

Short Note

First record of a known-age juvenile loggerhead turtle (*Caretta caretta*) at the Sanriku Coast in the Northwest Pacific Ocean

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Abstract — Loggerhead turtles (*Caretta caretta*) in the North Pacific Ocean are primarily born in the southern coast of the Japanese Archipelago. After a developmental period of several years in Central and East Pacific Oceans, they re-migrate to Japanese waters at a larger juvenile stage. However, the exact duration until re-migrating to Japanese waters is not known because of methodological limitations of current age estimation among wild sea turtles. On 27 August 2018, a juvenile loggerhead turtle (straight carapace length: 60.8 cm, body mass: 35.0 kg) with a passive integrated transponder (PIT) tag was incidentally captured by a set net at the Sanriku Coast, Northeastern Japan (39°22'21"N, 141°58'41"E). The PIT tag number revealed that it is a 10-year old turtle born in Yakushima Island (30°24'21"N, 130°25'58"E) in 2008. Total 1,095 loggerhead hatchlings with PIT tags were released from Yakushima Island in 2008. To the best of our knowledge, this is the first record of a known-age and non-head started loggerhead turtle in the North Pacific population. The tagged loggerhead turtle provides important knowledge about the pelagic stage duration of this species in the North Pacific population.

Key words: Bycatch, Passive integrated transponder (PIT) tag, Mark-recapture, Known-age turtle, Temperate habitat

Introduction

Sea turtles are typically long-lived, slow-growing, and wide-ranging, occupying multiple habitats over the course of their development (Musick and Limpus 1997, Happell et al. 2003, Avens and Snover 2013). For example, loggerhead turtles (*Caretta caretta*) in the North Pacific Ocean are primarily born in the southern coast of Japan, from Ryukyu Archipelago to Kanto District (Kamezaki et al. 2003, Fig. 1). Loggerhead turtles are then dispersed eastward, transported by the Kuroshio and North Pacific Currents, reaching as far as the Central and East Pacific Oceans (Bowen et al. 1995, Hatase 2012). After a developmental period in these oceans, these turtles re-migrate to Japanese waters at the later juvenile stage (straight carapace length (SCL) 60–70 cm, Ishihara et al. 2011) for subsequent growth and reproduction when they reach sexual maturity (SCL 70–100 cm, Kamezaki 2003). However, the timing of these events is currently uncertain.

To elucidate the duration of each life stage, several methods of age estimation (e.g., skeletochronology and mark-recapture using external tags) have been suggested for sea turtles (reviewed by Chaloupka and Musick 1997, Avens

and Snover 2013). However, these methods have some limitations (Chaloupka and Musick 1997). For example, skeletochronology analysis, which is frequently used as an age estimation method of sea turtles, assumes that bony rings on the humerus are created annually as lines of arrested growth (Castanet et al. 1994). Although verification studies have been conducted (Zug et al. 1986, Zug 1990, Avens and Goshe 2007), the rings are not fully understood. Moreover, resorption of early growth marks has been observed in larger (older) turtles, making it difficult to obtain direct age estimates (Zug et al. 1986). Mark-recapture studies using external tags (e.g., plastic and Inconel) can determine the absolute age of turtles; however, these studies are limited to head-starting turtles or turtles in the later life stages (reviewed by Avens and Snover 2013) because external tags (2.5–4.5 cm) are too big to attach to hatchlings (SCL of approximately 5 cm). In addition, the loss of external tags is also a problem with this method (Chaloupka and Musick 1997, Nishizawa et al. 2018). As a consequence, an accurate age assessment method for wild turtles has not been established. Therefore, the exact duration that it takes for turtles born in the south coast of Japan to re-migrate to Japanese waters is still unknown. This problem makes it challenging to understand the life history of North Pacific loggerhead turtles.

