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SEA TURTLE TAGGING IN THE MARIANA ISLANDS RANGE COMPLEX (MIRC) PROGRESS REPORT[1]

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PREPARED FOR THE U.S. PACIFIC FLEET ENVIRONMENTAL READINESS OFFICE Under Interagency Agreement NMFS-PIC-14-003

PREPARED BY:

NOAA FISHERIES

MARINE TURTLE BIOLOGY AND ASSESSMENT PROGRAM

PROTECTED SPECIES DIVISION

PACIFIC ISLANDS FISHERIES SCIENCE CENTER

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[1] PIFSC Data Report DR-15-020
Issued 30 October 2015

BACKGROUND:

The U.S. Navy developed the Mariana Islands Range Complex (MIRC) Monitoring Plan to provide required monitoring of protected species under the Marine Mammal Protection Act (1972) and the Endangered Species Act (1973). Of the 5 species of sea turtles associated with MIRC this annual report provides data on the habitat and movements of green turtles (*Chelonia mydas*) and hawksbill turtles (*Eretmochelys imbricata*) that were tagged by PIFSC staff and satellite-tracked in the nearshore waters of Saipan, Tinian, and Guam. The other 3 species are not generally associated with neritic nearshore waters and were not observed during this monitoring year.

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/or habitat use of sea turtles in areas where the Navy conducts underwater detonations?

SUMMARY OF TASKS:

1. Capture and tag sea turtles in the MIRC, and deploy biotelemetry devices

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

3. Send tissue samples to analytical laboratories

4. Prepare interim and final report

PROGRESS ON FIELD RESEARCH:

On July 15-18, 2014, Dr. T. Todd Jones and a research team (consisting of Guam DAWR, OLE, and Navy personnel) conducted snorkel and boat surveys of Cocos Lagoon and Apra Harbor, Guam. The team observed a total of 35 turtles, of which 15 were captured. While boat-based snorkel surveys were conducted, some observed turtles were beyond capture range or fled at the sight of snorkelers. All of the captures took place inside Apra Harbor along the beaches of San Luis, Gab Gab, and Spanish Banks as well as along the outer beaches of Dadi and Tipalao. The observations and captures were in the nearshore waters typically within a 20-m depth. Captured turtles ranged in straight carapace length (SCL) from 42 to 66 cm and in mass from 8 to 41 kg. Of the 35 turtles, 1 was a hawksbill. Turtles were captured while resting or foraging on the bottom and while in transit. Eight of the captured turtles were outfitted with GPS-capable SPLASH tags from Wildlife computers. Based on drag constraints from transmitters (Jones et al. 2011, 2013), some of the captured turtles were too small to satellite tag. These tags provide information on location, dive depths, dive durations, and temperature profiles. This project represents the first in-water surveys, capture, and satellite tagging of green and hawksbill turtles in Guam. This successful project is attributed to the collaborative effort of the U.S. Pacific Fleet, Naval Base Guam, NOAA PIFSC, Guam DAWR, Guam OLE, and the Apra Harbor Patrol.

On July 20-23, 2014, Dr. Jones and a 3-person crew from DFW (CNMI) conducted surveys of the western side of the island of Tinian and the northeastern side of the island of Saipan. Nine turtles including 2 hawksbills were captured along the areas known as Dumpcoke (Tinian), Fleming Point (Tinian), Spot Light (Saipan), and Cow Town (Saipan). The turtles ranged in SCL and mass of 37 to 72 cm and 7 to 49 kg, respectively. A 72.3-cm SCL hawksbill turtle was estimated to be male in gender based on tail length; this was the only turtle captured that was of mature carapace length. Satellite tags (described above) were deployed on 3 of the Tinian turtle captures (1 green /2 hawksbills) and on 2 of the northeastern Saipan captures (2 greens).

Full morphometric measurements were conducted on 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. Full account of tagging, ID #s, and morphometrics can be found in Table 1.

SUMMARY ITINERARY:

12-13 July	PIFSC staff flew to Guam
14 July	PIFSC staff met with DAWR, conducted mission preparation, inspected boats
15 July	PIFSC team deployed entanglement net in the Cocos Lagoon area
16-18 July	PIFSC team performed in-water survey and captures in Apra Harbor
19 July	PIFSC staff traveled to Saipan, met with DFW turtle team, conducted mission preparation
20 July	PIFSC staff continued preparations, inspected boats, conducted in-water surveys
21-23 July	PIFSC staff conducted in-water surveys and captures on Saipan and Tinian
24 July	PIFSC staff debriefed team, cleaned, organized, and stored field gear
25 July	PIFSC staff departed Saipan, en route to Guam, en route to Honolulu

PROGRESS ON DATA ANALYSIS:

Data analysis is ongoing from the 2013 and 2014 field seasons. 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 assess spatial and depth profiles for tagged turtles.

In July 2014, the PIFSC selected Ms. Summer Martin (then at Scripps Institution of Oceanography) as an analyst on this project through a postdoctoral fellowship program with the National Academies of Sciences, National Research Council. This position was contingent upon Ms. Martin's successful defense and completion of her Ph.D. at Scripps, which transpired in November 2014. On 1 December 2014, Dr. Martin began her work at the PIFSC and is currently stationed onsite at the IRC laboratory facility. At this point, she began analyzing the sea turtle observations in the Guam DAWR aerial-survey data series. These surveys occurred irregularly during the following years: 1963-1965, 1975-1979, and then in a regular semi-monthly format from 1989 to 2012 (contingent upon funding and weather conditions). DAWR and PIFSC staff had previously coordinated entry and quality-checking these data. Dr. Martin developed these into a relational database and designed analyses that will focus on synoptic trends and spatial patterns in turtle observations around Guam. These analyses will guide survey and tagging efforts, inferring areas of greater abundance and hence habitat use within the neritic waters of Guam. These analyses will also reveal temporal patterns in turtle abundance. Additionally, closer examination of the data indicated that analysis of additional taxa, including reef sharks, reef manta rays, small delphinids and large delphinids, was feasible. The data have now been organized into a master database containing counts for the 5 taxa for each survey date and geographic zone (with the exception that pre-1989 count data are aggregated at the annual scale).Thus, this report summarizes findings for all 5 taxa based on DAWR's aerial survey data.

The findings presented here provide essential biogeographical and historical context for understanding the spatial distribution and abundance of sea turtles and other large marine vertebrates in MIRC. Furthermore, these data and analyses described above have helped to inform Critical Habitat for the proposed ruling of 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).

PROGRESS ON DATA AVAILABILITY:

Included with this annual progress report are the raw survey track locations for the 2013 and 2014 surveys, the location data derived from satellite tags, and a running file of all surveyed sea turtles to date (including those tagged under previous agreements).

METHODS:

In-water surveys and capture

The small boat surveys were conducted in the nearshore and coastal waters of Guam (e.g., Apra Harbor), northwestern and northeastern Saipan, and western Tinian. 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. Turtles were immediately brought to the surface, lifted into the boat, brought to shore, and placed in turtle holding bins. All research was authorized under the following permits: NMFS ESA10a1A 17022, USFWS Recovery Permit TE-72088A-0, IACUC Protocols NMFS SWPI 2011-04, and GUAM Department of Agriculture Special Permit for Scientific Research SP2013-004.

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 were outfitted with a satellite tag (Wildlife Computers SPLASH400 tag 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 hawksbills or greens.

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. Turtle tracks were created using all available x, y ARGOS locations; however, kernel density estimates (KDE) were generated from GPS x, y locations only. All tracks and density estimates were performed in ARCGIS (ESRI 2012). The data analysis is preliminary as the satellite tags are still transmitting and the data are still few. Final analyses will include the full range of GPS data for additional home range analysis and KDEs.

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

Genetic and Stable Isotope analysis NOAA, NMFS, SWFSC
3333 North Torrey Pines Court
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

Aerial Surveys

Guam's Division of Aquatic and Wildlife Resources (DAWR) has conducted aerial surveys semi-regularly since 1963. The primary goal of these surveys has been to collect information about fishing activities that occur between the coastline and the reef slope; however, data on the presence of turtles, cetaceans, and elasmobranchs were also collected. Surveys consisted of a single observer recording observations from the window of a small fixed-wing plane (or helicopter in the 1960s) as it was flown once around the perimeter of Guam, following the reef slope (at a maximum of 300 m seaward of the reef) at approximately 150-m altitude. Surveys began in the morning, at a randomly selected time, and last an average of 1.3 hours. In 1963-1965, 1975-1979, and 1989-2012, DAWR completed 2 flights per month when weather permitted; tropical storm weather and lack of a suitable aircraft caused some surveys to be cancelled. Prior to 1989, the island was divided into 12 geographic survey zones and sightings within each zone were recorded; from 1989 onward, the 12 zones were further subdivided into 92 different zones (DAWR 2010). We focus on the 12-zone system here to detect broad patterns.

Animals were identified to the following taxonomic groupings: sea turtles, sharks, manta rays, small delphinids, and large delphinids. The species and size class were not recorded. Data collection began in 1963 for turtles and sharks, 1978 for small delphinids, and 1989 for manta rays and large delphinids. Sea turtles included both green (*Chelonia mydas*) and hawksbill turtles (*Eretmochelys imbricata*), with green turtles generally recognized as the more common species around Guam (Pritchard 1995, Wiles et al. 1995). Cetaceans were divided into small delphinids and large delphinids. Small delphinids included spinner (*Stenella longirostris*) and bottlenose dolphins (*Tursiops truncatus*), and possibly pantropical spotted (*Stenella attenuata*) and rough-toothed dolphins (*Steno bredanensis*). Spinner dolphins were the most frequently observed cetacean in nearshore waters during recent small-boat cetacean surveys (Hill et al. 2014). Bottlenose dolphins were also encountered close to the reef environment (Hill et al. 2014). Pantropical spotted dolphins were typically observed several kilometers offshore, and rough-toothed dolphins were observed relatively close to shore elsewhere in the archipelago (Hill et al. 2014). Occasional sightings of the latter 3 species may have occurred during aerial surveys, but most small delphinid sightings were likely spinner dolphins due to their habitat preference and consistent presence around Guam. Large delphinids included short-finned pilot whales (*Globicephala macrorhynchus*) and possibly false killer whales (*Pseudorca crassidens*), pygmy killer whales (*Feresa attenuata*), and melon-headed whales (*Peponocephala electra*). The first 2 of those species are similar in size, as are the latter 2. Distinguishing among the 4 can be difficult from a moving aircraft, although group size and distance as seen from shore can aid in species identification. Pilot whales, false killer whales, and pygmy killer whales were observed within about 1 km from shore during small-boat surveys in the Marianas, with median group sizes of 23, 16, and 8, respectively (Hill et al. 2014). Melon-headed whales were encountered farther from shore (median: 10.8 km) and with much larger group sizes (median: 205 individuals) (Hill et al. 2014) than those observed in the aerial surveys (median: 14 individuals). Pilot whales made up the majority (56%) of sightings of those 4 species during small-boat surveys around Guam (Hill et al. 2014). Based on both the small-boat and aerial-survey observations, pilot whales likely comprise most of the aerial sightings of large delphinids. Elasmobranchs were separated into reef sharks and reef manta rays (*Manta alfredi*). Reef sharks most likely included gray (*Carcharhinus amblyrhynchos*), whitetip (*Triaenodon obesus*), and blacktip (*C. melanopterus*) reef sharks, and tawny nurse sharks (*Nebrius ferrugineus*). Those species comprised 51%, 38%, 3%, and 8% of 600 shark observations from 371 towed-diver surveys in the Marianas (Nadon et al. 2012).

