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Conservation considerations revealed by the movements of post-nesting green turtles from the Republic of the Marshall Islands*

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Abstract— In 2007, five adult female green turtles (*Chelonia mydas*) nesting at Erikub Atoll, Republic of the Marshall Islands (RMI), were satellite tagged and tracked to various parts of the Pacific. The turtles' travels ranged between approximately 2800 and 6900 km and showed different behaviors – directed travel and pelagic travel. The turtles traveled through multiple Exclusive Economic Zones (EEZs) in both the North and South Pacific and final positions were recorded near Palawan Island, Philippines; Tarawa, Republic of Kiribati; Bikini Atoll, RMI; South of Pohnpei, Federated States of Micronesia, and pelagic waters east of Mili Atoll, RMI. This study shows the international connectivity of green turtles nesting in this area and the results can be used to exchange information and enhance regional conservation efforts between nations that share these endangered and culturally important turtle resources.

Introduction

Conserving living marine resources is an important part of the multicultural group of people of the Pacific Islands. In the Republic of the Marshall Islands (RMI) sea turtles are legally used for food and have significant cultural and natural resource importance (Tobin 1952, FFA, Rudrud et al. 2007). The Republic of the Marshall Islands comprises 24 atolls located in the North Pacific (Figure 1). The main nesting sites for green turtles are on the atolls of Bikar, Jemo, and Erikub. There is also nesting on other northern RMI atolls; however, there is little information on nesting populations in the Marshall islands (Kabua and Edwards 2010). At Ulithi Atoll, Federated States of Micronesia (FSM) located west of RMI, returns from a flipper tagging program and satellite tracking of post-nesting turtles indicated travels from Ulithi, mainly north and west to southern

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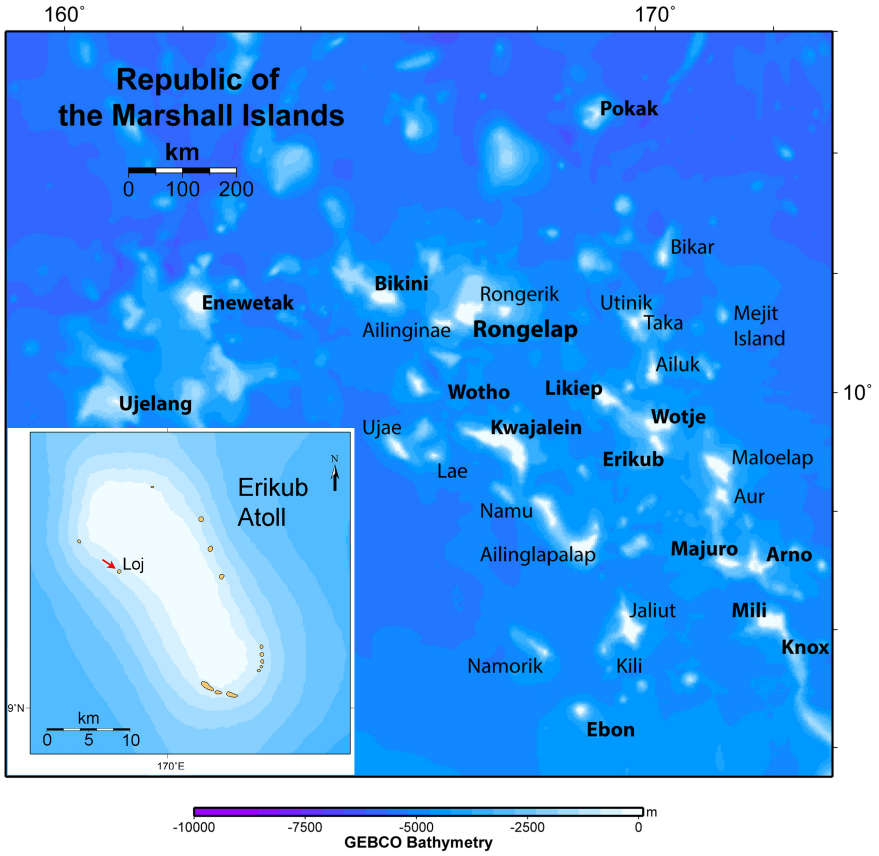

Figure 1. Map of Republic of the Marshall Islands – major atolls labeled. Inset map of Erikub Atoll, Republic of the Marshall Islands. Loj island, the nesting site where turtles were satellite-tagged, is indicated by red arrow.