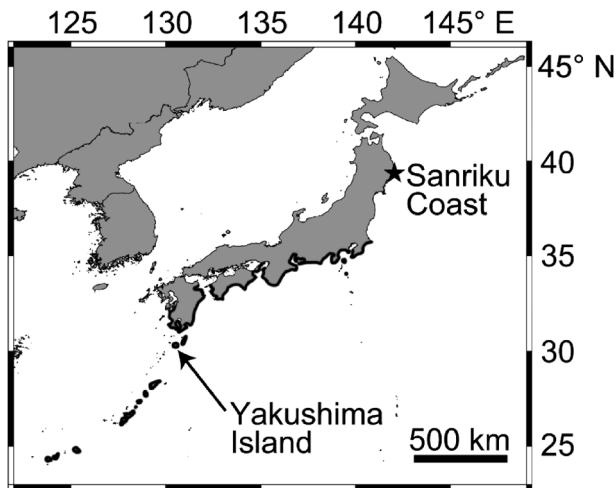


Fig. 1. Study site in the Japanese Archipelago. The coastline shown in bold illustrates the major nesting site of loggerhead turtles (Kamezaki et al. 2003). The arrow and star indicate the release and bycatch locations of a PIT tag-injected loggerhead turtle, respectively.

To elucidate this aspect, the Yakushima Sea Turtle Research Group has been injected passive internal transponder (PIT) tags for almost 20 years into loggerhead hatchlings in the Yakushima Island, which is the largest rookery of loggerhead turtles in the North Pacific population (Fig. 1). In this note, we report the first bycatch record of a loggerhead turtle with a PIT tag in the Sanriku Coast (Fig. 1), which is a summer-restricted (from June to October) foraging area for juvenile- to adult-sized loggerhead turtles (Narazaki et al. 2015).

Materials and Methods

Injecting PIT tags to hatchlings at the Yakushima Island

Since 1999, PIT tags were injected into loggerhead hatchlings on the Yakushima Island ($30^{\circ}24'21''\text{N}$, $130^{\circ}25'58''\text{E}$, Fig. 1). When newly emerged hatchlings were found, they were collected and transferred to the Yakushima Umigame-Kan, Yakushima Town, Kagoshima Prefecture, Japan. The PIT tags (ID-100A, 2 mm in diameter, 11 mm in length, Trovan Ltd, Douglas, UK) were injected into their abdominal cavity on the left side (observer's right). The injected hatchlings were then immediately released to the sea. The duration from collection to release was less than 2 hours.

Bycatch survey at the Sanriku Coast

Since 2005, a year-round bycatch survey has been conducted in the Sanriku Coast ($38^{\circ}55'$ to $39^{\circ}40'\text{N}$, $141^{\circ}40'$ to $142^{\circ}05'\text{E}$; Fig. 1). The captured turtles were transferred to an outdoor tank at the International Coastal Research Center (ICRC), Atmosphere and Ocean Research Institute, the University of Tokyo, Otsuchi Town, Iwate Prefecture, Japan. Their SCL and straight carapace width (SCW) were mea-

sured using calipers, and their curved carapace length (CCL) and curved carapace width (CCW) were measured using a tape measure with an accuracy of 0.1 cm. Their body mass (BM) was measured using a hanging scale with an accuracy of 0.5 kg. From 2014, the PIT tag information (15-digit code) was detected using an ARE H5 reader (Trovan Ltd) from outside the body of turtles.

Results and Discussion

From 1999 to 2017, 10,256 loggerhead hatchlings with the PIT tags were released from the Yakushima Island. In the Sanriku Coast, we attempted to detect the PIT tags in 210 loggerhead turtles (SCL 51.6–92.0 cm) during 2014–2018.

