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2013–2023 FINAL REPORT: SEA TURTLE SURVEYS AND TRACKING IN THE MARIANA ISLANDS TRAINING AND TESTING (MITT) STUDY AREA

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Marine Turtle Biology and Assessment Program (MTBAP)
Protected Species Division (PSD)
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List of Acronyms

BO – Biological Opinion	**MDD – Maximum Dive Depth**
C – Celsius	**MIRCMP – Mariana Islands Range Complex Monitoring Plan**
CM – Centimeter	**M – Meter**
CNMI – Commonwealth of the Northern Mariana Islands	**MITT – Mariana Islands Training and Testing**
DAWR – Division of Aquatic and Wildlife Resources	**MMPA – Marine Mammal Protection Act**
DD – Dive duration	**MTBAP – Marine Turtle Biology and Assessment Program**
DLNR – Department of Lands and Natural Resources	**NMFS – National Marine Fisheries Service**
DNA – Deoxyribonucleic Acid	**NOAA – National Oceanic and Atmospheric Administration**
ESA – Endangered Species Act	**PIFSC – Pacific Islands Fisheries Science Center**
FY – Fiscal Year	**PIT – Passive Integrated Transponder**
GIS – Geographic Information Systems	**PSD – Protected Species Division**
GPS – Global Positioning System	**SCL – Straight Carapace Length**
ICMP – Integrated Comprehensive Monitoring Program	**SD – Standard Deviation**
ID - Identification	**TAD – Time At Depth**
KM – Kilometer	**TAT – Time At Temperature**
LC – Location Class	**USFWS – United States Fish and Wildlife Service**

ABSTRACT

Understanding the spatio-temporal movements of animals is an integral component of wildlife conservation and management. Sea turtles are species of conservation concern; satellite telemetry is a primary research tool used to study their movements**,** providing high accuracy location data in near "real time," thus facilitating rapid identification of movements and key habitats. Although it has been recognized that both green (*Chelonia mydas*) and hawksbill (*Eretmochelys imbricata*) turtles inhabit the waters around Guam and the Commonwealth of the Northern Mariana Islands (collectively referred to as the Mariana Islands), their distribution and habitat use in the region remains unclear. In 2013, under an inter-agency agreement with the United States Navy, the National Oceanic and Atmospheric Administration (NOAA) began conducting in-water surveys to record and quantify observations of sea turtles around the Mariana Islands. When observed, attempts were made to hand-capture turtles and equip them with satellite tags in an effort to better understand their spatial ecology. Between 2013 and 2023, researchers encountered a total of 517 turtles, 111 of which were captured and equipped with satellite tags, including 97 green turtles and 14 hawksbill turtles. Four tags failed to transmit post-deployment. The overwhelming majority (97.5 %) of captures were juvenile or sub-adult turtles, with straight carapace length averaging 53.7 cm (SD = 9.5 cm) for green turtles and 50.9 cm (SD = 11.9 cm) for hawksbill turtles. Movements and habitat use were highly neritic for the overwhelming majority of tracked turtles, with home range estimates revealing limited movements for the majority of both species. Ninety−four (87.8%) of the tracked turtles remained within a less than 1 kilometer $(km)^2$ core area for the entire life of their tag (average tag retention time = 191 days), demonstrating limited movements and high foraging site fidelity. Notwithstanding this perspective, there were three more vagile movement patterns observed, including shifts in intra-island foraging areas (n = 5), transitions between inter-island foraging areas (n = 2), and a long-range migration departure from the Mariana Islands (n = 1). Dive patterns suggest that both green and hawksbill turtles spend most of their time in waters shallower than 25 meters. However, it is possible that habitat partitioning may exist between the two species, with hawksbill turtles spending more time in deeper waters than green turtles, using average depths of 15.3 meters and 10.5 meters, respectively. Spatial analysis of satellite tags deployed during this study has demonstrated sea turtle home ranges overlap extensively with Navy submerged lands but have limited direct overlap with Navy detonation sites (i.e., Agat Bay Mine Neutralization Site, Piti Point Mine Neutralization Site, and Outer Apra Harbor Underwater Detonation Site). The research detailed in this report provides important insights into the movement ecology of green and hawksbill turtles around the Mariana Islands, and in terms of sheer numbers of satellite tags deployed, represents the most rigorous individual study on these species in the world.

INTRODUCTION

The United States Department of the Navy (Navy) operates in Guam and the Commonwealth of the Northern Mariana Islands (CNMI) (collectively referred to as the Mariana Islands), which are located within the Navy's Mariana Islands Training and Testing (MITT) study area (www.mitt-eis.com; Figure 1). The Navy developed several monitoring questions for the MITT study area as required under the Marine Mammal Protection Act (MMPA) of 1972 and the Endangered Species Act (ESA) of 1973. In 2014, the Navy prepared a Mariana Islands Range Complex Monitoring Plan (MIRCMP) to assist the Navy and the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) by collecting data to better understand the distribution and habitat use of marine mammals and sea turtles in the Mariana Islands, as well as the potential impacts of Navy training and testing within the MITT.

Based on identified data needs, in 2013, the Navy and NOAA's Marine Turtle Biology and Assessment Program (MTBAP) at the Pacific Islands Fisheries Science Center (PIFSC) entered into an inter-agency agreement (IAA) under which MTBAP began research to understand the occurrence, distribution, and habitat use of sea turtles around the Mariana Islands. Although five species of sea turtles may be associated with the MITT study area, only the green (*Chelonia mydas*) and hawksbill (*Eretmochelys* imbricata) turtles are known to consistently inhabit the nearshore waters of the Mariana Islands (Summers et al., 2017; Martin et al., 2016).

Multiple approaches were implemented via the IAA to address data needs; the primary activity included free-diving transect surveys to quantify and capture sea turtles, then equip a portion of those turtles with high-resolution satellite transmitter tags to learn about their horizontal and vertical movement behavior and habitat use. Data generated via implementation of the IAA between the Navy and NOAA as part of the MIRCMP supports Navy environmental compliance, including the ESA Biological Opinion (BO) received by the Navy with respect to the MITT study area in 2020.

This final report summarizes the activities and outcomes of the multi-year NOAA-Navy IAA and provides unique insights into two primary questions set forth by the MIRCMP, including (1) what is the occurrence, habitat use, and population structure of sea turtles in the MITT study area? and (2) what is the exposure of sea turtles to explosives and/or sonar in the MITT study area?

METHODS

IN-WATER SURVEYS, TURTLE CAPTURES, AND TURTLE PROCESSING

Small boat surveys were conducted in the nearshore and coastal waters of Guam, Saipan, and Tinian (Figure 1). Surveys consisted of a team of 2 or more free divers swimming transects along the coast in an effort to observe and identify turtles. Information on species, size, and sex of turtles was communicated via hand signals to staff on-board the small boat, who then recorded that information, as well as time and location (GPS). Whenever feasible, attempts were made by free diving (2–25 meters [m]) to capture turtles resting/foraging on the seafloor or swimming in the water column. Captured turtles were immediately brought to the surface, lifted into a boat, then processed on deck or on shore.

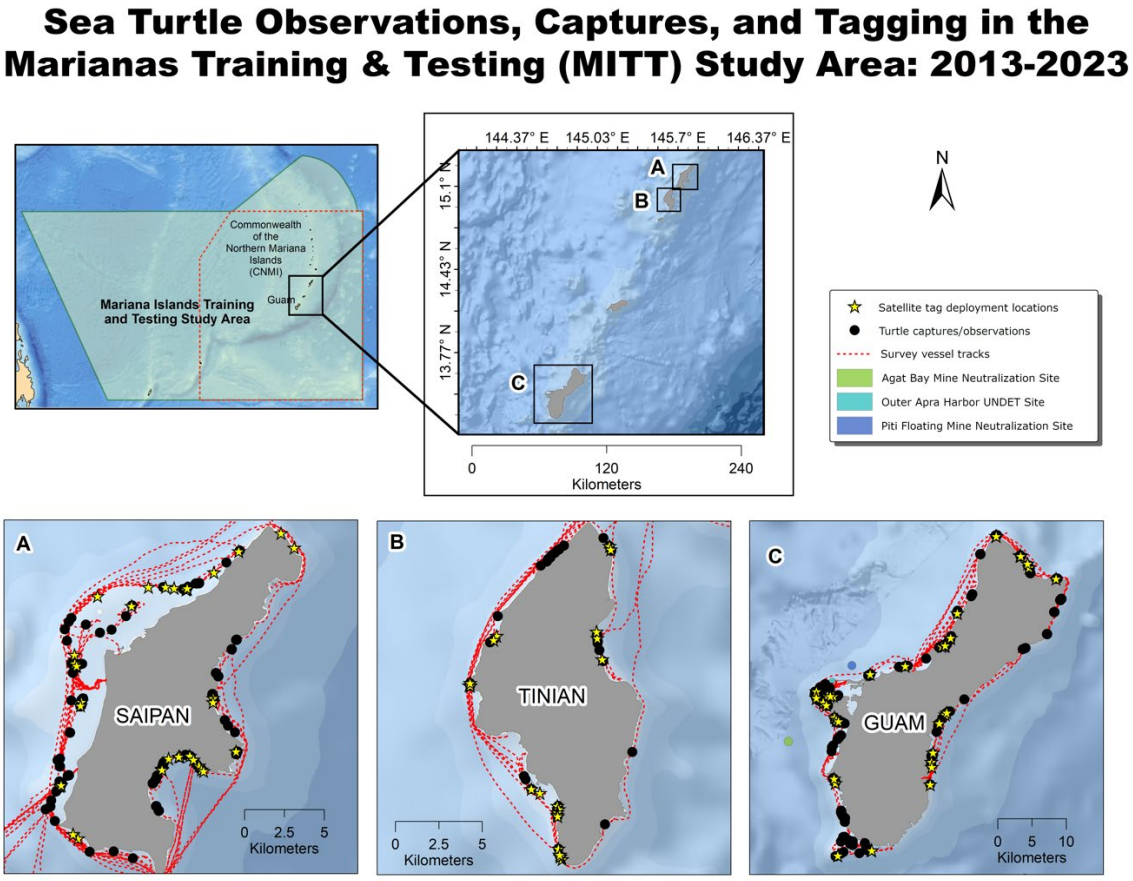


Figure 1. Sea turtle observations/captures (black dots) and satellite tag deployment locations (yellow stars) in the MITT study area. Red dashed lines on each map depict vessel movements on survey days.

All turtles were tagged with metal Inconel tags or 'flipper tags' (Style 681, National Band and Tag Company) using globally standardized techniques (Eckert et al., 1999), and with Passive Integrated Transponder (PIT) tags – small (14 mm length x 2 mm diameter) electromagnetically-coded glass-

encased “microchips” (Biomark, Inc., Boise, Idaho, USA). The Inconel flipper tags were attached to the trailing edge of the fore flippers and the PIT tags were injected subcutaneously into the rear flippers. Skin samples were obtained from the neck, shoulder, or hind flipper of each turtle (Dutton et al., 1996) for future DNA and stable isotope analysis. Straight carapace length (SCL) and curved carapace length (CCL) were measured (nuchal notch to posterior-most tip of marginal scutes) and turtles of appropriate SCL (see Jones et al., 2013) and condition were outfitted with a satellite tag. We opportunistically quantified and recorded any cetacean observations during transects.

SATELLITE TAGS

Satellite tag attachment procedures followed the drag recommendations of Jones et al. (2011, 2013) and methods described in Jones et al. (2018) or in the Wildlife Computers tag attachment protocol. Turtles with SCL greater than 45 cm were typically equipped with Wildlife Computers SPLASH satellite tags, which have both Fastloc-GPS and Argos location capabilities, as well as temperature and depth sensors. Turtles with SCL between 35 cm and 45 cm were typically equipped with Wildlife Computers SPOT satellite tags, which only have Argos location capabilities. Tag preparation included covering each tag with multiple layers of anti-fouling paint (Micron66; see Wildlife Computers anti-fouling paint protocol) to inhibit the growth of algae that can cover sensors and interfere with tag operation.

MOVEMENT TRACKS, LOCATION PROCESSING, AND HOME RANGE ESTIMATES

All satellite tag locations were acquired and transmitted via Argos (Landover, Maryland) satellites. This included both Fast-loc GPS locations (when equipped) and Argos locations derived using the Kalman geoprocessing algorithm, the latter being categorized into 1 of 6 location classes (LCs; 1, 2, 3, A, B, Z; see Table S1 for details). Using the *trip* package (Sumner et al. 2009, 2011) for the R statistical environment (R Core Team, 2022), we applied a filter to exclude biologically unreasonable results of location points, including travel speed (>7.2 km h^{-1}) and internal turning angles (<12.5°). We also filtered out all locations that occurred within the first day (i.e., 24 hr) of tag deployment to account for potentially non-normal behavior (Gaos et al., 2012a). We removed tags with 20 or fewer locations from all home range analyses.

We calculated home ranges, including 50% (core home ranges) and 95% (overall home ranges) volume contours, using a newly developed package in the R statistical environment. The package uses

all available locations (i.e., GPS and Argos), giving stepwise weighting to the more precise locations (e.g., GPS) over the less precise locations (e.g., LCB). In addition to calculating home range estimates for each turtle individually, we also created pooled home ranges by grouping the data by species and tag deployment location to visually evaluate habitat use across multiple individuals.

We used analysis of variance (ANOVA) tests to examine potential differences in the core and overall home range sizes for SPLASH tags versus SPOT tags. Because we found no significant differences (i.e., $P > 0.05$), we combined results of both tag models for subsequent analyses. We also used ANOVAs to compare home range sizes among groups of turtles, including: species (green [n = 95] vs. hawksbill [n = 12] turtles); sizes (SCL): (small [< 45 cm, n = 18], medium [45–60 cm, n = 52], large [> 60 cm, n = 37], and just small [< 55 cm, n = 49] and large [> 55 cm, n = 58]); and Island by species (Guam [green n = 45, hawksbill n = 2], Tinian [green n = 18, hawksbill [n = 6], Saipan [green n = 32, hawksbill n = 4]). Sample sizes varied due to various requirements (e.g., number of tag transmissions or morphometrics available) needed for each analysis. For the island home range comparisons, we removed any turtles that used foraging habitats on more than one island. For the one turtle that departed the Mariana Islands (see Results), we calculated the home range prior to departure.

