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Movements of Green Turtles (*Chelonia mydas*) Rescued from Pound Nets Near Jeju Island, Republic of Korea

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Abstract. – Green turtles (*Chelonia mydas*) are observed year-round in the Sea of Jeju Island, Republic of Korea; however, there is limited information on their migration and seasonal distribution outside of Korean waters. To investigate their spatial and temporal movement, we tracked 8 green turtles (straight carapace length range, 49.7–85.9 cm; mean ± SD, 63.36 ± 10.99 cm), taken as bycatch in pound nets near Jeju Island, using satellite transmitters from August 2015 to January 2017. Turtles were mainly juveniles and were tracked for 17–314 d. Three turtles traveled more than 400 km from their release site in 2 different directions: one individual moved westward to China within 17 d of release, and 2 individuals traveled eastward to Japan. One turtle that moved to Japan had been flipper-tagged at Kagoshima, Japan, 1 mo prior to its capture at Jeju Island. The other 5 individuals remained near the coast of Jeju Island. The individual tracked for the longest period (314 d) overwintered (water temperature, 12°–14°C) in the eastern area of Jeju Island. These results indicate that green turtles from different regions, including China and Japan, may use the areas around Jeju Island for foraging, for overwintering, and/or as a migratory corridor. To fortify the conservation of green turtles in the region, international cooperation and expanded research efforts, such as genetic studies, are needed.

Key Words. – satellite telemetry; spatial distribution; migration; foraging; conservation

Animals migrate large distances to access resources, such as food, mating partners, and breeding sites, or to survive under better conditions (Hoare 2009). Most sea turtles are known to undertake long-distance migration, traveling hundreds to thousands of kilometers between their nesting and foraging sites; they also conduct seasonal movements to avoid cold waters during winter months (Mortimer and Carr 1987; Papi et al. 1995; Luschi et al. 1996, 1998; Hughes et al. 1998; Polovina et al. 2004). Satellite tracking is one of the main methods used to monitor the distribution, movement, and habitat use of animals over large areas. In sea turtles, like many marine vertebrates, satellite tracking studies have provided critical information on habitat use (Godley et al. 2002), migration (Hughes et al. 1998), and foraging behavior (Balazs 2017) over spatiotemporal scales.

The green turtle, *Chelonia mydas*, is listed as endangered on the International Union for Conservation of Nature Red List (IUCN 2016), except for the Hawaiian population, which is listed as least concern. The species is distributed widely in tropical and subtropical areas of the Pacific, Atlantic, and Indian oceans. In the Indo-Pacific region, there are 17 genetically discrete subpopulations (Moritz et al. 2002), including those in Southeast and East Asian countries, such as Taiwan (Cheng 2000), Malaysia (Dethmers et al. 2006), and Japan (Okuyama et al. 2009). The largest rookery in the northwest Pacific is in the Ogasawara archipelago, Japan (Abe et al. 2003; Nishizawa et al. 2011); green turtles from this area migrate to the Pacific side of the Japanese archipelago and the East China Sea, including waters adjacent to the Republic of Korea (Bowen et al. 1992; Cheng 2000). However, only a few studies have been conducted to determine the local movements of sea turtles near the Republic of Korea; their results have been insufficient for assisting long-term conservation planning. Indeed, more information is needed

on sea turtle movements near the Republic of Korea, which has been described as one of the worst countries for both sea turtle research and conservation (Spotila 2004).

Jeju Island, in the South Sea of the Republic of Korea, is geographically located in the temperate zone, covering a latitudinal band at $\sim$ 33°–34°N and a longitudinal band at $\sim$ 126°–127°E. The island is surrounded by the northern part of the East China Sea and is influenced by several currents, including the Kuroshio Current and the Tsushima Warm Current (Ichikawa and Beardsley 2002). According to studies in the Republic of Korea, sea turtle strandings and bycatch were recorded along the eastern and southern coasts, including Jeju Island, an area where most of the sea turtles are observed in the Republic of Korea (Moon et al. 2008; Jung et al. 2012b). Notably, more than 50 pound nets are set around Jeju Island, in which sea turtles are occasionally caught (Jung et al. 2012b).

The green turtle is the most frequently observed sea turtle species at Jeju Island (Moon et al. 2009). However, little is known about this species in Korean waters despite previous satellite tracking studies (Moon et al. 2009, 2011). Moon et al. (2009) tracked an immature green turtle that had been incidentally caught in a pound net in the western area of Jeju Island and reported that this turtle spent the winter months, from November to February, near Jeju Island, where it was released. Moon et al. (2011) also tracked an adult female green turtle caught in a pound net at Geoje Island and released near Busan City on the southern coast of the mainland of the Republic of Korea. The green turtle migrated back to the south coast of the Republic of Korea after visiting Jeju Island and later traveled to Fukuoka Prefecture in Japan.

In this study, the movements of 8 green turtles caught in a pound net near Jeju Island were tracked after their release using satellite telemetry. This study aimed to investigate the distribution and migration routes of green turtles on a spatiotemporal scale and to examine the value of waters near Jeju Island as foraging and wintering areas for green turtles.

METHODS

Eight green turtles that were caught incidentally in nonentangling pound nets in Jeju Island, the Republic of Korea, were tracked from 12 August 2015 to 8 January 2017 (Fig. 2; Table 1). The pound net was approximately a $25 \times 15 \times 10$-m cuboid (Fig. 1). It had an open-trap design with the upper side open to the air; net corners were anchored firmly to minimize fluttering of the net. Turtles accidentally entering the net are generally safe and can breathe freely at the water's surface. Fishers normally check their own net and collect captured fishes every morning. However, in poor weather, the boat cannot access the pound net, and the captured animals, including sea turtles, stay in the net unhurt for the duration of the poor weather. Each turtle was removed from the net and appeared relatively healthy without any visible injuries or obvious signs of disease. Turtles were measured (straight carapace length [SCL] and straight carapace width) to the nearest 0.1 cm with metal forester calipers. Satellite transmitters (Model TAM-2638; Telonics Inc, Mesa, AZ) were attached to the carapace of each turtle with polyester resin and thin layers of fiberglass cloth. Each tag measured $6.6 \times 2.79 \times 1.9$ cm and weighed 49 g. Before applying the fiberglass, we cleaned the carapace using abrasive sandpaper to remove grease and debris, wiped the carapace with isopropyl alcohol to remove natural oils, and then used Silicon Elastomer to properly mount the transmitter (Balazs et al. 1996). Once the resin hardened, turtles were released in the area near their capture sites (Table 1). Seven turtles fitted with transmitters were juveniles, and 1 ($>$ 81 cm SCL) was likely an adult (Balazs 1980; Zug et al. 2002), although further research is needed on Jeju Island to unequivocally determine maturity status in resident turtles.

