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**SEA TURTLE TAGGING IN THE NAVAL BASE GUAM AREA**  
**25 JANUARY 2017<sup>1</sup>**



**PREPARED FOR THE U.S. NAVAL BASE GUAM**  
**Under Interagency Agreement NMFS-PIC-14-004-0001-000**  
**Conducted under NOAA ESA 10a1A 17022 / 15661**

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<sup>1</sup>PIFSC Data Report DR-17-026  
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## **BACKGROUND:**

Naval Base Guam is responsible for the management and conservation of threatened and endangered species on Department of Navy (DoN) lands on Guam, including the DoN submerged lands around the island. Green turtles (*Chelonia mydas*) and hawksbill turtles (*Eretmochelys imbricata*) are known to use habitat in the near shore waters on DoN submerged lands, and both species have past nesting activity on beaches on Naval Base Guam. Currently there is very limited information on the distribution, abundance, and habitat use of federally protected species on DoN lands on Guam. The lack of this information limits management actions to protect sea turtles and assess potential impacts from proposed actions in DoN submerged lands. This project will provide information to address these concerns, meet requirements specifically identified in the Integrated Natural Resources Management Plan (Sikes Act), and maintain compliance with federal requirements (e.g., Endangered Species Act, National Environmental Protection Act). The overall objective of this project is to collect field data that will enable the DoN and National Marine Fisheries Service (NMFS) to better understand the distribution and habitat use of sea turtles on DoN submerged lands, including Apra Harbor. The questions below from the Navy's FY13-15 monitoring plan guide this research.

## **GUIDING QUESTIONS FROM THE FY13-15 MONITORING PLAN:**

- i. Are there locations of greater sea turtle concentration within Apra Harbor and other DoN submerged lands around Guam?
- ii. What is the occurrence and/or habitat use of sea turtles in areas within Apra Harbor and other DoN submerged lands around Guam?

## **SUMMARY OF TASKS:**

1. Capture and tag sea turtles on Naval Base Guam
2. Analyze capture and tracking data
3. Prepare interim and final report

## **PROGRESS ON FIELD RESEARCH:**

Drs. T. Todd Jones and Summer Martin of the Marine Turtle Biology and Assessment Program (PIFSC, NOAA Fisheries), together with local partners, conducted marine turtle surveys and in-water captures of green turtles (*Chelonia mydas*) and hawksbill turtles (*Eretmochelys imbricata*) in May 2015 and May 2016. Captured turtles were weighed, measured, biopsied, and tagged (i.e., flipper, PIT, satellite tracking) in an effort to expand our knowledge of the population demographics, population structure, and fine-scale habitat use of the turtles. The aforementioned activities were permitted under National Marine Fisheries Service ESA10a1A Take permit #17022 and NMFS IACUC SWPI2013-05R. Additionally, biologists from the Guam Department of Agriculture Division of Aquatic and Wildlife Resources (DAWR) were provided with hands-on training. Local partners continue to be engaged in this collaborative research effort. Many of these activities are part of the larger collaborative effort with NOAA Fisheries, Guam DAWR, Commonwealth of the Northern Mariana Islands Department of Lands and Natural Resources (CNMI DLNR), and the U.S. Pacific Fleet Environmental Readiness Office. The project continues to be successful due to the collaborative effort of these entities, as well as the Guam DAWR Office of Law Enforcement and the Apra Harbor Patrol.

In May 2015, in-water surveys and turtle captures were conducted in Apra Harbor and the nearshore waters extending south to Dadi Beach. Survey sites included Gab Gab Beach, Kilo Wharf, Western Shoals, Dadi Beach, and neighboring reef areas. The team deployed each day from the dock on the north side of Apra Harbor on the eastern end of Glass Breakwater. The research vessel was provided by collaborators at Guam DAWR, and DAWR biologists participated in all research efforts. Partners from the Commonwealth of the Northern Mariana Islands (CNMI) Department of Lands and Natural Resources (DLNR) were also key contributors to this collaborative research project. Additionally, Kevin Brindock (Naval Base Guam partner) joined the field research activities each day. Each day, three to six turtles were captured and two to five satellite tags were deployed. Observations of additional turtles were also recorded with locations whenever possible. The team observed a total of 90 turtles, 23 of which were captured, and 16 of which were outfitted with satellite transmitters. One hawksbill turtle was captured and equipped with a satellite tag; all other observations and captures were of green turtles (or “unknown” species for 12 observations). Full morphometric measurements were made of all captured turtles. Turtles received Inconel metal flipper tags on the trailing edge of the fore flippers and microchips (PIT tags) inter-digitally in the rear flippers. These observations are summarized in Table 1, with further details provided in Tables 2 and 3.

In May 2016, in-water activities were conducted in Apra Harbor at Gab Gab Beach, San Luis Beach, Jade Shoals, and inner Glass Breakwater. The team deployed from the dock on the north side of Apra Harbor again, where a shore base was set up for satellite tagging operations and to allow for local partners and Navy media staff to participate and observe. The team observed 25 turtles, 5 of which were captured, and 4 of which were equipped with satellite tags. One of the satellite tags was deployed on a hawksbill turtle (59 cm straight carapace length, SCL) near inner Glass Breakwater; the others were attached to sub-adult green turtles (55 cm mean SCL). The capture that did not receive a transmitter was a 68 cm SCL hawksbill turtle at Gab Gab Beach that still had an active transmitter from May 2015, when it was tagged in the same location. Again, full morphometric measurements were made of all captured turtles and they received Inconel metal flipper tags on the trailing edge of the fore flippers and microchips (PIT tags) inter-digitally in the rear flippers. These observations are summarized in Table 1, with further details provided in Tables 2 and 3.

#### **PROGRESS ON DATA ANALYSIS:**

Data analysis and collection is ongoing from the 2015 season. The PIFSC project staff are currently processing satellite tracking data as they arrive from Collecte Localisation Satellites America (CLSA) which collects and stores the Argos satellite information. These data will be organized and analyzed to understand spatial distribution and depth and temperature profiles for tagged turtles.

The findings presented here provide essential biogeographical context for understanding the spatial distribution and abundance of sea turtles in the Naval Base Guam study area. Furthermore, these data and analyses have helped to inform Critical Habitat for the proposed endangered status for the Central West Pacific distinct population segment from the 5-year review on the global green turtle status by NOAA and USFWS (NMFS and USFWS 2015). They have also informed incidental take statements and impact assessments for NOAA Fisheries ESA Section 7 and Biological Opinion needs.

PIFSC researchers are working on a major manuscript targeting a marine turtle special edition in *Frontiers of Marine Science* this February 2017. The manuscript, “Reef-dwelling turtles of the Mariana Archipelago: nearshore habitat use revealed by multiple in-water survey methods and GPS telemetry” combines the boat-based and snorkel surveys (this study and studies supported by the U.S. Pacific Fleet), satellite telemetry efforts (this study), 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 over 1,688 observations. The synthesis of results from three in-water survey methods with data from the first in-water satellite transmitter deployments in this archipelago will advance our understanding of the distribution, horizontal movements, and habitat use patterns of green and hawksbill turtles throughout the Mariana Archipelago.



**Top Left:** Vessel used for in-water surveys and captures, provided by collaborators at Guam Department of Agriculture Division of Aquatic and Wildlife Resources (DAWR). **Top Right:** Shore base for satellite tagging operations at Family Beach along inner Glass Breakwater in Apra Harbor, May 2015. Collaborators include (from the left) Jay Gutierrez (DAWR), Dr. T. Todd Jones (PIFSC), Kevin Brindock (Navy), Shawn Wusstig (DAWR), and Jessy Hapdei (CNMI DLNR). **Bottom Left:** Dr. T. Todd Jones and Kevin Brindock release a satellite tagged green turtle back to the water in Apra Harbor. **Bottom Right:** Shore base operations for satellite tagging at the dock on the north side of Apra Harbor in May 2016.

#### **PROGRESS ON DATA AVAILABILITY:**

The supplementary materials list all data available to date. The listed files include (1) all boat survey tracks from the 2015-2016 field seasons in the Naval Base Guam study area, (2) all metadata on turtle observations, captures, and satellite tag deployments in 2015-2016 (date, location, species, numbers of all tags applied, turtle length measurement, etc.), (3) time-at-depth histogram data from satellite tags deployed in 2015-2016 (raw data are provided as the proportion of time spent at binned depths for

designated periods of time), (4) time-at-temperature histogram data from satellite tags deployed in 2015-2016 (raw data are provided as the proportion of time spent at binned temperatures for designated periods of time), (5) raw x,y Argos location data from Wildlife Computers SPLASH Satellite tags deployed in 2015-2016 (with table for interpretation of Argos derived locations), and (6) raw x,y GPS location data from Wildlife Computers SPLASH Satellite tags deployed in 2015-2016 (with table for interpretation of GPS locations).

