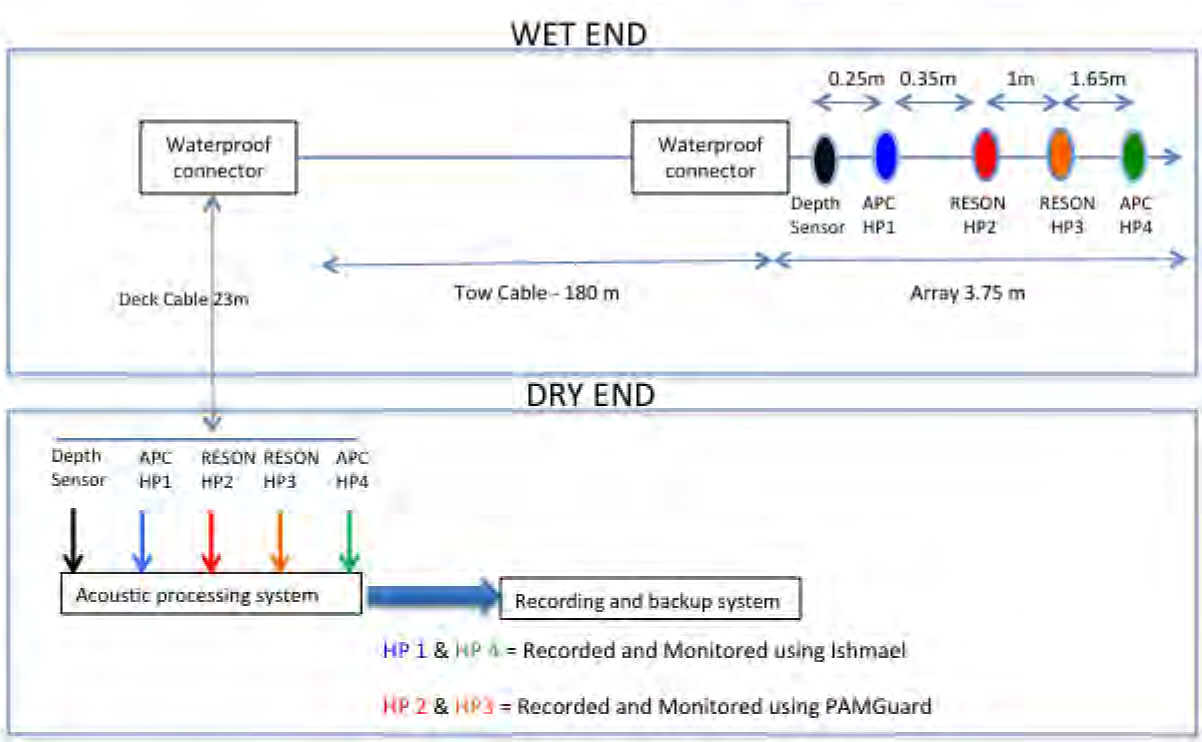


Figure H-1. Schematic of the Towed Hydrophone Array System Used on the Thorfinn

The towed acoustic array system allowed recordings to be made simultaneously using either semiautomated or manual detection and localization of marine mammal sounds. The signal processing and recording system consisted of a mid-frequency subsystem (192 kilohertz sample rate) and a high-frequency subsystem (500 kilohertz sample rate; Figure H-2).