We visually plotted in-water turtle observations and capture locations, as well as tracks for boat movements during surveys (Figure 1) using a combination of ArcGIS (ESRI, 2012) and the R statistical environment. Public access to all of the satellite tags deployed under the NOAA-PACFLEET IAA was achieved via creation of a NOAA-PACFLEET web project (https://portal.atn.ioos.us/, search Projects page for MITT) within the Animal Tracking Network. We categorized all satellite tracked turtles into one of four movement behavior categories.

- Movement behavior 1–Remain in the vicinity of a single foraging area.
- Movement behavior 2–Shifts in intra-island foraging areas.
- Movement behavior 3–Transition between distinct inter-island foraging areas.
- Movement behavior 4–Departure from the Mariana Islands.

TEMPERATURE AND DEPTH DATA

Temperature and depth data (SPLASH tags only) were collected every 10 seconds and binned across 6-hour (hr) periods, then transmitted via satellite along with Argos and GPS (if applicable) location data when the turtle surfaced. The temperature and dive sensor bins are user-defined and offer insights into different aspects associated with in-water behavior, including: Time at Temperature

(TAT: the proportion of dives spent at each temperature bin); Time at depth (TAD: the proportion of overall dive time spent within each depth bin); Max Dive Depth (MDD: the maximum depth bin reached for each dive); Dive Duration (DD: the time duration bin of each dive). The TAT, TAD, MDD, and DD bins were programmed as follows:

- TAT (°C): 19, 21, 23, 24, 25, 26, 27, 28, 29, 30, 31, 33, 35, >35
- TAD (m): 0, 2, 5, 10, 15, 20, 25, 30, 40, 50, 60, 70, 100, >100
- MDD (m): 4, 6, 8, 10, 14, 18, 24, 30, 40, 60, 80, >80
- DD (min) (2013–2017): 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 40, 50, 60, >60
- DD (min) (2018–2022): 1, 5, 10, 20, 30, 40, 50, 60, 75, 90, 105, 120, 150, >150.

In the early years of this IAA, we recorded DDs that lasted longer than the maximum bin (see previous reports); starting in 2018 we adjusted the DD bins. Several tags deployed at the start of the project (green turtles n = 4, hawksbill turtles n = 2) had variable depth bin programs, and data for each sensor were included when feasible. The data were separated by species, and we also evaluated potential differences between diurnal and nocturnal time periods. We determined the weighted average for in-water behaviors by finding the mean percent of each bin, multiplying each mean by its corresponding bin header, summing all products together, and dividing by 100. Mean percentages for TAT, MDD, and DD in-water dive behaviors were calculated by dividing the sum of each bin by the total sum and multiplying by 100. TAD in-water dive behavior consisted of proportions, so mean percentages were calculated by finding the average of each bin.

RESULTS

IN-WATER SURVEYS AND TURTLES

A total of 517 turtles were encountered over the course of the study period (Table 1). Of those encounters, 357 turtles were observed but not captured (94 Saipan, 47 Tinian, 216 Guam), 49 turtles were captured but not outfitted with a satellite tag (11 Saipan, 18 Tinian, 20 Guam) due to small size, inadequate body condition (e.g., emaciation or a missing limb), or study design (e.g., geographic distribution of satellite tags across sites), and 111 turtles were captured and outfitted with satellite tags (38 Saipan, 24 Tinian, 49 Guam). Of the 49 turtles captured but released without a SPLASH or SPOT tag, 43 (87.8 %) were green turtles and 6 (12.2 %) were hawksbill turtles. Of the 357 non-capture observations, 258 (72.3 %) were identified as green turtles, 19 (5.3 %) as hawksbill turtles, and 80 (22.4 %) as "unknown" species (but most likely either green or hawksbill turtles). Of the 49 turtles captured but released without a SPLASH or SPOT tag, 43 (87.8 %) were green turtles and 6 (12.2 %) were hawksbill turtles. Ninety-seven of the 111 satellite tags, (87.4 %) were deployed on green turtles and 14 (12.6 %) on hawksbill turtles. Two of the tags on green turtles and two on hawksbills failed within a week of deployment; these tags were not included in our analyses. Table 1 provides a breakdown of observations, captures, and satellite tags by species and location for each year. The boat tracks on survey days, turtle observations by species, turtle captures, and satellite tags deployed for the entire study time frame are shown in Figure 1.

The frequency distribution of SCL for green and hawksbill turtles in 5 cm increments is shown in Figure 2. Captured green turtle sizes (SCL) averaged 53.7 cm (SD = 9.5 cm) and ranged from 36.9 cm to 84.9 cm (n = 139). Captured hawksbill sizes averaged 50.9 cm (SD = 11.9 cm) and ranged from 34.4 cm to 72.6 cm (n = 19). The overwhelming majority (97.5 %) of captures were juveniles or sub-adults for which sex could not be determined using visual observations or morphometric techniques. A total of five turtles were tagged and recaptured during the project timeframe, including two green turtles and three hawksbills (Table 2). Two of the hawksbills were captured on a total of three occasions. The average time between recaptures was 714 days (SD = 370), with a minimum of 307 days and a maximum of 1,119 days.

Table 1. Summary of boat-based snorkel surveys and turtle captures over the timeframe of this IAA. Data include survey dates, site locations, turtle observations (number of individuals), captures, and satellite tag deployments. CM = green turtle (*Chelonia mydas*); EI = hawksbill turtle (*Eretmochelys imbricata*); UN = unknown turtle species (either green or hawksbill turtle).

		Observation only				Captures (no sat tags)			Captures (sat tags)			Cetaceans
Survey Date	**Location (focal areas)**	**CM**	**EI**	**UN**	**Total**	**CM**	**EI**	**Total**	**CM**	**EI**	**Total**	**CET**
8/15/2013	Guam (Cocos Lagoon)	1	-	5	**6**	-	-	**-**	-	-	**-**	**-**
8/16/2013	Guam (Cocos Lagoon)	-	-	3	**3**	-	-	**-**	-	-	**-**	**-**
8/18/2013	Saipan (Balisa)	-	-	-	**-**	-	-	**-**	1	1	**2**	**-**
8/19/2013	Saipan (Balisa)	-	-	-	**-**	-	-	**-**	2	-	**2**	**-**
8/20/2013	Tinian (Fleming Point)	-	-	-	**-**	-	-	**-**	-	1	**1**	**-**
8/21/2013	Saipan (Balisa)	-	-	-	**-**	-	-	**-**	1	-	**1**	**-**
	2013 Subtotals	**1**	**-**	**8**	**9**	**-**	**-**	**-**	**4**	**2**	**6**	**-**
7/15/2014	Guam (Cocos Lagoon + Apra Harbor)	8	-	-	**8**	-	-	**-**	-	-	**-**	**-**
7/16/2014	Guam (Apra Harbor + Dadi Beach)	5	-	-	**5**	2	-	**2**	4	-	**4**	**-**
7/17/2014	Guam (Apra Harbor + Dadi Beach)	8	-	-	**8**	1	1	**2**	3	-	**3**	**-**
7/18/2014	Guam (Apra Harbor)	-	-	-	**-**	2	-	**2**	1	-	**1**	**-**
7/21/2014	Tinian (Fleming Point + Dumpcoke)	-	-	-	**-**	4	-	**4**	1	2	**3**	**-**
7/22/2014	Saipan (Spotlight + Cowtown)	-	-	-	**-**	-	-	**-**	2	-	**2**	**-**
	2014 Subtotals	**21**	**-**	**-**	**21**	**9**	**1**	**10**	**11**	**2**	**13**	**-**
11/12/2015	Tinian (Red Wall)	4	-	2	**6**	2	-	**2**	6	-	**6**	**-**
11/13/2015	Saipan (Lao Lao Bay)	1	-	8	**9**	1	-	**1**	5	-	**5**	**-**

		Observation only				Captures (no sat tags)			Captures (sat tags)			Cetaceans
Survey Date	**Location (focal areas)**	**CM**	**EI**	**UN**	**Total**	**CM**	**EI**	**Total**	**CM**	**EI**	**Total**	**CET**
11/14/2015	Saipan (Chalan Kanoa Reef)	-	-	4	**4**	1	-	**1**	5	-	**5**	**-**
11/17/2015	Guam (Agat Bay + Dadi Beach)	1	-	4	**5**	-	1	**1**	1	-	**1**	**-**
11/18/2015	Guam (Agat Bay + Dadi Beach)	1	-	9	**10**	-	-	**-**	2	-	**2**	**-**
	2015 Subtotals	**7**	**-**	**27**	**34**	**4**	**1**	**5**	**16**	**-**	**16**	**-**
5/12/2016	Guam (Apra Harbor + Orote Point)	11	-	4	**15**	6	-	**6**	1	1	**2**	**-**
5/13/2016	Guam (Orote Point)	12	1	11	**24**	-	-	**-**	2	-	**2**	**-**
5/15/2016	Tinian (Dangkolo + Chulu)	1	-	8	**9**	1	-	**1**	2	1	**3**	**-**
5/16/2016	Tinian (Babui Beach + LamLam + Tohgong)	5	1	4	**10**	5	3	**8**	2	-	**2**	**-**
5/17/2016	Tinian (Chulu + Babui Beach)	4	-	-	**4**	1	1	**2**	-	-	**-**	**-**
10/26/2016	Tinian (circumnavigate + Tachungnya Bay)	8	1	1	**10**	1	-	**1**	4	1	**5**	**12**
10/27/2016	Saipan (Chalan Kanoa + Coral Ocean Point)	4	2	-	**6**	2	-	**2**	2	1	**3**	**-**
10/28/2016	Tinian (Tinian Harbor + Dumpcoke Cove)	7	-	1	**8**	-	-	**-**	3	1	**4**	**-**
10/29/2016	Saipan (Tanapag Lagoon + Balisa)	5	-	2	**7**	2	-	**2**	1	-	**1**	**27**
11/1/2016	Guam (Bile Bay + Sella Bay)	27	2	1	**30**	-	-	**-**	3	-	**3**	**30**
11/2/2016	Guam (Piti Bomb Holes)	4	-	-	**4**	-	-	**-**	-	-	**-**	**-**
	2016 Subtotals	**88**	**7**	**32**	**127**	**18**	**4**	**22**	**20**	**5**	**25**	**69**

		Observation only				Captures (no sat tags)			Captures (sat tags)			Cetaceans
Survey Date	**Location (focal areas)**	**CM**	**EI**	**UN**	**Total**	**CM**	**EI**	**Total**	**CM**	**EI**	**Total**	**CET**
5/22/2017	Guam (Piti Bomb Holes)	1	-	-	**1**	-	-	**-**	1	-	**1**	**-**
5/23/2017	Guam (Orote Point)	-	-	-	**-**	-	-	**-**	-	1	**1**	**-**
10/17/2017	Guam (Tanguisson/ Tumon)	17	2	3	**22**	-	-	**-**	4	-	**4**	**-**
10/18/2017	Guam (Tumon Bay)	15	-	-	**15**	3	-	**3**	4	-	**4**	**-**
10/19/2017	Guam (Hagatna)	6	-	-	**6**	-	-	**-**	1	-	**1**	**-**
10/25/2017	Saipan (Pau Pau Beach)	7	-	1	**8**	-	-	**-**	2	1	**3**	**2**
10/26/2017	Saipan (Wing Beach)	4	1	-	**5**	2	-	**2**	4	-	**4**	**-**
10/27/2017	Saipan (Managaha/ Tanapag)	8	-	-	**8**	-	-	**-**	2	1	**3**	**-**
	2017 Subtotals	**58**	**3**	**4**	**65**	**5**	**-**	**5**	**18**	**3**	**21**	**2**
8/5/2018	Saipan (Puntan Gloria)	5	2	-	**7**	-	-	**-**	2	-	**2**	**50**
8/7/2018	Guam (Talofofo Bay + Yona)	8	-	-	**8**	-	-	**-**	4	-	**4**	**-**
8/8/2018	Guam (Pago Bay)	11	-	1	**12**	-	-	**-**	3	-	**3**	**-**
8/9/2018	Guam (Achang Reef + Cocos Island)	11	-	1	**12**	3	-	**3**	4	-	**4**	**40**
8/10/2018	Guam (Mangilao)	1	3	-	**4**	-	-	**-**	-	-	**-**	**-**
	2018 Subtotals	**36**	**5**	**2**	**43**	**3**	**-**	**3**	**13**	**-**	**13**	**90**
9/3/2019	Saipan (Forbidden Island)	4	1	1	**6**	-	-	**-**	4	-	**4**	**-**
9/4/2019	Saipan (Dan Dan)	7	1	2	**10**	-	-	**-**	1	1	**2**	**-**
9/5/2019	Saipan (Hidden Beach/ Fishing Basin)	22	1	1	**24**	3	-	**3**	2	-	**2**	**3**

		Observation only				Captures (no sat tags)			Captures (sat tags)			Cetaceans
Survey Date	**Location (focal areas)**	**CM**	**EI**	**UN**	**Total**	**CM**	**EI**	**Total**	**CM**	**EI**	**Total**	**CET**
9/7/2019	Guam (Jinapsan/Pati Pt./Lafac)	5	-	1	**6**	-	-	**-**	1	-	**1**	**-**
9/8/2019	Guam (Jinapsan/Pati Pt./Yigo)	4	1	1	**6**	1	-	**1**	2	-	**2**	**3**
9/9/2019	Guam (Tarague/Ritidian)	5	-	1	**6**	-	-	**-**	5	1	**6**	**20**
	2019 Subtotals	**47**	**4**	**7**	**58**	**4**	**-**	**4**	**15**	**2**	**17**	**26**

Summary for Turtles	
Survey days	47
Encounters	517
Captures	160
Satellite tags	111

2013-2023 Totals	**258**	**19**	**80**	**357**	**43**	**6**	**49**	**97**	**14**	**111**	**187**

Combined Totals	**CM**	**EI**	**UN**	**Total**
	398	39	80	517

Table 2. Information on five turtles tagged and recaptured during the study timeframe, including species, island, capture/recapture location, days between captures, SCL (cm) and SCL growth rate (cm/yr), and weight increase rate (kg/yr).