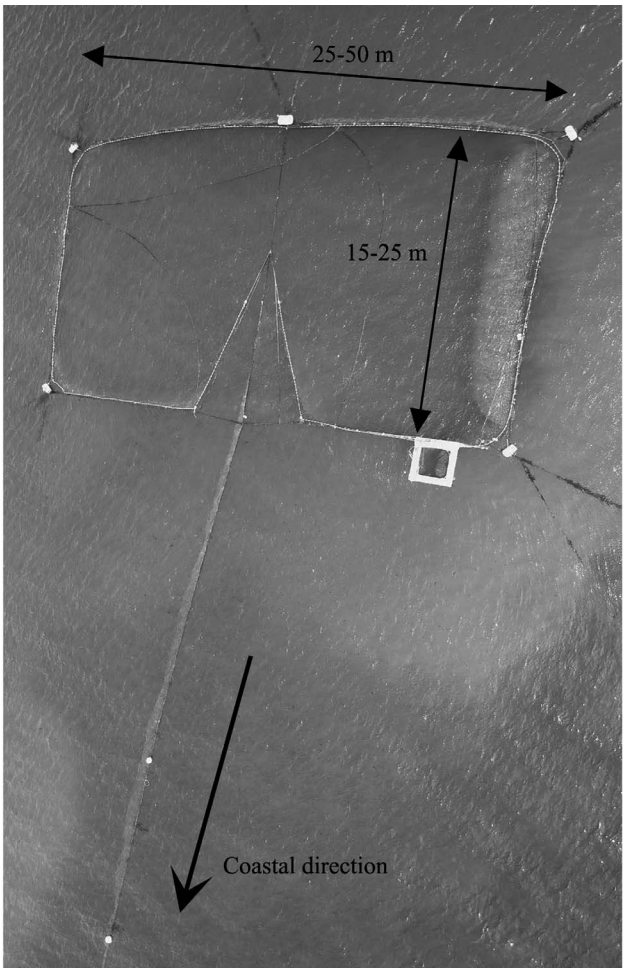

Figure 1. Aerial view of the structure of the pound net that is most commonly used at Jeju Island.

The duty cycle for each transmitter was programmed as 6 hrs on, 24 hrs off. The transmitted data were obtained using the Argos System (CLS America, http://www.clsamerica.com). The Argos system assigns 6 location

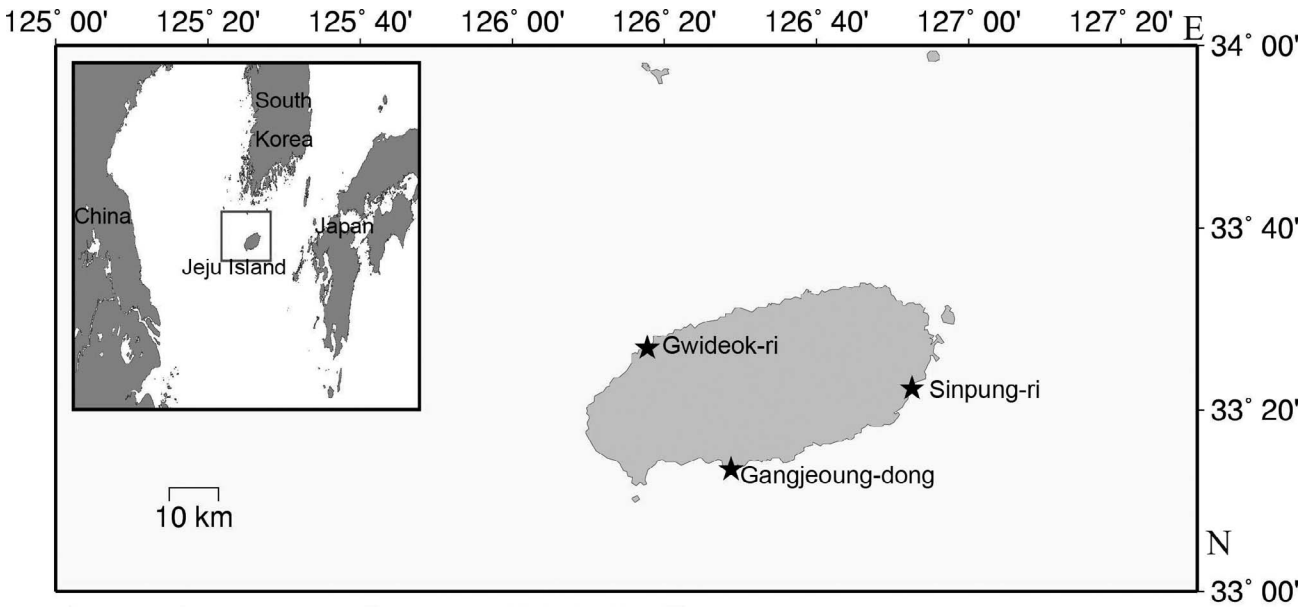

Figure 2. Map of Jeju Island, Republic of Korea, showing the 3 bycatch and release sites of the 8 green turtles that were satellite tracked during this study.

accuracy classes (LC) to indicate the variable accuracy of each location. Positional accuracy was classified into 6 classes by Argos (LC 3, < 250 m; LC 2, within 250–500 m; LC 1, within 500–1500 m; and LC 0, > 1500 m; LC A and LC B, no accuracy estimation; LC Z, invalid location). The location data used were LC 3, 2, 1, 0, A, and B. If 1) positions were located on land or 2) speeds between 2 positions indicated a travel speed of > 5 km/hr, the positions were considered unacceptable (Luschi et al. 1998). If more than 2 positions for an individual were obtained within a day, the data with the most accurate location class were used. The total distance moved by each individual was the sum of the shortest distance between each successive position. The minimum distance traveled was calculated, using the positions with the highest location accuracy level of the day, with the haversine formula (Sinnott 1984). The average travel speed (km/hr) was calculated as the minimum distance traveled between 2 successive positions divided by the time spent traveling between the 2 positions. A map of each individual's movement was created using Maptool (Sea Turtle Inc 2002).