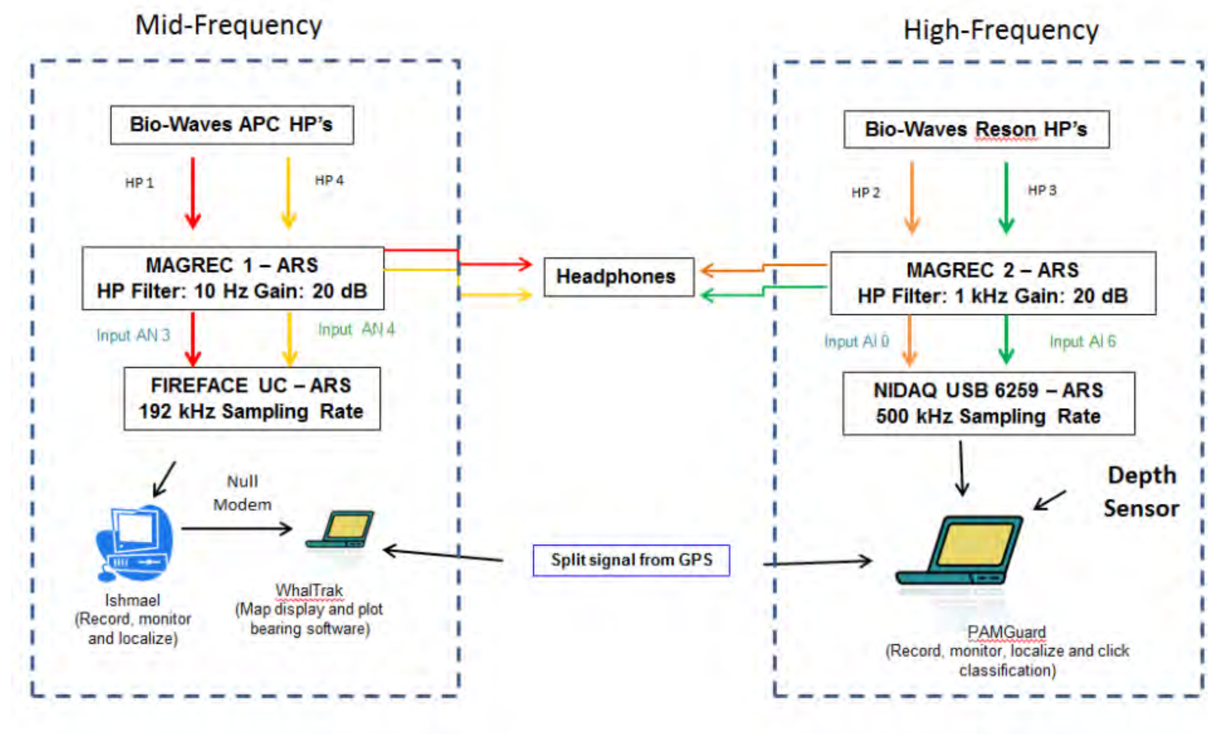


Figure H-2. Diagram of the Acoustic Data Processing and Recording System Used Onboard the *Thorfinn*

Mid-frequency and high-frequency subsystems are indicated with dashed boxes.

Inputs to the processing system from the primary towed hydrophone array included digitized signals from all four hydrophones. Analog signals from APC hydrophones #1 and #4 were digitized at a 192-kilohertz sampling rate. Analog signals from Reson hydrophones #2 and #3 were sent to a digital acquisition board (NIDAQ USB6259) and digitized at a 500-kilohertz sampling rate. Three computers provided real-time data processing and monitoring of the digitized signals from the hydrophones.

Three primary software programs were used for localization, recording, and data logging and documentation. The primary software programs were Ishmael 2.0, Whaltrak 2.6, and PAMGuard v1.12.05. Ishmael is acoustic localization and digital recording software, developed by Dave Mellinger, Oregon State University Pacific Marine Environmental Laboratory, Newport, Oregon. Whaltrak is a data logging and mapping program, developed by Jay Barlow, NOAA Fisheries Southwest Fisheries Science Center, La Jolla, California, and designed to interface with Ishmael. PAMGuard is an open-source software program developed for real-time acoustic monitoring and post-processing applications. It was developed by Doug Gillespie, St. Andrews University, St. Andrews, Scotland, United Kingdom (Gillespie et al. 2008).

Ishmael and Whaltrack communicate via a null-modem serial (RS-232) connection to send bearing information from Ishmael to Whaltrak, where it is plotted on a map display. PAMGuard uses a customized Microsoft Access database to allow users to enter ancillary information and metadata, which are used in post processing. Latitude and longitude obtained from a Garmin GPS Map 421 were sent to both the PAMGuard and Whaltrak software programs, using a serial RS-232 interface. Collectively, this suite of software provides real-time monitoring, recording, and post-processing capabilities for a variety of marine mammal species.

After the acoustic signals from the array were digitized, the mid-frequency signals were sent to a 12-volt computer running Ishmael software for monitoring, bearing estimation, and recording. Whaltrak software received bearing information from Ishmael and plotted it, so that locations could be determined. Two-channel recordings of acoustic data were made in .wav file formats. Continuous recordings were obtained when the *Thorfinn* towed the array, and files were saved automatically every 10 minutes. The digitized high-frequency data streamed to a laptop computer running PAMGuard software.

Marine mammal vocalizations were manually selected from the Ishmael spectrogram to calculate bearings. The bioacoustician on watch reviewed each bearing for reliability, and if reliable, sent it to Whaltrak via the network connection, where it was plotted on the map display. Whaltrak also plotted the ship's position, which was received from the GPS serial connection. Sequential bearings were plotted in Whaltrak. The estimated localization was the point where the bearings converged. This technique for determining localization is known as target motion analysis, and is commonly used for localizing marine mammals using towed hydrophone arrays. There is a left/right ambiguity inherent in this technique which can only be resolved by turning the vessel and obtaining additional bearings to determine which side is the true localization.

Each localization was labeled with an identification number when bearings converged (Figure H-3). PAMGuard, which can be automated to detect and localize odontocete clicks, was the primary method for obtaining localizations to echolocating animals. Whaltrak and Ishmael were the primary methods for localizing whistles and tonal calls (e.g., whale calls) from marine mammals. Due to their variable nature, these types of calls are not suitable for automatic detection. Only Ishmael allows a bioacoustician to manually identify and select (i.e., window) these calls for processing.

PAMGuard was configured with an automatic click classification module that uses an energy band comparison to classify echolocation clicks to species level for sperm whales, killer whales, Cuvier's beaked whales, and Baird's beaked whales. The bioacoustician monitored the click classifier outputs in real-time to track echolocation click trains and to estimate the perpendicular distance of the vocalizing animal from the track line. The echolocation click trains were assigned to individual animals, and bearings were automatically plotted to PAMGuard's map display to estimate localizations (Figure H-3).

