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Citation	Proceedings of the 2nd International symposium on SEASTAR2000 and Asian Bio-logging Science (The 6th SEASTAR2000 Workshop) (2005): 63-68
Issue Date	2005
URL	http://hdl.handle.net/2433/44086
Right	
Type	Conference Paper
Textversion	publisher

Dispersal processes of head-started hawksbill turtles (*Eretmochelys imbricata*) in the Yaeyama Islands waters, Okinawa, Japan

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ABSTRACT

Behaviors of five head-started hawksbill turtles (*Eretmochelys imbricata*) attached with ultrasonic transmitters were monitored using 12 ultrasonic receivers set up along the reef edge. The head-started turtles were reared for two years in the Yaeyama Station, National Center for Stock Enhancement. Four of five head-started turtles moved out of the monitoring area, but their movements are not linearly. The duration the four head-started ones stayed in the monitoring area ranged from 4 to 14 days. All of the head-started turtles had a circadian rhythm to their behaviors. The other head-started turtle stayed around the release point for 88 days until it was recaptured by a fisherman. There was not much difference in diving depth between the head-started and the wild turtles reported by other sites. These results indicate that the head-started turtles tend to wander aimlessly in the natural environment, although they have natures of a circadian rhythm and diving technique.

KEYWORDS: *Eretmochelys imbricata*, head-starting, ultrasonic telemetry, circadian rhythm

INTRODUCTION

Head-starting is the practice of growing hatchlings in captivity to a size that (theoretically) will protect them from the (presumably) high rates of natural predation that would have otherwise occurred in their early months (Mortimer, 1995). This is expected to enhance the population of sea turtles as a positive conservation program for them, because the head-started turtles could acquire the ability to survive in the wild. Although head-starting has been conducted for population enhancement or environmental education in virtually every country where sea turtles occur, there are only a few reports on Kemp's ridley, *Lepidochelys kempii* (Bowen *et al*., 1994; Caillouet *et al*., 1995; Shaver & Caillouet, 1998; Fortaine & Shaver, 2005; Shaver, 2005), and green turtles (Bell & Parsons, 2002; Bell et al., 2005) that the head-starting programs were planned well and these outputs were researched. In the cases of Kemp's ridley in Texas (Shaver, 1998; Fortaine & Shaver, 2005) and green turtle in the Cayman Islands (Bell & Parsons, 2002; Bell et al., 2005), it was reported that some head-started turtles grew to maturity in the wild and that females returned to the beach to nest near the place where they had been released. However, it has argued that head-starting is not a proven management technique and may actually be harmful to turtles (Mortimer, 1995). Critics cite that biological concerns like nutritional deficiencies and behavioral modifications associated with the captivity (including insufficient exercise, lack of or inappropriate sensory stimuli, unavailability of natural food, etc.) may interfere with the ability of head-started turtles to survive in the open sea and with those imprinting mechanisms necessary to guide their breeding migration (Woody, 1990; 1991; Mortimer, 1995).

In order to determine the effect of successful head-starting, it is necessary to clarify how the head-started turtles behave and where they move in the open sea after release. This study was conducted to monitor the behavior and dispersal processes of the head-started hawksbill turtles in the Yaeyama Islands which is located in the southwestern part of Japan.

MATERIALS AND METHODS

Study area

This study was conducted in the Urasoko Bay on the north part of Ishigaki Island which was one of the Yaeyama Islands. The Yaeyama Islands have several small nesting sites of hawksbill turtles (Kamezaki, 1986; 1989). Also, Kamezaki & Hirate (1992) reported that there were some immature hawksbill turtles, in which the Straight Carapace Length (SCL) of his captured samples was between 393 mm and 631 mm, and these size distribution showed multimodal with the highest peak in the class size 440-460 mm.

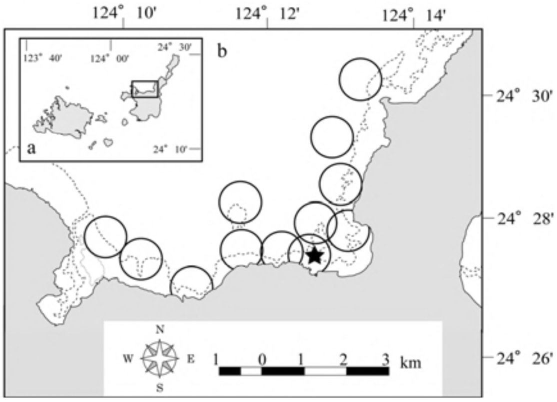

Fig.1 Study site. **a** the Yaeyama Islands; **b** the release point of the head-started turtles and the monitoring area. Asterisk represents the release point. The circles mean the locations of the receivers and the expected detection range of receivers which is 500 m in radius. The dotted line represents the reef edge of coral reef.