Dr. Martin analyzed the aerial survey data for temporal trends for the 5 taxa. Observations (individuals) per survey (OPS) were used as an index of abundance. The OPS for years 1963-1979 was an annual mean, as the existing database combined all observations in those calendar years. For surveys occurring between 1989 and 2012, both annual and quarterly OPS values were calculated, as all survey observations were retained with corresponding survey dates. The quarterly mean was used in a time-series trend analysis to maximize temporal resolution of the data while minimizing the error associated with small samples. The annual mean was used for all other analyses.

Changes in OPS over time were quantified for each taxon using regression models and population growth rate (PGR) calculations. LOESS models were fit to the calculated time-series of observed abundance data to describe general trends. Here, the annual OPS was used for 1963-1975 and quarterly OPS for 1989-2012. R statistical software (R Core Team 2014) was used to estimate the models and compute means and 95% confidence intervals. PGR is the annual per capita rate of population increase, which was calculated as the following: $PGR = (\ln(y_2) - \ln(y_1))/(t_2 - t_1)$, where t_1 and t_2 are sequential survey years, and y_1 and y_2 are the predicted mean values of observed abundance for those years from the LOESS model. This PGR calculation was used for all 5 taxa; however, for cetaceans, it is not a good approximation of actual population changes. Unlike the turtles and elasmobranchs included in this study, cetaceans are not tied to the reef and thus the aerial surveys only sample a portion of their habitat. Therefore, the PGR calculation for cetaceans only reflects changes in the annual observation rate, not the underlying populations, and is referred to instead as the observation growth rate (OGR).

Dr. Martin also analyzed the survey data for spatial patterns and trends. For each taxon, she calculated the annual OPS density for each zone and created a fishnet grid (heat map) with survey zones on the x-axis, years on the y-axis, and color shading in the grid cells corresponding to density for each year and zone. Grid rows show the spatial pattern in density for each year, while columns show the temporal trend for each zone. To illustrate the connection between the fishnet grids and the geographic distribution of the zones around Guam, she produced a map for each taxon for a single year, with zones shaded according to their density value for that year. The map displays the year with the highest annual OPS for each taxon.

RESULTS AND DISCUSSION:

In-water surveys and capture

The following is a synopsis of surveys, captures, and analyses to date (including 2013 and 2014). The survey tracks, turtle observations by species, and turtle captures by location for the 2013 and 2014 field seasons can be seen in Figures 1 and 2. A total of 59 turtles have been observed (29) or captured (30). The 29 observations were all green turtles, of the 30 captures 5 were hawksbills. The captured green turtles ranged in straight carapace length of 37.2 cm to 66.1 cm and in mass from 6.6 kg to 40.7 kg. Fourteen green turtles were caught in the nearshore waters inside and in the surrounding beaches outside of Apra Harbor on Guam, 5 were caught in the nearshore waters of western Tinian, and 6 were caught around northwestern and northeastern Saipan. The captured hawksbills ranged in straight carapace length from 42.3 cm to 72.3 cm and in mass from 7.6 kg to 48.9 kg. One hawksbill was caught in Guam on the outside of Apra Harbor, 1 was caught on the northwestern side of Saipan, and 3 were caught on the western side of Tinian. The captured turtles were sub-adults and their sex could not be determined through visual observation except for 1 male that was sexed by tail length (western Tinian). All of the captures by year are depicted in Figure 2.

Satellite tags were outfitted on 19 of the captured turtles: 4 on hawksbills and 15 on green turtles. Eight turtles were satellite tagged in the Apra Harbor area on Guam (all green), 4 in the waters of western Tinian (1 green / 3 hawksbills), and 7 in the nearshore waters of northwestern and northeastern Saipan (6 greens / 1 hawksbill). Kernel density estimates (Sheather and Jones 1991) revealed high site fidelity and limited movements for the green turtles as well as for 2 of the hawksbills while resident of Guam, Tinian and Saipan (see Figures 3-5). Two hawksbill turtles tagged off Tinian made long-range movements with 1 turtle leaving Tinian and now residing off southern Guam in the Cocos Lagoon region (migration covered a distance of 286 km and lasted 7 days) and the other still currently on the move heading eastward along the northern edge of FSM (see Figures 6 and 7).

Dive patterns suggest that both hawksbill and green turtles remain in deeper waters during daylight hours and move nearshore during the night (Figure 6); however, the trend is more pronounced in hawksbills. Hawksbills spent more time in deeper waters than the greens, reaching depths of 100 m or more. Green turtle average depth was less than 10 m for day and night, respectively. The data suggest a dichotomy in selected habitat and habitat use for green and hawksbill turtles, which is unsurprising given their unique foraging habits. However, both species display small home ranges typically less than 4 km^2 and limited movement between islands with only two turtles, both hawksbills, making treks from Tinian to Guam and Federated States of Micronesia FSM.

Tag Longevity

Of the 19 Wildlife Computers SPLASH400 tags deployed in 2013 and 2014, 6 are still transmitting. The longest transmissions to date are 781 and 783 days, respectively; from tags 85496 and 85493 (see Table 1). Tags 85496, 131989, 131991, and 131995 are still reporting from there general capture areas of Apra Harbor, western Tinian, and northwestern/northeastern Saipan. These deployments include 2 green turtles and 2 hawksbills. Tag 85493, deployed on a Hawksbill in Tinian, is still signaling from southern Guam where the animal moved to after foraging near Tinian in 2013 (Figure 6). Tag 138963, also deployed on a hawksbill in 2014 season is reporting just north of the FSM and the turtle is currently swimming eastward (Figure 7).

Aerial Surveys

In 32 years over a 50-year span, 632 surveys were completed, representing approximately 809 hours of survey effort of Guam’s nearshore marine environment. In total, these surveys recorded 10,622 turtle, 1026 shark, 60 manta ray, 7,515 small delphinid, and 95 large delphinid observations. The aerial survey results displayed a variety of patterns in megafauna temporal trends, trend variability, abundance, and spatial distribution over time.

Turtles

Turtle observations increased from 1963 to 2012 (Figure 9a) and varied spatially, with the highest densities occurring in the south in recent years (Figures 9b, 9c). OPS ranged from 1.1 to 44.6 across years (mean = 16.4, SD = 12.5, CV = 76%). PGR was relatively high across all years (mean = 0.07, SD = 0.06, CV = 90%) and increased during 1989-2012, the most recent contiguous survey period (mean = 0.10, SD = 0.04, CV = 37%). OPS was highest in 2010 (44.6 turtles per survey), when density reached 2.7 turtles km^{-2} in the Cocos Lagoon area (zone 8), but was less than 0.3 turtles km^{-2} elsewhere (Figure 9b). Prior to 2000, density was 0-0.2 turtles km^{-2} in zone 8; it increased dramatically to 0.4-2.7 turtles km^{-2} after 2000 (Figure 9c). Most of the regional increase in turtles was driven by a local increase in this zone. After the 1970s, the west side (zones 1-7) generally had lower turtle densities than other areas (Figure 9c).

Sharks

Shark observations decreased from 1963 to 2012 (Figure 10a). Spatial patterns differed from those observed for turtles, with the highest densities on the east coast in recent years (Figures 10b, 10c). OPS ranged from 0.1 to 8.6 across years (mean = 1.7, *SD* = 1.8, *CV* = 107%). PGR was negative across all years (mean = -0.03, *SD* = 0.04, *CV* = 138%) but slightly lower for 1989-2012 (mean = -0.02, *SD* = 0.05, *CV* = 200%), with the highest OPS occurring in 1965 (8.6 sharks per survey), early in the time series. In 1965, densities were highest along the west coast (zones 1-4), reaching 0.42 sharks km^{-2} in zone 3; densities were 0-0.16 sharks km^{-2} elsewhere, with no sharks observed in Apra Harbor (zone 5) (Figure 10b). After 1976, observations on the west coast became more sporadic and densities generally decreased (Figure 10c). On the east coast (zones 9-11), densities remained relatively high through the early 1990s, and then decreased slightly.

Manta Rays

Manta ray observations were low, but increased slightly over time (Figure 11a) and became locally concentrated along the northwest coast (Figures 11b, 11c). OPS ranged from 0 to 0.57 across years (mean = 0.12, *SD* = 0.14, *CV* = 116%). PGR was relatively high, but with high variability due to the low number of observations (mean = 0.19, *SD* = 0.61, *CV* = 321%). OPS was highest in 2010 (0.57 mantas per survey), when density reached 0.06-0.09 mantas km^{-2} in zones 1-2 along the northwest coast (Figure 11b). Since 2008, nearly all observations have occurred in the northwest, though there were a few observations in the southwest (zones 5-6, and 8) (Figure 11c). This pattern contrasts with earlier years, when observations were scattered throughout the zones (Figure 11c).

Small Delphinids

Small delphinid observations fluctuated over time and space (Figure 12). OPS ranged from 0 to 38.2 across years (mean = 13.5, SD = 10.6, CV = 79%). OGR varied over time; it was negative in 1978-1989 (mean = -0.22, SD = 0.06, CV = 28%; but note there are only 3 points in this period, Figure 12a) and 1999-2009 (mean = -0.15, SD = 0.07, CV = 44%), and positive in 1990-1998 (mean = 0.35, SD = 0.30, CV = 87%)

and 2010-2012 (mean = 0.06, SD = 0.03, CV = 52%). Due to these changes in the direction of OGR, its variability across all years was extremely high (mean = 0.05, SD = 0.30, CV = 611%). OPS was highest in 2001, when density reached 3.47 small delphinids km^{-2} along the northeast coast (zone 11) (Figure 12b). Intermediate densities (0.06-1.89 small delphinids km^{-2}) occurred in most other areas in 2001, except no small delphinids were observed in zones 3 and 5 in the west, 8 in the south, and 10 in the east (Figure 12b). Over time, historically high densities in the north (zone 12) and northeast (zone 11) decreased (Figure 12c). On the west coast, densities were consistently low in zones 3-5, while they were frequently intermediate in zones 1 and 7. Densities were high in many zones during the 1990s and early 2000s, after which they decreased and became more localized to fewer zones (7, 8 and 11).

Large Delphinids

Large delphinid observations were low, but increased slightly over time (Figure 13). OPS ranged from 0 to 1.43 across years (mean = 0.20, SD = 0.39, CV = 197%). OGR and its variability were high due to the low number of observations (mean = 0.16, SD = 0.83, CV = 508%); this OGR is particularly unreliable in a population context, as it may reflect up to four species across only six total encounters, and the survey area only captures a small portion of the habitat range for those species. OPS was highest in 2010 (1.43 large delphinids per survey), when density was 0.55 large delphinids km^{-2} in southwest (zone 7) and 0 elsewhere (Figure 13b). Large delphinids were never observed in zones 1-5 on the west coast or zone 10 on the east coast (Figure 13c). Density was only positive in one zone per year, and only in the south (zones 6-9) and northeast (zones 11-12). Since 2007, observations have been slightly higher (mean density of 0.014 vs. 0.001 prior to 2007) and more frequent (Figure 13c).

