Sea Turtle Tagging in the Mariana Islands Training and Testing (MITT) Study Area

Programmatic Report
May 2019

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Cover: Photo courtesy of Pacific Islands Fisheries Science Center, Protected Species Division.

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List of Acronyms

BO – Biological Opinion

C – Celsius

CLS – Collection and Location by Satellite

CM – Centimeter

CNMI – Commonwealth of the Northern Mariana Islands

DAWR – Division of Aquatic and Wildlife Resources

DLNR – Department of Lands and Natural Resources

DNA – Deoxyribonucleic Acid

ESA – Endangered Species Act

FY – Fiscal Year

GIS – Geographic Information Systems

GPS – Global Positioning System

ICMP – Integrated Comprehensive Monitoring Program

ID - Identification

KIWB – Kernel Interpolation

KM – Kilometer

MIRCMP – Mariana Islands Range Complex Monitoring Plan

M – Meter

MITT – Mariana Islands Training and Testing

MMPA – Marine Mammal Protection Act

MTBAP – Marine Turtle Biology and Assessment Program

NIST – National Institute for Standards and Technology

NMFS – National Marine Fisheries Service

NOAA – National Oceanic and Atmospheric Administration

PIFSC – Pacific Islands Fisheries Science Center

PIT – Passive Integrated Transponder

PSD – Protected Species Division

SCL – Straight Carapace Length

SD – Standard Deviation

USFWS – United States Fish and Wildlife Service

Background

The U.S. Navy developed monitoring questions for the Mariana Islands Training and Testing (MITT) study area under the Mariana Islands Range Complex Monitoring Plan (MIRCMP) as required under the Marine Mammal Protection Act (MMPA) of 1972 and the Endangered Species Act (ESA) of 1973. The MITT monitoring questions outline the scope of monitoring the Navy will conduct to understand marine mammal and sea turtle distribution and, ultimately, impacts from Navy training and testing. The monitoring and analyses outlined in this annual report support the ESA Biological Opinion (BO) received for the MITT in 2015. The overall objective of the MIRCMP is to collect field data that will enable the Navy and the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) to better understand the distribution and habitat use of sea turtles in Guam and the Commonwealth of the Northern Mariana Islands (CNMI) (collectively referred to as the Mariana Archipelago). Data generated via implementation of the MIRCMP will be integrated into the Navy-wide Integrated Comprehensive Monitoring Program (ICMP). Of the five species of sea turtles associated with the MITT, this annual report provides data on the habitat and movements of two species; the green (*Chelonia mydas*) and hawksbill (*Eretmochelys imbricata*) turtle. Individuals of both species were tagged and satellite-tracked in the nearshore waters of Saipan, Tinian, and Guam by staff from NOAA Pacific Islands Fisheries Science Center's Marine Turtle Biology and Assessment Program (PIFSC MTBAP). Juvenile and adult life-stages were targeted for tagging and satellite tracking, with juveniles making up the majority of turtles observed, captured and equipped with electronic tags. The other three species of sea turtle present in the North Pacific are not generally associated with neritic nearshore waters and were not observed during monitoring activities.

To date, PIFSC MTBAP has spent a total of 41 field days conducting sea turtle surveys around the Mariana Archipelago. These surveys have been conducted during a total of eight field expeditions to Guam, five expeditions to Saipan and four expeditions to Tinian. During that time researchers have observed a total of 438 turtles, 139 of which were captured and 94 of which were equipped with satellite tags. The expeditions have included meetings and collaborative fieldwork with numerous local partners, including representatives from Guam Department of Agriculture Division of Aquatic and Wildlife Resources (DAWR), CNMI Department of Lands and Natural Resources (DLNR), USFWS, University of Guam/SeaGrant, Naval Base Guam, and the U.S. Pacific Fleet Environmental Readiness Office.

Guiding Questions from the FY13-15 Monitoring Plan

- Are there locations of greater cetacean and/or sea turtle concentration around Guam, Saipan, and Tinian?
- What is the occurrence and habitat use of sea turtles in the MITT study area?
- What is the exposure of cetaceans and sea turtles to explosives and/or sonar in the MITT study area?

Summary of Tasks

1. Capture and tag sea turtles in the MITT study area, and deploy biotelemetry devices
2. Process and analyze biotelemetry data and other survey data
3. Prepare annual reports

Progress on Field Research

The most recent field research was conducted during August 1–12, 2018. Drs. T. Todd Jones, Summer Martin, Camryn Allen and Alexander Gaos of the PIFSC MTBAP, as well as Julie Rivers of U.S. Pacific Fleet, collaborated with local partners to conduct marine turtle surveys and in-water captures of green and hawksbill turtles. Captured turtles were weighed, measured, biopsied, tagged [i.e., flipper, passive integrated transponder (PIT), satellite tracking] in an effort to expand our knowledge of the population demographics, population structure, and fine-scale habitat use of turtles in the area. Blood samples were also collected for two studies: 1) hormone analysis to determine population sex ratios, and 2) metabolite analysis to determine nutritional/feeding state. The aforementioned activities were permitted under NMFS ESA10a1A Take permit #17022 and NMFS IACUC SWPI2013-05R. Additionally, in Guam, the Division of Aquatic and Wildlife Resources (Guam DAWR) biologists were provided with hands-on refresher training by MTBAP staff. In both Guam and CNMI, local partners continue to be engaged in this collaborative research effort. Many of these activities are part of a larger collaborative effort with PIFSC MTBAP, Guam DAWR, CNMI DLNR, Naval Base Guam, and the U.S. Pacific Fleet Environmental Readiness Office.

The most recent field expedition consisted of 12 days on Guam and Saipan, including 5 days of travel, 5 days of in-water surveys and turtle captures, and 2 days during which inclement weather conditions prohibited operations. During most of the year both Guam and Saipan experience strong easterly trade winds, which create hazardous boating and monitoring conditions. These conditions have previously made it impossible to survey much of the eastern coasts of these islands. MTBAP staff programmed the most recent survey trip to coincide with months when easterly trade winds occasionally abate (August and September), with the goal of conducting research in these hard-to-study areas. The team was rewarded for its planning with successful monitoring efforts carried out along the northeast coast of Saipan (e.g., Tank Beach and Marine Beach), as well as both the eastern (e.g., Talofofo Bay, Pago Bay, Paget Point) and southern (e.g., Cocos Island, Cocos Lagoon, Achang Reef Flat) coasts of Guam. None of these areas have previously been surveyed, thus encountering turtles and deploying satellite tags has provided novel opportunities to collect important information in these data deficient areas. Surveying and tagging in multiple locations around the perimeters of Guam, Saipan, and Tinian is important for understanding sea turtle occurrence, distribution, relative abundance, and habitat use throughout the MITT study area. In Saipan, all captured turtles were processed and satellite tagged onboard the research boat. In Guam, in addition to a primary research boat, we were able to mobilize collaborators from DAWR to deploy a second boat. We then set up terrestrial processing centers, which were staged out of Achang Bay (southern coast) and Talofofo Bay (eastern coast), and DAWR transferred captured turtles from the primary research boat to the land-based processing centers, thus allowing the primary boat to focus on in-water capture of turtles. Turtles with straight carapace length (SCL) > 45 cm and good body condition were equipped with Wildlife

Computers SPLASH 297A satellite tags, which have both Fastloc-GPS and Argos location capabilities, as well as temperature and depth sensors. Turtles with SCL between 35 and 45 cm and good body condition were equipped with Wildlife Computers SPOT-311A satellite tags, which have Argos location capabilities and temperature sensors.

Over the 5 field days, the team observed a total of 66 turtles, 16 of which were captured, 11 of which were outfitted with Wildlife Computers SPLASH satellite transmitters and two of which were outfitted with SPOT-311A satellite transmitters.

Progress on Data Analysis

Under Interagency Agreement NMFS-PIC-16-008 through NMFS-PIC-18-008 between NOAA and the Navy, data analysis and collection have been ongoing from 2013 through 2018. The PIFSC MTBAP project staff currently continue to process satellite tracking data as they arrive from Collection and Location by Satellite America (CLS America), which collects and stores the Argos satellite information. These data are being organized and analyzed to understand spatial distribution, depth use and temperature profiles for habitat used by tagged turtles.

The findings presented in this report provide robust and essential biogeographical context for understanding the abundance, spatial distribution and habitat use of sea turtles in the MITT, as well as preliminary data on the abundance and distribution of other large marine vertebrates in the region. Furthermore, these data and analyses have helped to inform the proposed Critical Habitat for the Endangered Central West Pacific distinct population segment of green turtle (NMFS and USFWS 2015). They have also informed incidental take statements and impact assessments for NOAA Fisheries ESA Section 7 and Biological Opinion needs.

In January of 2016, the first manuscript derived from this Navy/NOAA Interagency Agreement, “Five Decades of Marine Megafauna Surveys from Micronesia, ” was published (Martin et al. 2016, Frontiers in Marine Science, doi.org/10.3389/fmars.2015.00116). The analysis suggested a substantial but isolated increase in sea turtles over the last 5 decades in Guam. Specifically, there was an observed island-wide trend in turtle counts from semi-monthly aerial surveys (surveys conducted by Guam DAWR). The mean annual population growth rate of turtles (primarily green sea turtles) was 8.0% (SD = 5.7%) since 1963 and 9.3% (SD = 3.5%) since 1989.

PIFSC MTBAP staff are currently working on the second major manuscript associated with the program and have set a target publication date for early 2020. The manuscript, tentatively titled, “Reef-dwelling turtles of the Mariana Archipelago: fine-scale habitat use revealed by in-water surveys and GPS telemetry,” will provide further analysis of the boat-based surveys and satellite telemetry efforts presented in this study, including in-depth analyses of horizontal, vertical, temporal, and temperature-based habit use. The research will encompass the largest sample size for satellite tracking of juvenile green and hawksbill turtles included in a single study available to date in the scientific literature.

A third manuscript, with a 2021 target date, will focus on producing abundance estimates by integrating the survey data from this study with small boat cetacean surveys (Hill et al. 2016) and presence/absence data collected during underwater towed-diver coral reef surveys (NOAA data). These survey data and analyses document the widespread presence of turtles throughout the

Mariana Archipelago, with >1,700 observations. The synthesis of results from in-water surveys, along with data from the first in-water satellite transmitter deployments in this island chain, will advance our understanding of the distribution, relative abundance, and habitat use patterns of the juvenile-dominated green and hawksbill turtle foraging populations throughout the Mariana Archipelago.

Progress on Data Availability

The supplementary materials list all data available to date. The listed files include the following:

1) all boat survey tracks from the 2013–2018 field seasons throughout the MITT study area;
2) all metadata on turtle observations, captures, and satellite tag deployments in 2013–2018 (date, location, species, numbers of all tags applied, turtle length measurement, etc.);
3) all metadata on cetacean observations for 2016–2018 (date, location, species);
4) time-at-depth histogram data from satellite tags deployed in 2014–2018 (raw data are provided as the proportion of time spent at binned depths for designated periods of time);
5) time-at-temperature histogram data from satellite tags deployed in 2014–2018 (raw data are provided as the proportion of time spent at binned temperatures for designated periods of time);
6) raw Argos location data from Wildlife Computers SPLASH and SPOT Satellite tags deployed in 2013–2018 (with a table for interpretation of Argos derived locations); and
7) raw GPS location data from Wildlife Computers SPLASH Satellite tags (with a table for interpretation of GPS locations) deployed in 2013–2018.

The PIFSC MTBAP plans to make the data publicly accessible through the Animal Telemetry Network, which will satisfy Public Access to Research Results (PARR) requirements for both NOAA and the Navy.

Methods

In-water surveys and capture

Small boat surveys were conducted in the nearshore and coastal waters of Guam, Saipan, and Tinian (Figure 1). During surveys, the boat team recorded all observations of turtles seen by both the in-water snorkel team and the boat team, along with approximate GPS coordinates. Observed turtles were visually assessed as to the feasibility of capture (e.g., turtle behavior and distance from diver). Turtles of all size classes were targeted for capture, either by hand capture while snorkeling or after diving from a slow-moving boat. Hand captures involved free-diving (2–25 m) to capture turtles resting/foraging in the water column or on the substrate. Captured turtles were immediately brought to the surface, lifted into the boat and processed on deck or after being brought to shore and placed in turtle holding bins. All research was authorized under the following permits: NMFS ESA10a1A 17022 / 1556 / 15661, USFWS Recovery Permit TE-72088A-1, IACUC Protocols NMFS SWPI 2013-05, and Guam Department of Agriculture Special Permit for Scientific Research SP2013-004 and SC-MPA-17-010.