Table1 *Eretmochelys imbricata*. Summary of biological data of the head-started turtles with or without the depth sensor. SCL means Straight Carapace Length, and BW means Body Weight.

Turtle ID	SCL (cm)	BW (kg)	Depth sensor
HS 1	39.6	6.6	*
HS 2	42.0	7.8	*
HS 3	40.2	7.2	*
HS 4	41.2	7.0	*
HS 5	38.8	5.8	

Experimental animals

Five head-started turtles were used, which were reared for two and a half years since they were hatched Yaeyama station, National Center for Stock Enhancement, Japan without imprinting from the eggs. Their size was almost the same as the original wild turtles in Yaeyama Islands (Table1).

Tracking

We employed ultrasonic telemetry to monitor the behavior of the turtles. The turtles were attached with transmitters V16P-6H (16 mm in diameter, 106 mm in length, and weight 16 g in water; VEMCO, Nova Scotia, Canada) or V16-6H (16 mm in diameter, 90 mm in length, and weight 14 g in water) to the center of turtle's carapace using epoxy resin. The transmitters were coded with a unique pulse series for each turtle and transmitted signals at randomly spaced intervals between 5-30 seconds. The V16P-6H transmitters were equipped with depth sensors (See Table1).

The monitoring system for the fixed receivers (VR2; VEMCO, Nova, Scotia, Canada) was 60 mm in diameter and 340 mm long. The system had a flash memory to record data and was powered by a lithium battery with a life of up to 180 days. Twelve receivers were deployed on the sea floor at about 18 m in depth along the reef edge on the north of Ishigaki Island (Fig.1). Turtle ID, depth, date and time were recorded when a tagged turtle came within the expected detection range of the receiver, which was about 300 - 500 m in radius. The depth data was not continuous, so that it was not possible to analyze it in detail as time-series data. We therefore focused on the maximum depth of turtles during dives in addition to the mean depth.

RESULTS

Horizontal movement

All head-started turtles were released from the release point (Fig.1) at the same time on 19th April 2005.This experiment was conducted until 15th July 2005. Four of five head-started turtles (HS1, HS2, HS3 and HS5) moved out of the monitoring area during the experiment (Fig.2). HS1 moved east after release and then was detected by an adjacent receiver the next day. After four days, however, this turtle moved north and out of the monitoring area via the release point. HS1 seemed to have moved into northwest deeper water, because it was not detected by other receivers at all. HS2 moved out of the monitoring area in four days, but went east and then north along the reef edge. HS3 had a similar movement pattern to HS2, but more slowly taking 14 days. HS5 moved west and stayed around the receiver point from about 700 m west of the release point for six days. After that, it returned near the release point and then went north in one day. Exactly 34 days after disappearance from the monitoring area, however, HS5 came back to the monitoring area, and moved southwest directly through deeper area. It then went west, reached the reef edge and moved out of the monitoring area along the reef edge in only two days. HS4 showed different movement from other four turtles (Fig.2). It stayed around the release point and adjacent area for 88 days until it was recaptured by a fisherman. The home range of this turtle was less than 1 km^2 in this period.

Diel data reception pattern

The average number of data receptions per hour of each turtle was calculated (Fig.3). All of the head-started turtles were detected many times in the diurnal period (05:00 to 18:59), although the data receptions in the nocturnal period (19:00 to 04:59) varied individually. The data receptions of HS1, HS3 and HS4 in the diurnal period were significantly more than in the nocturnal period (Man-Whitney *U*-test; $P < 0.05$). In contrast, HS2 was detected in the nocturnal period significantly more than in the diurnal period (Man-Whitney *U*-test; $P < 0.05$). As for HS5, there was no significant difference between the diurnal and nocturnal periods (Man-Whitney *U*-test; $P > 0.05$).