PROGRESS TOWARDS SUMMARY OF TASKS:

(1) Capture and tag sea turtles in the MIRC, and deploy biotelemetry devices

Thirty captures of turtles in the MIRC and 19 satellite tags deployed.

(2) Process and analyze biotelemetry data, and other survey data

Kernel density estimates include all tags to date and all areas of capture. Analysis revealed high site fidelity and limited movements of turtles. Tags are still signaling and complete analysis is forthcoming. NRC post-doctorate Dr. Summer Martin will be conducting in-depth analysis of satellite tagging data including KDE analysis, dive depth and duration of turtles, and influence of temperature on habitat use. See Figures 3-5 for KDE, Figures 6 and 7 for turtle migratory movements, and Figure 8 for dive depth.

Analysis has begun of the DAWR aerial survey data and provides preliminary information about the abundance and distribution of Guam's turtles. Figures 9-13 show the distribution and index of abundance trends for turtles (multiple species), sharks, manta rays, small delphinids, and large delphinids.

(3) Send tissue samples to analytical laboratories

Ongoing.

(4) Prepare interim and final report

Complete.

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

The 2013 and 2014 in-water surveys and capture in the Mariana Archipelago represent a continuation of the collaborative effort between the PIFSC Marine Turtle Biology and Assessment Program and the U.S. Navy towards a better understanding of the occurrence, distribution, and habitat use of marine turtles in waters off of Guam and the islands of CNMI (including Saipan and Tinian).

The NMFS (PIFSC) is responsible for the assessment of marine turtle populations and abundance in the Exclusive Economic Zone (EEZ) waters of Guam and CNMI. The U.S. Navy is mandated by permits and Biological Opinions issued under the Endangered Species Act (ESA) to monitor marine turtle presence within the Mariana Island Range Complex (MIRC). The following are the guiding questions for marine turtle research and assessment from the FY13-15 MIRC monitoring plan.

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

Efforts are on-going to answer this question and we expand our survey efforts to new areas of the Mariana Archipelago with each field season. The waters inside Apra Harbor near San Luis, Gab Gab, out to Spanish Steps including Dadi and Tipalao beaches outside of the harbor (Guam) as well as the area stretching from the Balisa Channel to Managaha Island (Saipan) are both areas of high turtle density. These areas are dominated by patch reef communities were the turtles both forage and rest.

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

Eight turtles have been outfitted with satellite tags inside and out of Apra Harbor. Many of these tags are still transmitting and future analysis will show movements or GPS locations from satellite tags in relation to the Agat Bay Mine Neutralization Site, Piti Point Mine Neutralization Site, and Outer Apra Harbor Underwater Detonation Site.

Activities Planned for 2015:

In November 2015 we will conduct in-water surveys and capture in Saipan, Tinian, and Guam. Survey locations will be concentrated on the UNDET sights where possible (Agat Bay and Piti Mine) of eastern shores of Guam, eastern side of Saipan, and all areas of Tinian (weather depending). During these surveys/in-water capture we plan to deploy an additional 18 Wildlife Computers Fast-Loc GPS satellite tags.

Continued analyses of the satellite data will allow understanding of home range, habitat preferences, preferred depths and temperature, as well as movement within the archipelago. We will provide further analyses using the aerial survey data from Guam, including examination of finer-scale spatial patterns of animal densities using the current 92 zone system. Additionally, we will analyze the underwater towed-diver survey data collected by the Coral Reef Ecosystem Division (CRED) at PIFSC. Continued analysis of these two data streams will further improve our understanding of the abundance and distribution of turtles throughout the Mariana Archipelago, as well as cetaceans and elasmobranchs around Guam.

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We thank our collaborative partners at Guam DAWR (Tino Aguon, Jay Gutierrez, Shawn Wusstig, Jamie Bass), Guam OLE for logistic and boat support, CNMI DFW collaborators (Tammy Summers, Jessy Hapdei, and Joe Ruak), and the crew of MiniMax Charters. Olivia Hughes assisted with data management, tracking, and mapping of Argos data. Brent Tibbatts entered data and performed quality control of historical DAWR aerial data.

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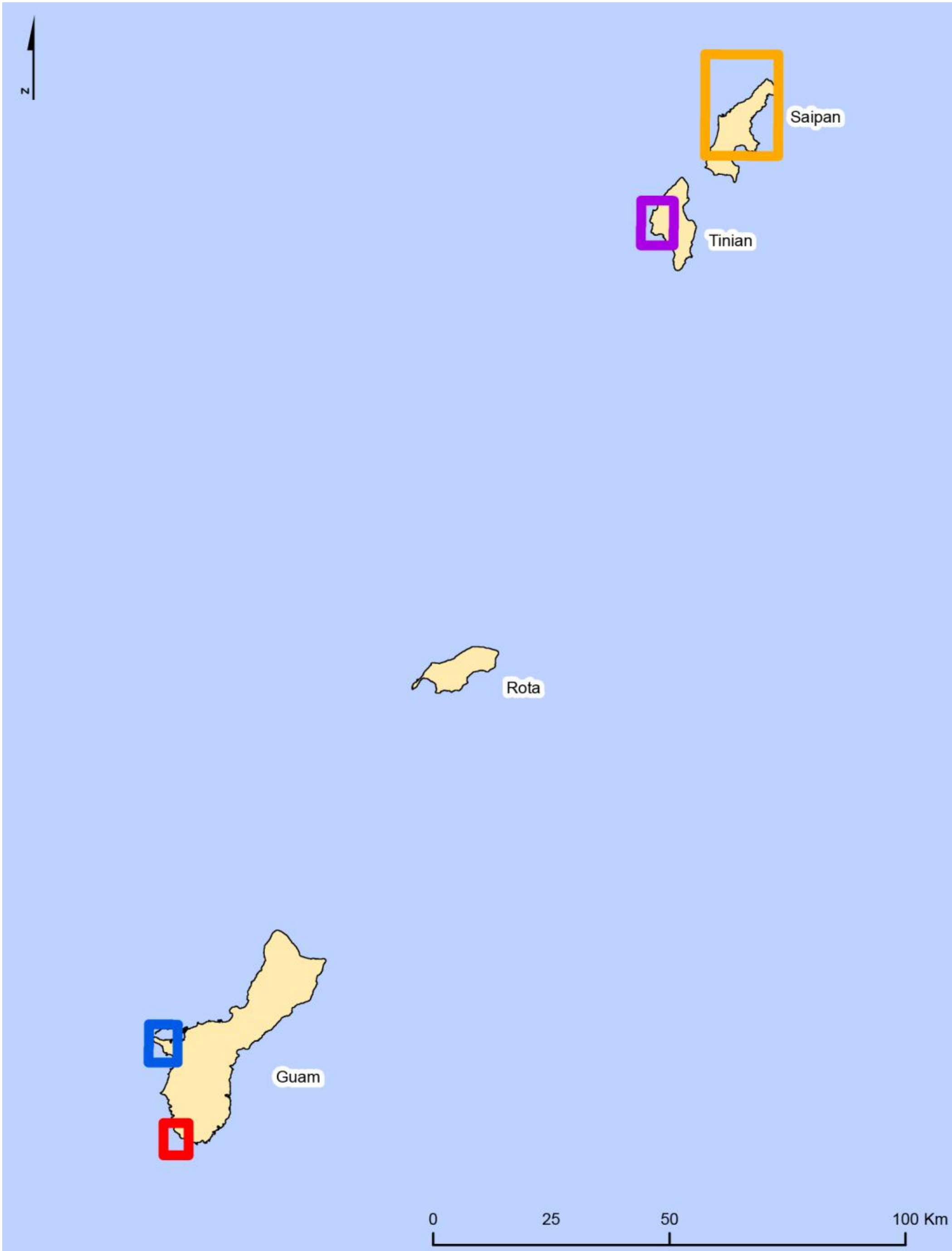

Figure 1. Map of Guam and the main islands of the Commonwealth of the Northern Mariana Islands. Colored boxes show areas of marine turtle surveys and targeted capture.

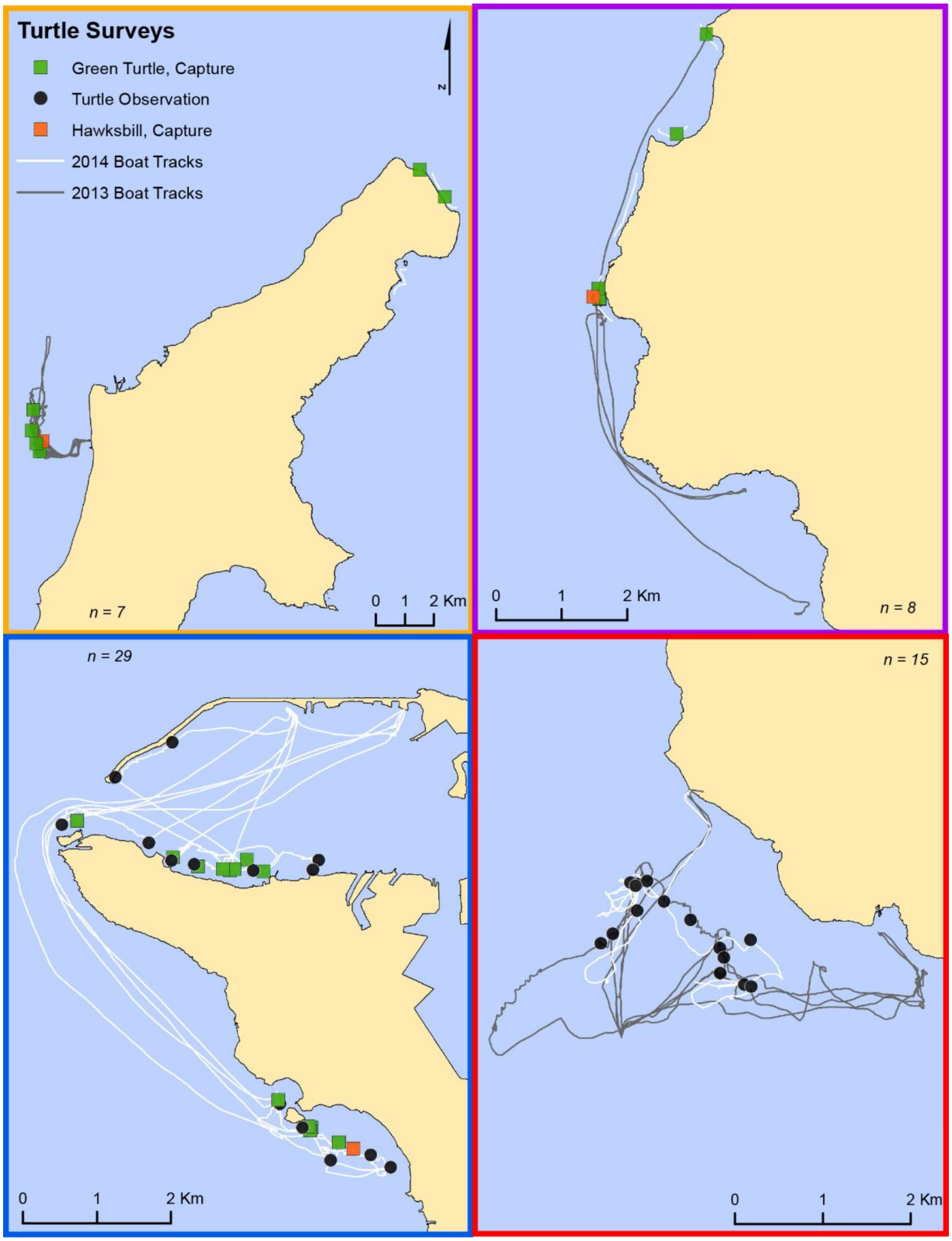

Figure 2. Individual maps of the marine turtle survey areas with colored borders corresponding to boxed areas in Figure 1. Surveys tracks are shown for 2013 (black) and 2014 (white). The points depict turtle observations (black circle) and captures (green or orange squares for green turtles and hawksbills, respectively). Total observations and captures are shown in each frame.