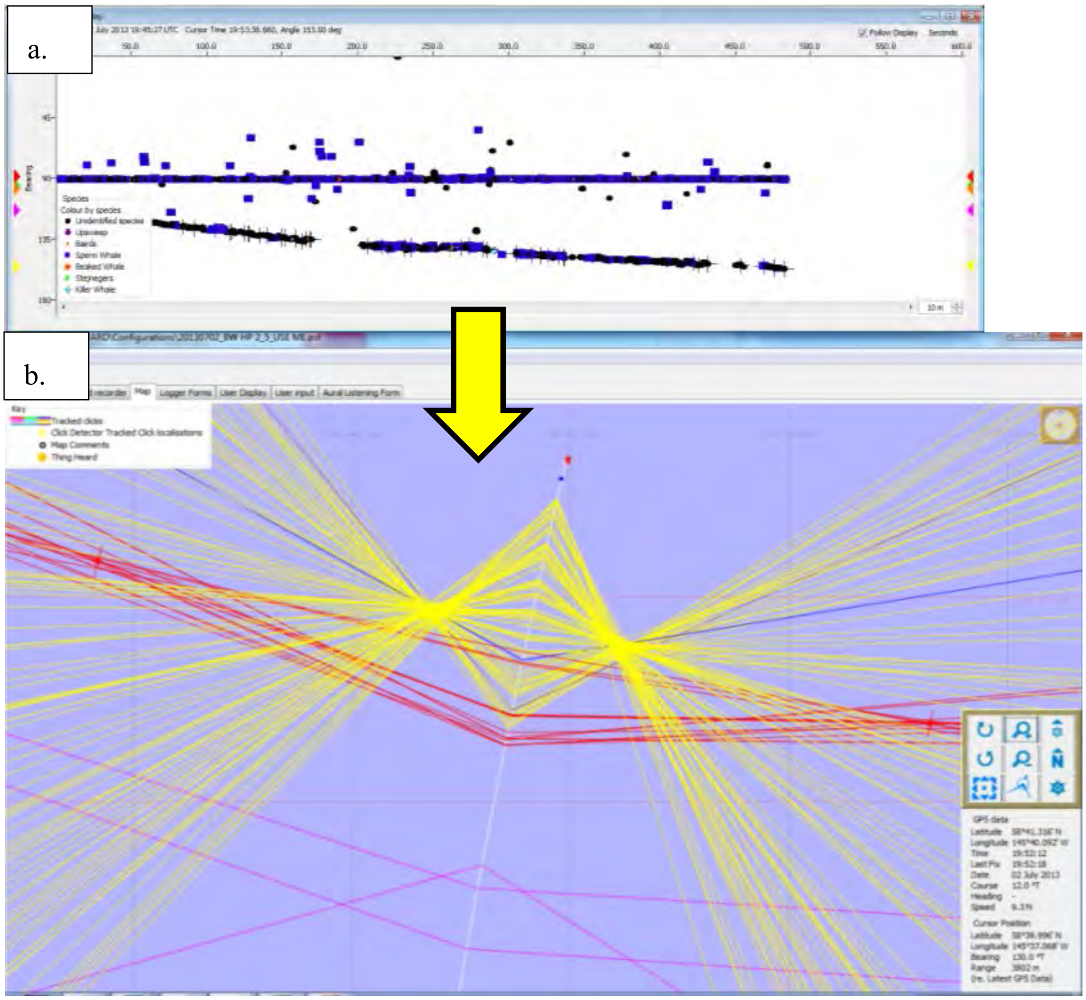


Figure H-3. Example of Localization within PAMGuard

(a) PAMGuard time-bearing display over a 10-minute period, with bearings on the Y axis and time on the X axis. Symbols indicate detected clicks with bearings ranging from approximately 110^0 to 180^0. (b) PAMGuard map display depicting bearing angles (yellow and red lines) used to automatically detect clicks. Ship (red dot) is traveling NNE; towed hydrophone array (blue dot) is behind the ship. Converging lines indicate a localization (note the left/right ambiguity in localization; see text for an explanation).

PAMGuard saved all click and whistle detections to an embedded, user-customized, Microsoft Access database (PAMGuard database). Additionally, binary files for each survey day were saved for post processing. PAMGuard uses proprietary data files in binary format to efficiently and compactly store acoustic data for use in post-processing with PAMGuard's ViewerMode software. Any unidentified click events that were noted during real-time monitoring or Long-Term Spectral Average (LTSA) review were post-processed to extract click features and analyze the data further to classify them to the lowest taxonomic level (species, if possible).