RESULTS

Summaries of the movements of the 8 turtles tracked during this study are shown in Table 2. Two turtles in 2015 and 1 in 2016 were caught incidentally in a pound net in Gwideok-ri in the northern area of Jeju Island (Fig. 2). After release, the first turtle (ID 88060) moved northwest and turned to the south along the western coast of Jeju Island and traveled a minimum distance of 70 km in 50 d. The turtle tagged in 2016 (ID 163603) also moved in a path similar to that of turtle 88060 but was tracked for 145 d and 319 km and moved back and forth along those routes twice. This individual stayed in the southern area of Jeju Island from 4 November 2016 to 8 January 2017, perhaps overwintering due to cold water temperatures (Figs. 3 and 4; Table 2). One turtle (ID 57144) caught in 2015 traveled to the north of Chuja Island located between Jeju Island and the southern part of the mainland of the Republic of Korea. This turtle moved continuously to the north and turned to the west on 18 August 2015, when it reached the area between Jindo and Haenam in the southern part of the Republic of Korea. This turtle moved

Table 1. Summary of 8 satellite-tagged green turtles around Jeju Island, including straight carapace length (SCL) and straight carapace width (SCW).

Capture and release location	ID	Capture date	SCL (cm)	SCW (cm)
Gwideok-ri (lat 33°26′51.8892″N, long 126°17′23.2476″E)	88060	10 Aug 2015	64.6	53.9
	57144	10 Aug 2015	55.1	45.4
	163603	16 Aug 2016	58.5	46.0
Sinpung-ri (lat 33°21′52.7076″N, long 126°52′26.0292″E)	53752	15 Aug 2015	68.4	55.5
	53764	2 Sep 2015	49.7	40.1
	163604	24 Sep 2016	85.9	61.8
Gangjeong-dong (lat 33°13′30.2196″N, long 126°28′31.0188″E)	53759	29 Sep 2015	58.5	46.5
	163602	29 Sep 2016	66.2	57.1

Table 2. Information on the movement of 8 satellite-tagged green turtles.

ID	Release date	Date of last transmission	Movement speed (mean ± SD) (km/hr)	Movement speed (min./max.) (km/hr)	Maximum displacement (km)	Track duration (d)	Total movement distance (km)	Location of last transmission
Turtles traveling eastward to Japan								
53759	03 Oct 2015	26 Dec 2015	1.01 ± 0.01	0.007/2.99	506	84	1393	lat 34°05′13.2000″N, long 129°23′34.8000″E
163604	24 Sep 2016	12 Oct 2016	1.28 ± 0.28	0.15/2.78	295	18	489	lat 31°55′53.7240″N, long 129°26′23.6760″E
Overall (mean ± SD)	—	—	1.11 ± 0.86	0.079 ± 0.10/ 2.99 ± 2.89	—		—	—
One turtle traveling westward to China								
57144	12 Aug 2015	29 Aug 2015	1.12 ± 0.12	0.16/2.11	691	17	514	lat 32°48′39.6000″N, long 122°25′01.2000″E
Turtles staying around Jeju Island								
53752	19 Aug 2015	10 Sep 2015	0.05 ± 0.05	0.009/0.07	40.2	22	36	lat 33°25′44.4000″N, long 126°55′08.4000″E
53764	02 Sep 2015	12 Jul 2016	0.15 ± 0.29	0.001/1.88	6.3	314	581	lat 33°21′28.8000″N, long 126°50′27.6000″E
88060	12 Aug 2015	01 Oct 2015	0.46 ± 0.46	0.05/1.21	24.5	50	70	lat 33°28′58.8000″N, long 125°59′27.6000″E
163602	1 Oct 2016	27 Nov 2016	0.08 ± 0.08	0.05/0.28	29.8	59	124	lat 33°13′36.8760″N, long 126°25′28.0200″E
163603	16 Aug 2016	8 Jan 2017	0.24 ± 0.24	0.0007/1.69	26.5	145	319	lat 33°12′11.3400″N, long 126°18′56.5920″E
Overall (Mean ± SD)	—	—	0.24 ± 0.62	0.045 ± 0.06/ 1.21 ± 0.78	—	—	—	—

514 km in total in 17 d, with a final position approximately 120 km east of Nantong, China (Fig. 3; Table 2).

Three turtles were found in a pound net in Sinpung-ri at the east area of Jeju Island (Fig. 2). Two turtles were captured in 2015, and the other turtle was captured in 2016. The first turtle (ID 53752) stayed near its release point along the shore for 22 d (Figs. 3 and 4) until the last signal was transmitted on 10 September 2015 (Table 1). The other turtle (ID 53764) captured in 2015 stayed near its release area for 37 d. On 9 October 2015, this turtle was recaptured incidentally in the same pound net and was released immediately in the same location. After that, it stayed nearshore in the southeast area of Jeju Island and occasionally moved 10–50 km from the shore prior to returning to the Sinpung area. The greatest displacement of this turtle from the pound net in the Sinpung area was 53 km (Figs. 2 and 3). The cumulative minimum distance traveled was 581 km in 314 d of tracking (Table 2). A turtle caught at the same pound net in 2016 (ID 163604) moved toward Seogwipo City, which is located on the south of Jeju Island. This turtle traveled a total of 229.9 km as of 5 October 2016, reaching Ukusima Island, Japan. It then moved southward along the western side of Nagasaki Prefecture until the last signal was received from waters east of Shimo-Koshiki on 5 October 2016 (Fig. 3). The total distanced traveled by this turtle was 489 km in 18 d (Table 2).

Two turtles were caught in a pound net in Gangjeong-dong, a village in the southern part of Jeju Island between 2015 and 2016 (Fig. 2). After release, 1 turtle (ID 53759) moved to Tsushima Island through the northern area between Hallim port and Biyang Island, to the north of Jeju Island, in 9 d. Subsequently, it traveled to the north of Tsushima Island (115 km), returned to Biyang Island, and then moved to the Kitakushu area of southern Japan. The turtle then moved through the coastal waters and returned to Tsushima Island after reaching the area near Hirado Island (Fig. 3). The turtle traveled at least 1393 km in 84 d, until the last signal was received on 26 December 2015. The other turtle caught in 2016 (ID 163602) moved to Biyang Island off the northern part of Jeju Island and returned to the southern part of Jeju, staying in the waters near Gangjeong-dong until the last signal was received (Figs. 3 and 4; Table 2).