All turtles were tagged with two metal (Inconel) self-piercing sea turtle tags or 'flipper tags' (Style 681, National Band and Tag Company) using the standard technique described in the Marine Turtle Specialist Group Manual on Research Techniques (Eckert et al. 1999) and with two PIT tags – small (14-mm length × 2-mm diameter) electromagnetically-coded glass-encased "microchips" – Destron Tx 1406L. All Inconel and PIT tags had unique identification numbers. The Inconel flipper tags were attached to the trailing edge of a fore flipper and the PIT tags were injected subcutaneously into the rear flippers. Skin samples were obtained for DNA and stable isotope analysis (Dutton et al. 1996). Straight carapace length (SCL) and turtle mass were measured, and turtles of appropriate SCL (see Jones et al. 2013) were outfitted with a satellite tag.

The majority of satellite tags attached to turtles were the SPLASH10-F series Platform Transmitting Terminals designed by Wildlife Computers. These are data-archiving tags that transmit via the Argos satellite system. In addition to Argos-derived location data, the tags also upload sensor data that include GPS derived locations, depth, temperature, light level, and wet/dry (based on conductivity). For this study we used SPLASH10-F tags with a frontal area of approximately 12 cm^2; however, some size variation of the SPLASH tags is due to the differences in the battery capacity (and hence battery life) of the various versions, with the smaller tags allowing us to apply them to smaller juvenile turtles (minimum 45-cm SCL). Wildlife Computers SPOT-311A tags were also deployed to track turtles of even younger life-stages (i.e., 35 cm–45 cm SCL). In contrast to the SPLASH tags, SPOT tags are much smaller (frontal area = 4.79 cm^2) and only have the capability of collecting data on Argos locations and water temperature. Captured turtles with SCL < 35 cm or that had poor body condition or physical abnormalities were not outfitted with a satellite tag.

Satellite tag attachment followed the drag recommendations of Jones et al. (2011, 2013) and the attachment methods as described in Jones et al. 2018. In short, the attachment area on the carapace was lightly sanded to remove algae and cleaned with denatured ethanol. A 0.75-cm layer of a two-part epoxy (Powers T308 or Superbond) was used to affix the tag to the carapace, and a second putty-type epoxy (J.B. WaterWeld) was form-molded around the tag to protect it from damage by reef and rock ledges during the course of normal turtle behavior. This tag attachment technique is widely used and works well with reef-dwelling hawksbill or green turtles. All satellite tags were subsequently covered with a layer of anti-fouling paint (Interlux Ulta Micro Extra or Micron66) to inhibit the attachment of algae and other growth that can cover sensors and interfere with tag operation.

Movement tracks, home range estimates, and dive behavior

GPS locations, dive depth, dive duration, and temperature data were obtained in raw form over the Argos system, and processed to produce data ready for analysis. For turtles equipped with SPLASH tags, two turtle movement tracks were created, one using all available Argos locations and another using all GPS locations. Only the former track was created for turtles equipped with SPOT tags. For calculating migration distances and timing of movements, we used the difference in time and distance of path between (i) the last GPS location point (Argos location point for SPOT tags) of a turtle before it began its long-distance movement out of an area and (ii) the first GPS location point (Argos location point for SPOT tags) associated with its arrival at the new location.

Home range estimates were generated using GPS locations for the SPLASH tags due to the increased accuracy of these location points (over Argos). However, we also generated home range estimates for turtles equipped with SPOT tags using Argos locations, omitting the less precise and invalid Argos location classes 0 and Z, respectively (Argos 2008). Home ranges and the associated 50% and 95% density volume contours were generated using kernel interpolation with barriers (KIWB). The KIWB method was selected to calculate home range over traditional kernel density estimation (KDE) due to the ability of KIWB to account for land barriers, which is particularly relevant for nearshore marine species as topological features can inadvertently be incorporated into the analysis in traditional KDE analyses (Sprogis et al. 2016). All tracks and density estimates were performed in ArcGIS (ESRI 2012). The data analysis remains preliminary as some of the satellite tags are still transmitting. Final analyses will include the full range of GPS data for additional home range analysis and KIWB estimates.

Further details on the KIWB estimates in ArcGIS are provided here. The KIWB tool is available within the 'Geostatistical Analyst' toolbox section of ArcGIS. Prior to performing a KIWB estimate on a set of GPS points, we grouped the data by species and tagging location and filtered out (i) all points that occurred within the first two weeks of tag deployment (to remove erratic behavior and displacement from capture), (ii) all points erroneously appearing on land, and (iii) all points suggesting a swim speed greater than 5 km per hour. We generated a point density surface with a cell size of 10 m as a necessary intermediate step. Then we used the point density surface and an output cell size of 10 m to construct the KIWB estimate. Using the KIWB estimate, we produced 50% and 95% volume contour polygons to describe the core area and home range, respectively, for turtles pooled by deployment location. We calculated the area of each volume contour polygon (km^2) to quantify core area and home range and allow for qualitative comparisons across sites.

Temperature data and depth data were collected every 10 seconds and archived by the corresponding tags; these data were then binned across 6-hour periods and sent via satellite transmissions with the Argos and GPS (if applicable) location data when the turtle surfaced. Bins are user-defined and give insights into different aspects associated with dive behavior, including:

Temperature: the proportion of dives spent at each temperature bin.

Depth: the proportion of overall dive time spent within each depth bin.

Max dive depth: the maximum depth bin reached for each dive.

Dive duration: the time duration bin of each dive.

The temperature, depth, maximum dive depth, and dive duration bins were programmed as follows:

Temperature: (in degrees Celsius)	19, 21, 23, 24, 25, 26, 27, 28, 29, 30, 31, 33, 35, > 35
Depth: (in meters)	0, 2, 5, 10, 15, 20, 25, 30, 40, 50, 60, 70, 100, > 100
Max Dive Depth: (in meters)	4, 6, 8, 10, 14, 18, 24, 30, 40, 60, 80, > 80
Dive Duration (2013–2017): (in minutes)	1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 40, 50, 60, > 60

In previous years we have recorded dive durations that lasted longer than the maximum bin (see previous reports), so for 2018 we adjusted the dive duration bins as follows: 1, 5, 10, 20, 30, 40, 50, 60, 75, 90, 105, 120, 150, > 150 (in minutes). The total time a turtle was in a depth, temperature, or duration bin was averaged, and the data were represented in a histogram providing an average of averages of the life of a tag (transmission days) and across turtles. Several tags deployed at the start of the project (green turtles n = 4, hawksbill turtles n = 2) had variable depth bin programs and these data were included when feasible, but leading to some discrepancy in the sample sizes available for dive data analysis. The data were separated by species and we also evaluated potential differences between diurnal and nocturnal time periods.

Sample archiving and analysis

Tissue samples collected for DNA, stable isotope analysis (SIA), and health assessment were sent to analytical laboratory collaborators within NOAA and the National Institute for Standards and Technology (NIST):

Genetic and Stable Isotope analysis NOAA, NMFS, Southwest Fisheries Science Center
8901 La Jolla Shores Drive
La Jolla, CA 92037

Biological and Environmental Monitoring and Archival of Sea Turtle Tissues
National Institute of Standards and Technology
Hollings Marine Laboratory
331 Fort Johnson Road
Charleston, SC 29412

Results and Discussion

In-water surveys and turtle observation, capture and processing

The following is a synopsis of surveys, captures, and analyses between 2013 and 2018. The survey tracks, satellite tags deployed and additional turtles observed or captured (i.e., not equipped with satellite tags) by location for the field seasons are shown in Figure 1. A total of 41 days of boat-based snorkel survey effort were conducted; 21 days in Guam, 12 days in Saipan, and 8 days in Tinian (Table 1, Appendix Tables A2-A6).

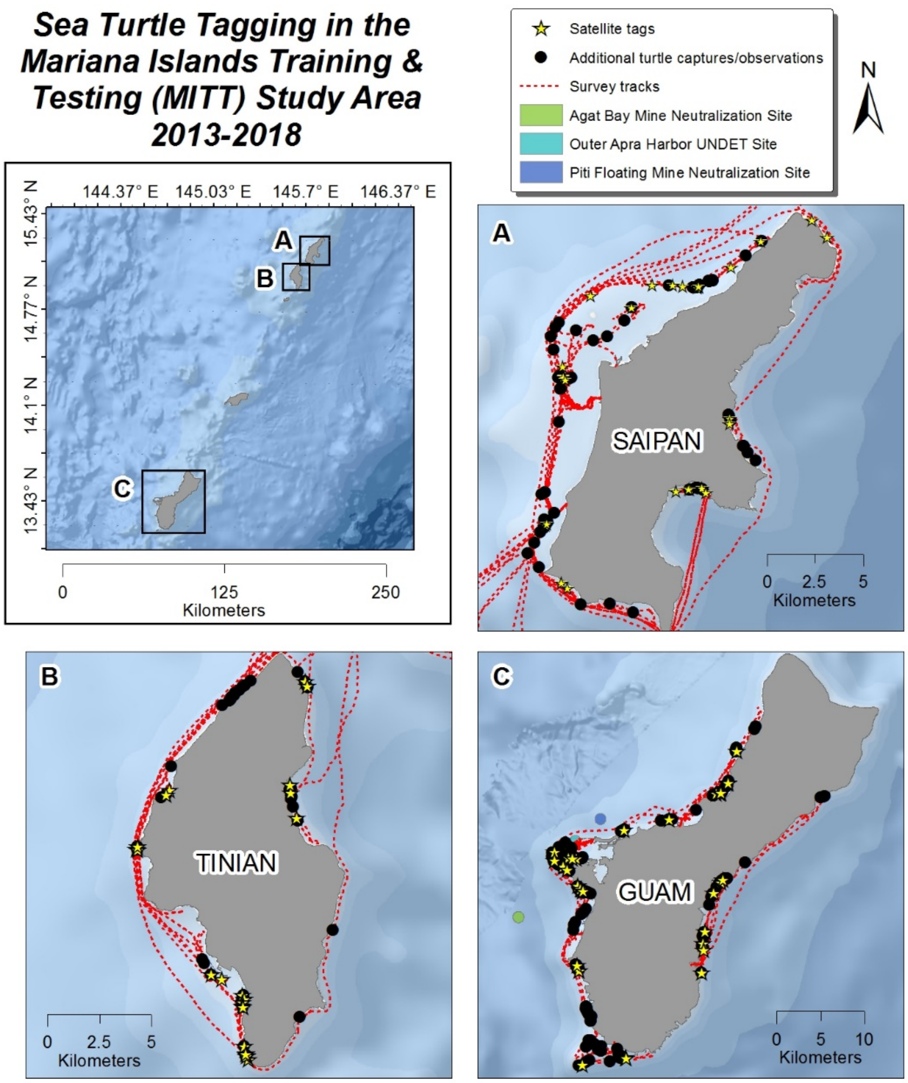

Figure 1. Marine turtle surveys, satellite tag deployment locations and turtle observations/captures in the Mariana Islands Training and Testing (MITT) study area. Red lines on each map are small-boat GPS tracks from sea turtle surveys conducted in the nearshore waters of Saipan, Tinian, and Guam in 2013–2018. Yellow stars indicate locations of satellite tag deployments on green and hawksbill turtles captured during surveys. Black circles indicate locations where additional turtles were observed/captured.

Table 1. Summary of boat-based snorkel surveys and turtle captures from 2013-2018. Data columns from left to right include: survey dates, site locations, turtle observations (number of individuals), captures, satellite tag deployments, and cetacean observations (number of individuals). CM = green turtle (*Chelonia mydas*); EI = hawksbill turtle (*Eretmochelys imbricata*); UN = unknown turtle species (either green or hawksbill turtle). Cetacean observations were of spinner dolphins (*Stenella longirostris*) or unknown species.