Ryukyu Islands of Japan and the Philippines (Kolinski et al. 2014). Since a regular flipper tagging program has not been established in RMI, satellite transmitters were deployed on RMI turtles to learn about the distribution of the green turtles that nest on atolls in that area. The main questions we were interested in answering were: Would the turtles 1) travel short distances and stay within the RMI group of atolls like Hawaiian green turtles (Balazs 1994, Balazs & Ellis 1996) or 2) travel through international waters similar to post-nesting migrations like those seen from the Ulithi, FSM tracks (Kolinski et al. 2014) and post-nesting satellite tracking from Rose Atoll, American Samoa (Craig et al. 2004).

Materials and Methods

Study Area

Erikub Atoll is an uninhabited coral atoll approximately 8.5 km south of Wotje Atoll in the RMI. The atoll covers an area of 230 km^2 and consists of six small islands with a total land area of approximately 1.5 km^2 (Figure 1, inset). The nesting area within the atoll was located on Loj (9° 9.497' N 169° 56.761' E). Loj is roughly 0.1 km^2 in size and mostly covered in vegetation with a sand and coral rock beach rimming the north, south and east sides of the island.

PROCEDURES

Telonics, Inc. (Mesa, Arizona) ST-20 model A-1010 ARGOS-linked satellite transmitters were attached to the carapaces of five adult female green turtles nesting on Loj, Erikub Atoll during July 23-24, 2007; attachment was done with polyester surfboard resin and fiberglass using a protocol similar to Balazs et al. (1996). Curved carapace length (CCL) was measured to the nearest 0.1 cm and Inconel alloy flipper tags were applied to each turtle.

Duty cycle for each transmitter was programmed as 6 hrs on, 48 hrs off. Positional and location accuracy data were collected and processed using Least square analysis by Argos and provided by email to the authors (CLS-America, Inc. 2008, Boyd & Brightsmith 2013). Decisions for determining an unacceptable, therefore excluded, position were based on the following criteria: 1) a position was located on land once the turtles left Erikub, 2) the speed traveled between two locations was over 5 km/hr, or 3) two adjacent positions during the 6-hr collection period created a turn angle greater than 90 degrees. Distance traveled was computed using the best daily location and the great circle equation with the WGS84 ellipsoid (Bowditch 1995, Wessel & Smith 1998). Speed (km hr-1) was calculated as the distance traveled between adjacent positions divided by the time spent traveling that distance. Speed over the total track was averaged, and the mean speed of transit was recorded. When available, Location Codes (LC) of 1, 2, or 3 were used for distance and speed calculations; when unavailable, distance and speed were calculated using positions closest to noon UTC (Coordinated Universal Time) after unacceptable positions had been removed. The final location or end point of a track was determined either by the last Argos position or when positional locations clustered in one general area for more than 1 month. The earliest date at an end point was considered the end date for distance and speed calculations. The satellite tag also transmitted percent time underwater.