DISCUSSION

The movements of 8 green turtles rescued and released in Jeju Island can be divided into 3 categories: 1) traveling westward to China, 2) traveling eastward to Japan, and 3) staying near Jeju Island. The individual tracked for the longest period overwintered in the area east of Jeju Island.

In previous studies, green turtles tagged in the South Sea or Jeju Island of the Republic of Korea migrated to Japan or stayed around Jeju Island (Moon et al. 2009, 2011). Our study shows similar results to these previous studies. In the present study, 2 turtles moved to Japanese

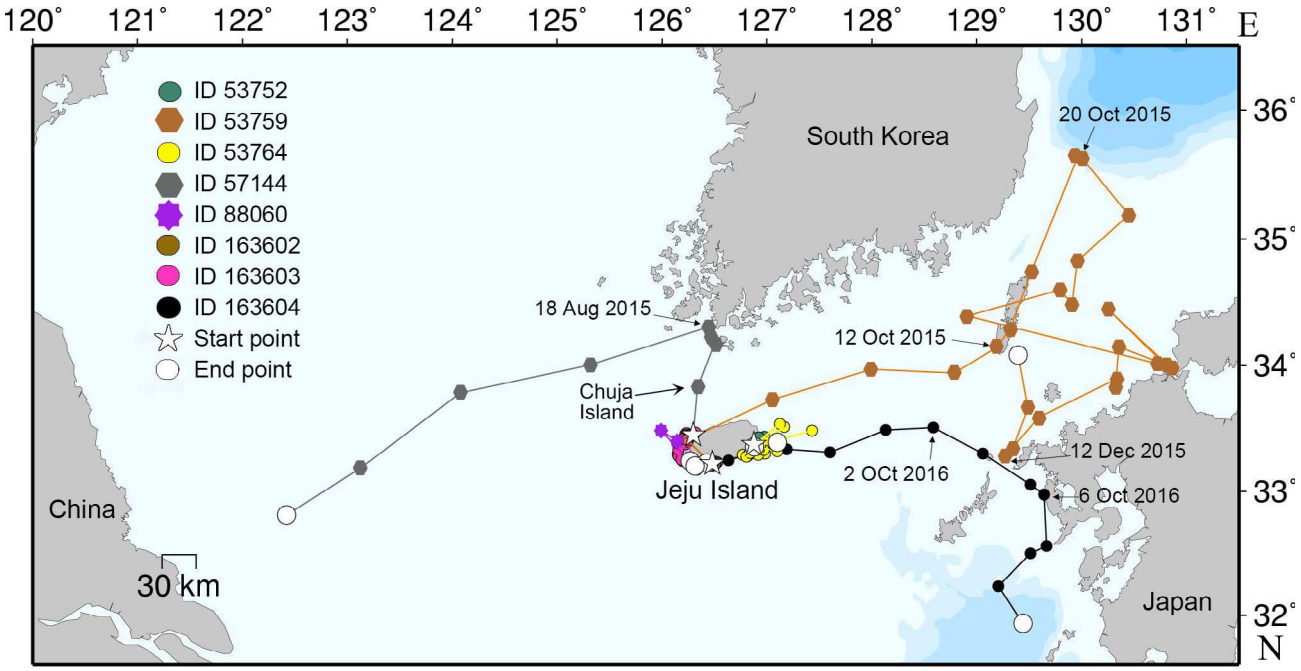

Figure 3. Pathways of 8 green turtles released from 3 separate sites (stars) on Jeju Island, Republic of Korea. Colored circles represent each tracked turtle, white circles represent the end position of each turtle, and solid lines show the movement over 2 consecutive days. (Color version is available online.)

waters, and 5 stayed around Jeju Island. Interestingly, the juvenile green turtle (ID 53759) that was caught in Gangjeong-dong on 29 September 2015 had also been incidentally captured and released on 11 September 2015 in Kagoshima Prefecture, Japan (lat 31°24′38.72″N, long 130°6′43.87″E), which is one of the nesting sites for green turtles in Japan. The turtle moved twice between Japan and Jeju in 3 mo.

In addition to identifying green turtle movements between the Republic of Korea and Japan, our study also tracked a green turtle moving from the Republic of Korea toward China, which to our knowledge is the first report of this sea turtle route. Here, a turtle (ID 57144) traveled toward China via the South Sea of the Republic of Korea within a relatively short period (17 d). Our scope of inference is limited due to sample size; however, these

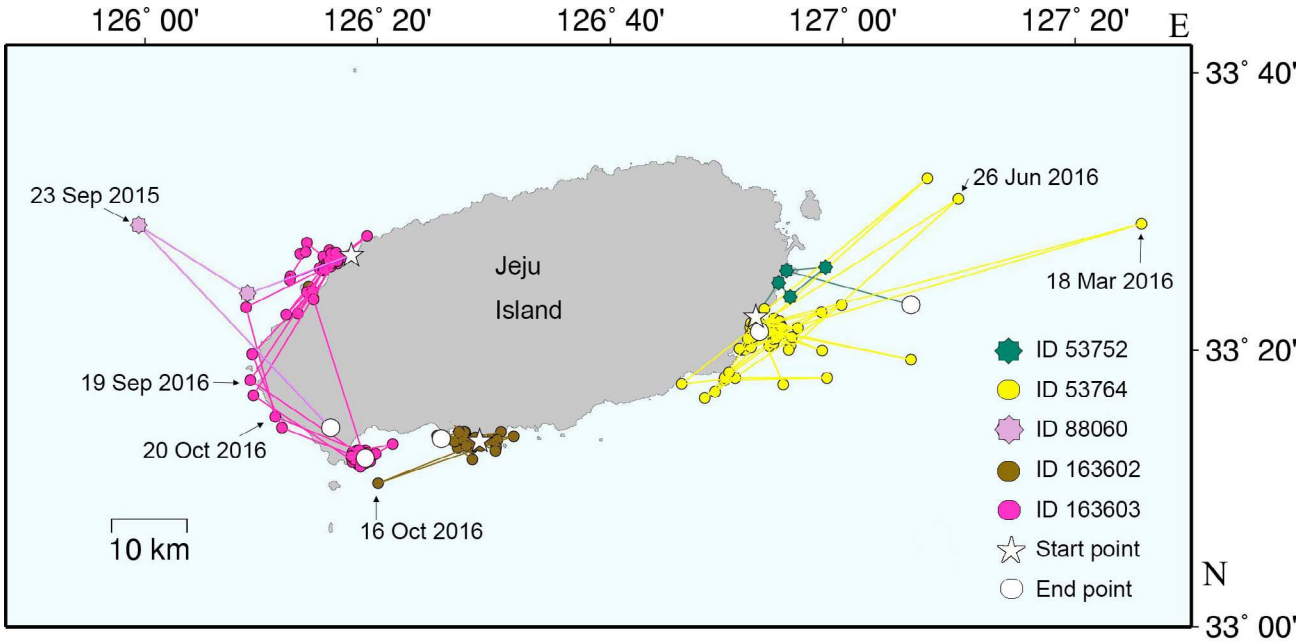

Figure 4. Localized movements of 5 green turtles that resided near the 2 release areas at Jeju Island, Republic of Korea. (Color version is available online.)