APPENDIX I

Description of Sonobuoy System

This page is intentionally left blank

Description of Sonobuoy System

We used Model AN/SSQ-53F sonobuoys, which are programmed before they are deployed. The bioacoustician selected the channel number (which determines the VHF frequency), operational mode, deployment period (in hours), depth, and automatic gain setting from a control panel on the front of the buoy. Several operational modes are available (e.g., directional frequency analysis and recording, calibrated omnidirectional, and shallow omnidirectional). The audio frequency range depends on the mode selected. All sonobuoy deployments in this study used the calibrated omnidirectional mode. This mode provides a frequency response range of 5 hertz to 20 kilohertz, with a linear frequency roll-off in the lower frequencies to compensate for natural ambient noise (Figure I-1). The automatic gain control was set to off, and the deployment duration was set to the maximum setting of eight hours. After eight hours, a fuse inside the flotation bag ignited and burst the bag, causing the sonobuoy to scuttle (sink).

Two sonobuoy radio receivers (WinRadio Model G39WSBe) on the *Thorfinn* received independent VHF signals from either one sonobuoy or two sonobuoys simultaneously (Figure I-2). Each receiver was connected to an omnidirectional VHF antenna (Ringo-Ranger II Model ARX-220B) on the upper deck of the *Thorfinn*, at a height of 26.2 feet (8 meters) above the waterline. The antennas were tuned to the VHF frequency for radio channels that were programmed into the sonobuoys before they were deployed.

All audio signals obtained from the receivers were passed to an external sound digitizer (Creative External SoundBlaster Live 24 bit SB0490) and recorded on a laptop running Ishmael software. The analog signal was also backed up by recording onto flash cards, using a digital audio-recorder (TASCAM DR-680). All audio signals were recorded at a sample rate of 48 kilohertz.

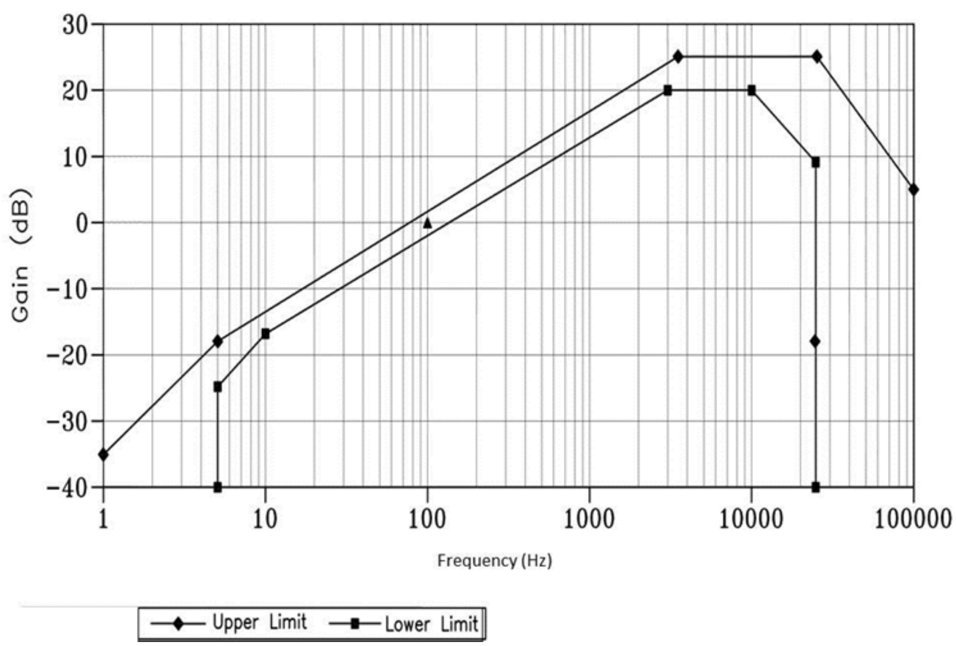


Figure I-1. Relative Audio Frequency Response of the AN/SSQ-53F Sonobuoys

Note the linear decrease in gain from approximately 2 kilohertz to 5 hertz, which is used to offset the ambient noise that inversely increases in this range.

