Current Herpetology 30(1): 63–68, June 2011

Reentery of Juvenile and Subadult Loggerhead Turtles into Natal Waters of Japan

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Abstract: We measured the straight carapace length (SCL) of 1392 loggerhead turtles of the Japanese aggregation that were incidentally captured between July 2002 and November 2009 by pound nets set near the eastern coast of Cape Muroto, Kochi Prefecture, Japan. Each specimen was categorized as adult, subadult, or juvenile on the basis of their maturity status inferred from SCL. In the present sample, SCL exhibited a unimodal distribution with the mode located in the 740–749 mm class ($\bar{x}\pm$SD: 757±67 mm; range: 563–1050 mm). The majority of loggerhead turtles composing the Japanese aggregation was subadult (75.9%). The SCL of smaller specimens suggested that reentery into Japanese waters of individuals once flown to the northeastern Pacific occurs in the later juvenile stage. A unimodal histogram implies that the major size classes in SCL of turtles reentering Japanese waters range from 560–749 mm. A comparison between the Japanese aggregation and the Mexican aggregation indicates that turtles at the later juvenile stage start to migrate westward, taking only a few years to cross the North Pacific to Japanese waters.

Key words: Loggerhead turtle; North Pacific; Size distribution; Migration; Japanese aggregation

Loggerhead turtles (*Caretta caretta*) are widely distributed in the world's temperate oceans (Pritchard, 1997). Studies on the distribution of mitochondrial DNA (mtDNA) haplotypes have revealed the presence of certain levels of reproductive isolation between breeding assemblages of different oceans and of different hemispheres (Bowen et al., 1994; Bowen, 2003). In both the Pacific and Atlantic oceans, nesting sites are mostly restricted to western coasts. Hatchlings are thought to migrate from their natal beaches to the eastern waters of the ocean with the aid of ocean currents, and then re-migrate to the western waters (Bolten et al., 1998; Boyle et al., 2009). Some authors argued that the turtles start remigration after growing to approximately 50 cm in curved carapace length in the North Atlantic (Bjorndal et al., 2000) and approximately 70 cm in the South Pacific (Limpus and Limpus, 2003).

Japan is known to be the sole breeding area for loggerhead turtles in the North Pacific, and has a number of nesting beaches along the coastlines from Kanto District of Honshu to the Ryukyu Archipelago (Kamezaki et al., 2003). Such strict limitation of nesting sites to Japan, along with the absence of haplotypes other than those found in hatchlings from Japan, indicate that loggerhead turtles of the North Pacific belong to a single population (Bowen et al., 1995). Furthermore, eastward and westward trans-Pacific migrations were demonstrated by mark-recapture (Uchida and Teruya, 1991; Resendiz et al., 1998) and satellite tracking techniques (Nichols et al., 2000). It is therefore assumed that the North Pacific loggerhead turtles hatch on Japanese beaches, disperse eastward, and then return to Japanese waters.

For the Japanese aggregation, the status of

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nesting females has been relatively well studied. With respect to the status of non-nesting turtles, however, information is available only from fragmented observations (e.g. Nomura, 1993; Miyawaki, 1994; Maeda and Kimura, 1995; Iwamoto et al., 2005; Tanaka and Ishihara, 2006). In this study, we investigated the size distribution of the Japanese aggregation of loggerhead turtles on the basis of a relatively large sample from incidental capture. Our purposes were to estimate their age structure and to infer stages in their life history at which they re-migrate to Japanese waters after dispersing to the western North Pacific.

MATERIALS AND METHODS

Loggerhead turtles, incidentally captured by three large-size pound net fishery associations, were examined. The pound nets were set at a depth of 35–78 m near the edge of the continental slope off the coast of Cape Muroto, southeast of Shikoku, Japan (33°15' N, 134°11' E, Fig. 1). The continental slope is steep, leading to nutrition-rich marine upwelling of the North Pacific intermediate current ranging from 500 to 1000 m deep (Fukasawa, 1998). Each fishery association caught approximately 1500–2000 tons of fish per year, with yellowtail (*Seriola quinqueradiata*), spotted mackerel (*Scomber australasicus*), and bullet tuna (*Auxis rochei*) being the main harvested species. The pound nets also caught loggerhead turtles and green turtles (*Chelonia mydas*) incidentally. Because the pound net is a set net that is not relocated throughout the year, we assumed that loggerhead turtles migrating through Cape Muroto were sampled at random. The captured loggerhead turtles were brought back to fishing ports where they were measured for straight carapace length (SCL) and examined for various external character states. Then the specimens were released from the fishing ports or off the pound nets within a day.