		Observations only				Captures (no sat tags)			Captures (sat tags)			Cetaceans
Survey Date	Location	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	-
11/14/2015	Saipan (Chalan Kanoa Reef)	-	-	4	4	1	-	1	2	-	2	-
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**
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**
	2013-2017 Totals	**211**	**15**	**73**	**299**	**39**	**6**	**45**	**82**	**12**	**94**	**161**

Summary for Turtles	
Survey days:	*41*
Encounters:	*438*
Captures:	*139*
Satellite tags	*94*

A total of 438 turtles were encountered during the 2013–2018 surveys (Table 1). Of those encounters, 299 turtles were observed but not captured (54 Saipan, 47 Tinian, 198 Guam), 45 turtles were captured but not outfitted with a satellite tag (8 Saipan, 18 Tinian, 19 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 94 turtles were captured and outfitted with satellite tags (30 Saipan, 24 Tinian, 40 Guam) (Table 1). Of the 94 turtles outfitted with satellite tags, 84 were equipped with SPLASH tags and 10 were equipped with SPOT tags. Recaptures included two green turtles in Saipan in 2013 (60 cm and 63 cm), which were tagged by a previous in-water project (Summers et al. 2017), and a 56-cm hawksbill in Guam in 2017 which had been tagged one year prior in 2016 by this project when it was 53 cm. Of the 299 non-capture observations, 70.6% were identified as green turtles, 5.0% as hawksbill turtles and 24.4% as "unknown" species (but either green or hawksbill turtles) (Table 1). Of the 45 turtles captured but released without a SPLASH or SPOT tag, 86.7% were green turtles and 12.8% were hawksbill turtles (Table 1). For the 94 satellite tags, 87.2% were deployed on green turtles and 12.8% on hawksbill turtles (Tables 1 to 4). Three of the tags on green turtles failed within 2 weeks of deployment and 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.

Table 2. Saipan: summary of 2013–2018 satellite tags by deployment location, turtle size (SCL), tag model, and tag life as transmission days. Yellow highlights tags that were still transmitting data ("active") on December 18, 2018.

Fig.	Island	Deploy Location	Deploy Date	Sp.	Argos ID	SCL (cm)	Tag Model	Last Signal Argos	Tag Life (Argos days)	Tag Status 12/18/18
2a	SAIPAN	Wing Arch	10/26/17	CM	171252	54.3	SPLASH	NA	NA	tag failed
		Pau Pau Beach	10/26/17	CM	171245	59.5	SPLASH	1/7/18	73	inactive
		Pau Pau Beach	10/26/17	CM	171253	49.2	SPLASH	10/28/18	367	inactive
		Pau Pau Beach	10/26/17	CM	171257	37.6	SPOT	3/28/18	153	inactive
		Pau Pau Beach	10/27/17	EI	171258	42.4	SPOT	11/16/17	20	inactive
		Aqua Reef	10/25/17	CM	171250	55.7	SPLASH	5/3/18	190	inactive
		Tanapag Lagoon	10/29/16	CM	166347	47	SPLASH	6/30/17	244	inactive
2b	SAIPAN	Aqua Reef	10/25/17	EI	171251	50.3	SPLASH	12/18/18	419	Active
		Aqua Reef	10/25/17	CM	171256	43.3	SPOT	4/21/18	178	inactive
2c	SAIPAN	Outer Managaha	10/27/17	CM	171254	46.3	SPLASH	1/5/18	70	inactive
		Outer Managaha	10/27/17	CM	171259	42.1	SPOT	5/27/18	212	inactive
		Balisa	8/18/13	CM	85491	60.9	SPLASH	10/15/13	59	inactive
		Balisa	8/19/13	CM	85495	66.1	SPLASH	1/19/14	154	inactive
		Balisa	8/19/13	CM	85494	60.4	SPLASH	5/3/14	257	inactive
		Balisa	8/21/13	CM	85492	62.5	SPLASH	9/17/14	392	inactive
2d	SAIPAN	Balisa	8/18/13	EI	85496	66.6	SPLASH	2/8/17	1270	inactive
3a	SAIPAN	Chalan Kanoa	11/14/15	CM	152585	50.2	SPLASH	4/18/16	157	inactive
		Chalan Kanoa	11/14/15	CM	152575	67.1	SPLASH	2/1/16	79	inactive
		Chalan Kanoa	10/27/16	CM	166343	64.3	SPLASH	7/25/17	271	inactive
3b	SAIPAN	Coral Ocean Point	10/27/16	CM	166346	44	SPLASH	3/7/17	132	inactive
		Coral Ocean Point	10/27/16	EI	166354	40	SPOT	2/12/17	108	inactive
3c	SAIPAN	Lao Lao Bay	11/13/15	CM	152576	55.6	SPLASH	3/28/16	137	inactive
		Lao Lao Bay	11/13/15	CM	152572	63.5	SPLASH	12/29/15	46	inactive
		Lao Lao Bay	11/13/15	CM	152571	56.7	SPLASH	1/13/16	62	inactive
		Lao Lao Bay	11/13/15	CM	152579	65	SPLASH	1/18/16	67	inactive
		Lao Lao Bay	11/13/15	CM	152581	53.6	SPLASH	12/21/15	38	inactive
3d	SAIPAN	Spotlight	7/22/14	CM	131995	61.7	SPLASH	7/11/16	721	inactive
		Cow Town	7/22/14	CM	138958	63.9	SPLASH	1/19/15	181	inactive
Pending	SAIPAN	Puntan Gloria	8/5/18	Cm	171235	54.9	SPLASH	10/5/18	61	inactive
		Puntan Gloria	8/5/18	Cm	171255	47.1	SPLASH	12/18/18	135	active

Details on dates, locations, and species of all satellite tag deployments, turtle captures, and turtle observations are provided in Tables 2 to 4, Appendix Tables A1–A5, and as supplementary files. In 2016–2018, cetacean observations were also recorded during surveys and transit periods; sightings details are provided in Appendix Table A6. For all captured and tagged turtles, measurements and tag identification numbers are also provided in Tables 2 to 4 and Appendix Tables A1-A5. Captured green turtles ranged in straight carapace length from 34.4 cm to 84.1 cm (mean = 53.4, SD = 9.1 cm, n = 121) and in mass from 6.4 kg to 76.2 kg (mean = 22.0, SD = 12.6 kg, n = 121). Captured hawksbills ranged in straight carapace length from 34.4 cm to 72.3 cm (mean = 50.4, SD = 11.0 cm, n = 18) and in mass from 4.4 kg to 48.9 kg (mean = 18.2, SD = 12.5 kg, n = 18). Two large captured green turtles were determined to be male based on tail length. All other captured turtles were sub-adults for which sex could not be determined using visual observation and morphometric techniques.

The size distributions of green and hawksbill turtles captured in this study are typical for turtles throughout the Mariana Archipelago. From an analysis of more than 500 in-water captures from 2006 to 2014, Summers et al. (2017) suggest that turtles recruit to the nearshore waters of the Mariana Islands around 34 cm SCL to 36 cm SCL and depart to adult foraging and nesting grounds around 78-81 cm SCL, remaining in the nearshore waters for an estimated 17 years (13–28 years: 95% confidence interval) between recruitment and maturity. Except for the two adult males, the turtles captured in this study appear to mostly be juveniles and sub-adults residing in developmental foraging grounds.

Table 3. Tinian: summary of 2013–2018 satellite tags by deployment location, turtle size (SCL), tag model, and tag life as transmission days. Yellow highlights tags that were still transmitting data (“active”) on December 18, 2018.

Fig.	Island	Deploy Location	Deploy Date	Sp.	Argos ID	SCL (cm)	Tag Model	Last Signal Argos	Tag Life (Argos days)	Tag Status 12/18/18
4a	TINIAN	Dumpcoke Cove	10/28/16	CM	166341	84.1	SPLASH	2/8/17	104	inactive
		Fleming Point	7/21/14	CM	138959	54.3	SPLASH	11/26/14	128	inactive
4b	TINIAN	Dumpcoke Cove	10/28/16	EI	166342	56.2	SPLASH	2/9/17	104	inactive
		Fleming Point	8/20/13	EI	85493	61.7	SPLASH	2/28/16	922	inactive
		Fleming Point	7/21/14	EI	138963	72.3	SPLASH	4/27/16	647	inactive
		Fleming Point	7/21/14	EI	131989	58.1	SPLASH	12/8/16	872	inactive
4c	TINIAN	Tohgong	5/16/16	CM	152584	54.9	SPLASH	12/16/16	214	inactive
		Tohgong	5/16/16	CM	142753	56.5	SPLASH	5/31/16	15	tag failed
		Dangkolo	5/15/16	CM	142747	52.6	SPLASH	11/19/16	188	inactive
		Chulu	5/15/16	CM	142750	51.6	SPLASH	10/31/16	169	inactive
4d	TINIAN	Dangkolo	5/15/16	EI	142755	62.8	SPLASH	12/28/17	592	inactive
5	TINIAN	Tinian Harbor	10/28/16	CM	166348	47.6	SPLASH	5/12/17	196	inactive
		Tinian Harbor	10/28/16	CM	166338	44.4	SPLASH	2/15/17	111	inactive
		Tachungnya Bay	10/26/16	CM	166339	44.4	SPLASH	3/1/17	126	inactive
		Tachungnya Bay	10/26/16	CM	166344	52.8	SPLASH	2/17/17	114	inactive
		Tachungnya Bay	10/26/16	CM	166337	48.2	SPLASH	2/8/17	105	inactive
		Tachungnya Bay	10/26/16	CM	166345	44	SPLASH	1/4/17	70	inactive
		Tachungnya Bay	10/26/16	EI	166355	40	SPOT	8/17/17	295	inactive
		Red Wall	11/12/15	CM	152580	56	SPLASH	9/30/16	323	inactive
		Red Wall	11/12/15	CM	152586	61.1	SPLASH	4/17/16	157	inactive
		Red Wall	11/12/15	CM	152583	54.2	SPLASH	9/17/16	310	inactive
		Red Wall	11/12/15	CM	152578	59.5	SPLASH	1/9/16	58	inactive
		Red Wall	11/12/15	CM	152569	53	SPLASH	7/18/16	249	inactive
		Red Wall	11/12/15	CM	152574	55.4	SPLASH	3/27/16	136	inactive

Fig.	Island	Deploy Location	Deploy Date	Sp.	Argos ID	SCL (cm)	Tag Model	Last Signal Argos	Tag Life (Argos days)	Tag Status 12/18/18
6a	GUAM	Tanguisson	10/17/17	CM	171249	48.2	SPLASH	7/11/18	267	inactive
		Tumon Bay	10/17/17	CM	171248	48.8	SPLASH	9/1/18	319	inactive
		Tumon Bay	10/17/17	CM	171247	62.7	SPLASH	10/12/18	360	inactive
		Tumon Bay	10/17/17	CM	171246	53.6	SPLASH	6/28/18	254	inactive
		Tumon Bay	10/18/17	CM	171240	66.6	SPLASH	12/7/17	50	inactive
		Tumon Bay	10/18/17	CM	171241	73.2	SPLASH	4/1/18	165	inactive
		Tumon Bay	10/18/17	CM	171242	58.2	SPLASH	2/24/18	129	inactive
		Tumon Bay	10/18/17	CM	171243	56.4	SPLASH	12/15/17	58	inactive
6b	GUAM	Sewer Island	10/19/17	CM	171244	47.1	SPLASH	NA	NA	tag failed
		Piti Bomb Holes	5/22/17	CM	166336	56	SPLASH	10/23/17	154	inactive
6c	GUAM	Apra Harbor	7/16/14	CM	131994	49.2	SPLASH	12/26/14	163	inactive
		Apra Harbor	7/16/14	CM	131991	58.3	SPLASH	3/4/15	231	inactive
		Apra Harbor	7/17/14	CM	138960	58.6	SPLASH	1/4/15	172	inactive
		Apra Harbor	7/18/14	CM	138965	59.3	SPLASH	2/23/15	220	inactive
6d	GUAM	Orote Point	5/12/16	CM	131996	60.8	SPLASH	8/24/16	104	inactive
		Orote Point	5/13/16	CM	142752	82.3	SPLASH	11/12/16	183	inactive
		Orote Point	5/13/16	CM	142748	63.8	SPLASH	4/2/17	325	inactive
7a	GUAM	Dadi Beach	7/16/14	CM	131998	64.3	SPLASH	12/18/14	155	inactive
		Dadi Beach	7/16/14	CM	131990	54.3	SPLASH	1/7/15	175	inactive
		Dadi Beach	7/17/14	CM	138961	66	SPLASH	9/13/14	58	inactive
		Dadi Beach	7/17/14	CM	131997	55.2	SPLASH	12/26/14	162	inactive
		Dadi Beach	11/17/15	CM	152577	65.6	SPLASH	4/30/16	165	inactive
		Dadi Beach	11/18/15	CM	152582	73.4	SPLASH	1/16/16	59	inactive
		Dadi Beach	11/18/15	CM	152570	76	SPLASH	3/17/16	121	inactive
7b	GUAM	Sella Bay	11/1/16	CM	166335	49.3	SPLASH	6/15/17	226	inactive
		Sella Bay	11/1/16	CM	166351	43.7	SPOT	3/18/17	137	inactive
		Sella Bay	11/1/16	CM	166353	40.8	SPOT	3/27/17	146	inactive
7c	GUAM	Orote Point	5/12/16	EI	142756	52.9	SPLASH	NA	NA	tag failed
		Orote Point	5/23/17	EI	166340	55.7	SPLASH	12/17/17	208	inactive
7d	GUAM	Fleming Point, Tinian to Achang Reef, Guam	8/20/13	EI	85493	61.7	SPLASH	2/28/16	922	inactive
Pending	GUAM	Talofofo	8/7/18	Cm	171233	44.7	SPLASH	11/29/18	114	inactive
		Talofofo	8/7/18	Cm	171234	55.9	SPLASH	10/26/18	80	inactive
		Talofofo	8/7/18	Cm	176760	69.8	SPLASH	12/18/18	133	active
		Talofofo	8/7/18	Cm	176761	53.2	SPLASH	12/18/18	133	active
Pending	GUAM	Pago Bay	8/8/18	Cm	176762	50	SPLASH	11/29/18	113	inactive
		Pago Bay	8/8/18	Cm	176763	44.8	SPLASH	11/8/18	92	inactive
		Pago Bay	8/8/18	Cm	176764	47.9	SPLASH	11/13/18	97	inactive
Pending	GUAM	Cocos Island, Achang	8/9/18	Cm	176765	64.7	SPLASH	12/18/18	131	active
		Cocos Island, Achang	8/9/18	Cm	176766	63.9	SPLASH	12/18/18	131	active
		Cocos Island, Achang	8/9/18	Cm	171260	36.9	SPOT	12/18/18	131	active
		Cocos Island, Achang	8/9/18	Cm	171261	41.4	SPOT	12/18/18	131	active