## **METHODS:**

### *In-water surveys and capture*

The small boat surveys were conducted in the nearshore and coastal waters of Guam, in and near Apra Harbor (Figure 1). When turtles were encountered on surveys they were hand captured while snorkeling or by diving from a slow-moving boat. Hand capture involved free-diving (2-25 m) to capture turtles resting/foraging on bottom substrate or in the water column. Turtles were immediately brought to the surface, lifted into the boat and sampled on deck or 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 through SC-MPA-17-001.

All turtles were tagged with metal Inconel 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 Passive Integrated Transponder (PIT) tags – small (14 mm length x 2 mm diameter) electromagnetically-coded glass-encased “microchips” – Destron Tx 1406L. 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. 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 (Wildlife Computers SPLASH/SPOT tags with GPS Fast-Loc technology, temperature, and depth).

Satellite tag attachment followed the drag recommendations of Jones et al. (2011, 2013) and the attachment methods as described in Jones and Van Houtan (2012). 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) was used to affix the tag to the carapace, and a second putty-type epoxy (J.B. WaterWeld) was form-molded over the tag to protect the tag from damage from reef and rock ledges during the course of normal turtle behavior. This technique is widely used and works well with reef-dwelling hawksbill or green turtles. Captured turtles that were too small, had poor body condition, or physical abnormalities were not outfitted with a satellite tag.

### *Home range estimates*

GPS and ARGOS 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. Kernel interpolation with barriers (KIWB) and the associated 50% and 95% density volume contours were generated from GPS x, y locations only. The KIWB method was selected over traditional kernel density estimation (KDE) due to its ability to account for land barriers for nearshore marine species (Sprogis et al. 2016). All density estimates were performed in ARCGIS (ESRI 2012). The data analysis is 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 given 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, (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. We calculated the area of each volume contour polygon (km<sup>2</sup>) to quantify core area and home range and allow for comparisons across sites.

Temperature data and depth data were collected every 10 seconds and archived by the Wildlife Computers tags; these data were then binned and sent via satellite transmissions with the ARGOS and GPS location data when the turtle surfaced. The binned data give the percentage of time the turtle was at a particular temperature or depth for every 6-hour period. The temperature and depth bins were as follows:

Temperature: 19, 21, 23, 24, 25, 26, 27, 28, 29, 30, 31, 33, 35, >35 (in degrees Celsius)

Depth: 0, 2, 5, 10, 15, 20, 25, 30, 40, 50, 60, 70, 100, >100 (in meters)

The total time a turtle was at a particular depth or temperature bin was averaged and the data were represented in a histogram providing an average of averages of the life of a tag and across turtles. The data were separated by species.

#### *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 NIST:

Genetic and Stable Isotope analysis NOAA, NMFS, SWFSC  
3333 North Torrey Pines Court  
La Jolla, CA 92037

## **RESULTS AND DISCUSSION:**

### *In-water surveys and capture*

The following is a synopsis of surveys, captures, and analyses to date (2015-2016). The survey tracks, turtle observations by species, turtle captures, and satellite tags deployed by location for the 2015-2016 field seasons can be seen in Figure 1. See Table 1 for a summary of the boat-based snorkel survey effort. A total of 115 turtles were encountered (Table 1). Of those encounters, 87 turtles were observed but not captured, 8 turtles were captured but not outfitted with a satellite tag, and 20 turtles were captured and outfitted with a satellite tag (Table 1). For the 87 observations, 69% were identified as green turtles, 2% as hawksbill turtles, and 29% as "unknown" species but either green or hawksbill

turtles (Table 1). Of the 8 turtles captured but released without satellite tags, 75% were green turtles and 25% were hawksbill turtles (Table 1). For the 20 satellite tags, 85% were deployed on green turtles and 15% on hawksbill turtles (Table 1).

Details on dates, locations, and species of all turtle observations, captures, and satellite tag deployments are provided in Tables 2-3 and as supplementary files. For all captured and tagged turtles, measurements and tag identification numbers are also provided in Tables 2-3. Captured green turtles ranged in straight carapace length from 42.2 cm to 75.0 cm ( $n = 23$ ; mean = 55.2,  $sd = 9.2$  cm) and in mass from 9.4 kg to 66.5 kg ( $n = 23$ ; mean = 25.7,  $sd = 15.2$  kg). Captured hawksbills ranged in straight carapace length from 46.9 cm to 68.2 cm ( $n = 5$ ; mean = 59.1,  $sd = 9.3$  cm) and in mass from 15.7 kg to 34.4 kg ( $n = 5$ ; mean = 25.9,  $sd = 7.2$  kg). All captured turtles were sub-adults for which sex could not be determined using visual observation and morphometric techniques.

The demographic data for green and hawksbill turtle captures in the Naval Base Guam study area are typical for turtles throughout the Marianas Archipelago (see Figure 2). Summers et al. (*in press*) incorporates captures from another Navy-funded study in CNMI in 2013 and 2014 with over 500 captures from 2006 to 2014, suggesting that turtles recruit to the nearshore waters of the Mariana Islands around 34-36 cm SCL and depart to adult foraging and nesting grounds around 78-81 cm SCL. The growth rate analysis from the capture-mark-recapture data estimates residency time of 17 years (13 – 28 95% CI) from recruitment to maturity.

#### *Satellite tag deployment, tag longevity, and home range*

The KIWB estimates and volume contours in Figures 3-6 elucidate the general habitat use, home range, and core area for turtles tagged in each location based on their horizontal movements. Of the 20 satellite devices deployed, one was not included in this analysis due to lack of sufficient data; it was deployed in May 2015 on a 66 cm SCL green turtle off Dadi Beach but stopped transmitting after 12 days, suggesting it malfunctioned. Details on the number, species, and carapace lengths of turtles tagged at each site are provided in Figures 3-6, along with the longevity (i.e., transmission days), Argos IDs, and current status (e.g., active) of the tags.

Tag longevity, calculated from the 19 tags that transmitted a signal for more than two weeks, varied by species. For green turtles, tags transmitted data for an average of 133 days in Apra Harbor ( $sd = 85$ ,  $n = 10$  tags) and 136 days near Dadi Beach ( $sd = 123$  days,  $n = 6$  tags). For hawksbill turtles, tag life was 321 days in Apra Harbor ( $sd = 240$ ,  $n = 3$  tags). Maximum tag life was 382 days for green turtles (Argos ID 149126 tagged off Dadi Beach; Figures 5-6) and at least 593 days for hawksbill turtles (Argos ID 149125 tagged off Gab Gab beach in Apra Harbor; Figure 4). Two tags were still active and transmitting data at the end of December 2016; one was deployed on a hawksbill turtle off Gab Gab Beach in May 2015 (Argos ID 149125), and the other on a hawksbill turtle tagged in May 2016 (Argos ID 149129) at Inner Glass Breakwater in Apra Harbor (Figure 4).

KIWB estimates revealed high site fidelity and limited movements for both green and hawksbill turtles while resident in the Apra Harbor area (Figures 3-6). Across sites, the core area (50% KIWB volume contour) was geographically concentrated for both green turtles (mean = 0.17  $km^2$ ;  $sd = 0.02$   $km^2$ ; range = 0.16 – 0.18  $km^2$ ; 2 sites) and hawksbill turtles (0.14  $km^2$ ; 1 site). Home ranges (95% KIWB volume contour) were also geographically restricted, with green turtles using an average area of 1.79  $km^2$  ( $sd = 0.52$   $km^2$ ; range = 1.42 – 2.16  $km^2$ ; 2 sites) and hawksbill turtles 0.74  $km^2$  (1 site). Summary statistics specific to each tagging location and species are provided in Figures 3-6.

While the majority of tagged turtles remained within a 1-3  $km^2$  area for the entire life of the tag, there were a couple 12-14 km movements. One 60 cm SCL turtle tagged at Gab Gab beach in May

2016 (Argos ID: 149118) moved out of Apra Harbor into the Piti Bomb Holes area (traveling roughly 12 km) 3 weeks after being tagged and remained there until November 2016, when the tag stopped transmitting a signal. One 75 cm SCL turtle tagged off Dadi Beach in May 2015 (Argos ID: 149124) moved south past Facpi Point 38 days after being tagged (traveling roughly 12 km) and remained near Umatac for 3 weeks before the tag stopped transmitting a signal.

Dive patterns suggest that green and hawksbill turtles spend most of their time in waters shallower than 25 m and temperatures of 28-31 °C (Figures 7 and 8). Binned depth data from the tags suggest both species made dives down to 60-100 m; however, hawksbill turtles spent slightly more time in deeper waters than green turtles, with an average depth of 11.0 m compared to 9.1 m. Hawksbill turtles spent more time in slightly warmer waters, experiencing an average water temperature of 30.5 °C compared to 29.7 °C by green turtles. Time-at-depth and time-at-temperature histograms in Figures 7 and 8 provide a detailed breakdown of these two habitat variables for each species, and suggest potential subtle differences in their preferred habitat.