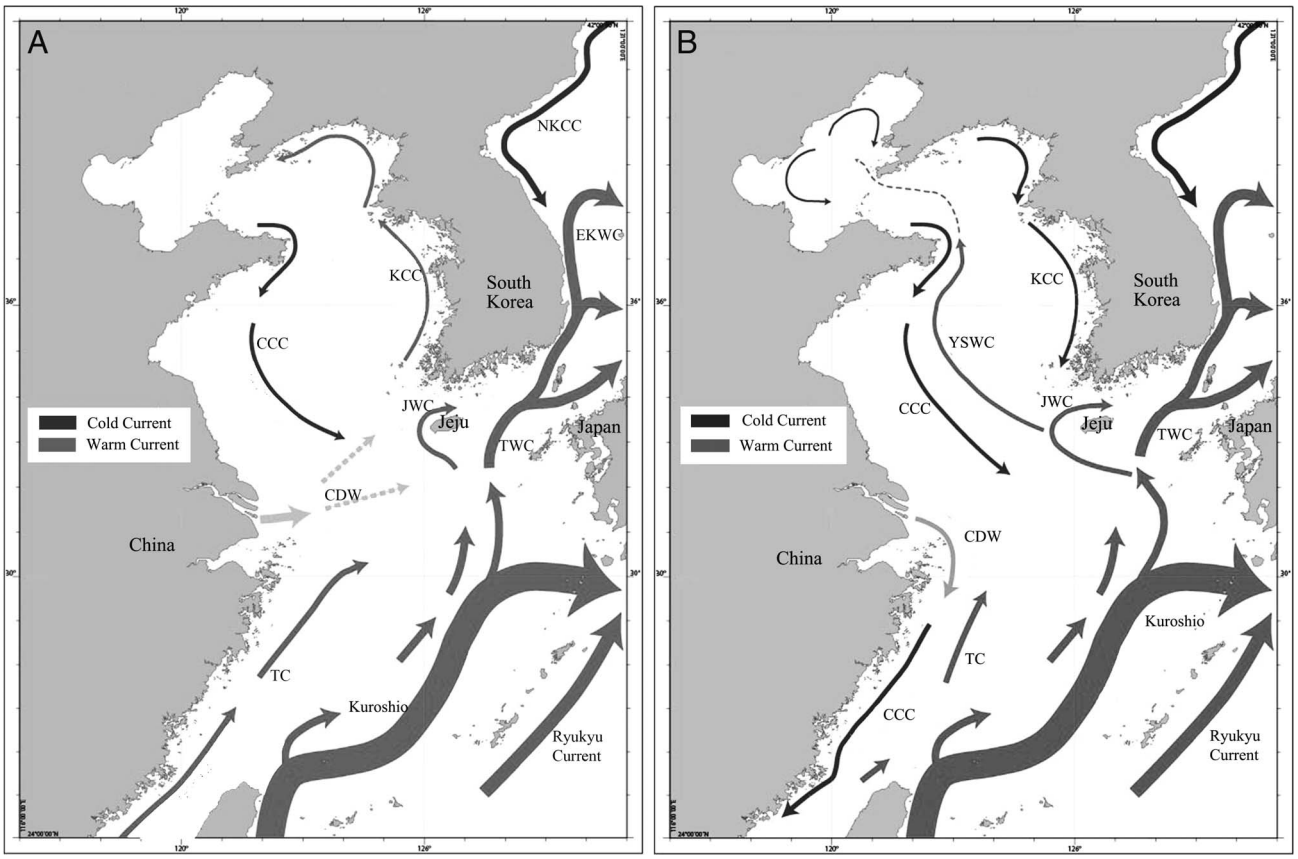

Figure 5. Oceanic currents in the vicinity of the Korean Peninsula. (A) Ocean current in summer and (B) ocean current in winter. CCC = Chinese Coastal Current; KCC = Korean Coastal Current; CDW = Changjiang Discharge Water Flow; JWC = Jeju Warm Current; TC = Taiwan Warm Current; TWC = Tsushima Warm Current; EKWC = East Korea Warm Current; YSWC = Yellow Sea Warm Current; NKCC = North Korean Cold Current. Adapted from Ocean Research Division (2017).

results suggest that green turtles around Jeju Island may originate from regions not only in Japan but also in China. However, the fact that this individual moved in a different direction from individuals in previous research suggests that there may be individuals visiting Jeju Island outside of Japan. This result highlights the necessity for long-term movement and habitat utilization studies of sea turtles observed around Jeju Island.

The rookeries and migration routes of green turtles in the Southeast Asian and western Pacific regions have been inferred using genetic analyses and satellite tagging studies (Bowen et al. 1992; Cheng 2000; Moritz et al. 2002; Hatase et al. 2006; Ng et al. 2014b). Notably, there are green turtle nesting sites at Yaeyama, Ogasawara, and Kagoshima in Japan (Nishizawa et al. 2011), and the Ogasawara archipelago is known as the largest rookery in the northwest Pacific region (Seminoff et al. 2015). According to recent genetic studies, green turtles from the South China Sea were closely related to those from Japan (Yang et al. 2015), and rookeries in Japan are among the primary sources of green turtle foraging in the South China region (Ng et al. 2017). However, Japanese green turtles do not move eastward to the central Pacific or eastern Pacific for foraging (Dutton et al. 2008; Nishizawa et al. 2013). In Taiwan, nesting green turtles migrated to various locations on the continental shelf east of mainland China or moved to Okinawa, Japan (Cheng 2000). This further suggests that the seas of the Korean Peninsula, which are sandwiched between China and Japan, possibly form part of the habitat used by these green turtles. This warrants further studies on the genetic composition of green turtles found in the areas around the Republic of Korea.