Species	Island	Capture/ recapture location	Capture/ recapture date	Days between recaptures	SCL	SCL growth rate (cm/yr)	Weight (kg)	Weight increase rate (kg/yr)
Green	Guam	Dadi Beach	7-16-2014	1037	54.3	2.4	20.3	3.6
			5-18-2017		61.2		30.6	
Hawksbill	Guam	Dadi Beach	7-17-2014	307	42.3	5.5	7.6	9.6
		Apra Harbor	5-20-2015		46.9		15.7	
Hawksbill	Guam	Apra Harbor	5-19-2015	729	68.2	1.5	32.5	2.0
			5-11-2016		68.2		34.4	
			5-17-2017		71.1		36.4	
Green	Guam	Apra Harbor	5-11-2016	376	60.3	2.8	26.4	6.4
		Piti Bomb Holes	5-22-2017		63.2		33	
Hawksbill	Guam	Orote Point	5-12-2016	1119	52.9	2.3	14.6	3.3
			5-23-2017		55.7		19.2	
			6-5-2019		60.1		24.6	

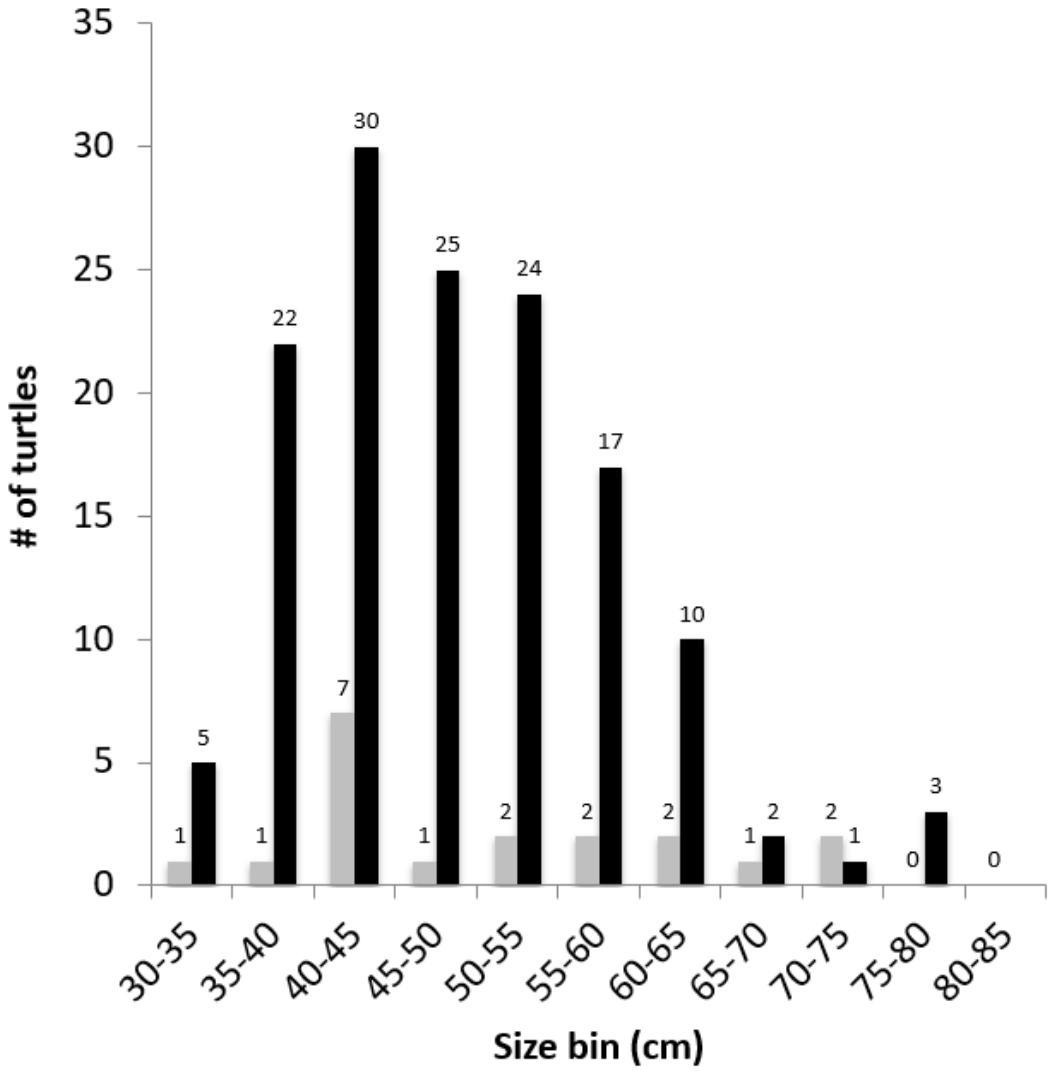


Figure 2. Frequency (number of turtles) distribution of SCL for green turtles (black bars) and hawksbill turtles (grey bars) captured (excluding re-captures) during the study period. For green turtles, the mean straight carapace length (SCL) was 53.7 cm± 9.5 (range, 36.9 – 84.9 cm; n = 139). For hawksbill turtles, the mean SCL was 50.9 cm ± 11.9 (range, 34.4 – 72.6 cm; n = 19).

SATELLITE TELEMETRY OF TURTLES

Of the 111 satellite tags we deployed on turtles captured during surveys, 97 (87.4 %) were deployed on green turtles and 14 (12.6 %) on hawksbill turtles (Tables 3–5). This included 100 SPLASH tags and 11 SPOT tags. Details on these tag deployments, including species, Argos ID number, tag type, foraging habitat location, tag deployment date, turtle size (SCL), last Argos signal, tag life (days), and

tag status, for the islands of Tinian, Saipan, and Guam, are available in Table 3, Table 4, and Table 5, respectively. Two tags deployed on hawksbill turtles and two tags on green turtles failed to transmit.

Tags on green turtles transmitted data for an average of 174 days for Saipan (sd = 138.1, n = 33 tags), 154 days for Tinian (sd = 82.1, n = 18 tags), and 168 days for Guam (sd = 78.4, n = 46 tags). Tags on hawksbill turtles transmitted for 426 days on Saipan (sd = 498.0, n = 5 tags), 572 days on Tinian (sd = 320.6, n = 6 tags), and 477 days on Guam (sd = 388.3, n = 3 tags). All tags combined lasted an average of 168 days (sd = 101.7, n = 97 tags) on green turtles and 500 days (sd = 379.0, n = 14) on hawksbill turtles. Maximum tag life was 721 days for green turtles (Argos ID 131995 tagged on the northern shore of Saipan at Spotlight) and 1,270 days for hawksbill turtles (Argos ID 85496 tagged on the west coast of Saipan at Balisa). Hawksbill turtle shells are thicker and more keratinized than green turtle shells, which tend to be thinner and oilier; this difference likely contributed to the longer tag retention times observed on hawksbill turtles.

Pooled overall (i.e., 95 % volume contour) and core (i.e., 50 % volume contour) home ranges for Guam, Tinian, and Saipan are shown in Figures 3 – 8 and elucidate the general habitat use for turtles tagged in each location based on their horizontal movements. The average overall home range and core home range area for green turtles (n = 95) was 9.88 km^2 (SD = 20.8 km^2, range = 0.11 – 135.85 km^2) and 1.13 km^2 (SD = 1.84 km^2, range = 0.03 – 11.23 km^2), respectively. For hawksbill turtles (n = 13), the average overall home range was 7.96 km^2 (SD = 5.85 km^2, range = 0.72 – 18.4 km^2) and the core come range was 0.95 km^2 (SD = 0.72 km^2, range = 0.09 – 2.27 km^2).

We found no significant difference in any of the home range comparisons we conducted, including comparisons by species, sizes, or islands. As shown in Figure 9, the overwhelming majority (n = 99, 92.5 %, 89 greens and 10 hawksbills) of the turtles whose tags transmitted successfully (n = 107) remained in the vicinity of a single foraging area for the duration of their tracking period (i.e., movement behavior 1). Five turtles (4.7 %, all green turtles) used multiple foraging areas or travelled between distinct areas on the same island where they were tagged (i.e., movement behavior 2). Two turtles (1.9 %, 1 green and 1 hawksbill) moved from one island to another (i.e., movement behavior 3), and one turtle (0.9 %, a hawksbill) departed the Mariana Islands (i.e., movement behavior 4).

Table 3. Summary of satellite tags deployed on Guam, including species, Argos ID, foraging site, general foraging area, turtle size (SCL on first capture), deploy date, last Argos signal, tag life as transmission days, tag model, tag status, 95% (overall home range), and 50% (i.e., core home range) volume contours (km^2).

Guam Satellite Tag Deployments												
Species	**Argos ID**	**Island**	**Foraging site**	**General Area**	**SCL (cm)**	**Deploy Date**	**Last Signal Argos**	**Tag Life**	**Tag model**	**Tag Status**	**95% Home range (sq. km)**	**50% Core use area (sq. km)**
Hawksbill	85493	Guam	Achang Reef*	Achang/Cocos	61.7	8/20/13	2/28/16	922	SPLASH	successful	18.40	2.27
Green	176765	Guam	Cocos Island, Achang Reef	Achang/Cocos	64.7	8/9/2018	6/1/19	296	SPLASH	successful	29.80	4.99
Green	176766	Guam	Cocos Island, Achang Reef	Achang/Cocos	63.9	8/9/2018	5/28/19	292	SPLASH	successful	9.56	1.67
Green	171260	Guam	Cocos Island, Achang Reef	Achang/Cocos	36.9	8/9/2018	12/13/18	126	SPOT	successful	22.18	2.45
Green	171261	Guam	Cocos Island, Achang Reef	Achang/Cocos	41.4	8/9/2018	12/10/18	123	SPOT	successful	15.14	1.76
Green	176762	Guam	Pago Bay	Pago Bay	50	8/8/2018	11/29/18	113	SPLASH	successful	5.03	0.54
Green	176763	Guam	Pago Bay	Pago Bay	44.8	8/8/2018	11/8/18	92	SPLASH	successful	2.25	0.42
Green	176764	Guam	Pago Bay	Pago Bay	47.9	8/8/2018	11/13/18	97	SPLASH	successful	0.23	0.03
Green	131994	Guam	Apra Harbor	Piti/Apra/Orote/ Dadi	49.2	7/16/14	12/26/14	163	SPLASH	successful	2.40	0.29
Green	131991	Guam	Apra Harbor	Piti/Apra/Orote/ Dadi	58.3	7/16/14	3/4/15	231	SPLASH	successful	0.34	0.05
Green	131998	Guam	Dadi Beach	Piti/Apra/Orote/ Dadi	64.3	7/16/14	12/18/14	155	SPLASH	successful	1.63	0.33
Green	131990	Guam	Dadi Beach	Piti/Apra/Orote/ Dadi	54.3	7/16/14	1/7/15	175	SPLASH	successful	0.84	0.19
Green	138960	Guam	Apra Harbor	Piti/Apra/Orote/ Dadi	58.6	7/17/14	1/4/15	172	SPLASH	successful	11.59	2.26
Green	138961	Guam	Dadi Beach	Piti/Apra/Orote/ Dadi	66	7/17/14	9/13/14	58	SPLASH	successful	0.71	0.06
Green	131997	Guam	Dadi Beach	Piti/Apra/Orote/ Dadi	55.2	7/17/14	12/26/14	162	SPLASH	successful	1.85	0.30

Guam Satellite Tag Deployments												
Species	**Argos ID**	**Island**	**Foraging site**	**General Area**	**SCL (cm)**	**Deploy Date**	**Last Signal Argos**	**Tag Life**	**Tag model**	**Tag Status**	**95% Home range (sq. km)**	**50% Core use area (sq. km)**
Green	138965	Guam	Apra Harbor	Piti/Apra/Orote/ Dadi	59.3	7/18/14	2/23/15	220	SPLASH	successful	0.88	0.21
Green	152577	Guam	Dadi Beach	Piti/Apra/Orote/ Dadi	65.6	11/17/15	4/30/16	165	SPLASH	successful	1.48	0.30
Green	152582	Guam	Dadi Beach	Piti/Apra/Orote/ Dadi	73.4	11/18/15	1/16/16	59	SPLASH	successful	3.08	0.52
Green	152570	Guam	Dadi Beach	Piti/Apra/Orote/ Dadi	76	11/18/15	3/17/16	121	SPLASH	successful	1.28	0.28
Green	131996	Guam	Orote Point	Piti/Apra/Orote/ Dadi	60.8	5/12/16	8/24/16	104	SPLASH	successful	2.89	0.12
Hawksbill	142756	Guam	Orote Point	Piti/Apra/Orote/ Dadi	52.9	5/12/16	NA	NA	SPLASH	tag failed	NA	NA
Green	142752	Guam	Orote Point*	Piti/Apra/Orote/ Dadi	82.3	5/13/16	11/12/16	183	SPLASH	successful	135.85	11.12
Green	142748	Guam	Orote Point*	Piti/Apra/Orote/ Dadi	63.8	5/13/16	4/2/17	325	SPLASH	successful	17.11	1.35
Green	166335	Guam	Sella Bay	Piti/Apra/Orote/ Dadi	49.3	11/1/16	6/15/17	226	SPLASH	successful	0.92	0.21
Green	166351	Guam	Sella Bay	Piti/Apra/Orote/ Dadi	43.7	11/1/16	3/18/17	137	SPOT	successful	2.64	0.56
Green	166353	Guam	Sella Bay	Piti/Apra/Orote/ Dadi	40.8	11/1/16	3/27/17	146	SPOT	successful	1.66	0.26
Green	166336	Guam	Piti Bomb Holes	Piti/Apra/Orote/ Dadi	56	5/22/17	10/23/17	154	SPLASH	successful	1.99	0.47
Hawksbill	166340	Guam	Orote Point	Piti/Apra/Orote/ Dadi	55.7	5/23/17	12/17/17	208	SPLASH	successful	4.42	0.61
Green	171244	Guam	Sewer Island	Piti/Apra/Orote/ Dadi	47.1	10/19/17	NA	NA	SPLASH	tag failed	NA	NA
Green	171233	Guam	Talofofo	Talafofo	44.7	8/7/2018	11/29/18	114	SPLASH	successful	6.26	0.71
Green	171234	Guam	Talofofo	Talafofo	55.9	8/7/2018	10/26/18	80	SPLASH	successful	6.82	1.31