#### **PROGRESS TOWARDS SUMMARY OF TASKS:**

(1) Capture and tag sea turtles on Naval Base Guam

Twenty-eight captures of turtles in the Naval Base Guam study area and 20 satellite tags deployed.

(2) Analyze capture and tracking data

Kernel interpolation estimates include all tags to date (with sufficient data) and all areas of capture. Analysis revealed high site fidelity and limited movements of turtles. Two tags are still signaling and complete analysis is forthcoming. NRC post-doctoral researcher Dr. Summer Martin 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 3-6 for kernel interpolation estimates and details of short-range movements and Figures 7-8 for dive depth and temperature histograms.

(3) Prepare interim and final report

In progress.

#### **PROGRESS TOWARDS GUIDING QUESTIONS FROM THE FY13-15 MONITORING PLAN:**

- i. Are there locations of greater sea turtle concentration within Apra Harbor and other DoN submerged lands around Guam?

Efforts are on-going to answer this question. We have encountered and captured turtles in most locations we have surveyed in the Naval Base Guam area. The following areas appear to have high turtle density based on our survey experiences: (1) nearshore waters inside Apra Harbor near San Luis Beach and Gab Gab Beach, (2) nearshore waters near Spanish Steps, and (3) nearshore waters



near Dadi Beach and Tipalao Beach outside of the harbor to the south. These areas are primarily dominated by patch reef communities where the turtles both forage and rest.

- ii. What is the occurrence and/or habitat use of sea turtles in areas within Apra Harbor and other DoN submerged lands around Guam?

Thirteen turtles have been outfitted with satellite tags inside Apra Harbor and seven outside Apra Harbor, and 18 of those 20 tags have completed their data transmission period (Figure 1). The two tags that are still active are both on hawksbill turtles inside Apra Harbor. The habitats used by tagged turtles were relatively small, with core use areas (50% of GPS locations) of  $< 0.2 \text{ km}^2$  and home ranges (95% of GPS locations) of  $1\text{-}2 \text{ km}^2$  (Figures 3-6). Green turtles resided mostly between the surface and 20 m depth, with an average depth of 9.1 m (Figure 7a); hawksbill turtles spent slightly more time at greater depths, with most time spent between the surface and 25 m and an average depth of 11.0 m (Figure 7b). Green turtles spent most time in waters with temperatures  $28\text{-}31^\circ\text{C}$ , with an average temperature of  $29.7^\circ\text{C}$  (Figure 8a); hawksbill turtles spent slightly more time at warmer temperatures, with an average temperature of  $30.5^\circ\text{C}$  (Figure 8b). From the spatial analysis of the GPS locations and movements from these satellite tags, we have seen direct overlap of two turtles (one green and one hawksbill) with the Outer Apra Harbor Underwater Detonation Site (Figures 3 and 4) and no direct overlap with the Agat Bay Mine Neutralization Site or the Piti Point Mine Neutralization Site. However, turtles are spending significant amounts of time in and moving through areas within  $1\text{-}2 \text{ km}$  of these sites, and the lack of overlapping GPS points from more tagged turtles 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 2017:**

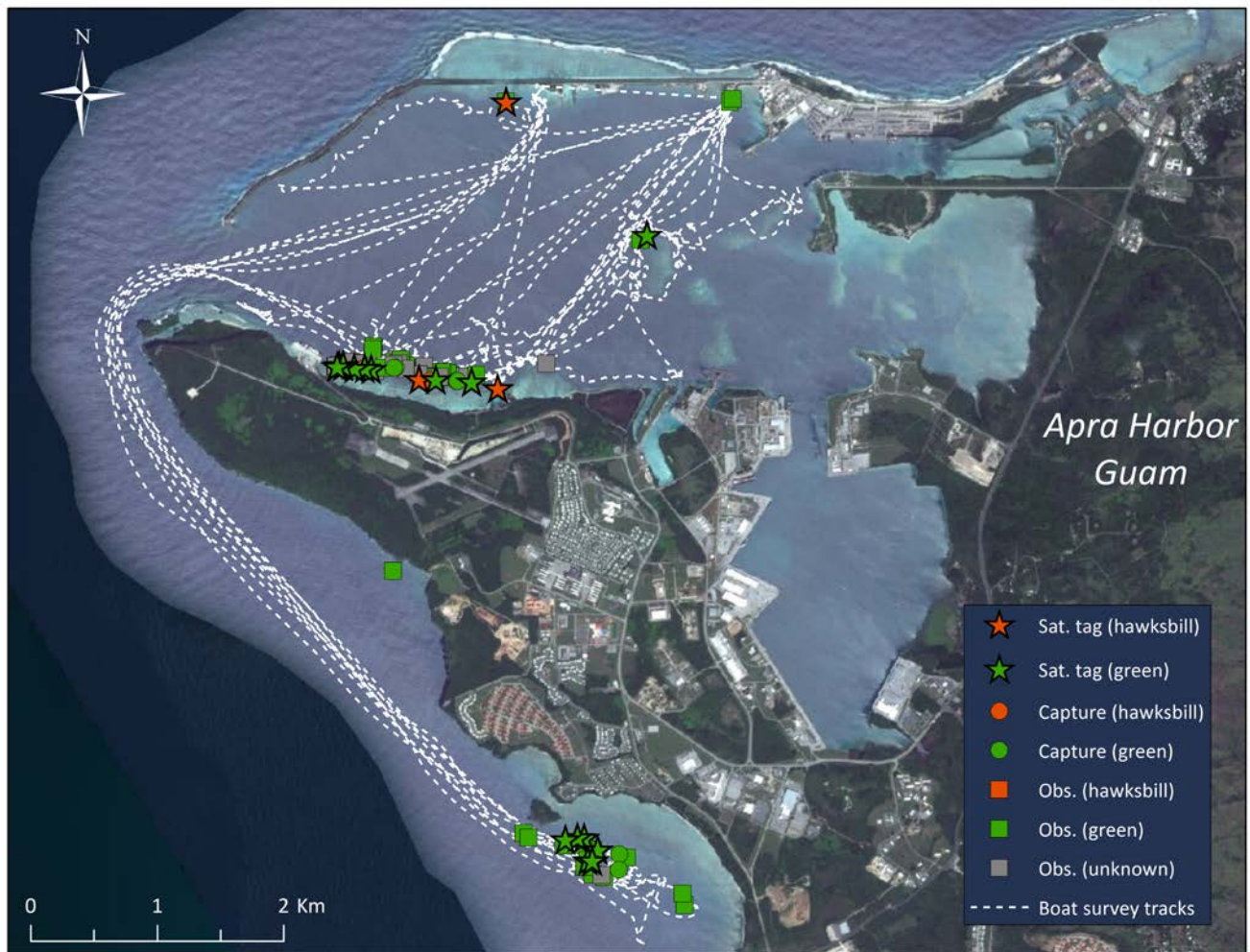
We have in-water surveys planned for the Naval Base Guam study area in May of 2017 and 2018 to deploy additional satellite tags. We will continue our analyses of the satellite data to understand home range, habitat preferences, preferred depths and temperature, as well as movements around Guam. These analyses will provide the basis of a manuscript intended for journal submission in late February 2017.