Although green turtles are active swimmers during migration, they do benefit from surface currents when migrating over long distances (Luschi et al. 2003; Howell et al. 2010). This also appears to be the case around Jeju Island and the seas around the Republic of Korea, where green turtle movement trajectories appear to overlap with ocean currents (Fig. 5). The Tsushima Warm Current and the Yellow Sea Current flow into the Yellow Sea from the south of Jeju Island (Ichikawa and Beardsley 2002). The Kuroshio Current enters the East China Sea through the strait between Taiwan and Yonagunijima, the easternmost island of the Ryukyu Islands, and flows northeastward along the shelf slope. The Kuroshio Current is an especially important driver to carry green turtles from multiple tropical rookeries to feeding and breeding grounds in the Japanese archipelago, and this influences the composition of consecutive neritic feeding aggrega-

tions of green turtles from the south to the north along the Kuroshio Current (Nishizawa et al. 2013). The movement to foraging grounds for pelagic-stage green turtles in the offshore waters of Keelung, northern Taiwan, is also possibly relevant to the Kuroshio Current (Ng et al. 2014a). This implies that green turtles found around Jeju Island, which migrate from various regions, such as Japan, China, and Southeast Asia from the South China Sea to Jeju Island, could possibly use the Kuroshio Current and Tsushima Warm Current around the East China Sea and the Yellow Sea.

Given the results of the present study, the sea around Jeju Island represents a possible foraging area and/or overwintering site for juvenile and adult green turtles in Asian regions. Five turtles tracked in this study stayed in the waters around Jeju Island for 17–314 d during winter. In the study by Moon et al. (2011), only adult green turtles moved to Japan, and juveniles stayed around Jeju Island. Contrary to those findings, the turtles in the present study moved in various directions. One adult and 1 juvenile ($<$ 60 cm in SCL) traveled to Japan (ID 53759 and ID 163604), and 1 juvenile traveled to China (ID 57144). The different migration patterns could be affected by the maturity status of the individuals (Moon et al. 2011); however, this might also be due to their fidelity to foraging grounds and overwintering sites. Green turtle nesting populations, like other benthic feeders in coastal waters, may access multiple foraging sites over broad regions (Liew et al. 1995; Godley et al. 2002; Hays et al. 2002; Balazs 2017). Foraging site selection is influenced by various factors, such as food resource limitation, territorial defense, facilitation of navigation, and the proximity of good overwintering sites (Hays et al. 2002; Broderick et al. 2007). Green turtles exhibit fidelity to their foraging ground and overwintering site (Limpus et al. 1992). In particular, 6 red algal species were previously identified as the food items of green turtles in Hong Kong in the South China region (Ng et al. 2016). Among them, 4 species are found in the waters around Jeju Island: *Grateloupia filicina*, *Gelidium pusillum*, *Chondrus ocellatus*, and *Gracilaria chorda* (Lee 2008). Macroalgae around Jeju Island, including these 4 species, could be potential food sources for Jeju green turtles.

During the winter, the mean sea surface temperatures around Jeju Island range from 12°C to 14°C (Ko et al. 2003). This area represents a transitional region between the temperate and subtropical zones, and tropical fish and invertebrates are found (Lee and Shah 2012). Previous records indicate that some beaches were used as nesting places for sea turtles (Moon et al. 2009; Jung et al. 2012a).

In Jeju Island, more than 50 pound nets are set within 200–300 m from the shore. The structures of the pound nets at Jeju Island are similar to those used in Japan, Taiwan, China, and other various locations throughout Asia. They have an especially wide internal area (maximum trap size: 60 × 30 × 15-m cuboid), and the surface is open, similar to Japanese pound nets in Mie, Kochi, and Kagoshima prefectures. The mesh of the nets is small (generally from 24 to 43 mm), and lines and nets anchor tightly. Sea turtles are at risk of entrapment in these fishing devices, but mortality is believed to be low in open-trap designs (Gilman et al. 2010). Because fishers drag the net up to the surface but do not tighten the open surface while they collect the fish in the net, sea turtles do not die of entanglement and forced submergence. Additionally, people in Jeju Island do not consume the meat or products of sea turtles and immediately release captured sea turtles from the pound net. For these reasons, sea turtles that die in pound nets are rarely reported. Hence, the possibility remains that turtles caught in pound nets die but are not reported. Although there are reports on the frequent capture of sea turtles in pound nets in Jeju Island (Jung et al. 2012b; Jang et al. 2016), these reports could not cover all bycatch cases in pound nets around Jeju Island. Thus, more research should be conducted in the future to quantify bycatch by pound nets and assess the impact of pound nets on the sea turtle population around Jeju Island.

The foraging areas of tracked animals such as sea turtles could be used as indicators of habitats worthy of protection (Scott et al. 2012). The studies on habitat use and migration using satellite telemetry can also help elucidate interactions between sea turtles and their marine environments. For the conservation of green turtles, which travel hundreds of kilometers between their nesting and foraging sites, intensive monitoring and ecological studies on this species in the Korean Peninsula should be conducted with national and international cooperation.

Our study contributes to the understanding of the movements and foraging site usage of East Asia subpopulations of green turtles. These results suggest that green turtles from different regions, such as China and Japan, may share the foraging area around Jeju Island during their lives. In previous studies, green turtles were observed from the east coast to the south around Jeju Island (Moon et al. 2008; Jung et al. 2012b), which is in accordance with the tracking results in this study. However, here we expand this view and show that green turtles are also present along the western shores of Jeju Island. Although this information is important for management purposes, we are pursuing genetic studies to determine the source rookery of the green turtles present near Jeju Island. Ultimately, such information will be useful for the conservation of sea turtles around Jeju Island and the broader East Asia.

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LITERATURE CITED

ABE, O., SHIBUNO, T., TAKADA, Y., HASHIMOTO, K., TANIZAKI, S., ISHII, H., FUNAKURA, Y., SANO, K., AND OKAMURA, Y. 2003. Nesting populations of sea turtle in Ishigaki Island, Okinawa. Proceedings on the 4th SEASTAR2000 Workshop, pp. 40–43.

BALAZS, G.H. 1980. Synopsis of biological data on the green turtle in the Hawaiian Islands. NOAA Tech. Memor. NMFS-NOAA-SWFC-7. US Department of Commerce.