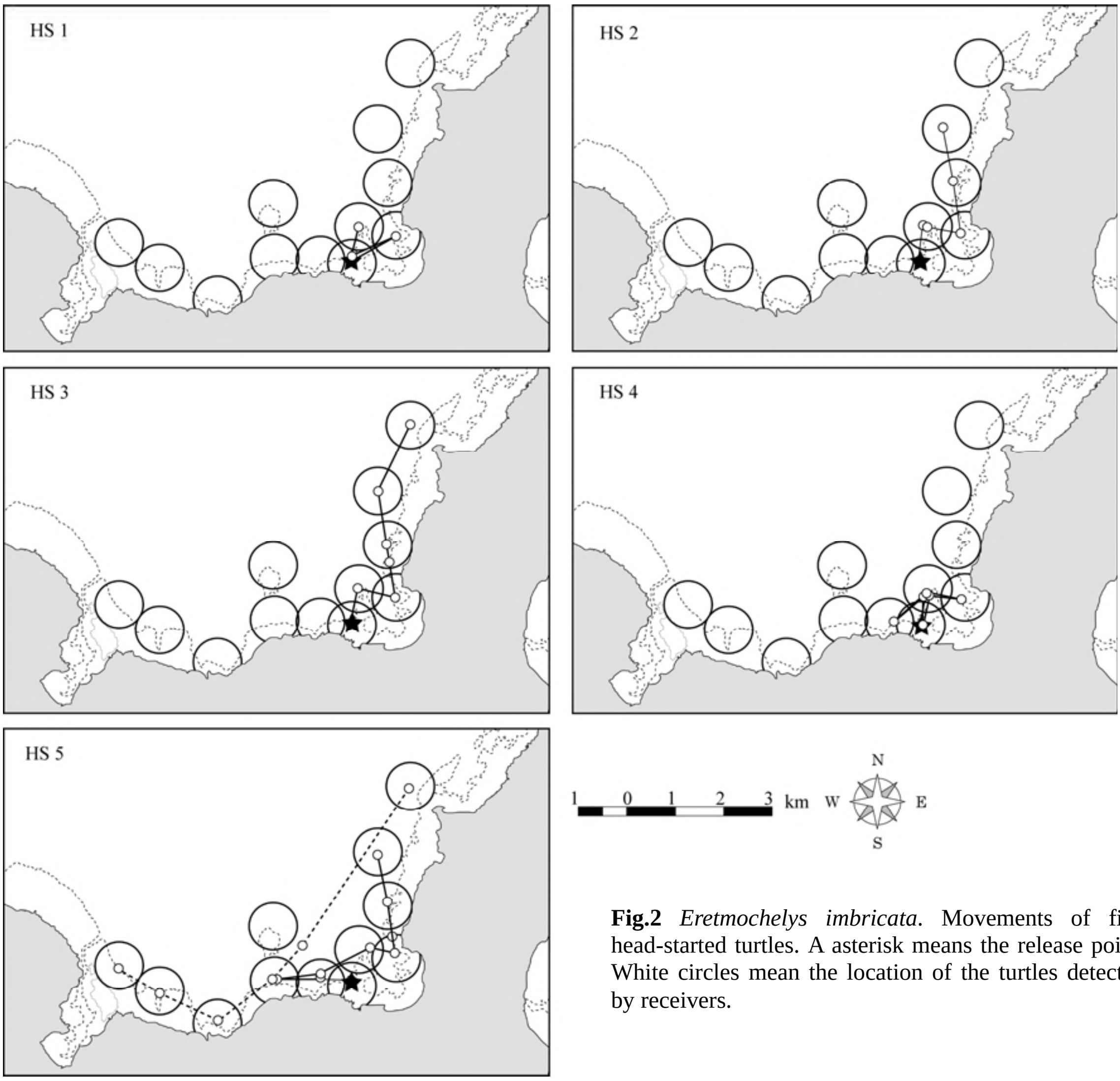

Fig.2 *Eretmochelys imbricata*. Movements of five head-started turtles. A asterisk means the release point. White circles mean the location of the turtles detected by receivers.

Diving depth

Depth data of four head-started turtles (See Table 2) were recorded. The mean depth of four head-started turtles was 9.8±3.8 m and the maximum depth was 28.5±7.4 m.