Satellite tag deployment, tag longevity, horizontal movements and home range

The KIWB estimates and volume contours in Figures 2–7 elucidate the general habitat use, home range (95% volume contour), and core area (50% volume contour) for the majority of turtles tagged in each location based on their horizontal movements. Of the 94 satellite devices deployed, three were not included in this analysis due to lack of sufficient data, either from immediate failure of the tag or less than two weeks of data collected from the deployment date. The 10 SPOT tags deployed on turtles are also not included here as we continue to develop the necessary data processing code, but will be incorporated into future reports. Maps include data generated through 1/1/18 and do not include results of tags deployed after this date, most of which are currently still active and will be included in future reports. Details on the number, species, and carapace lengths of turtles tagged at each site are provided in Tables 2–4, along with the longevity (i.e., transmission days), Argos IDs, and current status (e.g., active) of the tags.

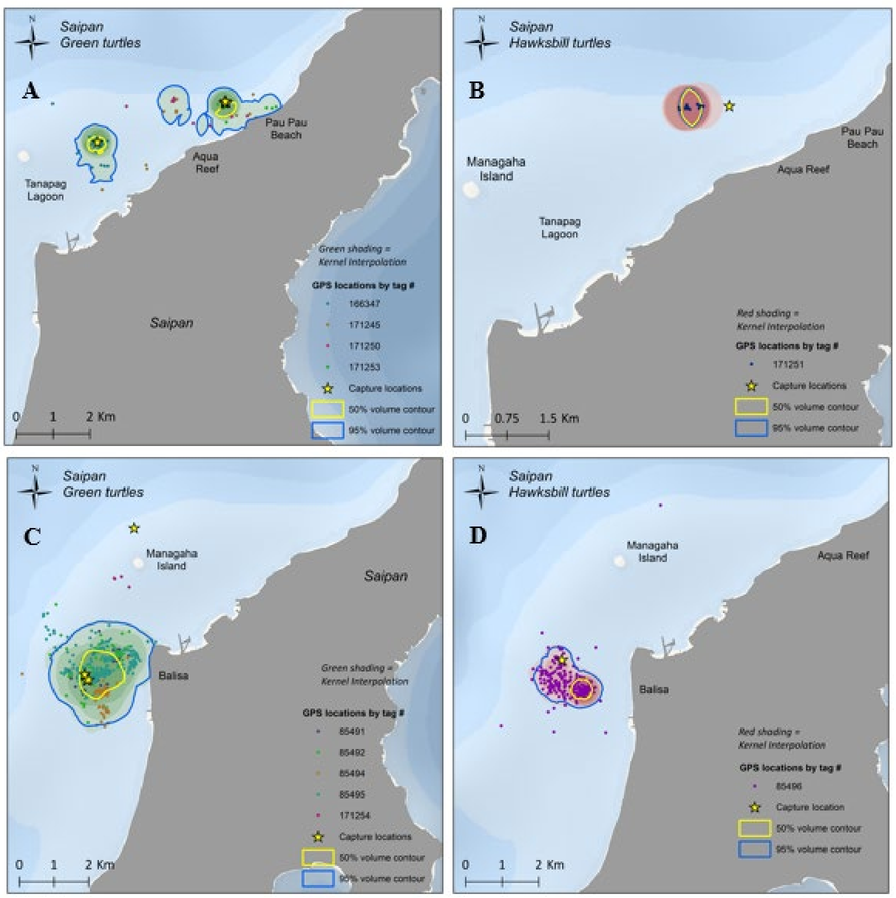

Figure 2. Habitat use maps for green and hawksbill turtles tagged in western Saipan (sites: Pau Beach, Aqua Reef, Tanapag Lagoon, Outer Mañagaha Island and Balisa). GPS location data were analyzed using a Kernel Interpolation with Barriers method. Darker shades of green (green turtles) or red (hawksbill turtles) indicate higher density of GPS location points, with the 50% (core area) and 95% (home range) volume contours outlined in yellow and blue, respectively. For each map, Table 2 provides additional details on individual tag deployments.

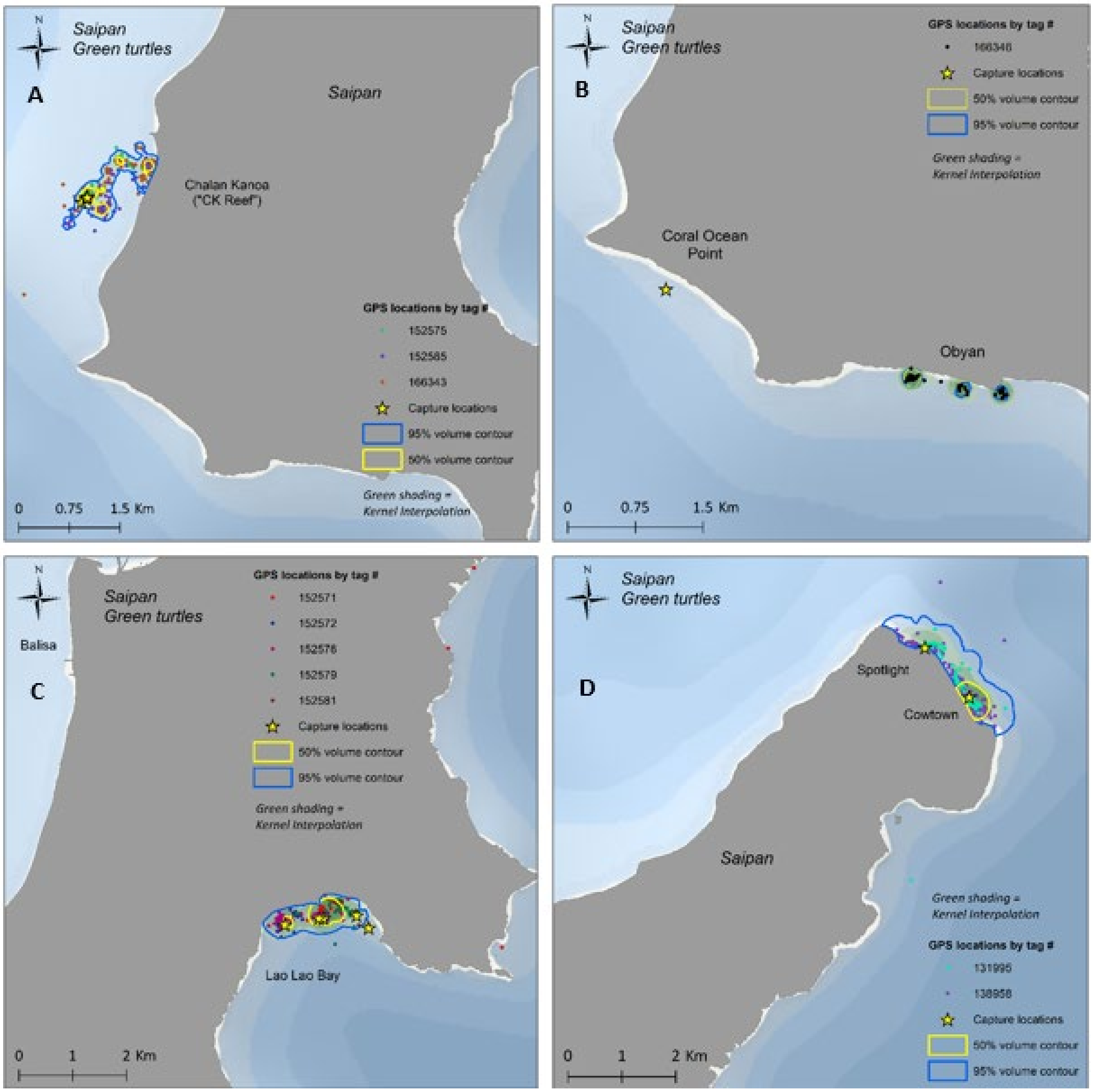

Figure 3. Habitat use maps for green and hawksbill turtles tagged in southern, eastern, and northern Saipan (sites: Chalan Kanoa Reef, Coral Ocean Point, Lao Bay, Cowtown, and Spotlight). GPS location data were analyzed using a Kernel Interpolation with Barriers method. Darker shades of green (green turtles) indicate higher density of GPS location points, with the 50% (core area) and 95% (home range) volume contours outlined in yellow and blue, respectively. For each map, Table 2 provides additional details on individual tag deployments.

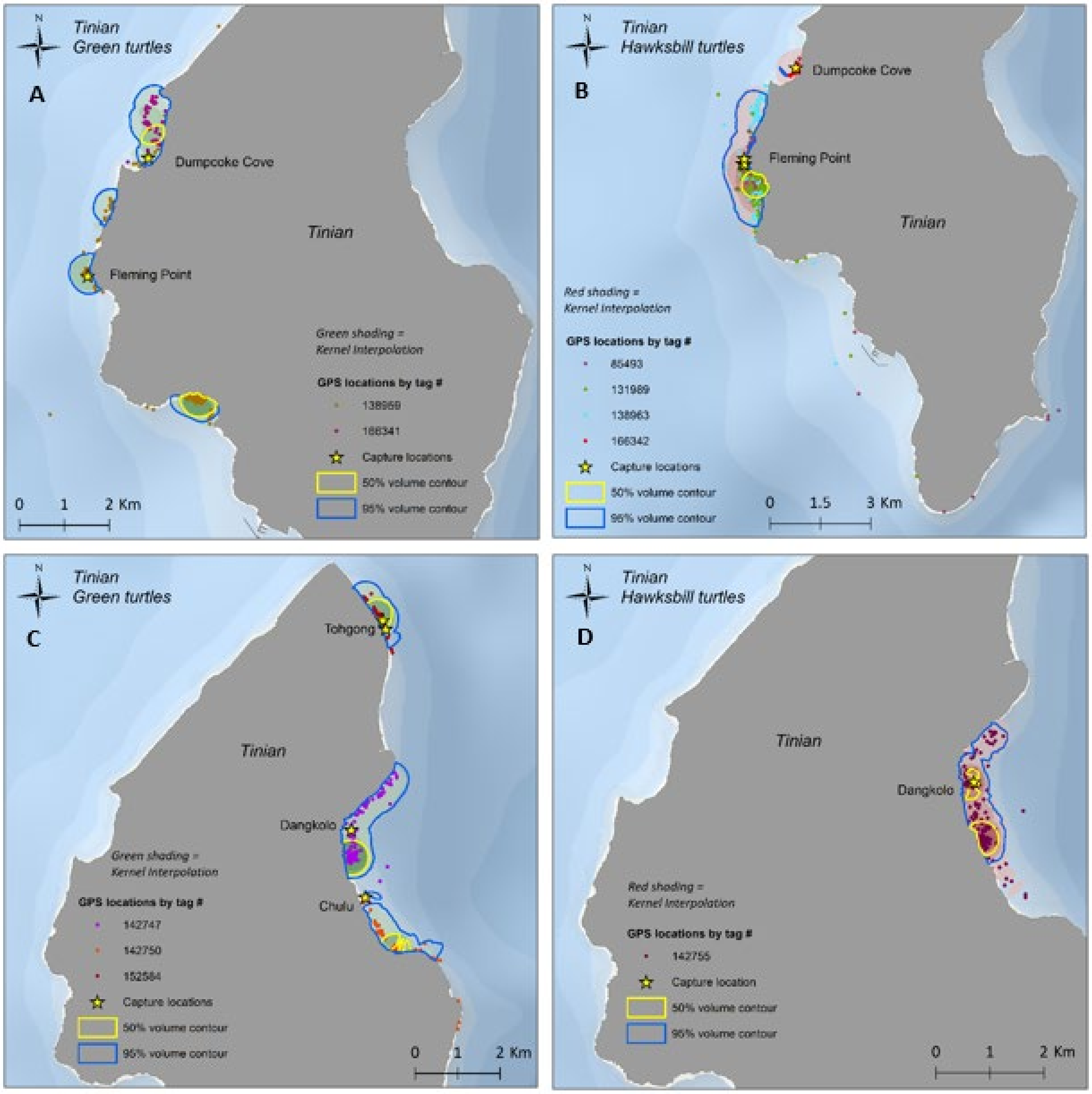

Figure 4. Habitat use maps for green and hawksbill turtles tagged in northwest and northeast Tinian (sites: Dumpcoke Cove, Fleming Point, Chulu, Dangkolo, and Tohgong). GPS location data were analyzed using a Kernel Interpolation with Barriers method. Darker shades of green (green turtles) or red (hawksbill turtles) indicate higher density of GPS location points, with the 50% (core area) and 95% (home range) volume contours outlined in yellow and blue, respectively. For each map, Table 3 provides additional details on individual tag deployments.