#### **ACKNOWLEDGEMENTS:**

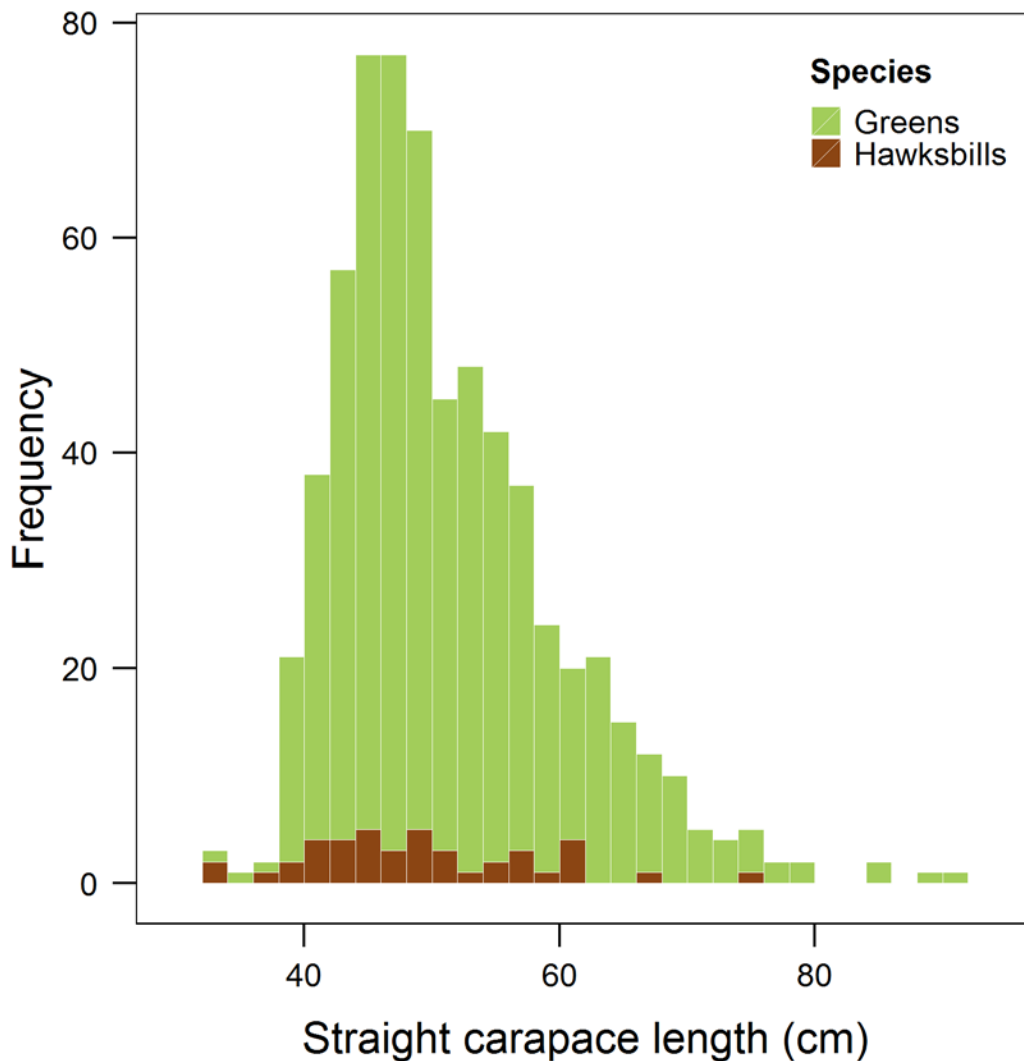
We thank our collaborative partners at Guam DAWR (Celestino F. Aguon, Jay T. Gutierrez, Shawn B. Wusstig, Jamie D. Bass, Francisco D. Manibusan, Carlos S. Quintanilla, Cristian M. Cayan, Johnedel H. Ducusin), Guam OLE for logistic and boat support, CNMI DLNR collaborators (Jessy Hapdei and Tammy Summers). From PIFSC, we thank Shawn Murakawa, Julie Whitaker, Karen Beck, Mary Zadlo, Jon Yun, Jennifer Craig, and Sujuan Situ for logistics and contracting support.

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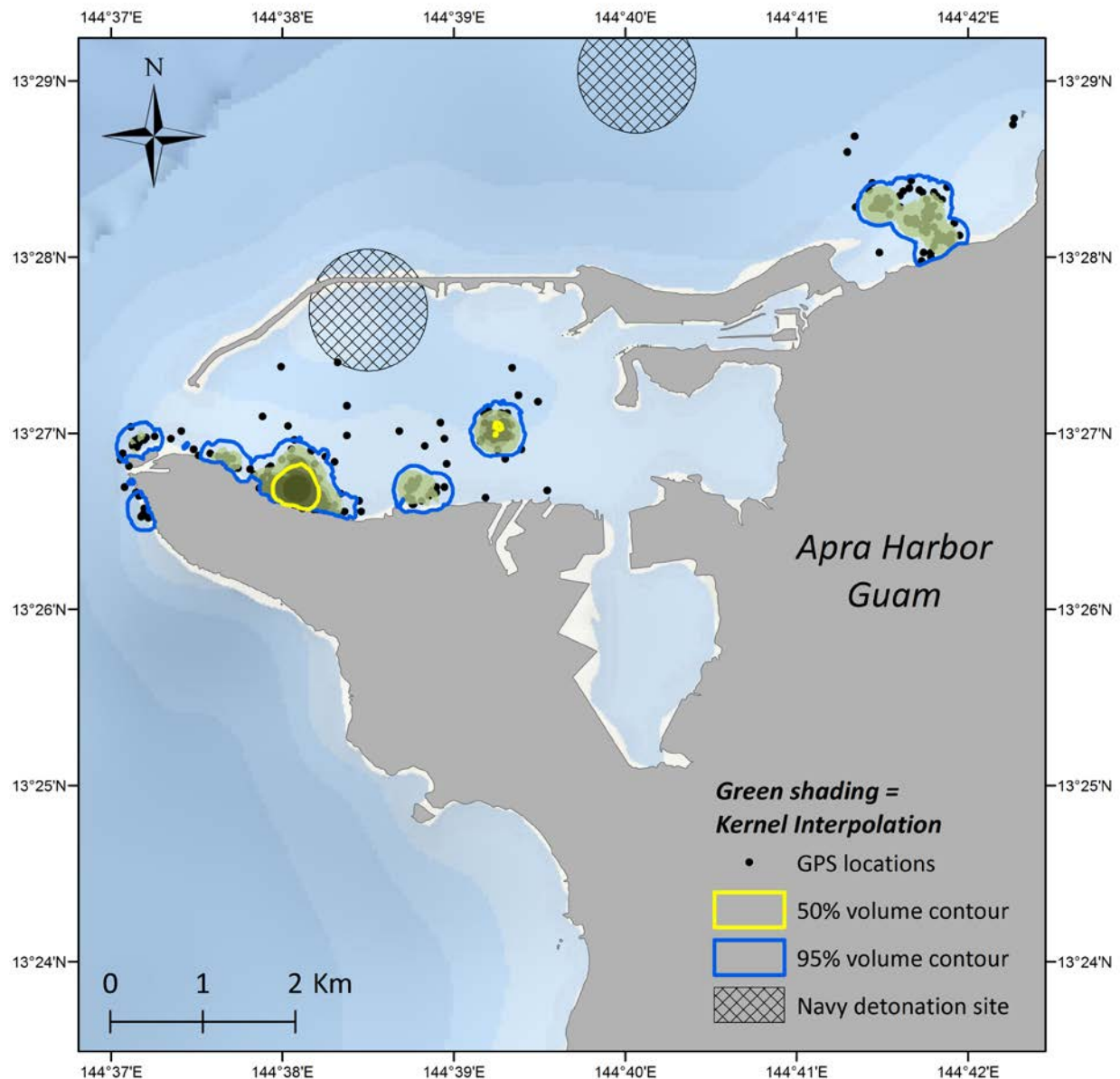
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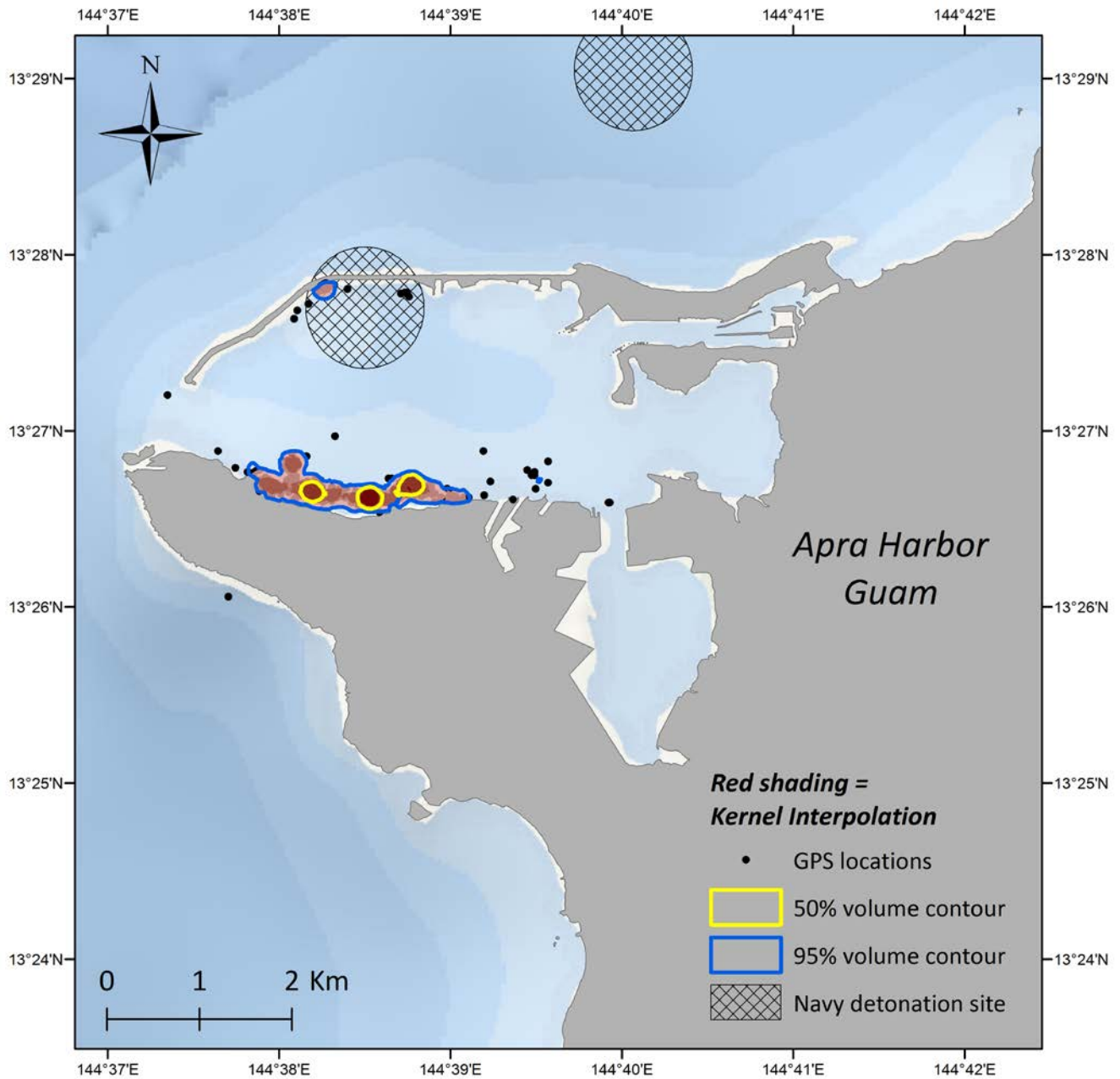
**Figure 1. Marine turtle surveys and observations (2015-2016) in the Naval Base Guam area, including Apra Harbor and Dadi Beach.** Symbols differentiate turtle species (green, hawksbill, or unknown) and types of encounters (observation only, capture without satellite tag, and capture with satellite tag deployment). Boat survey tracks depict vessel movement on survey days.