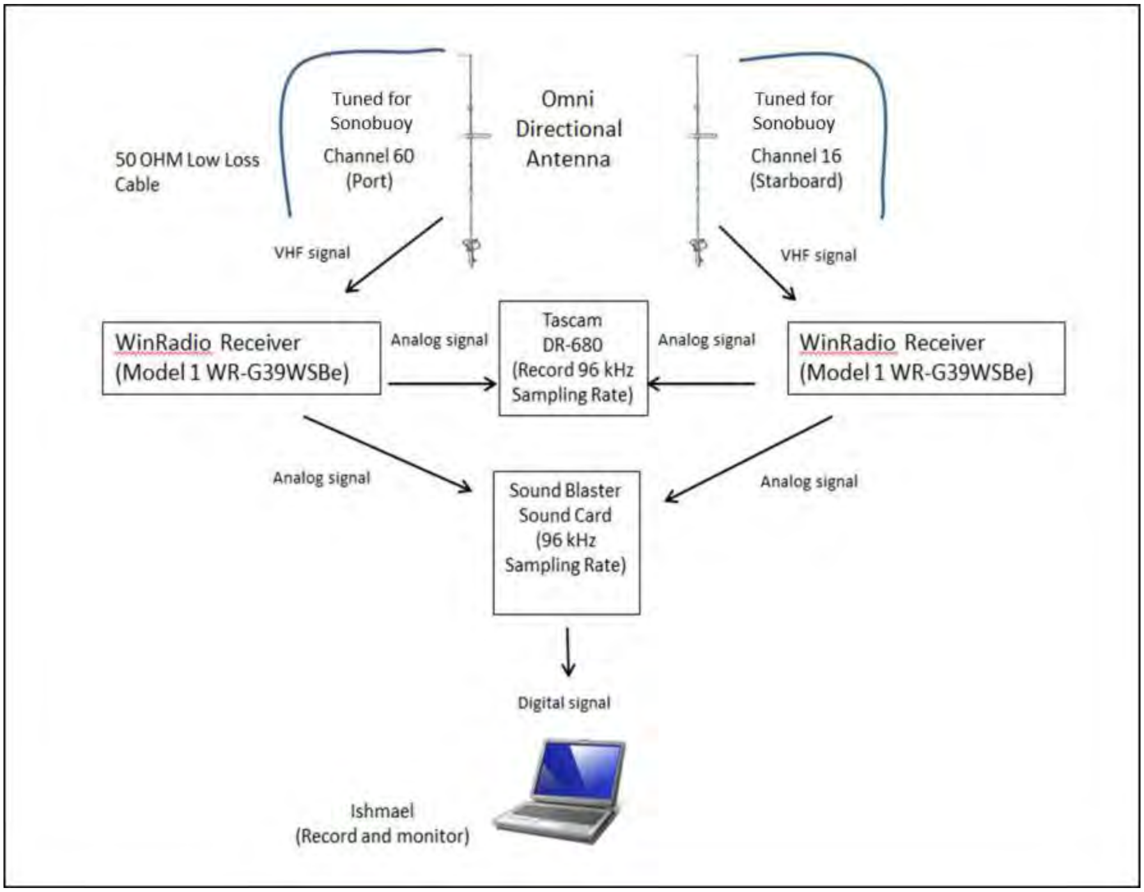


Figure I-2. Diagram of Sonobuoy System

APPENDIX J

ROCCA Analysis for Unidentified Dolphins

This page is intentionally left blank

ROCCA Analysis for Unidentified Dolphins

During the *Thorfinn* line transect survey with towed array, eight of the ten dolphin acoustic encounters could not be identified to species. This was because there were no corresponding visual sightings to confirm species. Without visual information on these eight encounters, the only way to classify them to species is by using an acoustic-based classification of the whistles (if present) in the recordings made.

ROCCA analyzes whistles produced by dolphins (and it requires whistle-type sounds to run its analysis). Dolphin whistles that were recorded acoustically but had no visual species confirmation were post-processed using the ROCCA module in PAMGuard to determine species identity. Single-species recordings from Pagan collected with the RHIB towed array were used in the classifier (for RHIB methods and data see Appendix E).

The ROCCA module in PAMGuard uses a random forest classifier model on new whistle recordings. The specific random forest classifier model used for this analysis was developed using whistles recorded in the tropical Pacific Ocean during five vessel-based, combined visual and acoustic, cetacean surveys that took place between 2000 and 2006. (See Table E-2 and Oswald et al. 2007 for details of the study sites and recording methods.) Typically, when building a classification model, it is desirable to collect samples from the region where the classifier will be used. However, due to the lack of recordings from dolphin species in the CNMI region, the model based on the tropical Pacific Ocean dolphins was used as the nearest approximation. The tropical Pacific model contains species expected in the CNMI region; recordings used to train this model were geographically the closest to the CNMI that were available.

Species validation is particularly important for this study, because the classifier was developed using whistle samples collected from regions that were outside of Pagan. Geographic variation in whistle structure has been demonstrated for many species of dolphins, such as bottlenose (Baron et al. 2008; Ding et al. 1995) and Indo-Pacific bottlenose dolphins (Morisaka et al. 2005), and for pilot whales (Rendell et al. 1999). However, little is known about the degree of geographic variation in whistles throughout the Pacific Ocean. If the whistles produced by dolphins around Pagan have different characteristics than those produced by the same species around Hawaii, this could negatively affect classifier results by reducing correct classification scores.

<u>ROCCA Methods</u>

To post-process whistles, acoustic data analysts first detected whistles manually, and then extracted them using semiautomated methods in the ROCCA module. To extract a whistle contour, the analyst selected the start and end points of the whistle on the spectrogram. ROCCA then automatically extracted the whistle contour by stepping through consecutive time-slices in the spectrogram. In each time-slice, ROCCA searched for the peak frequency within a user-defined bandwidth that was centered on the peak frequency in the previous time slice (see Oswald et al. 2007 and Barkley et al. 2011 for details). After extracting a whistle contour, ROCCA displayed it on the spectrogram so that the analyst could manually adjust the accuracy of the extraction (Oswald et al. 2013).

