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Received: 12 August 1997
Reviewed: 7 August 1997
Revised and Accepted: 17 October 1997

Chelonian Conservation and Biology, 1997, 2(4):600–603

Decline of the Loggerhead Turtle, *Caretta caretta*, Nesting on Senri Beach in Minabe, Wakayama, Japan

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Three species of sea turtles, *Caretta caretta*, *Chelonia mydas*, and *Eretmochelys imbricata* are known to nest in Japan (Nishimura, 1967; Uchida and Nishiwaki, 1982; Kamezaki, 1986). There are numerous nesting beaches for loggerhead turtles (*C. caretta*) around the main islands of Japan (Uchida and Nishiwaki, 1982) and the Japanese archipelago is an important nesting ground for the loggerhead turtle in the North Pacific Ocean (Nishimura, 1967; Dodd, 1988; Bowen et al., 1995; Kikukawa et al., 1996). The loggerhead turtle is listed as endangered worldwide by the IUCN, and it appears on Appendix I of CITES. In some areas, loggerhead populations appear to be declining (Dodd, 1988). However, there is very little information regarding the current status of loggerheads in Japan.

It is generally difficult to estimate the population size or trends of wild animals, especially marine species. Several indices may be used to estimate sea turtle nesting populations. The number of emergences can be estimated by counting tracks on nesting beaches, however, not all emergences result in successful nesting. The ratio of actual nesting success to number of emergences differs among nesting beaches (Dodd, 1988) and varies from year to year on a beach (Talbert et al., 1980). The number of nests does not represent the number of females nesting because nesting usually occurs repeatedly by a single female in a season. Direct count of nesting females with individual discrimination by tagging is the most reliable method. Even so, estimation of the total population size based on nesting females is impossible at the present time because the natural sex ratio and age structure of the population is not well understood (Meylan, 1982; Dodd, 1988).

The aim of this study was to elucidate the recent population trends of the adult female loggerhead turtles nesting on Senri Beach in Minabe, Wakayama, Japan, over 6 seasons from 1990 to 1995.

Materials and Methods. — Daytime and nightly patrols were conducted at Senri Beach in Minabe, Wakayama, Japan (Fig. 1). The beach is 1360 m in length and is a prominent nesting ground of the loggerhead turtle in Japan, others being Yakushima Island in Kagoshima (Oomuta, 1994) and Miyazaki (Iwamoto et al., 1985). Daytime patrols were conducted throughout the nesting season (May – August) from 1990 to 1995 and the daily number of nests were determined by counting new nests accompanied by emergence tracks. Non-nesting emergence were distinguished by their lack of body pits or nests.

Nightly patrols were conducted during the month of July, the peak of the nesting season, from 1990 to 1995. Nesting excursions for the loggerhead turtle take 45–60 min or more (Dodd, 1988). Every night from 1930 to 0400 hrs at 1-hr intervals, two people walked from the center of the beach to each end in 15 min, stayed there for 15 min, and then returned to the center. Patrollers walked along the shoreline seeking emergent tracks.

Turtles were measured and identified when they succeeded in nesting. If turtles failed to nest, neither measurements nor identifications were conducted so as not to disturb their next landing. Straight carapace length (SCL) was measured with calipers to the nearest 1 mm while laying eggs, and turtles were then tagged on both front flippers or, if they had already been tagged, existing tags were checked while they were covering the nests. Plastic and metal tags (monel, inconel, or titanium) inscribed with an identification number and address were used to mark turtles.

Some females laid eggs more than once during the nesting season. The number of nesting females was smaller than the number of nests. In any year, we estimated the number of nesting turtles making unidentified nests by multiplying the number of unidentified nests by the ratio of the number of identified turtles divided by the number of identified nests that they made. For example, if 84 identified females made 99 identified nests, the unidentified remaining 9 nests were estimated to have been made by 9 x (84/99) = 7.6 (= 8) turtles. Using this methodology, we added identified and estimated (unidentified) turtles for each season to give a total number of nesting females during July of each year.