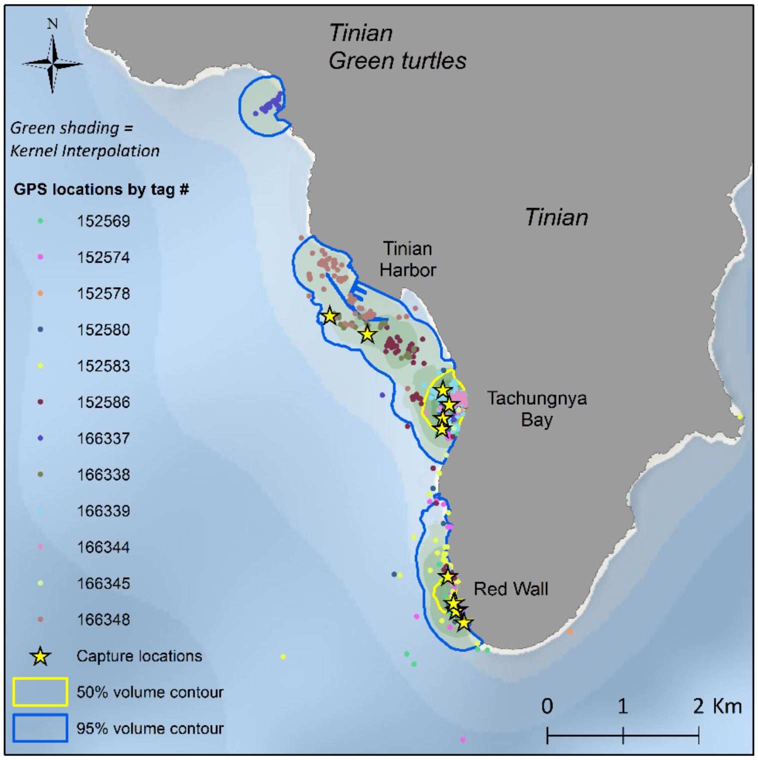

Figure 5. Habitat use map for green turtles tagged in southern Tinian (sites: Red Wall, Tachungnya Bay, Tinian Harbor). GPS location data were analyzed using a Kernel Interpolation with Barriers method. Darker shades of green indicate higher density of GPS location points, with the 50% (core area) and 95% (home range) volume contours outlined in yellow and blue, respectively. For each map, Table 2 provides additional details on individual tag deployments.

Tag longevity, calculated from 84 tags that were no longer transmitting a signal as of December 18th, 2018, was similar across islands. For green turtles, tags transmitted data for an average of 179 days on Saipan (SD = 151, n = 24 tags), 162 days on Tinian (SD = 77, n = 17 tags), and 163 days on Guam (SD = 81, n = 31 tags). For hawksbill turtles, tag life was 466 days on Saipan (sd = 698, n = 3 tags), 572 days on Tinian (SD = 321, n = 6 tags) and 565 days on Guam (SD = 505, n = 2 tags). For the three islands combined, tags lasted an average of 166 days (SD = 108, n = 73 tags) on green turtles and 542 days (SD = 420, n = 11) on hawksbill turtles. Maximum tag life was 721 days for green turtles (Argos ID 131995 tagged on the northern shore of Saipan at Spotlight; Table 2 and Figure 3D) and 1,270 days for hawksbill turtles (Argos ID 85496 tagged on the west coast of Saipan at Balisa; Table 2 and Figure 2D). Hawksbill turtle shells are thicker and more keratinized than green turtle shells, which tend to be thinner and oilier; this difference likely contributes to the longer tag retention times observed on hawksbill turtles. Eight tags were still active and transmitting data on December 18, 2018, seven of which deployed in 2018 and one of which was deployed in 2017 (Table 2 and Table 4). KIWB estimates revealed high site fidelity and limited movements for both green and hawksbill turtles in Guam, Tinian, and Saipan (Figures 2 to 7 and Table 2). Across all islands and sites, the core area (50% KIWB volume contour) was geographically concentrated for both green turtles (mean = 0.51 km^2, SD = 0.66 km^2, range = 0.03–2.58 km^2) and hawksbill turtles (mean = 0.26 km^2, SD = 0.13 km^2, range = 0.10–0.46 km^2). Home ranges (95% KIWB volume contour) were also similar for the two species, with green turtles using an average area of 3.20 km^2 (SD = 4.47 km^2, range = 0.07–18.17 km^2) and hawksbill turtles 3.29 km^2 (SD = 4.67 km^2, range = 0.20–12.57 km^2). For green turtles, there were some subtle inter-island differences in core area, with turtles in Guam (mean = 0.59 km^2, SD = 0.98 km^2, range = 0.08–2.58 km^2) and Tinian (mean = 0.57 km^2; SD = 0.19 km^2; range = 0.46–0.79 km^2) using slightly larger areas than in Saipan (mean = 0.39 km^2, SD = 0.48 km^2, range = 0.03–1.33 km^2). Home range of green turtles was also larger on Guam (mean = 4.20 km^2, SD = 6.88 km^2, range = 0.43–18.17 km^2) and Tinian (mean = 3.09 km^2, SD = 0.78 km^2, range = 2.24–3.76 km^2) than on Saipan (mean = 2.26 km^2, SD = 2.45 km^2, range = 0.07–6.59 km^2). The two hawksbill turtles tagged in Saipan had a similar core area (mean = 0.21 km^2, SD = 0.04, range = 0.18–0.24) to the two tagged on Tinian (mean = 0.37 km^2, SD = 0.13 km^2, range = 0.28–0.46 km^2) and the two residing in Guam (mean = 0.22 km^2, SD = 0.17 km^2, range = 0.10–0.34 km^2). The home range for the Saipan hawksbills (mean = 1.09 km^2, SD = 1.25 km^2, range = 0.20–1.97 km^2) was smaller than for those tagged on Tinian (mean = 2.20 km^2, SD = 1.36 km^2, range = 1.24–3.16 km^2) and those residing in Guam (mean = 6.58 km^2, SD = 8.48 km^2, range = 0.59–12.57 km^2). These geographic comparisons will be tested statistically in the final analysis of these data.

While the majority of tagged turtles remained within a 1–3 km^2 area for the entire life of the tag, there were a few long-range movements. One 61.7 cm hawksbill turtle tagged in 2013 on Tinian traveled 233 km south to the southern coast of Guam, where it remained for more than 2 years (Argos ID 85493; Figure 8A). This movement was somewhat unexpected, as hawksbill turtles of this size are not thought to be mature and thus are likely not making breeding migrations yet. Therefore, this turtle possibly moved to a different foraging site, reached maturity at a smaller size than expected and moved to breed, or moved for a different unknown reason. Another 72.3-cm hawksbill tagged in 2014 on Tinian migrated east 2,118 km in 74 days to Ant Atoll adjacent to Pohnpei, Federated States of Micronesia, where it remained in nearshore waters for 10 months (Argos ID 138963; Figure 8B). This individual was likely a mature adult making a long-distance breeding migration to a known breeding site; however, it is also possible that it was concluding a breeding season near Tinian and returning to Ant Atoll to forage.

One adult male green turtle (82.3 cm SCL) tagged off Orote Point in Guam in May 2016 moved 39 km north to Pati Point before making a 70 km roundtrip jaunt offshore and then traveling south again to Apra Harbor and Orote Point (Argos ID 142752; Figure 6D). Given there are known nesting sites near both Pati Point (e.g., along Andersen Air Force Base beaches) and Orote Point (e.g., Spanish Steps in Apra Harbor), this adult male could have been visiting multiple breeding grounds or possibly moving between a combination of foraging and breeding sites. These movements indicate some diversity in nearshore habitat use and movements around the Mariana Islands and beyond. This suggests that movement patterns, residency times, and thus exposure to nearshore threats, likely vary throughout an individual's life, with smaller juvenile turtles potentially spending most of their time in a localized reef area and larger mature turtles having intermittent periods of residency as they move between foraging and breeding grounds.

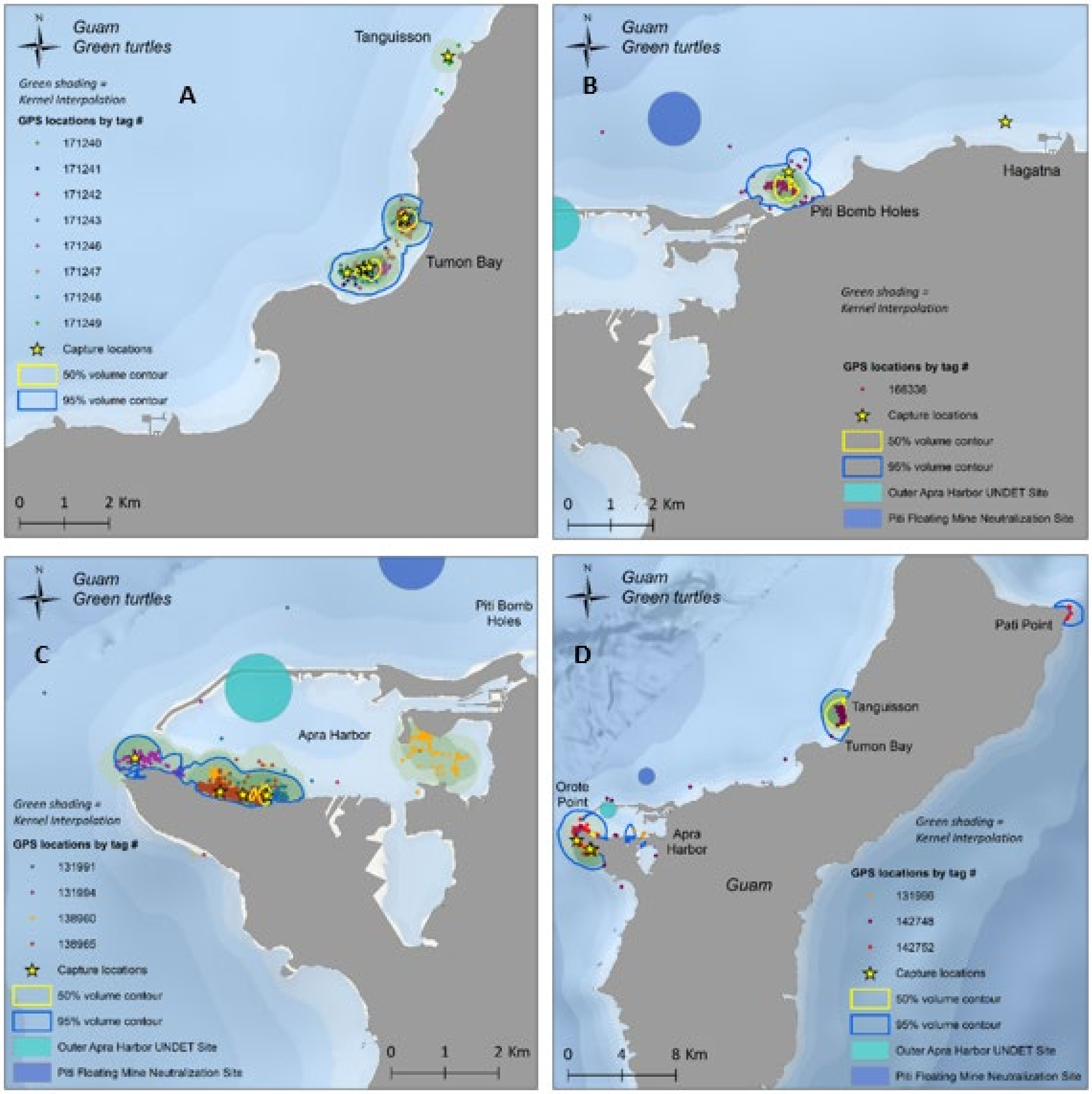

Figure 6. Habitat use map for green turtles tagged in western Guam (sites: Tanguisson, Tumon Bay, Piti Bomb Holes, Apra Harbor, and Orote Point). GPS location data were analyzed using a Kernel Interpolation with Barriers method. Darker shades of green indicate higher density of GPS location points, with the 50% (core area) and 95% (home range) volume contours outlined in yellow and blue, respectively (see Figure 8A). An adult male (Argos ID: 142752, red points in D) was tagged at Orote Point, then moved to Pati Point, then back to Orote Point (additional details provided at the end of this section). For each map, Table 4 provides additional details on individual tag deployments.

