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Vertical distribution of water temperature around female green turtles during the internesting period

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ABSTRACT
Time-depth-temperature data loggers were used to examine the vertical distribution of water temperature and diving behavior of female green turtles, *Chelonia mydas*, during the internesting period at Huyong Island in the Andaman Sea. The Andaman Sea of western Thailand experiences two main seasons: the relatively calm dry season from November to April and the stormy rainy season from May to October. The dry season is characterized by a north-easterly dry wind off the Asian continent. In contrast, heavy rain and strong winds characterize the rainy season. The vertical profile of ambient water temperatures showed that a thermocline did not develop in the dry season. In the rainy season, water temperature was stable to about 30 m, suggesting that an ocean surface mixed layer had developed. All turtles dived continuously during the internesting period. Dive depth ranged from 12.25 ± 6.24 m (n = 193) to 20.30 ± 10.95 m (n = 137) in the dry season and was 23.13 ± 16.32 m (n = 777) in the rainy season.

KEYWORDS: green turtles, *Chelonia mydas*, water temperature, diving behavior, internesting

INTRODUCTION

Huyong Island, Thailand has a rookery of green turtles (Kittiwattanawong, 2004; Yasuda et al. 2006). Previous satellite tracking studies showed that females remain around Huyong Island during the inter-nesting period (Kittiwattanawong 2004). For most of the population of green turtles, nesting occurs at a distinct time of the year (Miller 1997; Godley et al. 2002) because egg incubation is constrained by low sand temperature (Ackerman 1997). However, a population nested in tropic Huyong Island nests all the year round (Kittiwattanawong 2004; Yasuda et al. 2006). Although the seasonal climatic fluctuations were relatively weak compared to rookeries at higher latitudes, the seasonal fluctuations can be observed in Huyong Island in the Andaman Sea. The seasonal fluctuations observed in the Andaman Sea are usually related to the rather variable patterns of rain fall, with increase in the frequency of storms during the monsoon period. The Andaman Sea of western Thailand experiences two main seasons: the relatively calm dry season from November to April and the stormy rainy season from May to October. The dry season is characterized by a north-easterly dry wind off the Asian continent. In contrast, heavy rain and strong winds characterize the rainy season.

Female green turtles remain at the nesting area for several weeks while consecutive clutches are laid during the reproductive period. In this period, they perform a characteristic behavior to conserve energy for reproduction, i.e. they spend a large proportion of their time resting on the seabed or at a distinct depth, giving rise to a characteristic dive profile (Hochshied et al. 1999; Hays et al. 2000). Here, we have proposed a simple hypothesis on seasonal differences in water circulation around the nesting area between the dry season and the rainy season (Fig. 1). In the calm dry season, water circulation around the nesting site may be static because surface water is warmed by solar insulation and then the difference in water temperature between the surface layer and the lower layer will become large. In contrast, in the monsoonal rainy season, a surface mixed layer may be developed by cool rainfall and strong monsoonal winds. Therefore, active movement of water concerning the development of a mixed layer may occur. In this case, in the rainy season, resting on the seabed of turtles might be obstructed by active movement of water.

As the population reproduce all the year round in Huyong Island, environmental conditions which individuals experience may differ for each individual. In the present study, we examined the vertical distribution of water temperature around female turtles during the internesting period because vertical distribution of temperature can be an indicator of water circulation.

MATERIALS AND METHODS

Three types of time-depth-temperature data loggers (W380-PD2GT, 27 mm diameter, 118 mm length, 114 g; M190-D2GT, 15 mm diameter, 53 mm length, 16 g; UME190-DT, 15 mm diameter, 49 mm length, 14 g; Little Leonardo Co. Ltd., Japan) were used to examine the vertical distribution of water temperature around female turtles. Depth resolution was 0.05 m

for the M190-D2GT and UME190-DT data loggers and 0.1 m for the W380-PD2GT data loggers. The maximum depth that could be measured was 190 m for M190-D2GT and UME190-DT and 380 m for W380-PD2GT. Temperature resolution was 0.02°C for M190-D2GT and UME190-DT and 0.04°C for W380-PD2GT. Sampling intervals of depth and temperature were 1 s and 10 s, respectively, for all data loggers. The data loggers were attached to the carapace after nesting using epoxy resin. Data loggers required less than 30 min to attach and were recovered after subsequent nesting.

Dive data was analyzed using a macro in Igor Pro version 4.0 (WaveMetrics, Lake Oswego, OR, USA). To extract dive parameters for each dive, a dive was defined as a depth of more than 3 m for at least 30 s. The dive depth was defined as the maximum depth for each dive. Visual analysis of individual dive profiles confirmed that the macro successfully captured dives and each parameter.

RESULTS & DISCUSSION

Depth and ambient water temperature during the inter-nesting period were recorded for four individuals (dry season) and one individual (rainy season) (Table 1).

Ambient water temperature of the turtles ranged from 28.43 ± 0.79°C (n = 200000) to 29.5 ± 1.14°C (n = 35766). The vertical profile of ambient water temperatures showed that a thermocline did not develop in the dry season. In the rainy season, water temperature was stable to about 30 m, suggesting that an ocean surface mixed layer had developed (Fig. 2).