Guam Satellite Tag Deployments												
Species	**Argos ID**	**Island**	**Foraging site**	**General Area**	**SCL (cm)**	**Deploy Date**	**Last Signal Argos**	**Tag Life**	**Tag model**	**Tag Status**	**95% Home range (sq. km)**	**50% Core use area (sq. km)**
Green	176760	Guam	Talofofo	Talafofo	69.8	8/7/2018	11/9/18	94	SPLASH	successful	14.53	1.22
Green	176761	Guam	Talofofo	Talafofo	53.2	8/7/2018	1/5/19	151	SPLASH	successful	14.74	1.27
Green	178569	Guam	Pati Point*	Talafofo	67.5	9/7/19	6/4/2020	271	SPLASH	successful	98.18	2.14
Green	178570	Guam	Tarague	Tarague/Ritidian/ Jinapsan/EOD	64.6	9/8/19	5/5/20	240	SPLASH	successful	6.32	0.66
Green	178571	Guam	Tarague	Tarague/Ritidian/ Jinapsan/EOD	59.6	9/8/19	11/30/19	83	SPLASH	successful	16.96	1.51
Green	171263	Guam	Tarague*	Tarague/Ritidian/ Jinapsan/EOD	40.8	9/9/19	3/10/20	183	SPOT	successful	67.06	4.94
Green	178572	Guam	Tarague	Tarague/Ritidian/ Jinapsan/EOD	44.4	9/9/19	5/10/20	244	SPLASH	successful	4.69	0.40
Green	178573	Guam	Tarague	Tarague/Ritidian/ Jinapsan/EOD	84.9	9/9/19	2/26/20	170	SPLASH	successful	51.41	7.07
Green	178574	Guam	Ritidian Channel	Tarague/Ritidian/ Jinapsan/EOD	47.6	9/9/19	1/2/2020	115	SPLASH	successful	4.99	0.40
Green	178576	Guam	Ritidian Channel	Tarague/Ritidian/ Jinapsan/EOD	48.6	9/9/19	1/16/20	129	SPLASH	successful	3.76	0.39
Hawksbill	178575	Guam	Ritidian Channel	Tarague/Ritidian/ Jinapsan/EOD	43	9/9/19	7/6/2020	301	SPLASH	successful	10.34	1.00
Green	171249	Guam	Tanguisson	Tumon/Tanguisson	48.2	10/17/17	7/11/18	267	SPLASH	successful	2.72	0.44
Green	171248	Guam	Tumon Bay	Tumon/Tanguisson	48.8	10/17/17	9/1/18	319	SPLASH	successful	2.41	0.51
Green	171247	Guam	Tumon Bay	Tumon/Tanguisson	62.7	10/17/17	10/12/18	360	SPLASH	successful	4.25	1.13
Green	171246	Guam	Tumon Bay	Tumon/Tanguisson	53.6	10/17/17	6/28/18	254	SPLASH	successful	1.54	0.28
Green	171240	Guam	Tumon Bay	Tumon/Tanguisson	66.6	10/18/17	12/7/17	50	SPLASH	successful	4.50	1.18
Green	171241	Guam	Tumon Bay	Tumon/Tanguisson	73.2	10/18/17	4/1/18	165	SPLASH	successful	3.75	0.75
Green	171242	Guam	Tumon Bay	Tumon/Tanguisson	58.2	10/18/17	2/24/18	129	SPLASH	successful	1.15	0.22
Green	171243	Guam	Tumon Bay	Tumon/Tanguisson	56.4	10/18/17	12/15/17	58	SPLASH	successful	4.94	0.55

* Did not exhibit strict foraging site fidelity

Table 4. Summary of satellite tags deployed on Tinian, including species, Argos ID, foraging site, general foraging area, turtle size (SCL on first capture), deploy date, last Argos signal, tag life as transmission days, tag model, tag status, 95% (overall home range) and 50% (i.e., core home range) volume contours (km^2).

TINIAN Satellite Tag Deployments												
Species	**Argos ID**	**Foraging site**	**General Area**	**Island**	**SCL (cm)**	**Deploy Date**	**Last Signal Argos**	**Tag Life**	**Tag model**	**Tag Status**	**95% Home range (sq. km)**	**50% Core use area (sq. km)**
Green	142747	Dangkolo	Chulu/Dangkolo/ Tohgong	Tinian	52.6	5/15/16	11/19/16	188	SPLASH	successful	4.82	0.64
Green	142750	Chulu	Chulu/Dangkolo/ Tohgong	Tinian	51.6	5/15/16	10/31/16	169	SPLASH	successful	1.28	0.28
Hawksbill	142755	Dangkolo	Chulu/Dangkolo/ Tohgong	Tinian	62.8	5/15/16	12/28/17	592	SPLASH	successful	2.91	0.46
Green	152584	Tohgong	Chulu/Dangkolo/ Tohgong	Tinian	54.9	5/16/16	12/16/16	214	SPLASH	successful	1.40	0.11
Green	142753	Tohgong	Chulu/Dangkolo/ Tohgong	Tinian	56.5	5/16/16	5/31/16	15	SPLASH	successful	1.91	0.28
Green	138959	Fleming Point	Dumpcoke cover/Fleming Pt	Tinian	54.3	7/21/14	11/26/14	128	SPLASH	successful	11.89	2.13
Hawksbill	138963	Fleming Point*#	Dumpcoke cover/Fleming Pt	Tinian	72.3	7/21/14	4/27/16	647	SPLASH	successful	10.39	0.95
Hawksbill	131989	Fleming Point	Dumpcoke cover/Fleming Pt	Tinian	58.1	7/21/14	12/8/16	872	SPLASH	successful	11.51	0.55
Green	166341	Dumpcoke Cove	Dumpcoke cover/Fleming Pt	Tinian	84.1	10/28/16	2/8/17	104	SPLASH	successful	1.88	0.32
Hawksbill	166342	Dumpcoke Cove	Dumpcoke cover/Fleming Pt	Tinian	56.2	10/28/16	2/9/17	104	SPLASH	successful	0.72	0.09
Green	152580	Red Wall	Tinian Harbor/ Tachungnya/Redwall	Tinian	56	11/12/15	9/30/16	323	SPLASH	successful	24.40	2.59
Green	152586	Red Wall	Tinian Harbor /Tachungnya/ Redwall	Tinian	61.1	11/12/15	4/17/16	157	SPLASH	successful	3.92	1.14

TINIAN Satellite Tag Deployments												
Species	**Argos ID**	**Foraging site**	**General Area**	**Island**	**SCL (cm)**	**Deploy Date**	**Last Signal Argos**	**Tag Life**	**Tag model**	**Tag Status**	**95% Home range (sq. km)**	**50% Core use area (sq. km)**
Green	152583	Red Wall	Tinian Harbor/ Tachungnya/Redwall	Tinian	54.2	11/12/15	9/17/16	310	SPLASH	successful	9.21	0.57
Green	152578	Red Wall	Tinian Harbor/ Tachungnya/ Redwall	Tinian	59.5	11/12/15	1/9/16	58	SPLASH	successful	2.22	0.35
Green	152569	Red Wall	Tinian Harbor/ Tachungnya/Redwall	Tinian	53	11/12/15	7/18/16	249	SPLASH	successful	11.25	1.34
Green	152574	Red Wall	Tinian Harbor/ Tachungnya/Redwall	Tinian	55.4	11/12/15	3/27/16	136	SPLASH	successful	4.92	0.56
Green	166339	Tachungnya Bay	Tinian Harbor/ Tachungnya/Redwall	Tinian	44.4	10/26/16	3/1/17	126	SPLASH	successful	1.42	0.18
Green	166344	Tachungnya Bay	Tinian Harbor/ Tachungnya/Redwall	Tinian	52.8	10/26/16	2/17/17	114	SPLASH	successful	0.11	0.03
Green	166337	Tachungnya Bay	Tinian Harbor/ Tachungnya/Redwall	Tinian	48.2	10/26/16	2/8/17	105	SPLASH	successful	9.68	2.22
Green	166345	Tachungnya Bay	Tinian Harbor/ Tachungnya/Redwall	Tinian	44	10/26/16	1/4/17	70	SPLASH	successful	6.83	0.89
Hawksbill	166355	Tachungnya Bay	Tinian Harbor/ Tachungnya/Redwall	Tinian	40	10/26/16	8/17/17	295	SPOT	successful	2.23	0.54
Green	166348	Tinian Harbor	Tinian Harbor/ Tachungnya/Redwall	Tinian	47.6	10/28/16	5/12/17	196	SPLASH	successful	2.24	0.47
Green	166338	Tinian Harbor	Tinian Harbor/ Tachungnya/Redwall	Tinian	44.4	10/28/16	2/15/17	111	SPLASH	successful	2.10	0.52

*Did not exhibit strict foraging site fidelity, #Home range calculated prior to migrating to Pohnpei

Table 5. Summary of satellite tags deployed on Saipan, including species, Argos ID, foraging site, general foraging area, turtle size (SCL on first capture), deploy date, last Argos signal, tag life as transmission days, tag model, tag status, 95% (overall home range) and 50% (i.e., core home range) volume contours (km^2).

SAIPAN Satellite Tag Deployments												
Species	**Argos ID**	**Foraging site**	**General Area**	**Island**	**SCL (cm)**	**Deploy Date**	**Last Signal Argos**	**Tag Life**	**Tag model**	**Tag Status**	**95% Home range (sq. km)**	**50% Core use area (sq. km)**
Green	85491	Balisa	Balisa/Fishing Basin/Managaha	Saipan	60.9		10/15/13	59	SPLASH	successful	2.99	0.56
Hawksbill	85496	Balisa	Balisa/Fishing Basin/Managaha	Saipan	66.6		2/8/17	1270	SPLASH	successful	9.13	1.76
Green	85495	Balisa	Balisa/Fishing Basin/Managaha	Saipan	66.1		1/19/14	154	SPLASH	successful	5.77	1.18
Green	85494	Balisa	Balisa/Fishing Basin/Managaha	Saipan	60.4		5/3/14	257	SPLASH	successful	3.16	0.32
Green	85492	Balisa	Balisa/Fishing Basin/Managaha	Saipan	62.5		9/17/14	392	SPLASH	successful	7.22	1.51
Green	171254	Outer Managaha	Balisa/Fishing Basin/Managaha	Saipan	46.3		1/5/18	70	SPLASH	successful	9.53	1.88
Green	171259	Outer Managaha	Balisa/Fishing Basin/Managaha	Saipan	42.1		5/27/18	212	SPOT	successful	6.79	1.50
Green	178567	Fishing Basin	Balisa/Fishing Basin/Managaha	Saipan	55.4	9/5/19	2/17/20	165	SPLASH	successful	4.54	0.78
Green	178568	Fishing Basin	Balisa/Fishing Basin/Managaha	Saipan	67.4	9/5/19	NA	NA	SPLASH	tag failed	NA	NA
Green	152585	Chalan Kanoa	Chalan Kanoa/CK Reef/Coral Ocean	Saipan	50.2	11/14/15	4/18/16	157	SPLASH	successful	2.01	0.51
Green	152575	Chalan Kanoa	Chalan Kanoa/CK Reef/Coral Ocean	Saipan	67.1	11/14/15	2/1/16	79	SPLASH	successful	2.29	0.52
Green	166343	Chalan Kanoa	Chalan Kanoa/CK Reef/Coral Ocean	Saipan	64.3	10/27/16	7/25/17	271	SPLASH	successful	4.09	0.78
Green	166346	Coral Ocean Point	Chalan Kanoa/CK Reef/Coral Ocean	Saipan	44	10/27/16	3/7/17	132	SPLASH	successful	1.27	0.18

SAIPAN Satellite Tag Deployments												
Species	**Argos ID**	**Foraging site**	**General Area**	**Island**	**SCL (cm)**	**Deploy Date**	**Last Signal Argos**	**Tag Life**	**Tag model**	**Tag Status**	**95% Home range (sq. km)**	**50% Core use area (sq. km)**
Hawksbill	166354	Coral Ocean Point	Chalan Kanoa/CK Reef/Coral Ocean	Saipan	40	10/27/16	2/12/17	108	SPOT	successful	1.61	0.12
Green	152576	Lao Lao Bay	Dan Dan/Lao Lao	Saipan	55.6	11/13/15	3/28/16	137	SPLASH	successful	2.03	0.37
Green	152572	Lao Lao Bay	Dan Dan/Lao Lao	Saipan	63.5	11/13/15	12/29/15	46	SPLASH	successful	1.39	0.19
Green	152571	Lao Lao Bay*	Dan Dan/Lao Lao	Saipan	56.7	11/13/15	1/13/16	62	SPLASH	successful	10.70	0.77
Green	152579	Lao Lao Bay	Dan Dan/Lao Lao	Saipan	65	11/13/15	1/18/16	67	SPLASH	successful	1.30	0.24
Green	152581	Lao Lao Bay	Dan Dan/Lao Lao	Saipan	53.6	11/13/15	12/21/15	38	SPLASH	successful	0.57	0.09
Green	178566	Dan Dan	Dan Dan/Lao Lao	Saipan	65.5	9/4/19	2/7/20	156	SPLASH	successful	6.46	1.00
Hawksbill	178565	Dan Dan	Dan Dan/Lao Lao	Saipan	72.6	9/4/19	7/12/20	312	SPLASH	successful	6.09	0.76
Green	171235	Tank Beach	Marine Beach/ Tank Beach/ Forbidden Island	Saipan	54.9	8/5/18	10/5/18	61	SPLASH	successful	8.80	0.89
Green	171255	Tank Beach*	Marine Beach/ Tank Beach/ Forbidden Island	Saipan	47.1	8/5/18	1/6/19	154	SPLASH	successful	96.63	11.23
Green	176781	Forbidden Island	Marine Beach/ Tank Beach/ Forbidden Island	Saipan	50.3	9/3/19	9/24/19	21	SPLASH	successful	2.90	0.29
Green	178562	Forbidden Island	Marine Beach/ Tank Beach/ Forbidden Island	Saipan	63.3	9/3/19	11/30/19	88	SPLASH	successful	1.82	0.42
Green	178563	Forbidden Island	Marine Beach/ Tank Beach/ Forbidden Island	Saipan	50	9/3/19	5/26/20	266	SPLASH	successful	10.37	1.18