BALAZS, G.H. 2017. Ocean pathways and residential foraging locations for satellite tracked green turtles breeding at French Frigate Shoals in the Hawaiian Islands. Micronesica 2017-04: 1–19.

BALAZS, G.H., MIYA, R.K., AND BEAVERS, S. 1996. Procedures to attach a satellite transmitter to the carapace of an adult green turtle, *Chelonia mydas*. NOAA Tech. Memor. NMFS-SEFSC-537, pp. 21–26.

BOWEN, B.W., MEYLAN, A.B., ROSS, J.P., LIMPUS, C.J., BALAZS, G.H., AND AVISE, J.C. 1992. Global population structure and natural history of the green turtle (*Chelonia mydas*) in terms of matriarchal phylogeny. Evolution 46:865–881.

BRODERICK, A.C., COYNE, M.S., FULLER, W.J., GLEN, F., AND GODLEY, B.J. 2007. Fidelity and over-wintering of sea turtles. Proceedings of the Royal Society of London B: Biological Sciences 274:1533–1539.

CHENG, I.-J. 2000. Post-nesting migrations of green turtles (*Chelonia mydas*) at Wan-an Island, Penghu Archipelago, Taiwan. Marine Biology 137:747–754.

DETHMERS, K.E., BRODERICK, D., MORITZ, C., FITZSIMMONS, N.N., LIMPUS, C.J., LAVERY, S., WHITTING, S., GUINEA, M., PRINCE, R.I., AND KENNETT, R. 2006. The genetic structure of Australasian green turtles (*Chelonia mydas*): exploring the geographical scale of genetic exchange. Molecular Ecology 15:3931–3946.

DUTTON, P.H., BALAZS, G.H., LEROUX, R.A., MURAKAWA, S.K., ZARATE, P., AND MARTNEZ, L.S. 2008. Composition of Hawaiian green turtle foraging aggregations: mtDna evidence for a distinct regional population. Endangered Species Research 5:37–44.

GILMAN, E., GEARHART, J., PRICE, B., ECKERT, S., MILLIKEN, H., WANG, J., SWIMMER, Y., SHIODE, D., ABE, O., AND PECKHAM, S.H. 2010. Mitigating sea turtle by-catch in coastal passive net fisheries. Fish and Fisheries 11:57–88.

GODLEY, B., RICHARDSON, S., BRODERICK, A., COYNE, M., GLEN, F., AND HAYS, G. 2002. Long-term satellite telemetry of the movements and habitat utilisation by green turtles in the Mediterranean. Ecography 25:352–362.

HATASE, H., SATO, K., YAMAGUCHI, M., TAKAHASHI, K., AND TSUKAMOTO, K. 2006. Individual variation in feeding habitat use by adult female green sea turtles (*Chelonia mydas*): are they obligately neritic herbivores? Oecologia 149:52–64.

HAYS, G., BRODERICK, A., GODLEY, B., LOVELL, P., MARTIN, C., MCCONNELL, B., AND RICHARDSON, S. 2002. Biphasal long-distance migration in green turtles. Animal Behaviour 64:895–898.

HOARE, B. 2009. Animal Migration: Remarkable Journeys in the Wild. Berkeley: University of California Press.

HOWELL, E.A., DUTTON, P.H., POLOVINA, J.J., BAILEY, H., PARKER, D.M., AND BALAZS, G.H. 2010. Oceanographic influences on the dive behavior of juvenile loggerhead turtles (*Caretta caretta*) in the North Pacific Ocean. Marine Biology 157: 1011–1026.

HUGHES, G., LUSCHI, P., MENCACCI, R., AND PAPI, F. 1998. The 7000-km oceanic journey of a leatherback turtle tracked by satellite. Journal of Experimental Marine Biology and Ecology 229:209–217.

ICHIKAWA, H. AND BEARDSLEY, R.C. 2002. The current system in the Yellow and East China Seas. Journal of Oceanography 58: 77–92.

INTERNATIONAL UNION FOR CONSERVATION OF NATURE (IUCN). 2016. The IUCN Red List Of Threatened Species. http://www.iucnredlist.org/details/4615/0 (9 September 2016).

JANG, S., KIM, M.Y., KIM, T., BALAZS, G.H., PARKER, D.M., KO, H., AND KIME, B.-Y. 2016. Sea turtle monitoring and tracking in the sea of Jeju Island, Republic of Korea in 2015. KOFFST International Conference, pp. 347–347.

JUNG, M., MOON, D., KIM, S., KIM, H., AND KIM, J. 2012a. Environmental conditions as accidental nesting place of seaturtle located in Jeju Island of Korea. Journal of Fisheries and Marine Sciences Education 24:507–515.

JUNG, M., MOON, D., KIM, S., KIM, H., AND KIM, J. 2012b. Observation and record of sea turtles in bycatch and stranding from Jeju Island of Korea. Journal of Fisheries and Marine Sciences Education 24:662–669.

KO, J., KIM, J., KIM, S., AND RHO, H. 2003. Fluctuation characteristic of temperature and salinity in coastal waters around Jeju Island. Korean Journal of Fisheries and Aquatic Sciences 36:306–316.

LEE, J. AND SHAH, M.M.R. 2012. Study of benthic dinoflagellates and monitoring. Harmful Algae News 46:3–4.

LEE, Y. 2008. Marine Algae of Jeju. Seoul: Academybook.

LIEW, H.C., CHAN, E.H., LUSCHI, P., AND PAPI, F. 1995. Satellite tracking data on Malaysian green turtle migration. Rendiconti Lincei 6:239–246.

LIMPUS, C., MILLER, J., PARAMENTER, C., REIMER, D., MCLACHLAN, N., AND WEBB, R. 1992. Migration of green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles to and from Eastern Australian rookeries. Wildlife Research 19:347–357.

LUSCHI, P., HAYS, G., DEL SEPPIA, C., MARSH, R., AND PAPI, F. 1998. The navigational feats of green sea turtles migrating from Ascension Island investigated by satellite telemetry. Proceedings of the Royal Society of London B: Biological Sciences 265:2279–2284.

LUSCHI, P., HAYS, G.C., AND PAPI, F. 2003. A review of long-distance movements by marine turtles, and the possible role of ocean currents. Oikos 103:293–302.

LUSCHI, P., PAPI, F., LIEW, H., CHAN, E., AND BONADONNA, F. 1996. Long-distance migration and homing after displacement in the green turtle (*Chelonia mydas*): a satellite tracking study. Journal of Comparative Physiology A 178:447–452.