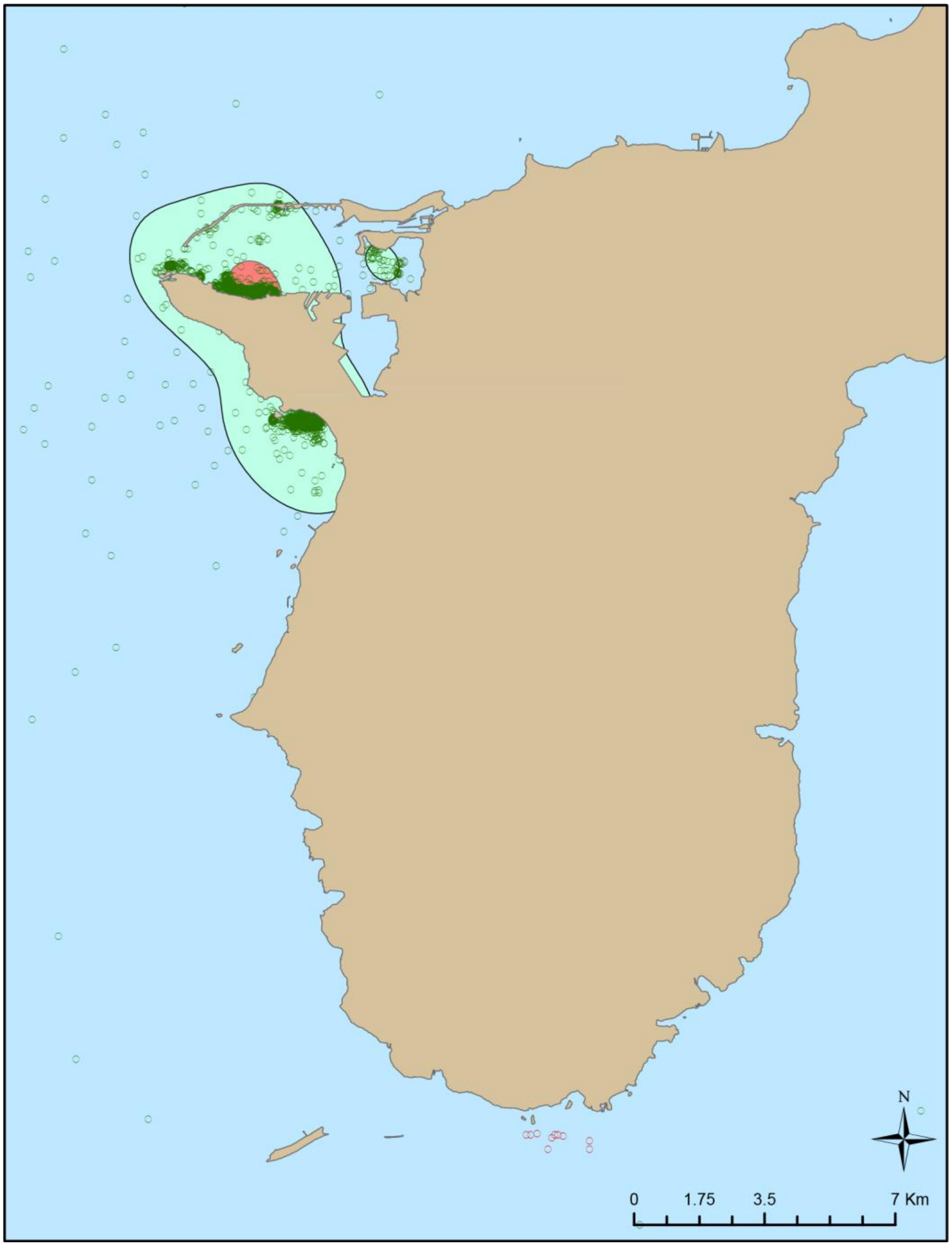

Figure 3. Map of Guam depicting spatial use of green turtles within Apra Harbor. The 95% (light green) and 50% (orange) volume contours are shown from the kernel density estimation. Green turtle locations are shown by open green circles and hawksbill locations by open orange circles (3,911 locations from 8 turtles).

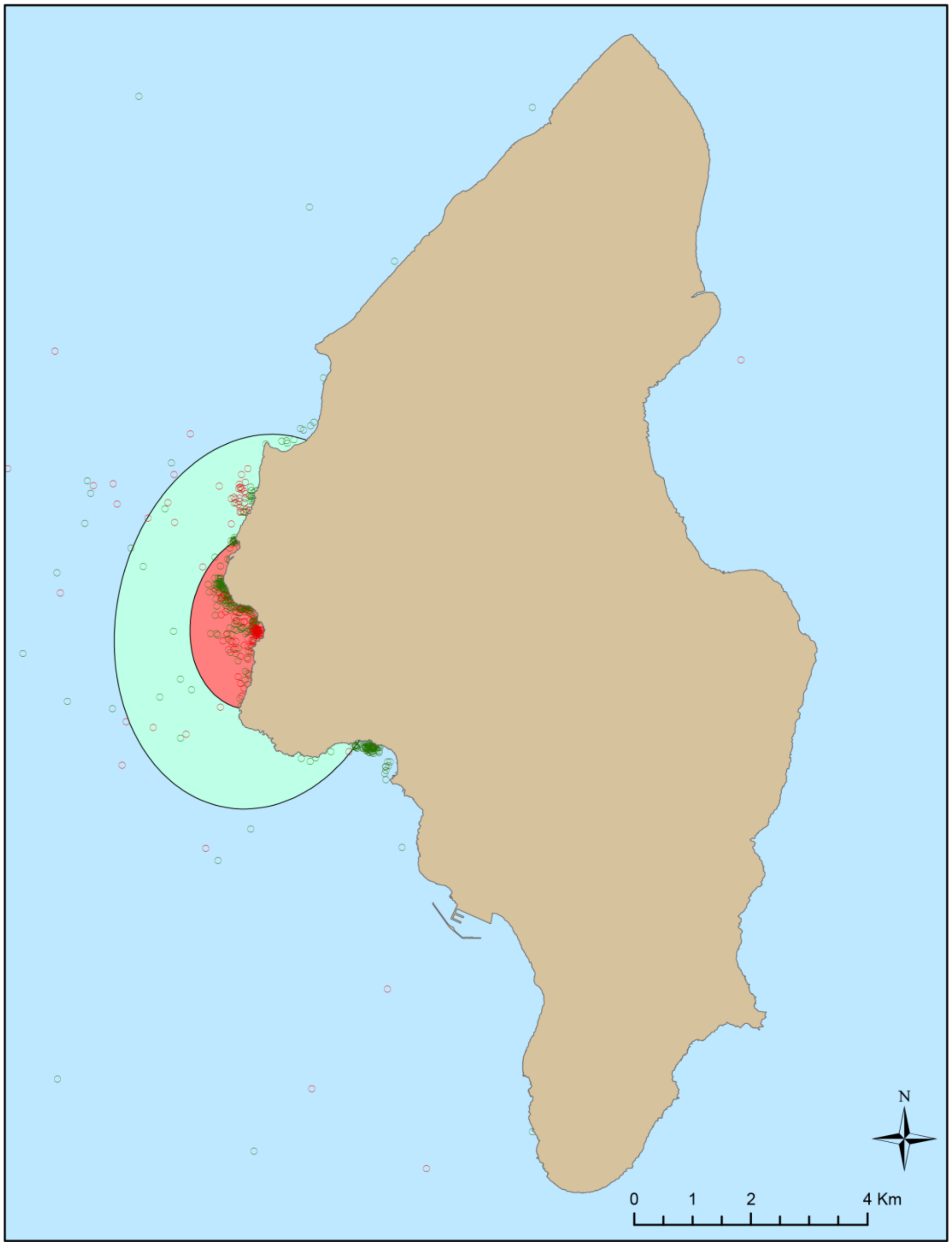

Figure 4. Map of Tinian depicting spatial use of green and hawksbill turtles. The 95% (light green) and 50% (orange) volume contours are shown from the kernel density estimation. Green turtle locations are shown by open green circles and hawksbill locations by open orange circles. The contours shown are for green and hawksbill turtles combined (652 locations from 4 turtles).