SAIPAN Satellite Tag Deployments												
Species	**Argos ID**	**Foraging site**	**General Area**	**Island**	**SCL (cm)**	**Deploy Date**	**Last Signal Argos**	**Tag Life**	**Tag model**	**Tag Status**	**95% Home range (sq. km)**	**50% Core use area (sq. km)**
Green	178564	Forbidden Island	Marine Beach/ Tank Beach/ Forbidden Island	Saipan	62.9	9/3/19	5/11/20	251	SPLASH	successful	8.18	0.86
Green	166347	Tanapag Lagoon	Pau Pau Beach/ Aqua Reef	Saipan	47	10/29/16	6/30/17	244	SPLASH	successful	0.85	0.14
Green	171250	Aqua Reef	Pau Pau Beach/ Aqua Reef	Saipan	55.7	10/25/17	5/3/18	190	SPLASH	successful	5.59	1.36
Hawksbill	171251	Aqua Reef	Pau Pau Beach/ Aqua Reef	Saipan	50.3	10/25/17	12/19/18	420	SPLASH	successful	7.38	1.04
Green	171256	Aqua Reef	Pau Pau Beach/ Aqua Reef	Saipan	43.3	10/25/17	4/21/18	178	SPOT	successful	2.11	0.44
Green	171252	Wing Arch	Pau Pau Beach/ Aqua Reef	Saipan	54.3	10/26/17	11/5/17	10	SPLASH	Successful	1.74	0.27
Green	171245	Pau Pau Beach	Pau Pau Beach/ Aqua Reef	Saipan	59.5	10/26/17	1/7/18	73	SPLASH	successful	13.24	3.22
Green	171253	Pau Pau Beach	Pau Pau Beach/ Aqua Reef	Saipan	49.2	10/26/17	10/28/18	367	SPLASH	successful	5.18	1.11
Green	171257	Pau Pau Beach	Pau Pau Beach/ Aqua Reef	Saipan	37.6	10/26/17	3/28/18	153	SPOT	successful	1.25	0.26
Hawksbill	171258	Pau Pau Beach	Pau Pau Beach/ Aqua Reef	Saipan	42.4	10/27/17	11/16/17	20	SPOT	Tag failed	NA	NA
Green	131995	Spotlight	Spotlight/ Cow Town	Saipan	61.7	7/22/14	7/11/16	721	SPLASH	successful	6.45	0.65
Green	138958	Cow Town	Spotlight/ Cow Town	Saipan	63.9	7/22/14	1/19/15	181	SPLASH	successful	5.98	0.54

*Did not exhibit strict foraging site fidelity

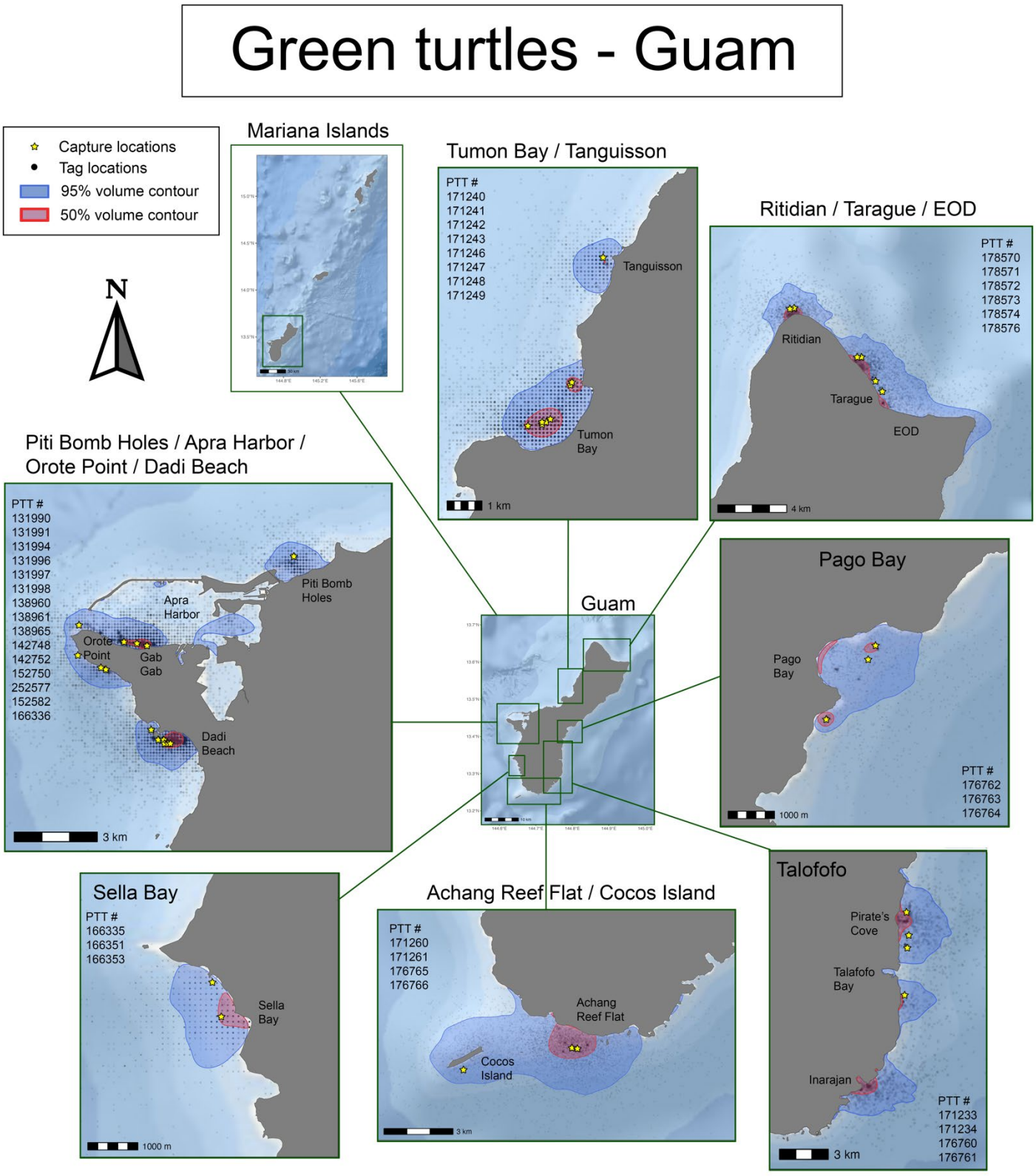


Figure 3. Habitat use map for green turtles equipped with satellite tags in Guam, with 50% (core home range) and 95% (overall home range) volume utilization distributions in red and blue, respectively.

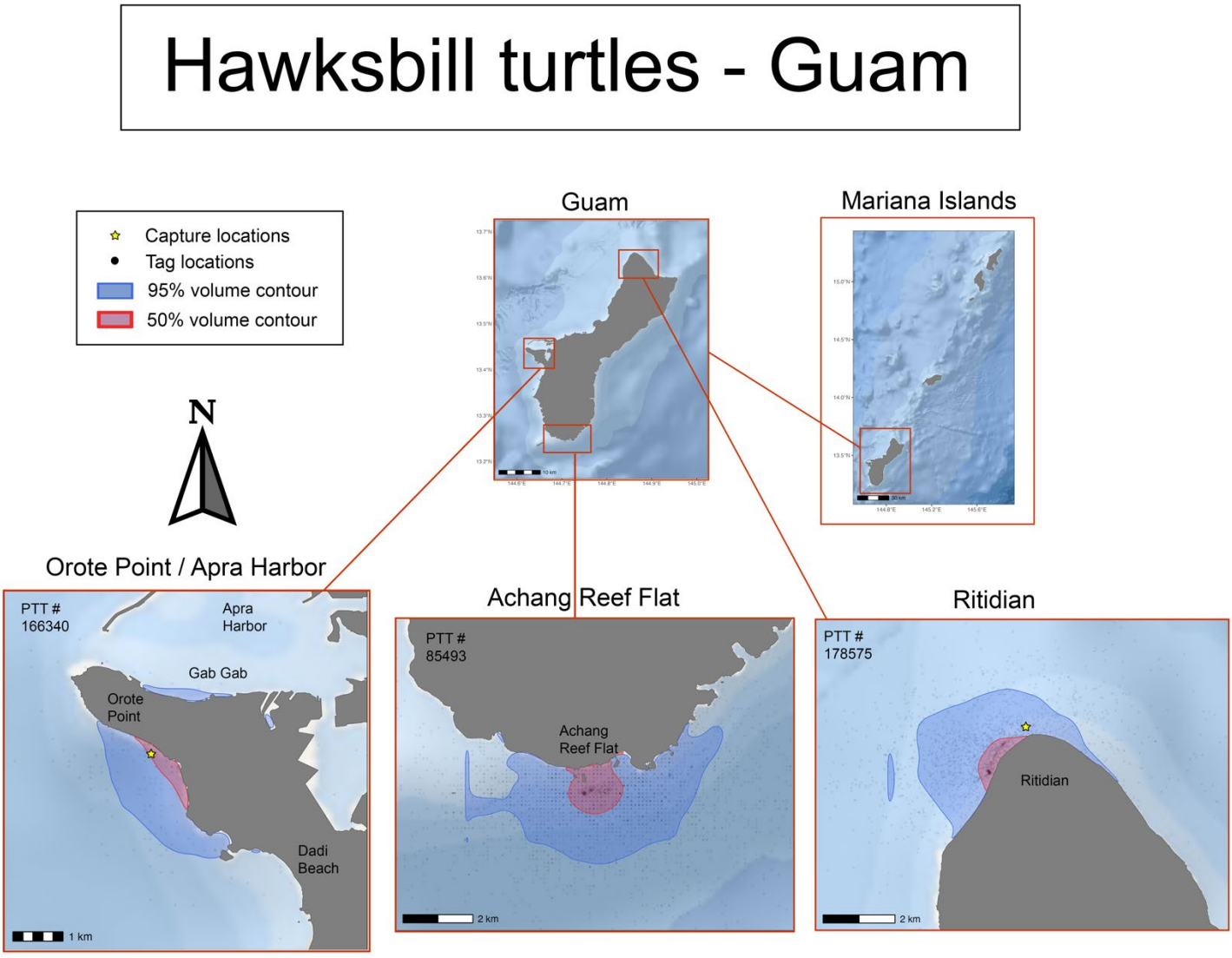


Figure 4. Habitat use map for hawksbill turtles equipped with satellite tags in Guam, with 50% (core home range) and 95% (overall home range) volume utilization distributions in red and blue, respectively. Turtle 85493 was originally tagged on Tinian, then migrated and established a foraging home range on Guam.

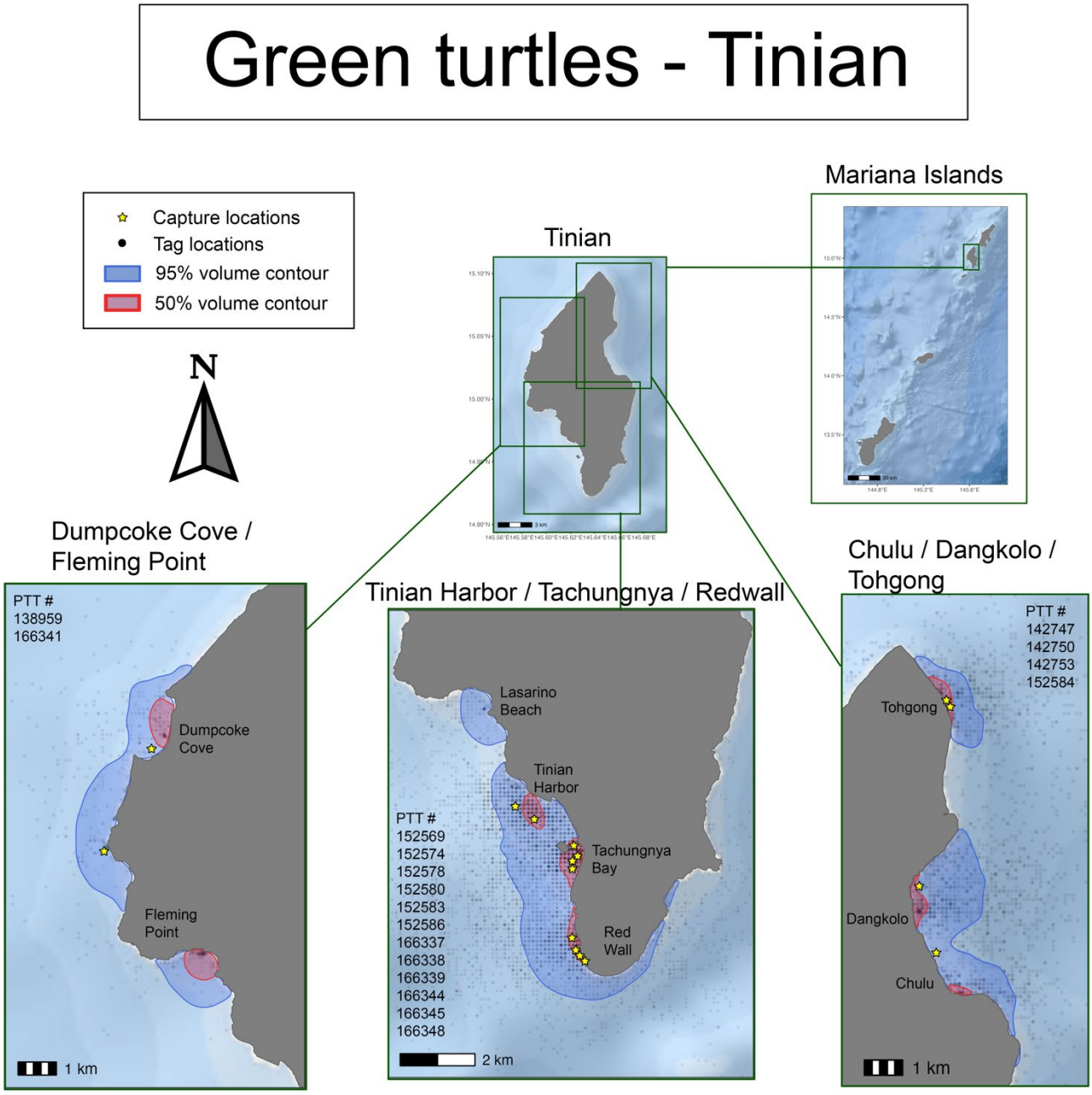


Figure 5. Habitat use map for green turtles equipped with satellite tags in Tinian, with 50% (core home range) and 95% (overall home range) volume utilization distributions in red and blue, respectively.

