

Final Report

Vessel-based Humpback Whale Survey in and around Farallon de Medinilla: 29 January – 4 February 2020

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Humpback Whale (*Megaptera Novaeangliae*) off FDM. Photo taken by Jessica Chen under National Marine Fisheries Service permit no. 21482 issued to Dan Engelhaupt.

Table of Contents

Abbreviations and Acronyms	iii
1. Abstract	1
2. Introduction	1
3. Methods	3
3.1 PREFERRED HUMPBACK WHALE HABITAT	3
3.2 VESSEL SURVEYS	3
4. Results	7
4.1 PREFERRED HUMPBACK WHALE HABITAT	7
4.2 VESSEL SURVEYS	8
4.3 HUMPBACK WHALE PHOTO-IDENTIFICATIONS	12
4.4 BEHAVIORAL OBSERVATIONS.....	12
5. Discussion	15
6. Acknowledgements	16
7. References	17

Appendices

Appendix A: Humpback Whale Preferred Breeding Habitat Maps

Figures

Figure 1. Commonwealth of Northern Mariana Islands (CNMI) and Guam. Red regions indicate preferred humpback whale habitat (depths less than 183 m).....	4
Figure 2. Live-aboard research vessel M/V <i>Liquid Soul</i>	5
Figure 3. Percent of preferred humpback whale breeding habitat (bathymetry less than 183 m) surrounding each island within CNMI including several offshore submerged reefs.....	8
Figure 4. Vessel tracks for the M/V <i>Liquid Soul</i> around FDM, ESE Reef, Sonome Reef and Anatahan during 29 January to 1 February 2020. Red regions indicate preferred humpback whale habitat (depths less than 183 m).....	9
Figure 5. Original marine mammal sightings and movements around FDM and ESE Reef during 29 January to 1 February 2020. Labels indicate the sighting number followed in parentheses by the genus and species initials (Mn = <i>Megaptera novaeangliae</i> , Tt = <i>Tursiops truncatus</i> , Gm = <i>Globicephala macrorhynchus</i>) and the group size. Red regions indicate preferred humpback whale habitat (depths less than 183 m).....	10

Tables

Table 1. Observers and roles.....	6
Table 2. Summary of preferred habitat (bathymetry less than 183 m) available around each island in CNMI as well as offshore submerged reefs starting from the most northern island.....	7
Table 3. Summary of vessel survey effort.....	8
Table 4. Summary of marine mammal sightings.....	11
Table 5. Summary of unique individual marine mammals sighted by species.....	11
Table 6. The sighting history of the 10 humpback whales photo-identified between 29 January and 2 February.	13

Abbreviations and Acronyms

BSS	Beaufort Sea State
CNMI	Commonwealth of the Northern Mariana Islands
DPS	distinct population segment
FDM	Farallon de Medinilla
GPS	global positioning system
hr	hour(s)
ICMP	Integrated Comprehensive Monitoring Plan
km	kilometer(s)
km ²	square kilometer(s)
m	meter(s)
MITT	Mariana Island Training and Testing Study Area
MSO	Marine Species Observer
NAVFAC	Naval Facilities Engineering Systems Command
SPUE	Sightings Per Unit Effort
U.S.	United States

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1. Abstract

In order for the U.S. military to conduct readiness training with the Mariana Island Training and Testing Study Area (MITT), including the area around Farallon de Medinilla (FDM), the Navy is required to monitor potential impacts of these activities on Marine Mammal Protection Act and Endangered Species Act-listed species. Humpback whales belonging to the North Pacific population are known to use portions of the MITT seasonally for breeding activities, specifically Marpi Reef and shallow waters around Saipan. A small-vessel visual survey for humpback whales was conducted between 29 January 2020 and 1 February 2020 to better understand the use of shallow-water habitat around FDM. Over the four-day survey, nine humpback whale sightings were made of ten uniquely identified individuals. Seven of these individuals were newly added to the Marianas photo-identification catalog. Three individuals were seen in prior years off the coast of Saipan. Individuals were seen on multiple days within the survey area and engaging in typical reproductive behavior suggesting that the whales are not just migrating past FDM and the surrounding area. All sightings were made in water depths less than 183 meters (m), which has been described as preferred breeding habitat for humpback whales. An analysis of preferred habitat for the entire Mariana Archipelago revealed that FDM accounted for 32 percent (354 square kilometers [km²]). Of interest for future surveys are the Galvez Banks and Santa Rosa Reef, approximately 35 to 50 kilometers (km) south of Guam, comprising nearly 150 km² of preferred habitat, and reef tracts 350 km to the southeast of Guam comprising of over 8,000 km² of preferred habitat, either of which may present additional important breeding habitat for a segment of the North Pacific humpback whale population.

2. Introduction

Humpback whale (*Megaptera novaeangliae*) populations have been well studied throughout the world. Most populations are known to migrate seasonally between high-latitude summer feeding grounds and low-latitude winter breeding grounds (Dawbin 1966). In 2016, the world's humpback whale population was designated as 14 distinct population segments (DPSs), named after their primary breeding locations (NMFS 2016). Four of these are part of the North Pacific Population and include the Mexico, Central America, Hawaii, and Western North Pacific (Philippines/Okinawa and Ogasawara, Japan) DPSs. A fifth DPS was proposed but ultimately included within the western North Pacific DPS based on genetic analyses that found significant differentiation between the Ogasawara breeding ground and the Philippines/Okinawa breeding grounds, as well as the identification of humpback whales feeding in the Aleutian Islands that could not be linked to any known breeding population (Bettridge et al. 2015). Since then, humpback whale surveys carried out between 2015 and 2018 off Saipan in the southern portion of the Mariana Archipelago identified the area as a contemporary breeding ground (Hill et al. 2020). DNA profiling of samples collected during the surveys confirmed that humpback whales observed in this region are part of the western North Pacific population and most closely related to whales on the Ogasawara breeding ground and Commander Islands feeding ground.

The Mariana Archipelago consists of fifteen mostly dormant volcanic mountains in the western North Pacific Ocean extending 2,519 km (**Figure 1**). The island chain can be broken into the

northern group of 10 uninhabited volcanic islands, the southern four inhabited, coralline, limestone islands (Saipan, Tinian, Rota, Guam) and the small uninhabited island of Aguijan just to the south of Tinian. Politically, two countries are recognized: the Territory of Guam in the very south and the islands to the north referred to as the Commonwealth of the Northern Mariana Islands (CNMI).