**Figure 2. Frequency distribution of straight carapace length for green and hawksbill turtles (CNMI 2006-2014).** The length frequency distribution is adapted from Summers et al. (*in press*) and represents captures from Rota, Tinian, and Saipan. Captures under Interagency Agreement NMFS-PIC-16-008 between PIFSC and U.S. Pacific Fleet Environmental Readiness Office from 2013 and 2014 are incorporated in the histogram. Green and hawksbill turtles recruit to nearshore waters ~ 35 cm SCL and depart to adult foraging/nesting areas at ~ 78 cm SCL.

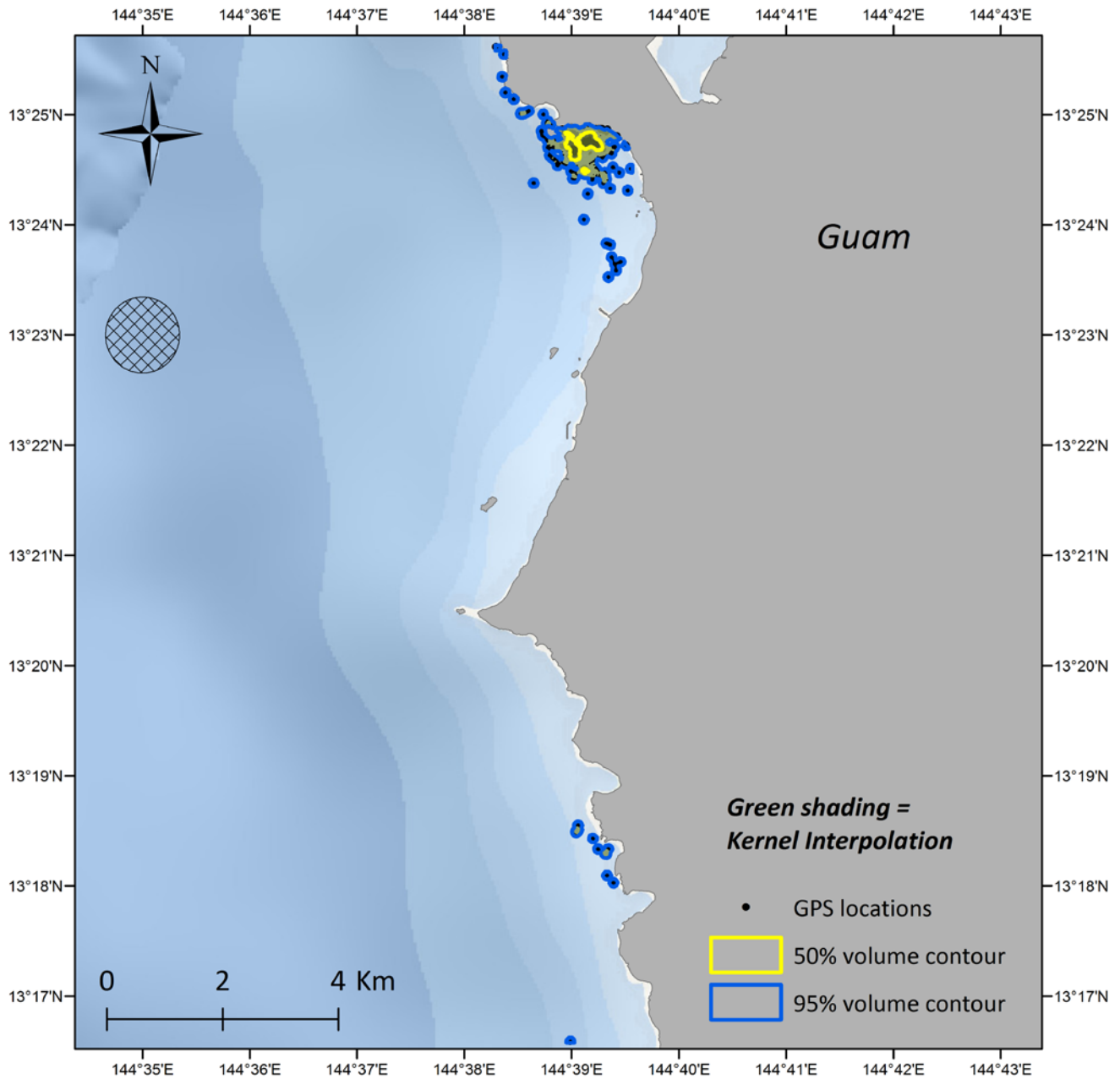


**Figure 3. Habitat use map for green turtles tagged in Apra Harbor, Guam (sites: Gab Gab Beach, Western Shoals, Kilo Wharf).** GPS location data from 10 green turtles tagged in May 2015 and May 2016 (straight carapace length: mean = 55.8 cm, sd = 4.4 cm). Location points were analyzed using a Kernel Interpolation with Barriers method. Darker shades of green indicate higher density of points, with the 50% (core area = 0.18 km<sup>2</sup>) and 95% (home range = 2.16 km<sup>2</sup>) volume contours outlined in yellow and blue, respectively. One 60 cm SCL turtle tagged at Gab Gab beach in May 2016 (Argos ID: 149118) moved out of Apra Harbor into the Piti Bomb Holes area (traveling roughly 12 km) 3 weeks after being tagged and remained there until November 2016, when the tag stopped transmitting a signal. The tags transmitted signals for 48-298 days (mean = 133, sd = 85 days), and are no longer active. Argos IDs: 149118, 149128, 149130, 149132, 149122, 149120, 149133, 149135, 149123, 149116.