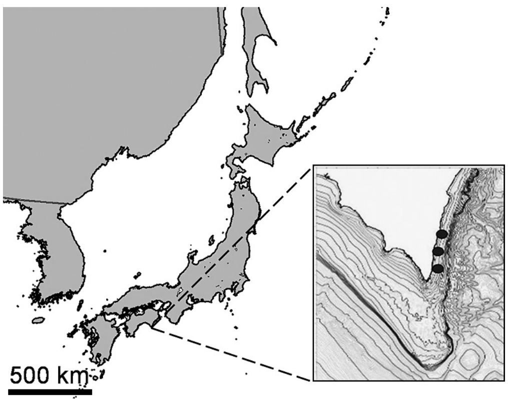

FIG. 1. Map of Japan and adjacent regions showing the location of Cape Muroto, Kochi Prefecture, Shikoku Island, Japan. The three black circles indicate the locations where pound nets were set.

We classified those turtles into one of the following four life history stages—hatchling, as characterized by possession of an internalized yolk sac; juvenile, as the intermediate stage between hatchling and subadult; subadults, as characterized by the presence of secondary sexual characteristics, but without maturity; and adult, as showing full maturity. For the North Pacific loggerhead populations, SCL of hatchlings is shown to be 41.9 ± 1.51 mm ($\bar{x}\pm$SD) (Matsuzawa and Sakamoto, 2002). Likewise, secondary sexual characteristics of males reportedly occur from around 688 mm in SCL (Ishihara et al., 2007), and SCL of nesting females is reported to be 848 ± 50.8 mm ($\bar{x}\pm$SD) (Kamezaki et al., 1995). We therefore regarded turtles with SCL $\leq$ 41.9 mm as hatchling, 42.0–687 mm SCL as juvenile, 688–847 mm SCL as subadult, and SCL $\geq$ 848 mm as adult. We did not take into account sexual size differences because the size at maturity does not differ significantly between males and females of the North Pacific loggerhead turtles (Kamezaki, 2003; Ishihara, 2007).

RESULTS AND DISCUSSION

A total of 1392 loggerhead turtles, incidentally captured from July 2002 to November 2009, were examined. SCL of these turtles exhibited a unimodal distribution, with the mode being located in the 740–749 mm class ($\bar{x}\pm$SD: 757 ± 67 mm; range: 563–1050 mm;

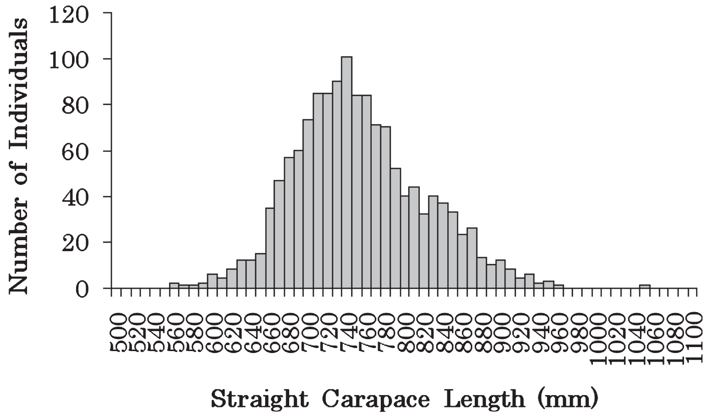

FIG. 2. Distribution of straight carapace lengths of loggerhead turtles captured around Cape Muroto (n=1392, x̄±SD: 757±67, range: 563–1050 mm).

Fig. 2). In the whole sample, subadults accounted for 75.9% (1056 specimens), followed by juveniles (13.5%, 188 specimens) and adults (10.6%, 148 specimens) in that order, while no hatchlings were included. The smallest specimen was 563 mm in SCL, and obviously represented the later phase of juvenile stage.

The sample of loggerhead turtles did not include individuals whose SCLs are smaller than those of large juveniles. This result is consistent with the current hypothesis that hatchling loggerhead turtles, emerging from Japanese beaches, immediately disperse to the eastern North Pacific instead of staying in waters adjacent to Japan (see above). SCL distribution in the present sample also indicates that loggerhead turtles from Japan, once flown to the eastern North Pacific, never reenter into the coastal waters of Japan until they reach to the later phase of the juvenile stage (SCL>563 mm in our sample).