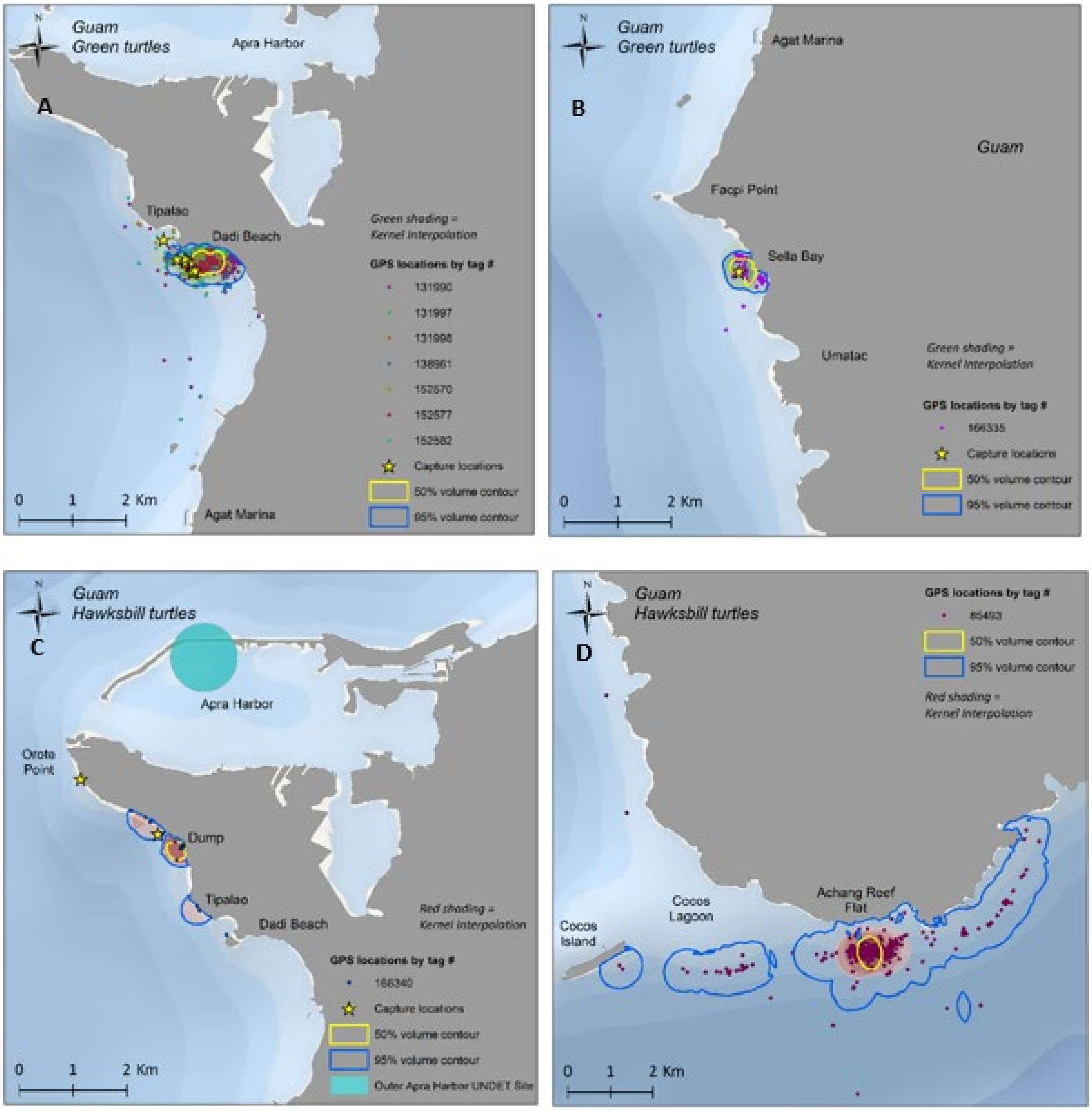

Figure 7. Habitat use map for green and hawksbill turtles tagged in western Guam and northwestern Tinian (sites: Dadi Beach, Sella Bay, Orote Point in Guam and Fleming Point in Tinian). Tags were deployed in Guam in A-C, but the hawksbill turtle in D was tagged at Fleming Point in Tinian and migrated to Guam (see Figure 8A). GPS location data were analyzed using a Kernel Interpolation with Barriers method. Darker shades of green (green turtles) or red (hawksbill turtles) indicate higher density of GPS location points, with the 50% (core area) and 95% (home range) volume contours outlined in yellow and blue, respectively. For each map, Table 4 provides additional details on individual tag deployments.

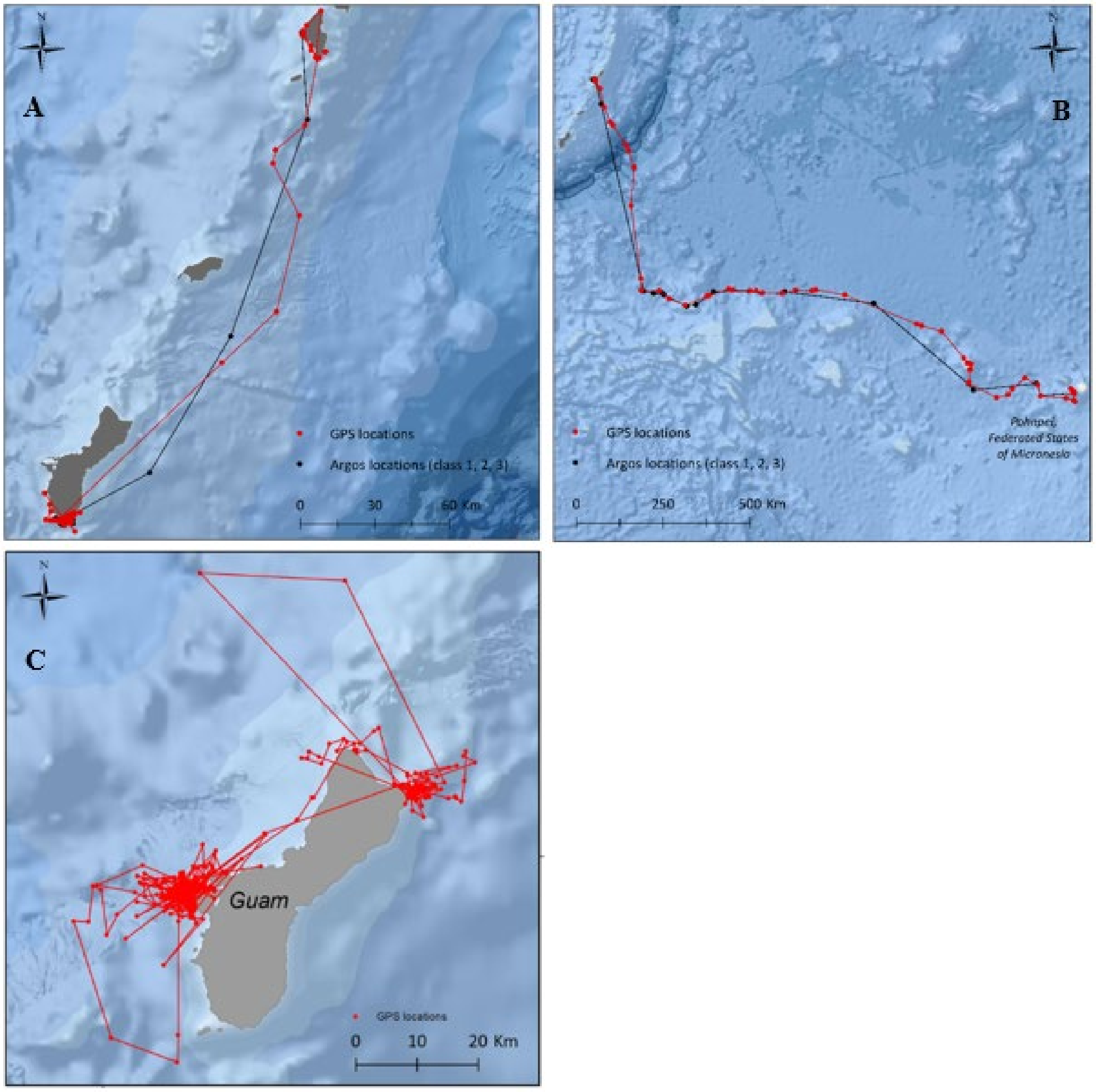

Figure 8. Turtle migrations. (A) A 61.7 cm hawksbill turtle (Argos ID: 85493) was tagged 20 August 2013 at Fleming Point, Tinian. It departed Tinian on 11 October 2013 and arrived 5 days later in Cocos Lagoon, southern Guam on 16 October 2013 after traveling a distance of 233 km. This turtle remained in nearshore waters along the south and southwest coasts of Guam for over 2 years until 27 February 2016, when the last signal was transmitted. Total tag transmission time was 922 days or 2.5 years. (B) A 72.3 cm hawksbill turtle (Argos ID: 138963) was tagged 21 July 2014 at Fleming Point, Tinian. It departed Tinian on 18 April 2015 and arrived 74 days later to Ant Atoll adjacent to Pohnpei, Federated States of Micronesia on 1 July 2015 after traveling a distance of 2,118 km. It remained in the nearshore waters of Ant Atoll for 10 months until its last signal transmission on 27 April 2016. Total tag transmission time was 646 days or 1.8 years. (C) An 82.3 cm adult male green turtle tagged in May 2016 at Orote Point (Argos ID: 142752). It left Orote Point on 13 September 2016 and arrived 5 days later at Pati Point, traveling >39 km. It then moved offshore from Pati Point (northeast) between 20 and 28 September, with a roundtrip distance of > 70 km. On 23 October, it moved south, arriving in Apra Harbor on 27 October after a > 39 km trip. It then moved back to its original tagging location at Orote Point between 29 and 31 October (> 2.6 km distance).

Dive behavior and vertical movement

Dive patterns suggest that both green and hawksbill turtles spend most of their time in waters shallower than 25 m (Figures 9 and 10), and despite a relatively small sample size (n = 7) for hawksbill turtles, it is possible that habitat partitioning may exist between the two species in this region. Binned depth data from the tags suggest both species made dives down to 100 m; however, hawksbill turtles spent more time in deeper waters than green turtles, with an average depth of 15.2 m compared to 10.9 m, respectively (Figure 9), and spending 59.5% of their time in waters < 10 m in depth, compared to 64.2% for greens. Additionally, the maximum dive depth of hawksbills was substantially deeper than those of green turtles, with averages of 20.9 m compared to 13.5 m, respectively (Figure 10).