In 1995 only, additional surveys were conducted at Iwashiro Beach in Minabe for 23 days in July and August. This beach is situated 800 m northwest of Senri Beach and is 1030 m in length (Fig. 1). Daily numbers of nests were counted between 2100 and 0000 hrs and all turtles encountered were tagged or checked for existing tags.

Results. — The results of the nesting surveys at Senri Beach for each year, 1990 to 1995, are shown in Fig. 2. Several hundred nests (range, 163–349) were deposited each

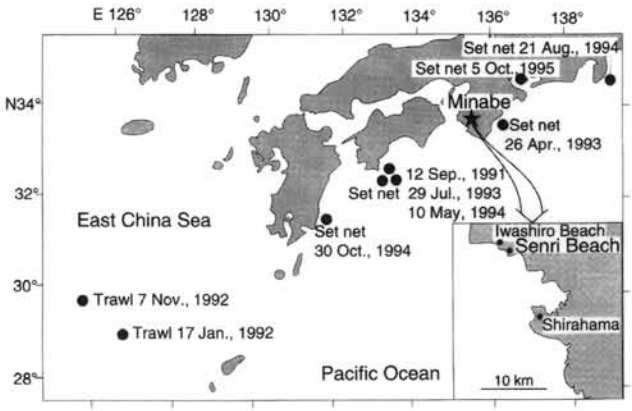

Figure 1. Location of the study area at Minabe, Wakayama, Japan, and distribution of incidental captures of loggerhead turtles in fishing gear.

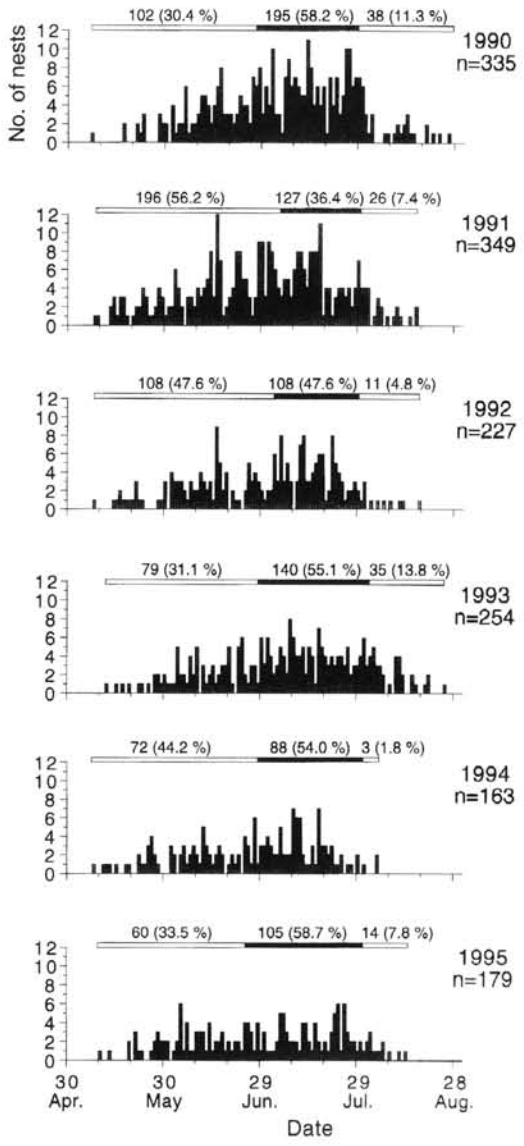

Figure 2. Daily number of nests on Senri Beach in Minabe, Wakayama, Japan, from 1990 to 1995. Total numbers of nests per year are shown for each year. Horizontal bars show the full extent of the nesting season and the solid parts of the bars indicate periods of nightly patrol during the core nesting season. Sub-total numbers of nests and percentages during each period are shown above the bars.

Table 1. Estimated number of nesting loggerhead turtles during the core nesting season in July on Senri Beach in Minabe, Wakayama, Japan, from 1990 to 1995.