In addition to the known use of the southern end of the Archipelago by humpback whales (Fulling et al. 2011; Hill et al. 2020), there have been sighting records around FDM (Uyeyama 2014) and recordings of humpback whale song on submerged stationary acoustic recorders deployed off Pagan (Allen et al. in review; Munger and Lammers 2020). Overall, little is understood about the significance of the northern islands of the Mariana Archipelago as part of this breeding ground first described in 2007 (DoN 2007, Rivers et al. 2007).

Extensive surveys of humpback whales in the Hawaiian breeding grounds, dating back four decades, have revealed humpback whale preference for water depths shallower than 100 fathoms (183 m; Herman and Antinaja 1977). In this study, the bathymetry of the Mariana Archipelago was examined to identify the most likely areas where humpback whales would be expected to be found.

As part of the compliance requirements of the Marine Mammal Protection Act of 1972 and the Endangered Species Act of 1973, the U.S. Navy developed the Integrated Comprehensive Monitoring Plan (ICMP) (DoN 2010). The ICMP applies to those activities on U.S. Navy training ranges and operating areas for which the U.S. Navy sought and received incidental take authorizations. FDM is actively used by the U.S. Navy for such training activities.

In order to support the U.S. Navy in meeting regulatory requirements for monitoring established under the Final Rules (NMFS 2020) and to provide a mechanism to assist with coordination of program objectives under the ICMP (DoN 2010), a pilot study to survey FDM was conducted to determine if humpback whales would be present in the shallow-water habitat near and around FDM and to assist in answering the following monitoring question:

- What is the occurrence and habitat use of humpback whales in the Marianas Islands Training and Testing (MITT) Study Area?

To help answer this question, the survey was structured around three objectives:

1. Visually validate humpback whale presence around FDM.
2. Obtain photo-identifications to confirm residency is occurring in waters around FDM and for comparison to existing catalogs for the North Pacific to help understand migratory movements and temporal patterns.
3. Document humpback whale behavior around FDM to better understand habitat use.

3. Methods

3.1 Preferred Humpback Whale Habitat

Gridded multibeam bathymetric data were obtained from surveys archived at the National Oceanic Atmospheric Administration's National Centers for Environmental Information¹ and from the University of Hawaii School of Ocean and Earth Science and Technology² and used in ArcGIS Pro where the CNMI region was extracted using the "Clip Raster Tool." Rasters were projected in the WGS 1984 UTM Zone 55N coordinate system. The "Contour Tool" was used to demarcate preferred humpback whale habitat by extracting areas of bathymetry shallower than 183 m in depth. The area was then calculated for these bathymetric polygons surrounding each island, seamount or shallow reef area. For marine mammal sighting locations where multibeam data were not available, depths were extracted from SonarChart by Navionics.³

3.2 Vessel Surveys

FDM is a small, uninhabited, 0.845 km² coral island in the Northern Mariana Islands chain located 83 km NE of Saipan (**Figure 1**). Significant shallow bathymetry exists on a plateau extending over 307 km² around FDM of preferred humpback whale breeding habitat with depths less than 183 m. The objective was to conduct small-boat, non-systematic, visual surveys from 29 January through 4 February 2020, with a primary focus on and around FDM. Surveys occurred 29 January through 1 February and the remaining survey days were cancelled due to a storm system. If extensive coverage was completed under good sighting conditions around FDM, the survey team would take advantage of the opportunity to survey two shallow seamounts 30 km and 45 km to the north known as ESE Reef and Sonome Reef (Trianni 2011), sometimes referred to as 37 and 35 Fathom Banks,⁴ respectively, as well as circumnavigate the uninhabited island of Anatahan 50 km to the northwest.

The live-aboard survey vessel used was the M/V *Liquid Soul*, a 17.7-m Riviera, with a top speed of 37.4 km/hour and a flying bridge height of 3.7 m above the water (**Figure 2**). An iPad equipped with the software *COMPASS*⁵ was connected to a Bad Elf Pro Bluetooth Global Positioning System (GPS) and used for environmental and sighting data entry and logging the vessels position every 30 seconds. A Garmin 76c GPS unit for recording the ship's tracks and sighting locations was also used as a backup.

¹ <https://noaa.maps.arcgis.com/home/item.html?id=0441041574c544dc9b6b8a513cad5e95>

² <https://www.soest.hawaii.edu/pibhmc/cms/data-by-location/cnmi-guam/>

³ <https://www.navionics.com/usa/charts/features/sonarchart>

⁴ <http://www.soest.hawaii.edu/pibhmc/cms/data-by-location/cnmi-guam/submerged-banks/35-37-fthm-banks/35-37-fthm-banks-bathymetry/>