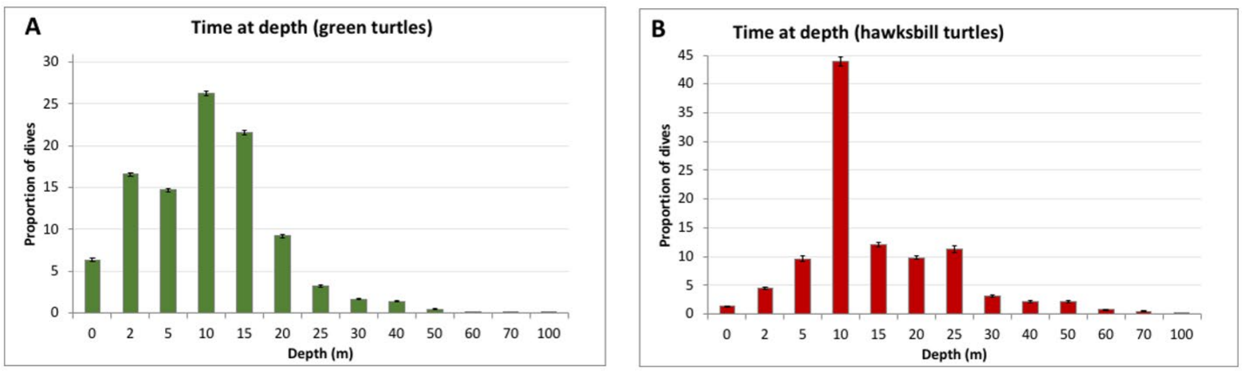

Figure 9. Proportion of time-at-depth profiles for 68 green turtles (A) and 7 hawksbill turtles (B) in the MITT study area in 2014–2018. Green turtles resided between the surface and 25 m depth 97.6% of the time, with an average depth of 10.9 m. Hawksbill turtles spent more time at deeper depths, with 92.7% of the time spent between the surface and 25 m and an average depth of 15.2 m. Histogram bars are time-at-depth averages; error bars represent standard error of the mean.

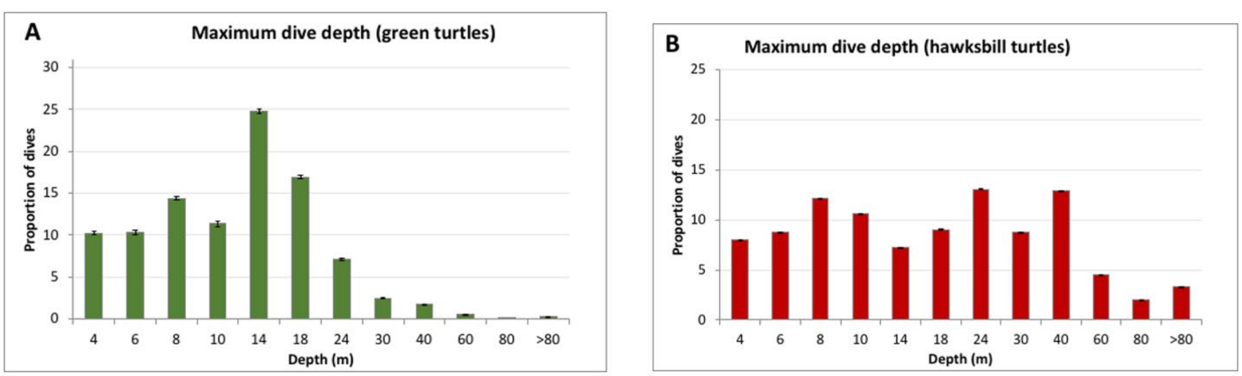

Figure 10. Maximum dive depth profiles for 72 green turtles (A) and 9 hawksbill turtles (B) in the MITT study area in 2014-2018. Green turtles dove to maximum depths of 24 m or less on 95.0% of their dives, with an average maximum depth of 13.5 m. Hawksbill turtles performed deeper dives more frequently, with only 68.6% of their dives occurring in the 0 –24 m depth range, and an average of 23.7 m maximum dive depth. Histogram bars are max dive depth averages; error bars represent standard error of the mean.

Green and hawksbill turtles primarily use waters with temperatures of 28–31 °C, but hawksbill turtles spent more time in slightly warmer waters, with 40.1% of their time in waters of 30 °C and an average water temperature of 29.8 °C, compared to green turtles that spent 40.7% of their time in waters of 29 °C by (Figure 11) and an average water temperature of 29.7 °C. In general hawksbill turtles prefer warmer waters than their green turtle counterparts and it is likely that hawksbills are actively seeking out slightly warmer waters during the day (Gaos et al. 2012).

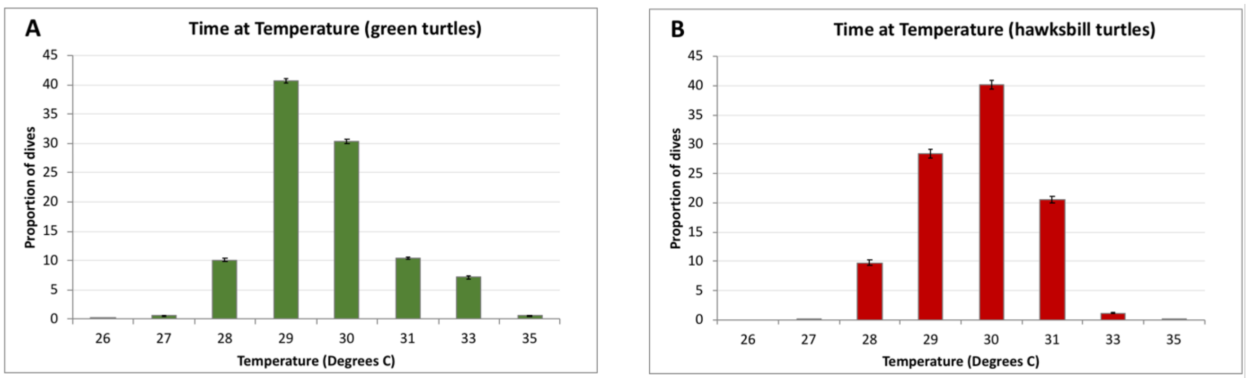

Figure 11. Proportion of time-at-temperature profiles for 68 green turtles (A) and 7 hawksbill turtles (B) in the MITT study area in 2014–2017. Green turtles spent 40.7% of their time in temperatures of 29 °C, with an average temperature of 29.7 °C. Hawksbill turtles spent more time in slightly warmer waters, with 40.1% of their time in temperatures of 30 °C, but had a similar average temperature of 29.8 °C. Histogram bars are time-at-temperature averages; error bars represent standard error of the mean.

Hawksbills tended to have longer dive durations than green turtles, with average dive durations of 46 minutes compared to 31 minutes, respectively (Figures 12A and 12B). Time-at-depth, time-at-temperature, maximum dive depth, and dive duration histograms in Figures 9–12 provide a detailed breakdown of these habitat and behavioral variables for each species and suggest that hawksbill turtles spend more time at depth and in warmer waters.

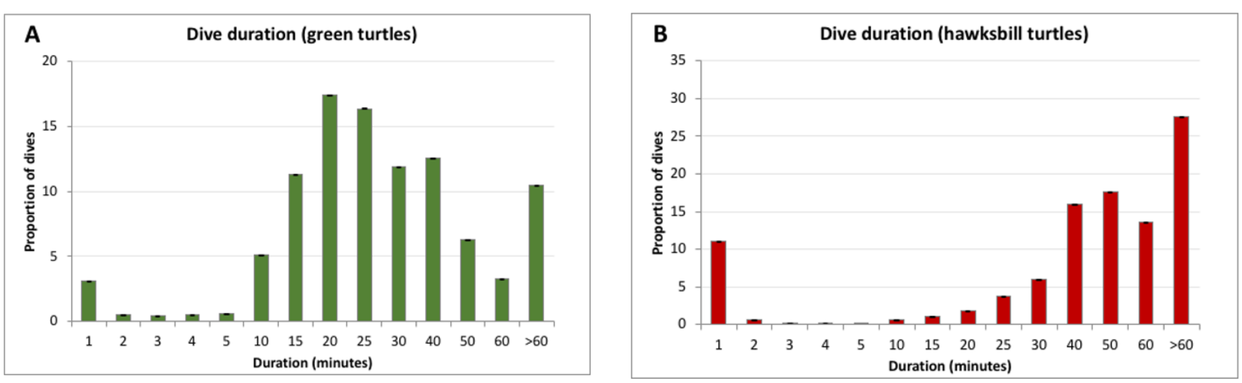

Figure 12. Dive duration profiles for 62 green turtles (A) and 9 hawksbill turtles (B) in the MITT study area in 2014–2017. Green turtles dove for 60 minutes or less on 89.6% of their dives, with an average dive duration of 31 minutes. Hawksbill turtles performed longer dives more frequently, with only 72.5% of their dives lasting 60 minutes or less, and an average dive duration of 46 minutes. Histogram bars are dive duration averages; error bars represent standard error of the mean.

In 2018 we adjusted our dive duration bins (see Methods), and we were able to obtain increased resolution on the dive duration of 11 green turtles equipped with SPLASH tags (no hawksbills turtles were captured in 2018). Results of the new bin settings indicated that although green turtle dive durations typically last < 60 minutes, they have the ability to remain submerged > 2.5 hours (Figure 13A). Diel comparisons demonstrated that green turtle dives are shorter during the day than at night, with an average duration of 34.8 minutes and 39.4 minutes, respectively, and the majority of dives lasting > 2.5 hours occurring at night (Figure 12B). For the dive durations lasting > 2.5 hours, 27.8% occurred during the day, while 72.2% occurred during the night. It is likely that the prolonged dive durations are indicative of green turtles resting during nocturnal time periods, during which they surface for air less frequently.

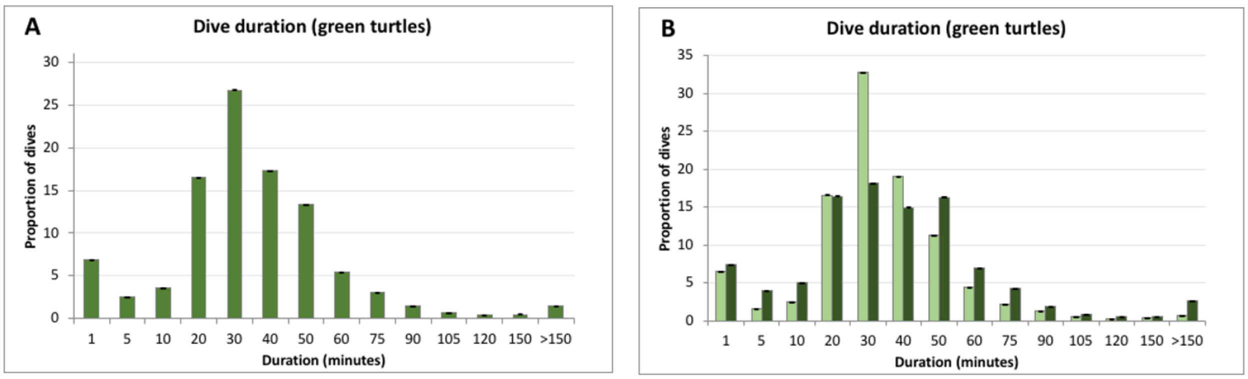

Figure 13. Overall dive duration profiles for 11 green turtles (A) and comparing between diurnal (lighter) and nocturnal (darker) time frames (B) in the MITT study area in 2018. Dive duration was > 50 minutes 26.5% of the time, with 43.3% of those dives occurring Overall dive duration profiles for 11 green turtles (A) and comparing between diurnal (lighter) and nocturnal (darker) time frames (B) in the MITT study area in 2018. Dive duration was > 50 minutes 26.5% of the time, with 43.3% of those dives occurring at day, compared to 56.7% at night.

Diel comparisons also indicated that green and hawksbill turtles use shallower water depths during diurnal timeframes (6 am–6 pm) compared to nocturnal timeframes (6 pm–6 am) (Figures 14A–14D). Green turtles spent 70.9% of their time in waters ≤ 10 m in depth during the day, compared 57.2% during the night, while hawksbills spent 70.0% compared to 49.2%. Similarly, 77.4% of the maximum dive depths for green turtles were to depths of ≤ 14 m during the day compared 66.3% during the night, while 67.2% of hawksbill dives were to depths of ≤ 14 m during the day compared 43.3% during the night. These findings suggest that green turtles and hawksbills are actively foraging in shallower waters during the day, then retreat to deeper waters to rest during the night, with hawksbill using deeper waters under both diel time periods. Both species spent time in slightly cooler waters during the day compared to night, although the average temperature between these to timeframes were very similar, with 29.6 °C vs. 29.9 °C for green turtles, and 29.7 °C and 29.8 °C for hawksbill turtles, respectively (Figures 14E and 14F).