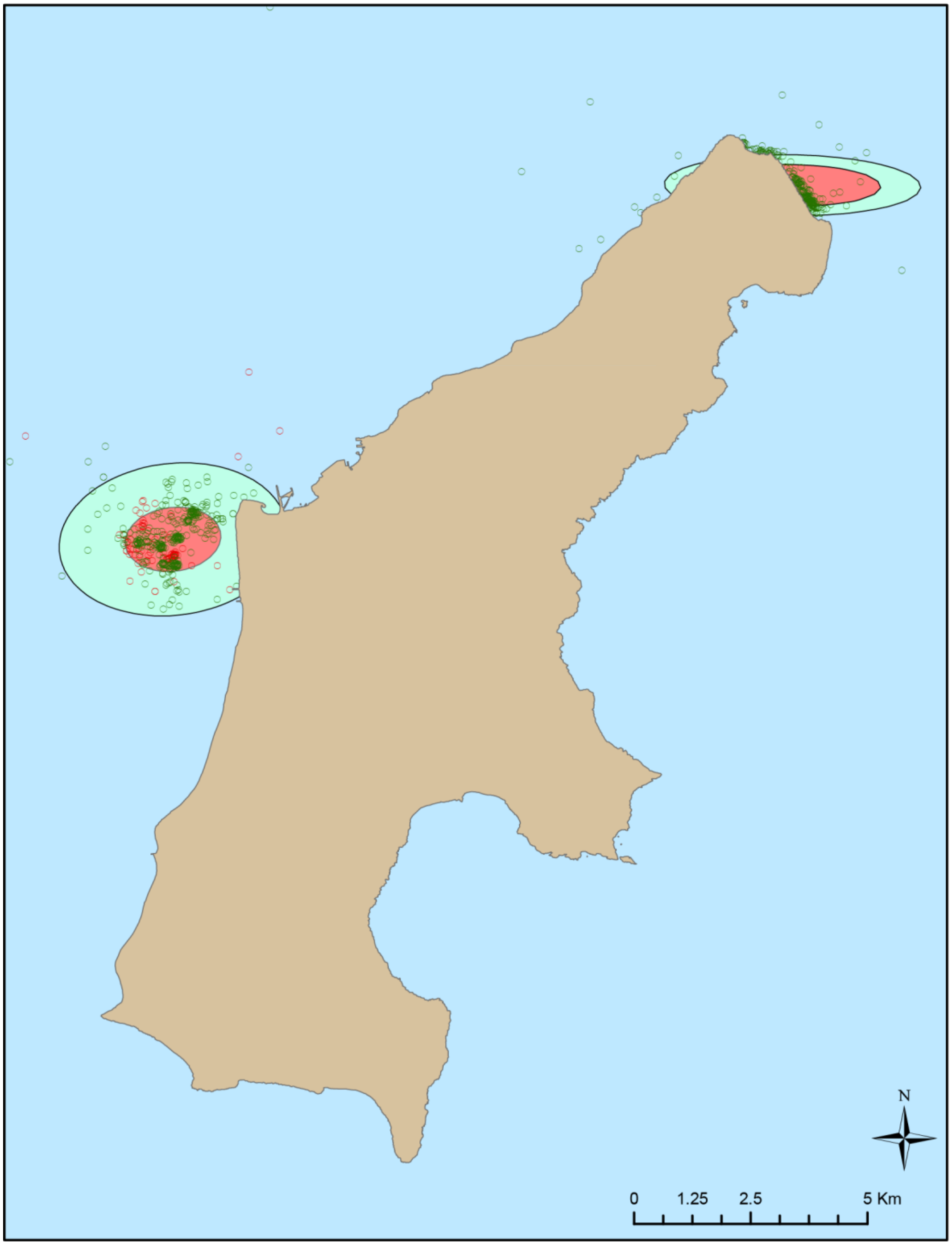

Figure 5. Map of Saipan depicting spatial use of green and hawksbill turtles. The 95% (light green) and 50% (orange) volume contours are shown from the kernel density estimation. Green turtle locations are shown by open green circles and hawksbill locations by open orange circles. The contours shown are for green and hawksbill turtles combined. The contours for Saipan were split for the western (675 locations from 5 turtles) and northern (299 locations from 2 turtles) shore captures as the turtles did not move between habitats.

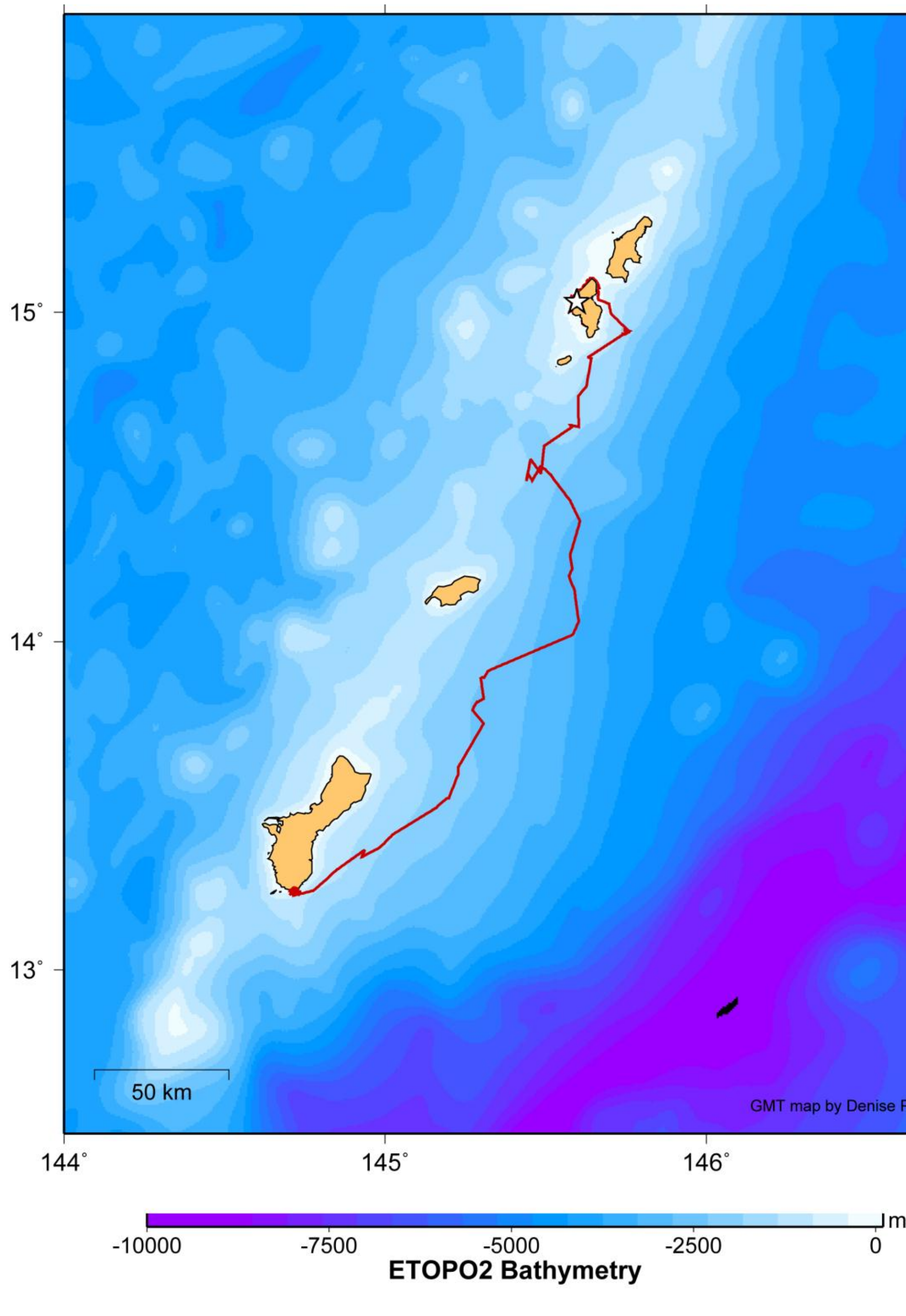

Figure 6. Migration of subadult hawksbill turtle (ID #85493) from Tinian, CNMI to Guam. Turtle was initially tagged on 20 August near Fleming Point, Tinian; left Tinian on 10 October; and arrived at Cocos lagoon, Guam on 17 October. The turtle resided off Tinian for 51 days, and remains in the Cocos lagoon area today. The migration covered a distance of 286 km and lasted 7 days.

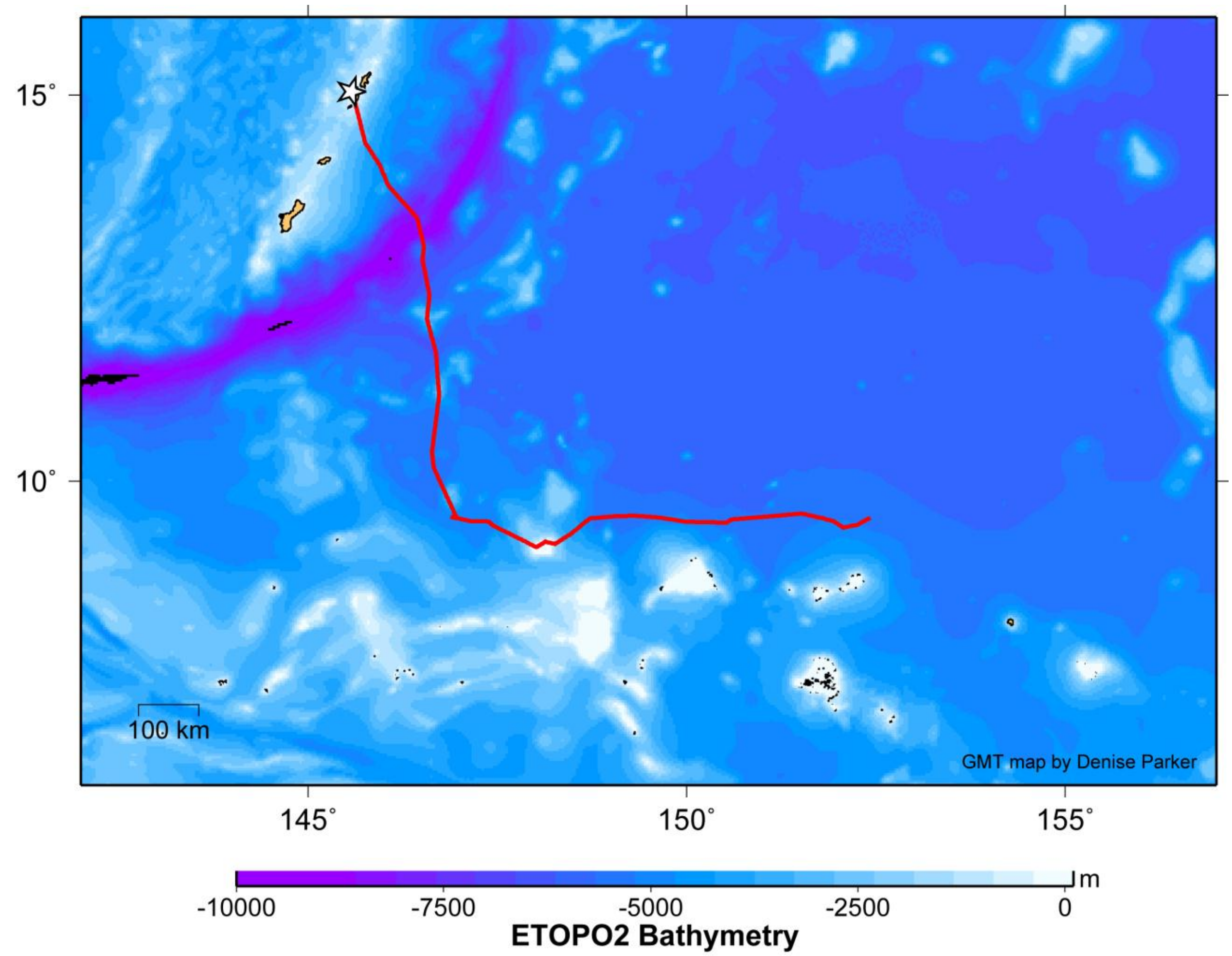

Figure 7. Migration of adult hawksbill turtle (ID #138963) from Tinian, CNMI to Federated States of Micronesia (FSM). Turtle was initially tagged on 21 July 2014 near Fleming Point, Tinian; left Tinian and had an eastern orientation just north of the FSM.