Results

The five satellite-tagged turtles, ranging in size from 96.2 – 105.4 cm CCL, stayed near Erikub Atoll for up to 54 days following tag deployment before leaving the atoll (Figure 2, Table 1). The total duration of the satellite tags ranged from 162 to 345 days. The mean speed of travel for the turtles ranged between 0.8 and 2.0 km hr-1(Table 1). When transmitters stopped, only 3 turtles, ID 40703, 40728, and 40719, had spent time in nearshore habitats (within 2 km), with times ranging from 13-196 days (Table 1). All tags recorded a range of 75-98% time spent underwater throughout the life of the tag, with average time underwater between75-95% when pelagic and 90-98% when in neritic habitat (PIFSC unpub. data). Due to the limited amount of data, a test of statistical significance for the percent time spent underwater between pelagic and neritic was not done.

Turtle Loj2 (ID 40719) migrated westward to the Philippines (Figure 3). After Loj2 left Erikub, she spent 95 days traveling west across the Pacific through the Commonwealth of the Northern Mariana Islands (CNMI) passing north of Saipan, before reaching the coast of the Philippines. Loj2 then spent 48 days traveling along the coast of Luzon Island, through the San Bernardino Strait and the Sibuyan and Sulu Seas to stop near Palawan Island. Turtle Loj1 (ID 40728) traveled to Tarawa, Republic of Kirbati (Figure 4), spending 73 days traveling south through the Ratak group of RMI and Northern Kiribati getting there. The other three turtles had extended pelagic residency and all traveled south through the Ratak group of RMI and into the Republic of Kiribati before traveling to different areas. Both Loj3 and Loj4 (ID 40703 and 40605, respectively) spent time in the South Pacific. Loj3 spent 163 days traveling in the North and South Pacific before the transmitter ended after 13 days near Bikini Atoll (Figure 5). Loj4 spent 115 days traveling before ending 100 km south of Pohnpei, FSM (Figure 6). The track for turtle Loj5 (ID 40702) ended east of the islands of RMI and Republic of Kiribati in pelagic waters after 229 days at sea (Figure 7, Table 1).

Table 1. Data for five adult female green turtles deployed 23-24 July 2007 and satellite tracked from Loj, Erikub Atoll, Republic of the Marshall Islands.

Argos ID	Flipper Tags - Other ID	Curved Carapace Length, cm	Final Date	Final Location	Travel Distance km	Speed of Travel km/hr	Days at Erikub	Days Pelagic	Days at Final Location	Total Days Transmitting
40728	R31201 R31202 "Loj1"	100.0	3/13/08	Tarawa, Kiribati 1.5N 173.0E	2,795	1.6	43	73	118	234
40719	R31203 R31204 "Loj2"	105.4	7/2/08	Palawan, Philippines 10.8N 119.2E	6,935	2.0	54	95	196** (148)	345
40703	R31205 R31206 "Loj3"	96.2	2/24/08	Bikini, RMI 11.5N 165.4E	6,739	1.7	38	164	13	215
40605	R31207 R31208 "Loj4"	99.9	12/23/07	Pohnpei, FSM 5.8N 158.3E	4,039	1.5	47	115	0	162
40702	R31209 R31210 "Loj5"	100.5	8/27/08	East of RMI 6.6N 179.2E	4,212	0.8	49	229	0	278

** Total days spent traveling near shore along the coast of the Philippines – 148 of these were spent near Palawan Island.