On August 27, 2018, one loggerhead turtle with a PIT tag (Fig. 2) was incidentally captured by a commercial set net at Otsuchi Bay, Iwate Prefecture ($39^{\circ}22'21''\text{N}$, $141^{\circ}58'41''\text{E}$). The other 209 turtles have no PIT or external tags attached by researchers at the nesting sites. The 15-digit number of the PIT tag revealed that this turtle was born in 2008 (10 years old). A total of 1,095 loggerhead hatchlings with the PIT tags were released from the Yakushima Island in 2008. To the best of our knowledge, this is the first record of the known-age and non-head-started juvenile loggerhead turtle in the North Pacific population. A previous mtDNA analysis suggested that the loggerhead turtles migrating to the Sanriku Coast are mainly derived from the Yakushima Island (Nishizawa et al. 2014). The identification of a tagged turtle supports this estimation. The PIT tag was located on the right side (observer's left) of the abdominal cavity, which is the opposite side to the injected location in the Yakushima Island (Fig. 2b). Previous studies have suggested that the PIT tags move within the body of an individual (Balazs 1999, Kamezaki and Kuroyanagi 2004). Hence, the PIT tag found in this turtle might have moved within its body during growth.

The SCL, CCL, SCW, CCW, and BM of this turtle were 60.8 cm, 64.4 cm, 51.6 cm, 63.5 cm, and 35.0 kg, respectively. The minimum SCL of nesting females in Japan is 69 cm (Kamezaki 2003), indicating that this turtle was still a juvenile. Captive studies of loggerhead turtles maintained under favorable conditions yielded growth trajectories that allowed the turtles to attain the adult size in as little as 6–7 years (Caldwell 1962, Uchida 1967). Our result demonstrated that wild turtles display much slower growth rate than captive turtles do under favorable conditions.

It has been reported that juvenile loggerhead turtles with the SCL of approximately 60–70 cm re-migrate to Japanese waters (Ishihara et al. 2011) and that this growth takes more than 16 years estimated using a skeletochronology analysis (Ishihara 2011). The turtle in the current study (SCL 60.8 cm) provided evidence that loggerhead turtles re-migrate to Japanese waters much faster than previously thought. One possi-

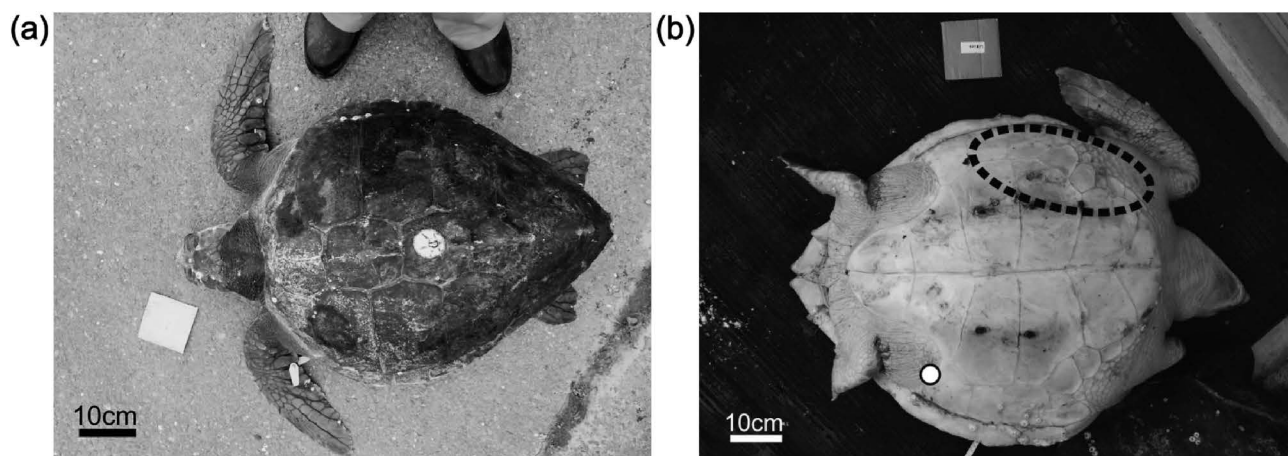


Fig. 2. (a) Dorsal and (b) ventral sides of the PIT tag-injected loggerhead turtle captured by a commercial set net along the Sanriku Coast, Japan. The white circle and the area enclosed by a dashed line in (b) indicate the injected and read locations of a PIT tag, respectively.

ble explanation is that the turtle in the current study exhibited fast growth; however, one cannot rule out the limitation of skeletochronology age estimation (i.e. resorption of early growth marks). If recapture data of PIT-tagged turtles are accumulated in the future, the exact age of these turtles until re-migration to Japanese waters will become clear.