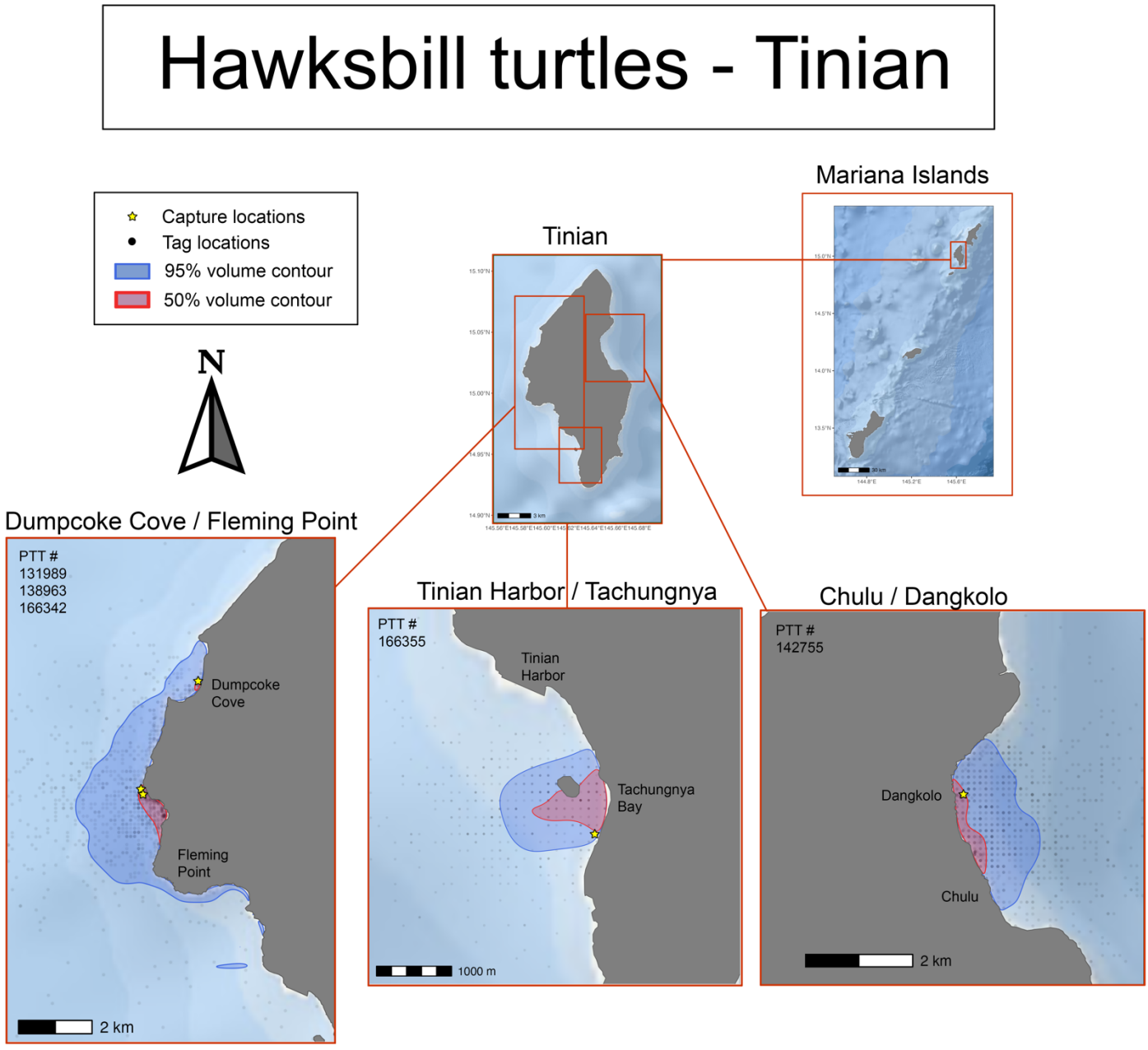


Figure 6. Habitat use map for hawksbill turtles equipped with satellite tags in Tinian, with 50% (core home range) and 95% (overall home range) volume utilization distributions in red and blue, respectively.

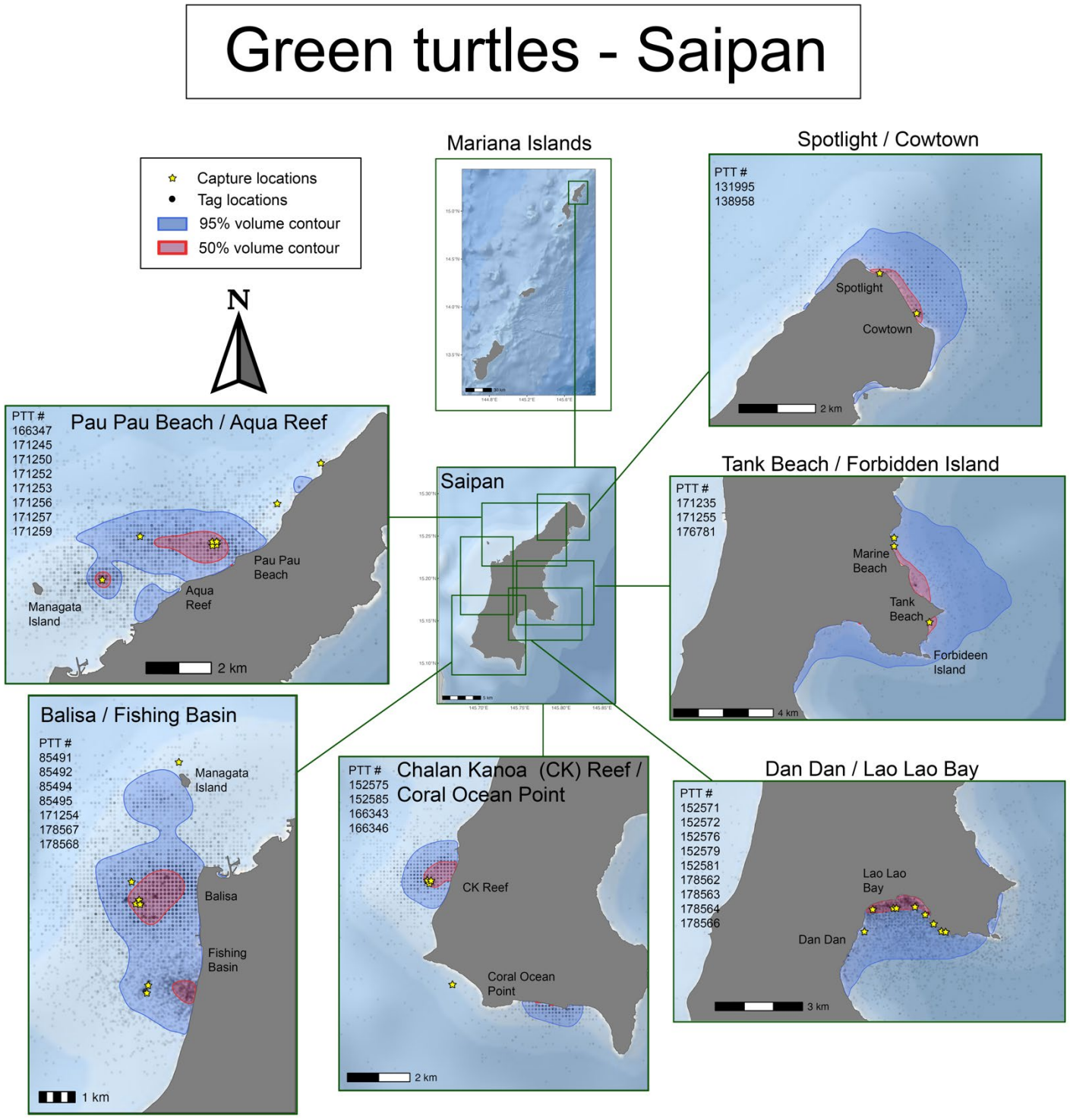


Figure 7. Habitat use map for green turtles equipped with satellite tags in Saipan, with 50% (core home range) and 95% (overall home range) volume utilization distributions in red and blue, respectively.

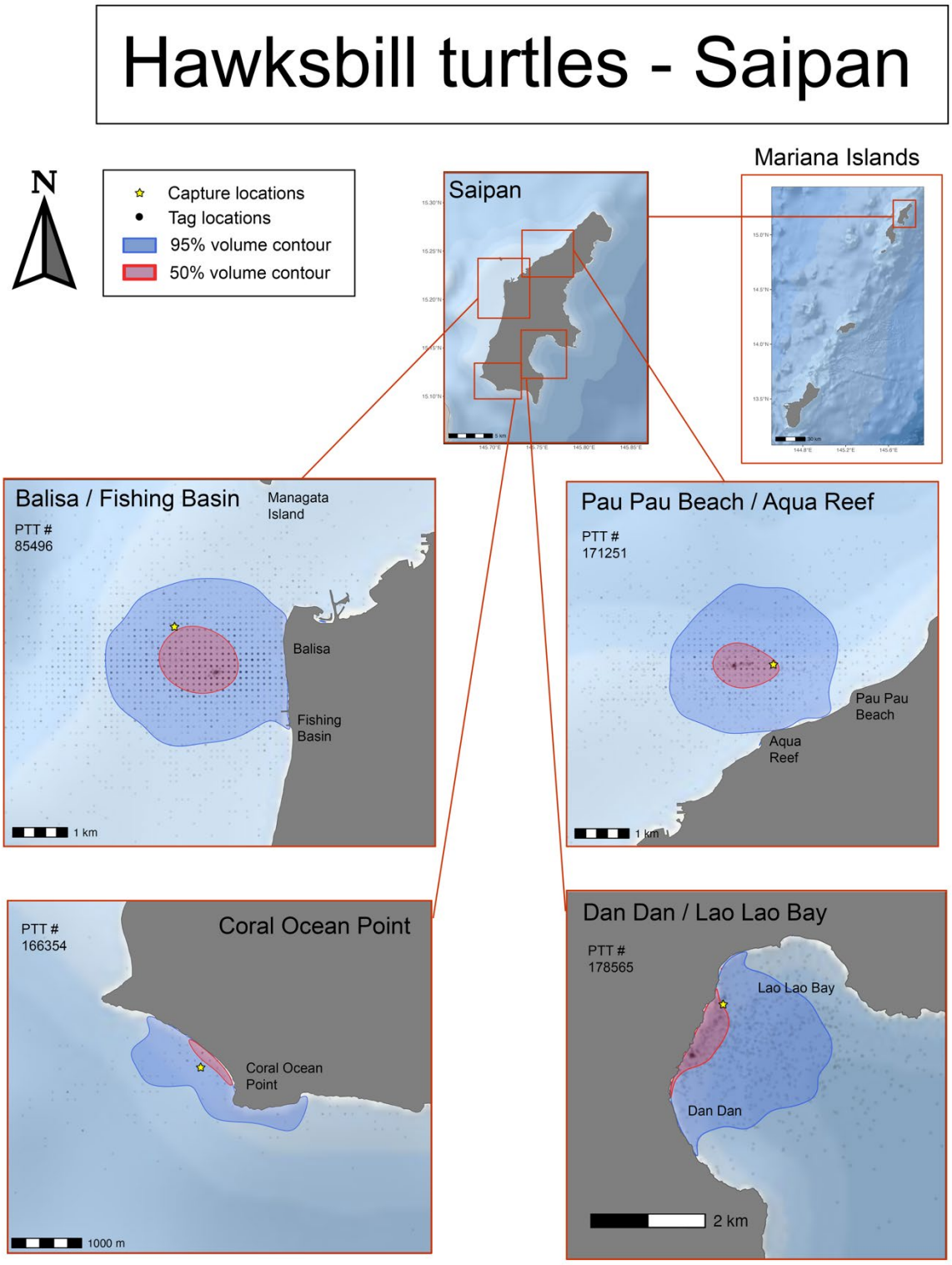
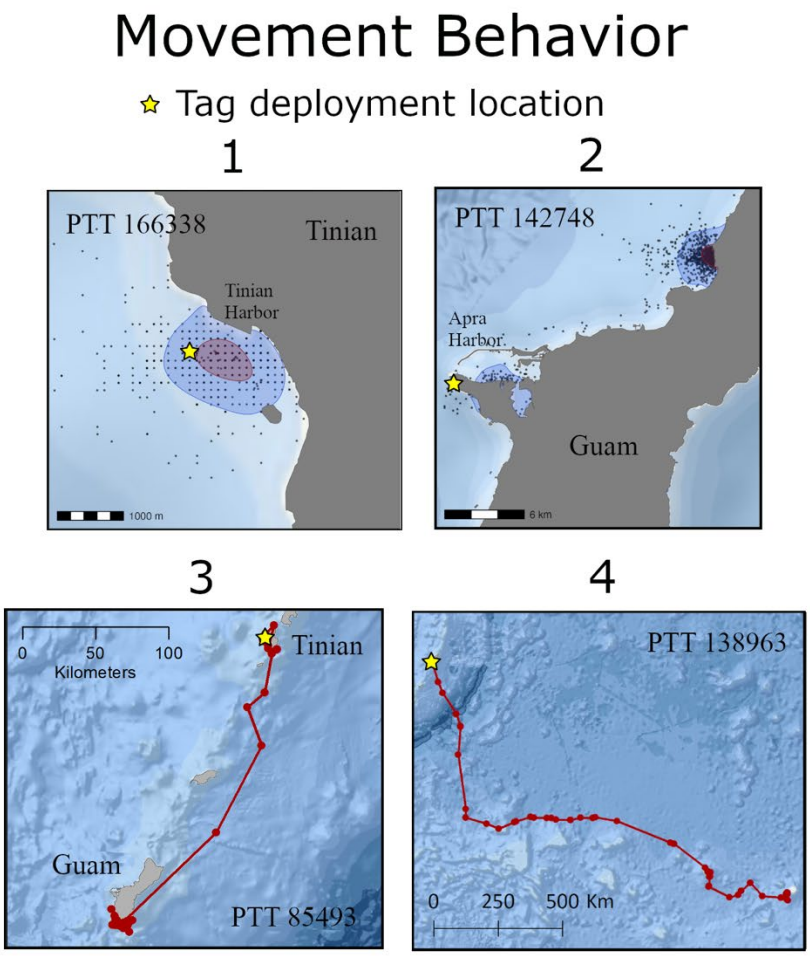


Figure 8. Habitat use map for hawksbill turtles equipped with satellite tags in Saipan, with 50% (core home range) and 95% (overall home range) volume utilization distributions in red and blue, respectively.



Movement Behavior	Number of turtles	%
1	103	92.8%
2	5	4.5%
3	2	1.8%
4	1	0.9%
Total	111	100.0%

Figure 9. (A) Examples of movement behaviors 1-4 (MB1–Remain in the vicinity of a single foraging area; MB2–Shifts in intra-island foraging areas; MB3–Transition between distinct inter-island foraging areas; MB4–Departure from the Mariana Islands) and (B) the number (and percent) of turtles demonstrating each behavior.