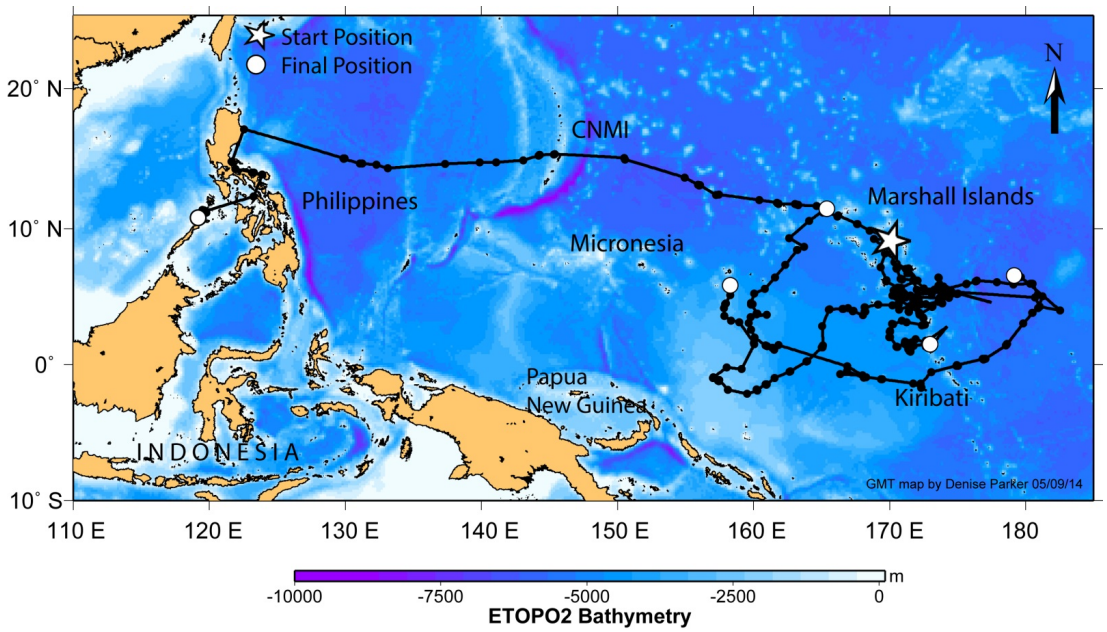

Figure 2. 2007-2008 post-nesting movement of five green turtles from Erikub Atoll, Republic of the Marshall Islands.

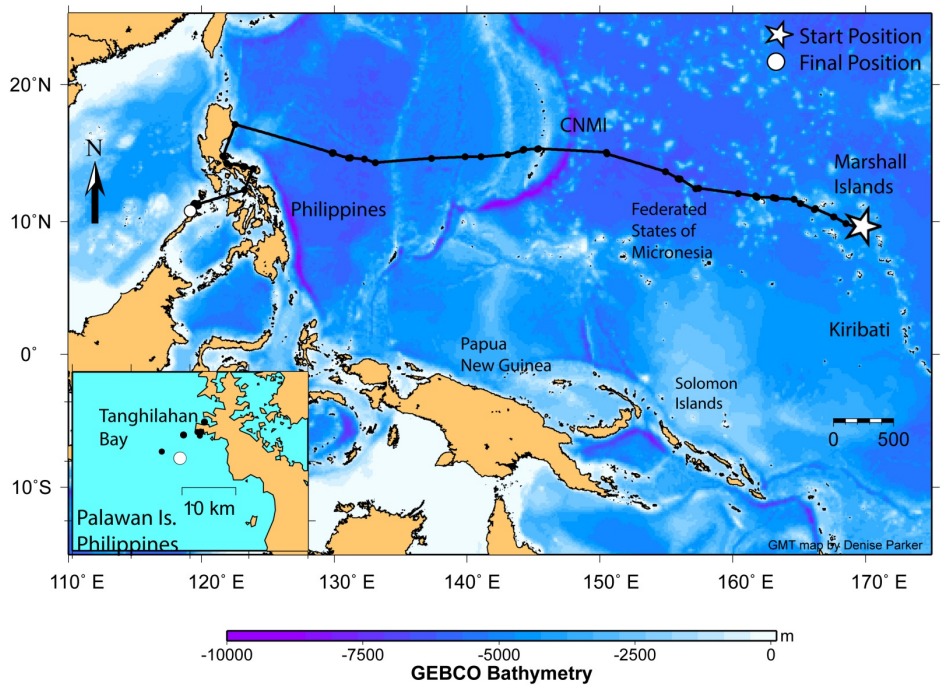

Figure 3. 2007-2008 post-nesting movement of a 105 cm CCL green turtle ID 40719, “Loj2”, from Erikub Atoll, Republic of the Marshall Islands to Palawan Island, Philippines. Loj2 traveled a total distance of 6,935 km, in the 345 days the satellite tag transmitted.