A maximum of 50 whistles were selected randomly for analysis from each acoustic encounter. An acoustic encounter was analyzed only if it was located at least 3 nautical miles (5.6 kilometers) away from any other visual or acoustic dolphin encounter. Mean acoustic detection distances for dolphin whistles in the eastern tropical Pacific Ocean have been found to range from 1 to 2.87 nautical miles (1.9 to 5.32 kilometers; Rankin et al. 2008). Based on this, whistles produced more than 3 nautical miles (5.6 kilometers) from the hydrophones were assumed to not be detectable or to be too faint to affect the analysis. Restricting whistles to those at least 3 nautical miles from each other reduces the likelihood of including whistles produced by a species other than those in the intended encounter.

After extracting a whistle contour, 50 variables were measured from it. These variables included frequencies and slopes at various points along the contour, the number and position of inflection points and steps, and whistle duration (see Barkley et al. 2011 for a complete list and description of measured variables). These variables were input into a random forest classifier model. The model was developed using whistles recorded in the tropical Pacific Ocean during five vessel-based, combined visual and acoustic cetacean surveys that were conducted between 2000 and 2006 (Oswald et al. 2007). During this survey, four visually-identified acoustic encounters of dolphins around Pagan, from the RHIB, were added to the tropical Pacific Ocean training dataset (Table J-1). Although it would be preferable to use a model developed using only whistles recorded in this study area, not enough data exists to train a model specifically for the Mariana Islands.

Table J-1. Species and Number of Whistles Included in the Classifier Model Training Dataset

Species	Number of Whistles	
	Tropical Pacific	Pagan and Saipan
Bottlenose dolphin	155	28
Spotted dolphin	297	0
False killer whale	309	0
Short-finned pilot whale	109	0
Rough-toothed dolphin	145	0
Striped dolphin	452	0
Spinner dolphin	170	136

A two-stage random forest classifier model was used. In the first stage, whistles were classified to one of two broad species categories, either large dolphins or small dolphins. The large dolphin class included false killer whales, short-finned pilot whales, and rough-toothed dolphins. The small dolphin class included bottlenose dolphins, spotted dolphins, and a combined species category of striped and spinner dolphins. Striped and spinner dolphins were combined into one class, because the classifier algorithm commonly confused the whistles produced by these species in classifier tests. Combining species into species groups can dramatically improve the performance of the classifier, which is important when using it to identify unknown whistles. In the second stage, whistles within each species category were classified to the species level (or combined species level in the case of spinner and striped dolphins). Once all of the whistles in an encounter had been classified, the overall school was classified based on the cumulative results of the whistle classifications.

Before the classifier was run, its performance was evaluated by dividing the test data randomly into two equal subsets. One subset was used to train the model and the other was used to test it. The datasets were then switched so that each dataset was used as both a test and a training dataset. Therefore, every whistle in the full dataset was classified. Data were divided such that all whistles from a single school occurred in the same subset. This avoided whistles produced by one group or individual being in both the test and train datasets and artificially inflating correct classification scores. Each subset contained an equal number of whistles for each species to avoid any one class dominating the data and skewing the results.

<u>Results of the ROCCA Classifier</u>

The performance of the classifier model we used to identify the eight encounters of unidentified dolphins is presented in Table J-2. Overall, 87% of encounters in the test dataset were correctly classified. For individual species, correct classification scores ranged from 83% for rough-toothed dolphins to 100% for false killer whales and spotted dolphins. The addition of whistles recorded around Pagan to the training dataset improved the performance of the model on the test dataset. Correct classification scores increased from 88% to 100% for spotted dolphins and from 73% to 80% for striped/spinner dolphins. It is likely that additional improvements could be made to the classifier model if more validated samples of whistles were recorded in this study area.

Table J-2. Results of the Tropical Pacific Whistle Classifier, Showing Percent of Schools Classified as Each Species and Sample Size by Species (including Pagan Samples)

	Percent Classified As						
Actual Species	***Short-Finned Pilot Whale***	***False Killer Whale***	***Spotted Dolphin***	***Rough-Toothed Dolphin***	***Spinner Dolphin/Striped Dolphin***	***Bottlenose Dolphin***	***Number of Samples***
Short-finned pilot whale	**92**	0	0	0	8	0	12
False killer whale	0	**100**	0	0	0	0	9
Spotted dolphin	0	6	**100**	0	6	0	16
Rough-toothed dolphin	0	0	0	**83**	17	0	12
Spinner dolphin/Striped dolphin	0	4	9	7	**80**	7	46
Bottlenose dolphin	0	0	0	13	0	**89**	9

Note:
Bold = The percent of schools correctly classified for each species.

Four of the five visually validated recordings were used to validate the random forest model (Table J-3).

One recording was omitted from the analysis because it was within 3 nautical miles (5.6 kilometers) of another dolphin detection. Of the four visually validated encounters included in the analysis, one was of bottlenose dolphins that ROCCA incorrectly identified as spinner/striped dolphins.