If the PIT tags are injected into hatchlings of wild turtles, their exact age can be determined (Gibbons and Andrews 2004) although their recovery ratio is low (Avens and Snover 2013). Therefore, this method will provide helpful information to validate and/or improve accuracy of various age estimations and absolute age determination. Furthermore, the PIT tags can also help determine the birth place of tagged turtles, providing valuable data for molecular studies such as mtDNA analysis. Since 1999, more than 10,000 hatchlings have been injected the PIT tags and released from the Yakushima Island, with the assumption that some of them have re-migrated to Japanese waters in recent years or will in the near future. In Japan, while several volunteer and scientist groups are investigating sea turtles in various areas, the PIT tags are checked by only a few groups. In addition, sharing of injected location (e.g. front flipper and abdominal cavity) and number-related information of PIT tags remain insufficient compared with those of the external tags. Hence, introducing the PIT tag reader at various study sites, unification of injected location, and management of tag information can help detect more known-age loggerhead turtles. The PIT tag information will contribute to the understanding of life history traits, such as duration of each life stage, somatic growth rate, and migration pattern of loggerhead turtle in the North Pacific population.

Acknowledgments

This study was conducted as a part of a bycatch survey in which sea turtles caught by fisherman along the Sanriku Coast were brought to researchers. The program was performed in accordance with the

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References

- Avens, L. and Goshe, L. R. 2007. Comparative skeletochronological analysis of Kemp's ridley (*Lepidochelys kempii*) and loggerhead (*Caretta caretta*) humeri and scleral ossicles. *Mar. Biol.* 152: 1309–1317.
- Avens, L. and Snover, M. L. 2013. Age and age estimation in sea turtles. *In* The biology of sea turtles vol. 3. Wyneken, J., Lohmann, K. J. and Musick, J. A. (eds.), pp. 97–133, CRC Press, Florida.
- Balazs, G. H. 1999. Factors to consider in the tagging of sea turtles. *In* Research and management techniques for the conservation of sea turtles. Eckert, K. L., Bjorndal, K. A., Abreu-Grobois, F. A. and Donnelly, M. (eds), pp. 101–109, IUCN/SSC Marine Turtle Specialist Group Publication, Washington DC.
- Bowen, B. W., Aberu-Grobois, F. A., Balazs, G. H., Kamezaki, N., Limpus, C. J. and Ferl, R. J. 1995. Trans-Pacific migrations of the loggerhead turtle (*Caretta caretta*) demonstrated with mitochondrial DNA markers. *Proc. Natl. Acad. Sci. USA.* 92: 3731–3734.
- Caldwell, D. K. 1962. Growth measurements of young captive Atlantic sea turtles in temperate waters. *Contrib. Sci.* 50: 1–8.
- Castanet, J. 1994. Age estimation and longevity in reptiles. *Geron-*