⁵ <https://compass.hdrgateway.com/>

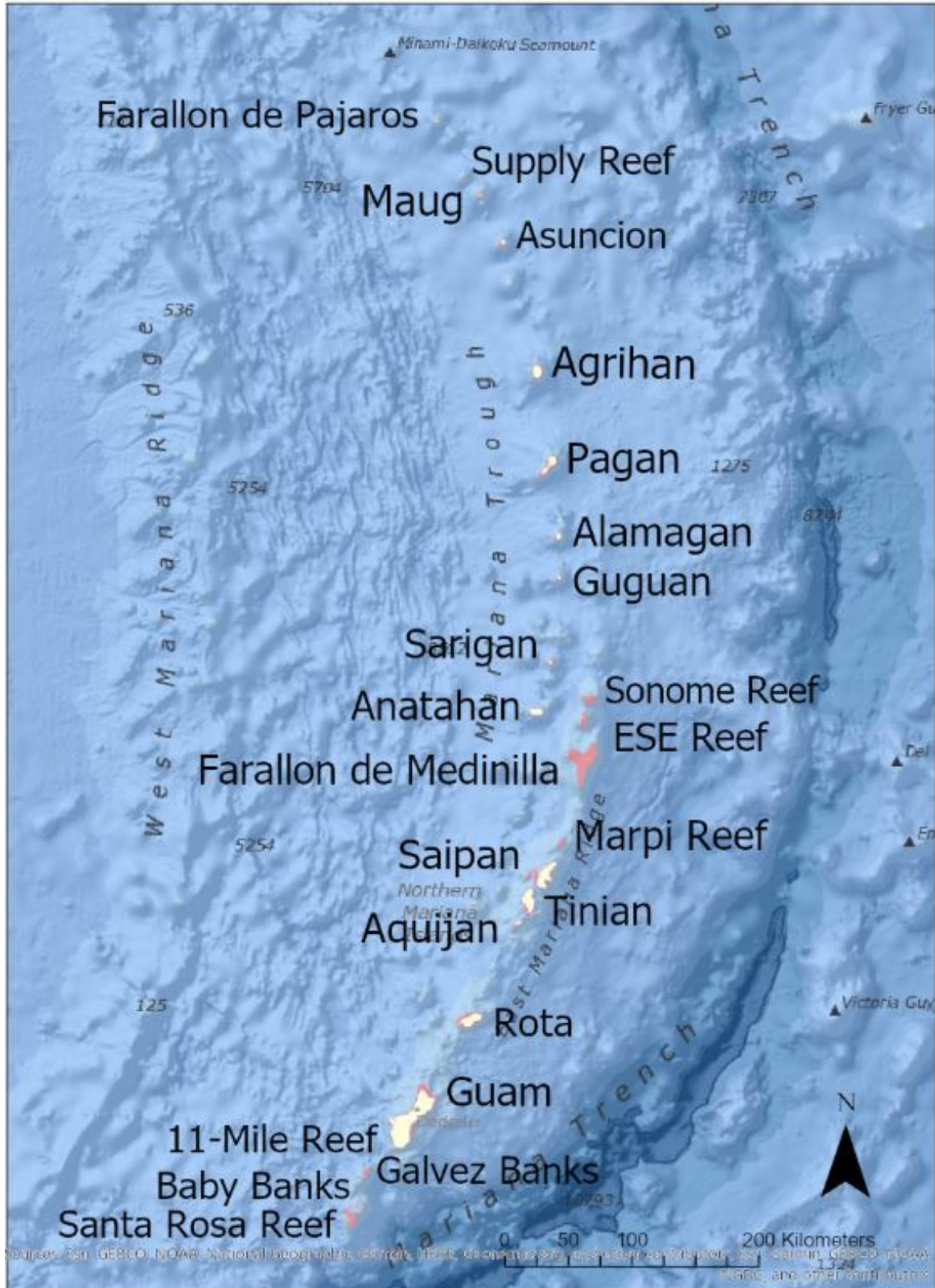


Figure 1. Commonwealth of Northern Mariana Islands (CNMI) and Guam. Red regions indicate preferred humpback whale habitat (depths less than 183 m).



Figure 2. Live-aboard research vessel *MN Liquid Soul*.

The scientific team aboard the *M/V Liquid Soul* consisted of a core group of three marine species observers (MSOs), experienced in the identification of Pacific marine mammal species (**Table 1**). All MSOs were responsible for taking photographs during sighting encounters for species verification and photo-identification purposes.

Table 1. Observers and roles.

Observer	Affiliation	Role(s)
Jessica Chen	NAVFAC Pacific	Cruise Leader and MSO
Marie Hill	PIFSC	MSO
Mark Deakos	HDR, Inc.	MSO, Driver

Key: NAVFAC = Naval Facilities Engineering Command, MSO = Marine Species Observer; PIFSC = Pacific Islands Fisheries Science Center

All food provisioning and equipment were loaded on the *M/V Liquid Soul* in Guam on 27 January 2020. The boat transited from Guam to Saipan on 28 January 2020 and was joined by the scientific team in Saipan. The boat began its transit to FDM early morning on 29 January 2020 and surveys were initiated at first light. At the end of each survey day, the *M/V Liquid Soul* was secured to an anchorage spot on the leeward side of FDM. For one night, anchorage was on the leeward side of Anatahan.

Dedicated observers on the port and starboard sides scanned a 120-degree sweep from the front of the ship towards the back while the third observer scanned a 120-degree sweep behind the vessel. Surveys were done using naked eye and assisted by 7 × 50 hand-held Fujinon binoculars to investigate any suspicious cues.

Sighting data were collected during daylight hours when weather conditions permitted (e.g., no heavy rain, Beaufort Sea State [BSS] <6). The recorder operating *COMPASS* was responsible for recording BSS and sighting information (e.g., species; minimum, maximum, and best estimates of group size; photographer; camera used; and any photo frames taken; and any additional notes). *COMPASS* was programmed to continuously record the track of the ship using the attached GPS.

A Parrott Anafi drone was approved by the Navy for assisting with obtaining photo-identifications during encounters if the animals proved to be too evasive to successfully photo-identify from the boat.

4. Results

4.1 Preferred Humpback Whale Habitat

The area of available humpback whale preferred habitat (<183 m depth) around each island is presented in Table 2. Saipan, Tinian and Aquijan (STA) were combined given their proximity and lack of deep water separating them. Among the 13 island regions, five alone represented over two thirds of the ideal habitat (FDM, STA, Guam, Rota, Pagan) while submerged reefs (Supply Reef, Sonome Reef, ESE Reef, Marpi Reef, 11-Mile Reef, Galvez Banks, Baby Banks and Santa Rosa Reef) represented another 24 percent of preferred habitat (**Figure 3**). FDM alone made-up 28.9 percent of the preferred habitat and increased to almost 38 percent if we include the two submerged reefs closely positioned to the north (Sonome and ESE Reef). Maps showing the areas of preferred humpback habitat throughout the Mariana Archipelago are shown in **Appendix A**.

Table 2. Summary of preferred habitat (bathymetry less than 183 m) available around each island in CNMI as well as offshore submerged reefs starting from the most northern island.

Mariana Island or Offshore Shallow Reef	Humpback Whale Preferred Habitat (km ²)	% Area
Farallon De Pajaros Island	3.5	0.3%
Supply Reef	3.2	0.3%
Maug Island	14.1	1.2%
Asuncion Island	15.4	1.3%
Agrihan Island	24.1	2.0%
Pagan Island	52.2	4.3%
Alamagan Island	10.0	0.8%
Guguan Island	13.1	1.1%
Sarigan Island	14.4	1.2%
Anatahan Island	10.3	0.8%
Sonome Reef	57.0	4.7%
ESE Reef	47.6	3.9%
FDM Island	353.5	28.9%
STA ⁶ Islands	162.6	13.3%
Marpi Reef	27.4	2.2%
Rota Island	80.3	6.6%
Guam Island	179.4	14.7%
11 Mile Reef	0.8	0.1%
Galvez Banks	28.6	2.3%
Baby Banks	3.8	0.3%
Santa Rosa Reef	120.4	9.9%
Total	1,221.6	