The remaining three encounters were of spinner dolphins that ROCCA correctly identified as spinner/striped dolphins. Results of this analysis suggest that the tropical Pacific classifier has the potential to perform well for spinner dolphin whistles. However, it is difficult to generalize about these results, due to the small sample size. More visually confirmed recordings need to be collected in the CNMI area to fully validate the classifier. Whistles from these visually validated acoustic encounters were added to the classifier training data set before the classification analysis was made on acoustic encounters that did not have associated observations.

Table J-3. Classification Results for Visually Identified Encounters

Local Date and Time (2013)	*Actual Species*	*Number of Whistles Analyzed*	*Identified as*	*Reason Omitted from ROCCA*
August 13 8:06 a.m.	Bottlenose dolphin	27	Spinner dolphin/striped dolphin	NA
August 13 10:22 a.m.	Spinner dolphin	35	Spinner dolphin/striped dolphin	NA
August 13 12:24 p.m.	Spinner dolphin	50	Spinner dolphin/striped dolphin	NA
August 14 8:46 a.m.	Spinner dolphin	15	Spinner dolphin/striped dolphin	NA
August 14 11:44 a.m.	Spinner dolphin	NA	NA	Within 3 nautical miles of another dolphin detection

Note:
NA = not applicable

Results of ROCCA Species Classifications

After demonstrating the reliability of the random forest model for classifying dolphin whistles, we used the classifier model to identify three of the eight unidentified acoustic encounters during the *Thorfinn* line transect survey to a species or species group, using the ROCCA classifier. Four of the eight encounters were omitted from the classification analysis because they were less than 3 nautical miles (5.6 kilometers) from other visual or acoustic dolphin detections. One encounter was omitted because the recording did not contain whistles.

The three detections that were included in the classification analysis were all classified as spinner/striped dolphins. Although it is optimal to identify encounters to the species level, whistles produced by spinner and striped dolphins have similar time-frequency characteristics; for this reason, the classifier performed better when these two species were combined. Because spinner dolphins were the most commonly sighted species in the nearshore waters surrounding Pagan, and striped dolphins are generally found in more offshore waters (Au and Perryman 1985), it is very likely that the encounters classified as spinner/striped dolphins were all spinner dolphins.

Discussion of ROCCA Species Classifications

Although the results of classification indicate that the tropical Pacific classifier performs well on whistles recorded around Pagan (from the *Thorfinn*), the test sample size was small (n = 4 encounters). Improvements were made to whistle classification results when whistles from four visually-validated schools recorded around Pagan (from the RHIB) were added to the training dataset. Geographic variation has been described in the whistles of some species (e.g., bottlenose dolphins, Baron et al. 2008; Indo-Pacific bottlenose dolphins, Morisaka et al. 2005; pilot whales, Rendell et al. 1999; bottlenose dolphins, Ding et al. 1995). However, very little is known about the degree of geographic variation in whistles throughout the Pacific Ocean. More whistle samples from visually-validated recordings of dolphin from the Northern Mariana Islands are needed to further improve the classifier model for this geographic region

APPENDIX K

Analysis of Beaked Whale Clicks

This page is intentionally left blank

Methods for Beaked Whale Click Analysis

Beaked whale echolocation clicks can be classified to species based on several time and frequency characteristics (Baumann-Pickering et al. 2013; Yack et al. 2013). Four features of clicks were used to classify them to species or species groups:

1. Click duration (range for beaked whales: 0.15 to 0.5 milliseconds)
2. Frequency spectrum peaks (frequency peaks: Cuvier's = 38-40 kilohertz and Blainville's = 34-36 kilohertz)
3. IPI (Cuvier's = 0.34 milliseconds and Blainville's = 0.28 milliseconds)
4. Presence of an upsweep pattern on the Wigner-Ville transform (Figure K-1)