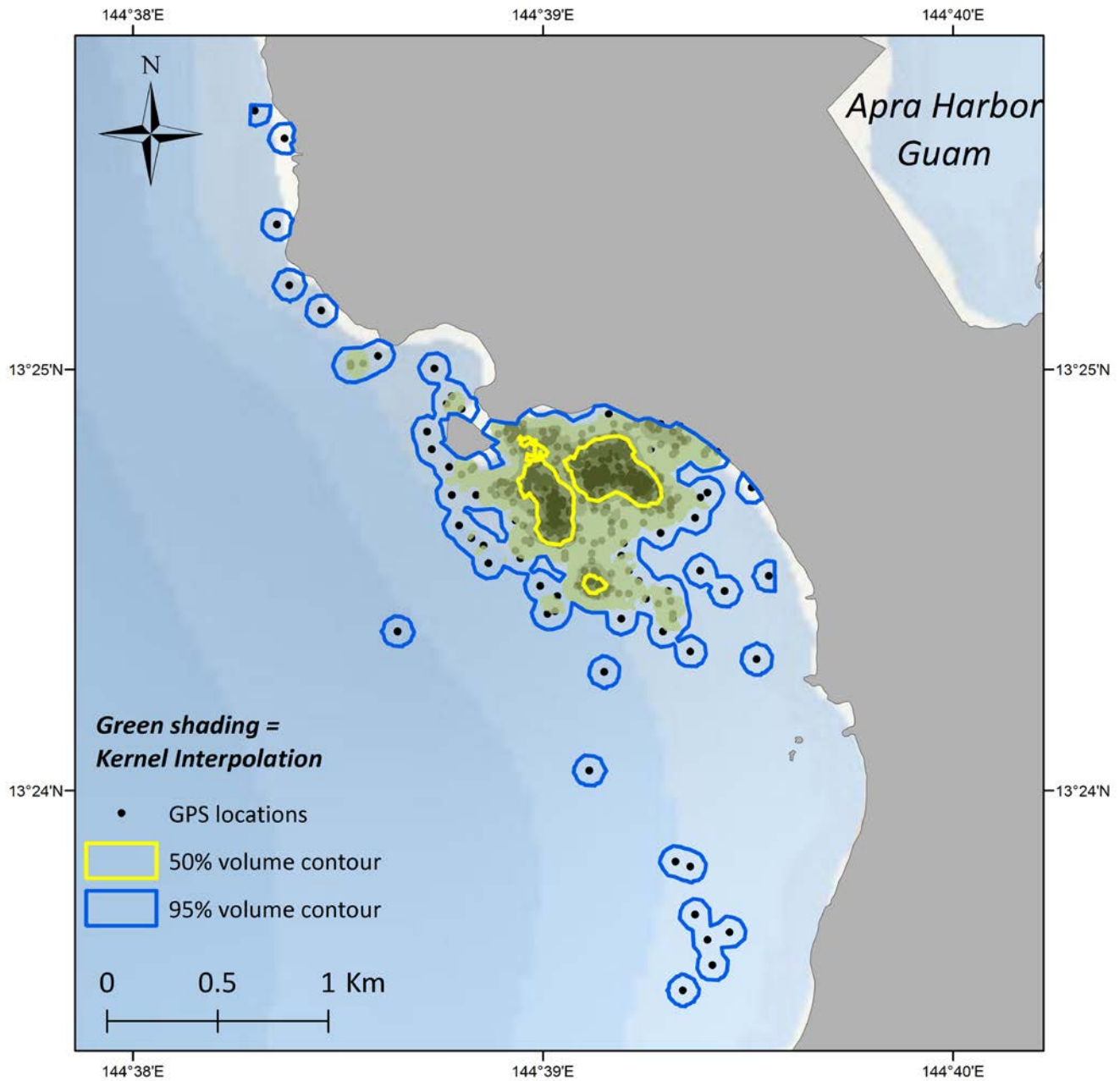


**Figure 4. Habitat use map for hawksbill turtles tagged in Apra Harbor, Guam (sites: Gab Gab Beach and Inner Glass Breakwater).** GPS location data from 3 hawksbill turtles tagged in May 2015 and May 2016 (straight carapace length: mean = 60.1 cm, sd = 7.5 cm). Location points were analyzed using a Kernel Interpolation with Barriers method. Darker shades of green indicate higher density of points, with the 50% (core area = 0.14 km<sup>2</sup>) and 95% (home range = 0.74 km<sup>2</sup>) volume contours outlined in yellow and blue, respectively. The tags transmitted signals for 137-593 days (mean = 321, sd = 240 days), and two were still active on 12/31/16. Argos IDs: 149125, 149127, 149129.

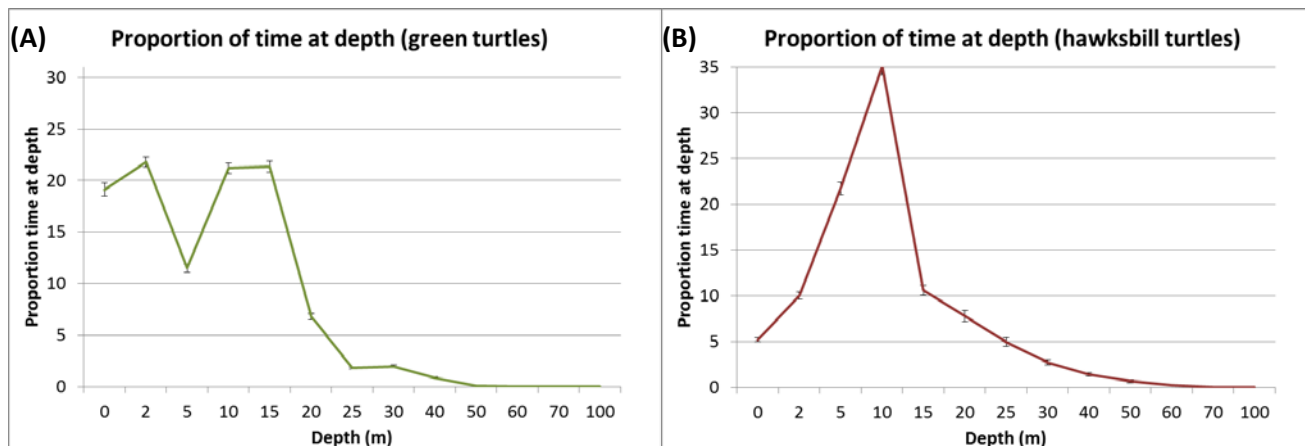




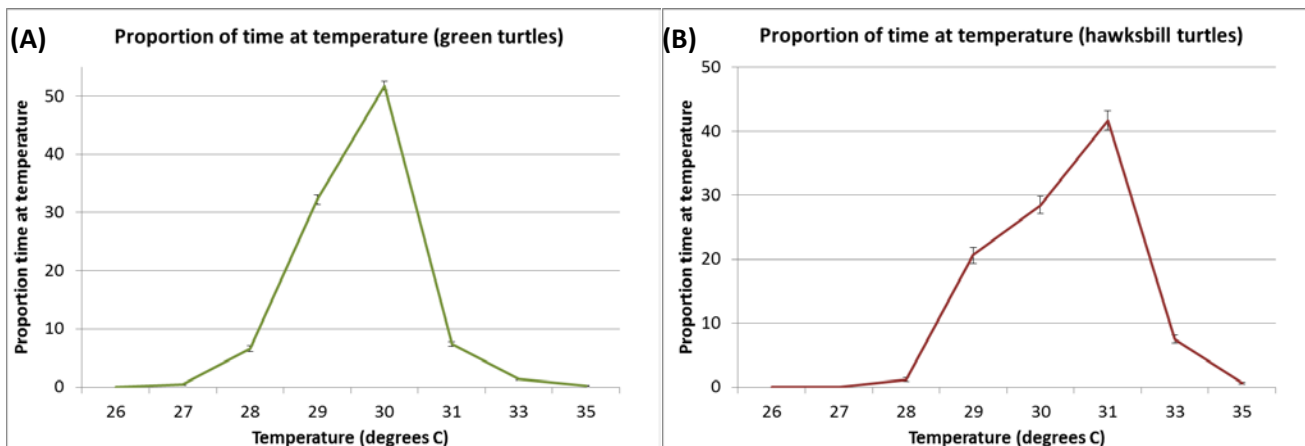
**Figure 5. Habitat use map for green turtles tagged off Dadi Beach, Guam (zoomed out).** GPS location data from 6 green turtles tagged in May 2015 (straight carapace length: mean = 62.0 cm, sd = 12.0 cm). Location points were analyzed using a Kernel Interpolation with Barriers method. Darker shades of green indicate higher density of points, with the 50% (core area = 0.16 km<sup>2</sup>) and 95% (home range = 1.42 km<sup>2</sup>) volume contours outlined in yellow and blue, respectively. One 75 cm SCL turtle tagged off Dadi Beach in May 2015 (Argos ID: 149124) moved south past Facpi Point 38 days after being tagged (traveling roughly 14 km) and remained near Umatac for 3 weeks before the tag stopped transmitting a signal. The tags transmitted signals for 63-382 days (mean = 136, sd = 123 days), and are no longer active. Argos IDs: 149131, 149121, 149117, 149119, 149124, 149126.



**Figure 6. Habitat use map for green turtles tagged off Dadi Beach, Guam (zoomed in).** GPS location data from 6 green turtles tagged in May 2015 (straight carapace length: mean = 62.0 cm, sd = 12.0 cm). Location points were analyzed using a Kernel Interpolation with Barriers method. Darker shades of green indicate higher density of points, with the 50% (core area = 0.16 km<sup>2</sup>) and 95% (home range = 1.42 km<sup>2</sup>) volume contours outlined in yellow and blue, respectively. The tags transmitted signals for 63-382 days (mean = 136, sd = 123 days), and are no longer active. Argos IDs: 149131, 149121, 149117, 149119, 149124, 149126.



**Figure 7. Time-at-depth profiles for 16 green turtles (A) and 3 hawksbill turtles (B) in the Naval Base Guam study area in 2015-2016.** Green turtles resided mostly between the surface and 20 m depth, with an average depth of 9.1 m. Hawksbill turtles spent slightly more time at deeper depths, with most time spent between the surface and 25 m and an average depth of 11.0 m. Green and red lines are time-at-depth averages; error bars represent standard error of the mean.