⁶ Saipan, Tinian, Aquijan

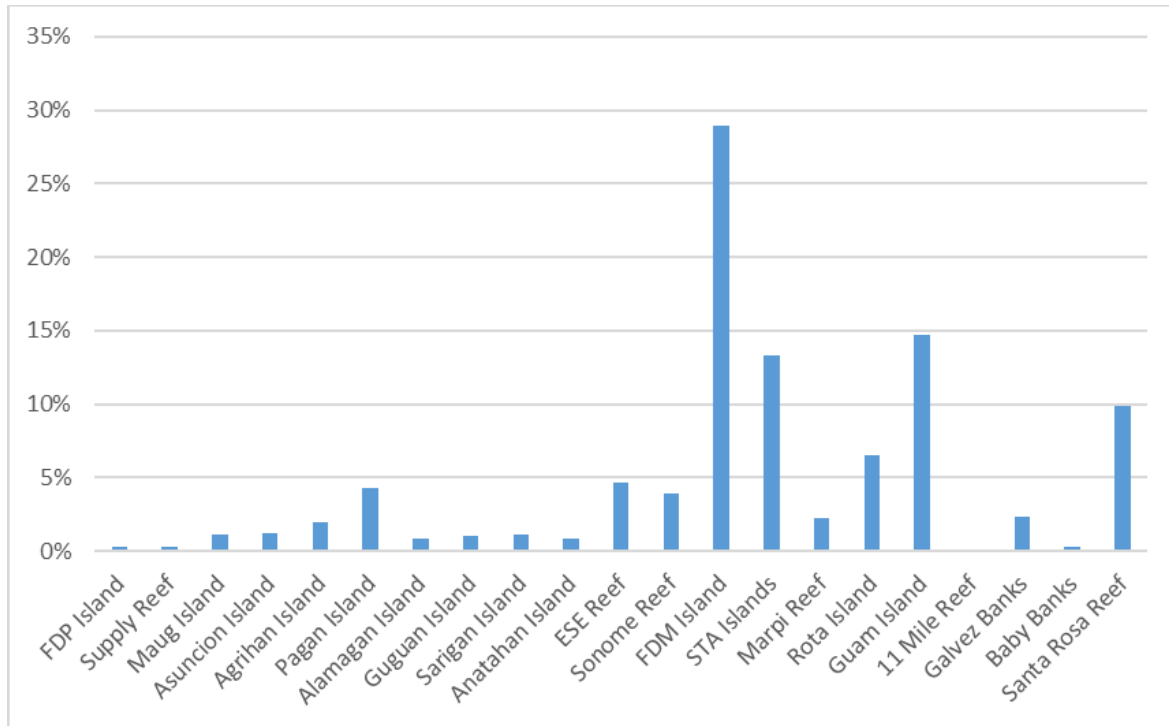


Figure 3. Percent of preferred humpback whale breeding habitat (bathymetry less than 183 m) surrounding each island within CNMI including several offshore submerged reefs.

4.2 Vessel Surveys

More than 40 hours of observation was conducted during the four days of surveying, covering a total distance of 456 km (Table 3). Effort occurred around FDM, ESE Reef, Sonome Reef, and Anatahan (Figure 4).

Table 3. Summary of vessel survey effort.

Day	Start Time	End Time	Total Time	Total Distance (km)	Deep Water Effort (>183 m)	Shallow Water Effort (<183 m)
29 January 2020	6:39:38	17:31:13	10:51:35	38	8.9	29.0
30 January 2020	7:25:09	17:49:04	10:23:55	108	36.7	71.7
31 January 2020	7:40:13	16:09:33	8:29:20	126	82.3	43.9
1 February 2020	7:43:53	18:31:16	10:47:23	184	136.9	48.1
Total			40:32:13	456	264.8	192.7

A total of 12 cetacean sightings were made (Figure 5, Table 4), 9 (75 percent) were of humpback whales, two (17 percent) were of bottlenose dolphins (*Tursiops truncatus*) and one (8 percent) of short-finned pilot whales (*Globicephala macrorhynchus*). Out of the 9 humpback whale sightings, 10 unique individual humpback whales were identified, including resights between days and years (Table 5).