DIVE BEHAVIOR

Both green and hawksbill turtles spent the overwhelming majority of their time at depths (i.e., TAD) of 25 m or less, with 98.1 % and 94.6 % of all time spent within the 20 m or less depth bins, respectively (Figure 10A). Despite this similarity, overall, hawksbill turtles spent more time in deeper waters than green turtles, with an average TAD depth of 15.0 m compared to 10.2 m, respectively. In line with this finding, 32.9 % of hawksbill TAD were in bins 20 m or more compared to only 12.7% for green turtles. When comparing the TAD across the three size classes, turtles in the smallest size class (i.e., < 45 cm) spent less time (26.5 % of all records) in bins deeper than 10 m, compared to the medium size class (45–60 cm; 32.2 % of all records) and the large size class (> 60 cm; 47.8 % of all records), with virtually no time in bins deeper than 25 m (Figure 10B). Diel comparisons of TAD for green turtles show similar time spent across depth bins during day and night. Hawksbill turtles tend to spend more time in shallower depth bins at night compared to during the day; 56.6 % of nocturnal records come from bins 10 m or less compared to 41.7 % during diurnal periods (Figure 10C).

Fourteen m was by the most common MDD (25.9 % of records) bin reached during dives by green turtles (Figure 11A), while the most common MDD for hawksbills was 24 m (15.3% of records). Similar to our TAD findings, turtles in the smallest size class dove to deeper MDDs (i.e., ≥ 18 m) less often (12.8 % of all records) than medium (29.2 % of all records) and large (38.5 % of all records) turtles, including no time in bins in water deeper than 40 m (Figure 11B). Diel comparisons of MDD for hawksbill turtles indicated that a greater number of records during the night (62.9 %) come from depth bins of 14 m or less, versus during the day (43.5 %) (Figure 11C).

Hawksbills tend to spend more time underwater than green turtles. The most common dive duration bin for green turtles was 30 minutes (25.2 % of all records), followed by 20 minutes (24.1 % of all records), compared to those for hawksbill turtles, which was 40 minutes (21.6 % of all records), followed by 50 minutes (20.4 % of all records) (Figure 12A). Beginning in 2018, we adjusted our dive duration bins (see Methods) which provided increased resolution on dive durations beyond 60 minutes, revealing that both green and hawksbill turtles can remain submerged for over 2.5 hr (Figure 12B).

Green and hawksbill turtles primarily occur in waters with a temperature range of 28–33 °C. TAT records for both species most commonly registered in the 29° C and 30° C bins (Figure 13) representing 35.4 % and 35.1 % of total records for green turtles, respectively, and 27.9 % and 37.8 % of total records for hawksbill turtles, respectively.

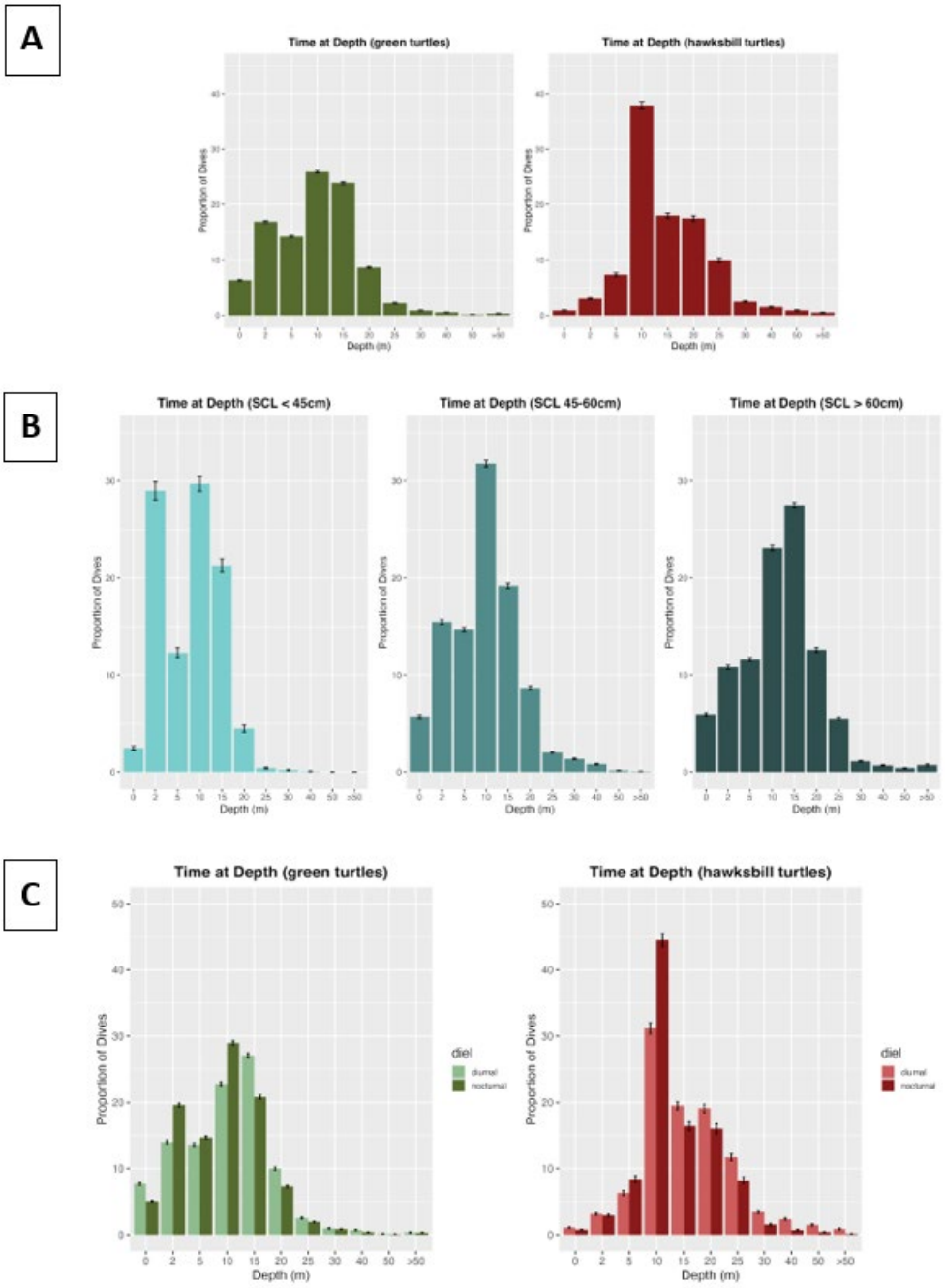


Figure 10. Proportion of time-at-depth profiles for (A) green and hawksbill turtles, (B) small, medium, and large turtles, and (C) night vs. day in the study area in 2015–2022.

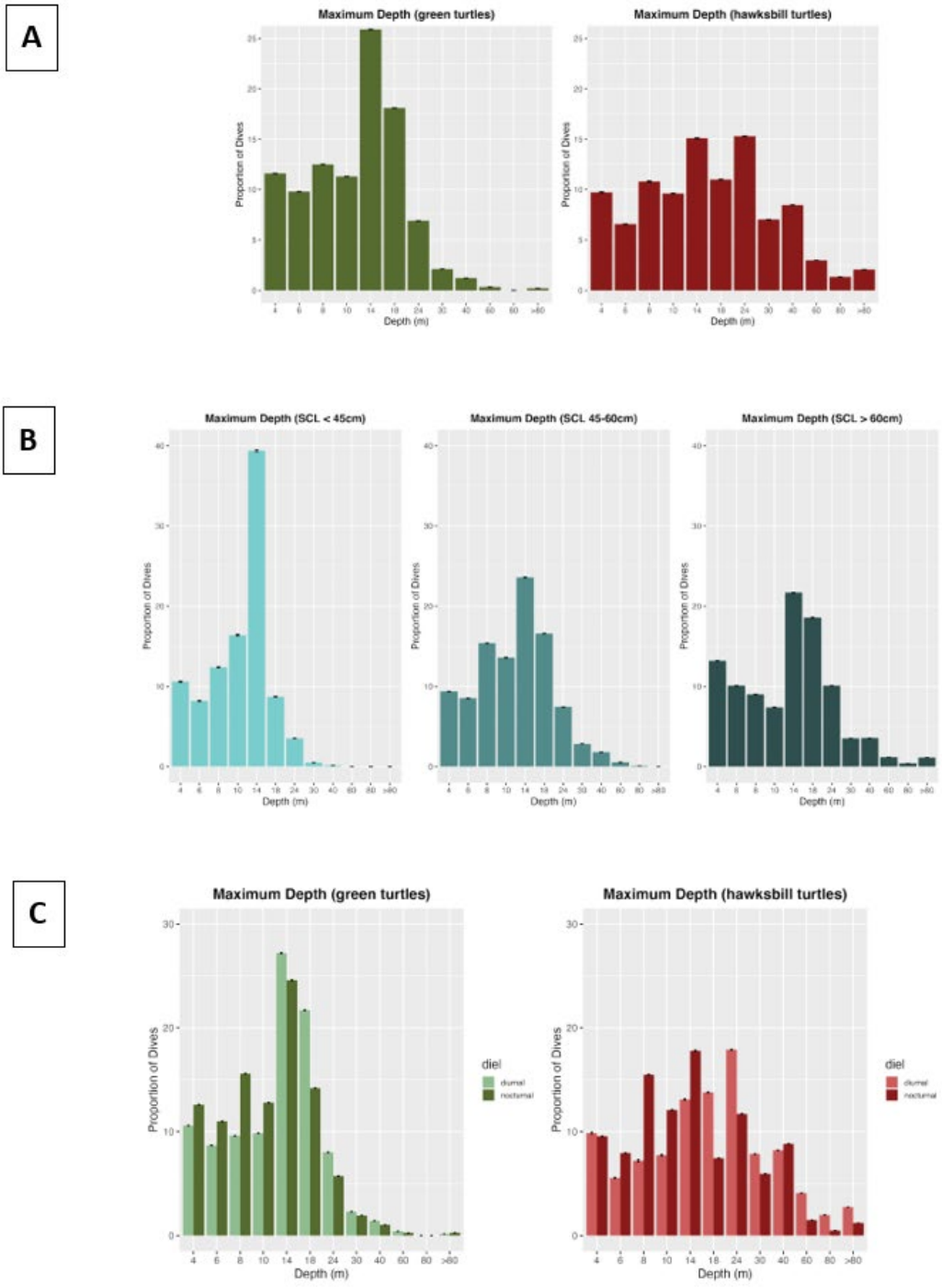


Figure 11. Proportion of maximum dive depth profiles for (A) green and hawksbill turtles, (B) small, medium, and large turtles, and (C) night vs. day in the study area in 2015–2022.

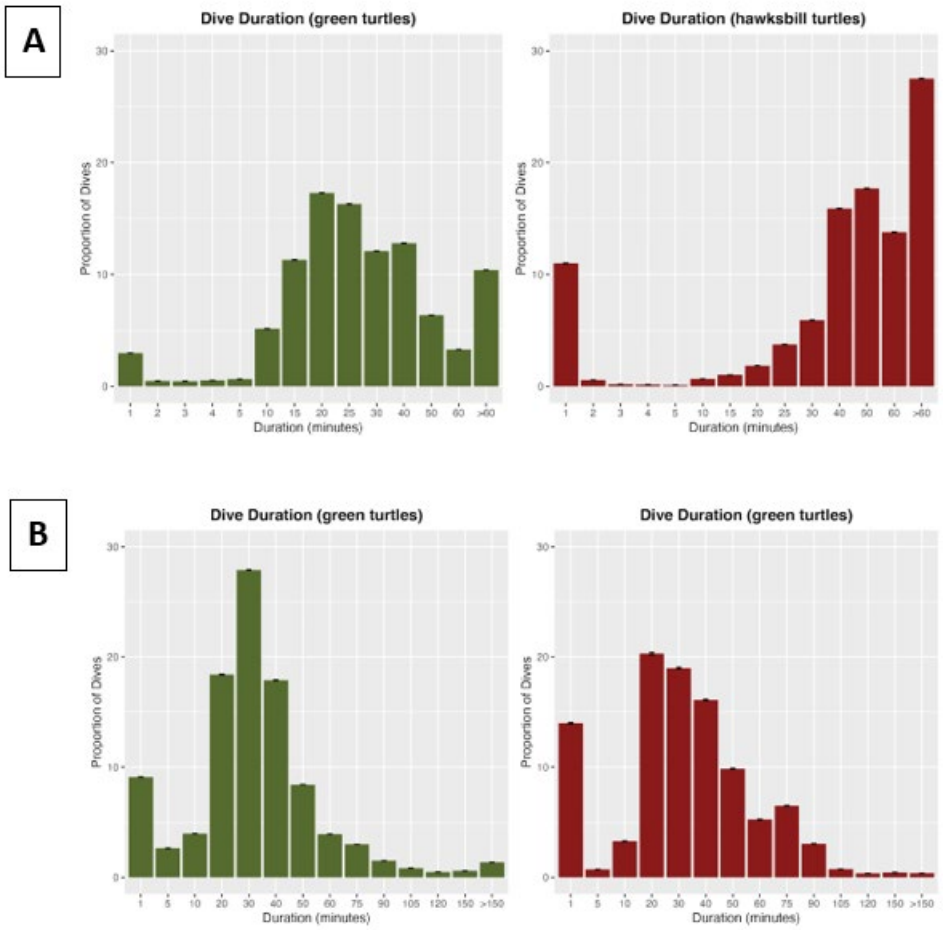


Figure 12. Dive duration profiles for green and hawksbill turtles in the study area in A) 2015–2017 with max time bin of 60 minutes, and B) from 2018 – 2022 with max time bin of 150 minutes (2.5 hours).