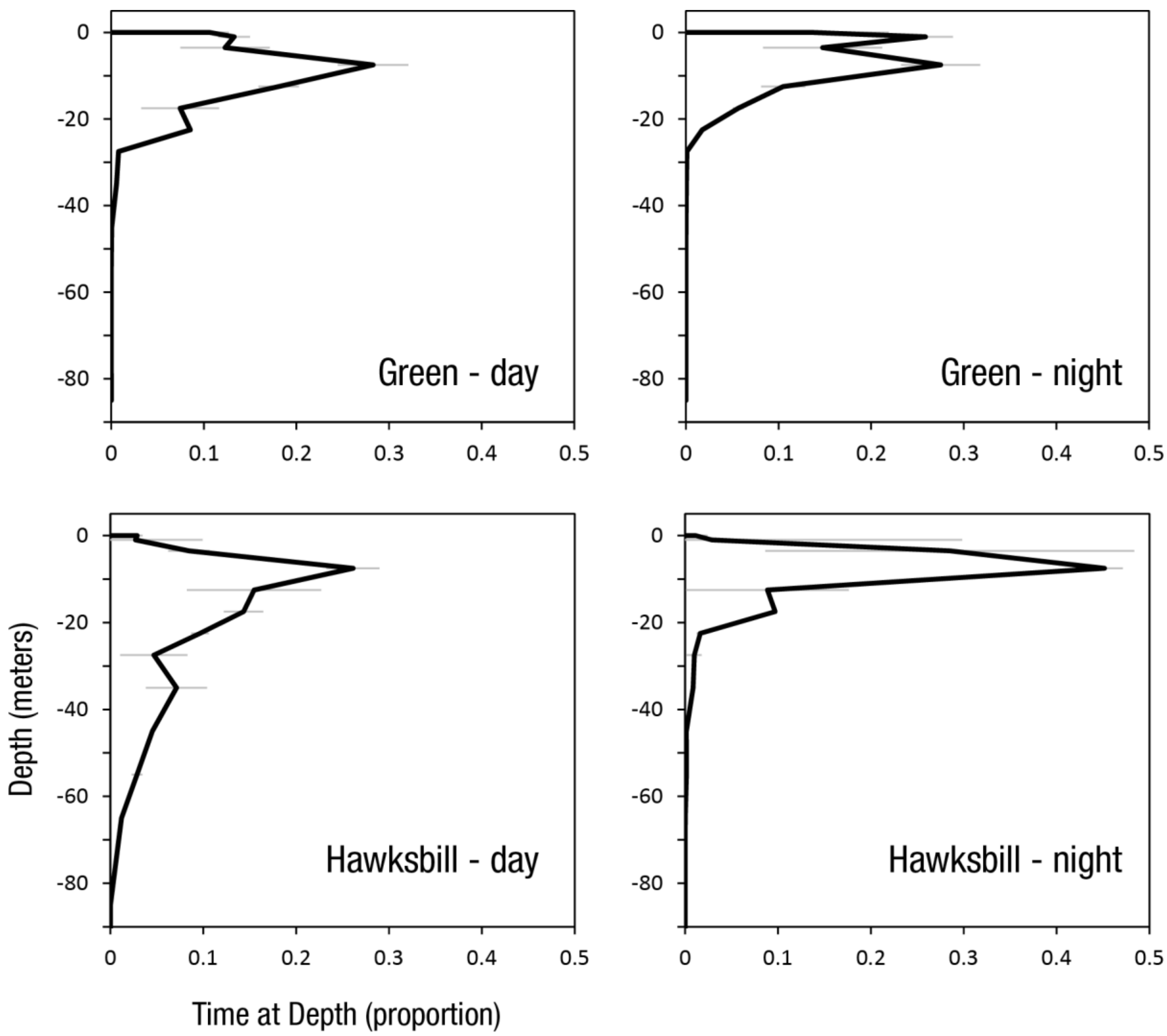

Figure 8. Time-at-Depth profiles for 15 subadult green turtles and 3 subadult and 1 adult hawksbill turtles in the Marianas region (n=19). Green turtles resided mostly at surface, emitting little diurnal signal; Hawksbills dive deeper during the day. During the day, the 15 observed green turtles maintained an average depth of less than 10 m. Hawksbills had a deeper, but more variable behavior. Dark lines are time-at-depth averages, error bars represent standard error of the mean, and axis titles are conserved from lower left panel. Data from a larger sample of individual turtles (but not necessarily more samples from the same individuals) would decrease the error bars.

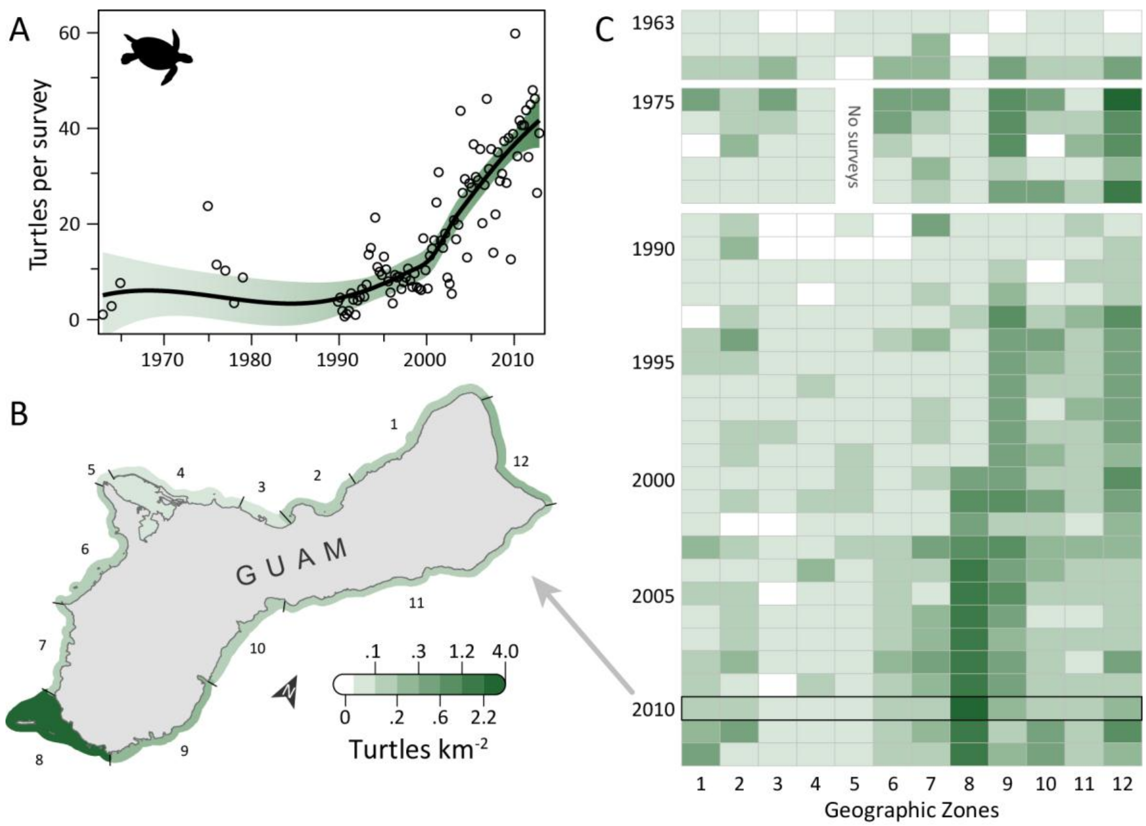

Figure 9. Eight-fold increase in observed sea turtles on Guam's reefs in the last five decades. (A) Trend in turtle observations from semimonthly aerial surveys conducted by Guam Division of Aquatic and Wildlife Resources (DAWR). Open circles are annual or quarterly observations (turtles) per survey (OPS). Smoothed line is a LOESS model fit, with 95% confidence interval shaded. Mean population growth rate (PGR) was 0.07 (SD = 0.06, CV = 90%) since 1963 and 0.10 (SD = 0.04, CV = 37%) since 1989. (B) Map of 12 geographic survey zones; shading depicts observed densities for 2010, when annual OPS was highest. (C) Trends in densities for the 12 zones. Zone 5 was closed to surveys in 1975-1979 due to military restrictions. The west coast (zones 1-7) generally had lower densities than the rest of Guam after the 1970s. The increase in zone 8 drives the overall increase observed in (A).

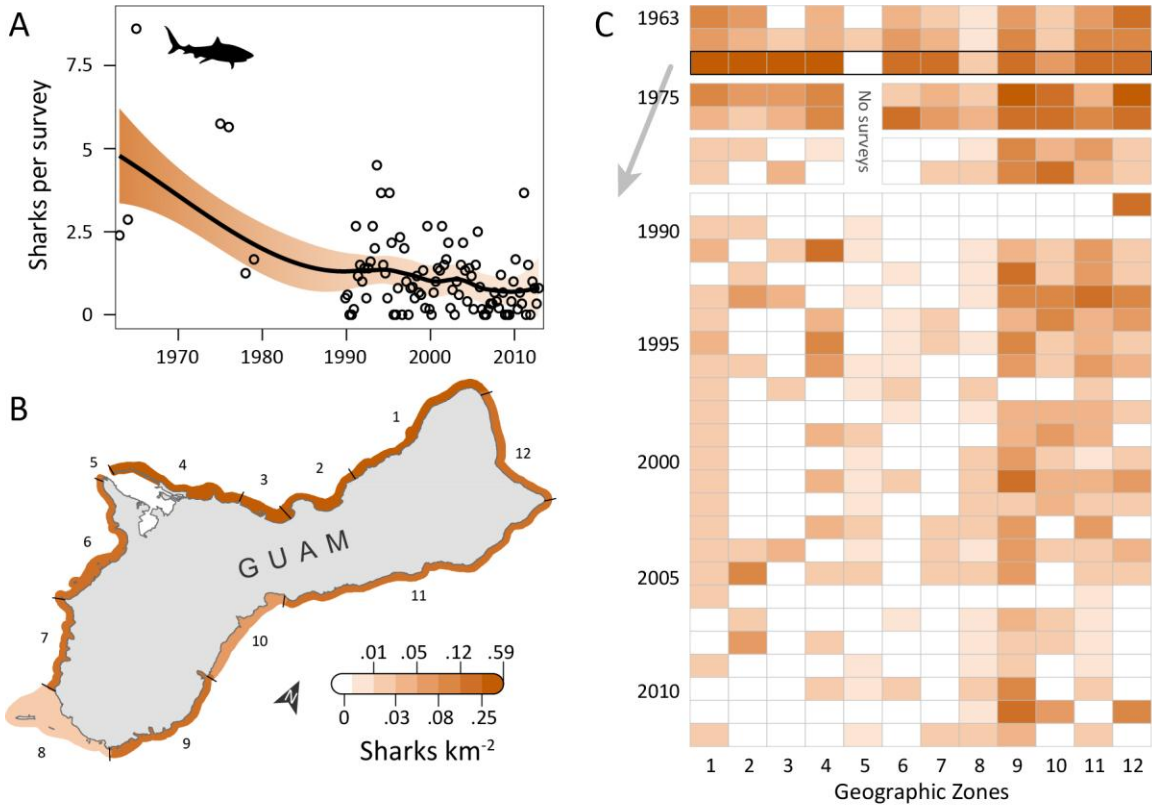

Figure 10. Five-fold decline in reef shark observations around Guam in the last five decades. (A) Trend in shark observations from aerial surveys conducted semimonthly by Guam Division of Aquatic and Wildlife Resources (DAWR). Observations (sharks) per survey (OPS) by year or quarter are indicated by open circles. Smooth trend line and shaded 95% confidence interval are from a LOESS model fit. Since 1963, mean population growth rate (PGR) was - 0.03 (SD = 0.04, CV = 138%). (B) Map of observed densities for 1965, when annual OPS was highest; densities were particularly high for western zones 1-4, especially compared to densities there in later years. (C) After 1976, west coast observations became sporadic and densities generally decreased. On the east coast (zones 9-11), densities were high through the 1990s, then decreased slightly, but remained generally higher than west coast densities. No surveys occurred in zone 5 in 1975-1979 due to military restrictions.