Year	Period of Nightly Patrol (days)	No. of Emergences	No. of Nests			Nesting Success (%)	No. of Nesting Females			
			Identified	Unidentified	Total		Identified	Estimated	Total	Total/Day
1990	33	572	59	136	195	34.1	48	111	159	4.8
1991	26	386	61	66	127	33.2	55	60	115	4.4
1992	28	256	99	9	108	42.2	84	8	92	3.3
1993	36	290	130	10	140	47.9	94	7	101	2.8
1994	34	299	84	4	88	29.9	62	3	65	1.9
1995	42	259	101	4	105	40.5	66	3	69	1.6

nesting season. The nesting season began in early May each year, reached a peak in mid-July, and ended by August. Most nests (45–55%) were deposited in July. At Iwashiro Beach, 33 nests were laid during 23 survey days in 1995, 64% of the total nests laid at Senri Beach during the same time period. The mean SCL for the nesting population at Senri Beach from 1990 to 1995 was 83.6 cm (range, 70.8–103.1 cm; s.d. = 5.0 cm; $n = 398$).

In each year, nightly patrols were conducted for 26–42 days and 256–572 emergences were counted, 88–195 of them accompanied by nests (Table 1). Annual nesting success varied from 29.9% to 47.9%. There were no distinct trends in nesting success (Fig. 3). During the first and second years (1990–91), 136 (70%) and 66 (52%) of the total nests were unidentified (Table 1). This was because turtles had not previously been tagged and the number of new, untagged turtles was so large in comparison to the number of patrollers that it was impossible to tag all nesting turtles. Since 1992, more than 92% of the nests have been identified by tagging or checking for existing tags, and the rest (less than 8%), were unidentified because the turtles were missed (Table 1).

The total number of nesting loggerhead turtles (identified plus estimated) during July was 65–159 females at Senri Beach (Table 1). Because the periods of nightly patrol were different in duration, the total number of nesting females could not be directly compared among the years 1990–95. However, the calculated number of loggerhead turtles that nested per night during the core nesting season in July declined steadily from 4.8 in 1990 to 1.6 in 1995 (Table 1; Fig. 3).

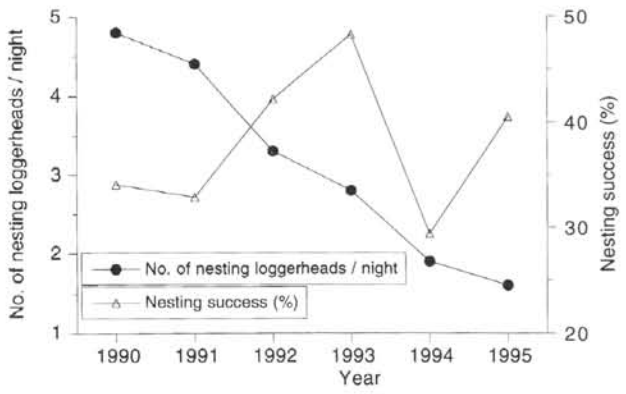

Figure 3. The estimated numbers of loggerhead turtles nesting per night on Senri Beach in Minabe, Wakayama, Japan, during the core nesting season in July from 1990 to 1995, are shown as dots. The percentages of nesting success are indicated by open triangles.

Table 2 shows the frequency of remigration intervals at Senri Beach. During 1990–95, between 50 to 114 females (new plus remigrants) were identified by tags. For example, 50 females were tagged in 1990, but none of them returned in 1991. Three (6.0%) were observed on the beach in 1992, and four (8.0%) in 1993, with no remigrants observed in 1994 or 1995. The modal remigration interval was 2 years with the ratio from 6.0 to 18.3% (Table 2). One-year remigration ranged from 0.0 to 2.6%, 3-year remigration from 3.3 to 10.1%, 4-year from 0.0 to 6.7%, and 0.0% at 5-year intervals. In 1995, 74 nesting turtles were identified, of which 31 (42%) were remigrants. At Iwashiro Beach in 1995, 38 turtles were identified, of which 11 (29%) had previously been tagged at Senri Beach.

Of the 395 loggerhead turtles tagged on Senri Beach during the nesting season from 1990 through 1995, 9 (2.3%) were later incidentally captured by trawl or set net (as of August 1996). Two were captured by trawl in the East China Sea in winter, and 7 were captured by set net along the Japanese coast from spring to autumn (Fig. 1).