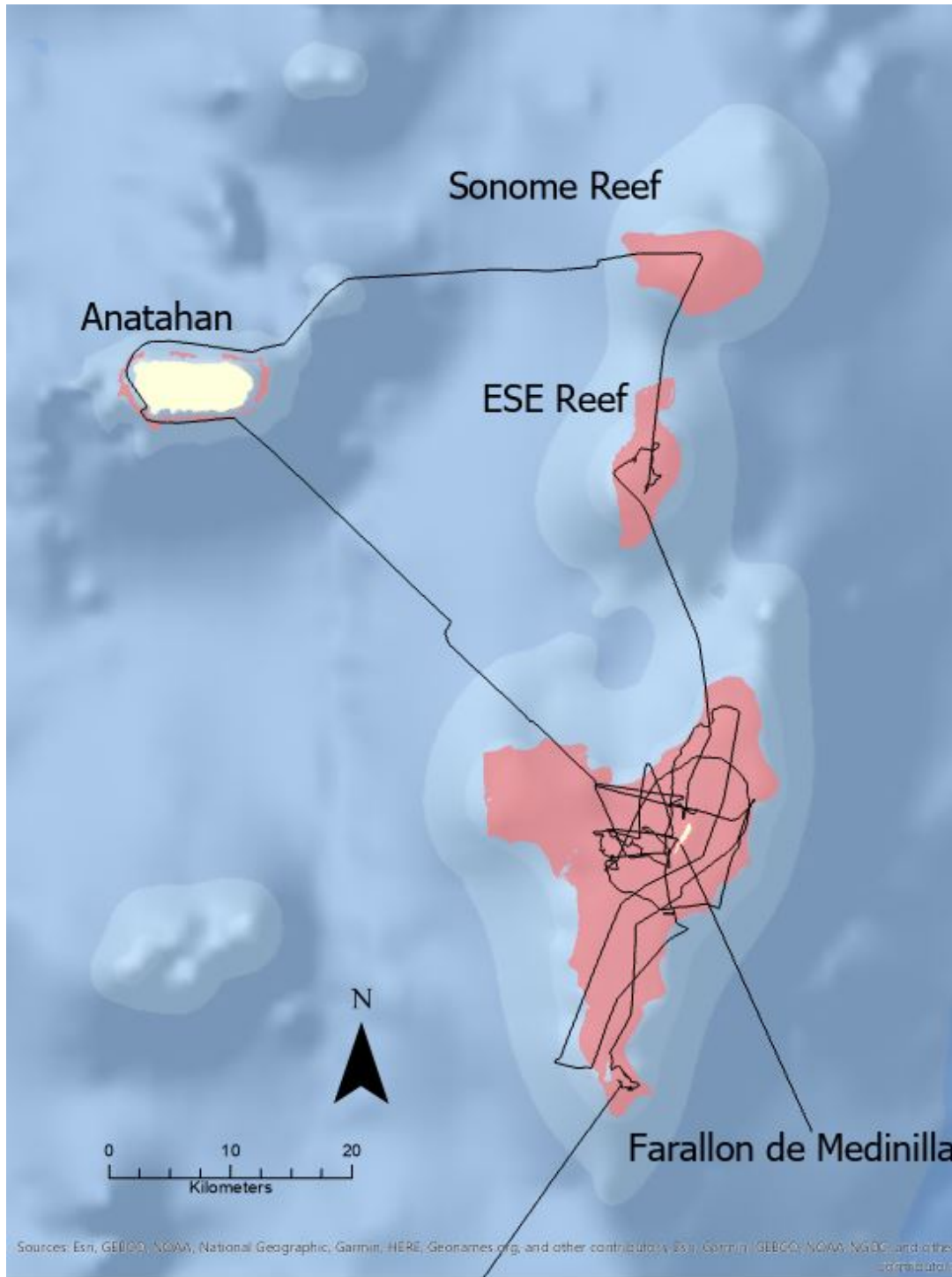


Figure 4. Vessel tracks for the M/V *Liquid Soul* around FDM, ESE Reef, Sonome Reef and Anatahan during 29 January to 1 February 2020. Red regions indicate preferred humpback whale habitat (depths less than 183 m).



Figure 5. Original marine mammal sightings and movements around FDM and ESE Reef during 29 January to 1 February 2020. Labels indicate the sighting number followed in parentheses by the genus and species initials (Mn = *Megaptera novaeangliae*, Tt = *Tursiops truncatus*, Gm = *Globicephala macrorhynchus*) and the group size. Red regions indicate preferred humpback whale habitat (depths less than 183 m).

Table 4. Summary of marine mammal sightings.

Sighting No.	Date	Time	BSS	Species	Best Count	Latitude	Longitude	Swell (m)	Depth (m)	Photos
1	1/29/20	07:01:39	4	<i>Mn</i>	1	16.00976	146.02493	1.2	96	156
2	1/29/20	11:11:17	5	<i>Mn</i>	3	16.01613	146.02333	1.2	94	687
3	1/29/20	16:54:10	5	<i>Mn</i>	1	16.01198	146.04437	1.8	70	68
4	1/30/20	08:01:28	4	Gm	7	15.96070	146.05237	1.2	84	32
5	1/30/20	12:43:42	3	<i>Mn</i>	4	16.11516	146.08746	1.5	84	2214
6	1/30/20	12:48:34	3	<i>Tt</i>	15	16.11516	146.08746	1.5	84	31
7	1/30/20	16:53:37	3	<i>Mn</i>	2	16.04063	146.04642	1.5	74	78
8	1/30/20	17:11:36	3	<i>Mn</i>	1	16.03937	146.05783	1.5	60	16
9	1/31/20	09:39:49	3	<i>Mn</i>	2	16.29742	146.01942	1.2	82	116
10	2/1/20	10:25:45	3	<i>Tt</i>	3	16.10348	145.94180	1.5	144	0
11	2/1/20	13:14:59	5	<i>Mn</i>	2	15.86097	146.00539	2.1	71	215
12	2/1/20	14:59:51	6	<i>Mn</i>	2	15.83598	146.00937	2.1	71	151

Key: Gm = *Globicephala macrorhynchus*; Mn = *Megaptera novaeangliae*; Tt = *Tursiops truncatus*;
 BSS = Beaufort sea state

Table 5. Summary of unique individual marine mammals sighted by species.

Species	Number of Sightings	Total Unique Individuals	Number resighted during 2020 survey	Number resighted from previous years	Humpback Whales Seen on Multiple Days on Survey
Humpback Whale	9 (75%)	10	6	4	5
Pilot Whale	1 (8%)	7	0		
Bottlenose Dolphin	2 (17%)	18	0		
Total	12	35			

A total of 3,816 photos were taken of three different species. The majority (98 percent) were taken of humpback whales, 1 percent of bottlenose dolphins and 1 percent of pilot whales.

The sightings per unit effort (SPUE) for humpback whales was calculated as the total number of humpback whale sightings ($n=9$) divided by the total distance surveyed (456 km). The SPUE overall for humpback whales was 0.02 sightings/km, but in preferred habitat, the SPUE doubled to 0.04. Humpback whale sightings occurred in depths ranging from 60 to 96 m (Table 4). The BSS ranged from 2 to 6 with sightings made primarily in BSS 3 (Table 3). Sightings occurred at

FDM, ESE Reef, and Sonome Reef. No sightings occurred around Anatahan although humpback whale song was audible in this area.

4.3 Humpback Whale Photo-Identifications

During nine sightings of humpback whales in which photos were collected, ten unique individuals were identified (Table 6), seven males, two females and one gender unknown.

Four of these individuals were matched to individuals photographed in previous years. A likely adult male (#31) was previously seen off Okinawa, Japan, and the Commander Islands, Russia, in 2000 and 2012 respectively, and then seen at Marpi Reef and off Saipan in 2017 (Hill et al. 2020). Another likely male whose age class was undetermined (#33) was previously sighted at Marpi Reef in 2017 and off Saipan in 2019. A confirmed adult female (#50) was previously seen off Saipan in 2018. A likely adult male (#62) was seen at Marpi Reef in 2007 (Fulling et al. 2011). Due to the poor quality of the 2007 photo-ID, this whale was not in the PIFSC catalog but has since been included with the 2020 photo-ID adding a total of seven new individuals to the catalog. Three of the four humpback whales identified in prior years and three newly identified individuals were resighted across multiple days during this survey.





4.4 Behavioral Observations


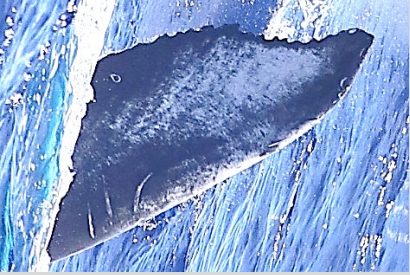



Although most survey effort (58 percent) occurred in non-preferred humpback whale breeding habitat, all humpback whales were sighted in preferred breeding habitat. Humpback whale song, a competitive group with a clear nuclear animal, defending male and challenging male and dyads were observed over the four days but no mother-calf pairs were present.