DISCUSSION

Dispersal process of the head-started turtles

During the experiment, four of five head-started turtles moved out of the monitoring area, and their behavior patterns and traveling times varied. In addition, one turtle did not move so far, and stayed at the release point for a long time. These facts indicate that head-started turtles do not have a pre-determined destination to go to, but a fidelity to the specific site after release, which implies that the head-started turtles may wander aimlessly in the new surroundings. The immature hawksbill turtles in Mona Island, Puerto Rico were reported to tend to remain in the same developmental habitat for extended periods (van Dam and Diez, 1998). Limpus (1992) documented strong site fidelity among hawksbills tagged on their feeding ground in Heron Island area, Australia. Due to this tendency of the site fixity, one would not expect to see immature hawksbill move extensively unless they are relocating to other developmental habitats or from developmental habitats to adult feeding ground (Meylan, 1999). In the Yaeyama Islands water, some tag returns of hawksbill turtles were also reported. Kamezaki (1987), and Kamezaki & Hirate (1992) reported that the recapture of the hawksbills in the Yaeyama Islands tend to occur in these Islands water, including some multiple recaptures, although the site fidelity was not seen like other regions. Kamezaki & Hirate (1992) reported that the SCL of captured hawksbill turtles in the Yaeyama Islands was between 393 mm and 631 mm, which indicated most of the hawksbill turtles in this area was immature. Because the Yaeyama Islands water is a favorable habitat for immature hawksbill turtles, the head-started turtles may be able to survive in the wild
if they can be residents.

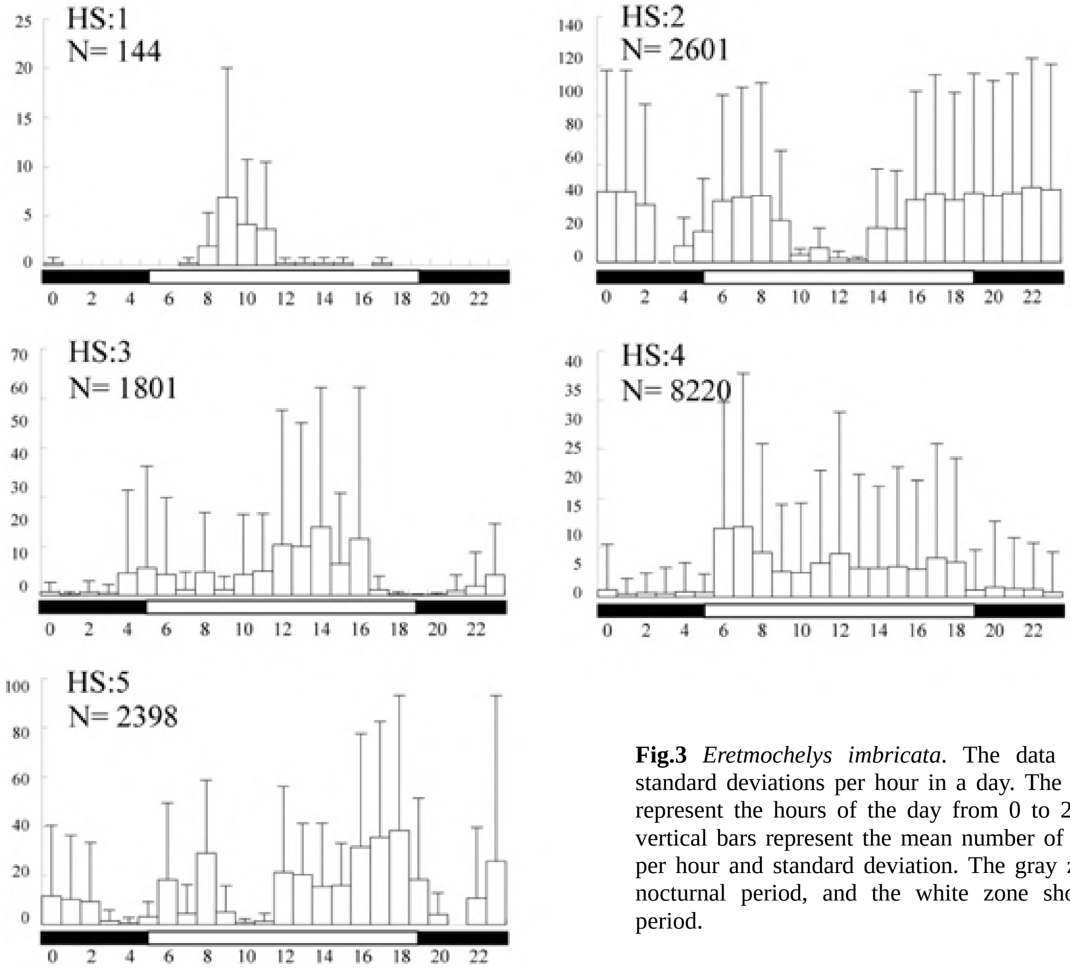

Fig.3 *Eretmochelys imbricata*. The data receptions and standard deviations per hour in a day. The horizontal axes represent the hours of the day from 0 to 23 o'clock. The vertical bars represent the mean number of data receptions per hour and standard deviation. The gray zones show the nocturnal period, and the white zone show the diurnal period.