Discussion.—The number of female loggerhead turtles nesting on Senri Beach during the core nesting season in July declined by 67% in six years from 4.8 to 1.6 females per day (Fig. 3). Ruling out random effects, in that the decline was very steady, two causes are possible: 1) turtles changed nesting beaches, or 2) the total population size dropped.

The decline might be caused by individual movements from Senri Beach to other nesting beaches. Iwashiro Beach is only 800 m away from Senri Beach. In 1995, 33 nests were deposited at Iwashiro Beach in 23 days, with 48 nests deposited at Senri Beach during the same period, and 11 (29%) of the turtles that landed at Iwashiro Beach had previously been tagged at Senri Beach. These data indicate that some turtles had moved from Senri Beach to Iwashiro Beach. However, this appears to be an insufficient explanation for the decline because the number of nests on Senri Beach remains higher than that on Iwashiro Beach. Moreover, tagging demonstrated that a larger percent of turtles remigrated to Senri Beach (42%) than moved to Iwashiro Beach (29%). Nishimura (1967) reported that Shirahama, located 12 km southeast of Senri Beach (Fig. 1), was a nesting beach for loggerheads. But Shirahama has undergone extensive resort development, and only a few loggerheads nest there now. Thus, the steady decline in the number of nesting females on Senri Beach (Fig. 3) seems to reflect an actual population decline. However, more

Table 2. Remigration numbers and percentages for loggerheads nesting on Senri Beach in Minabe, Wakayama, Japan.

Year	Identified Females (No.)	Remigrations 1991 (No.) (%)	1992 (No.) (%)	1993 (No.) (%)	1994 (No.) (%)	1995 (No.) (%)
1990	50	0 0.0	3 6.0	4 8.0	0 0.0	0 0.0
1991	60	—	0 0.0	11 18.3	2 3.3	4 6.7
1992	89	—	—	1 1.1	13 14.6	9 10.1
1993	114	—	—	—	3 2.6	18 15.8
1994	76	—	—	—	—	0 0.0

surveys are needed to quantify this relationship and its possible causes.

Kamezaki et al. (1997) reported on 2219 marked loggerhead turtles from 16 nesting beaches from Ryukyu Archipelago to Shizuoka of Japan, and documented that 37 (1.7%) of these were incidentally captured by fisheries. Nine of these 37 turtles were tagged on Senri Beach in Minabe. The impact of the fisheries industry on the population of loggerheads nesting on Senri Beach, and on other beaches in Japan, is not well investigated, and further quantification of this impact is needed.

Acknowledgments. — Nightly patrols over 6 years were facilitated by 96 volunteers. Although we cannot list all of their names here, we would like to express special thanks to all of them. We especially thank F. Fukuhara for tagging many turtles. We are grateful to the Japan Sea Turtle Association for supplying tags and tagging pliers. Information on the incidental recapture of tagged loggerhead turtles was gathered by I. Miyawaki, Kushimoto Marine Park. This work was financially supported by grants from the Ministry of Education, Science, Sports and Culture (No. 05454093) and the Research Fellowships of the Japan Society for the Promotion of Science (JSPS) for Young Scientists (KS, YM, and HT).

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Received: 20 August 1996
Reviewed: 8 August 1997
Revised and Accepted: 23 September 1997

Chelonian Conservation and Biology, 1997, 2(4):603–607

A Comparison of Plastral Scute Lengths Among Members of the Box Turtle Genera *Cuora* and *Terrapene*

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The turtle shell is one of the most conservative derived vertebrate structures known, having remained substantially unchanged since the Triassic (Romer, 1956, 1966). The arrangement of the epidermal scutes on the shell of turtles belonging to the families Bataguridae and Emydidae is particularly uniform, especially those of the plastron (Cherepanov, 1989), and provides few systematically important variants. However, research by Lovich and Ernst (1989) demonstrated that a great deal of variability occurs in the relative lengths of plastral scutes and plastral formulae in several emydid species. Later research indicated that closely related species could be differentiated from each other, as well as more distant relatives, by using the length relationships of plastral scutes (Lovich et al., 1991).

Several genera of "box turtles" belonging to the families Bataguridae (*Cuora, Cyclemys, Notochelys, Pyxidea,*