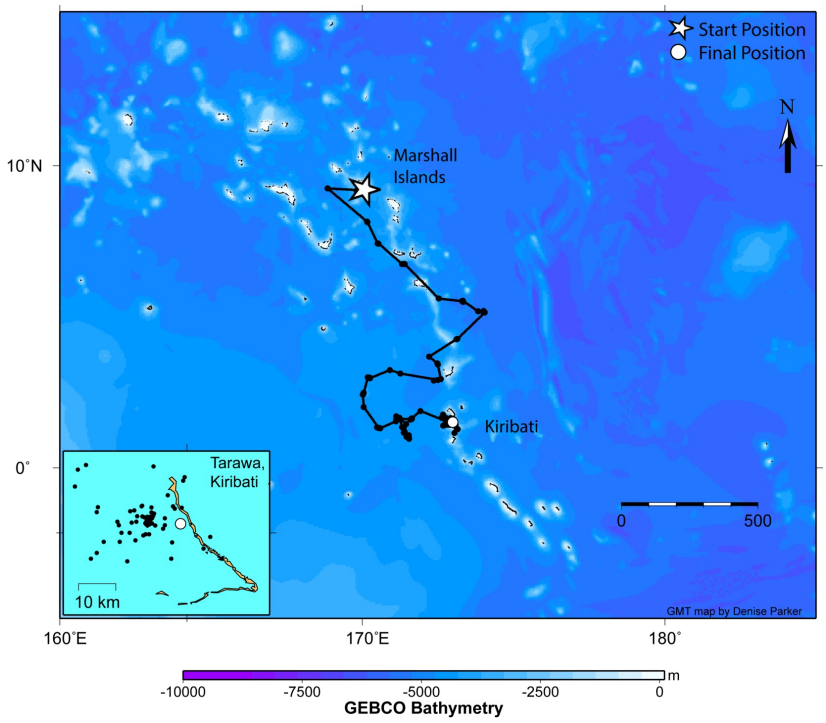

Figure 4. 2007-2008 post-nesting movement of a 100 cm CCL green turtle ID 40728, "Loj1", from Erikub Atoll, Republic of the Marshall Islands to Tarawa, Kiribati. Loj1 traveled a total distance of 2,795 km, in the 234 days the satellite tag transmitted.

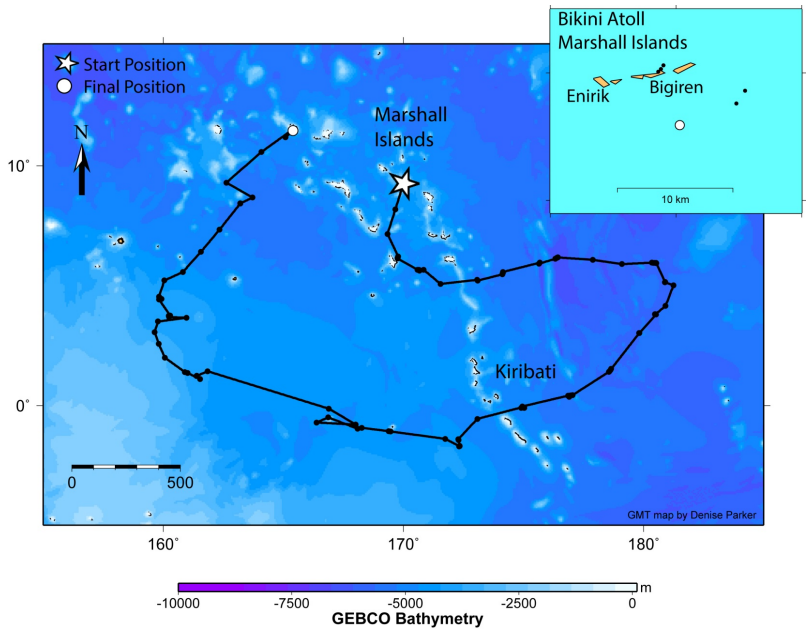

Figure 5. 2007-2008 post-nesting movement of a 96 cm CCL green turtle ID 40703, "Loj3", from Erikub Atoll, Republic of the Marshall Islands to the southern islands of Bikini Atoll. Loj3 traveled a total distance of 6,739 km, in the 215 days the satellite tag transmitted.