MOON, D., AN, Y., JUNG, M., KIM, S., CHOI, S., LEE, H., YOO, J., AND KIM, M. 2011. Satellite tracking of green sea turtles *Chelonia mydas* in Korean waters. Korean Journal of Fisheries and Aquatic Sciences 44:709–716.

MOON, D., HWANG, S., LEE, H., AND YOO, J. 2008. Strandings of sea turtles on Korean shores. Proceedings of 2008 Joint Conference of Korean Association of Ocean Science and Technology Societies, pp. 457–460.

MOON, D., JUNG, M., AN, Y., CHOI, S., OH, B., KIM, Z., LEE, C., KIM, M., AND KIM, S. 2009. Distribution and strandings of endangered sea turtles in Korean waters. Korean Journal of Fisheries and Aquatic Sciences 42:657–663.

MORITZ, C., BRODERICK, D., DETHMERS, K., FITZSIMMONS, N., AND LIMPUS, C. 2002. Population genetics of Southeast Asian and Western Pacific green turtles, *Chelonia mydas*. Final report to UNEP/CM0053, pp. 1–42.

MORTIMER, J.A. AND CARR, A. 1987. Reproduction and migrations of the Ascension Island green turtle (*Chelonia mydas*). Copeia 1987:103–113.

NG, C.K., ANG, P.O., RUSSELL, D.J., BALAZS, G.H., AND MURRHY, M.B. 2016. Marine macrophytes and plastics consumed by green turtles (*Chelonia mydas*) in Hong Kong, South China Sea region. Chelonian Conservation and Biology 15:289–292.

NG, C.K.Y., CHEN, T.H., AND BALAZS, G.H. 2014a. Flying fish egg harvest off Keelung, Taiwan uncovers occurrence of pelagic-phase green turtles. Marine Turtle Newsletter 14.

NG, C.K.Y., DUTTON, P.H., CHAN, S.K.F., CHEUNG, K.S., QIU, J.W., AND SUN, Y.N. 2014b. Characterization and conservation concerns of green turtles (*Chelonia mydas*) nesting in Hong Kong, China. Pacific Science 68:231–243.

NG, C.K.Y., DUTTON, P.H., GU, H.X., LI, T.H., YE, M.B., XIA, Z.R., DUAN, J.X., HSU, C.K., BALAZS, G.H., AND MURPHY, M.B. 2017. Regional conservation implications of green turtle (*Chelonia mydas*) genetic stock composition in China. Chelonian Conservation and Biology 16(2):139–150.

NISHIZAWA, H., ABE, O., OKUYAMA, J., KOBAYASHI, M., AND ARAI, N. 2011. Population genetic structure and implications for natal philopatry of nesting green turtles *Chelonia mydas* in the Yaeyama Islands, Japan. Endangered Species Research 14: 141–148.

NISHIZAWA, H., NAITO, Y., SUGANUMA, H., ABE, O., OKUYAMA, J., HIRATE, K., TANAKA, S., INOGUCHI, E., NARUSHIMA, K., KOBAYASHI, K., ISHII, H., TANIZAKI, S., KOBAYASHI, M., GOTO, A., AND ARAI, N. 2013. Composition of green turtle feeding aggregations along the Japanese Archipelago: implications for changes in composition with current flow. Marine Biology 160:2671–2685.

OCEAN RESEARCH DIVISION. 2017. Schematic current map around Korea. Korea Hydrographic and Oceanographic Agency. http://www.khoa.go.kr/koofs/kor/seawf/sea_wflow.do?menuNo=02&link=.

OKUYAMA, J., ABE, O., NISHIZAWA, H., KOBAYASHI, M., YOSEDA, K., AND ARAI, N. 2009. Ontogeny of the dispersal migration of green turtle (*Chelonia mydas*) hatchlings. Journal of Experimental Marine Biology and Ecology 379:43–50.

PAPI, F., LIEW, H., LUSCHI, P., AND CHAN, E. 1995. Long-range migratory travel of a green turtle tracked by satellite: evidence for navigational ability in the open sea. Marine Biology 122: 171–175.

POLOVINA, J.J., BALAZS, G.H., HOWELL, E.A., PARKER, D.M., SEKI, M.P., AND DUTTON, P.H. 2004. Forage and migration habitat of loggerhead (*Caretta caretta*) and olive ridley (*Lepidochelys olivacea*) sea turtles in the central North Pacific Ocean. Fisheries Oceanography 13:36–51.

SCOTT, R., HODGSON, D.J., WITT, M.J., COYNE, M.S., ADNYANA, W., BLUMENTHAL, J.M., BRODERICK, A.C., CANBOLAT, A.F., CATRY, P., AND CICCIONE, S. 2012. Global analysis of satellite tracking data shows that adult green turtles are significantly aggregated in marine protected areas. Global Ecology and Biogeography 21:1053–1061.

SEA TURTLE INC. 2002. Maptool. http://www.seaturtle.org/maptool.

SEMINOFF, J.A., ALLEN, C.D., BALAZS, G.H., DUTTON, P.H., EGUCHI, T., HAAS, H.L., HARGROVE, S.A., JENSEN, M.P., KLEMM, D.L., LAURITSEN, A.M., MACPHERSON, S.L., OPAY, P., POSSARDT, E.E., PULTZ, S.L., SENEY, E.E., VAN HOUTAN, K.S., AND WAPLES, R.S. 2015. Status review of the green turtle (*Chelonia mydas*) under the U.S. Endangered Species Act. NOAA Tech. Memor. NOAA-NMFS-SWFSC-539.

SINNOTT, R.W. 1984. Virtues of the haversine. Sky and Telescope 68:159–161.

SPOTILA, J.R. 2004. Sea Turtles: A Complete Guide to Their Biology, Behavior, and Conservation. Baltimore: Johns Hopkins University Press.

YANG, W., WANG, Y., AND CHEN, M. 2015. Genetic structure and diversity of green sea turtle (*Chelonia mydas*) from South China sea inferred by mtDna control region sequence. Biochemical Systematics and Ecology 60:95–98.

ZUG, G.R., BALAZS, G.H., WETHERALL, J.A., PARKER, D.M., AND MURAKAWA, S.K. 2002. Age and growth of Hawaiian seaturtles (*Chelonia mydas*): an analysis based on skeletochronology. Fishery Bulletin 100: 117–127.

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