Examples of mating behavior were observed on the first day when a surface-active nuclear animal (#61), likely the female due to her behavior (Deakos 2002), was with a primary male escort (#31) who was performing typical head lunge threat displays (Baker & Herman 1984) and successfully defended himself against a challenging male (#62) that eventually disaffiliated. The remaining male-likely female dyad was seen again as a pair the following day. The disaffiliated challenger (#62) was also seen in a dyad with a known adult female (#50) two and three days later.

The largest group observed during the surveys was a group of four humpback whales (#33, #63, #64, #65) with no obvious nuclear animal, and no obvious primary escort performing stereotypical threat displays (e.g., head lunging, linear bubble trails). The randomness of the group was typical of all male groups frequently observed in Hawaii containing all juvenile males (Deakos pers. obs.). One of the four whales (#64) was clearly a juvenile based on its small size. One of the three larger whales (#65) was seen alone later that same day and in a pair with an individual (#66) of similar size but unknown gender two days later.

Table 6. The sighting history of the 10 humpback whales photo-identified between 29 January and 1 February.

PIFSC Catalog ID	Photo	Gender	Age Class	Across Year Resight	FDM Within Year Resight and Behavioral Role
MIMn-31		M	A	2000 – OJ 2012 – CR 2017 - MR 2017 - S	1/29/20 - N1E 1/30/20 - DA
MIMn-33		M	U	2017 - MR 2019 - S	1/30/20 - A(4A)
MIMn-50		F	A	2018 - S	1/31/20 – DA 2/1/20 – DA
MIMn-60		M	U	-	1/29/20 - 1A 1/29/20 - 1A
MIMn-61	Dorsal only	F	A	-	1/29/20 - NA 1/30/20 - DA
MIMn-62	Dorsal only	M	A	2007 - MR	1/29/20 - N2E 1/31/20 – DA 2/1/20 – DA

PIFSC Catalog ID	Photo	Gender	Age Class	Across Year Resight	FDM Within Year Resight and Behavioral Role
MIMn-63a		M	U	-	1/30/20 - A(4A)
MIMn-63b					
MIMn-64		M	J	-	1/30/20 - A(4A)
MIMn-65		M	U	-	1/30/20 - A(4A)/1A 2/1/20 - DA
MIMn-66		U	U	-	2/1/20 - DA

1A = Lone Adult; A = Adult; CR = Commander Islands, Russia; DA = Dyad; M = Male; F = Female; MR = Marpi Reef; NA = Nuclear Animal; N1E = Nuclear Primary Escort; N2E = Nuclear Secondary Escort; OJ = Okinawa, Japan; S = Saipan

5. Discussion

It has been shown that humpback whales prefer depths less than 183 m when visiting their breeding grounds (Herman and Antinaja 1977). The bathymetric analysis of the Mariana Archipelago that included 15 islands and several offshore submerged reefs found that only a few had areas of preferred humpback whale breeding ground habitat that are of significant size. The shallow plateau surrounding FDM had almost twice as much preferred habitat (354 km²) as the next most likely island, which is Guam (179 km²). FDM alone accounted for 32.2 percent of the preferred habitat and if combined with nearby ESE and Sonome Reef to the north, the area comprises 38 percent of the preferred habitat within the entire Archipelago. Guam is the largest island of the Archipelago but has only a thin band of preferred habitat surrounding the island, which may explain the low number of sightings of humpback whales observed in this area. Anecdotal accounts of humpback whales seen off Guam suggest they may be transiting through the area. Galvez Banks is only 20 km to the southwest of Guam and provides a concentrated space of 28 km² of preferred habitat and 48 km southwest of Guam is Santa Rosa Reef with over 120 km² of preferred breeding habitat that may be more suitable for humpback whales. The third area with the most preferred habitat is around Saipan and Tinian (163 km²) where 41 non-calf and 14 calf humpback whales were documented between 2015 and 2018 (Hill et al. 2020). It is important to note that nearly a third of the humpback whale sightings in 2015–2018, which included mother-calf pairs and competitive groups, were on Marpi Reef where the estimated preferred habitat is 27 km². Among the islands north of FDM, Pagan has the largest area of preferred habitat with just under 5 percent (52 km²) of the total area across the Archipelago. Humpback whale song has been recorded at Pagan but not at Maug (Allen et al. in review; Munger & Lammers 2020), which represents 1.3 percent (14 km²) of the total preferred habitat. It should be noted that the acoustic receiver at Maug was inside the atoll, which may have impeded its ability to detect song outside of the atoll (Munger & Lammers 2020).

Despite weather conditions only allowing a four-day window to effectively survey FDM and the surrounding areas, nine humpback whale sightings were made. This resulted in the identification of six new individuals and resighting records for four individuals seen in prior years off Saipan, one as far back as 2007. Individuals were seen on multiple days within the survey area suggesting that the whales are not just migrating past FDM and the surrounding area.

The observed competitive behaviors and behavioral roles of individuals were typical of those observed on humpback whale breeding grounds like Hawaii (Tyack 1983). Despite Hill et al. (2020) identifying 14 mother-calf pairs off Saipan no mother calf pairs were observed at FDM. The late January – early February survey at FDM may have been too early to detect calves. Dawbin (1966) described the migratory parade in which pregnant females are the last to arrive on the breeding grounds. Calves were seen off Saipan in mid-February to mid-March in 2015-2018 (Hill pers. comm.). In Hawaii (Baker & Herman 1984) and in Okinawa, Japan (Kobayashi et al. 2016), the peak numbers of calves on the breeding grounds are seen in March. It has also been shown that females with a calf prefer shallower habitat (<50 m) than females without a calf, possibly as a way to reduce harassment from males (Craig et al. 2014). Craig & Herman

(2000) found that in Hawaii, in years when they were with a calf, females preferred Maui over the Big Island where there is more of the shallowest habitat. It is possible that pregnant females in the Marianas may bypass FDM for the preferred habitat to the south because waters are not shallow enough off FDM for calves.

To better understand which habitats within the Mariana Archipelago are important for humpback whale reproductive activities, additional visual and/or acoustic monitoring around FDM at different times of the winter season would be informative. Additionally, a survey conducted later in the season at FDM may reveal a greater proportion of mothers with calf and help to better understand the importance of FDM as habitat for calf rearing.

Additional monitoring should also be conducted in other parts of the Archipelago with large bathymetric areas that are less than 183 m deep such as around Pagan Island, ESE and Sonome Reef and Rota Island to confirm or eliminate these habitats as being significant breeding areas for humpback whales. Although not part of the Mariana Archipelago, 350 km southeast of Guam extends a conglomerate of shallow reefs (Mogami Bank & Gray Feather Bank) totaling 8,730 km² of preferred humpback breeding habitat within a 500 km × 200 km area. The largest reef tract alone covers over 5,000 km². This shallow water habitat is seven times the preferred humpback whale breeding habitat than the entire Mariana Archipelago combined and therefore cannot be dismissed as a potential prime breeding area for North Pacific humpback whales.