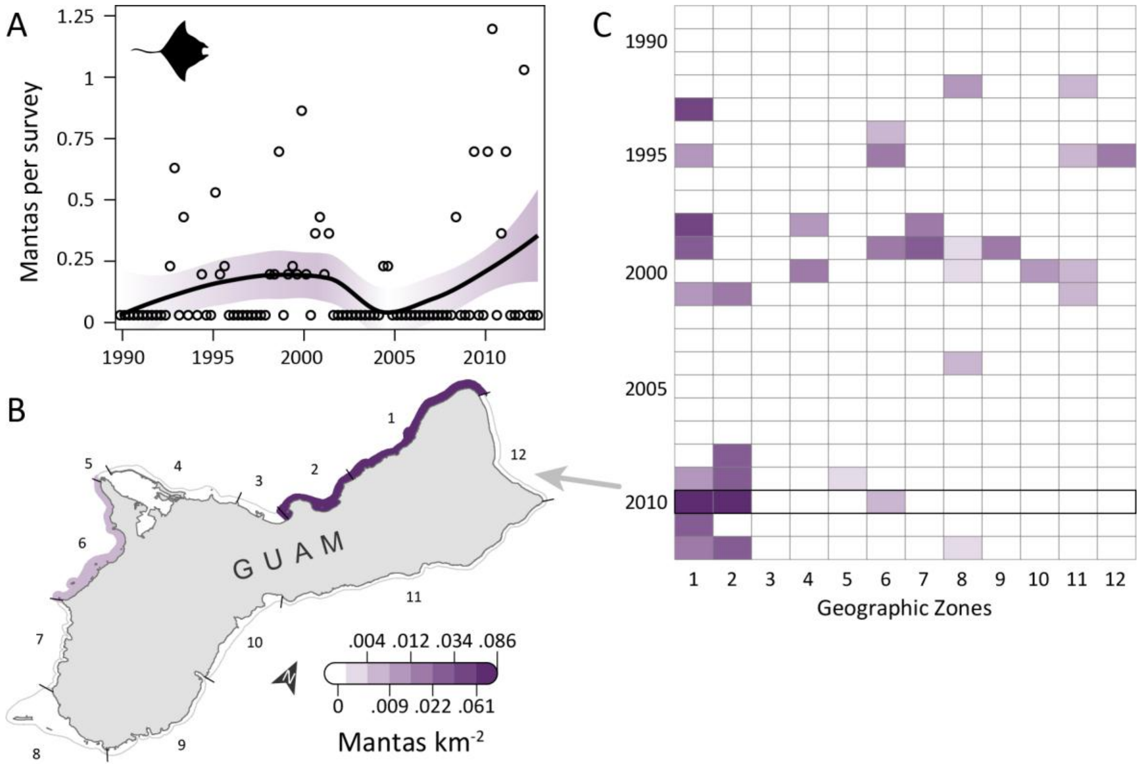

Figure 11. Infrequent, increasingly aggregated manta ray observations on Guam's reefs since 1989. (A) Trend in manta ray observations from semimonthly aerial surveys conducted by Guam Division of Aquatic and Wildlife Resources (DAWR). Observations (manta rays) per survey (OPS) by quarter are depicted with open circles. LOESS model fit with shaded 95% confidence interval suggests observations became slightly more common over time. Mean population growth rate (PGR) was 0.19 (SD = 0.61, CV = 321%), but should be viewed with caution due to the low number of observations. (B) Map of observed densities for 2010, the year with the highest annual OPS; densities were high in the northwest (zones 1-2) and low elsewhere. (C) Since 2008, most observations were in the northwest, with a few sightings in the southwest (zones 5, 6, and 8).

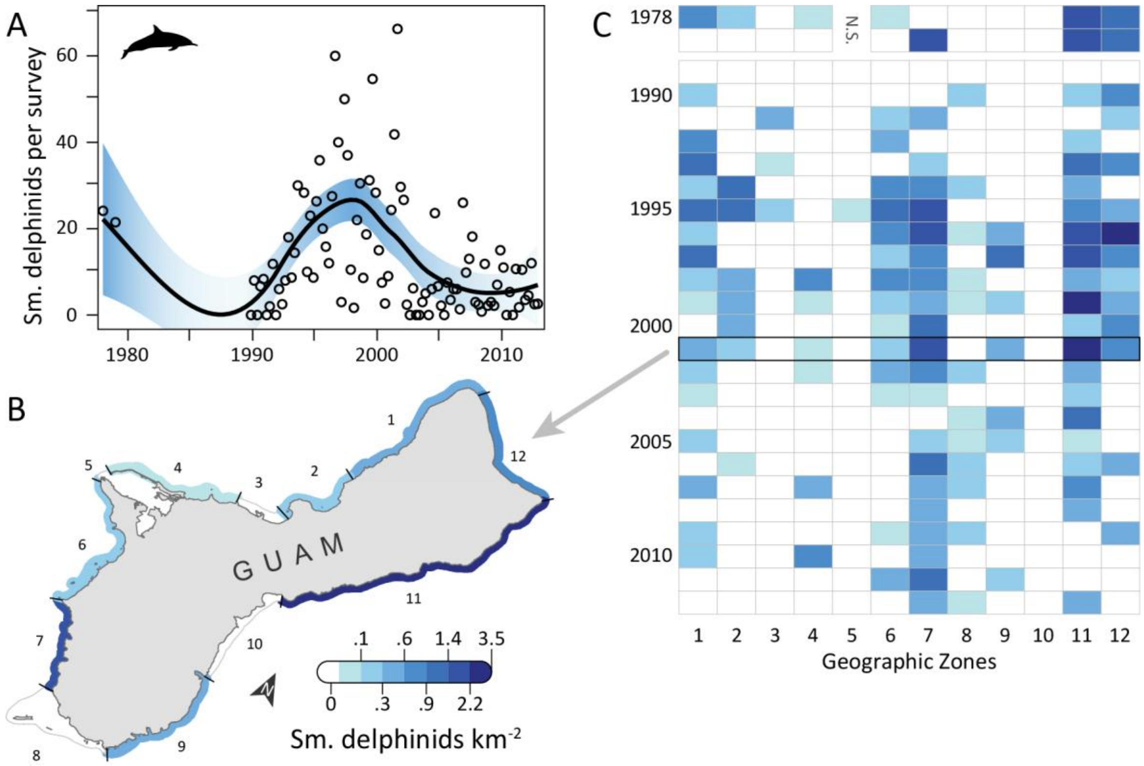

Figure 12. Fluctuating trend in small delphinid observations around Guam since 1978. (A) Trend in small delphinid observations from semimonthly aerial surveys conducted by Guam Division of Aquatic and Wildlife Resources (DAWR). Open circles are observations (individuals) per survey (OPS) by year or quarter. LOESS model fit with shaded 95% confidence interval shows that observations were highly variable over the time series. Correspondingly, mean observation growth rate (OGR) was negative in 1978-1989 (mean = -0.22, SD = 0.06, CV = 28%) and 1999-2009 (mean = -0.15, SD = 0.07, CV = 44%) and positive in 1990-1998 (mean = 0.35, SD = 0.30, CV = 87%) and 2010-2012 (mean = 0.06, SD = 0.03, CV = 52%). (B) Map of observed densities for 2001, the year with the highest annual OPS. Density was highest in zone 11 and lowest in zones 3, 5, 8 and 10. (C) The highest, most widespread positive densities were observed throughout the 1990s and early 2000s. Densities decreased over time in zones 1, 2, 6, 11 and 12. Observations were rare in zones 3-5, and never occurred in zone 10. Military restrictions prohibited surveys in zone 5 in 1978-1979.

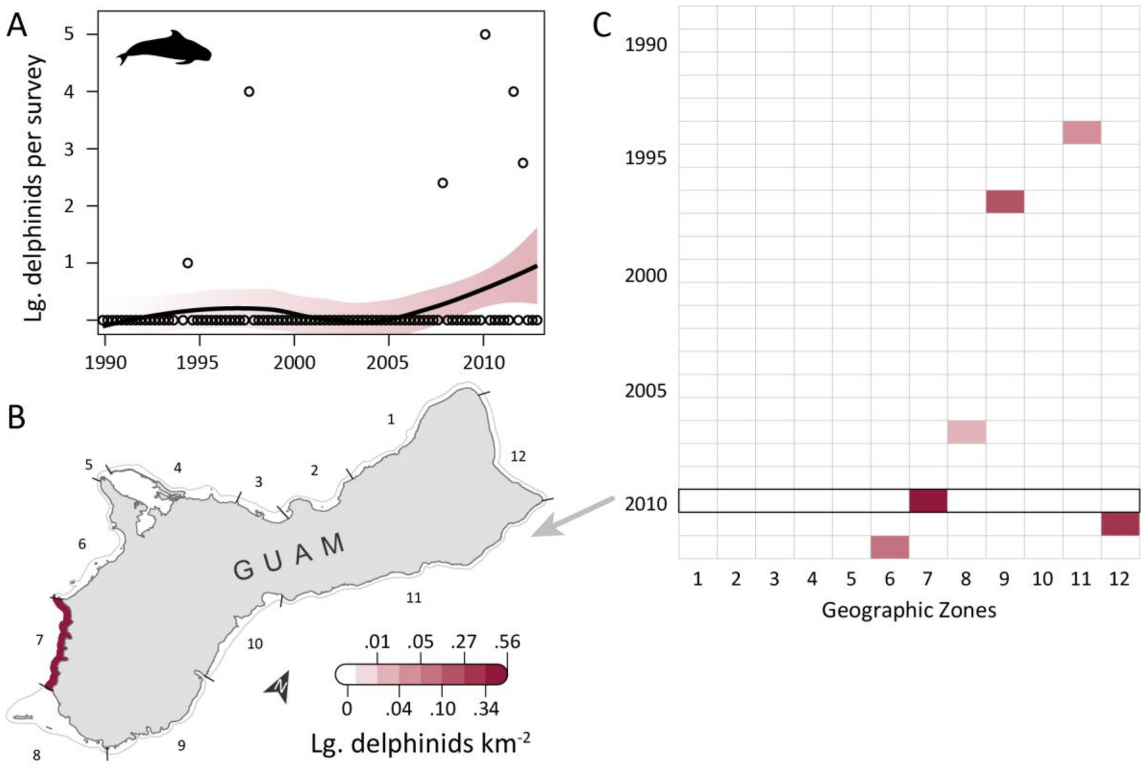

Figure 13. Rare, possibly increasing observations of large delphinids in coastal waters of Guam since 1989. (A) Trend in large delphinid observations from aerial surveys conducted semimonthly by Guam Division of Aquatic and Wildlife Resources (DAWR). Open circles indicate quarterly observations (individuals) per survey (OPS). Smoothed line and shading are from a LOESS model fit with 95% confidence interval. Observations were rare, with no large delphinids recorded in 75% of survey years. (B) Map of observed densities for 2010, the year with the highest OPS. Density was positive in the southwest (zone 7), but zero elsewhere. (C) No large delphinids were observed in zones 1-5 along the west coast or in zone 10 on the east coast. Large delphinids were recorded in a maximum of one zone per year (zones 6-9 and 11-12). Sightings appear to be more frequent since 2007.