Dive depths ranged from 12.25 ± 6.24 m (n = 193) to 20.30 ± 10.95 m (n = 137) for dry season individuals and was 23.13 ± 16.32 m (n = 777) for the rainy season individual. Peak dive depth was in 3-10 m for dry season individuals and 20-30 m for rainy season individual, respectively. Dive duration ranged from 20.97 ± 15.90 min (n = 229) to 37.08 ± 27.80 min (n = 137) for dry season individuals and was 22.66 ± 17.77 min (n = 777) for the rainy season individual.

To save the energy of remaining at the nesting area during inter-nesting period, marine turtles are known to spend a large proportion of their time resting on the seabed or at a distinct depth, giving rise to a characteristic dive profile (Minamikawa et al. 2000; Hochshied et al. 1999; Houghton et al. 2000). These studies suggested gravid females rest in the shallow water (Houghton et al. 2000; Minamikawa et al. 2000), especially at depths of less than 20 m in green turtles because 19 m may represent the maximum depth at which individuals can still attain near-neutral buoyancy after diving with full lungs (Hays et al. 2000). This diving strategy of green turtles implies that the energy conserved by resting dives may affect reproductive output (Hays et al. 2000). In contrast, deep diving behaviour of female logger turtles *Caretta caretta* was recorded when turtles encountered typhoons (Sakamoto et al. 1991), suggesting that diving behaviour during the internesting period may have flexibility, according to weather. However, in the present study, because of the small sample size for the diving records (n = 1 only for the rainy season), we make no further discussion than to mention the possibility of a relationship between internesting behavior and vertical distribution of water temperature around Huyong Island; the rainy season turtle tended to use more varied depths than the dry season turtles (Fig. 3).

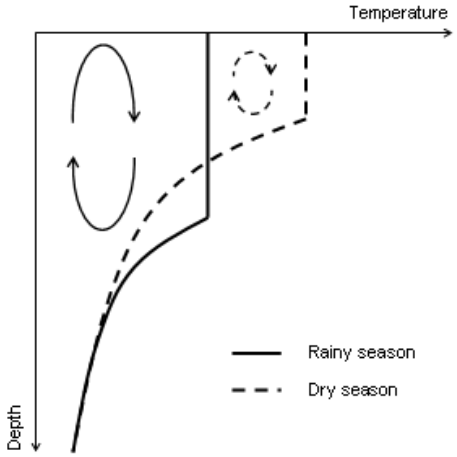

Fig. 1. Schematic diagram showing a hypothesis on vertical distribution of water temperature around Huyong Island.

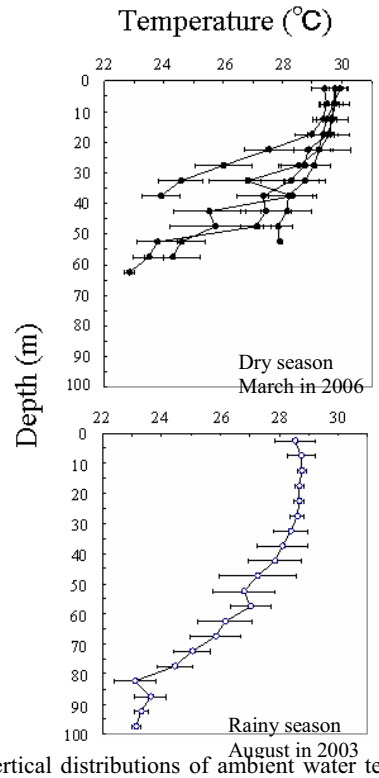

Fig. 2. Vertical distributions of ambient water temperature of green turtles during the internesting period at Huyong Island.

Table1. Summary of turtles with data loggers

Turtle (season)	Instrument	Recording period (d/m/yr)	Recordin g	Recovering date (d/m/yr)	CCL (cm)	No. of dives
1 (dry)	W380-PD2GT	6/3/2006 - 11/3/2006	132	17/3/2006	99	193
2 (dry)	W380-PD2GT	9/3/2006 - 15/3/2006	133	22/3/2006	90	348
3 (dry)	M190-D2GT	14/3/2006 - 17/3/2006	91	25/3/2006	103	137
4 (dry)	M190-D2GT	14/3/2006 - 18/3/2006	100	25/3/2006	101	229
5 (rainy)	UME190-DT	17/8/2003 - 31/8/2003	360	31/8/2003	98	777

† CCL, curved carapace length

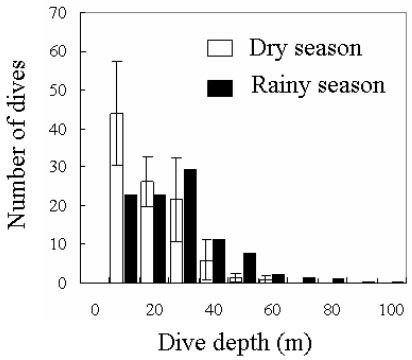

Fig. 3. Distribution of dive depth of female green turtles during internesting period.

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