In conclusion, the *M/V Liquid Soul* survey was successful in meeting its three objectives: 1) to visually validate humpback whales in waters around FDM, 2) photo-identify individuals to document multiple day site fidelity to the area and connectivity to sightings elsewhere, and 3) to document humpback whale behavior to support use of the FDM area for reproductive purposes.



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A

Humpback Whale Preferred Breeding Habitat Maps



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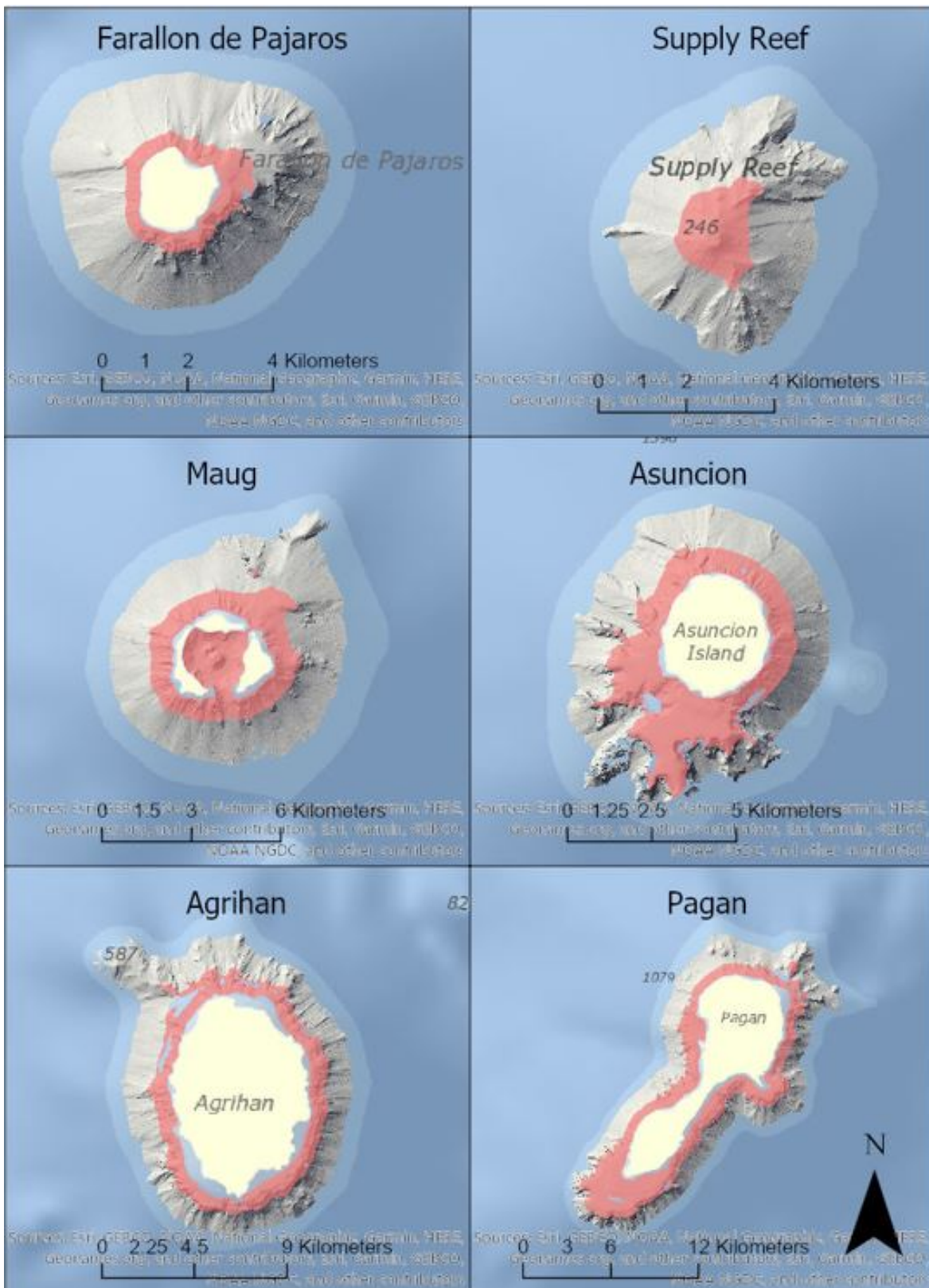


Figure A-1. Maps showing preferred humpback whale habitat (less than 184 m depth) in red around Farallon de Pajaros, Supply Reef, Maug, Asuncion, Agrihan and Pagan from north to south.