**Figure 8. Time-at-temperature profiles for 16 green turtles (A) and 3 hawksbill turtles (B) in the Naval Base Guam study area in 2015-2016.** Green turtles spent most time in waters with temperatures 28-31 °C, with an average temperature of 29.7 °C. Hawksbill turtles spent slightly more time at warmer temperatures, with an average temperature of 30.5 °C. Green and red lines are time-at-temperature averages; error bars represent standard error of the mean.

**Table 1.** Summary of boat-based snorkel surveys and turtle captures from May 2015 and May 2016. Data include survey dates, site locations, turtle observations (number of individuals), captures, and satellite tag deployments. CM = green turtle (*Chelonia mydas*); EI = hawksbill turtle (*Eretmochyls imbricata*); UN = unknown turtle species (either green or hawksbill turtle).

Survey Date	Location	Observations only				Captures (no sat tags)			Captures (sat tags)		
		CM	EI	UN	Total	CM	EI	Total	CM	EI	Total
5/19/2015	Apra Harbor (Gab Gab Beach + Western Shoals)	3	-	-	3	1	-	1	1	1	2
5/20/2015	Apra Harbor (Western Shoals + Kilo Wharf) + Dadi Beach	5	-	-	5	1	1	2	3	-	3
5/21/2015	Apra Harbor (Western Shoals + Gab Gab) + Dadi Beach	12	-	6	18	1	-	1	2	-	2
5/22/2015	Apra Harbor (Gab Gab Beach) + Dadi Beach	10	-	-	10	1	-	1	2	-	2
5/23/2015	Apra Harbor (Gab Gab Beach + Kilo Wharf) + Dadi Beach	4	2	9	15	1	-	1	4	1	5
5/24/2015	Apra Harbor (Gab Gab Beach + Kilo Wharf)	16	-	-	16	1	-	1	2	-	2
<b>2015 Subtotals</b>		<b>50</b>	<b>2</b>	<b>15</b>	<b>67</b>	<b>6</b>	<b>1</b>	<b>7</b>	<b>14</b>	<b>2</b>	<b>16</b>
5/11/2016	Apra (Jade Shls. + San Luis + Gab Gab + Inner Glass Break.)	10	-	10	20	-	1	1	3	1	4
<b>2016 Subtotals</b>		<b>10</b>	<b>-</b>	<b>10</b>	<b>20</b>	<b>-</b>	<b>1</b>	<b>1</b>	<b>3</b>	<b>1</b>	<b>4</b>
<b>Summary</b>											
Survey days:	7										
Encounters:	115										
Captures:	28										
Satellite tags:	20										
<b>2015-2016 Totals</b>		<b>60</b>	<b>2</b>	<b>25</b>	<b>87</b>	<b>6</b>	<b>2</b>	<b>8</b>	<b>17</b>	<b>3</b>	<b>20</b>

**Table 2.** Summary of 2015-2016 turtle observations, captures, and satellite tag deployments from boat-based snorkel surveys in nearshore waters of Guam (in and near Apra Harbor). Data fields from left to right: Survey date, Site location, Longitude, Latitude, Type of Event (Obs. = observation only, SatTag = capture with satellite tag deployment, Capt. = capture but no satellite tag deployed), Species (CM = green turtle, EI = hawksbill turtle, UN = unknown species, but green or hawksbill turtle), Number of individuals, Attachments (instruments; “WC” = Wildlife Computers), Argos ID (satellite tags), Straight Carapace Length (cm), Mass (kg), Sex (U = unknown, M = male), Turtle ID (species, date, location, length), Flipper tag ID (left front flipper), Flipper tag ID (right front flipper), PIT tag microchip ID (left hind flipper), PIT tag microchip ID (right hind flipper).

Date	Site	Long.	Lat.	Type	Sp.	No.	Attach.	ArgosID	SCL	Mass	Sex	TurtleID	Flipper_LFF	Flipper_RFF	PIT tag_LHF	PIT tag_RHF
5/19/2015	Western Shoals	144.654	13.454	Capture-SatTagApplied	CM	1	WC SPLASH	149123	47.6	12.2	U	167799194	PI1311	PI1312	982.000167799194	982.000167776657
5/19/2015	Gab Gab Beach	144.644	13.443	Capture-SatTagApplied	EI	1	WC SPLASH	149125	68.2	32.5	U	167776458	PI1313	PI1314	982.000167776458	982.000167772369
5/19/2015	Gab Gab Beach	144.641	13.444	Capture	CM	1			45.5	12.4	U	167845544	PI1315	PI1316	982.000167845544	982.000167799070
5/19/2015	Apra Harbor	144.635	13.446	Observation	CM	1										
5/19/2015	Apra Harbor	144.635	13.446	Observation	CM	1										
5/19/2015	Apra Harbor	144.635	13.446	Observation	CM	1										
5/20/2015	Western Shoals	144.636	13.431	Observation	CM	1										
5/20/2015	Kilo wharf	144.635	13.445	Capture-SatTagApplied	CM	1	WC SPLASH	149116	56.0	29.6	U	167772398	PI1317	PI1318	982.000167772398	982.000167792399
5/20/2015	Kilo wharf	144.634	13.445	Capture	EI	1			46.9	15.7	U	190720929	PI1077	PI1076	982.000190720929	982.000190220237
5/20/2015	Dadi Beach	144.650	13.411	Observation	CM	1										
5/20/2015	Dadi Beach	144.652	13.411	Capture	CM	1			45.5	11.2	U	167776838	PI1319	PI1320	982.000167776838	982.000167777175
5/20/2015	Dadi Beach	144.650	13.412	Capture-SatTagApplied	CM	1	WC SPLASH	149131	55.2	21.8	U	167826530	PI1321	PI1322	982.000167826530	982.000167772176
5/20/2015	Dadi Beach	144.649	13.412	Capture-SatTagApplied	CM	1	WC SPLASH	149121	50.8	16.4	U	167771454	PI1323	PI1324	982.000167771454	982.000167771853
5/20/2015	Dadi Beach	144.646	13.413	Observation	CM	2										
5/20/2015	Dadi Beach	144.646	13.412	Observation	CM	1										
5/21/2015	Western Shoals	144.654	13.454	Observation	CM	1										
5/21/2015	Western Shoals	144.654	13.454	Observation	CM	1										
5/21/2015	Apra Harbor	144.642	13.444	Observation	UN	1										
5/21/2015	Gab Gab Beach	144.641	13.444	Capture	CM	1			46.5	14.8	U	167799859	PI2726	PI2727	982.000167799859	982.000167826867
5/21/2015	Apra Harbor	144.640	13.444	Observation	UN	1										
5/21/2015	Apra Harbor	144.640	13.444	Observation	CM	1										
5/21/2015	Apra Harbor	144.639	13.444	Observation	CM	1										
5/21/2015	Apra Harbor	144.638	13.444	Observation	UN	1										
5/21/2015	Apra Harbor	144.637	13.445	Observation	UN	1										
5/21/2015	Apra Harbor	144.635	13.445	Observation	UN	1										
5/21/2015	Apra Harbor	144.637	13.445	Observation	UN	1										
5/21/2015	Dadi Beach	144.650	13.411	Observation	CM	1										
5/21/2015	Dadi Beach	144.651	13.412	Capture-SatTagApplied	CM	1	WC SPLASH	149117	47.8	14.7	U	167798827	PI2728	PI2729	982.000167798827	982.000167791598
5/21/2015	Dadi Beach	144.650	13.411	Observation	CM	1										
5/21/2015	Dadi Beach	144.650	13.411	Observation	CM	1										
5/21/2015	Dadi Beach	144.650	13.412	Observation	CM	1										
5/21/2015	Dadi Beach	144.657	13.408	Observation	CM	1										
5/21/2015	Dadi Beach	144.657	13.408	Observation	CM	1										
5/21/2015	Dadi Beach	144.653	13.411	Observation	CM	1										
5/21/2015	Dadi Beach	144.650	13.411	Capture-SatTagApplied	CM	1	WC SPLASH	149119	72.0	48.2	U	167798813	PI2731	PI2730	982.000167798813	982.000167771617
5/21/2015	Dadi Beach	144.648	13.412	Observation	CM	1										
5/22/2015	Apra Harbor	144.640	13.444	Observation	CM	1										
5/22/2015	Apra Harbor	144.638	13.445	Observation	CM	1										
5/22/2015	Apra Harbor	144.637	13.445	Observation	CM	2										
5/22/2015	Gab Gab Beach	144.636	13.445	Capture	CM	1			43.9	10.9	U	167799823	PI2732	PI2733	982.000167799823	982.000167826537
5/22/2015	Gab Gab Beach	144.634	13.445	Capture-SatTagApplied	CM	1	WC SPLASH	149132	60.3	32.1	U	167794139	PI2735	PI2734	982.000167794139	982.000167841014
5/22/2015	Dadi Beach	144.651	13.410	Observation	CM	1										
5/22/2015	Dadi Beach	144.650	13.410	Observation	CM	1										
5/22/2015	Dadi Beach	144.650	13.411	Observation	CM	1										
5/22/2015	Dadi Beach	144.650	13.411	Capture-SatTagApplied	CM	1	WC SPLASH	149134	65.5	43.6	U	167840953	PI2737	PI2736	982.000167840953	982.000167799763
5/22/2015	Dadi Beach	144.650	13.410	Observation	CM	1										
5/22/2015	Apra Harbor	144.636	13.445	Observation	CM	1										
5/22/2015	Apra Harbor	144.636	13.445	Observation	CM	1										

**Table 3.** Continued – Summary of 2015-2016 turtle observations, captures, and satellite tag deployments from boat-based snorkel surveys in nearshore waters of Guam (in and near Apra Harbor). Data fields as in Table 2.