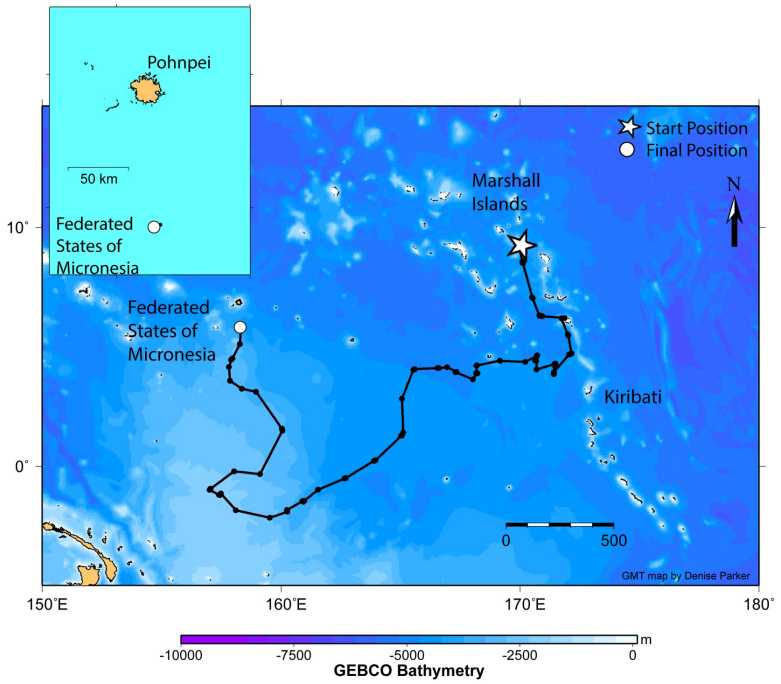

Figure 6. 2007 post-nesting movement of a 100 cm CCL green turtle ID 40605, "Loj4", from Erikub Atoll, Republic of the Marshall Islands to Pohnpei, Federated States of Micronesia. Loj4 traveled a total distance of 4,039 km, in the 162 days the satellite tag transmitted.