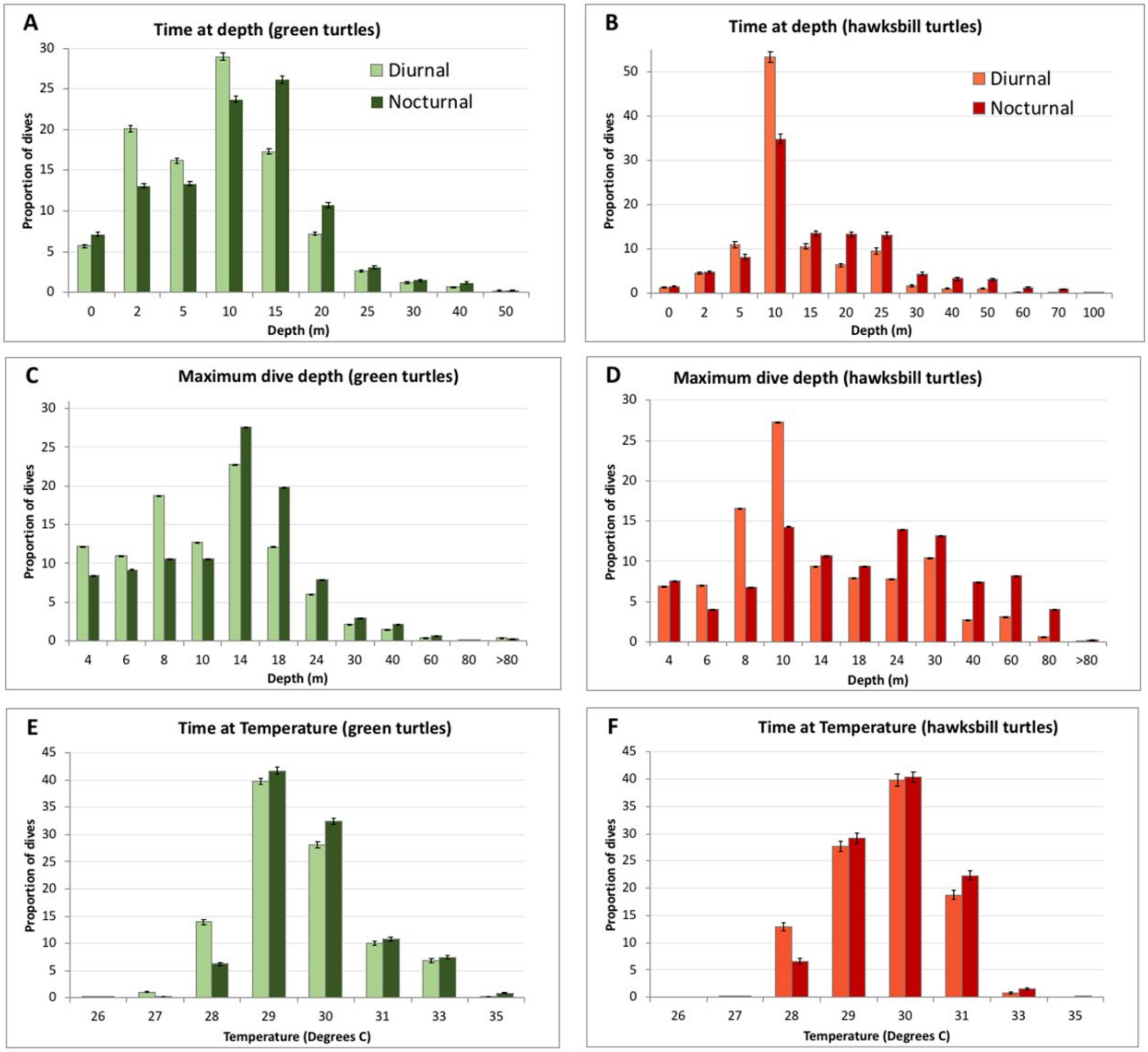

Figure 14. Diurnal (6 am – 6 pm) vs. nocturnal (6 pm – 6 am) time at depth profiles for 68 green turtles and 7 hawksbills, including time at depth (A & B), maximum dive depth (C & D) and time at temperature (E & F) in the MITT study area in 2014-2018. The average depth during the day vs. night for green turtles was 9.5 m compared 11.2 m, respectively, and for hawksbill turtles was 12.8 m vs. 17.5 m. The average maximum dive depth during the day vs. night for green turtles was 12.5 m versus 14.5 m, respectively, and for hawksbills was 16.0 vs. 24.5 m, respectively.

Progress towards Summary of Tasks

1) Capture and tag sea turtles in the MITT study area, and deploy biotelemetry devices.

From 2013 through 2018, there were 139 turtles captured (with identification tags applied) and 94 satellite tags deployed in the MITT study area.

2) Process and analyze biotelemetry data and other survey data.

Kernel interpolation estimates include all tags to date (2013–2018, tags with sufficient data) and all areas of capture. Analysis revealed high site fidelity and limited movements of turtles, although some long-distance movements were recorded. Tagging results suggest that movement patterns, residency times, and thus exposure to nearshore threats, likely vary throughout an individual's life. Smaller juvenile turtles potentially spend most of their time in a localized reef area, and larger mature turtles have intermittent periods of residency as they move between foraging and breeding grounds. These habitat use patterns are consistent with previous telemetry studies on reef-dwelling green and hawksbill turtles in other locations, yet possibly reveal habitat niches that are specific to the region.

Eight tags are possibly still active, and complete analysis is forthcoming. Dr. Summer Martin and PIFSC MTBAP staff will continue conducting in-depth analysis of satellite tagging data including spatial analysis, dive depth and duration of turtles, and influence of temperature on habitat use. See Figures 2–7 and Table 2 for kernel interpolation estimates, Figure 8 for turtle migratory movements, and Figures 9–14 for dive depth and temperature histograms, as well as maximum dive depth and dive duration profiles.

3) Prepare annual reports.

Completed annually.

Progress towards Guiding Questions from the FY13–15 Monitoring Plan

Are there locations of greater cetacean and/or sea turtle concentration around Guam, Saipan, and Tinian?

Efforts are ongoing to answer this question.

We have expanded our survey efforts to new areas of the Mariana Archipelago with each field season and have encountered turtles in most locations we have surveyed around Guam, Saipan, and Tinian. The following areas appear to have high turtle density based on the boat-based snorkel survey observations and captures, as well as analysis of aerial survey data from Guam: (1) in Guam, the waters inside Apra Harbor near San Luis, Gab Gab, out to Spanish Steps including Dadi and Tipalao beaches outside of the harbor, as well as Tumon Bay. Our most recent in-water surveys (August) also confirmed high turtle densities in around Cocos Island, Cocos Lagoon and Achang Bay (Martin et al. 2016), as well as between Pago Bay and Talofofo Bay; (2) in Saipan, the area stretching from the Balisa Channel to Managaha Island, as well as Lao Lao Bay and Puntan Gloria along the east side of the island; and (3) virtually the entire west coast of Tinian. These areas are primarily dominated by patch reef communities where the turtles both forage and rest. While these areas stand out as having relatively high turtle density, this is only in relation to the areas surveyed thus far (or studied through historical aerial data); we may discover additional high-density areas as we continue expanding our in-water survey coverage around each island.

What is the occurrence and/or habitat use of sea turtles in areas that the Navy conducts underwater detonations?

Seventeen turtles have been outfitted with satellite tags inside and just outside of Apra Harbor (including capture sites at Orote Point, Dadi Beach, and Piti Bomb Holes), and all but one of the tags have completed their data transmission period. From the spatial analysis of the GPS locations and movements from these satellite tags shown in Figures 6 and 7, we have not seen direct overlap of the turtles or their core use or home range areas with the Agat Bay Mine Neutralization Site, Piti Point Mine Neutralization Site, and Outer Apra Harbor Underwater Detonation Site. However, turtles are spending significant amounts of time in and moving through areas within 1-2 km of these sites, and the lack of overlapping GPS points could be due to the relatively low frequency of GPS locations obtained from these tags (often a maximum of one per day). Analysis and filtering of Argos location classes (see supplemental materials) may provide more data on daily locations.

Activities Planned for 2019

We have multiple in-water surveys planned for Guam, Saipan, and Tinian for June through November (weather dependent) of 2019 to survey new areas and deploy additional satellite tags. We will continue our analyses of the satellite data to understand home range, habitat preferences, preferred depths and temperature, as well as movement within the archipelago. These analyses will provide the basis of a manuscript intended for journal submission in 2020. The research to date has largely focused on in-water surveys and expansion to regions/areas throughout the archipelago. Moving into FY21 and beyond, our efforts will build from presence/absence to population status and trends and eventually abundance estimates. To get to trends and abundance, the PIFSC MTBAP will use data derived from the Navy/NOAA Interagency Agreement as well as Guam DAWR, PIFSC Habitat and Living Marine Resources Program, and PIFSC Cetacean Research Program turtle sighting data to gain a more robust understanding of the population distribution and abundance. The MTBAP is also incorporating genetic and hormone assays to get at regional management units and to understand environmental impacts such as climate change. In the coming 2 years our research portfolio will include manuscripts (publications and submissions) describing the in-water and nesting populations, modeling for habitat use, and population abundance.

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References

Argos. 2008. Location and data collection satellite system user's guide. Argos, Toulouse.

Eckert KL, Bjorndal KA, Abreu-Grobois FA, Donnelly M (Editors). 1999. Research and Management Techniques for the Conservation of Sea Turtles. IUCN/SSC Marine Turtle Specialist Group Publication No. 4.

ESRI. 2012. ArcGIS. Environmental Systems Research Institute, Inc., Redlands (CA).

Dutton PH. 1996. Methods for collection and preservation of samples for marine turtle genetic studies. Pp. 17–24 in Bown BW, Witzell WN, editors. Proceedings of the international symposium on marine turtle conservation genetics. NOAA Tech Memo NMFS-SEFSC-396, National Technical Information Service, Springfield (VA).

Gaos AR, Lewison RL, Wallace B, Yañez IL, Liles Baquero A, Seminoff JA. 2012. Dive behaviour of adult hawksbills (*Eretmochelys imbricata*, Linnaeus 1766) in the eastern Pacific Ocean highlights shallow depth-use by the species. Journal of Experimental Marine Biology and Ecology. 432-433:171-178.

Hill MC, Oleson EM, Baumann-Pickering S, Van Cise AM, Ligon AD, Bendlin AR, U AC, Trickey JS, Bradford AL. 2016. Cetacean Monitoring in the Mariana Islands Range Complex, 2015. Prepared for the U.S. Pacific Fleet Environmental Readiness Office. PIFSC Data Report DR-16-01. 36 pp.

Jones TT, Bostrom BL, Carey M, Imlach B, Mikkelsen J, Ostafichuk P, Eckert S, Opay P, Swimmer Y, Seminoff JA, Jones DR. 2011. Determining transmitter drag and best practice attachment procedures for sea turtle biotelemetry studies. NOAA Technical Memorandum NMFS-SWFSC-480.

Jones TT, Martin S, Gaos A. 2018. Platform Transmitter Terminal (PTT) application and deployment protocol for hard-shelled marine turtles around the Pacific Islands Region. NOAA Internal Report. 11.

Jones TT, Van Houtan KS, Bostrom BL, Ostafichuk P, Mikkelsen J, Tezcan E, Carey M, Imlach B, Seminoff J. 2013. Calculating the ecological impacts of animal-borne instruments on aquatic animals. Methods in Ecology and Evolution. 4(12):1178-1186.

Martin SL, Van Houtan KS, Jones TT, Aguon CF, Gutierrez JT, Tibbatts RB, Wusstig SB, Bass JD. 2016. Five decades of marine megafauna surveys from Micronesia. Frontiers in Marine Science, 2(116): 1-13. doi:10.3389/fmars.2015.00116

NMFS and USFWS. 2015. Green turtle *(Chelonia mydas*) Status Review under the U.S. Endangered Species Act. Report of the Green Turtle Status Review Team. May 2014. 567 pp.

Sprogis KR, Raudino HC, Rankin R, MacLeod C, Bejder L. 2016. Home range size of adult Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in a coastal and estuarine system is habitat and sex- specific. Marine Mammal Science. 32(1): 287-308.

Summers TM, Jones TT, Martin SL, Hapdei JR, Ruak JK, Lepczyk CA. 2017. Demography of marine turtles in the near-shore environments of the Northern Mariana Islands. Pacific Science, 71(3): 269-286.