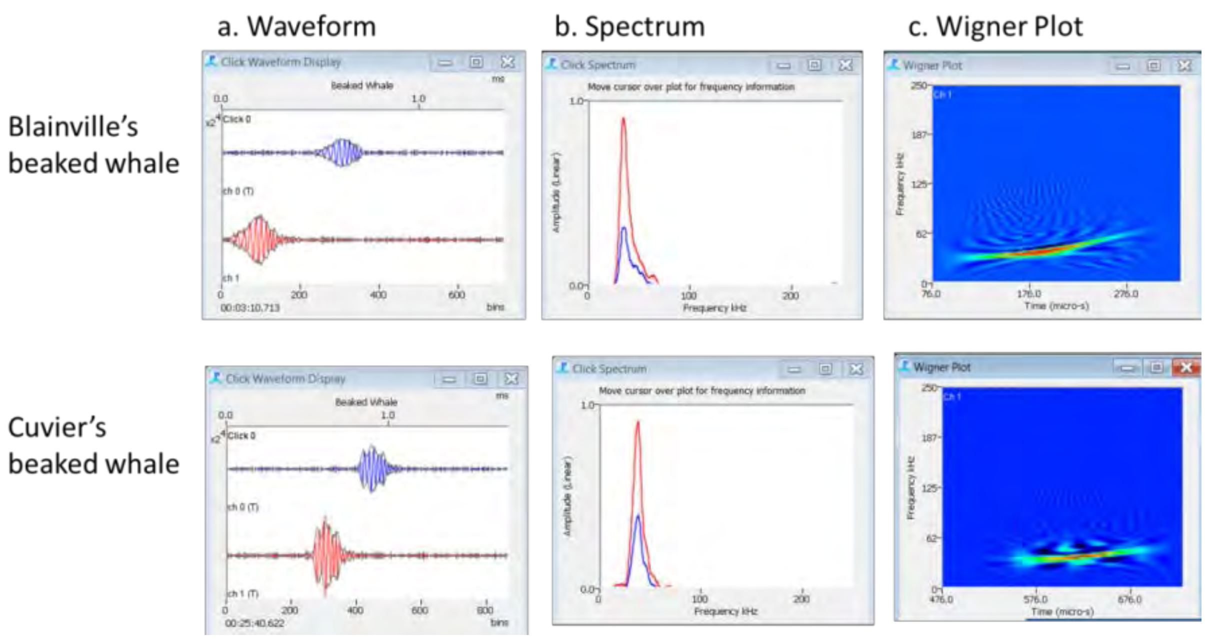


Figure K-1. Graphical Examples of Important Beaked Whale Click Features

(a) A waveform depicting time (x axis) versus amplitude (y axis) for data from hydrophones # 1 (blue) and #2 (red) in the towed hydrophone array.
(b) Frequency (x axis) versus amplitude (y axis) demonstrates the frequency of peak energy in each click.
(c) A Wigner plot of echolocation clicks, depicting time (x axis) versus frequency (y axis), with energy represented by color. The Wigner plot (i.e., Wigner-Ville transform) represents time and frequency in greater detail than possible from a traditional spectrogram and provides a simple way to view short duration signals, such as echolocation clicks.

PAMGuard ViewerMode software was used to review recorded clicks and to measure and extract click features required for species or species group classification. The software produced graphs of median peak frequency versus median IPI, which were used to help classify clicks (Figure K-2). Medians instead of means and percentiles instead of standard deviations were used because beaked whale click data typically exhibit a non-normal distribution, often with numerous outliers (S. Baumann-Pickering, pers. comm., November 6, 2013. A data analyst experienced with beaked whale click classifications reviewed and classified all unidentified beaked whale click events to the lowest taxonomic level possible.

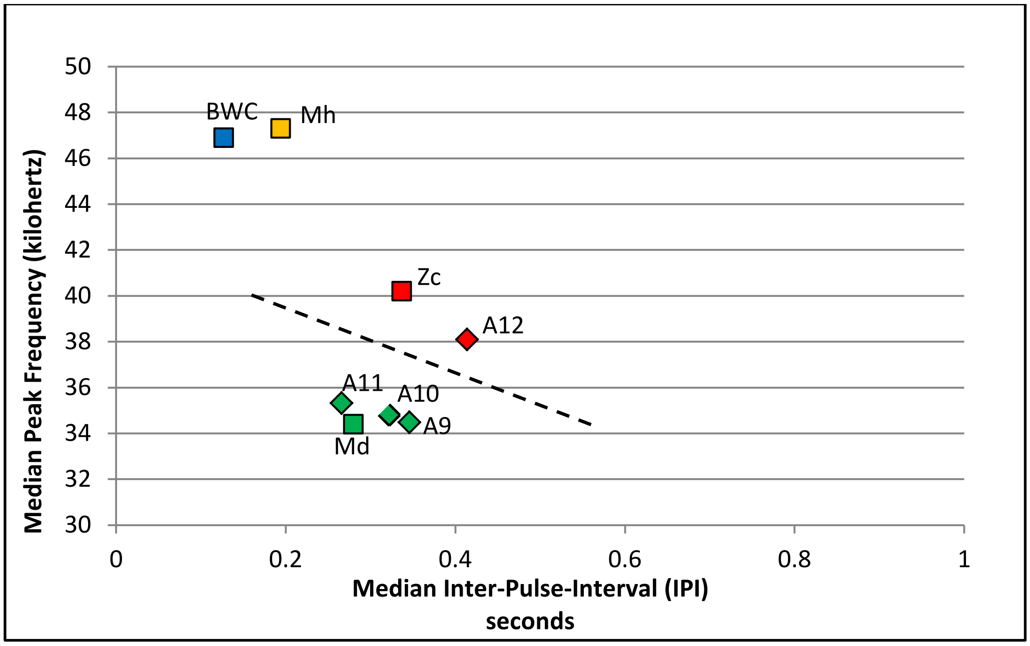


Figure K-2. Beaked Whale Click Median Peak Frequency Versus IPI for Species Identification

Median peak frequency (kilohertz; y axis) is plotted against IPIs for each beaked whale acoustic encounter (A9-A12) and for reported values of species of beaked whales expected to occur in the study area. Cuvier's beaked whales (Zc), Blainville's beaked whales (Md), Deraniyagala's beaked whale (Mh), and an unidentified beaked whale click type from the tropical Pacific (BWC) (Baumann-Pickering et al. 2013).