Table 1. Capture data for marine turtles within the Marianas Archipelago during 2013 and 2014 small boat surveys. Date is ChST, latitude is decimal degrees north, longitude is decimal degrees east. "SCL" is the straight carapace length of each turtle. Turtle sex is listed as undetermined ("U") or male ("M").

Date	Species	Type	Capture Location	Capture Longitude	Capture Latitude	Attachments	ARGOS_ID	SCL (cm)	Mass (kg)	sex	turtle ID	fliper tag (LFF)	fliper tag (RFF)	PIT (LHF)	PIT (RHF)
8/15/2013	Green	Observation		144.66799515300	13.24887234700										
8/15/2013	Green	Observation		144.66791829100	13.25150242060										
8/15/2013	Green	Observation		144.66479150600	13.25433986260										
8/15/2013	Green	Observation		144.66200008100	13.25620391440										
8/15/2013	Green	Observation		144.66017492100	13.25830685040										
8/15/2013	Green	Observation		144.65898335000	13.25780217510										
8/16/2013	Green	Observation		144.65540612100	13.25184851030										
8/16/2013	Green	Observation		144.65664169800	13.25282642590										
8/16/2013	Green	Observation		144.66838415700	13.25049701090										
8/18/2013	Green	Capture	Balisa, Saipan	145.70035000000	15.19910000020	SPLASH	85491	60.9	32.5	U	CM08182013CN50.9	RI08566	RI08565	982.000149990073	n/a
8/18/2013	Hawksbill	Capture	Balisa, Saipan	145.70110000000	15.20226666690	SPLASH	85496	66.6	34.0	U	EI08182013CN66.6	RI08560	RI08561	982.000150012839	n/a
8/19/2013	Green	Capture	Balisa, Saipan	145.69785000000	15.20548333320	SPLASH	85495	66.1	39.1	U	CM08192013CN66.1	RI08563	RI08552	982.000153675029	n/a
8/19/2013	Green	Capture	Balisa, Saipan	145.69831666600	15.21189999960	SPLASH	85494	60.4	30.2	U	CM08192013CN60.4	RI01207	RI01208	982.000153662662	n/a
8/20/2013	Hawksbill	Capture	Fleming Pt., Tinian	145.58096666700	15.01610000030	SPLASH	85493	61.7	27.5	U	EI08202013CN61.7	RI08553	RI08558	982.000149986359	n/a
8/21/2013	Green	Capture	Balisa, Saipan	145.69923333400	15.20161666660	SPLASH	85492	62.5	34.6	U	CM08212013CN62.5	RI01351	RI01352	982.000153662001	n/a
7/15/2014	Green	Observation		144.67053686400	13.24770230650										
7/15/2014	Green	Observation		144.67125686300	13.24750630650										
7/15/2014	Green	Observation		144.67116186400	13.25235430700										
7/15/2014	Green	Observation		144.65846786400	13.25813030630										
7/15/2014	Green	Observation		144.65918386500	13.25795730640										
7/15/2014	Green	Observation		144.65915586400	13.25523430670										
7/16/2014	Green	Observation		144.65002987500	13.44509029360										
7/16/2014	Green	Observation		144.64933087500	13.44390329280										
7/16/2014	Green	Capture	Apra Harbor, Guam	144.64334687500	13.44372129340	SPLASH	131991	58.3	26.66	U	CM07162014GM58.3	PI1028	PI1029	982.000167824346	982.000167776941
7/16/2014	Green	Capture	Apra Harbor, Guam	144.63833487500	13.44401029320			47.3	13.78	U	CM07162014GM47.3	PI1030	PI1031	982.000167772196	982.000167771931
7/16/2014	Green	Capture	Apra Harbor, Guam	144.63224087600	13.44541329410			53.5	19.54	U	CM07162014GM53.5	PI1037	missing flipper	982.000167827186	n/a
7/16/2014	Green	Observation		144.63208087600	13.44501629380										
7/16/2014	Green	Observation		144.62931887600	13.44717429350										
7/16/2014	Green	Capture	Apra Harbor, Guam	144.62061087600	13.44982329420	SPLASH	131994	49.2	16.14	U	CM07162014GM49.2	PI1035	PI1036	982.000167772276	982.000167799783
7/16/2014	Green	Observation		144.61872087700	13.44938929400										
7/16/2014	Green	Observation		144.65633487300	13.40919929500										
7/16/2014	Green	Capture	Apra Harbor, Guam	144.64916087300	13.41250529640	SPLASH	131998	64.3	32.08	U	CM07162014GM64.3	PI1034	PI1033	982.000167777159	982.000167772316
7/16/2014	Green	Observation		144.64530587300	13.41542929540										
7/16/2014	Green	Capture	Apra Harbor, Guam	144.64898987300	13.41215329540	SPLASH	131990	54.3	20.3	U	CM07162014GM54.3	PI1051	PI1032	982.000167792000	982.000167850045
7/17/2014	Green	Observation		144.65147487300	13.40853829600										
7/17/2014	Green	Observation		144.65879687200	13.40769029560										
7/17/2014	Hawksbill	Capture	Apra Harbor, Guam	144.65425187300	13.40994929540			42.3	7.62	U	EI07172014GM42.3	PI1071	PI1076	982.000190720929	982.000190220237
7/17/2014	Green	Capture	Apra Harbor, Guam	144.65250487200	13.41075829590			50.1	16.9	U	CM07172014GM50.1	PI1078	PI1079	982.000190724529	982.000190219933
7/17/2014	Green	Capture	Apra Harbor, Guam	144.65248387300	13.41073929590			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7/17/2014	Green	Capture	Apra Harbor, Guam	144.64877187300	13.41265329600	SPLASH	131997	55.2	24.48	U	CM07172014GM55.2	PI1085	PI1084	982.000190685832	982.000190657337
7/17/2014	Green	Observation		144.64807987300	13.41251229580										
7/17/2014	Green	Capture	Apra Harbor, Guam	144.64514087400	13.41588129560	SPLASH	138961	66.0	40.7	U	CM07172014GM66.0	PI1086	PI1082	982.000167777401	982.000167769582
7/17/2014	Green	Observation		144.63216487600	13.45943829330										
7/17/2014	Green	Observation		144.62524187700	13.45517129440										
7/17/2014	Green	Observation		144.64206887500	13.44380829380										
7/17/2014	Green	Capture	Apra Harbor, Guam	144.63531487600	13.44433829400	SPLASH	138960	58.6	26.72	U	CM07172014GM58.6	PI1088	PI1089	982.000167832019	982.000190686081
7/17/2014	Green	Observation		144.63485187500	13.44453729420										
7/18/2014	Green	Capture	Apra Harbor, Guam	144.63920000000	13.44380000030	SPLASH	138965	59.3	24.46	U	CM07182014GM59.3	PI1095	PI1096	982.000190220432	982.000190550517
7/18/2014	Green	Capture	Apra Harbor, Guam	144.64130000000	13.44510000000			49.7	14.62	U	CM07182014GM49.7	PI1099	PI1100	982.000167845961	982.000167846072
7/18/2014	Green	Capture	Apra Harbor, Guam	144.63980000000	13.44399999960			48.8	15.9	U	CM07182014GM48.8	PI1098	PI1097	982.000167777299	982.000167777349
7/21/2014	Green	Capture	Dumpcoke, Tinian	145.59638333400	15.05216666710			49.1	17.3	U	CM07212014CN49.1	RI11221	RI11220	982.000190546954	n/a
7/21/2014	Hawksbill	Capture	Fleming Pt., Tinian	145.58181666700	15.01580000000	SPLASH	138963	72.3	48.9	M	EI07212014CN72.3	RI11218	RI11217	982.000167825272	n/a
7/21/2014	Green	Capture	Fleming Pt., Tinian	145.58181666700	15.01586666670			46.6	13	U	CM07212014CN46.6	RI11219	RI11216	982.000167843811	n/a
7/21/2014	Green	Capture	Fleming Pt., Tinian	145.58176666700	15.01591666630	SPLASH	138959	54.3	20.5	U	CM07212014CN54.3	RI11215	RI11214	982.000167831575	n/a
7/21/2014	Hawksbill	Capture	Fleming Pt., Tinian	145.58170000000	15.01726666650	SPLASH	131989	58.1	21.3	U	EI07212014CN58.1	RI11213	RI11212	982.000167836199	n/a
7/21/2014	Green	Capture	Fleming Pt., Tinian	145.58170000000	15.01726666650			47.8	14.6	U	CM07212014CN47.8	RI11211	RI11210	989.001000126187	n/a
7/21/2014	Green	Capture	Dumpcoke, Tinian	145.59233333300	15.03846666660			37.2	6.6	U	CM07212014CN37.2	RI11209	RI11208	989.001000126213	n/a
7/22/2014	Green	Capture	Spot Light, Saipan	145.82586666700	15.27820000020	SPLASH	131995	61.7	35.4	U	CM07222014CN61.7	RI11205	RI11204	989.001000126251	n/a
7/22/2014	Green	Capture	Cow Town, Saipan	145.81815000000	15.28648333360	SPLASH	138958	63.9	36	U	CM07222014CN63.9	RI11207	RI11206	989.001000126236	n/a

Supplementary Material:

1) Text file: PACFLEET_Turtle_Surveys_2013-2014.txt

   Includes all survey tracks from the 2013 and 2014 field seasons throughout the Marianas Archipelago.

2) Text file: PACFLEET_Turtle_Satellite_Data_2013-2014.txt

   Includes all raw x,y location data from Wildlife Computers SPLASH400 Satellite tags. Below table provides interpretation of the location classes for Argos derived locations and GPS locations.

Class	Type	Estimated error*		Number of messages received per satellite pass	
		Least Squares	Kalman Filter	Least Squares	Kalman Filter
G	GPS	< 100 m		1 message or more	
3	Argos	< 250 m		4 messages or more	
2	Argos	250 m < < 500 m		4 messages or more	
1	Argos	500 m < < 1500 m		4 messages or more	
0*	Argos	> 1500 m		4 messages or more	
A	Argos	No accuracy estimation	Unbounded accuracy estimation	3 messages	
B	Argos	No accuracy estimation	Unbounded accuracy estimation	messages	1 or 2 messages
Z	Argos	Invalid location (available only for Service Plus/Auxiliary Location Processing)			