Toward a relatively large subadult class of 740–749 mm SCL, the number of individuals almost consistently increased with an increase of SCL. Conversely, the number of individuals gradually decreased with an increase of SCL in the classes larger than that with 740–749 mm SCL (Fig. 2). This latter pattern may possibly reflect scarcity of subadult and adult turtles that newly reenter into the Japanese coastal waters. Also, decrease of individuals with larger SCL may possibly reflect mortality from various causes, such as shark predation (Witzell, 1987), prevalence of diseases (George, 1997), and fatal by-catches through various fishery activities (Gilman et al., 2010; Peckham, 2007). Besides these, subadult and adult loggerhead turtles that have been "lost" from around the current sampling sites may also include those that have left this area subsequent to their reentry. Analyses of recapture records and satellite tracking data for individuals once captured around the present study sites are desired to verify this possibility, but as far as the currently available information is concerned (Sea Turtle Association of Japan, unpublished), substantial contributions of such individual re-migrations to the decline of larger turtles (Fig. 2) are much unlikely.

On the other hand, increase of individuals with larger SCLs, observed in juvenile classes with smaller SCL in the putatively randomly collected sample suggest that reentry into Japanese coastal waters by loggerhead turtles that had dispersed from Japan to the eastern North Pacific largely involves individuals that are yet immature but have substantially grown up from the hatchling state. Taking generally higher mortality in smaller turtles (National Research Council, 1990) into considerations higher frequency of reentry by juvenile turtles just inferred from Fig. 2 histograms may still suffer underestimation.

SCLs ($\bar{x}\pm SD$) of loggerhead turtles occurring in the eastern North Pacific off the western coast of Mexico (well-known nursery area for juvenile loggerhead turtles from Japan: Bowen et al., 1995) reportedly correspond to those in the small to middle-sized juveniles, i.e., 469 ± 130 mm (Ramirez-Cruz et al., 1991), 585 ± 111 mm (Gardner and Nichols, 2001), or 619 ± 21 mm (Seminoff et al., 2004). For the Mexican aggregation of loggerhead turtles, Gardner and Nichols (2001) also provided unimodal histograms of SCL with the mode ranging from 500–700 mm, i.e., slightly smaller than the modal range of SCL in juveniles from our sampling sites. Considering this modal range as the standard SCL range in individuals just starting the westward trans-Pacific migration, possession of slightly larger carapaces by the putative reentering juveniles in our sample (740–749 mm in modal range: see above) could be attributed to growth during migration. Several previous authors yielded data from satellite tracking and inadvertent recaptures of marked individuals that indicate that juvenile loggerhead turtles usually spend only a few years or even less for trans-Pacific migration from Mexican to Japanese coastal waters (Resendiz et al., 1998; Nichols et al., 2000; Polovina et al., 2000). On the other hand, Parham and Zug (1997) estimated growth rates of juvenile loggerhead turtles with 500–599 and 600–699 mm SCL to be 28–38 and 27–39 mm/yr, respectively. All these data do not contradict with each other, and offer a circumstantial support to the idea that the juvenile loggerhead turtles captured in the coastal waters of Cape Muroto represent the majority of size classes of the species reentering Japanese coastal waters just after trans-Pacific migration from Mexican waters.

ACKNOWLEDGMENTS

We thank Takaoka, Shiina, and Mitsu pound net fishery associations for their cooperation in collecting loggerhead turtles. We also thank T. Maeda, K. Ebisui, Y. Yasuoka, K. Hashimoto, S. Yamashita, M. Wakatsuki, S. Ohara, Y. Kasai, H. Miyanohara, T. Nakamura, Y. Eguchi, K. Murai, K. Kusakabe, H. Tanaka, K. Saito, K. Mori, M. Matsumoto, K. Sato, A. Abe, T. Nakazatomi, and H. Mizuno for their help in examining these turtles. This study was supported by the Sea Turtle Association of Japan, Research Fellowships of the Japan Society for the Promotion of Science for Young Scientists, the Western Pacific Regional Fishery Management Council, the Keidanren Nature Conservation Fund, Lush Japan Co. Ltd., Patagonia Japan, the AEON Environmental Foundation, and the Mobile Communication Fund.

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Accepted: 19 December 2010