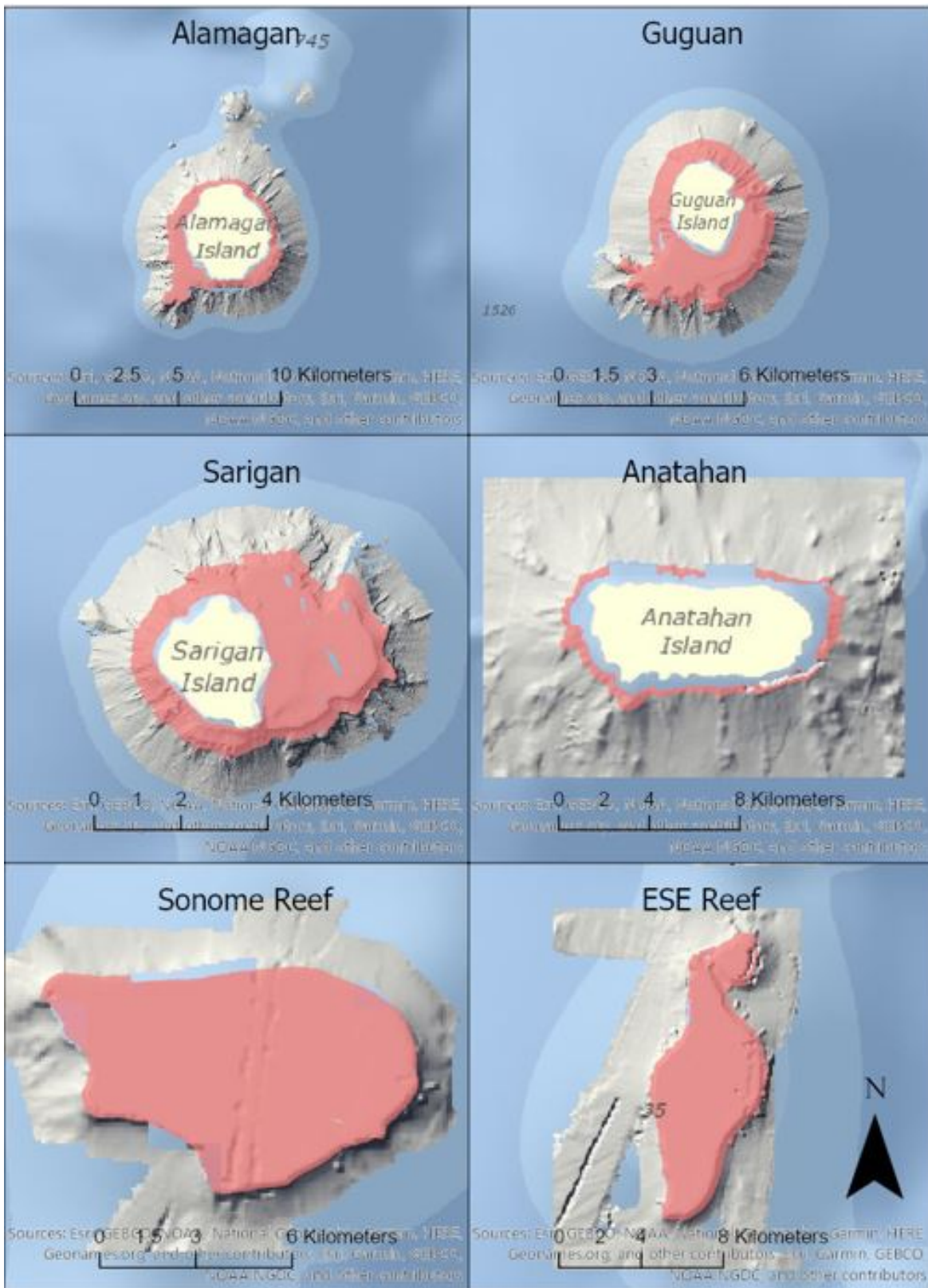


Figure A-2. Maps showing preferred humpback whale habitat (less than 184 m depth) in red around Alamagan, Guguan, Sarigan, Anatahan, Sonome Reef and ESE Reef from north to south.

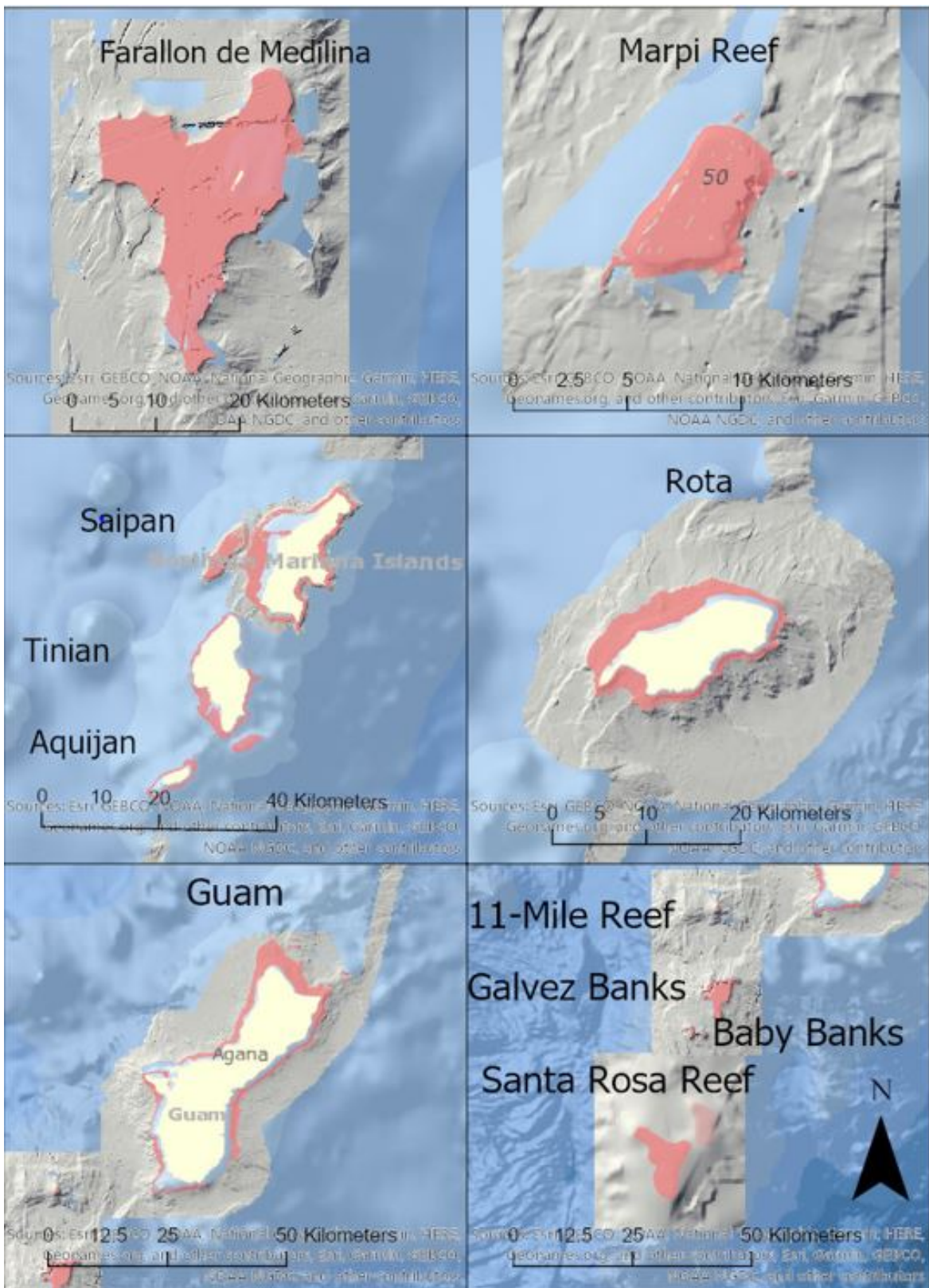


Figure A-3. Maps showing preferred humpback whale breeding habitat (less than 183 m depth) in red around Farallon de Medilina, Marpi Reef, Saipan, Tinian, Aquijan, Rota, Guam, 11-Mile Reef, Galvez Banks, Baby Banks, and Santa Rosa Reef from north to south.