Table2 *Eretmochelys imbricata*. Summary of the mean and maximum diving depth of four head-started turtles.

ID	Mean±S.D.(m)	Max.(m)	N
HS 1	6.6±6.0	26.9	144
HS 2	6.8±3.4	24.6	2593
HS 3	10.7±3.6	23.1	1801
HS 4	8.9±2.9	39.4	8231

From the results, however, the head-started turtles were considered to disperse gradually after release. Wandering in the open sea may possibly lead them to drift on the big ocean current or gyre. Though reared in the tank, however, they are able to swim against a certain level of current (*personal observation*). Consequently, head-started turtles might end up where generally hatchlings would never go. The destination where hatchlings will drift should be considered for evaluating the behavior and dispersion of head-started turtles in the future.

Diel behavior pattern

van Dam & Diez (1996; 1997) reported that the immature hawksbill turtles in Mona Island, Puerto Rico were active in the diurnal period with foraging, and inactive in the nocturnal period with resting. Also, the immature green turtles were observed by Ogden *et al.* (1983) to be generally active during daylight hours and usually inactive at night in the US Virgin Islands. The juvenile hawksbill turtles in the Yaeyama Islands have similar behavior patterns to those of the previous two regions, and the turtles were observed to rest under the coral in resting behavior (Okuyama, unpublished). The transmitter pulse in this experiment could not be detected by the receivers due to shielding when the transmitter was surrounded by some objects such as raised corals. Therefore, many data receptions of the head-started turtles in the diurnal period positively indicate that the head-started turtles were active like wild turtles. In addition, the significant fewer data receptions of HS1, HS3, and HS4 in the nocturnal period indicating they were inactive may be due to resting under the coral. As to the nocturnal data reception of HS2, it was considered to be rest diving because this data consisted of only one nocturnal period and these depths were fairly constant at a depth of 7.8 m. To sum up, we can conclude the head-started turtles tend to have a circadian rhythm which is active in the diurnal period and resting in the nocturnal period like wild turtles. The very few data receptions in the nocturnal period however, might indicate that the head-started turtles were poor in hiding under coral.

Diving depth

Head-started turtles were considered to be poor at diving or not to prefer the deeper water because they had been raised in the very shallow tank of about two meter depth. Diving depths of wild immature hawksbill turtles were investigated in the Caribbean cliff-wall habitat (van Dam & Diez, 1996), in the Caribbean reef habitat (van Dam & Diez, 1997) and, in the shallow water coral reef of Mahé Island, Republic of Seychelles (Houghton *et al*. 2003), where the mean depths ranged from 2.6 – 14.7 m, and the maximum depth from 11.2 – 72.0 m. Compared with these reports, the mean and maximum diving depths of the head-started turtles in the present study have not varied much indicating that they have the same vertical home range as wild ones. Therefore, it is considered that the small space of captivity did not affect the vertical range of their living space.

Conclusion

This experiment showed that the head-started turtles tend to wander aimlessly in the natural environment unlike wild hawksbills residing in a certain habitat, although they have by nature a circadian rhythm and diving technique. One of most likely causes of their wandering is considered to be attributed to their first experience when they enter into the sea like hatchlings. Hatchlings of hawksbill turtles were reported to move to the sea immediately after emergence at night, and join into the pelagic stage by ocean current, like other turtles (review; Musick & Limpus, 1997). Head-started turtles would make a similar migration to that of wild hatchlings if head-started turtles were small enough so as not to swim against current. In this experiment, however, the swimming ability of these head-started turtles might disturb their drifted migration to where wild hatchlings go by nature on big ocean currents. Thus, for appropriate head-starting, it might be better if turtles of a small enough size be released to protect them from the natural predation.

ACKNOWLEDGEMENTS

The authors thank staffs of the Ishigaki Tropical Station, Seikai National Fisheries Research Institute and Yaeyama station, National Center for Stock Enhancement for research help and constructive comments. Thanks also Dr. H. Mitamura, T. Yasuda, and K. Ichikawa for committed experimental support. This study was supported by the Sasakawa Scientific Research Grant from The Japan Science Society, a grant from Fujiwara Natural History foundation, and also partly a grant from the Research Fellowships of JSPS for Young Scientists (J.O.) (grant no. 17・1976)

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