- tology 40: 174–192.
- Chaloupka, M. Y. and Musick, J. A. 1997. Age, growth, and population dynamics. *In* The biology of sea turtles. Lutz, P. L. and Musick, J. A. (eds.), pp. 233–276, CRC Press, Florida.
- Gibbons, W. J. and Andrews, K. M. 2004. PIT tagging simple technology at its best. *Bioscience* 54: 447–454.
- Hatase, H. 2012. Migration. *In* Natural history of sea turtles in Japan. Kamezaki, N. (ed.), pp. 195–226, University of Tokyo Press, Tokyo. (in Japanese)
- Heppell, S. S., Snover, M. L. and Crowder, L. B. 2003. Sea turtle population ecology. *In* The biology of sea turtles vol. 2. Lutz, P. L., Musick, J. A. and Wyneken, J. (eds.), pp. 275–306, CRC Press, Florida.
- Ishihara, T. 2011. Life history in maturation process of loggerhead turtle (*Caretta caretta*) in North Pacific. Ph.D. dissertation, University of Tokyo, Tokyo.
- Ishihara, T., Kamezaki, N., Matsuzawa, Y., Iwamoto, F., Oshika, T., Miyagata, Y., Ebisui, C. and Yamashita, S. 2011. Reentry of juvenile and sub-adult loggerhead turtles into natal waters of Japan. *Curr. Herpetol.* 30: 63–68.
- Kamezaki, N. 2003. What is a loggerhead turtle? The morphological perspective. *In* Loggerhead sea turtles. Bolten, A. B. and Witherington, B. E. (eds.), pp. 28–43, Smithsonian Books, Washington DC.
- Kamezaki, N. and Kuroyamagi, K. 2004. Pit-tag application for sea turtle hatchlings. *UMIGAME Newsl. JAPAN* 62: 2–5. (in Japanese with English abstract)
- Kamezaki, N., Matsuzawa, Y., Abe, O., Asakawa, H., Fujii, T., Goto, K., Hagino, S., Hayami, M., Ishii, M., Iwamoto, T., Kamata, T., Kato, H., Kodama, J., Kondo, Y., Miyawaki, I., Mizobuchi, K., Nakamura, Y., Nakashima, Y., Naruse, H., Omura, K., Samejima, M., Suganuma, H., Takeshita, H., Tanaka, T., Toji, T., Uematsu, M., Yamamoto, A., Yamato, T. and Wakabayashi, I. 2003. Loggerhead turtles nesting in Japan. *In* Loggerhead sea turtles. Bolten, A. B. and Witherington, B. E. (eds.), pp. 210–217, Smithsonian Books, Washington DC.
- Musick, J. A. and Limpus, C. J. 1997. Habitat utilization and migration in juvenile sea turtles. *In* The biology of sea turtles. Lutz, P. L., Musick, J. A. (eds.), pp. 137–163, CRC Press, Florida.
- Narazaki, T., Sato, K. and Miyazaki, N. 2015. Summer migration to temperate foraging habitats and active winter diving of juvenile loggerhead turtles *Caretta caretta* in the western North Pacific. *Mar. Biol.* 162: 1251–1263.
- Nishizawa, H., Narazaki, T., Fukuoka, T., Sato, K., Hamabata, T., Kinoshita, M. and Arai, N. 2014. Genetic composition of loggerhead turtle feeding aggregations: migration patterns in the North Pacific. *Endanger. Species Res.* 24: 85–93.
- Nishizawa, H., Joseph, J., Chew, V. Y. C., Liew, H. C. and Chan, E. H. 2018. Assessing tag loss and survival probabilities in green turtles (*Chelonia mydas*) nesting in Malaysia. *J. Mar. Biol. Assoc. U.K.* 98: 961–972.
- Uchida, I. 1967. On the growth of the loggerhead turtle, *Caretta caretta*, under rearing conditions. *Bull. Japanese Soc. Sci. Fish.* 33: 497–506. (in Japanese with English abstract)
- Zug, G. R. 1990. Age determination of long-lived reptiles: some techniques for seaturtles. *Ann. des Sci. Nat. Zool. Biol. Anim.* 13: 219–222.
- Zug, G. R., Wynn, A. H. and Ruckdeschel, C. 1986. Age determination of loggerhead sea turtles, *Caretta caretta*, by incremental growth marks in the skeleton. *Smithson. Contrib. to Zool.* 427: 1–34.