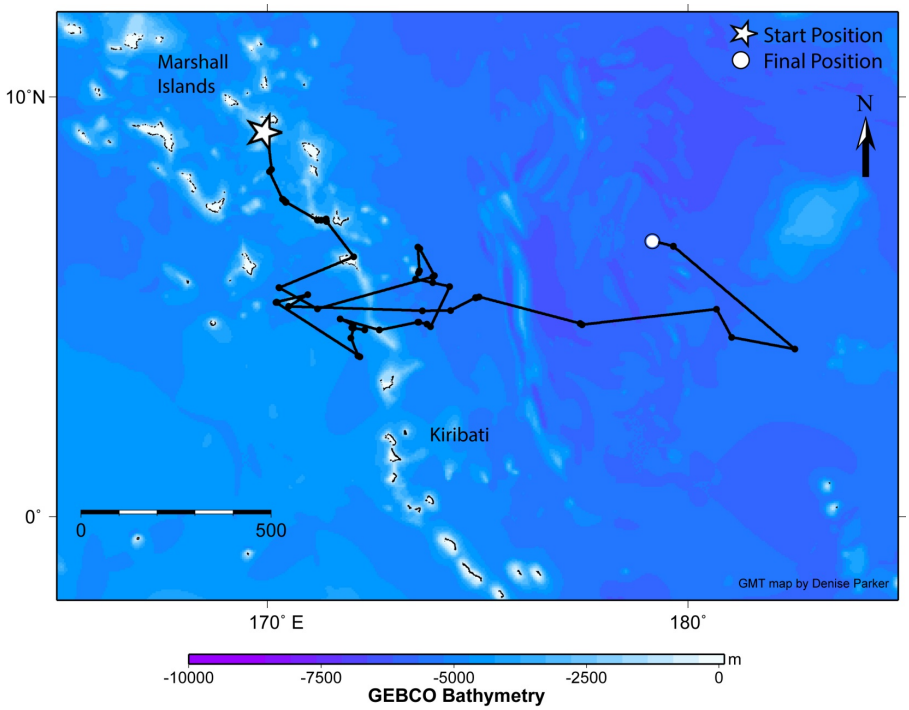

Figure 7. 2007-2008 post-nesting movement of a 101 cm CCL green turtle ID 40702, "Loj5", from Erikub Atoll, Republic of the Marshall Islands to pelagic waters east of Erikub. Loj5 traveled a total distance of 4,212 km, in the 278 days the satellite tag transmitted.

Discussion

The movements of the five satellite tracked RMI nesters highlight the international range of green turtles in the Western Pacific as they traveled through the nations of RMI, Republic of Kiribati, FSM, and the Philippines as well as the US territory of CNMI and international waters. The post-nesting turtles showed two distinct patterns of travel: 1) directed travel toward a neritic foraging area and 2) extended pelagic residency with little time spent in neritic habitat. Two turtles traveled directly to neritic areas and settled into potential foraging areas. Turtle Loj2 traveled directly to the Philippine Islands and moved along the coastline of Luzon Island to get to Palawan Island where the turtle spent 6 months before the tag stopped transmitting (Figure 3). While Philippine laws protect sea turtles, the area of the South China Sea around Palawan is a contested area and sea turtles are subject to illegal harvest from this area (Yotsukura 2012, Sun.Star 2014, Yeh et al. 2014). The tag on Loj2 stopped likely due to battery exhaustion. Turtle Loj1 traveled directly to Tarawa, an important atoll in Kiribati and home 50,182 people as of 2010, approximately half of the total human population of Kiribati (Wikipedia 2015). Kiribati is an island nation that legally protects sea turtles and their eggs throughout their waters. Loj1 spent four months on the slopes of western reef edge of Tarawa (Figure 4) and its tag also likely stopped due to battery exhaustion.

Two turtles, Loj3 and Loj4, spent more than 3 months traveling throughout the Pacific before the transmitters stopped near neritic foraging areas (Figure 5 and 6). It is interesting to note that both of these turtles crossed the equator spending time traveling through both South Pacific and North Pacific waters. The turtle Loj5 stayed pelagic for over 200 days (Figure 7). We suggest that perhaps this pelagic behavior is similar to the pelagic behavior noted in other green turtles near Japan and the East Pacific green turtle (Hatase et al. 2006, Senko et al. 2010, Seminoff & Zárate 2008), and stable isotope studies should be done to confirm pelagic foraging behavior in this population. While turtles that spend more time in pelagic waters may be vulnerable to international fishing pressure due the extended time they are spending in the open ocean traveling through the different island nations, those turtles settling into neritic foraging areas may be more vulnerable to fishing pressure due constant interaction with local small-scale coastal fisheries. Kolinski et al. (2014) suggests that outreach is needed to raise awareness of turtles as a shared resource in the international community and we feel our data support this suggestion showing variability in the behavior of the green turtles that nest in RMI. More research on the nesting populations of RMI is also needed as Erikub is only one small area where nesting occurs and the study of turtles nesting on other atolls could increase understanding of movement and habitat use of the green turtle within the Marshall Islands and the Western Pacific.

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