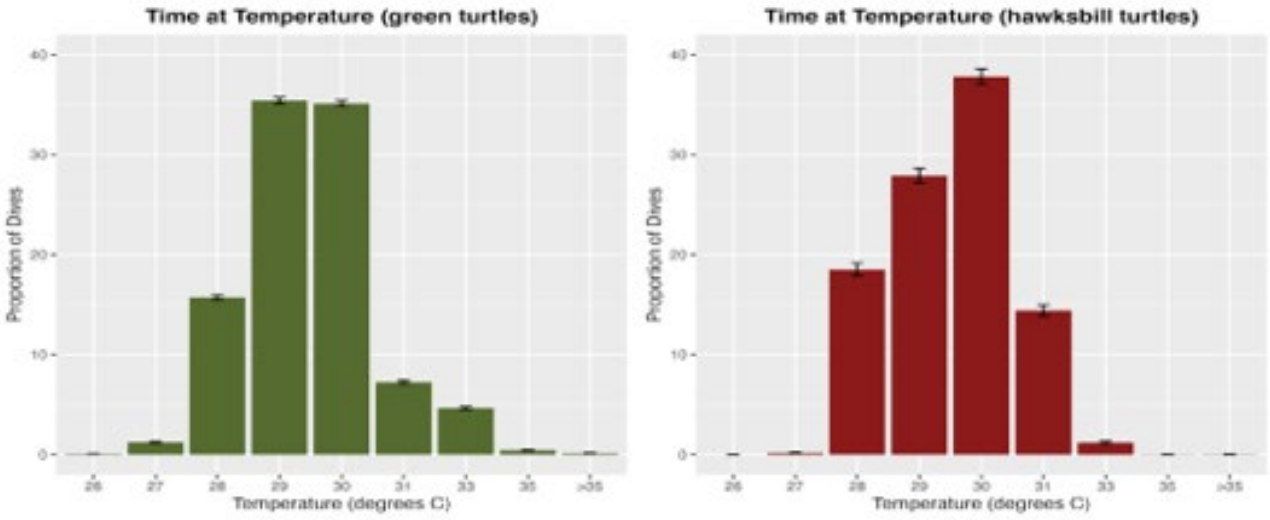


Figure 13. Proportion of time-at-temperature profiles for green and hawksbill turtles in the study area in 2015–2022.

DISCUSSION

Green and hawksbill turtles were commonly observed in most locations that were surveyed during this study. This is particularly true for green turtles, which were observed in greater numbers compared to hawksbills by a ratio of approximately 10:1 (Table 1). Home range estimates revealed high foraging site fidelity and limited movements (i.e., movement behavior 1) for the overwhelming majority (92.8 %) of turtles (Tables 3–5, Figures 3–9). Data from the five recaptured turtles, including both green and hawksbill turtles, indicated they remained in the vicinity of their original capture location, with time spans averaging nearly two years and a maximum of more than 3 years (Table 2). The size distributions of green and hawksbill turtles captured in this study (Figure 2) suggest that turtles recruit to the nearshore waters of the Mariana Islands in the 30–35 cm SCL size class. These findings coincide with previous research (Summers et al., 2017) indicating sea turtles in the region remain in the nearshore waters for an estimated 17 years (13−28 years: 95 % confidence interval), departing the Mariana Islands at around 78 – 81 cm SCL. Combined, these findings suggest both juvenile green and hawksbill turtles in the Mariana Islands rely on a highly restricted area (average core area < 1 km^2) for prolonged periods of time for growth.

A limited number of turtles did transit between foraging areas or switch foraging areas altogether, both on the same island (i.e., movement behavior 2) and on other islands (i.e., movement behaviors 3 and 4), indicating they do have the capacity to shift habitats. Nonetheless, switching foraging habitats across islands was rare (2.7 % of all turtles tagged) and restricted to new recruits, turtles approaching sexual maturity, or adult turtles. Indeed, one of the turtles exhibiting movement behavior 3 was a small (40.8 cm SCL) green turtle (Argos ID 171263) encountered off the coast of northern Guam. Turtles of this size class represent recent recruits to neritic habitats after spending their first years of life in the pelagic habitat (i.e., the “lost years”). It is likely that this turtle had very recently recruited to neritic areas and had still not settled in a fixed foraging habitat, and the 210 km migration north to Saipan represented the turtle’s ongoing search for a suitable location to settle.

The second turtle exhibiting movement behavior 3 was a subadult hawksbill (Argos ID 85493) measuring 61.7 cm. It was tagged in 2013 on Tinian and traveled 233 km south to the southern coast of Guam, where it remained for over 2 years. It is possible this turtle underwent some sort of ontogenetic habitat shift

as it was getting closer to maturity, or that it reached maturity at a smaller size than expected and relocated to breed.

We only documented one turtle departing the Mariana Islands (i.e., movement behavior 4), a 72.3 cm adult female hawksbill (Argos ID 138963) tagged in 2014 on Tinian. After approximately 9 months of tracking in waters off Tinian, the hawksbill migrated southeast 2,118 km (over 74 days) to Ant Atoll, adjacent to Pohnpei, in the Federated States of Micronesia (FSM), where it continued to transmit for approximately 10 more months. These findings are somewhat perplexing. Once reaching adulthood, hawksbill (and green) turtles typically only migrate long distances from foraging grounds to nesting grounds, spending 2–3 months depositing multiple clutches during what is known as the inter-nesting period, before returning to the former foraging ground. Nonetheless, the amount of time the turtle was tracked pre- and post-migration (9 and 10 months, respectively) is much longer than what is considered the inter-nesting phase, indicating this female did not nest at either site. Furthermore, our high-resolution tracking data (i.e., GPS locations) show no evidence that the turtle emerged to nest at either site. Given this context, it is possible she simply switched foraging habitats. However, to our knowledge, a long-distance foraging ground switch by an adult female hawksbill has never previously been documented anywhere across the globe.

Dive patterns suggest that both green and hawksbill turtles spend most of their time in waters shallower than 20 m (Figures 10–11) and use similar areas of the water column, with average TAD spent at 10.2 m and 15.2 m, respectively. However, our TAD and MDD findings do suggest that hawksbills tend to spend more time and make maximum dives to deeper depths than green turtles, with the latter rarely reaching depths greater than 40 m. Additionally, our dive duration analysis indicated hawksbills often remained submerged longer between breathing bouts than green turtles. Diel comparisons suggest both green and hawksbill turtles use shallower waters during the night compared to the day and this is particularly true for hawksbills turtles. This could indicate that turtles are actively foraging in deeper waters during the day, with hawksbills doing so at even greater depths. Given these findings, it is likely that fine-scale habitat partitioning is occurring, and the cohabitation by the two species may be facilitated by differential diets typical of these two species (Meylan, 1988; León and Bjorndal, 2002; Carrión-Cortez et al., 2013).

Satellite tags deployed on hawksbill turtles transmitted an average of more than 100 days longer than tags deployed on green turtles (283.3 days and 176.9 days, respectively). Hawksbill turtle shells are thicker and

more keratinized than green turtle shells, which tend to be thinner and oilier. This difference likely leads to longer tag retention times on hawksbills and thus the longer transmission periods.

Genetic work currently underway indicates the majority of green turtles foraging in waters of the Mariana Islands originate from nesting beaches in the Republic of the Marshall Islands. There are substantial contributions from FSM and minor contributions from other countries (Michael Jensen, Pers Comm, 15 March 2021). As mentioned previously, one large hawksbill (Argos ID 138963) captured at Fleming Point in Tinian also migrated to FSM, suggesting migrations can occur in both directions.

Working with the Integrated Ocean Observing System (IOOS), a national-regional partnership aimed at providing current and past integrating ocean information, we granted public access to all of the satellite tags deployed under the NOAA-PACFLEET IAA. This was achieved via the creation of a NOAA-PACFLEET web project (https://portal.atn.ioos.us/, search Projects page for MITT) within the Animal Tracking Network (ATN). This collaboration currently provides "real-time" visualization of all satellite tags deployed as part of the project, thus serving as an accessible community resource and advancing the project toward fulfilling its Public Access to Research Results (PARR) requirements.

The new algorithm we developed for processing satellite tracking data and estimating home ranges incorporated increased weighting for locations of higher accuracy classes. This resulted in more accurate home range estimations, particularly for SPOT tags that are not capable of collecting Fastloc GPS locations but are essential for understanding the movement behavior of smaller turtles. The new home range estimation approach produced home range values that were comparable (i.e., not significantly different) among tag models and allows us to combine the results from these tags.

CONCLUSIONS

The conclusions discussed in this section focus on two baseline questions identified in the MIRC Monitoring Plan relative to sea turtles, which also served to guide much of the research undertaken during this IAA:

1. WHAT IS THE OCCURRENCE, HABITAT USE, AND POPULATION STRUCTURE OF SEA TURTLES IN THE MITT STUDY AREA?

In summary, turtles were common at most sites surveyed, exhibited strong foraging site fidelity, and consisted primarily of juveniles, with limited numbers of both new recruits and putative adults. The majority of turtles tracked in this study undertook limited movement behavior and demonstrated strong fidelity to a single foraging area. Although this project did not systematically collect data on bottom substrates, visual observations

of habitat during surveys indicated turtles are often found in areas characterized by broad, relatively shallow substrates (rather than steep cliffs or drop offs) consisting of either sea grass flats or rocky and coral patch reefs. The healthy coral reef at Gab Gab, within Apra Harbor on Guam, is somewhat of an exception in that the coral reef has developed over an abrupt drop off, providing extensive caves that serve as resting habitats for turtles extending to depths over 40 m depth. Hawksbill turtles were more common in areas that had coral reefs growing on rocky substrates. Of note, we observed and captured numerous small hawksbills near Lam Lam Beach on Tinian, indicating this area may be particularly important for recent recruits of the species. The individuals captured were too small to equip with the SPLASH satellite tags we had available at the time, thus collecting telemetry data was not possible. Logistical challenges limited more robust surveying of Tinian during the study timeframe (Table 1), and MTBAP is currently planning additional research efforts around the island.

2. WHAT IS THE EXPOSURE OF SEA TURTLES TO EXPLOSIVES AND/OR SONAR IN THE MITT STUDY AREA?

Many of the turtle home ranges we documented are located within Navy submerged lands (Figure 14). However, none of the overall or core home ranges estimated via this study overlapped with the Navy detonation sites around Apra Harbor (Figures 3–4).

Nearshore habitats, specifically areas25 m or less in depth, are essential to sea turtles in the study area. Larger turtles tended to spend more time at deeper depths than smaller turtles (Figures 10–11), indicating the slightly deeper habitats may be particularly relevant for larger size classes which have increased conservation value (Crouse et al., 1987).

Reproductive age female turtles represent the highest conservation value of all size classes (Heppel, 1998). Several important green turtle nesting sites are located on beaches in the Mariana Islands, including on: Guam – Anderson Air Force Base, Cocos Islands, and Spanish Steps; Tinian – Dangkolo, Chulu, and Turtle Cove; Saipan – Tank Beach, Marine Beach, and Obyan Beach (Maison et al., 2010; Summers et al., 2018). Recent satellite telemetry research on nesting females in the Mariana Islands indicates these turtles use foraging sites in the vicinity of their nesting grounds during their inter-nesting period, then most depart the Mariana Islands once nesting is completed (PIFSC unpublished data).

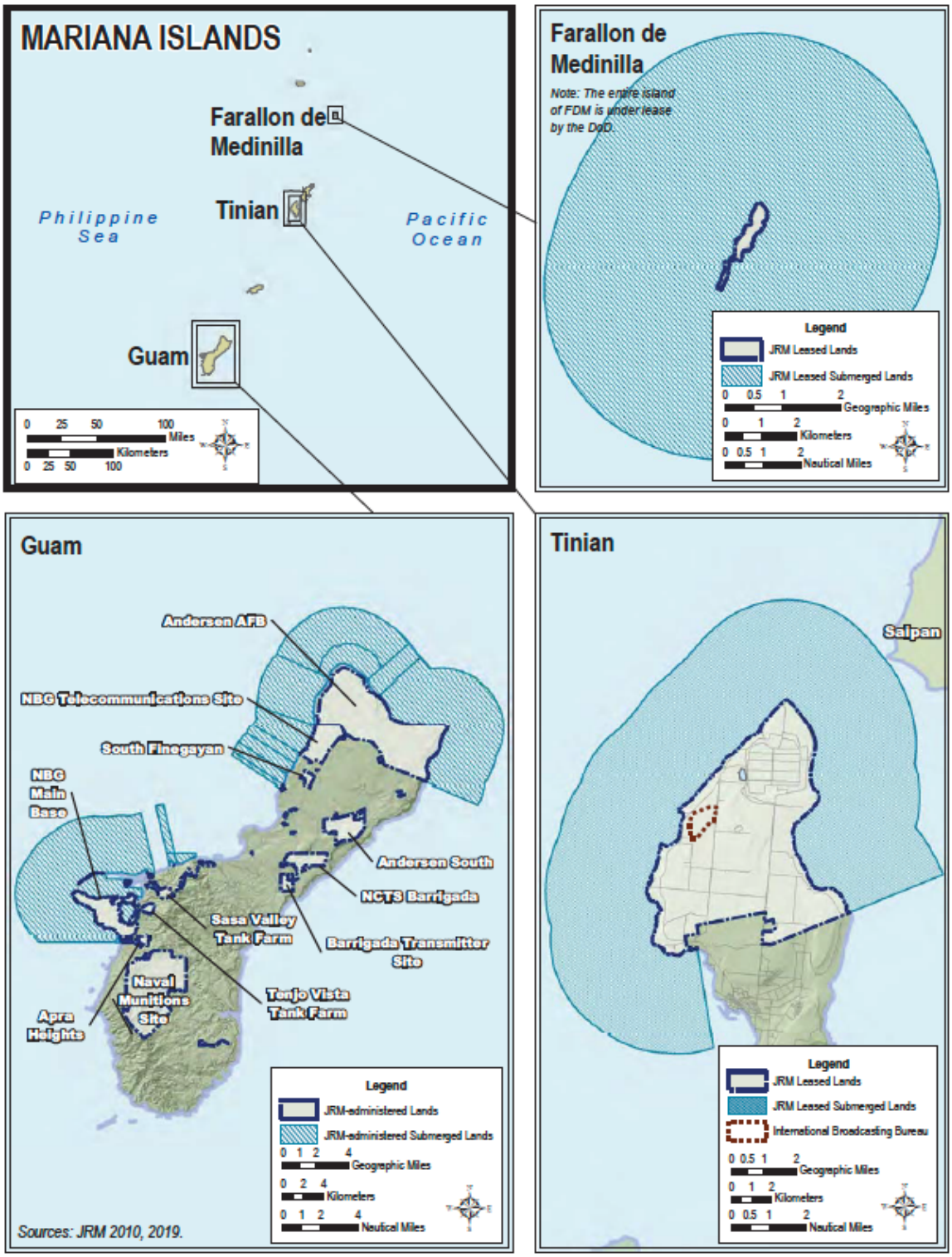


Figure 14. Department of Navy submerged lands in the Mariana Islands. Image courtesy of Navy Joint Region Marianas.

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