Date	Site	Longitude	Latitude	Type	Sp. No.	Attach.	ArgosID	SCL	Mass	Sex	TurtleID	Flipper (LFF)	Flipper (RFF)	PIT tag (LHF)	PIT tag (RHF)	
5/23/2015	Gab Gab Beach	144.642	13.444	Capture-SatTagApplied	CM	1	WC SPLASH	149122	54.0	20.1	U	167799732	PI2750	PI1325	982.000167799732	982.000167799780
5/23/2015	Apra Harbor	144.641	13.444	Observation	UN	1										
5/23/2015	Apra Harbor	144.640	13.444	Observation	UN	1										
5/23/2015	Kilo Wharf	144.634	13.445	Capture-SatTagApplied	CM	1	WC SPLASH	149120	58.4	36.8	U	167794048	PI2748	PI2749	982.000167794048	982.000167777182
5/23/2015	Apra Harbor	144.633	13.445	Observation	CM	1										
5/23/2015	Apra Harbor	144.633	13.445	Observation	CM	1										
5/23/2015	Apra Harbor	144.633	13.445	Observation	CM	1										
5/23/2015	Dadi Beach	144.652	13.410	Capture	CM	1		42.2	9.4	U	190552286	PI2747	PI2746	982.000190552286	982.000167797203	
5/23/2015	Dadi Beach	144.651	13.410	Observation	UN	1										
5/23/2015	Dadi Beach	144.650	13.411	Capture-SatTagApplied	CM	1	WC SPLASH	149126	71.0	50.2	U	1000124583	PI2744	PI2745	982.001000124583	982.001000124610
5/23/2015	Dadi Beach	144.649	13.412	Capture-SatTagApplied	CM	1	WC SPLASH	149124	75.0	66.5	U	167792775	PI2743	PI2742	982.000167792775	982.000167822773
5/23/2015	Gab Gab Beach II	144.638	13.444	Capture-SatTagApplied	El	1	WC SPLASH	149127	53.5	21.9	U	190556182	PI2740	PI2741	982.000190556182	982.000167792891
5/23/2015	Apra Harbor	144.638	13.445	Observation	UN	3										
5/23/2015	Apra Harbor	144.637	13.445	Observation	UN	2										
5/23/2015	Apra Harbor	144.637	13.445	Observation	El	2										
5/23/2015	Apra Harbor	144.637	13.445	Observation	CM	1										
5/23/2015	Apra Harbor	144.637	13.445	Observation	UN	1										
5/24/2015	Apra Harbor	144.642	13.444	Observation	CM	1										
5/24/2015	Apra Harbor	144.640	13.444	Observation	CM	1										
5/24/2015	Apra Harbor	144.640	13.445	Observation	CM	1										
5/24/2015	Gab Gab Beach	144.636	13.445	Capture	CM	1		50.2	15.8	U	190690799	PI2738	PI2739	982.000190690799	982.000167771990	
5/24/2015	Kilo Wharf	144.633	13.445	Capture-SatTagApplied	CM	1	WC SPLASH	149133	55.3	24.5	U	167826108	PI2724	PI2725	982.000167826108	982.000190721250
5/24/2015	Kilo Wharf	144.632	13.445	Capture-SatTagApplied	CM	1	WC SPLASH	149135	61.2	38.5	U	190215119	PI2722	PI2723	982.000190215119	982.000167792190
5/24/2015	Apra Harbor	144.632	13.445	Observation	CM	12										
5/11/2016	Gab Gab	144.639	13.444	Observation	CM	1										
5/11/2016	Gab Gab	144.639	13.444	Observation	CM	2										
5/11/2016	Gab Gab	144.639	13.444	Observation	CM	1										
5/11/2016	Inner Glass Break	144.644	13.463	Observation	CM	1										
5/11/2016	San Luis	144.647	13.445	Observation	UN	1										
5/11/2016	Jade Shoals	144.660	13.463	Observation	CM	1										
5/11/2016	Gab Gab	144.639	13.444	Capture-SatTagApplied	CM	1	WC SPLASH	149118	60.3	26.4	U	190547469	PI1551	PI1562	982.000190547469	982.000190550522
5/11/2016	Gab Gab	144.640	13.444	Observation	UN	1										
5/11/2016	Gab Gab	144.639	13.444	Capture	El	1	WC SPLASH	149125	68.2	34.4	U	167776458	PI1313	PI1314		982.000167772369
5/11/2016	Gab Gab	144.638	13.444	Observation	UN	1										
5/11/2016	Gab Gab	144.637	13.445	Observation	UN	1										
5/11/2016	Gab Gab	144.636	13.445	Observation	UN	1										
5/11/2016	Gab Gab	144.633	13.445	Capture-SatTagApplied	CM	1	WC SPLASH	149128	50.8	15.8	U	190685622	RI11865	PI1566	982.000190685622	982.000190685598
5/11/2016	Gab Gab	144.632	13.445	Capture-SatTagApplied	CM	1	WC SPLASH	149130	54.3	19.6	U	167839044	PI2715	PI2716	982.000167839044	982.000190220196
5/11/2016	Gab Gab	144.632	13.445	Observation	UN	1										
5/11/2016	Gab Gab	144.632	13.445	Observation	UN	1										
5/11/2016	Gab Gab	144.633	13.445	Observation	UN	1										
5/11/2016	Gab Gab	144.634	13.445	Observation	UN	1										
5/11/2016	Gab Gab	144.634	13.445	Observation	UN	1										
5/11/2016	Gab Gab	144.635	13.446	Observation	CM	3										
5/11/2016	Inner Glass Break	144.644	13.463	Capture-SatTagApplied	El	1	WC SPLASH	149129	58.6	25.0	U	190220098	PI1576	PI1577	982.000190220098	982.000167834861
5/11/2016	Inner Glass Break	144.660	13.463	Observation	CM	1										



## Supplementary Material:

- 1) Text file: NBG1\_PIFSC\_Turtles\_Surveys\_GPS\_BoatTracks\_2015-2016.txt

Includes all boat survey tracks from the 2015-2016 field seasons in the Naval Base Guam study area.

- 2) Text file: NBG2\_PIFSC\_Turtles\_Obs\_Capts\_SatTags\_2015-2016.txt

Includes all metadata on turtle observations, captures, and satellite tag deployments in 2015-2016 (date, location, species, numbers of all tags applied, turtle length measurement, etc.).

- 3) Text file: NBG3\_PIFSC\_Turtles\_SatTags\_TimeAtDepth\_2015-2016.txt

Includes time-at-depth histogram data from satellite tags deployed in 2015-2016. Raw data are provided as the proportion of time spent at binned depths for designated periods of time.

- 4) Text file: NBG4\_PIFSC\_Turtles\_SatTags\_TimeAtTemp\_2015-2016.txt

Includes time-at-temperature histogram data from satellite tags deployed in 2015-2016. Raw data are provided as the proportion of time spent at binned temperatures for designated periods of time.

- 5) Text file: NBG5\_PIFSC\_Turtles\_SatTags\_Locations\_ARGOS\_2015-2016.txt

Includes raw x,y Argos location data from Wildlife Computers SPLASH Satellite tags deployed in 2015-2016. See table below for interpretation of Argos derived locations.

- 6) Text file: NBG6\_PIFSC\_Turtles\_SatTags\_Locations\_GPS\_2015-2016.txt

Includes raw x,y GPS location data from Wildlife Computers SPLASH Satellite tags deployed in 2015-2016. See table below for interpretation of GPS locations.

Class	Type	Estimated error*		Number of messages received per satellite pass	
		Least Squares	Kalman Filter	Least Squares	Kalman Filter
G	GPS	< 100m		1 message or more	
3	Argos	< 250m		4 messages or more	
2	Argos	250m < < 500m		4 messages or more	
1	Argos	500m < < 1500m		4 messages or more	
0*	Argos	> 1500m		4 messages or more	
A	Argos	No accuracy estimation	Unbounded accuracy estimation	3 messages	
B	Argos			messages	

		No accuracy	Unbounded accuracy		1 or 2 messages
Z	Argos	Invalid location (available only for Service Plus/Auxiliary Location Processing)			